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Taxonomic Review of the Cladoceran Genus *Simocephalus* (Branchiopoda, Anomopoda, Daphnidae) in Korea, with Redescription of *Simocephalus mixtus*

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한국산 시모물벼룩속(새각강, 이지목, 물벼룩과) 종들의 분류학적 검토와 요술시모물벼룩(*Simocephalus mixtus*)의 재기재. 윤성명* · 김 원[1](조선대학교 사범대학 생물교육과, [1]서울대학교 자연과학대학 분자생물학과)

1981년 5월부터 1999년 6월까지 남한의 97개 지소의 다양한 담수역에서 채집된 표본들에 근거하여 요술시모물벼룩(*Simocephalus mixtus* Sars)을 재기재하였으며, 한국에서의 시모물벼룩속 종들의 과거 기록들을 검토하였다. 이 종은 최근까지 극동아시아 지역에서 긴눈시모물벼룩(*S. vetulus* (O.F. Müller)) 및 *S. vetuloides* Sars와 분류학적으로 혼동되었거나 오동정되었던 종이다. 본 종은 갑각의 후배각이 낮고 넓게 돌출하였고, 갑각의 등쪽 가장자리의 뒷부분이 팽창하였으며, 머리의 부리에 가까운 배쪽 가장자리 부위가 깊게 함몰되어 있고, 길쭉한 모양의 단안을 가지며, 후복부 발톱의 기부에 빗모양의 가시군이 없다는 점에서 근연종들과 구별된다.

Key words : Redescription, Taxonomic review, *Simocephalus mixtus*, Korea

INTRODUCTION

Cladocerans are small-sized crustaceans that occur in all freshwater habitats and can be abundant enough to form conspicuous swarms. They occupy a key position in freshwater communities both as important herbivores eating algae and bacteria and as a major prey item of fish, birds or other predators (Dodson and Frey, 1991). Numerous investigators have been interested in these animals through the various fields of biology including taxonomy, ecology, environmental toxicology, embryology and developmental biology, physiology and biochemistry, and genetics, *etc.* (see Yoon, 1993).

In the cladoceran taxonomy it had been traditionally accepted that the most species could be world-widely distributed through the dispersal by means of the ephippium.

However, since Frey (1973) introduced new methods and the first serious evaluation of the theory of cosmopolitanism, many vigorous studies to reexamine previous works have been performed over various cladoceran taxa. It has been shown that many previous descriptions often concerned either species complexes or intraspecific units, and is believed that most described species need revision (see Korovchinsky, 1996).

Simocephalus Schödler is one of the common group of daphniid cladocerans found in littoral aquatic vegetation all over the world. Members of the genus have frequently been investigated as the subjects in the various limnological and ecological studies (Ferrari *et al*., 1991; Brock *et al*., 1992; Bertilsson *et al*., 1995; Koksvik, 1995;

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Lauridsen *et al*., 1996). Though having long history, the taxonomy of the genus had remained unsatisfactory before the recent work by Orlova-Bienkowskaja (1998). She redescribed and revised more than 60 previously recorded species and/or subspecies of the genus *Simocephalus*, and described two new species by the reexamination of previous works and materials. Through this study a lot of previously recorded species were synonymized and regarded as the invalid ones, and some were turned out to be the species groups. Presently 20 species of the genus are known as the valid ones in the world (Orlova-Bienkowskaja, 1988).

In the Far East total four *Simocephalus* species were recorded from Far Eastern China (Chiang and Du, 1979), Japan (Ueno, 1927a; Mizuno and Takahashi, 1991), and Korea (Yoon and Kim, 1987; Kim, 1988). Among them invalid records of *S. vetulus* (O.F. Müller, 1776) were included in the present point of view (Orlova-Bienkowskaja, 1988). Most of all the previous works were lacking precise descriptions and detailed drawings of the species, insufficient to tell their status exactly. The Far Eastern *Simocephalus* is therefore in need of the reinvestigation including the redescriptions of recorded species.

When studying cladoceran fauna, the senior author of the present study found out that *S. mixtus* Sars, 1903, new to Korean fauna, was widely distributed in Korea. He also suspected that most records of *S. vetulus* in the Far East were probably the erroneous ones of *S. mixtus*. In the present paper *S. mixtus* from Korea is redescribed, and the taxonomy of the genus *Simocephalus* in the Far East is discussed.

MATERIALS AND METHODS

The materials of *Simocephalus* were collected from the various freshwater habitats such as rice-fields, lakes, rivers, streams, and reservoirs of 97 localities in south Korea during the period from May 1981 to June 1999 (Fig. 1). Collections were made with a conical plankton net and a dipnet (both 155 μm in mesh size). Samples were fixed with 10% formalin, and preserved in 4% formalin.

The samples were inventoried to determine the presence and the reproductive state of the species under a Olympus stereomicroscope. Each specimen was transferred to a drop of glycerol in a reversed slide for subsequent study. Temporary mounts of whole specimens in glycerol were used for the measurements and the drawings of intact animals and their parts. Whole bodies were dissected with tungsten needles to examine antennules, antennae, carapaces, trunk limbs, postabdomens, postabdominal claws, and other parts. Drawing and measuring were made with a Olympus compound microscope attached by the drawing tube system. All specimens examined are deposited in the senior author's collection.

