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Long-term Changes of the Fish Fauna and Community Structure in the Jungrang Creek, Seoul, Korea

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중랑천의 어류상과 어류군집 구조의 장기 변동. 배경석* · 김교붕 · 길혜경 · 유병태 · 김민영 (서울특별시 보건환경연구원)

서울을 지나는 한강 하류수계의 중랑천 어류상과 어류 군집의 현황 및 변동을 1990년부터 2000년까지 조사하였다. 출현하는 어류의 총 종수는 6과 14종이었으며, 총 개체수는 108,366개체였다. 중랑천은 1980년대와 1990년까지는 수질의 악화와 하천변 환경 훼손으로 물고기가 서식하지 못했으나 1990년대 초반 이후 유역 수질개선정책으로 수질이 다소 회복됨에 따라 오염 내성종인 잉어 및 붕어 등이 처음으로 출현하였다. 그후 1996년 6종, 1998년 9종, 2000년 11종으로 어류의 다양성이 점차 증가하는 추세였다. 어류의 개체수현존량은 1996년 164개체, 1998년 146개체, 2000년 108,094개체로 1998년 이전에는 계절별로 변동이 적었으나 2000년도의 봄철과 이른 여름철의 산란기에는 중랑하수처리장 방류수가 유입되는 지점의 하류수역과 수중보에 의해 형성된 정체수역에서 105,225개체와 2,754개체가 조사되었다. 특히, 한강 하류에 풍부하게 서식하고 있는 잉어 및 붕어가 산란기에 중랑천으로 이동하는 과정에서 많은 개체수가 조사되었다. 2000년 4월 21일과 6월 11에는 중랑천 하수처리장 방류구 하류지점과 수중보내의 정체구역에서 용존산소가 고갈되어 많은 물고기가 수면으로 부상하는 사고가 발생하였다. 중랑천의 주요 우점종은 붕어와 잉어이며, 우점도지수는 0.79～1.00으로 매우 높았다. 종다양도지수와 종풍부도지수는 0～1.66과 0～1.41로 매우 낮았으며, 중류지역에서 이들 지수가 다소 높게 나타났다. 그러나, 아직까지 중랑천의 어류상은 매우 빈약하며, 군집구조도 단순한 것으로 나타났다.

Key words : Long-term changes, Fish fauna, Community structure, Jungrang Creek, Water pollution, DO depletion

INTRODUCTION

Stream ecosystems show a continuous gradient of physical conditions. Those also elicit a continuum of biotic adjusment and abiotic characteristics of loading, transport, utilization, and storage of organic matter (Hynes, 1970; Vannote *et al*., 1980; Allan, 1995). Although the Korean streams historically have been well preserved mountain streams, their water qualities have been severely degraded, and biological habitats have been severely destructed due to industrial development and urbanization since 1960s (Bae and Lee, 2001). Especially, biotic communities of urban streams according to the cityward tendency of the population have been greatly damaged (Yoon *et al*., 1992a, b; Bae *et al*., 1996; Bae *et al*., 1997a; Bae and Lee, 2001). The Jungrang Creek is a typical urban stream and discharges into the lower parts of the Han River with the heavy pollutants (Fig. 1). Fishes were not founded at the Jungrang Creek because of water pollution and habitat destruction since

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1980s. And then, fishes started to inhabit in the Jungrang Creek from the early 1990s. Thereafter, mass floating and death of fishes happened every year. In particular, many fishes from the main course of the Han River migrate to the upper part of the Jungrang Creek during the spawning season from April to June. When they migrate, a large number of fishes frequently died at the deficient zones of dissolved oxygen. Therefore, we have surveyed on the variations of dissolved oxygen concentration at this area polluted with domestic sewage and industrial wastewater.

Long-term changes of fish fauna and its commmuty structure in the Jungrang Creek have been little understood. Therefore, this study is to evaluate long-term changes on the faunistic and community characteristics of fishes according to various water quality factors such as dissolved oxygen and nutrients.

