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Thermocyclops dumonti sp. n. (Crustacea, Copepoda), from a Temporary Waterbody in China

key words: taxonomy, pore signature, limnology

Abstract

Six species of the genus *Thermocyclops* have hitherto been known from Chinese freshwaters. A new species is here recorded from a sample collected from an eutrophic pool in central China. It is described and compared using classical morphology and mapping of its pore signature. *Thermocyclops dumonti* differs from *T. kawamurai* by absence of ornamentation on prominences of intercoxal plates of P_1-P_3, by relative length of apical spines of Enp_3P_4 and caudal ramus. It differs from *T. dybowskii* by ornamentation of P_4 intercoxal plate, relative length of Enp_3P_4 and caudal ramus, by shape of Tmi. As in other species of *Thermocyclops*, the perforations are bilaterally symmetrical and, species-specific patterns occur on the cephalosome, metasome, and urosome. Conserved patterns are found elsewhere on the rostrum, cephalosome, metasome, and furcal branches. Based on pore pattern, *Thermocyclops dumonti* is separated from two close relatives, *T. schmeili* and *T. dybowskii*.

1. Introduction

Within the family copepod Cyclopidae, *Thermocyclops* Kiefer, 1927 is one of the most speciose genera. It includes species that dominate the plankton of a variety of continental waterbodies. Six species are known from China, namely *Thermocyclops crassus* (Fischer, 1853); *T. dybowskii* (Landé, 1890); *T. taihokuensis* Harada, 1931; *T. kawamurai* Kikuchi, 1940; *T. mongolicus* Kiefer, 1937 and *T. vermifer* (Lindberg, 1935) (Shen *et al.*, 1979; Defaye *et al.*, 1987; Guo, 1999). *Thermocyclops dumonti* sp. n. was collected from a temporary waterbody in central China. We used classical morphology in addition to pore-mapping in order to separate the new species from its congeners. Fleminger (1973) was the first to use pore signature as a character to classify marine species of *Eucalanus*. Strickler (1975) partially mapped the pore signature of a freshwater cyclopoid, *Macrocyclops albidus*. Koomen (1992) confirmed the usefulness of the pore pattern in the taxonomy of calanoids. Baribwegure and Dumont (1999) initiated the study of the pore signature of *Thermocyclops*, with *T. emini* (Mrázek, 1895) as the first species mapped. Baribwegure *et al.* (2001) documented the perforation pattern of *T. oblongatus* (Sars, 1927), *T. africae* Baribwegure and Dumont, 2001, and *T. neglectus* (Sars, 1909), thus confirming the uniqueness of the pore signature in these cyclopoids as it has been documented before for calanoids (Fleminger, 1973; Mauchline, 1977; Malt, 1983; Koomen, 1992; and Galassi *et al.*, 1998).

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2. Material and Methods

Males and females were collected from an eutrophic temporary pond in the village of Baisha, region of Lijiang, northwestern Yunnan, China (leg. H. J. Dumont). The perforation pattern was mapped following the methodology used by Fleminger (1973): animals were heated for three hours in 10% KOH. After cooling, they were cleaned in distilled water and 70% ethanol and stained in 1% chlorazol black dissolved in 70% ethanol. Specimens were dissected using tungsten needles under a Wild M3 dissecting microscope. Perforations were observed and mapped under immersion oil using an Olympus Medilux-12® microscope with a drawing tube. We studied the rostrum, the dorsum of the cephalosome and the metasome, the dorsum, the ventrum and sides of the urosome and the furcal rami. In order to facilitate interpretation, we developed a standard numbering system for perforations, which applies to the whole genus. Therefore, not all species have all positions represented. Full ellipses on the figures represent positions found in other species but absent in *T. dumonti*. Squares are used to compare males and females. To confirm the pore pattern of some zones scanning electron microscopy (S. E. M.) was performed on non-stained animals after dehydratation in alcohol and subsequent critical point drying. And, after sputter-coating with gold, specimens were examined with a JEOL JSM-840 microscope.

Abbreviations used are as follows: Me: lateral furcal seta; Ti: innermost apical furcal seta; Tmi: inner middle apical furcal seta; Tme: outer middle apical furcal seta; Te: outer apical furcal seta; Sd: dorsal furcal seta.

3. Results

***Type locality*:** A pool in the village of Baisha, region of Lijiang, northwestern of Yunnan province, central China.

Type material

***Holotype*:** Female without egg-sacs, dissected and mounted in glycerin on three slides labelled *Thermocyclops dumonti* sp. n., A_1-A_2 holotype; *Thermocyclops dumonti* sp. n., P_1-P_4 holotype; and *Thermocyclops dumonti* sp. n., urosome holotype, respectively. The species was found together with *Moina macrocopa* (Straus, 1820) and *Daphnia similis* Claus, 1876.