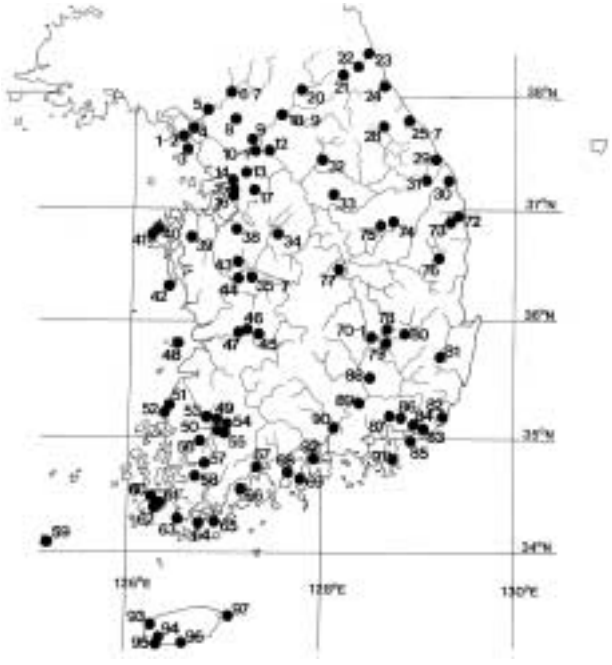

Fig. 1. Localities from which the specimens were collected.

More than 20 parthenogenetic female specimens were examined in every samples collected from 97 localities of the present study. The appendix includes the station number, its locality and other informations. Collectors were not referred when the specimens were collected by the authors themselves.

RESULTS AND DISCUSSION

1. Redescription of species

***Simocephalus mixtus* Sars, 1903 요술시모물벼룩 (신칭) (Figs. 2, 3)**

Simocephalus mixtus Sars, 1903, p. 174, Pl. 6, Figs. 4, 4a; Orlova-Bienkowskaja, 1998, p. 11, Fig. 23.

Simocephalus vetulus (non O.F. Müller, 1776): Ueno, 1927a, p. 281; 1927b, p. 160, Fig. 2; Chiang and Du, 1979, p. 125, Fig. 80; Du and Mizuno, 1981, p. 62, Fig. 25; Negrea, 1983, p. 138, Fig. 55H (part); Yoon and Kim, 1987, p. 184, Fig. 4a–d; Kim, 1988, p. 55, Figs. 19, 20; Mizuno and Takahashi, 1991, p. 143.

Simocephalus elizabethae (non King, 1853): Manuilova, 1964, p. 148, Fig. 50.

Simocephalus vetuloides (non Sars, 1898): Chiang and Du, 1979, p. 126, Fig. 81; Michael and Sharma, 1988, p. 75, Fig. 21e.

Material Examined: Numerous specimens of parthenogenetic females collected from every 97 localities listed in the 'Appendix'.

Parthenogenetic female: *General shape* (Fig. 2a). Body bilaterally compressed, almost oval in outline of lateral view. In lateral view, head short and wide, distinctly separated from body by indentation at dorsocephalic suture; ventral margin deeply concave. Dorsal margin of carapace strongly expanded posteriorly. Dorso–posterior caparace angle distinct. Color yellowish or red–brown.

Carapace (Figs. 2a–c). Surface reticulated; reticulation consisting of oblique stripes somewhat intersecting in most parts of carapace, and of irregular polygons along marginal area (Figs. 2a, c). Dorsal margin arched in middle, strongly expanded posteriorly, smoothly connected anteriorly to that of head shield, and distinctly indented near posterior end forming prominent dorso–posterior carapace angle with posterior part of ventral margin; dorso–posterior carapace angle short and very wide. Ventral margin nearly straight and posterior margin evenly curved. Dorsal, posterior and ventral margins ornamented with denticles; denticles on region from midway of dorsal margin to dorso–posterior carapace angle strong and naked, arranged in 2 rows, while those on posterior and ventral margins very weak and indistinct, finned with wide transparent membrane, and arranged in 1 row along margin (Figs. 2a, c). Inner surface with row of plumose setae on ventral margin, followed by row of minute spinules groups on posterior margins, and with 3～5 serrated denticles near ventro–posterior carapace angle (Fig. 2c).

Head (Fig. 2a). Comparatively small and short; length about 1/5 of carapace length. Anterior and dorsal margins evenly curved, ventral margin deeply depressed near rostrum; width increasing conspicuously into proximal part. Rostrum long and pointed. Frons rounded, right–angled and without denticles. Eye large, shifted ventrally and filling apart in short distance from anterior margin. Ocellus elongate, arrow–shaped.

Antennule (Fig. 2d). Tubular, having 9 aesthetes unequal in length at distal end and 1 sensory papilla arising from tubular mound on anterior proximal side.

Antenna (Fig. 2e). Small, slightly shorter than half of carapace length. Antennal formula 0(0)–0(1)–1(0)–3(0)/1(0)–1(0)–3(0); approximate length ratios of exopod segments relative to basipod length 0.10, 0.35, 0.30 and 0.20, endopod segments 0.40, 0.30, and 0.25. Basipod having 1 sharp and long spine on outer lateral side near distal end and with 3 plumose sensory setae; two of which originating from outer lateral side near base of segment, while other one present on distal end between 2 rami of endopod and exopod. Each of all segments covered with transverse rows of fine setules along whole length, and with transverse row of small spinules at distal end. Exopod and endopod segments with clumps of hairs on inner surfaces.

Trunk limbs. Five trunk limbs of general forms of genus (figures not given).

Postabdomen (Fig. 2f). Large, slightly tapering into postabdominal claw; dorsal margin somewhat protruding in middle and indented distally; ventral margin expanded proximally; distal margin strongly depressed to forming large anal bay on dorsal half, and making prominent supra–anal angle with distal part of dorsal margin. Distal margin provided with 2 rows of anal teeth increasing in size distally; each row comprising 10～13 curved teeth, distal 3～5 of which ornamented with fine setules and others smooth; curvature somewhat increasing in distal teeth; area near bases of anal teeth with groups of minute setules. Dosal and dorso–lateral surface covered with clusters of very fine spinules. Abdominal setae very short, slightly longer than postabdominal claws. Abdominal processes well developed, 2 in number; first process sparsely setulosed while second nearly naked.