MATERIALS AND METHODS

Study sites

The Jungrang Creek is a branch stream of the Han River located in northeast Seoul city. It is 20 km in length within Seoul city boundary and flows to the lower parts of the Han River (Fig. 1). The Jungrang Creek has 13 tributaries, but most of them were dried in the middle and lower region except for the rainy season. One third of the 10 million Seoul population is living in the Jungrang Creek area. And, a huge Jungrang sewage treatment plant (Secondary treatment with 1.7 million ton/day) was located at the lower part of the creek. Organic pollutants and water course modification have mainly affected the fish habitation in the creek. The following sites were surveyed for this study (Fig. 1).

Site 1 : Nowon bridge, Nowon-gu, Seoul (borderline between Seoul and Gyeonggi-do)
Site 2 : Jungrang bridge, Dongdaemun-gu, Seoul
Site 3 : Jangan bridge, Jungrang-gu, Seoul
Site 4 : Seongdong bridge, Seongdong-gu, Seoul

Sampling and Analysis

Fishes were seasonally surveyed in 1990, 1996, 1998, and 2000 at the sampling sites. Fishes were collected by a catch-net with 3 mm mesh size and preserved in 20% formalin. Collected fishes were classified by variuos identifiction sourse (Choi *et al*., 1990; Kim and Kang, 1993; Choi, 1994; Kim, 1997). Water quality was monthly checked 3 sites (site 1, 2, and 4) for the study period. pH, DO were measured by pH and DO meters in the field. BOD, SS, T-N, and T-P were analyzed in the laboratory by standard examination method of water quality (APHA *et al*., 1985; Choi *et al*., 1999).

Dominance indices (McNaughton, 1970), species diversity (Lloyed and Ghelardi, 1964; Pielou, 1966, 1969), and richness indices (Margalef,

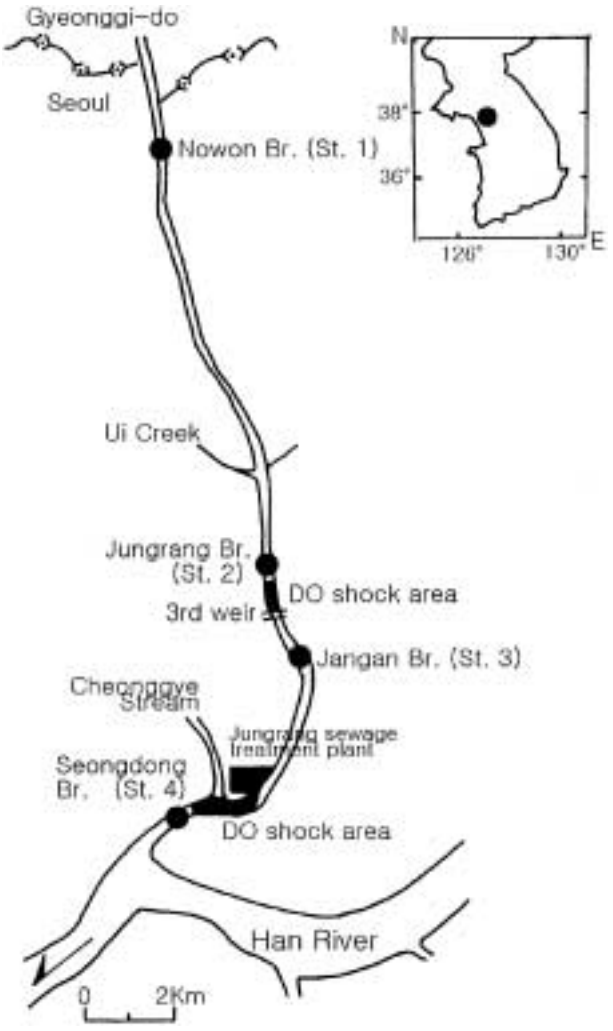

Fig. 1. A map showing the survey sites of the water quality and fishes in the Jungrang Creek of Seoul, Korea.

1958) were calculated to evaluated the fish community structure.