Paratypes: Five specimens, dissected and mounted in glycerin; 15 slides of which five are labelled *Thermocyclops dumonti* sp. n. A_1-A_2 paratype 1–5; five others are labelled *Thermocyclops dumonti* sp. n. P_1-P_4 paratype 1–5, and the last five slides are labelled *Thermocyclops dumonti* sp. n. urosome paratype.

Repository of type material

Holotype, paratypes and a flask (labelled: *T. dumonti* sp. n., 40 specimens) containing 20 females (10 with egg sacs) and 20 males are deposited in the Royal Belgian Institute for Natural Sciences KBIN (Koninklijk Belgisch Instituut voor Natuurwetenschappen), Brussels, Belgium; JG 29528: COP 4563 (Holotype), COP 4564–4566 (paratypes). Many other, non-paratype males and females are in the zooplankton collection (sample number 89.021) of the Laboratory of Animal Ecology, University of Ghent, Belgium.

***Derivatio nominis*:** The species is named after Prof. Dr. H. J. Dumont.

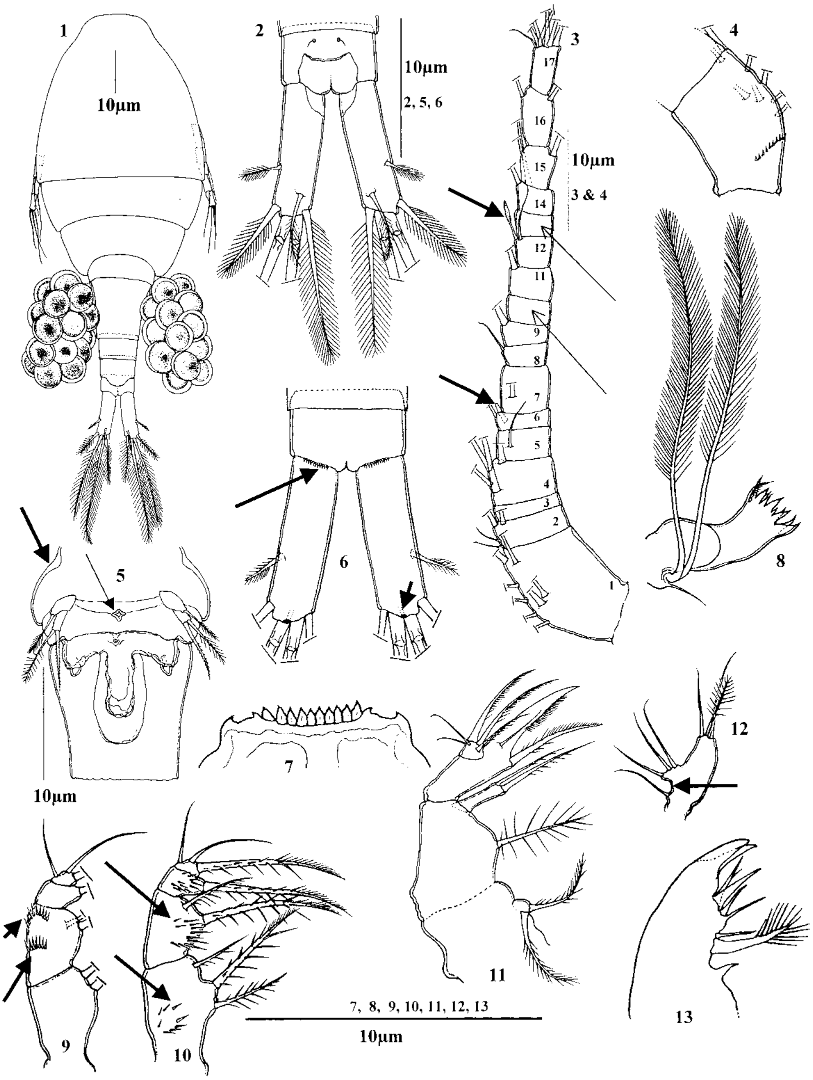
Description of holotype

Body length 1000 µm. Body widest at cephalothorax (Fig. 1). Lateral surface of fifth somite glabrous.

Genital somite (Figs 1, 5): As long as wide, receptaculum seminis resembling that of *T. hastatus* as drawn by Herbst (1986); lateral arms slightly curved backwards.

Anal somite: Operculum developed (Figs 2 and 32). Ventral surface of distal margins with continuous (Fig. 6) or discontinuous row of spinules (Fig. 35).

