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Acanthocyclops fonticulus (Cyclopoida, Cyclopidae), a New Species of Cyclopoid Copepods from Mountain Springs in Korea

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Abstract: A new cyclopoid species belonging to the genus *Acanthocyclops* is described from several mountain springs in South Korea. This species is allied to *A. kieferi* species group in sharing 11-segmented antennules, but is, clearly distinguished from them by its single apical spine on the third endopodal segment of leg 4 and an extra spine on the distal segment of leg 5 in both sexes.

Key words: Taxonomy, Copepoda, Cyclopoida, Cyclopidae, *Acanthocyclops fonticulus*, new species, mountain springs, Korea

As a result of a comprehensive faunistic study on freshwater copepods in South Korea, the authors examined various specimens collected from several mountain springs. Among them, some specimens belonging to the genus *Acanthocyclops* turned out to be new, and showed two peculiar characteristics of single apical spine on the third endopodal segment of leg 4 and an extra spine on the distal segment of leg 5 in both sexes.

The genus *Acanthocyclops* Kiefer, 1927 comprises 48 species or subspecies (Boxshall and Halsey, 2004), most of which were collected from various subterranean waters such as caves, wells, springs and interstitial waters. In East Asia, only one species from China (Tai and Chen, 1979), five from Japan (Ito, 1952, 1957, 1964; Mizuno, 1984; Ishida, 2002), and one from far-eastern region of U.S.S.R. (Borutzky, 1966) have been recorded.

Subterranean cyclopoid fauna, especially of the genus *Acanthocyclops* in Korea has been poorly known so far. Kim and Park (1969) and Kim and Lee (1978) reported *Acanthocyclops morimoroi* Ito, 1952 from the Han River, but it seems to have been be misidentified for the copepodid larva of *Cyclops vicinus* Uljanine, because the male of *A. morimotoi* is somewhat similar to copepodid larva of *C. vicinus* morphologically. Kim and Chang (1991) described a new species, *A. tokchokensis,* from wells at foothill of Deogjeogdo Island in the Yellow Sea. Chang et al. (1998) summarized the habitat distribution of the mountainous copepods in South Korea, including the report of *A. vernalis* (Fischer). Therefore, *A. fonticulus* n. sp. in the present study is the third record of the genus *Acanthocyclops* in Korea.

Following the taxonomic report (Lee et al., 2004) on two semi-subterranean cyclopoid species in Korea, *Ochridacyclops coreensis* Chang and *Itocyclops yezoensis* (Ito), herein we describe a new spring-dwelling species belonging to *Acanthocyclops.*

MATERIALS AND METHODS

Materials examined in the present study were collected from five localities (Fig. 1), among fallen leaves submerged in the small mountain springs. Samplings were made with a 63 μm mesh net. Copepods were fixed and stored in 4% buffered formalin. All the specimens were dissected, drawn, and measured in lactophenol on H-S slide (Shirayama et al., 1993), a recent variation of Cobb slide. Dissection was performed using two needles made from 0.35 mm diameter tungsten wire by electrolysis (Huys and Boxshall, 1991; Huys et al., 1996). Mounted specimens were observed under a differential interference contrast microscope (Olympus BX51) with Nomarski optics. Figures were prepared with the aid of a camera lucida.

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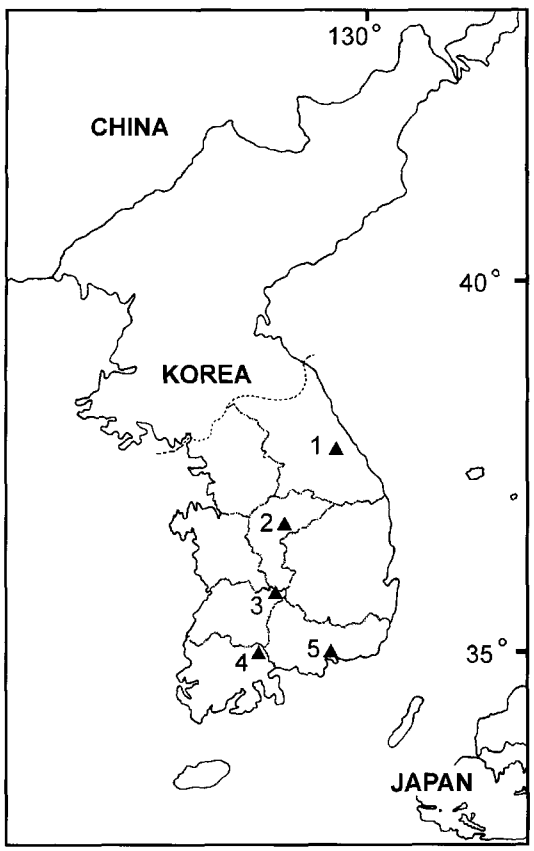