RESULTS AND DISCUSSION

1. Physico-chemical factors

The water qualities of the Jungrang Creek have been gradually improved since 1980s (Table 1, Figs. 2, 3, 4 and 5). The annual mean value of pH has been slightly raised since 1990. High alkali values at all study sites were caused by attached algae from the Creek bed. BOD has decreased since 1990. The annual mean value of BOD at the lower site (Site 4) was 36.9 mg/l in 1990, but it decreased to 10.9 mg/l in 1999, and 13.6 mg/l in 2000. Suspended solids at Site 4 has greatly reduced from 43.1 mg/l in 1990 to 8.1 mg/l in 2000. Total nitrogen and total phosphorus have increased since 1980s. Annual mean values of T-N at the lower site (Site 4) have greatly increased from 8.66 mg/l in 1990 to 19.13 mg/l in 2000. Also, annual mean values of T-P at site 4 has gradually increased from 0.98 mg/l in 1990 to 1.46 mg/l in 2000. Therefore, high level teatment of sewage at Jungrang and Euijeongbu sewage treatment plants are needed.

Monthly variations of each water quality parameter showed in Figs. 2-5. Monthly concentrations of BOD, T-N, T-P, and DO showed big fluctuations. Water quality in the dry season was worse than that of the rainy reason. The water quality at the Site 4 (Seongdong Br.) was the worst among the three sites and also was severely impacted by the sewage discharge of 1.7 million ton/day from the Jungrang sewage treatment plant.

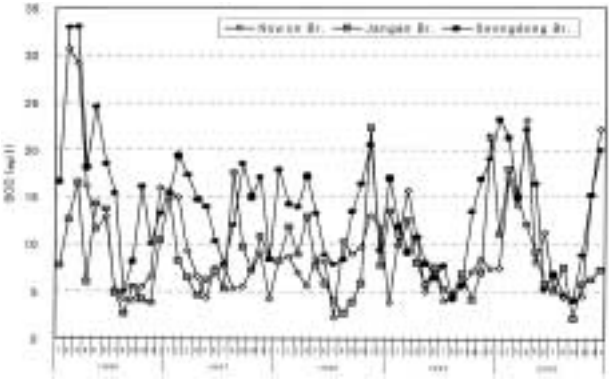

Fig. 2. Monthly changes of BOD (mg/l) at each site of the Jungrang Creek (1996~2000).

2. Fish fauna

Fishes had not been found at the Jungrang Creek in the 1980s (Bae *et al*., 1997b), but tole-

Table 1. Annual mean concentrations of water quality parameters at each site of the Jungrang Creek (1990~2000).

Item	Site	Year										
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
pH	St. 1	–	–	7.6	7.6	7.4	7.6	7.5	7.5	7.4	7.7	7.9
	St. 3	–	–	7.6	7.7	7.6	7.7	7.6	7.5	7.5	7.8	7.9
	St. 4	7.3	7.6	7.2	7.2	7.3	7.4	7.3	7.1	7.1	7.4	7.3
BOD (mg/l)	St. 1	–	–	13.4	13.8	16.1	23.5	16.2	8.1	8.8	7.5	11.4
	St. 3	–	–	13.9	12.6	15.1	20.9	8.5	8.9	7.9	8.9	8.8
	St. 4	36.9	42.6	38.9	24.3	19.7	30.5	17.7	14.2	13.5	10.9	13.6
SS (mg/l)	St. 1	–	–	32.1	51.6	52.0	32.2	29.7	19.3	16.7	34.6	15.0
	St. 3	–	–	21.2	21.0	34.7	36.2	15.4	10.9	14.1	29.0	11.4
	St. 4	43.1	42.2	25.8	28.0	33.3	21.9	18.7	16.8	16.0	11.4	8.1
T-N (mg/l)	St. 1	–	–	7.24	9.70	8.00	12.14	14.28	10.38	10.00	9.98	15.38
	St. 3	–	–	6.26	8.59	9.18	10.91	14.01	9.74	8.74	10.62	13.02
	St. 4	8.66	8.42	8.87	10.73	10.96	13.31	16.34	17.79	15.14	14.81	19.13
T-P (mg/l)	St. 1	–	–	0.73	0.71	0.80	0.80	0.92	0.84	0.62	0.60	1.05
	St. 3	–	–	0.54	0.60	0.75	0.53	0.57	0.54	0.43	0.51	0.56
	St. 4	0.98	0.97	1.02	1.21	0.97	1.16	1.02	1.22	1.03	1.04	1.46
DO (mg/l)	St. 1	–	–	7.0	7.0	5.9	8.3	7.7	8.8	8.4	9.4	11.2
	St. 3	–	–	6.1	7.9	6.3	8.9	8.5	10.0	8.2	9.4	10.4
	St. 4	–	5.2	4.4	4.8	5.0	4.5	5.7	5.6	6.9	7.4	8.0

