

**Taxonomy on *Canthocamptus semicirculus* and *C. coreensis* n. sp.
(Harpacticoida, Canthocamptidae), with a Key to the
C. mirabilis Species Group from South Korea**

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ABSTRACT

As one of the serial studies on the taxonomy of *Canthocamptus mirabilis* species group in South Korea, *C. semicirculus* Kikuchi, widely distributed in the southern part of the Far East, and *C. coreensis* n. sp. from the middle west of South Korea are recorded. Intraspecific variability of some important characters like outer caudal setae and the spinous process of male leg 3 exopod was examined in Korean population of *C. semicirculus*. *Canthocamptus coreensis* n. sp. possesses the plesiomorphic characters of the round and narrow hyaline membrane of anal operculum and lacking the sexual reverse transformation in female caudal rami, while it also evolves the apomorphic ones of the modified outer apical setae of male leg 4 exopod and the spinous process of male leg 3 exopod. A key to the five species of the species group known from Korea is prepared.

Key words: Taxonomy, *Canthocamptus mirabilis* species group, Canthocamptidae, key, Harpacticoida, freshwater Copepoda, Korea

INTRODUCTION

Canthocamptus mirabilis species group, first noticed as "Atthyella-like *Canthocamptus*" by Ito

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and Takashio (1980), and then thereafter named as “*mirabilis*-group” by Kikuchi and Ishida (1994), has been known from the various mountain water bodies of the Far East with great abundance and frequent occurrences [see the previous papers (Chang, 1998, 2001; Chang and Ishida, 2001) for the detailed history and review on the species group]. Total eight species are currently recognized in this species group: *C. mirabilis* Štěrba, 1968 from Beijing, China; *C. morimotoi* Miura, 1969, *C. incurvisetosus* Chang and Ishida, 2001, and *C. odaeensis* Chang and Ishida, 2001 from South Korea; *C. prominulus* Kikuchi, 1994, *C. semicirculus* Kikuchi, 1994, *C. resupinatus* Ishida, 1994, and *C. tomikoeae* Ishida, 1994 from Japan. *Canthocamptus mirabilis* sensu Ito and Takashio, 1980 reported from Japan are remaining as *incertae sedis* (see Chang, 2001).

As one of the serial studies on the *mirabilis*-group harpacticoids from South Korea, this paper deals with taxonomic accounts of a known species *C. semicirculus* Kikuchi and the description of a new species *C. coreensis*. In addition, a key to the five species of *C. mirabilis* group from South Korea is provided.

MATERIALS AND METHODS

Collections were made with a dipnet of no. 10 mesh aperture. All the specimens were dissected, drawn, and measured in lactophenol on H-S slide (Shirayama *et al.*, 1993), a recent variation of Cobb slide. Mounted specimens were observed under a differential interference contrast microscope with Nomarski optics. Figures were supplied with the aid of camera lucida.

Type specimens are deposited in the Natural History Museum of Ewha Womans University (EWNHM) and the Department of Biology, Daegu University (DB).

Abbreviations are used in the text and figure legend: enp 1-3 or exp 1-3 indicate the first to third endopodal or exopodal segment of each leg; Fn means the normal caudal ramus, and Fr the male-type caudal ramus of females resulted from the sexual reverse transformation.

TAXONOMIC ACCOUNTS

Family Canthocamptidae Sars, 1906 딱정장수노벌레과

Subfamily Canthocamptinae Chappuis, 1929 딱정장수노벌레아과

Genus *Canthocamptus* Westwood, 1836 딱정장수노벌레속

***Canthocamptus semicirculus* Kikuchi, 1994 반달딱정장수노벌레 (신칭) (Fig. 1)**

Canthocamptus semicirculus Kikuchi, in Kikuchi and Ishida, 1994, p. 40, fig. 5; Ishida and Kikuchi, 2000, p. 16, fig. 12.

Material examined. One ♀, 2 ♂♂, Naerincheon Stream, Inje, 6 Nov 1999, J. M. Lee; 4 ♀♀, 1 ♂♂, Yongmunsa Temple, Yangpyeong, 15 Nov 1999, C. Y. Chang and J. M. Lee; 3 ♀♀, 2 ♂♂, Cheoneunsa Temple, Chungju, 31 May 1991, S. H. Kim; 1 ♀, 1 ♂♂, Mt. Sudeok, 28 Oct 1995, C. Y. Chang; 1 ♀, 1 ♂♂, Magoksa Temple, Gongju, 19 Nov 1999, C. Y. Chang and J. M. Lee; 3 ♀♀, 10 ♂♂, Mt. Cheongryang, 5 Apr 1995, J. M. Lee; 1 ♀, 1 ♂♂, Chunyang, 5 May 1987, C. Y.