Fig. 1. Collection localities in South Korea of *Acanthocyclops fonticulus* n. sp.: 1, Nochusan Mt., Gujeol-ri, Jeongseon; 2, Simpi-gul Cave, Goisan; 3, Hyangjeogbong Hill, Deokyusan Mt., Muju; 4, Piagol Valley, Jirisan Mt., Gurye; 5, Muhaksan Mt., Masan.

Holotype and a paratype have been deposited in the National Institute of Biological Resources, Incheon (NIBR), Korea. Two other paratypic specimens are kept in the senior author's research collection at the specimen room of the Department of Biology, Daegu University (DB).

Abbreviations used in the text and figure legends follow the conventional ones frequently used in the taxonomy of freshwater copepods: enp 1-3 or exp 1-3, the first to third endopodal or exopodal segments of each leg.

DESCRIPTION

Acanthocyclops fonticulus n. sp. (Figs. 2-5).

Material examined

Holotype: ♀ (KB-152), spring at hilltop of Hyangjeokbong Hill (1,614m), Deogyusan Mt. (35°51'25"N, 127°44'51"E), 13 Oct. 1995, *leg.* H. S. Rho. Paratypes: 3♀♀, 3♂♂, collection details same as in holotype. Holotype and allotype (KB-153) are deposited in NIBR. Other 3 female and 2 male paratypes (DB10012) were dissected and mounted in glycerin on H-S slide.

Additional material

3♀♀, spring at Gujeol-ri Valley, Nochsan Mt., Jeongseon (37°30'00"N, 128°44'30"E), 3 May 1987 (C.Y. Chang); 2♀♀, spring at inlet of Simpi-gul Cave, Goisan, 31 Aug. 1996 (H. S. Rho); 2♀♀, spring at hilltop of Hyangjeokbong Hill, Deogyusan Mt. (water temperature: 7.1%, pH 5.9), 10 Nov. 1991 (S.H. Kim); 1♀, Piagol Valley, Jirisan Mt., Gurye, 5 Aug. 1988 (C.Y. Chang); 4♀♀ (copepodite V), spring at Muhaksan Mt., Masan, 30 May 1999 (J.M. Lee, Y.H. Song and H.S. Ahn).

Holotype female

Body (Fig. 2A) big, 1.11 mm long excluding caudal seta, and greatest width 0.37 mm. Prosome oval, 1.3 times longer than urosome; widest at posterior margin of cephalothorax, and gradually tapering behind. Rostrum reduced. Cephalothorax somewhat protruding anteriorly, more than 2 times longer than next three thoracic somites combined. Nauplius eye not observed. Genital somite 1.1 times longer than wide, anterior half rather swollen laterally (Fig. 2B). Upper part of seminal receptacle semicircular; lower part narrowed with 2 wings (Fig. 2C). Posterior margins of all urosomites with weakly crenulate hyaline fringes; posterolateral margin of anal somite with 15-18 fine spinules (Fig. 2B). Anal operculum not strongly convex, smooth on its posterior margin. Pair of spinule rows arranged in anal cleft.

Caudal rami parallel, 3.09 times as long as wide, without hairs along inner (medial) margin (Fig. 2B). Lateral seta inserted at about posterior 2/3 of lateral margin of ramus: much longer than width of ramus itself; proximal 1/3 of lateral margin interrupted by minute spinules. Outer caudal seta slightly shorter than caudal ramus, and a little less than half the length of inner caudal seta. Dorsal caudal seta naked, short, about 0.8 times the length of outer caudal seta, and about 0.75 times shorter than caudal ramus.

Antennule (Fig. 2D) very short and reaching 2/3 of cephalothorax, consisting of 11 segments. Eighth segment bearing 1 short asthetasc on lateral margin, its tip reaching midway of next segment.