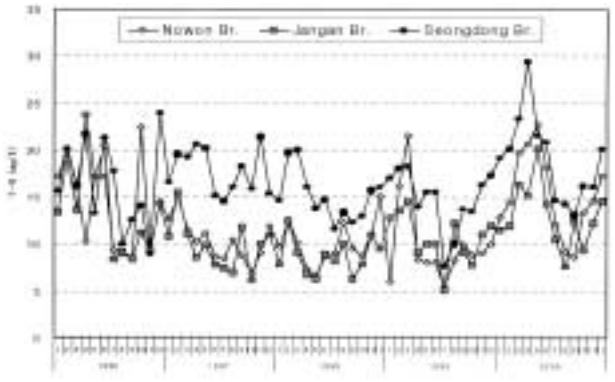

Fig. 3. Monthly changes of T-N (mg/l) at each site of the Jungrang Creek (1996~2000).

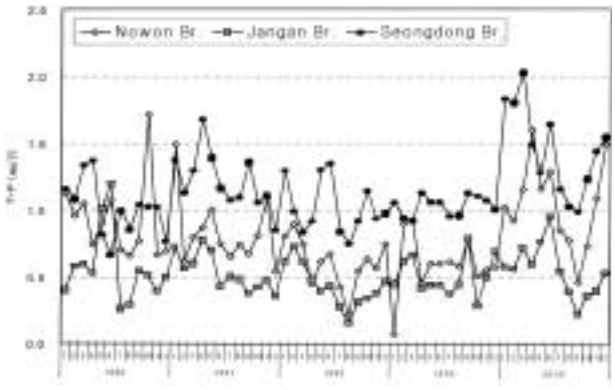

Fig. 4. Monthly changes of T-P (mg/l) at each site of the Jungrang Creek (1996~2000).

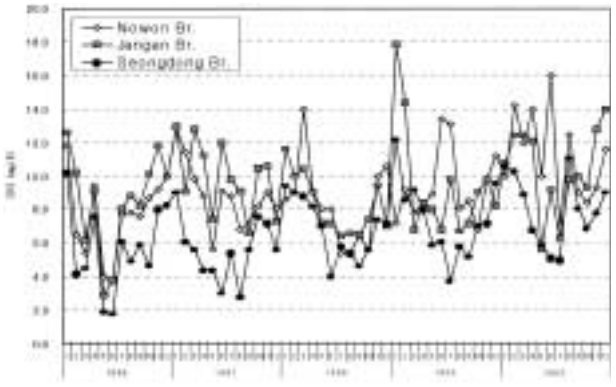

Fig. 5. Monthly changes of DO (mg/l) at each site of the Jungrang Creek (1996~2000).

rant species *Cyprinus carpio* and *Carassius auratus* (Cyprinidae) were first occurred in the early 1990s when the water quality improved because of enforcement of the water quality improvement policy of Seoul metropolitan government. The fishes collected during the whole survey period was classified into 14 species in 6 families (Table 2). They are composed of 8 species of Cyprinidae (57.1%), 2 species of Cobitidae (14.3%) and 4 species of other fishes (28.6%). Species number of fishes at each site during the whole survey period was 1 species at site 1, 11 species at site 2, 10 species at site 3, and 3 species at site 4. Fishes were appeared more abundant at the mid-stream section (Site 2 and Site 3) than the upper region or mouth of the creek. It appears that most fishes of the lower and middle areas of the creek could not migrate to the upper site (Site 1) by the obstacles such as weir and water pollution.

