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Description of *Bosmina longirostris* (O.F. Müller) (Branchiopoda, Anomopoda, Bosminidae) in Korea, with Notes on Its Ecology

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Specimens of *Bosmina longirostris* collected from various freshwater habitats of 84 localities in South Korea from October 1981 to August 1997 were examined, and seasonal changes of the cladoceran populations in Lake Kwangjuho from October 1995 to August 1977 were analysed. In this paper, *B. longirostris* in Korea was redescribed and figured, with a discussion of morphological characteristics. Some ecological features of the species were noted.

Bosmina Baird, 1845 is one of the major group of zooplanktons in lake waters and rivers. Since many species of *Bosmina* have diverse forms, various names were used to describe the variability in shape often apparent in *Bosmina* populations in early studies (Müller, 1867; Lilljeborg, 1901). Through the middle and late 20th century a lot of works have been added (Aurich, 1934; Deevey and Deevey, 1971; Flössner, 1972), but the taxonomy of *Bosmina* still remains unsatisfactory in many regions (Dodson and Frey, 1991).

Three species of *Bosmina* have been reported from the Far East so far (Chiang and Du, 1979; Yoon and Kim, 1987; Kim, 1988; Mizuno and Takahashi, 1991): *B. longirostris* (Müller, 1785), *B. coregoni* Baird, 1857, and *B. fatalis* Burckardt, 1924. However most of the previous investigators did not deal with the species carefully, and there are no detailed descriptions and figures. Therefore, a revision is required in the taxonomy of *Bosmina* in this region. *Bosmina* species are very poorly known, especially, in Korea. They had been mainly reported through limnological studies (see Yoon and Kim, 1987; Yoo et al., 1987). While Yoon and Kim (1987) made simple illustrations of *B. longirostis* and *B. coregoni* without descriptions, Kim (1988) provided the taxonomic key to 53 Korean cladocerans including the above two species. But these works were restricted to the parthenogenetic females and *B. fatalis* had not been examined taxonomically in Korea.

The present study was performed to elucidate the taxonomy of genus *Bosmina* in Korea. The authors investigated first the real distributions of three known species in Korea by examining the freshwater zooplankton materials collected from more than 400 localities. The authors also examined the seasonal change of bosminid populations with other cladoceran taxa in the lake by performing periodical sampling. However, only one *Bosmina* species, *B. longirostris,* was confirmed from the present study. In this paper *B. longirostris* from Korea is described and discussed with morphological characteristics. Furthermore, some ecological features of the species are discussed regarding the seasonal change of *B. longirostris population* in lake waters.

Materials and Methods

Materials of *Bosmina* were collected from various freshwater habitats such as lakes, rivers, streams, ponds, bogs, and reservoirs of 84 localities in South Korea during the period from October 1981 to August 1997 (Fig. 1). Qualitative collections were made with a conical plankton net and a dipnet (both 155 μm in mesh size). Periodical quantitative samplings were performed in Lake Kwangjuho (station 37 in Fig. 1) during the period from October to November in 1995, and on November in 1996, and the period from March to August in 1997 by the intervals of 7-14 d. Sampling of large volume (about 1.78 m^3) was roughly made by towing a conical plankton net, and sampling of small volume (10 liters) was made with a 2 liter beaker. 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 Nikon stereomicroscope. Each specimen was removed to a drop of glycerol in a reversed slide for subsequent taxonomic 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

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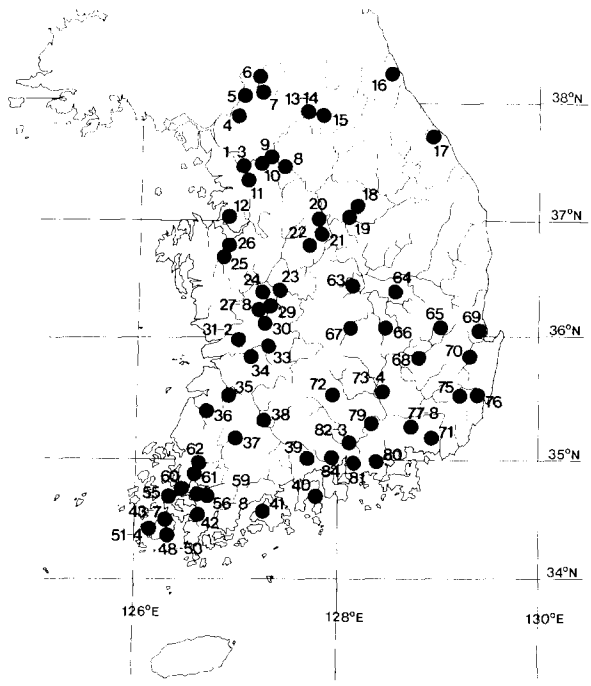

Fig. 1. Localities from which the specimens were collected.

needles to examine antennules, antennae, trunk limbs, postabdomens, postabdominal claws, and other parts. Drawing and measuring were made with a Nikon compound microscope with a drawing tube system.

Abundances of two bosminid species and other cladoceran taxa were made with counting all individuals of each taxon in every quantitative samples, under a Nikon stereomicroscope of the magnification between x20 and x80.

All specimens examined are deposited in the senior author's collection.

More than 30 parthenogenetic female specimens were examined in each of all the samples collected from 84 localities of the present study. The appendix includes the station number, its locality and other information. Collectors were not referred when the specimens were collected by the authors themselves.

Results and Discussion

Description of species

Bosmina longirostris (O.F. Müller, 1785)
(Figs. 2-4)

Lynceus longirostris O.F. Müller, 1785 [cited from Lilljeborg, 1901 (p. 227)].

Bosmina longirostris: Baird, 1850 (p. 105, Tab. 15, fig. 3); Birge, 1879 (p. 91); Lilljeborg, 1901 (p. 225, Tab. 30, figs. 13-16, Tab. 31, figs. 1-18, Tab. 32, figs. 1-3); Sars, 1903 (p. 180, Pl. 3, fig. 1); Keilhack, 1909 (p. 49, figs. 121-128); Ueno, 1927 (p. 285, Pl. 26, Figs. 15, 15a-f); Brehm, 1933 (p. 687, fig. 16); Rylov, 1935 (p. 136, Tab. 18, figs. 192-195); Sramek-Husek et al., 1962 (p. 277, fig. 101); Manuilova, 1964 (p. 267, fig. 148); Scourfield and Harding, 1966 (p. 26, figs. 60, 61a); Flössner, 1972 (p. 214, fig. 100); Khan et al., 1978 (p. 81, Pl. 3, figs. 12, 13); Mamaril and Fernando, 1978 (p. 133, figs. 94, 95); Chiang and Du, 1979 (p. 165, fig. 110); Margaritora, 1983 (p. 32, figs. 18A-B, 19A-B); Negrea, 1983 (p. 219, figs. 88-89); Yoon and Kim, 1987 (p. 193, figs. 8a-b); Kim, 1988 (p. 58, fig. 39); Michael and Sharma, 1988 (p. 97, fig. 29); Lieder, 1996 (p. 33, figs. 5g, 6a-d, 7a-i).

