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First Record of a Freshwater Jellyfish, *Craspedacusta sowerbii* Lankester, 1880 (Limnomedusae, Olindiidae) from Reservoirs in Korea

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Freshwater jellyfishes were collected from Taechong Dam reservoir in Korea on September 1994. Tiny nontentacled hydroids were also collected from Taechong Dam and Chuam Dam reservoirs in Korea between September 1995 to September 1997. The medusae were identified into *Craspedacusta sowerbii* Lankester, 1880 and tiny hydroids were found to be in its polyp stages. It belongs to the family Olindiidae in Limnomedusae and is first recorded from Korea. Environmental factors affecting the medusa occurrence are discussed.

The freshwater jellyfish, *Craspedacusta sowerbii* Lankester is intriguing among all cnidarian species, due to its unique biology and unpredictable occurrence. Though this medusa is a stage of its life cycle, it does not always appear. Their occurrence is influenced by several complicated factors, such as temperature (Lytle, 1961), pH (Tomita, 1942), feeding (Acker and Muscat, 1976), competition and predation (Pennak, 1956), and population size of their polyps (Payne, 1924). The sessile microscopic polyps give rise to relatively large medusae in the suitable condition, and then degenerate. They contribute in the regulation of the population size of the polyp (Payne, 1924) unlike other hydromedusae which serve in species dispersal.

Since Lankester named the peculiar freshwater medusae into *Craspedacusta sowerbii* after Mr. Sowerby, who donated them, studies on its taxonomy, sporadic occurrence, ecology, life cycle, development, origin and distribution have been done by Mayer (1910), Ryder (1885), Payne (1924), Dejdar (1934), Woodhead (1943), Kramp (1950), Uchida (1934, 1955), Pennak (1956, 1978), McClary (1959), Lytle (1960, 1961), Deacon and Haskell (1967), Bushnell and Porter (1967), Hubschman and Kishler (1972), Acker (1976), Acker and Muscat (1976), and Dodson and Cooper (1983). However, such studies on this species have not been done in Korea.

Materials and Methods

The nine reservoirs including Soyanggang Dam, Chungju Dam, Andong Dam, Imha Dam, Taechong Dam, Hapchon Dam, Namgang Dam, Somjingang Dam and Chuam Dam space (Fig. 1) in Korea were surveyed for the occurrence of medusae and polyps of *Craspedacusta sowerbii* between November 1995 to September 1997. However during that period freshwater medusae were not observed. For the examination of its polyp stage, gravels, old wood, plants, sticks and concrete mass samples were handpicked by scuba divers and the author from the bottoms about 2 m deep of nine dam reservoirs. Polyps were collected from the Taechong Dam reservoir on September 1995, October 1996, June and September

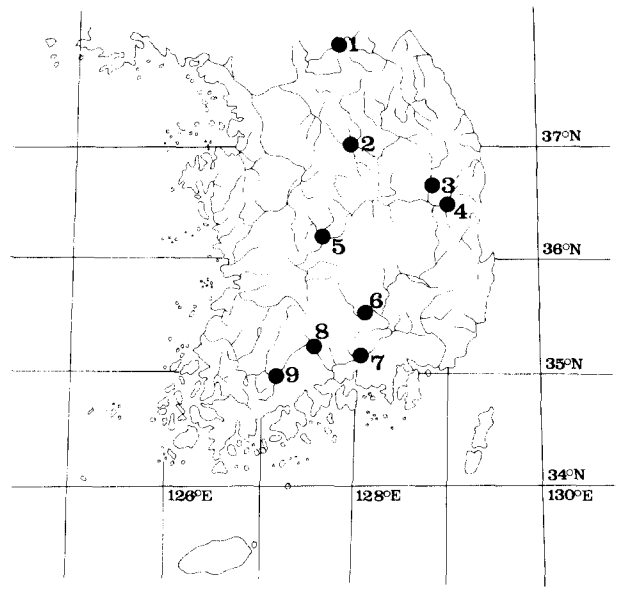

Fig. 1. Survey sites for the distribution of *Craspedacusta sowerbii* during the period of Nov. 1995 to Sept. 1997. 1, Soyanggang Dam; 2, Chungju Dam; 3, Andong Dam; 4, Imha Dam; 5, Taechong Dam; 6, Hapchon Dam; 7, Namgang Dam; 8, Somjingang Dam; 9, Chuam Dam.