Species number of fishes has gradually increased 6 species in 1996, 9 species in 1998, and 11 species in 2000 (Table 2). Species number at each site in 1996 was 3 species at Site 2, 6 species at Site 3, respectively. However, fishes were not collected at Site 1 and Site 4 in 1996 (Table 2). Species number at each site in 2000 was 7~8 species at site 2 and site 3, but they were 0~3 species at site 1 and site 4 (Table 2). Species number of fishes in the Jungrang Creek has gradually increased from 6 species in 1996 to 11 species in 2000. But mass floating of fishes on the water surface in dry season has frequently occurred at stagnant spot by weir and discharging point of the Jungrang sewage treatment plant because of DO depletion.

Korean endemic species in the creek was 3 species, *Odontobutis platycepha* (Odontobutidae), *Squalidus japonicus coreanas* and *Squalidus chankaensis tsuchihae* (Cyprinidae). And, dominant species is a *Cyprinus carpio* and *Carassius auratus* (Cyprinidae).

The individual number of fishes were not significantly increased seasonally before 1998, but they increased to 105,225 individuals in spring (April 21st) and 2,754 individuals in summer (June 11th) of 2000 (Table 2, Fig. 6). Individual number of fishes in 2000 was 105,247 individuals at site 4. In particular, the number of fishes in the Jungrang Creek was greatly abundant in spring and early summer in 2000. Mass migrations of *Cyprinus carpio* and *Carrassius auratus* from the Han River to the upper reaches of the

Table 2. Comparisons of species and individual numbers of fishes at each site of the Jungrang Creek (1990～2000).

Species name	Year	1990				1996			
	Site	St. 1	St. 2	St. 3	St. 4	St. 1	St. 2	St. 3	St. 4
Cyprinidae									
Cyprinus carpio							2	4	
Carassius auratus							14	59	
Pseudorasbora parva									
Hemibarbus labeo								1	
Squalidus tsuchidae									
Squalidus coreanus									
Erythroculter erythropterus								6	
Zacco platypus									
Cobotidae									
Misgurnus mizolepis								8	
Misgurnus anguillicaudatus									
Siluridae									
Silurus asotus							3	11	
Eleotrididae									
Odontobutis platycephala									
Oryziidae									
Oryzias latipes latipes									
Gobiidae									
Rhinogobius brunneus									
Species number		0	0	0	0	0	3	6	0
Individual number		0	0	0	0	0	19	89	0
Cyprinidae									
Cyprinus carpio			2	4	1		7 (101)	8 (2,000)	30 (100,000)
Carassius auratus		6	23	108	3		58 (505)	26 (100)	15 (5,000)
Pseudorasbora parva			6				10	2	
Hemibarbus labeo			1	2				1	
Squalidus tsuchidae							2		
Squalidus coreanus							1		
Erythroculter erythropterus				1					
Zacco platypus							10	4	
Cobotidae									
Misgurnus mizolepis				1			6		
Misgurnus anguillicaudatus								1	
Siluridae									
Silurus asotus			1	1				2 (2)	2 (200)
Eleotrididae									
Odontobutis platycephala				2					
Oryziidae									
Oryzias latipes latipes			2						
Gobiidae									
Rhinogobius brunneus							1		
Species number		1	6	7	2	0	8	7	3
Individual number		6	35	119	4	0	95 (606)	44 (2,102)	47 (105,200)

( ) = Qualitative data after the DO shortage outbreak

Jungrang Creek were observed in spring and summer of 2000. *Cyprinus carpio* was 100,012 individuals at the below discharging point of the Jungrang sewage treatment plant when the

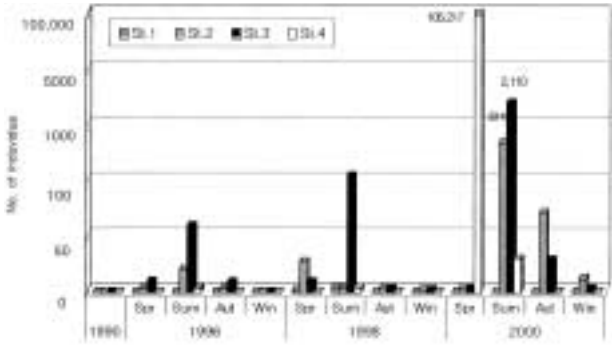

Fig. 6. Seasonal changes of individual number of fishes at each site in the Jungrang Creek.