Antenna (Fig. 3A, B) consisting of 4 segments, coxobasis and 3-segmented endopod; exopod represented by 1 long seta at outerodistal corner of coxobasis. Posterior face of coxobasis ornamented with a group of setules on outer distal corner, an oblique setule row on inner distal corner, and 3 groups of setules along outer margin; anterior face of coxobasis (Fig. 3B) relatively smooth, ornamented with 5 minute spinules near middle of outer margin. Mandible (Fig. 3C), gnathobase well developed, with 8-9 teeth, 3 spines, and 1 outerodistal plumose seta; mandibular palp reduced to small segment bearing 3 long plumose setae. Maxillule (Fig. 3D), praecoxal arthrite prominent with 9 elements in total; coxobasis bearing 3 setae distally on basal

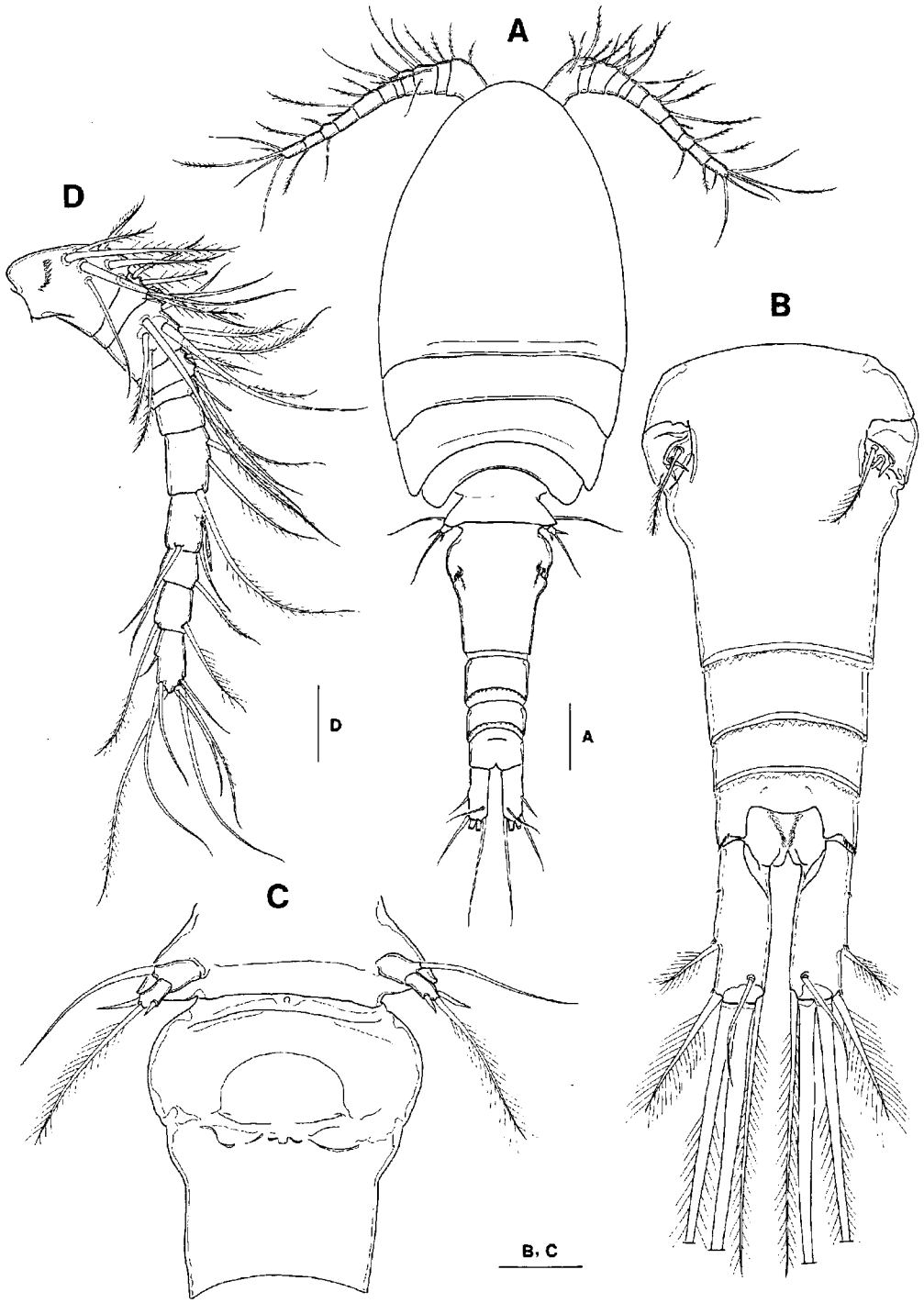

Fig. 2. *Acanthocyclops fonticulus* n. sp., female. A, habitus, dorsal; B, urosome, dorsal; C, 5th prosomite, leg 5 and genital somite, ventral; D, antennule. Scale bars = 0.1 mm (A) and 0.05 mm (B-D).