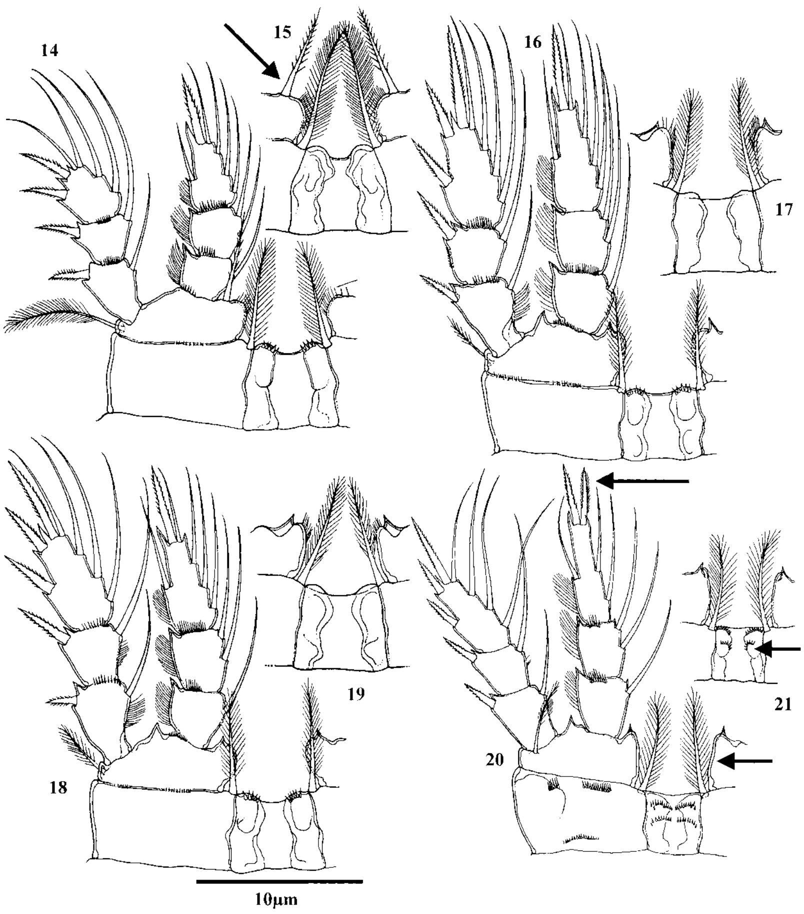
Furcal rami: 3.5 times as long as broad, insertion of lateral seta unarmed. Lateral seta implanted at 0.7 µm from insertion of Te. Ti 0.9 times as long as furcal rami, 1.50 times as



Figures 1–13. *Thermocyclops dumonti* sp. n. female. 1: habitus, 2: Anal somite and furcal rami (dorsal side), 3–4: Antennule, 5: Genital somite (ventral side), 6: Anal somite and furcal rami (ventral side), 7: Labrum, 8: Mandible, 9–10: Maxilliped (9: outer side, 10: inner side), 11: Maxilla, 12: Maxillular palp,13: Maxillule.

long as Te and 1.30 times as long as Sd. Presence of a relatively large terminal pore in ventral side of males and females (Figs 6 and 41).

Antennules: 17-segmented, reaching half length of first metasomal somite (Fig. 1). First segment with row of spinules (Fig. 4). Structure of antennule typical for genus; in females, segment 6 with an outgrowth protruding from the segment, 12th segment with an aesthetasc implanted near a seta; 10th and 13th segments devoid of setae (Fig. 3). In males, first segment with two aesthetascs (Fig. 43).



Figures 14–21. *Thermocyclops dumonti* sp. n. female. 14–15: P1 (14: caudal side, 15: frontal side), 16–17: P2 (16: caudal side, 17: frontal side), 18–19: P3 (18: caudal side, 19: frontal side), 20–21: P4 (20: caudal side, 21: frontal side).

Antenna: Basipodite with three setae. Endopodite 3-segmented. First endopodite with one outer seta at midlength of segment carrying a row of spinules on outer margin. Endopodite segment 2 with nine setae, endopodite segment 3 with seven terminal setae and a row of spinules on outer rim.