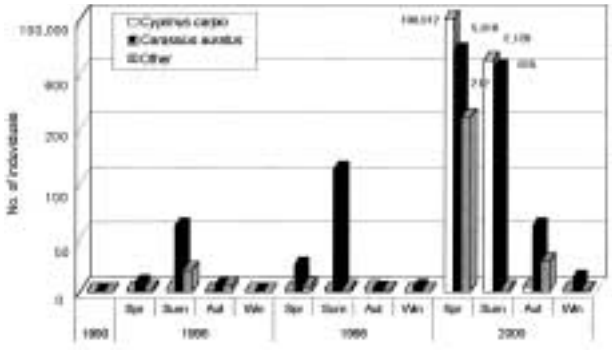

Fig. 7. Seasonal changes of individual number of major fishes at the Jungrang Creek.

mass floating of fishes occured on the 21st of April in 2000. And that time, *Carassius auratus* was 5,015 individuals (Table 2, Fig. 7).

Cyprinus carpio and *Carassius auratus* are very abundantly distributed in the Han River (Seoul metropolitan gov., 1994, 1998). They migrate to the upper reaches of the Jungrang Creek for spawning. First mass floating of dead and shocked fishes happened abruptly by dissolved oxygen deficiency at the below region of discharging point of Jungrang sewage treatment plant on the 21st of April in 2000. And, 2nd and 3rd mass floatings happened at the dammed pools in the lower reaches of site 3 and site 2 on June 10th and 11th, 2000. The DO depletion was caused by the heavy organic matter deposition and resuspension delivered by a rain (10~18 mm) after long time dry seson. The reason of DO decrease was caused by resuspension of organic silt from sediments of stagnant area and discharge of organic waste from the sewage treatment plant. The values of DO, BOD, and SS were tabulated in Table 3 and Table 4. The Jungrang Creek has been suffered from thermal variation by water volume shortage, water pollution due to organic waste in weirs and destructed banks. In these conditions, habitation and migration of fishes have been considerably limited.

Table 3. DO, BOD, and SS concentrations at the sites near of discharging point of the Jungrang sewage treatment plant (JSTP) when the 1st mass floating of fishes occured on the 21st of April in 2000.

Site	Lower site of J.S.T.P (Seongdong Br.)	discharging point of J.S.T.P	Upper site of J.S.T.P
DO (mg/l)	6.8	1.0	6.1
BOD (mg/l)	22.1	60.7	19.7
SS (mg/l)	18.7	100.0	44.0

Note : Rainfall of 10 millimeter precipitation before the DO depletion

Table 4. DO, BOD, and SS concentrations at the dammed pool with 3rd weir (below site 2) when the 3rd mass floating of fishes occured in the Jungrang Creek (June 11th, 2000).

Site	Lower site of 3rd weir (Stream site)	Dammed pool with 3rd weir (Stagnant site)	Upper site of 3rd weir (Stream site)
DO (mg/l)	3.7	1.8	6.6
BOD (mg/l)	19.8	28.1	15.4
SS (mg/l)	45.0	38.0	21.0

Note : Rainfall of 10 millimeter precipitation before the DO depletion

The water quality of the Jungrang Creek has been gradually improved since 1990, but the level of the improvement was not sufficient for the fish spawning and habitation. For ecosystem restoration of Jungrang Creek, more advanced level of the treatment of urban sewage, self purification ability, and habitat restoration of stream bed are needed.

3. Community structure

The major dominant species and subdominant species at the study sites during the survey period were *Carassius auratus*, *Cyprinus carpio*, *Pseudorasbora parva*, and *Silurus asotus* (Table 5). All these species are tolerant indicator species of water quality (Choi *et al*., 1990; Choi, 1994).