Postabdominal claw (Fig. 2g). Large, bent dorsally at about proximal 2/3 of length, without basal pecten of spines. Dorsal margin from base to tip having row of minute spinules arranged along concave dorsal edge. Ventral surface with semicircular row of fine spinules near base. Ven-

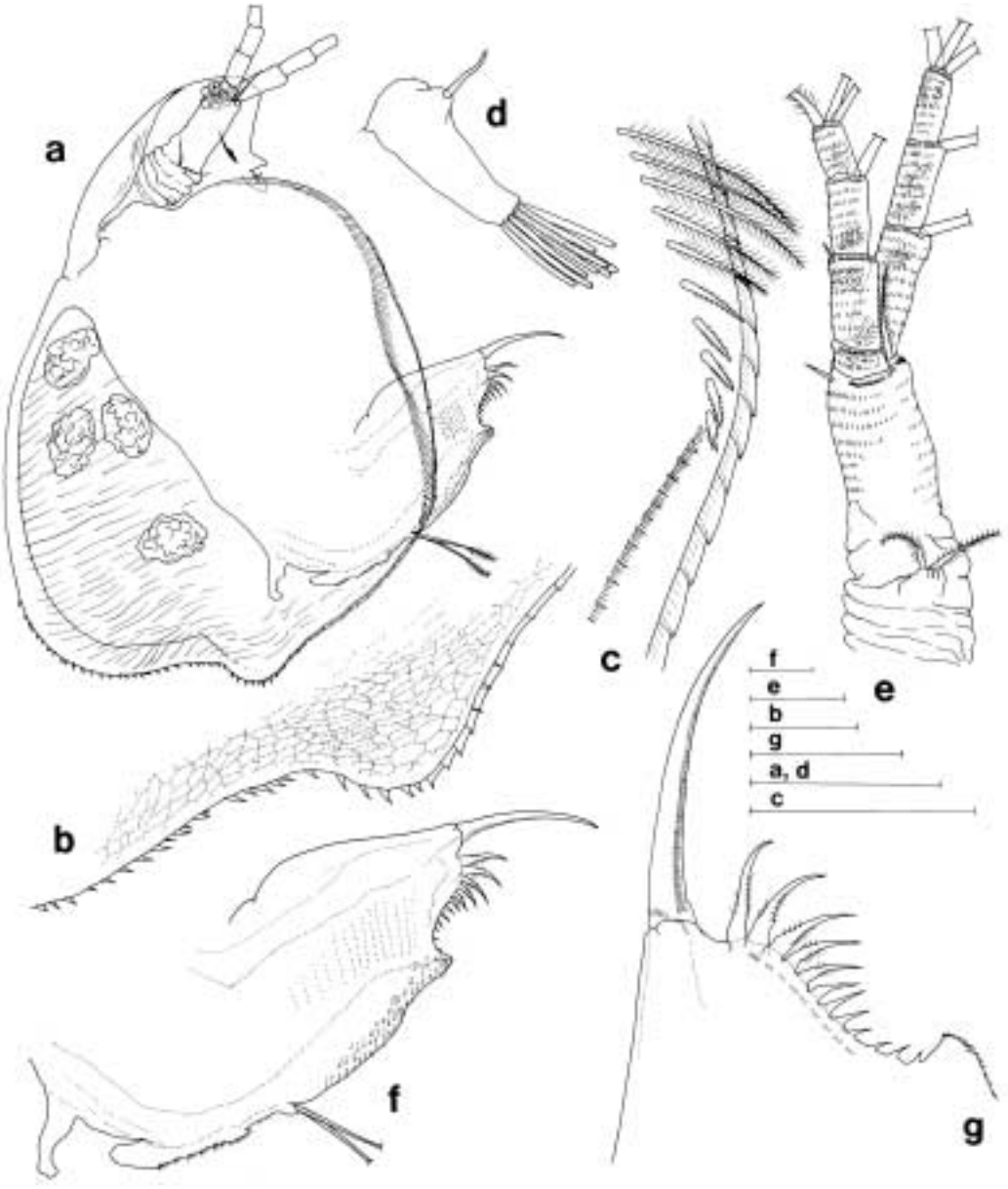

Fig. 2. *Simocephalus mixtus* Sars, lateral view of parthenogenetic female. a, habitus; b, carapace surface near dorso–posterior carapace angle; c, inner view of carapace near ventro–posterior carapace angle; d, antennule; e, antenna; f, postabdomen; g, distal part of postabdomen. Scales: a = 0.5 mm; b–g = 0.1 mm.

tral margin smooth, without any ornamentations.

Variation: Variabilities, especially on the shape of carapace, according to age could be easily found (Fig. 3). In immature parthenogenetic females, the brood pouch is small and the dorsal carapace margin is nearly straight. The prominence on the dorso–posterior carapace angle is not distinct. Mature females have a distinct dorso–posterior carapace angle prominence. The shape of brood pouch in mature female depends on the number of eggs and on the developmental stage of embryos. This much effect the whole shape of individuals. The head grows slower than the carapace. Ocellus is always elongate, but the size and the shape are more or less variable to individuals within populations, without the relation to age.