endite; exopod represented by single plumose seta on outer surface of coxobasis; endopod 1-segmented, armed with 3 long plumose setae. Maxilla (Fig. 3E), praecoxal endite with 2 plumose setae; coxa with 1 proximal seta and distal endite bearing 2 apical setae; basis armed with 3 elements; endopod with 5 elements (2 naked setae plus 3 spinuled and pectinate spines) in total. Maxilliped (Fig. 3F), syncoxa representing 3 coxal endites each with 1 seta; basis bearing 2 setae with a few setules proximal to their bases; endopod 2-segmented, each with 1 and 3 setae.

Legs 1-4 (Fig. 4A-D), biramous, both exopods and endopods 3-segmented. All intercoxal sclerites of legs 1-4 each with 2 naked lateral lobes, without particular setule/spinule ornamentation on distal margin or caudal face.

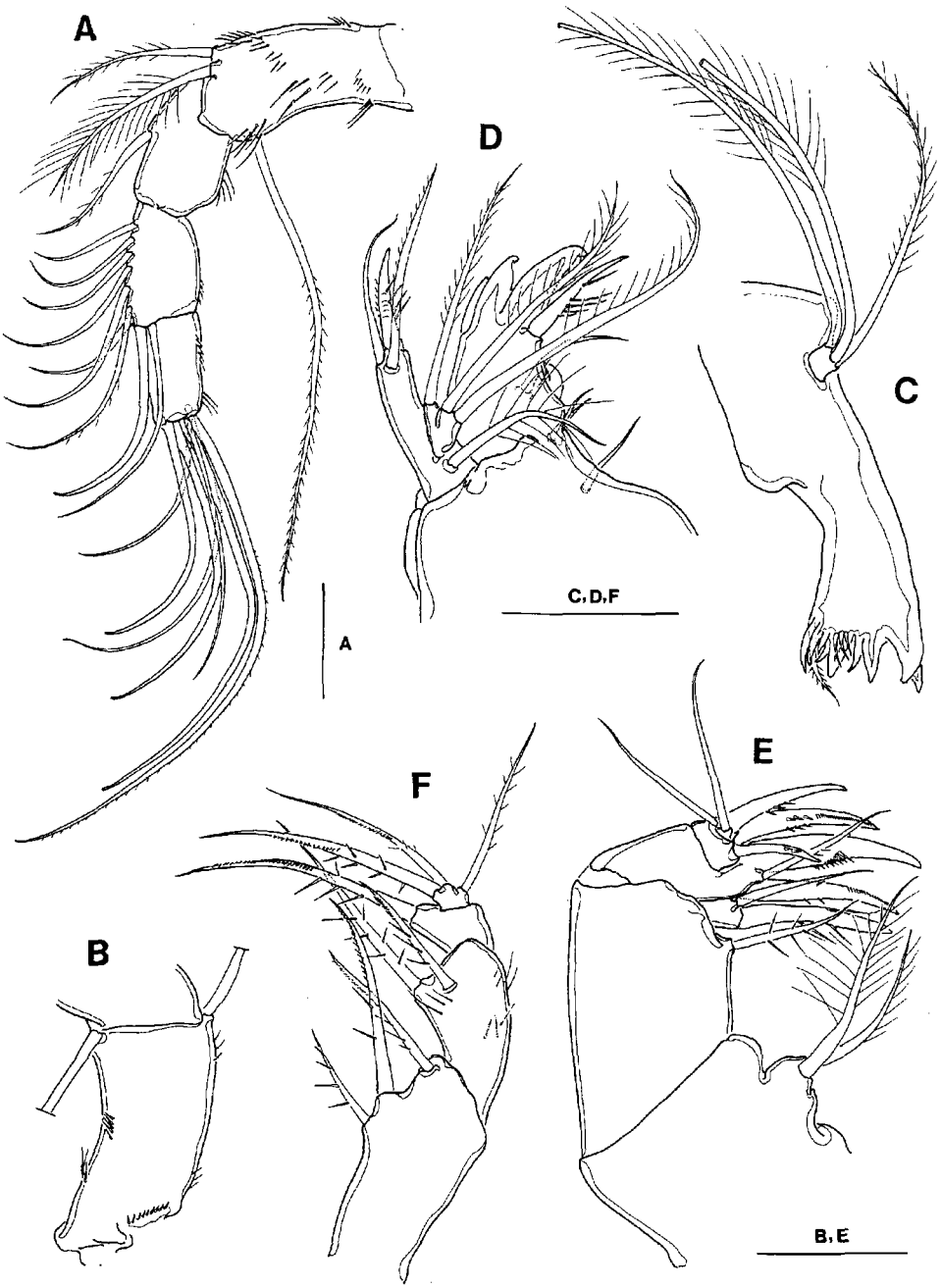

Fig. 3. *Acanthocyclops fonticulus* n. sp., female. A, antenna, posterior; B, coxobasis of antenna, anterior; C, mandible; D, maxillule; E, maxilla; F, maxilliped. Scale bars = 0.05 mm.