Material Examined: Numerous specimens of parthenogenetic females collected from every locality listed in the 'Appendix'; 22 specimens of ephippial females, of which five specimens collected from Lake Yŏngsanho (sta 60), nine from Yongyŏn Reservoir (sta 69), and eight from Chuksanri Reservoir (sta 72); nine specimens of males collected from Yongyŏn Reservoir (sta 69).

Parthenogenetic female: *General shape* (Fig. 2A). Body, short and high, bilaterally compressed, almost oval in outline of lateral view. Head large, not distinctly separated from body. Dorsal margin evenly curved from posterodorsal corner to base of antennule. Posterior and ventral margins nearly straight. Posterodorsal corner low and forming small protuberance of obtuse angle, distinctly farther backward than posteroventral corner. Anteroventral corner broadly rounded. Posteroventral corner forming spine (mucro). Color hyaline, yellowish or milky.

Carapace (Fig. 2A and 2C). Thin and without distinct marking. Dorsal margin evenly curved, and smoothly connected anteriorly to that of head sheld without any indentation. Ventral margin near anteroventral corner provided with 8-13 marginal plumose setae decreasing in length posteriorly (Fig. 2A); small setulose seta arising posteriorly from submarginal region near posteroventral corner (Fig. 2C). Mucro short, but always prominent, with 2-3 transverse rows of minute denticles on ventral surface (Fig. 2C); length usually less than 1/8 of carapace length in mature female. Posterior margin from about proximal 2/3 of mucro to posterodorsal corner provided with submarginal row of minute setules gradually becoming shorter dorsally.

Head (Fig. 2A-B and D-E). Relatively large; length about 2/5 of carapace length. Marking usually absent, but faint marking of subparallel and longitudinal lines rarely present on ventral part in mature female (Fig. 2D). Dorsal to anterior margin evenly curved while anterior margin more or less arched in front of eye. Ventral margin deeply concave behind eye. Rostrum blunt and forming elliptical semicircle. Eye large, filling apart in short distance from anterior margin. Frontal sensory bristle near midpoint between eye and tip of rostrum in mature female, usually closer to tip of rostrum than to eye; position of bristle variable according to age, and sometimes moved largely toward

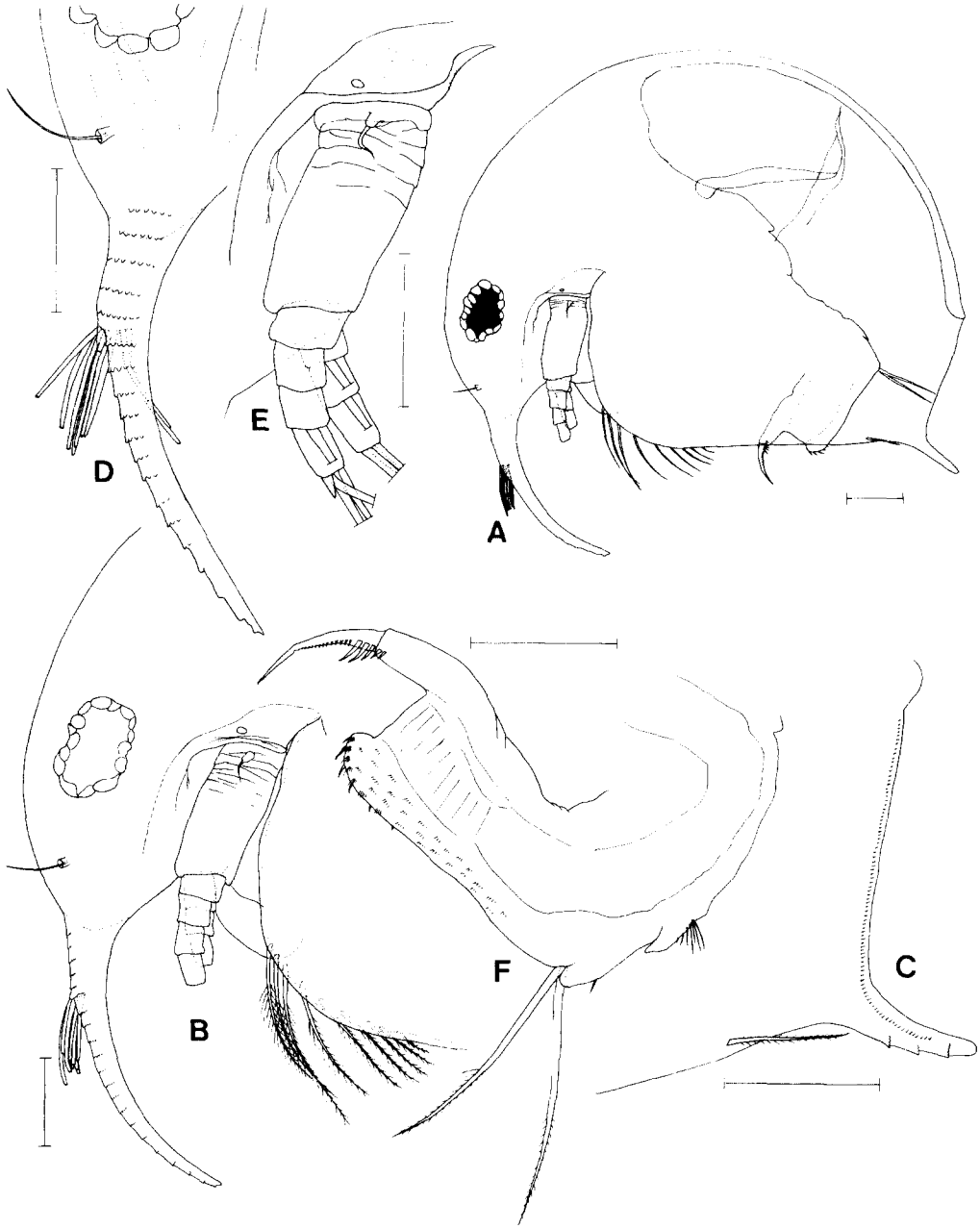

Fig. 2. *Bosmina longirostris* (O.F. Müller), lateral view of parthenogenetic female. A, habitus; B, anteroventral part of body; C, posterior part of carapace; D, ventral part of head and antennule; E, antenna; F, postabdomen. Scales bars=0.05 mm.

tip of rostrum in immature female. Fornix weakly developed, but distinct (Fig. 2B and 2E). Lateral head pore conspicuous, located on lateral margin of fornix near antennal articulation.