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1997 and Chuam Dam reservoir on November 1995 and October 1996. These polyps were preserved in 5% formalin after narcotization with menthol. The medusae, collected with nylon scape nets from the Taechong Dam reservoir on September 1994, were used for identification.

The identification was done on the basis of the morphological characteristics of medusa and polyp. Medusae were photographed with a camera equipped with a macrolense and pictures of polyps were taken with a microphotographic apparatus. The size measurements were done with an ocular micrometer. Temperature, pH, COD and EC of the habitats of the medusae in Taechong Dam reservoir were measured for the examination of the environmental parameters affecting the medusa occurrence. Temperature and pH were measured with HI 9025 HANNA instruments, COD official method by acid $KMnO_4$ and EC with WTW LF 191.

Results and Discussion

Systematic account

Phylum Cnidaria
Class Hydrozoa
Order Limnomedusae[1]
Family Olindiidae[2]

Craspedacusta sowerbii Lankester, 1880[3]
(Figs. 2A-H, 3A-D)

Craspedacusta sowerbii Lankester, 1880 (pp. 146, 177, 190, 241); Mayer, 1910 (p. 363, fig. 207); Dejdar, 1934 (p. 595); Uchida, 1934 (p. 1150, figs. 1, 6, 7); Jackson, 1953 (p. 428); Pennak, 1956 (p. 324); McClary, 1959 (p. 158, figs. 1-5); Lytle, 1960 (p. 461, figs. 1-2); Lytle, 1961 (p. 317, figs. 1-12); Acker, 1976 (p. 219, fig. 1); Acker and Muscat, 1976 (p. 323, figs. 1-4); Slobodkin and Bossert, 1991 (p. 135, figs. 5, 9).

Craspedacusta sowerbyi: Fuhrmann, 1939 (p. 363, figs. 1-3); Woodhead, 1943 (p. 379, figs. 1-3); Kramp, 1950 (p. 165, figs. 1-8); Uchida, 1955 (p. 14); Kramp, 1961 (p. 219); Deacon and Haskell, 1963 (p. 504); Matthews, 1966 (p. 246, figs. 1-4); Bushnell and Porter, 1967 (p. 22, figs. 1-2); Deacon and Haskell, 1967 (p. 155); Hubschman and Kishler, 1972 (p. 318, fig. 1); Pennak, 1978 (p. 104, figs. 65-66); Dodson and Cooper, 1983 (p. 345).

Craspedacusta ryderi: Payne, 1924 (p. 387, pls. 1-9, figs. 1-60); Payne, 1926 (p. 433, figs, 1-9).

Microhydra ryderi: Ryder, 1885 (p. 1232, figs. a-h).

Limnocodium sowerbii: Hargitt, 1908 (p. 304, figs. 1-7).

Material examined: Medusae— Taechong Dam reservoir, 5 Sep. 1994.

Polyps— Chuam Dam reservoir, on 14 Nov. 1995, colony found on old wood, composed of 2 polyps; 18 Oct. 1996, on sticks and gravels, colony composed of 2 polyps and a single polyp; Taechong Dam reservoir, 18 Sep. 1995, on plants, a solitary polyp; 18 Oct. 1996, on plants, gravels and sticks, colonies composed of 2 polyps; 18 Jun. 1997, on concrete, colonies composed of 2-7 polyps; 9 Sep. 1997, on concrete, colony composed of 4 polyps and 22 Sep. 1997, a solitary polyp.