Distomedial corner of basis of leg 1 with 1 stout seta, exceeding enp 2. Leg 4, exp 1 lacking inner seta; enp 3 about 1.4 times as long as wide; enp 3 with only 1 apical spine, and inner spine transformed into plumose seta; outer spine slightly (1.1 times) longer than enp 3. Spine formula (number of spines on exp 3 of legs 1-4) 2,3,3,3. Seta formula (number of setae on exp 3 of legs 1-4) 4,4,4,4. Spine/seta armature of legs 2-4 as follows (Arabic numerals representing setae, while Roman numerals indicating spines):

leg 1 basis 1-1 exp I-1; I-1; II,1,3 enp 0-1; 0-2; 1,I+1,3
leg 2 basis 1-0 exp I-1; I-1; II,I,4 enp 0-1; 0-2; 1,I+1,3
leg 3 basis 1-0 exp I-1; I-1; II,I,4 enp 0-1; 0-2; 1,I+1,3
leg 4 basis 1-0 exp I-0; I-1; II,I,4 enp 0-1; 0-2; 1,I+1,2

Leg 5 composed of 2 free segments; first segment not enlarged laterally, longer than wide, with 1 naked seta distolaterally. Distal segment also longer than wide, with 1 inner spine, 1 long plumose apical seta, and 1 extra spine distolaterally; inner spine rather short (less than half the distal segment); extra spine rather long, more than 2 times