Antennule (Fig. 2B and 2D). Paired antennules almost parellel to each other, long and slender, immobile, and fixed to head and curving backward. Anterior surface provided with 20-25 transverse rows of minute denticles becoming smaller distally, forming weak tiers along anterior margin of whole antennular length; small lobe-like process arising from anterior surface near proximal fourth of antennule, making base of aesthescs. Aesthescs 9 in number, unequal in length.

Antenna (Fig. 2E). Small, shorter than 2/5 of carapace length. Antennal formula 0(0)-0(0)-1(0)-3(1)/1(0)-1(0)-3(0); all setae nearly equal in length; distal spine on exopod small; approximate length ratios of exopod segments relative to basipod length 0.21, 0.21, 0.21, and 0.24, endopod segments 0.28, 0.21, and 0.24; approximate width/length ratios of each segments 0.49

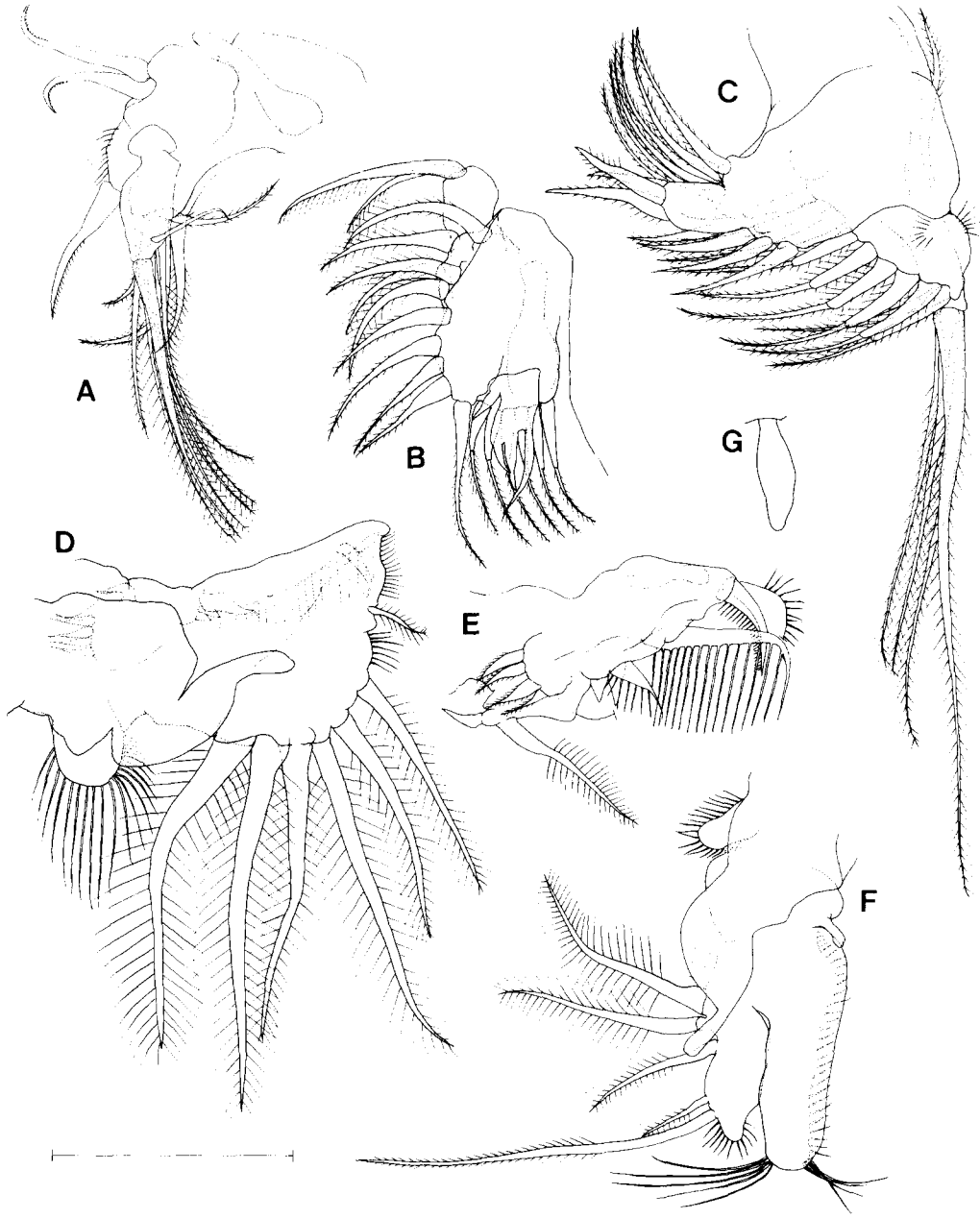

Fig. 3. *Bosmina longirostris* (O.F. Müller), trunk limbs of parthenogenetic female. A, left limb I, outer view; B, right limb II, inner view; C, left limb III, inner view; D, right limb IV, outer view; E, left limb IV, inner view; F, right limb V, outer view; G, left limb VI, inner view. Scale bars=0.05 mm.

in basipod, 1.40, 1.15, 1.00, and 0.69 in exopod, 0.78, 1.00, and 0.44 in endopod. Basipod with small seta having cylindrical mound on lateral surface near base. Surface nearly not ornamented.

Trunk limb I (Fig. 3A). Epipod pin-shaped. Two ejector hooks large and of unequal size, each finely serrated on distal half of concave margin, arising from anterior surface of protopod. Exopod with 1 long, finely serrated seta and 1 thin, short accessory seta. Endopod with 1 anterior seta and 7 distal setae; anterior seta robust and finely serrated on distal part of concave margin; 5 distal setae long and biserrate, subequal to each other in shape and length, and remaining 2 distal setae short and finely serrated; anterior surface with clusters of hairs. Gnathobase (maxillary process) well developed, provided with 3 short, curved setae on distal end.

Trunk limb II (Fig. 3B). Epipod pin-shaped. Exopod elongate, with 2 long plumose setae of unequal length at tip. Endopod comprising 3 lobes of endites; outer

distal lobe with 5 biserrated setae located irregularly on distal end; inner distal lobe with 5 thin, finely serrated setae arranged along margin; proximal lobe small, bearing 4 poorly developed, lobe-like setae. Gnathobase provided with 6 finely serrated setae.

Trunk limbs III (Fig. 3C). Epipod pin-shaped. Protopod bearing 2 plumose setae on anterior surface outeriorly. Exopod elongate, with 5 long, plumose setae of unequal length; longest seta about 3 times as long as shortest one; anterior surface with clumps of setules. Endopod comprising 2 lobes of endites; outer distal lobe with 10 long and thin, finely serrated setae arranged along distal margin; inner distal lobe provided with 3 stout serrated setae on distal end, 4 strong serrated setae along anterior margin, and with 2 slender, finely serrated setae on posterior margin; interior surface of inner distal lobe provided with clusters of setules distally. Gnathobase provided with 6 slender, finely serrated setae on distal margin.