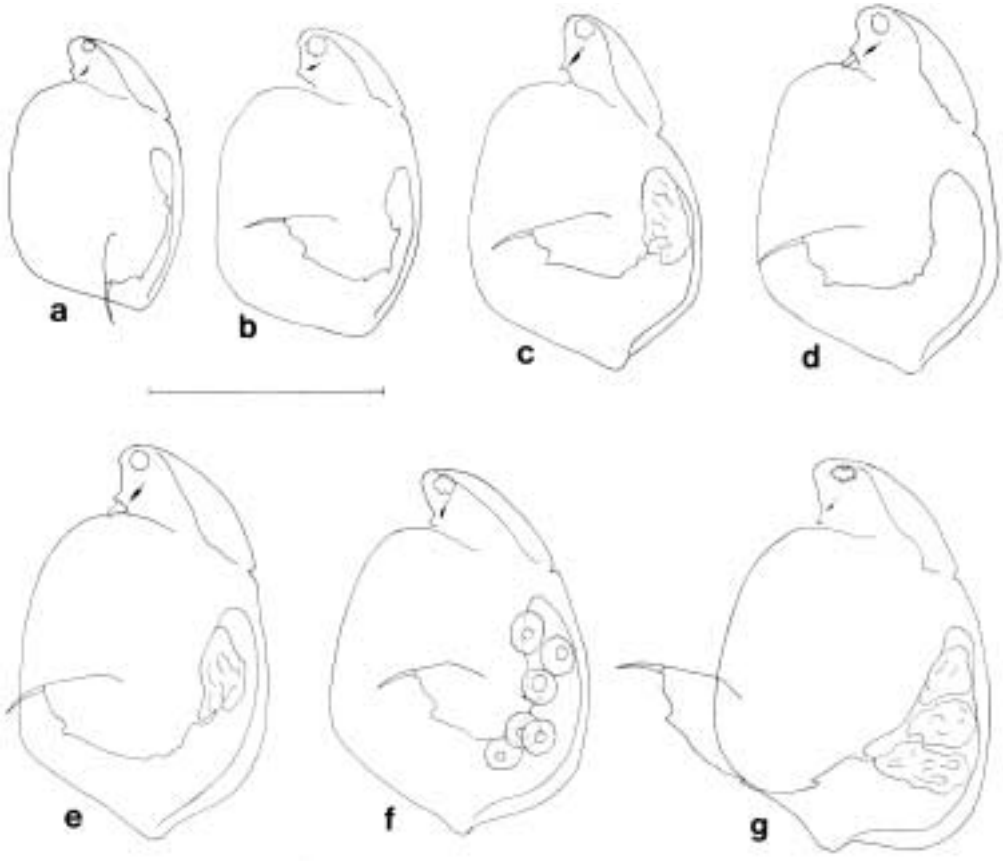

Fig. 3. Variability of *Simocephalus mixtus* Sars in parthenogenetic female. a–e, population collected from a small reservoir in Kwangju; f, population from the rice-fields in Yongin, Kyŏnggi-do; g, population from the Kanjung reservoir in Wanju, Chŏllabuk-do.

Size: Length range (from anteriormost part of head to posteriormost part of carapace) of mature parthenogenetic females carrying eggs is 1.11～2.04 mm.

Remarks: This species was usually recorded under the name of *S. vetulus* (O.F. Müller) or *S. vetuloides* Sars in the Far East (Ueno, 1927a, b; Chiang and Du, 1979; Du and Mizuno, 1981; Yoon and Kim, 1987; Kim, 1988; Mizuno and Takahashi, 1991). Though most previous descriptions and drawings are incomplete, they make it possible to recognize the species from diagnostic features such as short and wide dorso-posterior carapace angle prominence, distally protruding dorsal margin of the carapace, deep depression of the ventral head margin near the rostrum, and the elongate ocellus.

Distribution: Asia including the Far East (Russia, Korea, China, Japan), Eastern Europe, North Africa, North America.

2. Taxonomic review and ecological note

In Korea, Yoon and Kim (1987) first described Korean populations of two *Simocephalus* species, *S. vetulus* (O.F. Müller, 1776) and *S. exspinosus* (Koch, 1841), and Kim (1988) presented the taxonomic key for Korean cladocerans including additional species, *S. serrulatus* (Koch, 1841). After these, only *S. vetulus* was dealt in several limnological studies (Yoo and Lim, 1991; Ha *et al*., 1995; Kim, 1996; Lim *et al*., 1997), further taxonomic study has not been made. So total three *Simocephalus* species are reported in Korea. Among them, *S. vetulus* is known to be common and widely distributed over various types of lotic and lentic freshwater habitats, while other two species are very rare and usually restricted to the lentic habitats of ponds and reservoirs (Yoon and Kim, 1987; Kim, 1988). All of above three species are also recorded from China and Japan,

and another species, *S. vetuloides* Sars, 1898, is recorded from China in the Far East (Chiang and Du, 1979; Mizuno and Takahashi, 1991).

Because based on the theory of cosmopolitanism, previous works in Korea were not made carefully and including many erroneous informations as those in other countries were. Recently it was proved that many *Simocephalus* species had been incorrectly described under different names and a lot of different species were erroneously recorded under the same name in the world (see Orlova-Bienkowskaja, 1988). Among three species recorded from Korea, *S. vetulus* has long been known as the representative of world-widely distributed species, but it's practical geographic range seems to be restricted to Europe and North Africa (Orlova-Bienkowskaja, 1988). So the previous reports of *S. vetulus* from the Far East including Korea are questionable and unsubstantiated.

Only a few characters such as the shape of the frons of head, the ornamentation of postabdominal claw, and the protuberance of the dorsal margin of carapace have been used for discriminating *Simocephalus* species in the Far East (Chinag and Du, 1979; Yoon and Kim, 1987; Kim, 1988; Mizuno and Takahashi, 1991). All the previous descriptions and drawings are very short and somewhat doubtful. Previous authors overlooked several important characteristic features found on the carapace and the head, while exaggerated some variabilities like the number of anal teeth in the present point of view. Such problems included in the monograph of China (Chiang and Du, 1979), the representative work in this region, were recently pointed out by several authors over various cladoceran taxa including *Simocephalus* (Korinek, 1987; Orlova-Bienkowskaja, 1988; Korovchinsky and Mirabdullaev, 1995). Though having insufficient informations, the previous reports in the Far East show a remarkable characteristic feature of *S. exspinosus* and *S. serrulatus*, respectively. That is, the basal pecten of postabdominal claw in *S. exspinosus* and the frons having denticles in *S. serrulatus* are well noticeable (Chinag and Du, 1979; Yoon and Kim, 1987; Kim, 1988; Mizuno and Takahashi, 1991).