Description: Medusa— Bell nearly hemispherical, more or less the same size at the same time and place (Fig. 2B), about 11-12 mm in width and 5 mm in height. Gelatinous substance (mesoglea) very thin and soft. Tentacles variable in size and number arising from various levels slightly above bell margin (Fig. 2F). Four largest perradial tentacles arising from side of bell at some distance above margin, about 20 or more tentacles of medium size from lower and nearer margin and numerous smaller tentacles from the lowest of all. Therefore adult medusa having about 200 or more tentacles of various size, tentacles hollow, tapering toward distally, with batteries at nearly regular intervals and without any appendages. Statocysts scattered somewhat irregularly between tentacles (Fig. 2G), elongate pyriform, and within gelatinous substances of velum. Four radial canals (Fig. 2A, D) arising from stomach, straight and narrow (Fig. 2G). A ring canal more or less wide and sinuous around margin, rising at points of origin of largest perradial tentacles. The Manubrium somewhat long (Fig. 2C) with four pleated oral lobes (Fig. 2E). Gonads sac shaped (Fig. 2C, H), arising from a radial canal, placed somewhat nearer to center of radial canals than to bell margin and hanging down. Velum well developed (Fig. 2G) and bell margin able to evert backward (Fig. 2C).

Polyp— Polyps cylinder shaped, solitary (Fig. 3B) or as a colony (Fig. 3A), very small, below 1 mm in length, and consisting of capitulum (Fig. 3D) with several nematocysts and oral openings, with a contracted thin neck, expensible trunk and stocky base attached to a relatively stable substrata. They were found on plants, old wood, sticks, rocks and concrete. Colony consists of 2-7 polyps. Nematocyst microbasic euryteles (Fig. 3C), scattered on the surface of capitulum. Size measurements (in mm) as follows. Total length, 0.20-0.92; head width, 0.09-0.26; neck width, 0.09-0.24; trunk width, 0.10-0.32; base width, 0.10-0.52.

Remarks: *C. sowerbii* and *C. sinensis* possess similar features with each other as the simpatric species

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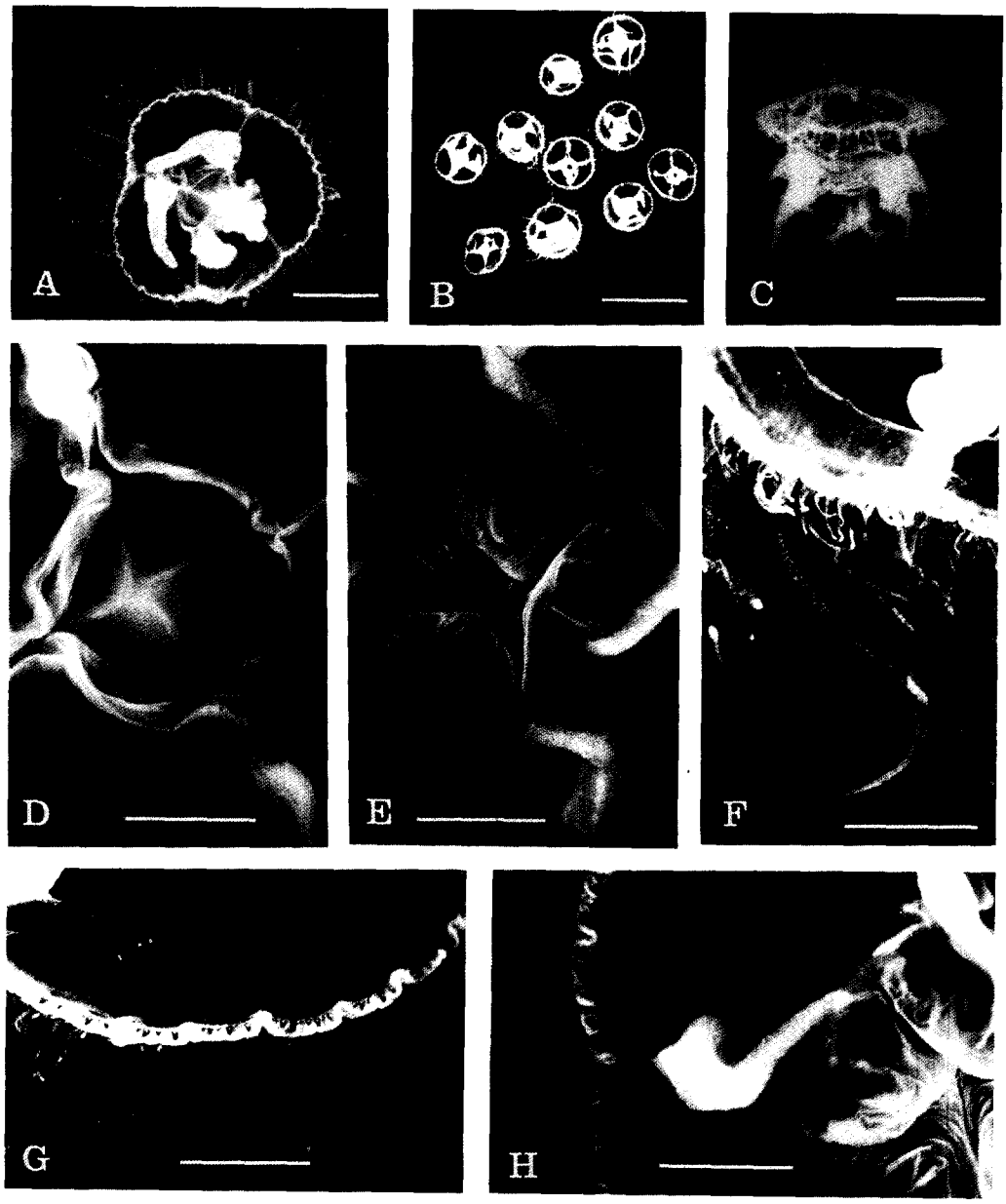

