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Fish Fauna and Guild Compositions in Geum River Watershed

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This study was to analyze fish composition and ecological indicator characteristics from eight sampling sites of Geum River, October 2007. Total number of family and species sampled were 9 and 40. The most dominant family was Cyprinidae (27 species, 85%), and then followed by Cobitidae, Odomtobutidae, and Gobiidae. Constancy values of *Zacco platypus* and *Zacco temminckii* were 1.00 and 0.30, respectively, and the relative abundance of *Acheilognathus koreensis* and *Pseudogobio esocinus* were greater than 5% of the total. The number of Korean endemic species sampled in this Geum River study was 7 family 19 species, which is 47.5% of total 40 species, and endangered species of *Pseudopungtungia nigra* and *Gobiobotia brevibarba* were only 0.5% of the total and these species were only distributed within the upstream regions. Exotic species, *Micropterus salmoides*, which is known as large-mouth bass, were observed in two sites of G3 and G7. Analytical results of fish community showed that community dominance index was 0.19, which is low, and the species evenness index (0.74), diversity index (2.03), and richness index (3.00) appeared high. These results indicate that structure of fish community is stable in the Geum River. According to various guilds analysis, the relative abundance of tolerant and omnivores at all sites were 40% and 47% of the total, respectively. This monitoring data may contribute changes of fish fauna and compositions in relation to habitat modifications and chemical water quality degradations in the future.

Key words : Geum River, fish composition, fish community, tolerance and trophic guilds

INTRODUCTION

It was well known that fish species composition and distributions are influenced by various factors in association with physical, chemical, and biological elements in stream ecosystems and the most direct impact to the aquatic environment was mainly attributed to habitat modifications and chemical pollutions by human activities (Rutherford *et al.*, 1987). The ecological disturbances were largely associated with toxic pollutions and eutrophication by effluents from intense agricultural land and industrial/domestic wastewater plants and habitat structure alteration by artificial dam and weir construction mostly influencing to the stream continuity (Choi and Kim, 2004). These disturbances resulted in decreases of fish diversity (Boon, 2000). and dominance of tolerant species (Desirree *et al.*, 2006; Walton *et al.*, 2007) and omnivore species (Barbour *et al.*, 1999) as well as increased anormalities in the lotic ecosystems (An

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et al., 2004).

Geum River, which is a study system in this research, is located mid-western part of Korean Peninsula with almost 395 km length from the headwater to the downstream, and is the one of the four major watersheds in Korea. It contains 12 primary tributaries, many secondary tributaries, two multi-propose dams (Yongdam and Daecheong Dams) and estuary reservoir (An *et al.*, 1992). Upstream region of the river was mostly consisted with forest mountain and partially agricultural lands, while human impacts and interferences are intense in the midstream region where the tributaries of Gap and Miho Streams are confluence. Also some impacts of dam construction on water quality and fish are frequently reported in the downstream near estuary reservoir. Inner barrier area (freshwater area) of the dam is becoming more eutrophic due to accumulation of organic matter on the river bed and longer water residence time. Also, migratory fishes such as eel are limited in the distribution because of barrier impacts by dam and fishes compositions are becoming more lentic-type from lotic or running-water type due to longer water residence time (Lee, 1992). Under these circumstances, fish survey in the Geum River is important in detecting ecological disturbance of the ecosystem.

Numerous researches on fish fauna (Choi *et al.*, 1977; Choi, 1978; Choi and Park, 1979), community structure (An *et al.*, 1992), and distributions (Choi and Heo, 1984; Hwang *et al.*, 1992) were conducted in the mainstream of Geum River since 1970s. Such studies pointed out that the number of fish species is getting decreasing, the community structure is modifying depending on the locations, and the composition are changing due to constructions of Daecheong Dam. For these reasons, fish species compositions and distribution characteristics may reflect these changes of these environmental conditions. Since the previous 1992 survey in Geum River, little is known about fish compositions and guild characteristics in Geum River. This study was to elucidate the fish fauna and composition patterns in trophic guild and tolerance guilds along with community structures of fish using community index analysis. In addition, we also comparatively analyzed changes of fish species compositions and distributions over time in comparison with previous studies of Geum River. Our research provide basic key information for biodiversity conservations of fishes in Geum River watershed.