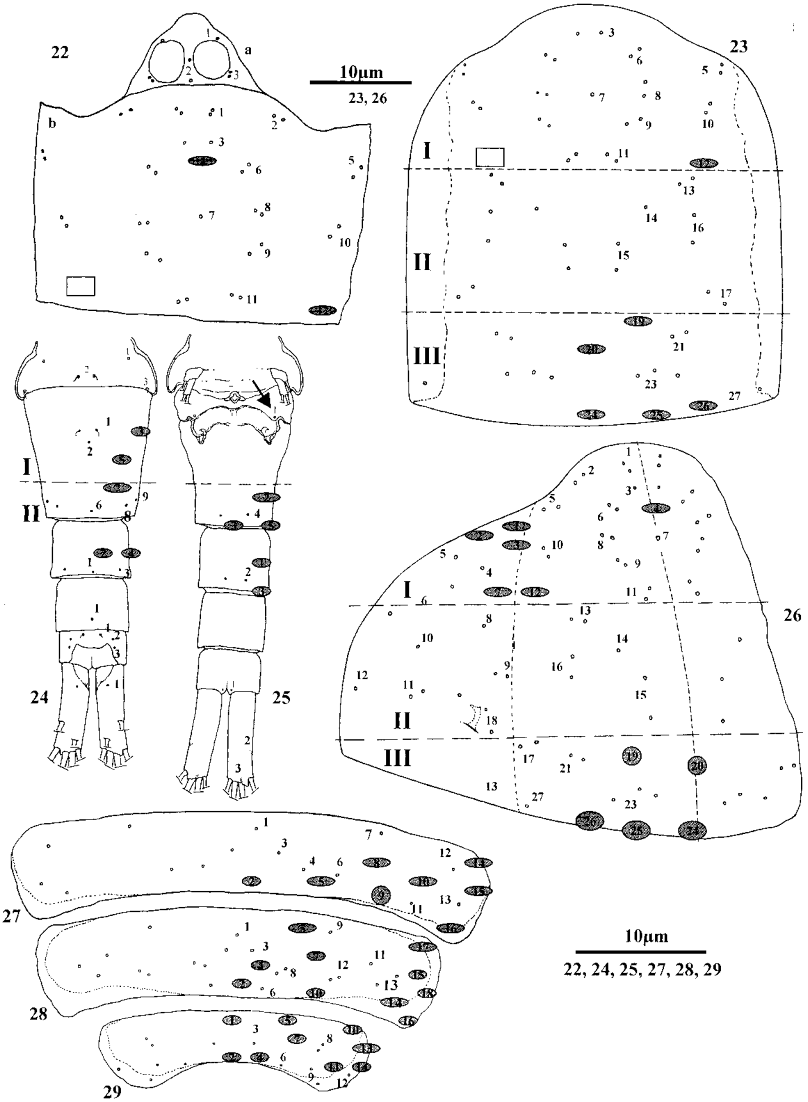
Labrum: with 12 teeth; lateral lobes serrated (Fig. 7).

Mandible: With two long and feathered setae and one small seta (Fig. 8).

Maxillule: Basis of maxillula palp glabrous (Fig. 12).

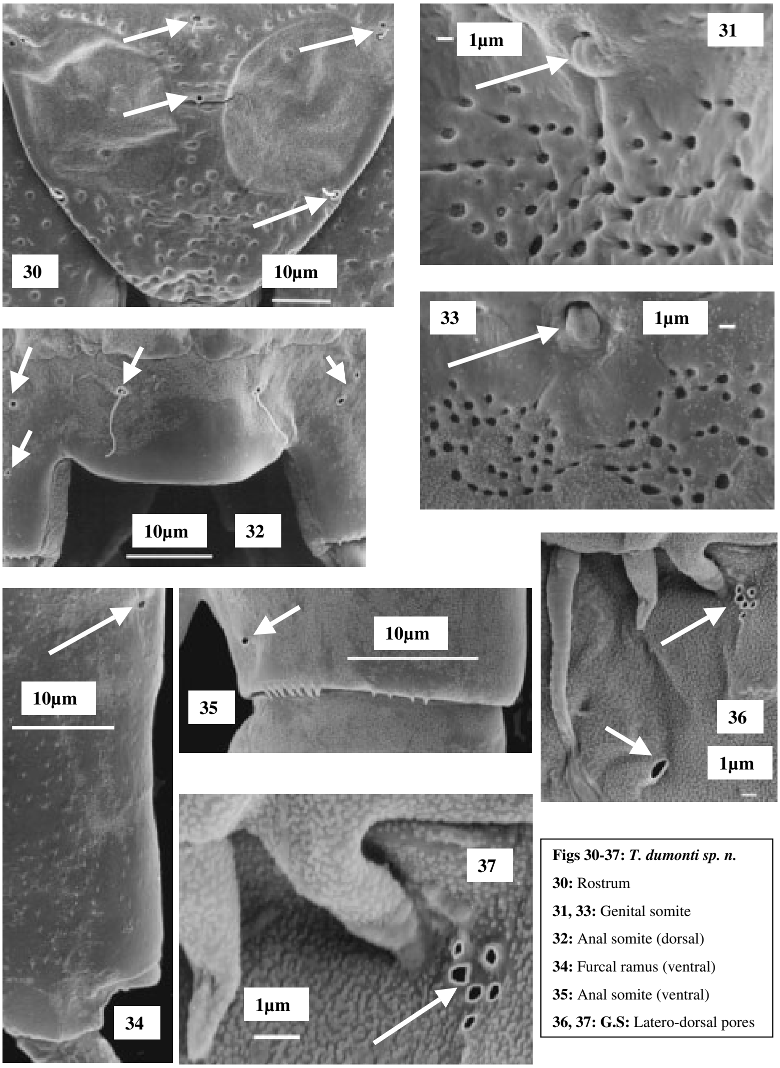
Maxilla (Fig. 11): With precoxa, coxa, basis and 2-segmented endopodite. Shortest seta of movable coxal endite 0.80 times as long as longest seta.