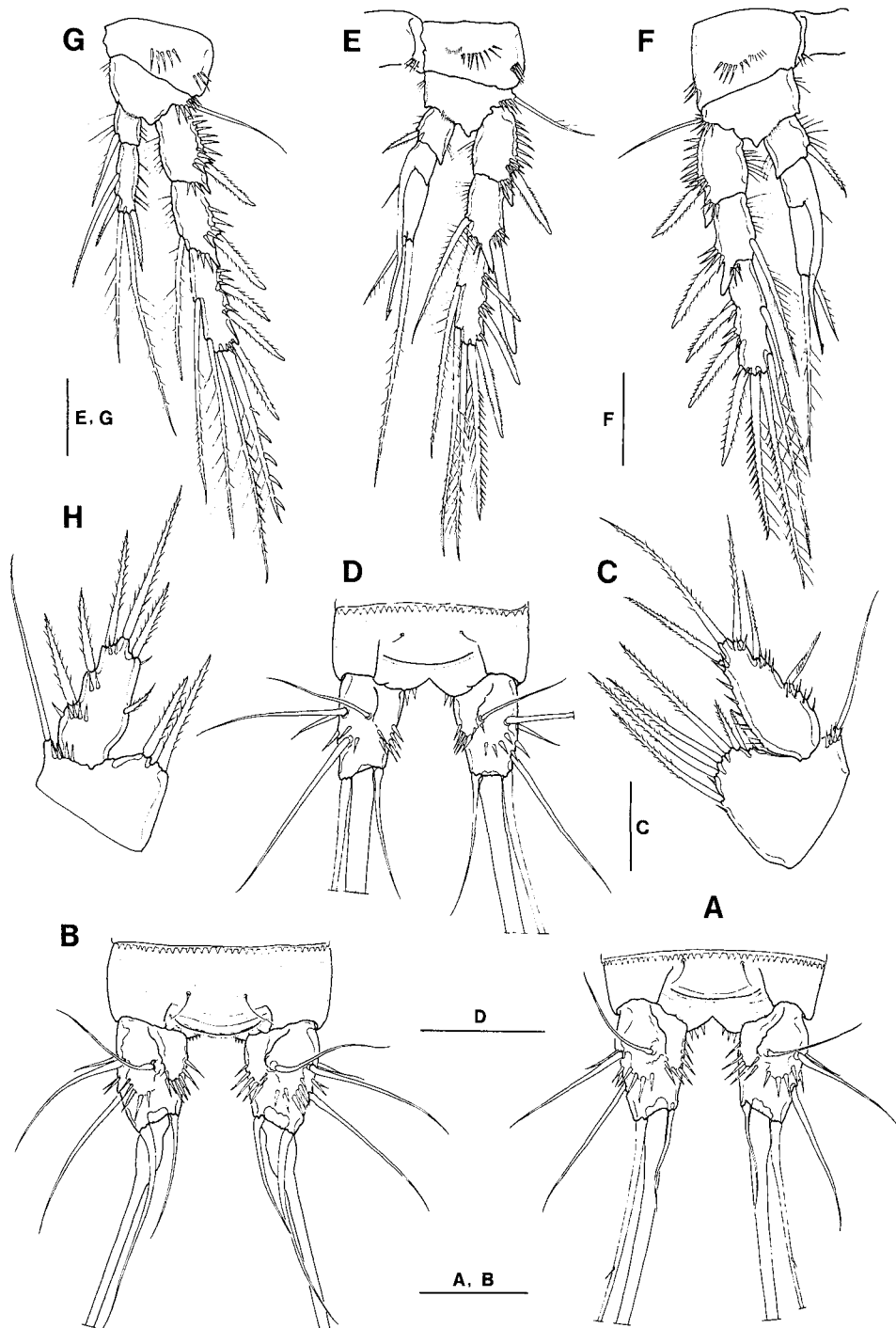


Fig. 1. *Canthocamptus semicirculus* Kikuchi. A-C, female: A, anal segment and caudal rami (normal); B, anal segment and caudal rami (variation); C, leg 5. D-H, male: D, anal segment and caudal rami; E, leg 3 (normal); F, leg 3 (variation); G-H, legs 4-5. Scale bars = 0.05 mm.

Chang and S. M. Yoon; 15 ♀ ♀, 12 ♂ ♂, Bulyeong Valley, Uljin, 1 Feb 2002, C. Y. Chang, J. M. Lee and E. H. Kwon; 1 ♀, 1 ♂, Jangyuksa Temple, Yeongdeok, 4 Dec 1999, C. Y. Chang and J. M. Lee; 1 ♀, 1 ♂, Mt. Hoimun, Sunchang, 4 Sep 1999, J. M. Lee and H. S. Ahn; 1 ♀ (ovi.), Mt. Seonun, 30 Oct 1999, C. Y. Chang; 15 ♀ ♀, 13 ♂ ♂, Unjusa Temple, Hwasun, 15 Jan 2000, C. Y. Chang and J. M. Lee; 25 ♀ ♀, 19 ♂ ♂, Ssanggyesa Temple, Jindo I., 1 Nov 1994, C. Y. Chang, S. J. Song and J. M. Lee.