According to recent work by Orlova-Bienkowskaja (1988), each of above features is one of the most useful characteristics in discriminating the species from other related species, respectively. From this with the consideration of other general shapes presented, previous records of the two species are acceptable. The previous reports also show that the species recorded as *S. vetulus* has a noticeable feature of the short and wide dorso-posterior carapace angle prominence. Another record of *S. vetuloides* from China shows the same feature. The two species could not be distinguishable from each other in any parts of descriptions and drawings except in the outline difference of the dorsal margin of carapace (Ueno, 1927b; Chiang and Du, 1979; Du and Mizuno, 1981; Yoon and Kim, 1987; Kim, 1988; Mizuno and Takahashi, 1991). Considering the variability for the shape of dorsal carapace margin according to age in *Simocephalus* species, there is a high possibility that the two species are the same one.

In the present study, the authors examined the Korean *Simocephalus* materials that have a short and wide prominence on the dorso-posterior carapace angle. The materials included a part of previous authors' specimens dealt as *S. vetulus* (Yoon and Kim, 1987; Kim, 1988). They superficially seemed to be composed of two different groups in the protrusion of dorsal carapace margin, the *vetulus*-type and the *vetuloides*-type referred to Chiang and Du (1979), but any other distinguishable features between the two were not found. So the authors investigated the variability, especially on the shape of carapace, in the present study (Fig. 3). It was found that above two types of individuals were usually mixed up within every large population samples examined. It also appeared that the differences of individuals were mostly the reflections of different growth stages. In immature parthenogenetic females, the brood pouch was small and the dorsal carapace margin was nearly straight. The prominence on the dorso-posterior carapace angle was relatively not distinct (Figs. 3a-d). But mature female had a distinct dorso-posterior carapace angle prominence. The shape of brood pouch in mature female depended on the number of eggs and on the developmental stage of embryos. It much effected the whole shape of individuals (Figs. 3e-g). All the Korean materials were eventually turned out to be *S. mixtus* Sars. This result strongly supports that previous records of both *S. vetulus* and *S. vetuloides* are erroneous ones of *S. mixtus* in the Far East.

Simocephalus mixtus was first described from

the Sudjil-gol river in Mongolia by Sars (1903). It was characterized by smooth and rounded frons of head, elongate ocellus, and protruding dorsal carapace margin in the original description (Sars, 1903). After the first description, *S. mixtus* had frequently been considered to be a synonym of *S. vetulus* or that of *S. elizabethae* (King, 1853) (Manuilova, 1964; Negrea, 1984). Recently Orlova-Bienkowskaja (1988) revealed that *S. mixtus* differs from both *S. vetulus* and *S. elizabethae* with examining the type materials. *S. mixtus* is now regarded as one of the most widely distributed *Simocephalus* species in the world (Orlova-Bienkowskaja, 1988).

Diagnostic features of *S. mixtus* are presently known as follows: (1) frons of head is smooth, without denticles, (2) ventral head margin near the rostrum is strongly depressed, (3) ocellus is elongate, (4) dorso-posterior carapace angle prominence is distinct, but short and wide, (5) dorsal margin of carapace is protruding posteriorly, and (6) postabdominal claw is lacking the pecten of denticles. *S. mixtus* especially has a close resemblances with *S. vetulus*, but it differs from the latter by the larger prominence on the dorso-posterior carapace angle, the strong depression on the ventral head margin near the rostrum, and the large protrusion of the dorsal margin of carapace in mature female. *S. vetuloides* is also closely related to *S. mixtus* in having that the dorsal carapace margin is expanded posteriorly. But it is differentiated from the latter by the high and narrow prominence on the dorso-posterior carapace angle. Previous record of *S. vetuloides* in China (Chiang and Du, 1979), which shows a large but short and wide prominence on the dorso-posterior carapace angle, is therefore turned to be a erroneous one of *S. mixtus*. On the other hand, *S. mixtus* can be easily distinguishable from *S. exspinosus* by having the naked postabdominal claw without pecten, and from *S. serrulatus* by having the smooth frons of head without denticles (Manuilova, 1964; Negrea, 1984; Orlova-Bienkowskaja, 1988).

The Korean materials are well accorded with those of other countries reported recently (Orlova-Bienkowskaja, 1988). Any remarkable differences or variations could not be observed except that of carapace shape mentioned above. Especially the structures of all the trunk limbs are the typical ones of the genus. Only minor variability of the ocellus in the elongation and the shape can be found (Fig. 3). It seems to be an accidental variation to individuals within populations, without the relation to age.

In conclusion, the above results show that only three species, *S. mixtus*, *S. exspinosus* and *S. serrulatus*, are presently acceptable in the Far East. However, there is a possibility that another species remains to be known because the taxonomy of *Simocephalus* is still very poor and needed further study in this region.

Among three species, *S. mixtus* is one of the most common species among the littoral cladocerans in various freshwater habitats including rice-fields, swamps, bogs, streams, ponds, lake waters, reservoirs and rivers in Korea (see Appendix). It much prefers small waters to large ones, and usually lives in the aquatic vegetation in large water bodies.

It can be found throughout all seasons except the period of freezing in the permanent water bodies (see Appendix). Individuals of the species often swarm in large water bodies such as reservoirs and rivers in warm season.

ABSTRACT

Simocephalus mixtus Sars was redescribed and illustrated from Korea. It had been frequently confused with *S. vetulus* (O.F. Müller) and *S. vetuloides* Sars in the Far East. Redescription was based on the materials collected from various freshwater habitats at 97 localities in South Korea during the period from May 1981 to June 1999. Previous records of *Simocephalus* species from Korea were examined. *S. mixtus* is well distinguishable from other related species by having short and wide dorso-posterior carapace angle prominence, distally protruding dorsal margin of carapace, deep depression of the ventral head margin near the rostrum, elongate ocellus, and postabdominal claw lacking the basal pecten of denticles.

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REFERENCES

Bertilsson, J., B. Berzins and B. Pejler. 1995. Occurrence of limnic micro-crustaceans in relation to

temperature and oxygen. *Hydrobiologia* **299**: 163–167.