Trunk limbs IV (Figs. 3D-E). Preepipod round, fringed with long setules. Epipod pin-shaped. Exopod flabelliform, with 7 plumose setae arranged from posterior margin to distal margin; distalmost seta very small; distal margin fringed with fine setules. Endopod somewhat reduced, comprising 3 lobes of endites; outer distal lobe relatively well developed, provided with 1 stout, curved seta finely setulated along concaved margin on distal end, and with basally 1 large comb-shaped seta, armed with long setules along posterior margin; inner distal lobe weakly developed, provided with 3 short and stout, spiniform setae, among which distalmost seta larger than others, and ornamented with setules along posterior margin; proximal lobe weakly developed, with 1 long plumose seta and 1 short spiniform seta. Gnothbase with 4 short biserrated setae subequal each other in shape and length.

Trunk limbs V (Fig. 3F). Preepipod small, fringed with setules. Epipod pin-shaped. Exopod flabelliform, with 5 setae; distalmost seta long, biserrated, and other 4 setae plumose, unequal in length. Endopod flabelliform, fringed with long setules.

Trunk limbs VI (Fig. 3G). Extremely reduced, forming small, simple lobe.

Postabdomen (Fig. 2F). Strong and slightly bulging toward distal end; length about 2.2 times of height. Abdominal process 1 in number, weakly developed, with clump of setules on dorsal surface proximally. Abdominal seta slightly shorter than dorsal margin of postabdomen, arising from anterodorsal corner forming right angle. Dorsal margin very weakly sinuate with distal part weakly expanded, provided with 4-6 small and thin anal spines; anal spines curved, decreasing in size proximally; except distal 2-3, proximal anal spines very small and usually not well observed. Ventral margin more or less expanded distally. Distal margin deeply depressed, forming truncated anal margin and ventral cylindrical structure; cylindrical structure as long as half of postabdominal claw, making base of postabdominal claws. Dorsolateral surface except region near anterodorsal corner with many clusters of fine setules; setules on dorsodistal part, especially arranged along dorsal margin, relatively strong and setiform.

Postabdominal claw (Fig. 2F). Slightly curved, bent dorsally at about proximal 2/3 of length, with 2 pectens. Proximal pecten extending to base proximally; spines 4-6 in number, large and strong, curved toward tip of claw; curvature and size of spines remarkably increased distally. Distal pecten composed of about 15 small spines decreasing in size distally, arranged along about proximal 1/5 to 2/3 of concaved dorsal margin. Dorsal margin with weak emargination at about proximal 2/3 of length, where claw usually bent.

Ephippial female: Except for partial differences in carapace by having ephippium, indistinguishable from parthenogenetic female in general form (Fig. 4A).

Carapace somewhat hardened and colored, with 2-3 grooves on region placing resting egg, each parallel to dorsal margin. Ephippium inconspicuous, containing 1 egg. Resting egg elliptical, rugged with distinct reticulation of irregular polygons and semicircles; ruggedness decreasing from margin to center (Fig. 4A).

Male: *General shape* (Fig. 4B). Small and slender. Body bilaterally compressed, subrectangular and narrow in outline of lateral view. Head not distinctly separated from body. Ventral, dorsal and posterior margins nearly straight. Posterodorsal corner low and forming small protuberance of obtuse angle. Anteroventral corner broadly rounded. Posteroventral corner forming mucro. Color hyaline and milky.

Carapace (Fig. 4B). Except forming straight dorsal margin by not having blood pouch, much similar in general structure to that of female. Marginal plumose setae on ventral margin 6-10 in number.

Head (Fig. 4C). Relatively large, short and wide, broadly rounded; length slightly shorter than half of carapace length. Marking usually absent. Dorsal margin evenly curved while anterior margin more or less arched in front of eye. Ventral margin round. Rostrum weakly developed, forming low triangular lobe. Eye, fornix, and lateral head pore as in female.

Antennule (Fig. 4C). Long and slender, mobile, not fixed to head, and slightly curving backward. Frontal sensory bristle near base; minute lobe-like process present near base anteriorly. Anterior surface provided with about 20 transverse rows of minute denticles becoming smaller distally, forming weak tiers along anterior margin of whole antennular length as in female; small lobe-like process arising from anterior surface at about proximal 5/13 of antennular length, making base of aesthescs. Aesthetascs 9 in number, unequal in length.

Antenna (Fig. 4D). Identical to that of female except for having additional small seta on basipod. Basipod provided with 2 small setae of subequal in form, arising crossly each other from lateral surface near