Diagnosis. Body stout, biggest in the Korean *mirabilis* species group, 0.88-1.12 mm long in females and 0.71-1.03 mm in males, excluding rostrum and caudal setae; anal operculum convex with round and very narrow hyaline membrane; caudal rami of both sexes (Fig. 1A, B, D) similar with each other, subconical but not so abruptly narrowing distally, about 1.65-1.75 times as long as wide, with a row of slender spinules on medial face and 6-8 spinules on posterolateral corner of dorsal surface; secondary setules on outer caudal seta lacking in general or rarely few; antennule, antennal exopod and female legs 2-4 with typical characteristics of *Canthocamptus mirabilis* species group; female leg 5 exopod (Fig. 1C) furnished with several setules along medial margin and 2 spinules on disteromedial corner; male leg 3 (Fig. 1E) armed with modified spinous process on outerodistal corner of exp 2, its tip slightly exceeding distal end of exp 3 (some Korean variations possessing unmodified spine as that of female as in Fig. 1F); outer terminal seta of male leg 4 exp 3 modified and furnished with 5-6 strong secondary spinules on outer margin of the seta (Fig. 1G).

Variability. Females possessed normal-type caudal rami (Fig. 1A) only, which were similar (isomorphic) to those of males (Fig. 1D); caudal rami of both sexes were always furnished with the setule array on the medial face of caudal rami. Terminal caudal seta often a little swollen at its base. Lots of specimens from six of 17 Korean samples had the incurved outer caudal setae, but without any secondary setules (Fig. 1B). Part (about 30%) of the specimens bearing the incurved outer caudal setae, showed the additional abnormality of not-modified (female type) apical seta of male leg 4 exopod. All females examined unexceptionally had their typical setule array on the medial margin of leg 5 exopod (Fig. 1C). Hardly were found the male individuals possessing three spiniform setae or only one seta on leg 5 baseoendopod. Nearly all males examined had spinous process on leg 3 exp 2 (Fig. 1E) as in original description (Kikuchi and Ishida, 1994), while three of 49 specimens had unmodified spine (Fig. 1F), similar to that of females. No particular difference was detected in the major setal ornamentation of legs 2-4 in both sexes.

Remarks. As mentioned above, in a few samples from Hwasun, Yeongdeok, and Mt. Cheongryang appeared the morphological variations in the significant traits which are characteristic to *mirabilis* species group, that is, incurved outer caudal seta, unmodified spine of male leg 3 exopod 2, unmodified apical seta of male leg 4 exopod, or combinations of them. Among the variable characters, the incurved outer caudal seta reminded that of *C. incurvisetosus*. Considering that those variations were found in the distribution range of *C. incurvisetosus*, especially when they co-occurred, the unstable gene expressions might be resulted by the sporadic introgressive hybridization between the two species.

However, most Korean subpopulations of *C. semicirculus* were coincided well with the original description (Kikuchi and Ishida, 1994) and Japanese specimens which Dr. T. Ishida kindly sent to me, except some minor morphological discrepancies like not too diminished distal inner seta of

male leg 4 endopod (cf. Kikuchi and Ishida, 1994, Fig. 5g; Ishida and Kikuchi, 2000, Fig. 12i), and a little elongated male leg 3 enp 3.

This species was often co-occurred with *C. incurvisetosus*, especially at the mountain streamlets in the southern part of South Korea, and sometimes with *C. coreensis* in the middle western part (Gyeonggi-do and Chungcheongnam-do Provinces) of South Korea.

Affinities are discussed together in the 'Remarks' section of the following species.

Distribution. Japan (Kyushu, Shikoku and Honshu), Taiwan, South Korea.

***Canthocamptus coreensis* new species** 고려딱정 장수노벌레 (신칭) (Figs. 2-4)

Type material. Holotype ♀ (DB10361), spring at Janggoksa Temple, Mt. Chilgap, Cheongyang (37° 45' 59"N, 128° 52' 27"E), 4 Mar 1991, C. Y. Chang; allotype (DB10362), and 9 paratypes (3 ♀♀, 4 ♂♂ -DB10363-10369; 1 ♀, 1 ♂ -EWNHM60267), same data as holotype.

Additional material examined. Two ♀♀, 1 ♂, Yongmunsa Temple, Yangpyeong, 15 Nov 1999, C. Y. Chang and J. M. Lee; 1 ♀, Hakgok-ri, Hoingseong, 20 Jul 1986, C. Y. Chang; 1 ♀, 3 ♂♂, Seopo-ri, Deokjeok I., 27 Oct 1995, M. O. Song; 1 ♀, 1 ♂, Mt. Gyeryong, 5 Jul 1987, C. Y. Chang; 1 ♀, 1 ♂, Gaetaesa Temple, Nonsan, 21 Sep 1999, C. Y. Chang; 1 ♀, Mt. Moak, Jeonju, 29 Oct 1999, J. M. Lee.