Table 5. Dominant species and subdominant species of fishes in the Jungrang Creek from 1990 to 2000.

Year	Site	1st and 2nd dominant species	DI
1990	St. 1	–	–
	St. 2	–	–
	St. 3	–	–
	St. 4	–	–
1996	St. 1	–	–
	St. 2	*Carassius auratus*, *Silurus asotus*	0.89
	St. 3	*Carassius auratus*, *Silurus asotus*	0.79
	St. 4	–	–
1998	St. 1	*Carassius auratus*	1.00
	St. 2	*Carassius auratus*, *Pseudorasbora parva*	0.83
	St. 3	*Carassius auratus*, *Cyprinus carpio*	0.94
	St. 4	*Carassius auratus*, *Cyprinus carpio*	1.00
2000	St. 1	–	–
	St. 2	*Carassius auratus*, *Cyprinus carpio*	0.96
	St. 3	*Cyprinus carpio*, *Carassius auratus*	0.99
	St. 4	*Cyprinus carpio*, *Carassius auratus*	0.99

Table 6. Dominance (DI), diversity (H′), and richness (RI) indices of fishes at each site of Jungrang Creek from 1990 to 2000.

Year	Site	DI	H′	RI
1990	St. 1	–	–	–
	St. 2	–	–	–
	St. 3	–	–	–
	St. 4	–	–	–
1996	St. 1	–	–	–
	St. 2	0.89	1.09	0.68
	St. 3	0.79	1.62	1.11
	St. 4	–	–	–
1998	St. 1	1.00	0.00	0.00
	St. 2	0.83	1.60	1.41
	St. 3	0.94	0.66	1.26
	St. 4	1.00	0.81	0.72
2000	St. 1	–	–	–
	St. 2	0.96	0.96	1.07
	St. 3	0.99	0.38	0.78
	St. 4	0.99	0.30	0.17

Annual values of dominance indices, species diversity indices, and species richness indices during the survey period were tabulated in Table 6. Dominance indices were relatively high (0.79～1.00) in 1996, 1998, and 2000. In particular, propotion of individuals of *Carassius auratus* and *Cyprinus carpio* was relatively high. Accordingly, species diversity indices were relatively low (0 to 1.62). These indices were slightly higher (0.38 to 1.62) in the middle reaches (Site 2 and Site 3). Richness indices were relatively low (0 to 1.41). Also, this values were slightly higher (0.68 to 1.41) in the middle reaches (Site 2 and Site 3). However, above biological indices during the survey period were little fluctuated because of simple fish fauna.

ABSTRACTS

Long−term changes of the fish fauna and its community structure from the Jungrang Creek of the Han River system in Seoul were investigeted from 1990 to 2000. Total species occurred during the survey period were 14 species in 6 families, and total individual number was 108,366. Fishes at the Jungrang Creek had not been distributed in the 1980s and 1990 because of heavy water pollution as well as environmental damage in the riparian areas. However, *Cyprinus carpio* and *Carassius auratus* in cyprinidae were rehabitated since the early 1990s when the water quality was improved because of foundation of sewage division pipe. Species numbers gradually increased to 6 species in 1996, 9 species in 1998, and 11 species in 2000. Individual numbers rapidly increased to 164 individuals in 1996, 146 individuals in 1998, and 108,094 individuals in 2000.

A large number of *Cyprinus carpio* and *Carassius auratus*, which are abundantly distributed in the main course of the Han River, were found when they migrate to the upper reaches of the Jungrang Creek for spawning. Mass fish floatings were occurred on the 21st of April and the 11th of June in 2000 due to DO depletion at the lower site (Site 4) of discharging point of Jungrang sewage treatment plant and stagnant spot (Site 3) of dammed pool. Major dominant species were *Cyprinus carpio* and *Carassius auratus* (Cyprinidae). Others dominant species were *Pseudorasbora labeo* (Cyprinidae) and *Silurus asotus* (Siluridae). Dominance indices were relatively high (0.79 to 1.00). Species diversity and richness indices were relatively low (0 to 1.66 and 0 to 1.41, respectively). Species diversity and richness indices were slightly higher at the middle reaches (Site 2 and Site 3) than the upper reaches and the mouth of the Jungrang Creek. However, the fish fauna of the Jungrang Creek was very poor and its community structure was very simple.