Fig. 2. Morphology of medusa stage of *Craspedacusta sowerbii*. A, Adult medusa. B, Several mudusae of similar size. C, Lateral view of everted medusa with sac-shaped gonads and a long manubrium. D, Aboral view showing four radial canals arising from the stomach. E, Oral view showing a mouth and four pleated oral lobes. F, Size difference of tentacles. G, Pyriform statocysts within velum. H, Gonad on radial canal. Scale bars=0.5 mm (A, C), 2 mm (D-H), and 20 mm (B).

(Acker, 1976). But the gonads of the latter appeared to be brownish yellow in color, thus readily distinguishable from the former with greenish gonads and the manubrium of *C. sinensis* (Kramp, 1950) relatively shorter than that of *C. sowerbii*.

Distribution in Korea: Soyanggang Dam (personal communication), Taechong Dam and Chuam Dam reservoirs.

Distribution outside Korea: Kramp (1950) suggested that this species originated from Yang-tse-kiang in China and transported to other parts of the world with the water hyacinth, *Eichornia* and other plants. Within any general locality, however, other agents, both physical and biological, assist its dispersal (Acker, 1976). It was widely distributed in Asia, Europe, Australia, and North and South America (Bushnell and Poter, 1967).

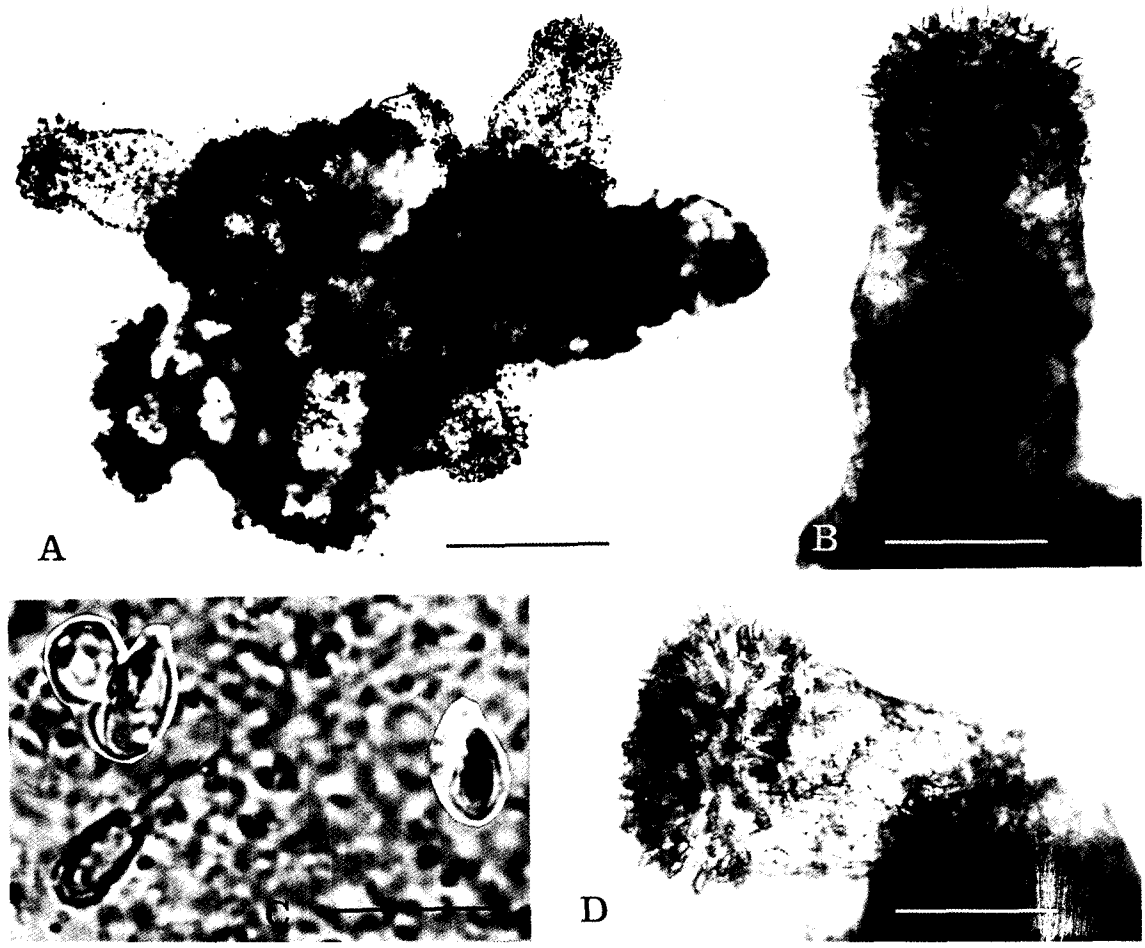

Fig. 3. Morphology of the polyp stage of *Craspedacusta sowerbii*. A, A Colony composed of seven polyps. B, Solitary polyp. C, Nematocysts. D, Head with nematocysts. Scale bars=0.02 mm (C), 0.1 mm (B, D), and 0.2 mm (A).

Environmental factors and discussion