Female. Body (Fig. 2A) 0.59-0.65 mm long (0.62 ± 0.03 mm, N = 4), excluding rostrum and caudal setae; broadest near posterior margin of cephalothorax, tapering behind. Cephalothorax a little protruding, much longer than succeeding three thoracic somites combined. Dorsal and lateral surface of thoracic somites sparsely haired; posterior part of cephalothorax with 7-8 longitudinal folds along its posterior margin, each bearing a hair at its tip; posterior margins of next somites furnished with a row of setules. Genital double somite a little wider than long, subdivided by a pair of lateral suture at about half of lateral margin, each with a seta near dorso-medial end of lateral suture. Genital area 'T'-shaped; flanks rather short. Each abdominal somite bearing 1 row of spinules on outerodistal corner, and hyaline frill with posterior margin serrated. Posteromedial corner of ventral side of anal segment bearing 2-3 sharp spinules (Fig. 2B). Anal operculum convex with smooth hind edge. Hyaline membrane (Figs. 2B) round and very narrow, its tip not beyond posterior margin of anal segment. No specimens examined carried egg sac.

Caudal ramus (Fig. 2B) stumpy, subconical, about 1.2 times as long as wide, medial margin rather straight and not so divergent while lateral margin much narrowing posteriorly; with a row of slender setules on medial face; strong spinules on posterolateral corner of ramus with semicircular arrangements (but usually shown as 2 inclined rows when observed with dorsal view); outer caudal seta with inward-pointing sharp secondary spinules from proximal one sixth to proximal quarter; terminal caudal seta stout, a little bent and swollen at its base, lacking proximal breaking plane; inner caudal seta plumose.

Rostrum (Fig. 2A) not prominent, protruding anteroventrally, not defined at its base. Antennule (Fig. 2C) with typical characteristics of genus *Canthocamptus*, of 8-articulated, bearing 1 aesthetasc on anterodistal edge of fourth article, its tip slightly beyond distal end of antennule; last segment with slender aesthetasc. Exopod of antenna (Fig. 2D) distinctly 2-segmented; proximal segment markedly slender, bearing 1 seta on inner distal edge; distal segment bearing 1 medial and 2 apical setae. Endopod nearly as long as allobasis, swollen distally; furnished with 2 stout spines