Maxilliped: With syncoxa, basis, and 2-segmented endopodite (Figs 9, 10). Length ratio of two shortest apical setae 1.35. Basal segment (fusion of precoxa and coxa) with three feathered setae. Outer side of basal segment with circular row of spines (Fig. 10). Basis with two feathered setae, outer surface with long strong spines, inner side with two rows of spines (Fig. 9). Endopodite 2-segmented; inner side with group of strong spines, outer side glabrous. Proximal segment with long feathered setae, distal segment with three unequal setae.



Figures 22–29. *Thermocyclops dumonti* sp. n. female. 22a: Rostrum, 22b: part of the cephalosome, 23: Cephalosome (dorsal), 24–25: Urosome (24: dorsal, 25: ventral), 26: Cephalosome (lateral), 27, 28, 29: First, Second, Third metasomal somites respectively.

Thoracopods: Three-segmented rami, spine formula P_1-P_4: 2.3.3.3; seta formula: 4.4.4.4 (Figs 14, 16, 18, 20). Inner margin of P_1 basipodite with long, spine-like seta, reaching distal margin of the endopodite second segment (Figs 14 and 15). Inner margins of basipodites P_1-P_3 hairy (Figs 15, 17, 19), of P_4 glabrous (Figs 20, 21). Intercoxal plates of P_1-P_4 with low rounded prominences bearing 4–5 spinules (Figs 14, 16, 18), fourth leg with two rows of spinules (Figs 20, 21). Enp_3 P_4: 2.67 times as long as broad. Inner spine of Enp_3P_4 0.67 times as long as bearing segment; 0.94 times as long as outer spine (Fig. 20).



Figures 30–37. *Thermocyclops dumonti* sp. n. female. 30: Rostrum, 31, 33: Genital somite (ventral side), 32: Anal somite (dorsal), 34: Furcal ramus (lateral side), 35: Anal somite (ventral side), 36–37: Genital somite (lateral side).

P_5: typical for genus, with inner apical spine 1.25 times as long as the outer spine (Fig. 5).

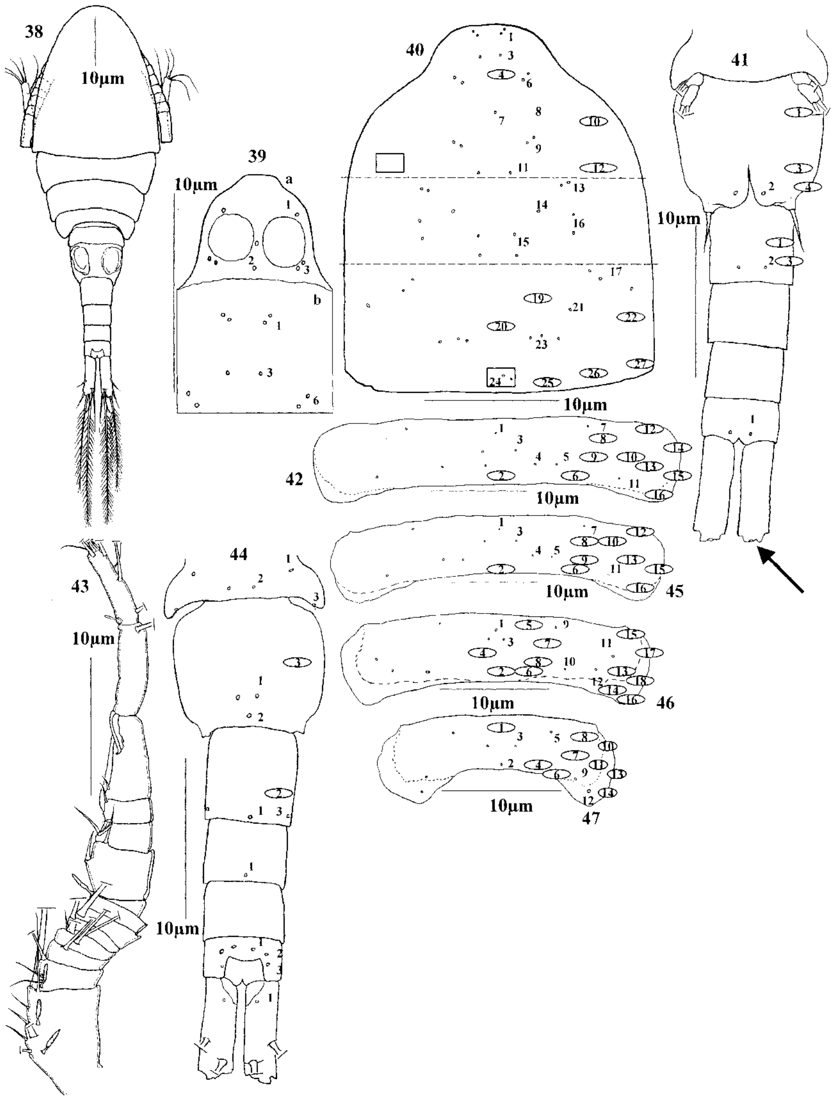
P_6: Based on three elements; two relatively long and one small, with of six pores near leg insertion (Figs 36, 37).