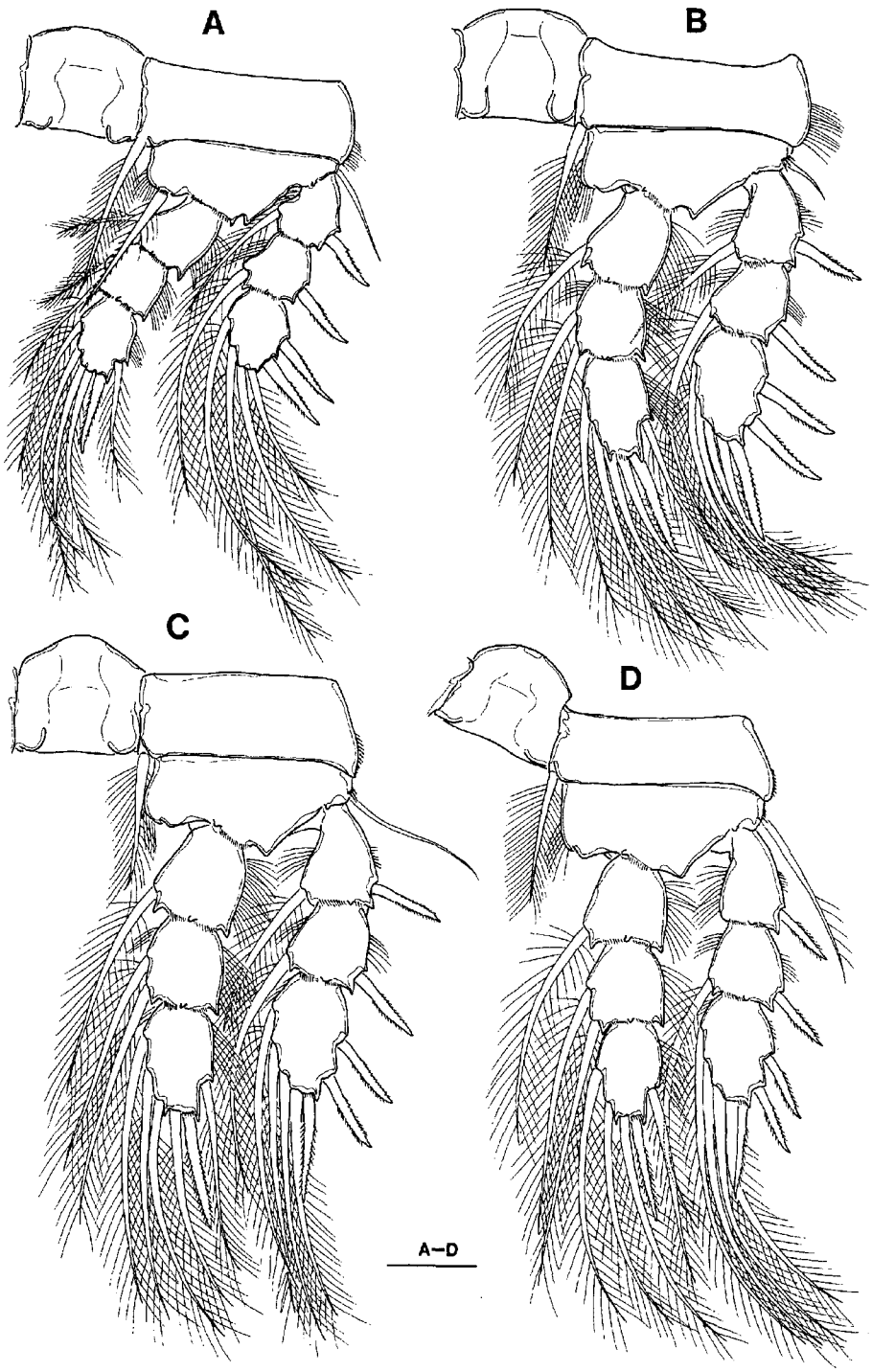

Fig. 4. *Acanthocyclops fonticulus* n. sp., female. A-D, legs 1-4. Scale bar = 0.05 mm.

as long as inner spine. Leg 6 represented by 2 strong conical projections and 1 long plumose seta on wrinkled genital operculum, dorsally locating at both sides of anterior part of genital somite (Fig. 2B).

Allotype male

Body (Fig. 5A) 0.74 mm long, about 2/3 of body length of holotype female. Antennules (Fig. 5B) geniculate, of 14-segmented; 1st, 9th and 14th segments each with 1 aesthetasc; first 3 segments bearing plumose setae. Leg 6 represented by indistinctly separated plate with innermost spine, middle seta (nearly as long as inner spine), and outer (subdorsal) seta (its tip a little beyond posterior margin of succeeding somite). Other characters, including caudal