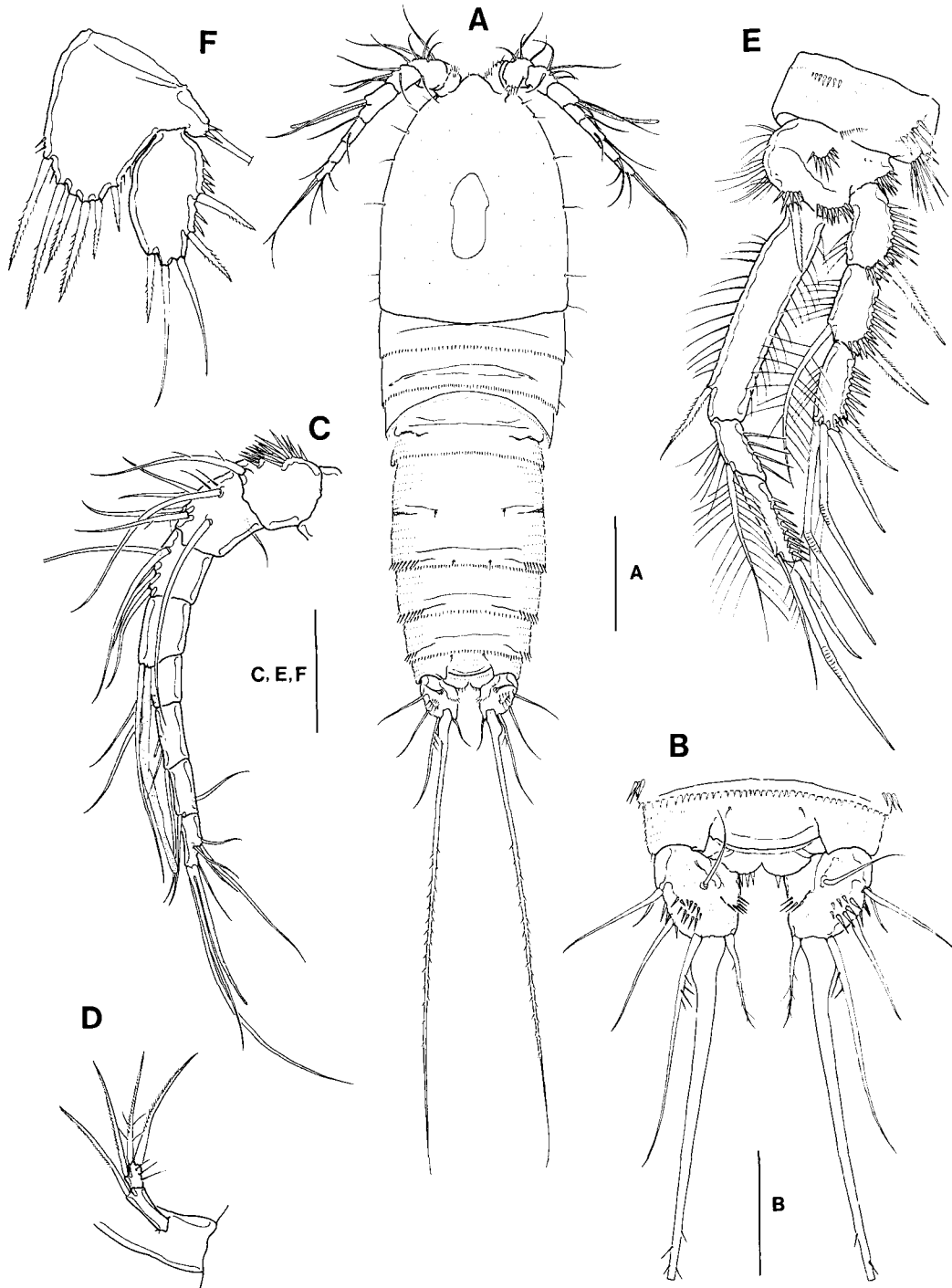


Fig. 2. *Canthocamptus coreensis* new species, female. A, habitus (dorsal). B, anal segment and caudal rami; C, Antennule; D, antennal exopod; E, leg 1; F, leg 5. Scale bars = 0.1 mm (A) and 0.05 mm (B-E).

on distal half of anterior face. Mandible, maxillule, maxilla, and maxilliped with typical characteristics of genus *Canthocamptus* and showing no significant difference from those of related members of *mirabilis* species group (cf. Ito and Takashio, 1980; Chang and Ishida, 2001).

Both exopod and endopod of legs 1-4 consisting of 3 segments except endopod of leg 4 with 2 segments. Leg 1 enp 1 (Fig. 2E) a little shorter than exopod, with 1 stout plumose seta on distal sixth of inner margin; enp 2 with 1 plumose seta on innerdistal corner and 3-4 sharp spinules on outer edge; enp 3 slender bearing 2 geniculate spines and 1 seta. Exopodal segments with similar length each other; exp 2 with 1 inner seta; exp 3 bearing 2 outer and 2 geniculate spines. Distal edge of intercoxal sclerites of legs 2-4 (Figs. 3A-C) with several spinules. The ornamentation of legs 2-4 as follow (Roman numerals indicating spines and Arabic numerals representing setae):

Leg 2	basis I-0	exp I-0; I-1; III,2,1
		enp 0-1; 0-1; I,2,2
Leg 3	basis 1-0	exp I-0; I-1; III,2,2
		enp 0-1; 0-1; I,2,2
Leg 4	basis 1-0	exp I-0; I-1; III,2,2
		enp 0-1; I,2,2

Distal end of leg 5 baseoendopod (Fig. 2F) reaching middle of exopod; baseoendopod not confluent at its base, connected by intercoxal sclerite; bearing 6 spiniform setae, of which outermost two smallest and second one from the inner longest. Exopod rather subovoidal, a little tapering distally, about 1.5-1.8 times as long as broad; inner margin swollen and roundish; armed with 5 'awn-type' setae, of which apical one slightly longer than exopod; inner seta locating subdistally; disteromedial corner of exopod usually smooth without spinules, but rarely with 2-3 spinules on ventral side.

Male. Body (Fig. 4A) 0.54-0.59 mm long (0.56 ± 0.03 mm, N = 7). Posteroventral margins of urosomes armed with a row of strong spinules. Each posteromedial corner of anal somite with 5-6 spinules, innermost two of which bigger, but relatively short and not so strong in comparison with those of other members. Anal operculum round and bearing narrow hyaline membrane along posterior margin. Caudal rami subconical and not spindle-shaped, nor reversed bottle-shaped, 1.24 times longer than wide, a little different from those of females; a row of setules on inner surface of rami; spinule array on posterolateral corner of ramus absent; outer caudal seta normal (Fig. 4B). Antennule as shown in Fig. 4A. Leg 2 (Fig. 4C), enp 1 with 1 inner seta; enp 2 bearing 3 inner, 2 long apical setae, with outer setules; exp 3 with 1 inner seta, distal part of which modified. Leg 3 (Fig. 4D), enp 2 armed with 1 sharp spine and 1 process (apophysis) slightly exceeding exp 3, possessing terminal barb; enp 3 much elongate, a little longer than sum of two preceding ones, tapering terminally, ending with 2 plumose setae; exp 2 armed with a stout spinous process on outerodistal corner, its tip much exceeding distal end of exp 3; exp 3 ornamented with 2 inner plumose setae, distal part of which modified (with a row of minute spinules on inner tip). Leg 4 (Fig. 4E) nearly same in shape with female's, except for outer terminal seta of exp 3 modified and furnished with 3-4 lanceolate secondary spinules on outer margin of the seta; inner proximal seta on exp 3 normally plumosed, while distal one modified on its distal part; distal inner seta on enp 2