MATERIALS AND METHODS

1. Sampling sites and periods

At eight sampling sites (Fig. 1), fishes were collected from all types of the habitats including riffle, run, and pool during October 2007 according to the method (Ohio EPA, 1989) of the catch per unit of effort (CPUE). Site G1 is located 32 km point from the headwater with high proportion of forests and no point sources, but has some sediments on the river bed. The area of G2 ~ G5 is located 64 km point from the headwater, which is the area between Yongdam Dam and Daecheong Dam, and riparian vegetations are well developed in the reach. The area of G6 ~ G8 is directly influenced by industrial complex and domestic wastewater disposal plants of Gap and Miho Streams tributaries, and massive accumulations of organic matter and sands/silts were observed on the river bed. The detail descriptions of sampling locations in Geum River (G) and the stream order (Strahler, 1957) are as follows:

G1 : Yeonpyeong-ri, Cheoncheon-myeon, Jangsu-gun, Jeonbuk Province, S. Korea
(N 35° 47′08″ E 127° 31′47″ 4th order stream)
G2 : Yongpo-ri, Muju-eup, Muju-gun, Jeonbuk

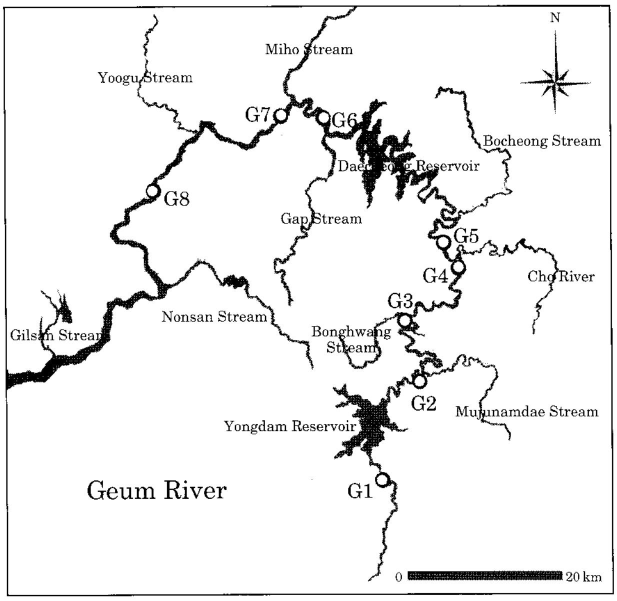

Fig. 1. Sampling sites (G) in the Geum River.

Province, S. Korea
(N 35° 59′12″ E 127° 37′09″ 4th order stream)

G3 : Jeogok-ri, Jaewon-myeon, Geumsan-gun, Chungnam Province, S. Korea
(N 36° 06′27″ E 127° 34′05″ 5th order stream)

G4 : Godang-ri, Simcheon-myeon, Yeongdong-gun, Chungbuk Province, S. Korea
(N 36° 12′32″E 127° 42′34″ 5th order stream)

G5 : Jeokha-ri, Dongi-myeon, Okcheon-gun, Chungbuk Province, S. Korea
(N 36° 14′14″ E 127° 40′12″ 6th order stream)

G6 : Simok-ri, Hyeondo-myeon, Cheongwon-gun, Chungbuk Province, S. Korea
(N 36° 29′15″ E 127° 24′03″ 6th order stream)

G7 : Naseong-ri, Nam-myeon, Yeongi-gun, Chungnam Province, S. Korea
(N 36° 28′46″ E 127° 16′12″ 6th order stream)

G8 : Bungang-ri, Tancheon-myeon, Gongju-city, Chungnam Province, S. Korea
(N 36° 20′18″ E 126° 59′05″ 6th order stream)

2. Sampling methods and sampling gears

At each sampling location, stream distance sampled was 100 m and the sampling time elapsed was 50 minutes according to the a quantitative sampling method (MEK, 2006), which was developed for fish monitoring in Korea. Conventional types of cast net and kick net were employed for the sampling and the mesh size of the nets were 5 × 5 mm and 4 × 4 mm, respectively, which are appropriate for collection of small size fish as well as large size fish. The number of species and the individual numbers were counted in the field. The sampling strategy in Geum River was applied to the all sampling sites, and the samplings were conducted toward the upstream direction. Fish species collected were identified according to the methods of species identification (Nelson, 1994; Kim and Park, 2002).

3. Community analysis

Community analysis in this study included species richness index (Margalef, 1958), species evenness index (Pielou, 1975), species diversity index (Shannon and Weaver, 1949) and community dominance index (Simpson, 1949) for analyzing community structure.

4. Ecological guilds characteristics

Tolerant guilds were classified, based on the previous approach of US EPA (1993) and Barbour *et al.* (1999), as three categories of sensitive species (SS), tolerant species (TS), and intermediate species (IS). Also, we analyzed trophic guilds after the approach of Ohio EPA (1989). The trophic guild were categorized as omnivores (O, feeding both animals and plants in the streams, insectivores (I, feeding aquatic macroinvertebrate), carnivores (C, feeding fish, piscivorous), and herbivores (H, feeding periphyton and phytoplankton). and this feeding guilds were based on the primary source of food.

RESULTS AND DISCUSSION

1. Fish fauna and compositions

Total number of family and species sampled were 9 and 40, respectively in the eight sites of Geum River. The most dominant family was Cyprinidae (27 species), and Cobitidae (3 species). Families such as Centropomidae, Odontobutidae, and Gobiidae had two species respectively and others such as Bagridae, Siluridae, Amblycipitidae and Centrarchidae had one species (Table 1). The relative abundance of Cyprinidae was > 85% in Geum River and this results were accord with the previous studies of streams which flow in west-southern part of Korea (An *et al.*, 1992; Choi *et al.*, 2000; Jang *et al.*, 2001).