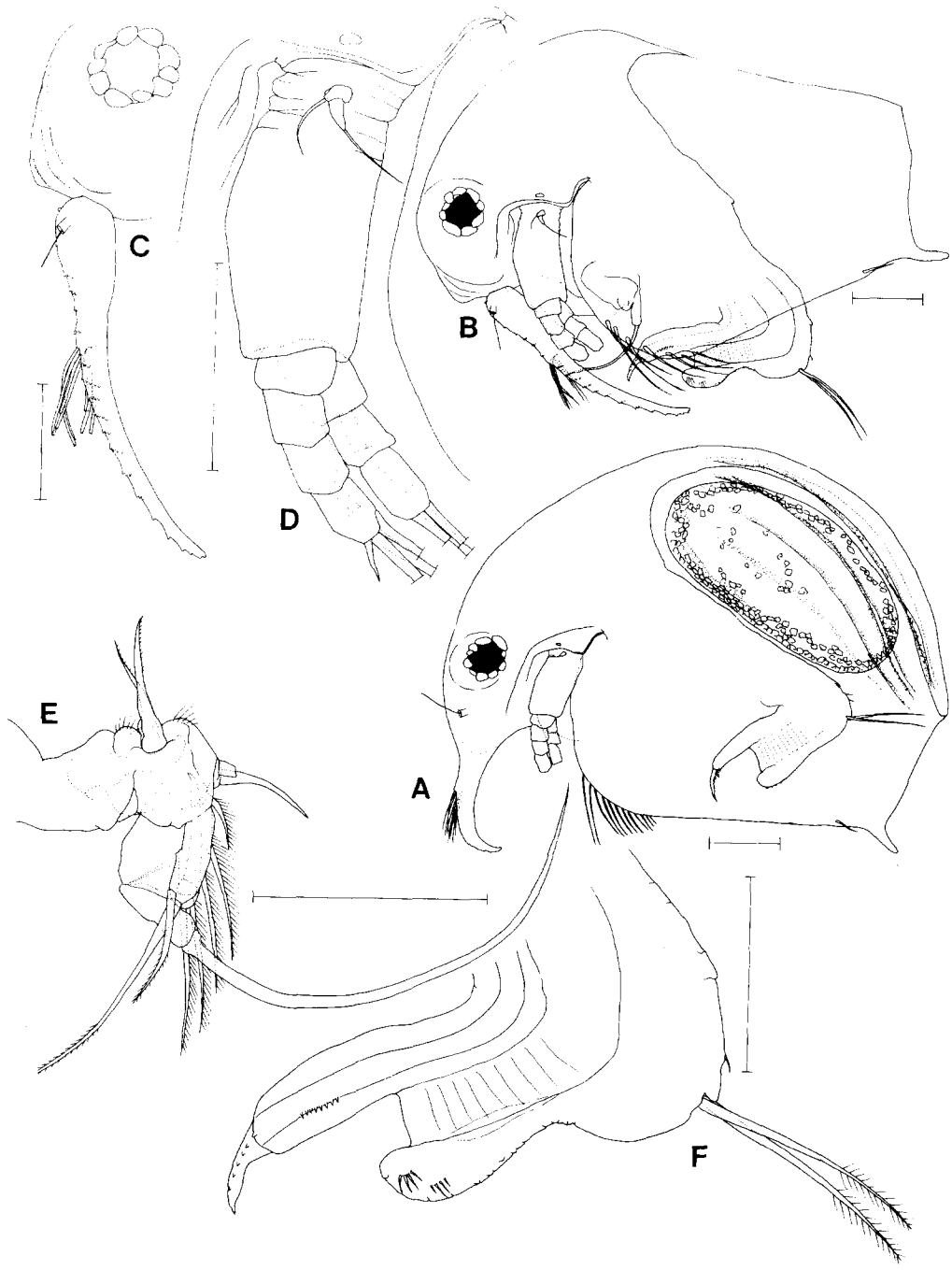

Fig. 4. *Bosmina longirostris* (O.F. Müller), lateral view of ephippial female (A) and male (B-F). A, habitus; B, habitus; C, ventral part of head and antennule; D, antenna; E, right limb I, outer view; F, postabdomen. Scale bars=0.05 mm.

base; setae having cylindrical mounds.

Trunk limb I (Fig. 4E). Epipod pin-shaped. Two ejector hooks strong, of nearly equal size, each finely serrated on distal half of concave margin, arising from anterior surface of protopod. Anterior surface of protopod with clusters of hairs. Exopod elongate, provided with 2 setae of unequal size on distal end. Endopod comprising 2 lobes of endites. Outer distal lobe strong and well developed, provided with long distal seta, male clasper, and small accessory seta; distal seta about 1.5 times as long as limb, with elongated base, and strongly curved; male clasper recurved against base, terminating into acute point at tip. Inner distal lobe weakly developed, provided with 1 short, strong seta and with cylindrical process. Gnathobase with 5 setulated setae.

Trunk limb II-VI. Identical in general form with those of female.

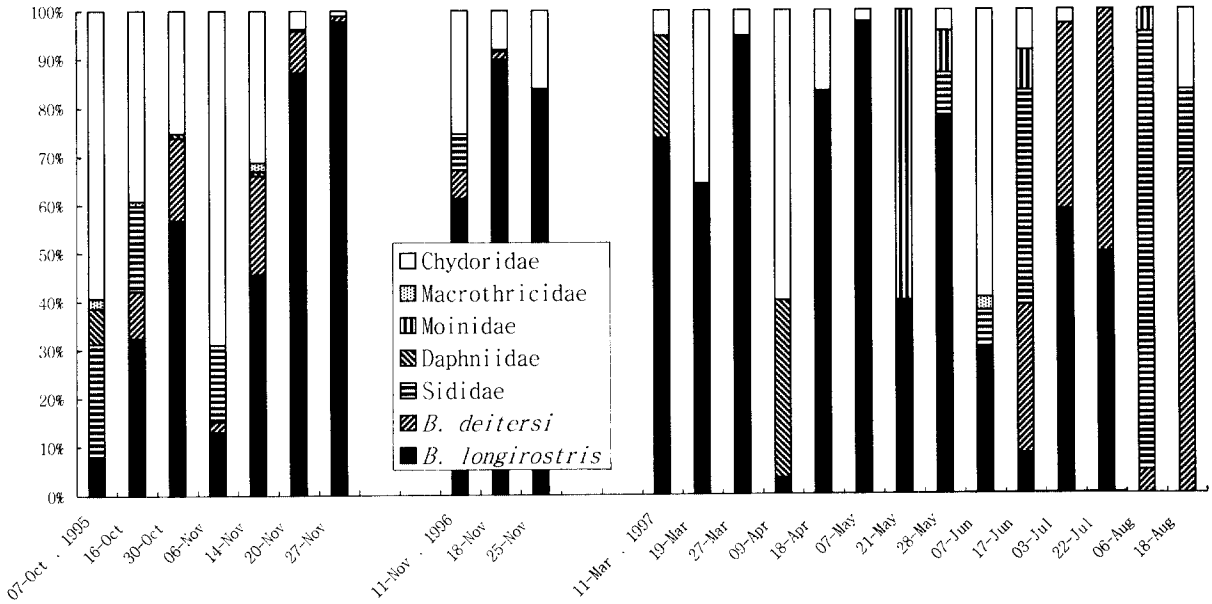

Fig. 5. Seasonal change of abundance (individuals per volume) in percentage occupation of the cladoceran taxa in Lake Kwangjuho during the period from October 1995 to August 1997.

Postabdomen (Fig. 4F). Strong and subrectangular; length about 2.3 times of height. Abdominal processes inconspicuous. Dorsal margin sinuate with deep indentation on middle, with 9-14 small tubercles irregularly arranged from posterodorsal corner to middle. Anal spine absent. Lateral surface near dorsal margin provided with 2 clusters of spiniform setules distally. Cylindrical base of postabdominal claws relatively large, provided with low of 8-9 denticles narrowly spaced on middle of lateral surface. Other structures nearly identical with those of female.

Postabdominal claw (Fig. 4F). Small and slightly curved, without pecten. Dorsal margin sinuated, ventral margin weakly indented. Lateral surface provided with row of denticles widely spaced along length.

Size: Length range (from anteromost part of head to posteromost part of carapace excluding mucro) of matured parthenogenetic females 0.34-0.50 mm. Ephippial females and males measuring 0.35-0.38 mm and 0.33-0.35 mm, respectively.