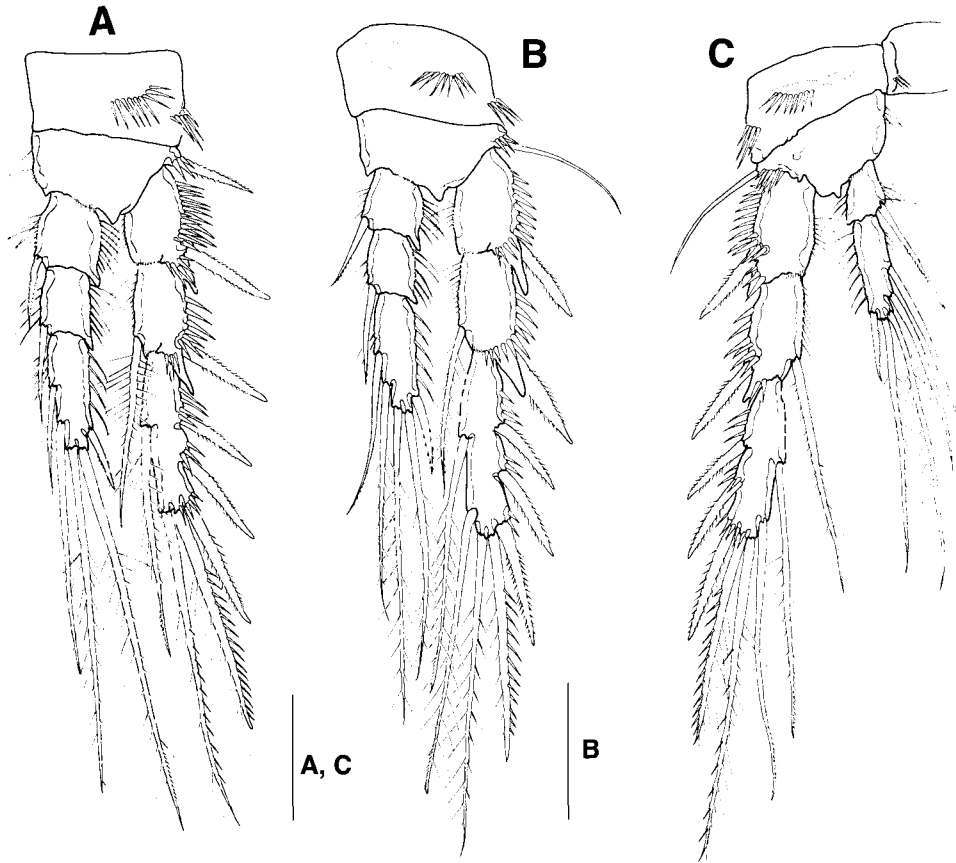


Fig. 3. *Canthocamptus corensis* new species, female. A-C, legs 2-4. Scale bars = 0.05 mm.

not diminished, with its tip modified. Baseoendopod of leg 5 (Fig. 4B) confluent; endopodal lobe protruding, nearly reaching middle of exopod; bearing 2 terminal spiniform setae, inner one about 1.7 times longer than the outer; inner margin smooth. Exopod 1.9 times longer than broad, armed with 6 setae in total, consisting of 1 weak plumose seta on inner middle, 1 inner subapical, 2 distal, and 2 outer setae. Leg 6 represented by a small plate bearing 1 stout inner spine and 2 slender setae.

Variability. Females possessed normal-type caudal rami (Fn) only, and the male type caudal rami (Fr) were not observed; caudal rami were always furnished with the setule array on the medial face of caudal rami in both sexes; the female terminal caudal setae were unexceptionally bent at its base, and swollen in 7 of 36 females examined; no significant variation was observed in the ornamentation of outer caudal seta of both females and males, which were consistently furnished with 2-3 pairs of slender secondary setules usually pointing inward in females, while 4-5 pairs pointing outward in males. Five of 36 female specimens examined possessed the spinules on the posteromedial corner of leg 5 exopod. All females unexceptionally had the awn-type setae on