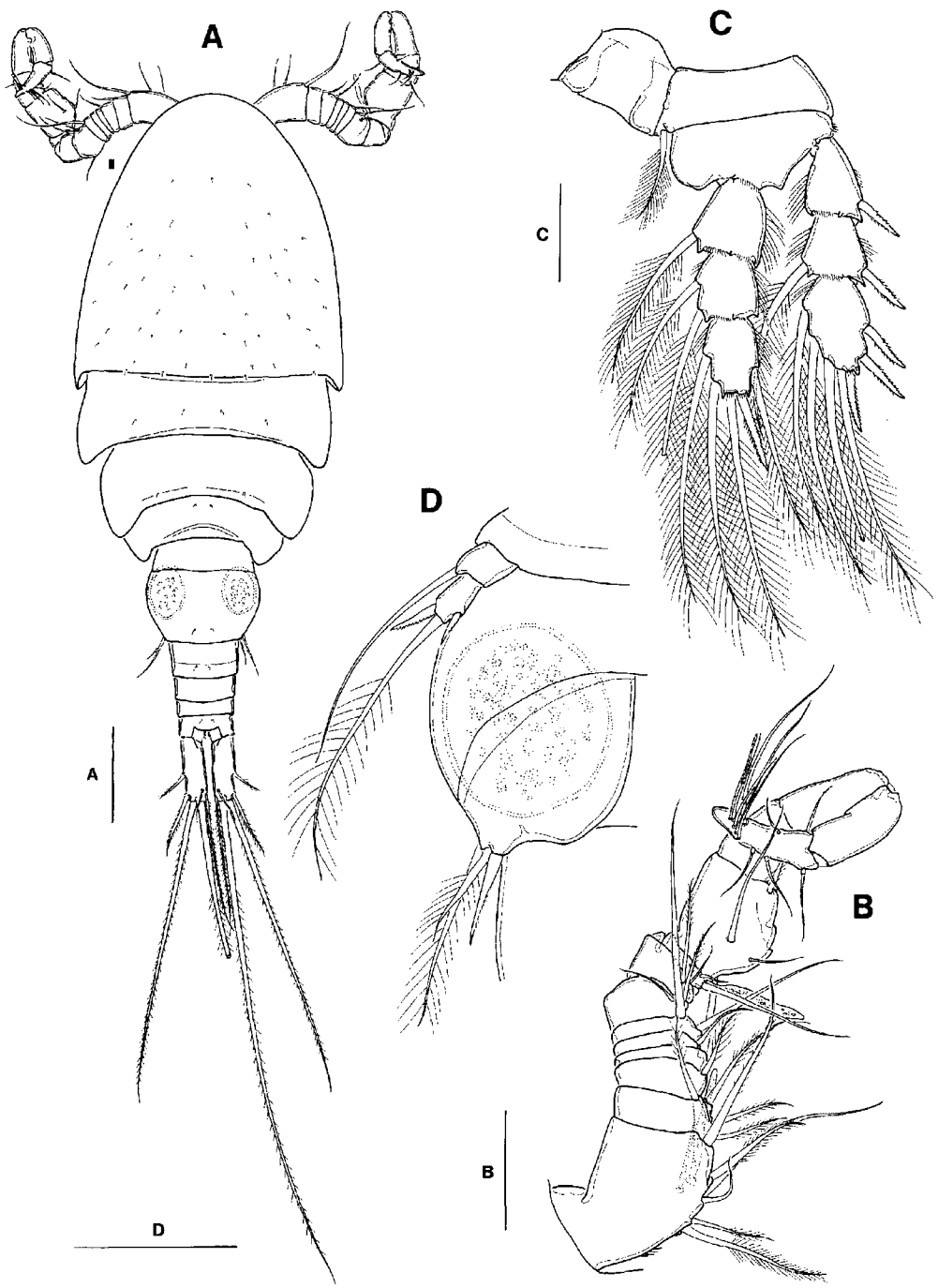

Fig. 5. *Acanthocyclops fonticulus* n. sp., male. A, habitus, dorsal; B, antennule; C, leg 4; D, legs 5-6 and genital somite, ventral. Scale bars = 0.1 mm (A) and 0.05 mm (B-D).

rami and caudal setae, single spine on leg 4 enp 3, extra outer spine on distal segment of leg 5, and disappearance of inner seta on leg 4 exp 1, much similar as in female holotype.

Variability

Body length ranges 1.06-1.11 mm in 9 females measured, and 0.74-0.78 mm in 3 males measured. Length to width ratio of caudal rami ranges 2.89-3.15 (mean 3.03, standard deviation 0.12, N = 12). Length ratio of inner caudal seta to outer caudal seta ranges 1.68-2.20 (mean 1.94, standard deviation 0.26, N = 12). Length ratio of dorsal caudal seta to caudal ramus ranges 0.78-0.93 (mean 0.86, standard deviation 0.07, N = 12). In all the specimens mounted, next characteristics are consistent and invariable: on leg 5, extra outer spine is present distolaterally, which is much longer than the inner spine; on leg 4 enp 3, only outer apical spine

is present, and inner one invariably substituted by a seta; on leg 4 exp 1, inner seta is fully lacking; inner surface of caudal ramus is naked without hairs or spinules. No significant differences are not found between two samples collected from same locality (a spring at hilltop of Hyangjeokbong Hill, Deogyusan Mt.) but in different times (on 10 November 1991 and 13 October 1995).

Habitat

Specimens were collected from small mountain springs, situated rather high in altitude (380-1,614 m high).