Remarks: Diagnostic characteristics of *B. longirostris* have been known as follows: (1) frontal sensory bristle is near midpoint between eye and tip of rostrum, (2) lateral head pore is inconspicuous, and located on the lateral margin of fornix near antennal articulation, (3) postabdominal claw is not emarginated on dorsal margin, and possesses distal pecten, (4) male clasper of trunk limb I is recurved against base, and terminates into acute point at tip, (5) cyclomorphosis is not observed. However many previous investigators had ignored some of these characteristics in distinguishing *B. longirostris* from its congeners. Especially in Far East *Bosmina* species had been distinguished mainly by the position of frontal bristle and by the presence of distal pecten on postabdominal claw (Chiang and Du, 1979; Yoon and Kim, 1987; Kim, 1988; Mizuno and Takahashi, 1991). But these two characteristics seem to be more or less variable and inconspicuous according to population and age. Their status are not easily noticed without a cautious observation. Some confusions might be included in many previous reports of *Bosmina* species in Far East. Occurrences of *B. coregoni* and *B. fatalis* are still not clear in Korea.

Among above five characteristics the position of lateral head pore seems the most valid and useful one, because males are very rarely found in natural populations, even though characteristics of male are known to be very important and useful in the taxonomy of *Bosmina* (Deevey and Deevey, 1971).

Although only a few previous works provide satisfying informations, Korean materials are generally well accorded with those of other countries (Lilljeborg, 1901; Sars, 1903; Keilhack, 1909; Ueno, 1927; Sramek-Husek et al., 1962; Manujlova, 1964; Scourfield and Harding, 1966; Flössner, 1972; Chiamg and Du, 1979; Negrea, 1983; Margaritora, 1983; Michael and Sharma, 1988). However, some different characteristics, which seem not to have been noticed or to have been neglected by most previous investigators, are observed in Korean specimens as follows: (1) distal segment of antennal exopod has a small distal spine in both sexes (Figs. 2E and 4D), (2) minute lobe-like process is present on anterior surface of male antennule basally (Fig. 4C), (3) antennal basipod of male possesses two basal setae while that of female has one (Fig. 4D), (4) male postabdomen has a group of denticles on the

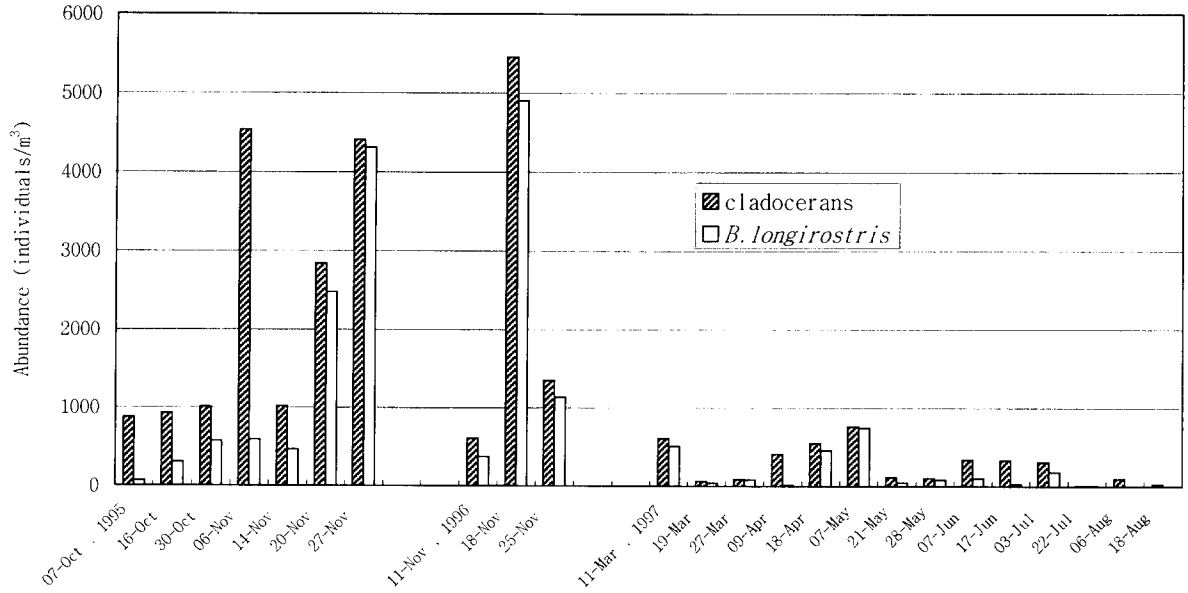

Fig. 6. Seasonal change of abundance concerning the populations of *B. longirostris* and other cladocerans in Lake Kwangjuho during the period from October 1995 to August 1997.

base of postabdominal claw laterally (Fig. 4F), (5) male postabdominal claw possesses a longitudinal row of denticles on lateral surface (Fig. 4F). Similar features for male postabdomen and postabdominal claw were observed from European materials (Flössner, 1972; Negrea, 1983), but the other features have not been noted yet. Based on the descriptions of Ueno (1927) and Chiang and Du (1979), both of Japanese and Chinese materials probably seem not to have common features with Korean, but the reality is not clear because their short and simple descriptions and illustrations could not show the whole aspects of them. Some cladocerologists believe that there are several groups or subspecies in many cladoceran species that have been traditionally recognized as widely distributed ones (Frey, 1987). Thus, there is a possiblity that Korean specimens belong to another distinct group of *B. longirostris*. However it has not been confirmed yet, and the actual status of *Bosmina* species has not been revealed in many regions (Dodson and Frey, 1991). Therefore further comparative studies with the specimens from various parts of the world are necessary to determine the valid taxonomic position of the Korean materials.

Distribution: Cosmopolitan.

Notes on ecology

Bosmina longirostris is one of the most common species among cladocerans in lake waters, reservoirs and rivers. It is a true plankton, and much prefers large waters to small ones. About 87% of the materials of the present study were collected from the habitats of large waters (Appendix). It could be found throughout all seasons while population size seems to be extremely decreased in winter. Materials examined in the present study include those of two localities collected from lake waters covered with ice in midwinter (sta 81 and 83 in Appendix). The temperatures of the waters from which the materials of *B. longirostris* were collected ranged between 4.3℃ and 35.0℃. The specimens of parthenogenetic females in reproductive stage carried 1-7 eggs, usually 2-4 eggs. Materials of ephippial females and males were collected in spring (April and May), and in autumn (September). Sexual reproduction seems to occur at least twice a year in natural populations.