Integumental pore signature:

Rostrum (Figs 22a, 30, 39a, b): Eight conserved pores in males and females in positions 1, 2 and 3.

Cephalosome

Zone I: In females, a ring complex of 19 perforations, in positions 3, 6, 7, 8, 9, and 11 (Figs 22, 23, 26). In males ring structure composed by 13 pores, of which position 7 is medi-



Figures 38–47: *Thermocyclops dumonti* sp. n. Males. 38: Habitus, 39: Rostrum plus a part of cephalosome, 40: Cephalosome (dorsal side), 41; 44: Urosome (41: ventral side, 44: dorsal side), 42: First metasomal somite, 43: Antennule, 45–46, 47: Second and third metasomal somites respectively.

an (Fig. 40). Males differ from females by absence of position 8; position 11 with two symmetrical pores in females (Figs 22 and 40).

Zone II: With 18 dorsal perforations whose distribution differs from that of zone I; similar distribution in males and females, median pores in a rectangle (position 15).

Zone III: Four dorsal positions 21, 23, 24, and 27 in males and females. Differences in positions 21 (one pore in males, two pores in females) and 24 (two pores in males, no pores in females) (Figs 23, 40).

Metasome

In females, first (Fig. 27), second (Fig. 28), third (Fig. 29), and fourth somites (Fig. 24) with 15, 21, 14 and six perforations respectively; same somites with 11, 11, nine and six pores in males. Possibility of pseudosymmetric patterns, as in position 4 (Fig. 42). Last metasomal somite with six conserved pores in males and females.

Urosome

In females, genital somite with 24 pores (Figs 24, 25). Posterior to the medio-ventral gland opening, some specimens with openings resembling normal pores (Figs 31, 33). These structures differ from normal perforations; thus we refrained from discussing them because of the lack of detailed information. In some females, anal positions form a pseudosymmetric pattern (Fig. 32). On ventral side and anterior to receptaculum, two symmetrical pores present (Fig. 36). Third somite glabrous. Anal somite with eight perforations, of which 6 dorsal plus 2 ventral (Figs 24, 25, 35). Laterally, six openings present close to implantation of sixth leg (Figs 36, 37).

In males, genital somite with three dorsal pores (Fig. 44) plus two ventral ones (Fig. 41). Genital and second urosomal somites with similar ventral pore signatures in males and females.

Furcal rami

Each branch carries 3 pores: dorsal, ventral, and latero-ventral (Figs 24, 25, 34).

Variability

Animals present sexual dimorphism, with average body length of 741 µm and 983 µm in males and females, respectively (Figs 1 and 38). Measurements are given in Table 1.

Differential diagnosis

Thermocyclops dumonti is related to a broad group of the genus *Thermocyclops*. This group includes *T. kawamurai* KIKUCHI, 1940; *T. schmeili* (POPPE and MRAZEK, 1895); *T. tinctus* LINDBERG, 1936; *T. uenoi* ITO, 1952; *T. ouadanei* VAN DE VELDE, 1978; *T. orientalis*

Table 1. Some measurements on *Thermocyclops dumonti* sp. n.