The medusae of *C. sowerbii* appeared in large numbers in the late summer of 1994 from the Taechung Dam reservoir, Korea, however, they were not found during this study. Though a number of studies on occurrrence of this freshwater medusa were reported by aquatic biologists, its occurrence and ecology are yet unknown. The effects of water temperature on the medusae occurrence were reported by McClarly (1959), Lytle (1961) and Deacon and Haskell (1967). According to them, when the water temperature suddenly increased from 20℃ to 25-27℃, medusae appeared, then disappeared with a decrease in temperature below 16℃. Medusa budding is closely related to feeding (Lytle, 1959; Acker and Muscat, 1976). The relative abundance of the medusae follows like a time shadow of zooplankton blooms (Acker and Muscat, 1976). This probably reflects the feeding pattern of the medusae. The medusae were found only in the pond where the pH readings ranged from 6.7 to 8.4, while in the lake with a pH range of 8.5 to 9.7, the medusae were not found (Tomita, 1942). In the lake with a pH range of 7.3 to 7.9, the medusae appeared (Bushnell and Porter, 1967). From these results, pH appears to have an important effect on medusa occurrence. Whether other factors, light, CO_2 or the movements of food organisms play a direct role in medusa budding is not clear (Acker and Muscat, 1976).

For the examination of environmental parameters affecting medusa occurrence, temperature, pH, COD and EC of surface waters were measured from four stations of the Taechong Dam reservoir (Fig. 4) early September and October 1994 (personal communication) when the medusae appeared and from the same stations in intervals of around 20 days during April to September 1997. In 1997, the temperature range was 15 to 35℃, pH 7.2 to 10.0, COD 1.9 to 7.0 mg/L and EC 95 to 156 μs/cm (Table 1). In September and October 1994, the temperature, pH, COD and EC were 21 to 29℃, 7.2 to 7.6, 2.2 to 3.8 mg/L and 114 to 156 μs/cm respectively. Comparing the temperature and pH of years 1994, and 1997, those in 1994 are closer