Etymology

The specific name (*fonticulus*, Latin) means "spring or fountain", taken from the main habitat the new species occurred.

Remarks

Acanthocyclops fonticulus n. sp. is similar to the subterranean species from Japan, *A. morimotoi* Ito, 1952, *A. miurai* Ito, 1957 and *A. kagaensis* Ito, 1964 in having the single apical spine on the last endopodal segment of leg 4. Among them, female of *A. morimotoi* has only one apical spine distally, while male has the normal character state of two apical spines. The female of *A. morimotoi* certainly has lost one apical spine considering the lack of apical seta besides the two setae on the inner margin. In the latter two Japanese species and this new species, both sexes have one spine and one seta apically by the transformation of the inner one of the two apical spines into a plumose seta. It's uncertain whether the loss and/or transformation are the genuine synapomorphy or a convergence resulted from the subterranean life adapting to groundwater environment. This new species differs from them by having 11-segmented antennules, while they have 12-, 12- and 17-segmented antennules in order.

The other peculiarity of *A. fonticulus* n. sp. is the extra outer spine on distal segment of leg 5 in both sexes, which apparently discriminates it from the Japanese subterranean species above as well as the European groundwater species with 11-segmented antennules. The single inner spine with an apical seta on the distal segment of leg 5 is one of the key characters of the genera *Acanthocyclops* and *Diacyclops*. However, leg 5 bearing an additional spine on distolateral corner have been reported in a few species of the genera. In the description of *A. montana* Reid and Reed from the groundwater in Montana, U.S.A., Reid et al. (1991) mentioned the variability of the extra spine on leg 5, that is, some had the feature (11 of 22 females examined had extra spine; 9 of 12 males did so) as well as intergrades (bearing leg 5 with the extra spine on the one side, while 'normal' leg 5 with 1 spine only on the other side of the body). They suggested the plasticity of this feature based on another case of *A. venustoides bispinosus* Yeatman, 1951 with discussion on the occurrences of the extra spine shown in other reports of the species (*see* Reid et al., 1991). Ishida (1994) recorded *Diacyclops dispinosus* from Hokkaido, Japan, which always has the extra spine on leg 5. All our specimens from several localities also consistently show the extra spine, including the copepodites.

Acanthocyclops fonticulus n. sp. is apparently allied with eleven congeneric species bearing 11-segmented antennules: *A. kieferi* (Chappuis, 1925), *A. reductus* (Chappuis, 1925), *A. exilis* Coker, 1934, *A. hispanicus* Kiefer, 1937, *A. notabilis* Mazepova, 1950, *A. profundus* Mazepova, 1950, *A. biarticulatus* Monchenko, 1972, *A. sambugarae* Kiefer, 1981, *A. petkovskii* Pesce and Lattinger, 1983, *A. similis* Flössner, 1984, and *A. parvulus* Strayer, 1988. Among them, except for the two peculiar features above, this new species closely resembles the *A. kieferi* group in sharing 3-segmented endopods and exopods in legs 1-4, spine formula of 2,3,3,3, similar style of seminal receptacle, lateral caudal seta locating at distal third of lateral margin of caudal rami, and smooth inner face of caudal rami. However, *A. fonticulus* is discernible from the *A. kieferi* group by having the character combination of elongate caudal rami (more than 3 times longer than wide, while less than 2.5 times in *A. kieferi, A. reductus, A. sambugarae* and *A. parvulus*), the long inner caudal seta (about 2 times longer than outer caudal seta, while shorter or at most nearly as long as outer one in *A. kieferi, A. reductus* and *A. parvulus*), and short dorsal caudal seta (shorter than caudal ramus and outer caudal seta in *A. fonticulus*, while much longer in *A. kieferi*, *A. hispanicus* and *A. parvulus*, and about equal or slightly longer in *A. exilis* and *A. similis*); outer spine on leg 4 enp 3 is much longer than enp 3 (while much shorter in the *A. kieferi* group). *Acanthocyclops notabilis* and *A. profundus* from the Lake Baikal and *A. biarticulatus* from a well in the Kisilkum Desert region, Samarkand, Uzbekistan differ clearly from this new species by haired caudal rami and laterally enlarged proximal segment of leg 5 in *A. notabilis*, and by 2-segmented endopod(s) in *A. profundus* and *A. biarticulatus*.

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