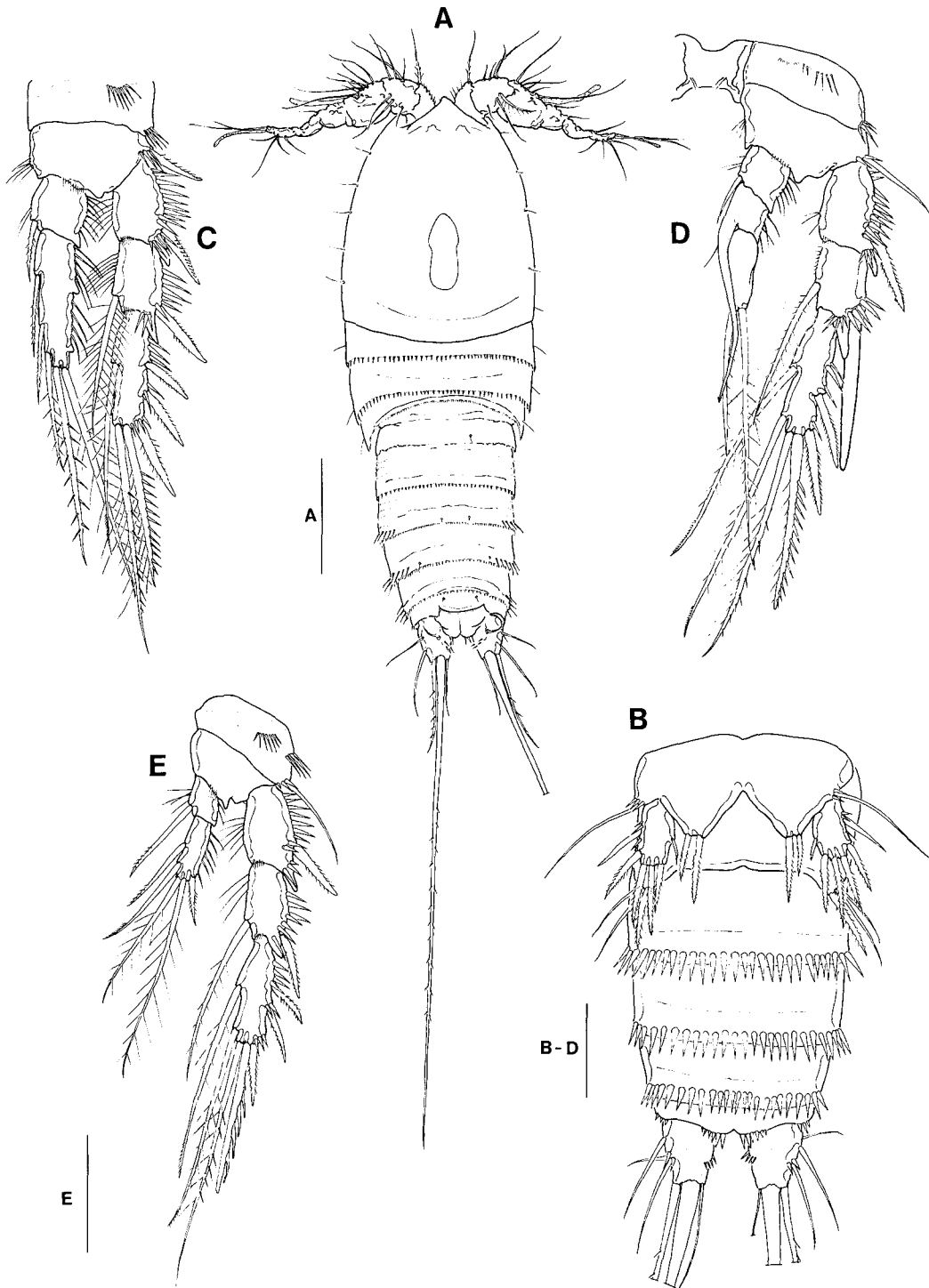


Fig. 4. *Canthocamptus coreensis* new species, male. A, habitus (dorsal); B, urosome (ventral); C-E, legs 2-4. Scale bars = 0.1 mm (A) and 0.05 mm (B-E).

exopods of leg 5. Rather plastic were the length of the spinous process on outerodistal corner of male leg 3 exp 2, its tip generally much exceeding the distal end of exp 3, but sometimes scarcely reaching the tip of exp 3. Two specimens of total 21 male specimens armed with two spines on one P5 exopod and one spine on other. No other particular difference was detected in the principal setal ornamentation of legs 1-5 among the specimens examined.

Remarks. As mentioned in the previous papers, *Canthocamptus mirabilis* species group is "Attheyella-like *Canthocamptus*" (Ito and Takashio, 1980) possessing its own intermediate features between the two genera. This peculiar *Canthocamptus* turned out to be a species group of closely related and largely allopatric or parapatric species, to be called as the *mirabilis* group (Kikuchi and Ishida, 1994).

As they are the member of species group or superspecies (cf. Mayr and Ashlock, 1991, p. 53), and recently diversified at their own distributional range via parapatric speciation, their morphological differences are usually rather subtle. So, during their adaptive radiation, they must have developed the reproductive isolation mechanism like a certain character displacement for avoiding the interspecific hybridization. In consideration of the coupling pattern (cf. Chang, 2001, Fig. 4A, B), the most important cognition markers for perceiving their sexual partner would be the caudal rami of both sexes, anal operculum, and inner or outer caudal setae. With those characters, the morphological difference of genital appendages like leg 5 of both sexes and male's legs 2-4 would reinforce the reproductive isolation. Furthermore, the distribution of each species and co-occurrences would also suggest their relationships and morphological diversification.

Among the ten species of *mirabilis* group so far recorded, including *C. coreensis* n. sp., *C. semicirculus* Kikuchi is the most distinct species. It has very wide distribution range throughout the southern part of the Far East from Taiwan via South Korea to Japan (south of Honshu). It is the only species in the *mirabilis* group that shows no sexual dimorphism in the shape of caudal rami between sexes. *Canthocamptus tomikoeae* Ishida, reported from southern part of Japan, is supposed to be the most allied species with *C. semicirculus* in sharing the character combination of medial setules of female leg 5 exopod and the undeveloped hyaline membrane extension of anal operculum. In South Korea, *C. semicirculus* sometimes shows the unstable character states when it meets *C. coreensis* or *C. incurvisetosus* as already mentioned.