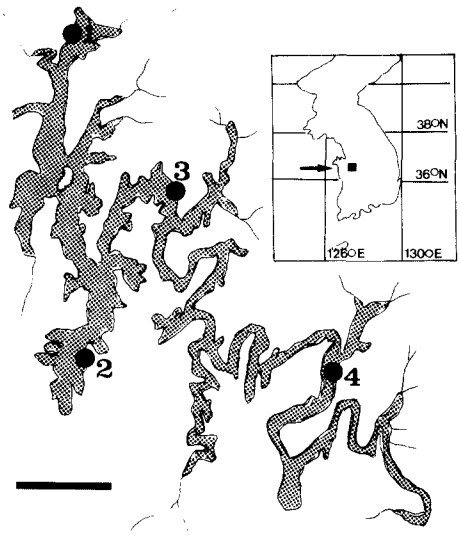

Fig. 4. Localities where the environmental parameters were measured in 1994 and 1997. 1, Munui; 2, Chudong; 3, Hoenamgyo; 4, Changgyogyo. Scale bar=1 km.

to values obtained by Tomita (1942) and Bushnell and Porter (1967). This result suggests that the temperature and pH are important factors on medusae appearance. The pH and temperature values in 1997 were not suitable on their occurrence generally. There were no significant difference in values of COD and EC between 1994 and 1997. Other factors, for example, predation and competition were suggested (Pennak, 1956). In addition, when its internal factors such as the size of the polyp population reached peak, polyps gave rise to medusae that are reported to regulate the population size of the polyp (Payne, 1924).

Most records of this species are for the active and relatively visible medusoid stage. The sessile and microscopic polyp stage is easily overlooked and less often reported. The polyp stage is tolerant to most ecological factors. The polyp, which can exit in lentic and lotic situations, can withstand long periods of food shortage, tolerates wide variations of temperature and light, and can reproduce asexually. The polyp exists throughout the year except when it contracts into its resting stage. The medusa requires a relatively lentic environment, needs abundant plankton to sustain its more active life and growth to maturity. It is less tolerant of temperature extremes and strong light, and can only recur with dependence upon the polyp (Acker, 1976). Polyps do not always give rise to medusae. So even without the appearance of the medusae, polyps can exist. Therefore, it is considered that this species may be more widely distributed in Korea.

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Table 1. Environmental parameters of surface waters in four stations of the Taechong Dam reservoir where the medusae appeared

Date	Station	Temperature (℃)	pH	COD (mg/L)	EC (μs/cm)
Sep. 5, 1994	1[a]	27	7.4	2.2	127
	2[b]	28	7.2	2.6	119
	3[c]	29	7.3	3.8	134
	4[d]	28	7.5	2.4	114
Oct. 5, 1994	1	21	7.3	2.8	156
	2	21	7.3	3.0	124
	3	21	7.6	3.2	128
	4	21	7.6	2.8	131
Apr. 16, 1997	1	18	8.7	3.5	140
	2	19	8.3	3.3	138
	3	15	8.4	2.9	140
Apr. 24, 1997	4	18	9.1	2.4	132
May 8, 1997	1	17	8.1	4.0	138
	2	17	8.2	3.8	136
	3	19	8.4	3.3	129
	4	21	8.3	3.8	138
May 28, 1997	1	20	9.0	3.5	137
	2	22	9.0	1.9	128
	3	24	7.9	2.2	111
	4	25	8.4	3.0	144
Jun. 18, 1997	1	29	8.6	3.2	129
	2	29	8.8	4.0	125
	3	32	9.2	3.8	156
	4	32	9.3	4.5	148
Jun. 29, 1997	1	31	9.4	3.8	117
	2	32	9.6	5.0	108
	3	33	10.0	7.0	111
	4	35	9.0	3.6	114
Aug. 19, 1997	1	27	9.9	6.2	113
	2	27	9.1	5.9	102
	3	27	8.9	3.8	95
	4	27	9.2	3.4	97
Sep. 9, 1997	1	29	9.5	3.6	103
	2	29	9.1	3.6	98
	3	29	9.9	4.7	101
	4	29	8.8	2.5	137
Sep. 22, 1997	1	24	7.5	3.8	99
	2	24	7.5	3.5	99
	3	24	7.2	3.2	99
	4	24	7.4	3.0	138

[a]Munui, [b]Chudong, [c]Hoenamgyo, [d]Changgyogyo.

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