Brock, T.C.M., S.J.H. Crum, R. van Wijngaarden, B.J. Budde, J. Tijink, A. Zuppelli and P. Leeuwangh. 1992. Fate and effects of the insecticide Dursban 4E in indoor *Elodea*-dominated and macrophyte-free freshwater model ecosystems: I. Fate and primary effects of active ingredient chlorpyrifos. *Arch. Environ. Contam. Toxicol.* **23**: 69–84.

Chiang, S.C. and N.S. Du. 1979. Fauna Sinica, Crustacea, Freshwater Cladocera. Science Press, Peking, pp. 297 (in Chinese).

Dodson, S.I. and D.G. Frey. 1991. Cladocera and other Branchiopoda, p. 723–786. In: Ecology and Classification of North American Freshwater Invertebrates (J.H. Thorps and A.P. Covich, eds.). Academic Press, New York.

Du, N.S. and T. Mizuno. 1981. Remarks on Freshwater Cladocerans of China and Japan. Tatara Publ., Kyoto, pp. 209 (in Japanese).

Ferrari, I., A. Bachiorri, F.G. Margaritora and V. Rossi. 1991. Succession of cladocerans in a northern Italian ricefield. *Hydrobiologia* **225**: 309–318.

Frey, D.G. 1973. Comparative morphology and biology of three species of Eurycercus (Chydoridae, Cladocera) with a description of *Eurycercus macracanthus* sp. nov. Int. Revue ges. *Hydrobiol.* **58**: 221–267.

Ha, H.J., S.T. Kim, J.U. Choi, S.H. Min, T.Y. Jang and G.H. Kim. 1995. Acute toxicity on water fleas and *Photobacterium phophoreum* for heavy metals. *Korean J. Lim.* **28**: 369–376 (in Korean).

Kim, I.H. 1988. Key to the Korean freshwater Cladocera. Korean J. Syst. Zool. Special Issue **2**: 43–65 (in Korean).

Kim, I.H. 1996. Occurrence of the planktonic crustaceans in relation to pH in the rice fields of the eastern Korea. *Korean J. Lim.* **29**: 233–240 (in Korean).

Koksvik, J.I. 1995. Seasonal occurrence and diel locomotor activity in littoral Cladocera in a mesohumic lake in Norway. *Hydrobiologia* **307**: 193–201.

Korinek, V. 1987. Revision of three species of the genus *Diaphanosoma* Fischer, 1890. *Hydrobiologia* **145**: 35–45.

Korovchinsky, M.M. 1996. How many species of Cladocera are there? *Hydrobiologia* **321**: 191–204.

Korovchinsky, M.M. and I.M. Mirabdullaev. 1995. A new species of the genus *Diaphanosoma* Fischer, 1850 (Crustacea: Daphniiforms: Sididae) from Central Asia and China. *Hydrobiologia* **304**: 235–242.

Lauridsen, T.L., L.J. Pedersen, E. Jeppesen and M. S ndergaard. 1996. The importance of macrophyte bed size for cladoceran composition and horizontal migration in a shallow lake. *J. Plankton Res.* **18**: 2283–2294.

Lim, B.J., B.C. Kim, K.I. Yoo and J.K. Yoo. 1997. Changes in zooplankton community during the blue-green algal bloom in the Nakdong River. *Korean J. Lim.* **30**: 337–346 (in Korean).

Manuilova, E.F. 1964. Vetviatousye Rachki Fauny SSSR (Cladocera). Nauka Publ. Moscow, pp. 326.

Michael, R.G. and B.K. Sharma. 1988. Fauna of India, Indian Cladocera (Crustacea: Branchiopoda: Cladocera). Zoological Survey of India Publicat-ions, Calcutta, pp. 262.

Mizuno, T. and E. Takahashi. 1991. An Illustrated Guide to Freshwater Zooplakton in Japan. Tokai Univ. Publ., Tokyo, pp. 532 (in Japanese).

Negrea, St. 1983. Cladodera, Fauna Republicii Socialiste Romania, 4(12). Academiei, Bucuresti, pp. 399.

Orlova-Bienkowskaja, M.J. 1998. A revision of the cladoceran genus *Simocephalus* (Crustacea, Daphniidae). *Bull. nat. Hist. Mus. Lond.* (*Zool.*) **64**: 1–62.

Sars, G.O. 1903. On the crustacean fauna of Central Asia, Part II, Cladocera. *Ann. Mus. Zool. St. Petersburg.* **8**: 157–194 (English Translation by Israel Program Scientific Translation, Jerusalem).

Ueno, M. 1927a. The freshwater Branchiopoda of Japan I. *Mem. Coll. Sci. Kyoto Imp. Univ. Ser. B* **2**: 259–311.

Ueno, M. 1927b. On some freshwater branchiopods from China. *Annot. Zool. Japon.* **11**: 157–163.

Yoo, K.I. and B.J. Lim. 1991. Seasonal variation in the zooplankton community structure of the lower Han River system. *Korean J. Lim.* **24**: 85–91 (in Korean).

Yoon, S.M. and H.S. Kim. 1987. A systematic study on the freshwater Cladocera from Korea. *Korean J. Syst. Zool.* **3**: 175–207 (in Korean).

Yoon, S.M. 1993. The Systematics and Molecular Evolution of the Korean Branchiopods (Crustacea, Branchiopoda). Ph.D. Thesis, Seoul National University, Seoul, pp. 364.

APPENDIX.

Station list

Inch'ŏn: sta 1, rice-fields at Tŏksŏng-ri, Pulŭn-myŏn, Kanghwa-gun, Apr. 24, 1991, H.B. Kong; sta 2, rice-fields at Shinhyŏn-ri, Pulŭn-myŏn, Kanghwa-gun, Apr. 26, 1991, M.K. Shin; sta 3, rice-fields at Chungsan-dong, Yŏngjong Is., Ongjin-gun, Mar. 22, 1996, C.Y. Chang.