	Females, n = 10		Males, n = 3	
	min-max	x	min-max	x
Body length (in µm)	950–1000	983	725–750	733
Anal somite spinules*	4–7	5.1	lots	lots
Caudal rami L/W	3.40–3.80	3.55	3.25–3.65	3.50
Ti/caudal rami L	1.05–1.20	1.12	1.17–1.30	1.23
Ti/Tmi	0.40–0.44	0.42	–	–
Ti/Tme	0.49–0.55	0.52	0.42–0.44	0.43
Ti/Te	1.71–2.08	1.82	2.43–2.76	2.56
Ti/Sd	1.95–2.22	2.11	1.42–1.75	1.54
Enp_2 A_2 setae**	8–9	8.1	6–6	6
Enp_3 P_4 L/W	2.47–2.80	2.67	2.82–3.43	3.04
Enp_3 P_4 med. sp./L	0.59–0.70	0.64	0.56–0.67	0.63
Enp_3 P_4 med. sp./lat. sp	0.85–1.00	0.94	0.83–1.00	0.90
P_5 med. sp./lat. seta	1.20–1.47	1.31	1.32–1.37	1.34
P_6 med. sp../lat. seta	–	–	1.42–1.69	1.71

* Number of spinules on caudal margin of caudal rami
** Number of setae on 2nd segment of antennae
x: Mean; Min: Minimum; Max: Maximum.

DUSSART et FERNANDO, 1985; *T. hastatus* KIEFER, 1952, etc… Among many characters these species are defined by almost similar spinulation pattern of caudal surface of intercoxal plate of P_4; short but broad genital (double) somite; relatively low ratio (<2.0) between length of apical spines of Enp_3P_4 and relatively short innermost apical furcal seta.

Within the group *T. dumonti* is distinguished by its smooth inner margins of furcal rami (these carry hair-setae in *T. uenoi*), relatively long Ti [Ti/Te <1.5 in *T. hastatus* KIEFER, 1952, *T. conspicuus* LINDBERG, 1950, *T. philippinensis* (MARSH, 1932)]; presence of few spinules distally on ventral side anal somite (a relatively rich spinulation in *T. schmeili* and *T. hastatus*) and ornamentation of intercoxal plates of P_1-P_4.

Among the chinese population of *Thermocyclops, T. dumonti* is more close to *T. kawamurai* KIKUCHI, 1940 and *T. dybowskii* (LANDE, 1890). The species differs from *T. kawamurai* by absence of ornamentation on outgrowths of the coupler of P_1-P_3; relatively short apical spines of Enp_3P_4 (inner spine 0.7–0.9 times as long as Enp_3P_4 in *T. kawamurai*) and relatively short furcal rami (L/W 3.80–4.40 in *T. kawamurai*). *T. dumonti* differs from *T. dybowskii,* by the ornamentation of the connecting lamella P_4, longer caudal ramus (L/W 2.80–3.30 in *T. dybowskii*), a relatively short Enp_3P_4 (L/W 2.9–3.2 in *T. dybowskii*) and slightly curved tips of Tmi (strongly curved in *T. dybowskii*).

Key to Chinese species of the genus *Thermocyclops*:

1. Inner spine of Enp_3P_4 at least twice longer than outer spine; caudal side of P_4 intercoxal plate with 1–2 rows of setules; genital segment markedly longer than wide 2

– Inner spine of Enp_3P_4 less than 1.5 times as long as outer spine; caudal side of P_4 intercoxal plate smooth or with rows of setules 5

2. Lateral surfaces of genital segment bearing short spinelike spines; lateral arms of the receptaculum seminis short (length/width ratio about 2) and slightly curved backwards; inner margin of P_4 basipodite bearing hairs; inner spine of Enp_3P_4 about 2 times as long as outer spine and bearing teeth on inner edge and setules on outer edge .... *T. crassus* (FISCHER, 1853)

– Lateral surfaces of genital segment smooth; lateral arms of the receptaculum seminis long (length/width ratio about 3); inner margin of P_4 basipodite smooth; inner spine of Enp_3P_4 2.2–4.0 times as long as outer spine 3

3. Lateral arms of the receptaculum seminis strongly curved caudally; intercoxal plate of P_4 with 2 rows of setules on caudal side; inner spine of Enp_3P_4 2.5–4.0 times as long as outer spine and bearing teeth on both edges .... *T. taihokuensis* HARADA, 1931

– Lateral arms of the receptaculum seminis slightly curved caudally 4

4. Inner spine of Enp_3P_4 2.2–2.5 times as long as outer spine and bearing teeth on both edges; intercoxal plate of P_4 with 1 row of setules on caudal side
....*T. mongolicus* KIEFER, 1937

– Inner spine of Enp_3P_4 2.5–3.0 times as long as outer spine and bearing teeth on inner and setules on outer edges; intercoxal plate of P_4 with 2 rows of setules on caudal side
.... *T. vermifer* LINDBERG, 1935

5. Intercoxal plate of P_4 without spinules except those on barely developed distal prominences; genital segment longer than wide; ventral caudal margin of anal somite bearing 2 groups of many tiny spinules and 4–5 larger spinules .... *T. dybowskii* (LANDE, 1891)

– Intercoxal plate of P_4 with 1–2 rows of spinules on caudal or frontal surfaces as well as spinules on the prominences; genital segment about as long as wide 6

6. Intercoxal plates of P_1-P_3 bearing rows of spinules on caudal surfaces
.... *T. kawamurai* (KIKUCHI, 1940)

– Intercoxal plates of P_1-P_3 naked .... *T. dumonti n. sp.*

Comparison of integumental pore pattern (Table 2)

Rostrum:

Rostral pore signature formed of 8 conserved pores, similar in all species studied.