The results of the study on the cladoceran populations in Lake Kwangjuho show that *B. longirostris* becomes one of the most important species among cladoceran species in lake waters. *Bosmina longirostris* also seems to have a wide range of tolerance in water temperature with effective adaptibility to coldness (Figs. 5-7). In the results of examining the quantitative samples of large volume, *B. longirostris* occupied a larger portion of cladocerans in terms of individuals per volume (m^3) at most of the times except midsummer in 1997 (Fig. 5). The relative portion of *B. longirostris* to cladocerans was mainly affected by that of chydorid cladocerans. But this seems to be a superficial result accrued by the simple joining of the occurrences of two taxa that changed independently of each other according to environmental conditions. There is little possibility that the two groups had some strong ecological relationship with each other, because most chydorid cladocerans are known as epibenthos (Dodson and Frey, 1991). It is remarkable that the portion of another bosminid cladoceran, *Bosminopsis deitersi* Richard, 1895, increased

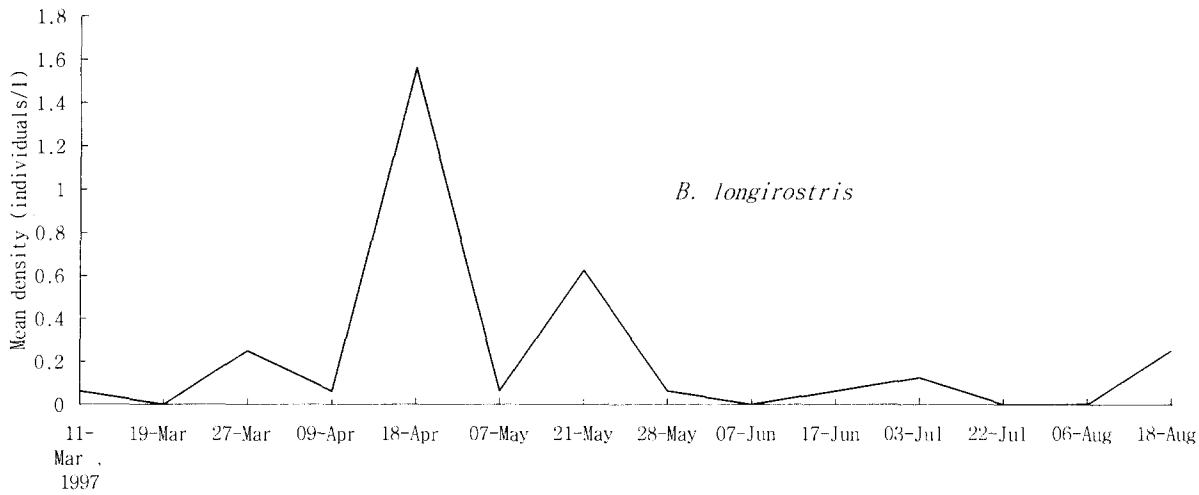

Fig. 7. Change of mean density (individuals/l) concerning the population of *Bosmina longirostris* in Lake Kwangjuho during the period of March to August in 1997.

much in midsummer when the portion of *B. longirostris* extremely decreased (Fig. 5).

Abundance of *B. longirostris* in terms of individuals per volume (m^3) was very high in autumn, and relatively low in spring and summer (Fig. 6). Also a tendency that the abundance increased with colder temperature in autumn, and decreased with hotter temperature in summer could be noticed in Fig. 6. It is probable that there are two annual growth cycles in natural population of *B. longirostris*. One cycle of low growth rate may begin at early spring and end in hot summer, and another cycle of high growth rate may begin with ending of hot summer, and end in winter as generally known in cladocerans.

While based on the results of examining the quantitative samples of small volume (each comprises four replicates of 2.5 l), mean density (individuals/l) of the population of *B. longirostris* in Lake Kwangjuho was measured between 0 and 1.6 during the period from March to August in 1997 (Fig. 7). When comparing Fig. 7 with the corresponding part in Fig. 6, the whole patterns of two figures are well accorded with each other, but show some differences in detail. Also values in Fig. 6 more or less differ from those in Fig. 7 with a tendency of underestimation. Much of these differences were resulted by using the different tools and scales in the samplings. Besides quantitative accuracy the sampling of large volume with many replicates of various scales is recommendable in the quantitave analyses of ecology.

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Appendix

Station list

Seoul: sta 1, Han-gang at Han-gang bridge, Apr. 5, 1990; sta 2, Sŏkch'onho, Chamshil, Apr. 13, 1986; sta 3, a pond in Kyunghee Univ., Oct. 26, 1984 (CY Chang).

Kyŏnggi-do: sta 4, a pond at Naehaeng-dong, Tongduch'ŏn-shi, Oct. 6, 1988 (CY Chang); sta 5, a small reservoir at Chŏngok-ŭp, Yŏnch'ŏn-gun, Oct. 6, 1988 (CY Chang); sta 6, Hantan-gang at Paekŭi-ri, Ch'ŏngsan-myŏn, Yŏnch'ŏn-gun, Oct. 6, 1988 (CY Chang); sta 7, Yŏngp'ŏng-ch'ŏn at Paekŭi-ri, Ch'ŏngsan-myŏn, Yŏnch'ŏn-gun, Oct. 6, 1988 (CY Chang); sta 8, Namhan-gang, Yangp'yŏng-ŭp, Yangp'yŏng-gun, Apr. 24, 1994; sta 9, Han-gang at Yangsu-ri, Yangsŏ-myŏn, Namyangju-gun, Aug. 11, 1991; sta 10, Han-gang at Choan-ri, Wabu-myŏn, Namyangju-gun, Jul. 15, 1984 (CY Chang); sta 11, a lake at Seoul Grand Park, Kwach'ŏn-shi, Sep. 12, 1991; sta 12, Namyangho, Mar. 26, 1986.

Kangwŏn-do: sta 13, Kongjich'ŏn, Ch'unch'ŏn-shi, Aug. 16, 1990; sta 14, a pond in Kangwon Univ., Oct. 31, 1981 (IH Kim); sta 15, Soyangho, Oct. 16, 1986; sta 16, Haksap'yŏng reservoir, Sokch'o-shi, Jun. 3, 1986 (IH Kim); sta 17, Chukhŏn reservoir, Kangrŭngshi, Oct. 25, 1985 (IH Kim).

Ch'unch'ŏngbuk-do: sta 18, Ŭirimji, Chech'ŏn-shi, May 2, 1987; sta 19, Ch'ungjuho at Kuryong-ri, Kŭmsŏngmyŏn, Chewŏn-gun, May 2, 1987; sta 20, Shindŏk reservoir, Shinni-myŏn, Chungwŏn-gun, Jul. 12, 1986 (SS Lee); sta 21, Ch'ilsŏng reservoir, Koesan-gun, Sep. 13, 1983 (CY Chang); sta 22, Myŏngamji, Ch'ŏngju-shi, Sep. 13, 1984 (CY Chang); sta 23, Taech'ŏngdaem, Mar. 15, 1984 (CY Chang).

Taejŏn: sta 24, Pangdong reservoir, Yusŏng-gu, Jul. 19, 1991.