Kyŏnggi-do: sta 4, rice-fields at Kunha-ri, Wŏlgot-myŏn, Kimp'o-gun, Sep. 10, 1990, K.S. Min; sta 5, Imjin-gang at Myŏndong-ri, Munsan-ŭp, P'aju-gun, May 6, 1988, C.Y. Chang; sta 6, a small reservoir at Chŏngok-ri, Chŏngok-ŭp, Yŏnch'ŏn-gun, May 6, 1988, C.Y. Chang; sta 7, Hant'an-gang at Changt'an-ri, Ch'ŏngsan-myŏn, Yŏnch'ŏn-gun, May 6, 1988, C.Y. Chang; sta 8, rice-fields at Changhyŏn-ri, Chinjŏp-myŏn, Namyangju-shi, May 5, 1991; sta 9, rice-fields at Mukhyŏn-ri, Hwado-ŭp, Namyangju-shi, Jun. 6, 1989, C.B. Kim; sta 10, Han-gang at Choan-ri, Choan-myŏn, Namyangju-shi, Jul. 15, 1984, C.Y. Chang; sta 11, Han-gang at Yangsu-ri, Yangsŏ-myŏn, Yangp'yŏng-gun, Aug. 11, 1991; sta 12, Han-gang at Yanggŭn-ri, Yangp'yŏng-ŭp, Yangp'yŏng-gun, Apr. 24, 1994; sta 13, rice-fields at Chubuk-ri, Yangji-myŏn, Yongin-shi, May 20, 1996; sta 14, rice-fields at Pyŏngjŏm-ri, T'aean-ŭp, Hwasŏng-gun, Apr. 28, 1996; sta 15, rice-fields at Such'ŏng-dong, Osan-shi, Apr. 21, 1991; sta 16, rice-fields at Sŏj'ŏng-dong, Songt'an-shi, Apr. 21, 1991; sta 17, Kosam reservoir at Kosam-myŏn, Ansŏng-gun, Jul. 21, 1986.

Kangwŏn-do: sta 18, Kongji-ch'ŏn, Ch'unch'ŏn-shi, Aug. 16, 1990; sta 19, a pond in Kangwon Univ., Ch'unch'ŏn-shi, Oct. 31, 1981, I.H. Kim; sta 20, P'aroho, Gandong-myŏn, Hwach'ŏn-gun, Jun. 22, 1986; sta 21, rice-fields at Shinnam-ri, Nam-myŏn, Inje-gun, May 22, 1996; sta 22, a swamp at Paektam valley in Sŏrak-san, Aug. 28, 1994; sta 23, a swamp near Songjiho, Chukwang-myŏn, Kosŏng-gun, Jul. 18, 1996, I.H. Kim; sta 24, rice-fields at Namae-ri, Hyŏngnam-myŏn, Yangyang-gun, May 24, 1981, I.H. Kim; sta 25, Kyŏngp'oho, Kangrŭng-shi, Jun. 22, 1986; sta 26, rice-fields at Chibyŏn-dong, Kangrŭng-shi, May 24, 1986, I.H. Kim; sta 27, Namdaech'ŏn, Kangrŭng-shi, Jun. 1, 1981, I.H. Kim; sta 28, a stream at Yongp'yŏng, Hŏinggye-myŏn, Pyŏngch'ang-gun, Jun. 26, 1986, I.H. Kim; sta 29, rice-fields at Kyo-dong, Samch'ŏk-shi, May 2, 1991; sta 30, rice-fields at Imwon-ri, Wondŏk-ŭp, Samch'ŏk-shi, Jun. 8, 1986, I.H. Kim; sta 31, rice-fields at Nŭkku-ri, Togye-ŭp, Samch'ŏk-shi, May 5, 1987; sta 32, a stream at Mugye-ri, Sŏwon-myŏn, Hoingsŏng-gun, Jul. 20, 1986, I.H. Kim.

Ch'ungch'ŏngbuk-do: sta 33, rice-fields at Kuhak-ri, Pongyang-ŭp, Chech'ŏn-shi, Jun. 24, 1986, I.H. Kim; sta 34, rice-fields near Myŏngamji, Ch'ŏngju-shi, Jun. 14, 1986, I.H. Kim.

Taejŏn: sta 35, Gapch'ŏn at Guam-dong, Yusŏng-gu, May 3, 1999; sta 36, Gapch'ŏn at Chŏnmin-dong, Yusŏng-gu, May 3, 1999; sta 37, a stream at Hakha-dong, Yusŏng-gu, Aug. 25, 1990, C.Y. Chang.

Ch'ungch'ŏngnam-do: sta 38, Ansŏ reservoir, Ch'ŏnan-shi, Jun. 4, 1988, K.S. Min; sta 39, Muhanch'ŏn at Changjae-ri, Kwangshi-myŏn, Yesan-gun, Sep. 15, 1996; sta 40, Ilho reservoir, Wŏnbuk-myŏn, Taean-gun, May 24, 1996; sta 41, a pond at the Ch'ŏllip'o Tree Garden, Sowŏn-myŏn, Taean-gun, Oct. 7, 1985; sta 42, rice-fields in Wŏnsan Is., Och'ŏn-myŏn, Poryŏng-shi, Aug. 1, 1986; sta 43, rice-fields at Pomul-ri, Chŏngam-myŏn, Kongju-shi, Apr. 28, 1996; sta 44, rice-fields at Chungjang-ri, Kyeryong-myŏn, Kongju-shi, Aug. 25, 1990, C.Y. Chang.

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Kwangju: sta 49, Yŏngsan-gang at Yonggang-dong, Puk-gu, Apr. 24, 1996; sta 50, a small reservoir at Ch'ŏngok-dong, Tong-gu, Apr. 17, 1996.