REFERENCES

Allan, J.D. 1995. Stream ecology. Structure and function of running water. Chapman & Hall. London.

APHA, AWWA and WPCF. 1992. Standard methods for the examination of water and waste water. 18th ed. American Public Health Association, Washington D.C.

Bae, K.S., B.K. Koo, S.K. Han, J.Y. Shin, and S.B. Park. 1997a. An ecological study on the quatic animal community in Tan Stream, Seoul. *Kor. J. Env. Hlth. Soc.* **23**: 1-8. (In Korean)

Bae, K.S., J.T. Park, G.C. Cho, H.K. Kil, and J.Y. Shin. 1997b. An ecological study on the quatic animals in Jungrang Stream of Seoul. *Kor. J. Env. Hlth. Soc.* **23**: 89-97. (In Korean)

Bae, Y.J. and B.H. Lee. 2001. Human impacts on stream ecosystems and freshwater arthropods in Korea. *Kor. J. Entomol.* **31**: 63-76. (In Korean)

Bae, Y.J., S.Y. Park, I.B. Yoon, J.H. Park, and K.S. Bae. 1996. Changes of benthic marcroinvertebrate community from a dredged section in Wangsuk Creek. *Kor. J. Lim.* **29**: 251-261. (In Korean)

Choi, G.C., S.T. Kang, Y.H. Kim, W.S. Lee, J.Y. Lee, and S.J. Jeon. 1999. Standard examination method of water quality pollution. Ministry of Environment. (In Korean)

Choi, K.C. 1994. Freshwater fishes of Korea. Seomundang, Seoul. (In Korean)

Choi. K.C., S.L. Jeon, I.S. Kim, and Y.M. Son. 1990. Coloured illustrations of the freshwater fishes of Korea. Hyagmunsa, Seoul. (In Korean)

Hynes, H.B.N. 1970. The ecology of running waters. Liverpool Univ. Press, Liverpool, U.K.

Goldman, C.R. and A.J. Horne. 1983. Limnology. McGra-Hill Inc..

Kim, I.S. 1997. Illustrated encyclopedia of fauna and flora of Korea. Vol 30. Freshwater fishes. Ministry of education. (In Korean)

Kim, I.S. and A.J. Kang. 1993. Coloured fishes of Korea. Academy, Seoul. (In Korean)

Lloyd, M. and R.J. Ghelardi, 1964. A table for calculating the "Equitability" component of species diversity. *J. Anim. Ecol.* **33**: 271-225.

Margalef, R. 1958. Information theory in ecology. *Gen. Syst.* **3**: 36-71.

McNaughton, S.J. and L.L. Wolf. 1970. Dominance and the niche in ecological systems. *Science.* **167**: 131-139.

Pielou, E.C. 1966. The measurement of diversity indifferent types of biological collections. *J. theo. Biol.* **13**: 131-144.

Pielou, E.C. 1969. Ecological diversity. Wiely. New York.

Seoul Metropolitan Government. 1994. Investigation and research of Han River ecosystem (III). (In Korean)

Seoul Metropolitan Government. 1998. Investigation and research of Han River ecosystem (IV). (In Korean)

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continumn concept. *Can. J. Fish. Aquat. Sci.* **37**: 130-137.

Yoon, I.B., D.S. Kong, and D.H. Won. 1992a. Seasonal and spatial distribution of the benthic macroinvertebrate community in Keumho River. *Kor. J. Lim.* **25**: 167-175. (In Korean)

Yoon, I.B., D.S. Kong, and S.H. Lee. 1992b. Biological Water Quality Evaluation of Keumho River by the benthic macroinvertebrate community. *Kor. J. Lim.* **25**: 177-183. (In Korean)

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