Ch'unch'ŏngnam-do: sta 25, Chisŏkri reservoir, Yesanŭp, Yesan-gun, Jul. 2, 1988 (JS Shin); sta 26, Sapgyoho, Oct. 6, 1985; sta 27, a stream at Hadae-ri, Kyeryong-myŏn, Kongju-shi, Jul. 16, 1990 (CY Chang); sta 28, a bog at Tŏkmyŏng-ri, Kyeryong-myŏn, Kongju-shi, Aug. 13, 1990 (CY Chang); sta 29, Kapsa resevoir, Kyeryong-myŏn, Kongju-shi, Jul. 28, 1988 (CY Chang); sta 30, ricefields at Kŭmdae-ri, Nosŏng-myŏn, Nonsan-shi, Aug. 25, 1990 (CY Chang).

Chŏllabuk-do: sta 31, Kŭmma reservoir, Tongjinmyŏn, Iksan-shi, May 3, 1988 (CY Chang); sta 32, Wanggung reservoir, Tongjin-myŏn, Iksan-shi, May 3, 1988 (CY Chang); sta 33, Yonghŭng reservoir, Yongjinmyŏn, Wanju-gun, Apr. 20, 1991 (CY Chang); sta 34, Paeksŏk reservoir, Chŏnju-shi, May 3, 1988 (CY Chang); sta 35, Tongsanri reservoir, Apr. 20, 1991.

Chŏllanan-do: sta 36, Changsŏngho, Nov. 4, 1984 (CY Chang); sta 37, Kwangjuho, Kosŏ-myŏn, Tamyang-gun, Oct. 10, 1995 - Aug. 18, 1997; sta 38, Chuktong reservoir, Koksŏng-gun, Jun. 2, 1988 (CY Chang); sta 39, Suŏji, Chinsang-myŏn, Kwangyang-shi, Jan. 20, 1987; sta 40, Chusamdong reservoir, Yŏch'ŏn-shi, Apr. 25, 1990; sta 41, Haktong reservoir, Todŏk-myŏn, Kohŭng-gun, Jan. 30, 1991 (CY Chang); sta 42, Samsan reservoir, Samsan-myŏn, Haenam-gun, Feb. 7, 1987 (CY Chang); sta 43, Namsan reservoir, Chindo-ŭp, Chindo-gun, Nov. 1, 1994; sta 44, Osan reservoir, Kogun-myŏn, Chindo-gun, Nov. 1, 1994; sta 45, Hoidong reservoir, Kogun-myŏn, Chindo-gun, Jun. 4, 1996; sta 46, Sach'ŏn reservoir, Ŭishin-myŏn, Chindo-gun, Nov. 1, 1994; sta 47, Songjŏng reservoir, Ŭishinmyŏn, Chindo-gun, Nov. 1, 1994; sta 48, Yongsan reservoir, Inhoi-myŏn, Chindo-gun, Nov. 1, 1994; sta 49, Paektong reservoir, Inhoi-myŏn, Chindo-gun, Nov. 1, 1994; sta 50, Yŏndong reservoir, Inhoi-myŏn, Chindo-gun, Jul. 23, 1994; sta 51, Shimdong reservoir, Chisan-myŏn, Chindo-gun, Nov. 2, 1994; sta 52, Pongam reservoir, Chisan-myŏn, Chindo-gun, Nov. 2, 1994; sta 53, Wau reservoir, Chisan-myŏn, Chindogun, Nov. 2, 1994; sta 54, Kilŭn reservoir, Chisanmyŏn, Chindo-gun, Nov. 2, 1994; sta 55, Yanghwari reservoir, Hwawŏn-myŏn, Haenam-gun, Apr. 20, 1996; sta 56, a bog in ricefields near Sajaje, Wŏlch'ulsan, Yŏngam-gun, Jul. 28, 1988 (CY Chang); sta 57, Naedong reservoir, Wŏlch'ulsan, Yŏngam-gun, Jul. 28, 1988 (CY Chang); sta 58, a small reservoir in Chukchŏng Valley, Wŏlch'ulsan, Yŏngam-gun, Jul. 28, 1988 (CY Chang); sta 59, Togap reservoir, Sŏ-myŏn, Yŏngam-gun, Nov. 19, 1988 (GS Min); sta 60, Yŏngsanho, Mokp'o-shi, Apr. 28, 1997 (SH Chung); sta 61, Yŏngsan-gang, Mongt'an bridge, Muan-gun, Apr. 28, 1997 (SH Chung); sta 62, Yŏngsan-gang, Tonggang bridge, Hamp'ŏng-gun, Apr. 28, 1997 (SH Chung).

Kyŏngsangbuk-do: sta 63, Konggŏmji, Sangju-gun, Jun. 19, 1986; sta 64, Kaŭm reservoir, Ŭisŏng-gun, May 26, 1988 (CY Chang); sta 65, Yŏngch'ŏnho, Chayang-myŏn, Yŏngch'ŏn-gun, May 26, 1988 (CY Chang); sta 66, Taewŏn reservoir, Sŏsan-gun, May 26, 1988 (CY Chang); sta 67, Kinalmot, Kimch'ŏn-shi, Apr. 20, 1986; sta 68, Munch'ŏn reservoir, Chinryangmyŏn, Kyŏngsan-shi, Sep. 20, 1996; sta 69, Yongyŏn reservoir, P'ohang-shi, May 27, 1988 (CY Chang); sta

70, Pomunji, Kyŏngju-shi, May 29, 1988 (CY Chang).

Pusan: sta 71, Chungrim-gang, Sŏnam bridge, Taejŏng-dong, Kangsŏ-gu, Apr. 23, 1984 (CY Chang).

Kyŏngsangnam-do: sta 72, Chuksanri reservoir, Sudong-myŏn, Hamyang-gun, Sep. 21, 1996; sta 73, Magonŭp, Changma-myŏn, Ch'angnyŏng-gun, Jul. 22, 1987; sta 74, Pŏngaenŭp, Samma-myŏn, Ch'angnyŏng-gun, Jul. 22, 1987; sta 75, Taeamdaem, Samdong-myŏn, Ulsan-shi, Jan. 30, 1987 (MK Shin); sta 76, Taewha-gang, Ulsan-shi, Jan. 30, 1987 (MK Shin); sta 77, Chunam reservoir, Ch'angwŏn-gun, Jul. 22, 1987; sta 78, Tongp'angemot, Ch'angwŏn-gun, Jul. 22, 1987; sta 79, Nam-gang, Pŏpsu-myŏn, Haman-gun, Jan. 17, 1987; sta 80, Taega reservoir, Taega-myŏn, Kosŏng-gun, Aug. 21, 1987; sta 81, Turyangmot, Sach'ŏn-gun, Jan. 19, 1987; sta 82, Nam-gang, Chinju-shi, Jun. 24, 1984 (GS Min); sta 83, Chinyangho, Chinju-shi, Jan. 19, 1987; sta 84, a stream at P'ŏngdang-ri, Chingyo-myŏn, Hadong-gun, Jul. 3, 1984 (GS Min).

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