Except *C. semicirculus*, the other four species from South Korea are endemic, of which *C. incurvisetosus* is widely distributed and frequently occurred from various mountain waters in South Korea, while the others are confined to the fairly narrow distribution ranges of their own (see Chang and Ishida, 2001). *Canthocamptus coreensis* n. sp. from the middle west of South Korea most resembles *C. mirabilis* Štěrba, 1968 from Beijing, China (= *Attheyella amurensis* sensu Shen and Sung, 1973 reported from Kirin, South Manchuria) and *C. mirabilis* sensu Ito and Takashio, 1980 from Japan in sharing the round and narrow hyaline membrane of anal operculum, the modified outer terminal setae of male leg 4 exopod and the spinous process of male leg 3 exopod. However, *C. coreensis* is evidently discernible from them in having the foliaceous female leg 5 exopod and detailed morphological discrepancies shown in caudal rami as well as lacking the sexual reverse transformation in female caudal rami (that is, only normal type of female caudal rami exists). The male caudal rami of *C. coreensis* is neither spindle-shaped nor reversed bottle-shaped but somewhat short subconical, which are similar to those of *C. morimotoi*

Miura, the subterranean species distributing from Goesan to west of Seorak.

Other species currently known, *C. incurvisetosus* and *C. odaeensis* in Korea, and *C. prominulus* and *C. resupinatus* in Japan, are thought to be the successive group of *C. coreensis* or *C. mirabilis* sensu Ito and Takashio respectively in the regional speciation seemingly by the recent acquirement of the apomorphic characters of hyaline membrane extension. They are differentiated from *C. coreensis* by the character combination of the ornamentation of outer apical seta in male leg 4 exopod, loss of the setule array in the medial face of male caudal ramus, and the modification of outer caudal seta.

A key to the five Korean species including the new species is prepared as follows.

A key to the species of the *Canthocamptus mirabilis* group from Korea

1. Hyaline membrane of anal operculum lacking or, if present, very narrow 2
 Hyaline membrane of anal operculum prominent, usually triangular 3
2. Caudal rami of both sexes isomorphic; leg 5 exopod with medial setules
 *C. semicirculus* Kikuchi, 1994
 Caudal rami of both sexes different; leg 5 exopod with smooth medial margin
 *C. coreensis* n. sp.
3. Apical seta of male leg 4 exopod modified, with 4-5 strong secondary spinules; Fn-type caudal rami lacking medial setules; outer terminal caudal seta incurved with 2-3 setules
 *C. incurvisetosus* Chang and Ishida, 2001
 Apical seta of male leg 4 exopod normal, with more than 20 pectinate spinules; Fn-type caudal rami with medial setules; outer terminal caudal seta normal 4
4. Male caudal rami elongate and spindle-shaped, with medial setules
 *C. odaeensis* Chang and Ishida, 2001
 Male caudal rami stumpy and subconical, without medial setules *C. morimotoi* Miura, 1969

ACKNOWLEDGEMENTS

I thank Ms Ji Min Lee and Eun Hee Kwon for their support in preparing the illustrations and collecting samples. I am grateful to Dr. Teruo Ishida who kindly sent me Japanese specimens with the valuable suggestion on *Canthocamptus mirabilis* group. This research was supported by the Taegu University Research Grant, 2001.

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RECEIVED: 24 September 2002

ACCEPTED: 4 October 2002

딱정장수노벌레속(갈고리노벌레목, 딱정장수노벌레과) *mirabilis* 종군에
속하는 1신종 1기록종의 분류학적 연구

장 천 영

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요 약

딱정장수노벌레 (*Canthocamptus*)속의 *mirabilis* 종군에 대한 분류학적 연구의 일환으로, 극동아시아의 남부에 널리 분포하는 반달딱정장수노벌레 (*C. semicirculus* Kikuchi)와 남한의 중서부 지역의 구릉지대 계류에 분포하는 1신종, 고려딱정장수노벌레 (*C. coreensis*)를 보고한다. 반달딱정장수노벌레의 한국산 표본에서는 암컷의 바깥꼬리털과 수컷의 제3다리 외지의 돌기형 가시와 같은 중요 형질에서 변이가 흔하게 나타났기에 종내변이에 대해 특기하였다. 고려딱정장수노벌레는 암컷에서 수컷모사변이형의 꼬리마디가 나타나지 않고 항문판의 투명막이 둥근 모양을 유지한다는 점 등의 조상형 형질을 유지하는 반면, 수컷 제3다리 외지 제2마디의 바깥가시와 수컷 제4다리 외지 끝마디 바깥강모가 심하게 변형되는 등의 파생형질을 소유한다. 현재까지 기록된 5종의 한국산 딱정장수노벌레속 *mirabilis* 종군에 대한 종검색표를 작성하였다.