Table 2. Number and distribution of pore patterns in some *Thermocyclops*.

Species	Rostrum*	Cephalosome			Metasome				Urosome						Furca*			Pattern	
									G. S										
		I	II*	III	S1	S2	S3	S4*	Dorsal	Ventr.	Later.*	S1	S2	S3* (anal)	Dorsal	Lateral	Ventral	Conserved	Species-specific
T. dumonti	8	19	4	12	15	21	14	6	8	2	12	5	1	8	2	2	2	R	C
T. schmeili#	8	20	4	16	33	42	29	6	11	4	12	10	0	8	2	2	2	C	M
T. dybowskii#	8	17	4	26	12	25	15	6	10	4	12	4	1	8	2	2	2	M	U
T. emini##	8	17	4	14	9	27	21	6	14	4	12	7	1	8	2	2	2	U, F	

*: Zones of conserved patterns; R: Rostrum; C: Cephalosome; Later.: Lateral; Ventr.: Ventral; M: Metasome; U: Urosome; F: Furca; G.S: Genital (double) somite; ##: From BARIBWEGURE and DUMONT, 1999; #: From BARIBWEGURE and DUMONT (unpublished data).

Cephalosome and metasome:

Differing from the 19 perforation of the anterior ring in *T. dumonti*, *T. schmeili* (with 20) has one more pore, *T. dybowskii* (with 17) lacks two pores (BARIBWEGURE and DUMONT, in prep.), and *T. emini* (with 17) lacks position eight; position 11 has only two symmetrical pores (BARIBWEGURE and DUMONT, 1999). Within the genus, the second zone with four median conserved pores (position 15), the first (with ring) and the third zones have a species-specific pore signature. Other species-specific patterns are found on the metasomal somites. The first somite has 15, 33, 12, and nine pores in *T. dumonti*, *T. schmeili*, *T. dybowskii* and *T. emini* respectively. Similarly, the second somite has 21, 42, 25, and 27 in *T. dumonti*, *T. schmeili*, *T. dybowskii* and *T. emini*. In the same order, the third somite has 14, 29, 15, and 21 pores.

Urosome and furcal rami:

Within the four species, the last metasomal somite carries six conserved pores. On the genital somite, the pore signature is as follows: Ten (eight dorsal, two ventral), 15 (11 dorsal, four ventral), 14 (10 dorsal, four ventral) and 14 pores (10 dorsal, four ventral) in *T. dumonti*, *T. schmeili*, *T. dybowskii* and *T. emini* respectively. Of these pores, three anterior ones form a conserved triangle in each species.

The second somite carries five (three dorsal, two ventral), 10 (six dorsal, four ventral), four (two dorsal, two ventral) and seven pores in *T. dumonti*, *T. schmeili*, *T. dybowskii* and *T. emini* respectively. In the same order, the third somite carries one dorsal pore in *T. dumonti*, *T. dybowskii* and *T. emini;* no sign of perforation in *T. schmeili*.

The genus is characterised by a conserved anal pore signature formed by eight perforations: six dorsal and two ventral. Each furcal branch with 3 conserved pores of which one dorsal, one lateral and one ventro-lateral.

4. Discussion

This study together with our earlier investigations on members of *Thermocyclops* (20 species studied), *Eucyclops* (five species studied), *Mesocyclops* (two species studied), *Halicyclops* (one species), *Paracyclops* (one species) and the results on calanoids by FLEMINGER

(1973), KOOMEN (1992), MALT (1983) and MAUCHLINE (1977) established the existence of a bilaterally symmetrical pore signature in cyclopoids and calanoids. The pore signatures reveal both species-specific and conserved zones. Species-specific patterns occur on the cephalosome, the metasome and the urosome, whereas conserved zones are found on the rostrum, cephalosome, metasome, urosome and furcal branches. Research based on traditional techniques complemented with the perforation patterns has also revealed the existence of traits with unknown functions. These include an outgrowth of the sixth segment of the antennules, segments 10 and 13 devoid of setae, segment 12 with an aesthetasc (Fig. 3), the male's and female's genital somite with a large ventral opening between the genital opening and proximal margin of the somite (Figs 5, 25, 33), and the furcal ramus with a relatively large terminal pore on the ventral side in males and females (Figs 6, 25, 41). In taxonomy, the pore signature and the traditional approches are complementary.

5. Acknowledgement

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