Chŏllanam-do: sta 51, rice-fields at Songam-ri, Yŏmsan-myŏn, Yŏnggwang-gun, Aug. 6, 1996; sta 52, rice-fields at Yawŏl-ri, Yŏmsan-myŏn, Yŏnggwang-gun, Aug. 6, 1996; sta 53, rice-fields at Punhyang-ri, Nam-myŏn, Changsŏng-gun, May 18, 1996; sta 54, rice-fields at Yŏnch'ŏn-ri, Nam-myŏn, Tamyang-gun, Apr. 17, 1996; sta 55, Kwangjuho, Kosŏ-myŏn, Tamyang-gun, Nov. 27, 1995; sta 56, Yŏngsan-gang at Yŏngsanp'o, Naju-shi, Apr. 28, 1997; sta 57, rice-fields at Kaesin-ri, Yŏngam-ŭp, Yŏngam-gun, Jul. 28, 1988, K.S. Min; sta 58, Wŏlnam reservoir, Sŏngjŏn-myŏn, Yŏngam-gun, Jul. 22, 1994; sta 59, a bog in Sohŭksan Is., Shinan-gun, Aug. 26, 1987, C.B. Kim; sta 60, rice-fields atŭpnae-ri, Chindo-ŭp, Chindo-gun, Jun. 4, 1996; sta 61, Osan reservoir, Kogun-myŏn, Chindo-gun, Nov. 1, 1994; sta 62, rice-fields at Hyangdong-ri, Kogun-myŏn, Chindo-gun, Jun. 5, 1996; sta 63, rice-fields at Songho-ri, Songji-myŏn, Haenam-gun, Jun. 2, 1990; sta 64, a pond at Wando Fishery High School, Wando-ŭp, Wando-gun, Jul. 8, 1986, I.H. Kim; sta 65, rice-fields in Shinji Is., Wando-gun, Jun. 15, 1996; sta 66, Haktong reservoir, Todŏk-myŏn, Kohŭng-gun, Jan. 30, 1991, C.Y. Chang; sta 67, rice-fields at Hoijŏng-ri, Pŏlgyo-ŭop, Posŏng-gun, Sep. 18, 1989; sta 68, rice-fields at Chusam-dong, Yŏch'ŏn-shi, Apr. 25, 1990; sta 69, rice-fields at Seguji, Tolsan Is., Yŏch'ŏn-shi, Apr. 26, 1990.

Taegu: sta 70, Kŭmho-gang at Tongho-dong, Tong-gu, Jun. 19, 1999; sta 71, Kŭmho-gang at P'aldal-dong, Puk-gu, Jun. 19, 1999.

Kyŏngsangbuk-do: sta 72, a bog at Yŏnji-ri, Uljin-ŭp, Uljin-gun, May 7, 1987, M.O. Song; sta 73, Sŏngryugul, Uljin, May 14, 1988, K.S. Min; sta 74, rice-fields at Soro-ri, Ch'unyang-myŏn, Ponghwa-gun, May 5, 1987; sta 75, rice-fields at Kang-dong, Yŏngju-shi, Jul. 4, 1986, I.H. Kim; sta 76, Map'ŏngch'ŏn at Wŏlmak-dong, Ch'ŏngsong-ŭp, Ch'ŏngsong-gun, May 27, 1988, C.Y. Chang; sta 77, a well at Kŭmsan-dong, Haep'yŏng-myŏn, Sŏnsan-gun, Apr. 17, 1991, C.Y.

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Chang; sta 78, Hayangch'ŏn at Hayang-ŭp, Kyŏngsan-shi, Sep. 20, 1996; sta 79, rice-fields at Naeri-ri, Chinryang-myŏn, Kyŏngsan-shi, Sep. 20, 1996; sta 80, Kŭmho-gang, Kŭmho-ŭp, Yŏngch'ŏn-shi, Jun. 19, 1999; sta 81, Pomun reservoir, Kyŏngju-shi, May 29, 1988, C.Y. Chang.

Pusan: sta 82, rice-fields at Songjŏng-dong, Haeundae-gu, Apr. 3, 1994; sta 83, Naktong-gang at Noksan-dong, Kangsŏ-gu, Aug. 10, 1987, M.O. Song; sta 84, Maekto-gang at Myŏngji-dong, Kangsŏ-gu, Aug. 7, 1986; sta 85, a spring at Nulch'a-dong in Kadŏk Is., Kangsŏ-gu, Sep. 23, 1987.

Kyŏngsangnam-do: sta 86, rice-fields at Mangch'ŏn-ri, Hanrim-myŏn, Kimhae-shi, May 29, 1991; sta 87, rice-fields at Shinbang-ri, Tong-myŏn, Ch'angwŏn-shi, May 29, 1991; sta 88, Up'onŭp, Ibang-myŏn, Ch'angnyŏng-gun, Jun. 26, 1988, M.O. Song; sta 89, Chilnalnŭp, Pŏpsu-myŏn, Haman-gun, Apr. 4, 1989; sta. 90, a swamp at Kaho-dong, Chinju-shi, Jul. 6, 1986, I.H. Kim; sta 91, rice-fields at Manch'i-ri, Ilun-myŏn, Kŏje-shi, May 5, 1989; sta 92, rice-fields at Och'ŏn-ri, Sŏlch'ŏn-myŏn, Namhae-gun, Jul. 20, 1990.

Cheju-do: sta 93, rice-fields at Yongsu-ri, Hangyŏng-myŏn, Namjeju-gun, Feb. 10, 1987; sta 94, a swamp at Posŏng-ri, Taejŏng-ŭp, Namjeju-gun, Nov. 1, 1986, I.H. Kim; sta 95, rice-fields at Tumo-ri, Taejŏng-ŭp, Namjeju-gun, Apr. 26, 1990, K.S. Min; sta 96, a swamp near Ch'ŏnjiyŏn, Sŏguip'o-shi, Feb. 10, 1987; sta 97, a bog in U Is., Feb. 2, 1987.