According to spatial distribution of fish, the total number of species increased as the stream order increases, so that the species in the downstream reach (G7) were 20, which was maximum in the study (Fig. 2). In contrast, some sites of G4, G6 and G8 had low number of species and this phenomenon was due to habitat simplifications by sand depositions and partially run-habitat. As shown in other streams, relative abundance of *Zacco platypus* and *Zacco temminckii* were 30% and 14%, respectively, and the abundance of *Acheilognathus koreensis* (8.0%) and *Pseudogobio esocinus* (6.7%) were greater than 5% of the total. Analysis of constancy values (number of sites observed/total number of visiting sites), *Zacco platypus*, which is tolerant to the water quality and not food-specific, was 1.0 and other species such as *Pseudogobio esocinus, Acheilognathus lanceolatus, Pungtungia herzi, Hamibarbus longirostris, Opsarichthys uncirostris amurensis*, and *Odontobutis interrupta* were > 0.75.

Table 1. Fish fauna and the various guilds of tolerance, trophic and habitat in Geum River.

Species	Tol. G	Tro. G	Hab. G	Sampling sites (G)								Total	RA(%)
				1	2	3	4	5	6	7	8		
Cyprinidae													
Cyprinus carpio	TS	O				1						1	0.08
Carassius auratus	TS	O							2	2		4	0.33
*Rhodeus uyekii**	IS	O			1							1	0.08
Rhodeus notatus	IS	O									1	1	0.08
Acheilognathus lanceolatus	IS	O				3	15	7	4	11	7	47	3.85
*Acheilognathus koreensis**	IS	O			56	15	1	26				98	8.03
*Acheilognathus yamatsuatea**	IS	O			4		7	2				13	1.06
Acanthorhodeus macropterus	IS	O									1	1	0.08
*Acanthorhodeus gracilis**	IS	O								9		9	0.74
Pseudorasbora parva	TS	O							7	5	2	14	1.15
Pungtungia herzi	IS	I		4	13	12	8	6		2		45	3.69
*Pseudopungtungia nigra** I	SS	I			1			1				2	0.16
*Coreoleuciscus splendidus**	SS	I	RB	1	4	1		3				9	0.74
*Sarcocheilichthys variegatus wakiyae**	SS	I						1				1	0.08
*Sarcocheilichthys nigripinnis morii**	IS	I								1		1	0.08
Gnathopogon strigatus	IS	I							1	9	2	12	0.98
*Squalidus gracilis majimae**	SS	I					1			3	1	5	0.41
*Squalidus japonicus coreanus**	TS	O				1		1	2			4	0.33
Hamibarbus labeo	TS	I							1	44	13	58	4.75
Hamibarbus longirostris	IS	I		15		3		2	1	2	14	37	3.03
Pseudogobio esocinus	IS	I		1	1	11		5	16	38	10	82	6.72
Abbottina rivularis	TS	O								1		1	0.08
*Gobiobotia brevibarba** II	SS	I	RB		1	4						5	0.41
*Microphysogobio yaluensis**	IS	O	RB	30		1		3		2		36	2.95
Zacco temminckii	SS	I		33	96	15	5	21				170	13.92
Zacco platypus	TS	O		81	10	9	4	12	78	134	34	362	29.65
Opsarichthys uncirostris amurensis	TS	C		1		4	5		1	3	6	20	1.64
Cobitidae													
Misgurnus mizolepis	TS	O			1		2		1	1		5	0.41
Misgurnus anguillicaudatus	TS	O		12				1			4	17	1.39
*Iksookimia koreensis**	IS	I		2				1				3	0.25
Bagridae													
*Pseudobagrus koreanus**	SS	I	RB	5	10					10		25	2.05
Siluridae													
*Silurus microdorsalis**	SS	C	RB		2							2	0.16
Amblycipitidae													
*Liobagrus mediadiposalis**	SS	I	RB	2								2	0.16
Centropomidae													
Siniperca scherzeri	SS	C					1	1				2	0.16
*Coreoperca herzi**	SS	C			2	2	2	1				7	0.57
Centrarchidae													
Micropterus salmoides†	TS	C				5					1	6	0.49
Odontobutidae													
*Odontobutis platycephala**	SS	C		1	11	6	4	4				26	2.13
*Odontobutis interrupta**	IS	C				2	2	4	21	10	1	40	3.28
Gobiidae													
Rhinogobius brunneus	IS	I	RB	13						11		24	1.97
Tridentiger brevispinis	IS	I	RB						22	1		23	1.88
Total number of species				14	15	17	13	19	13	20	14	40	
Total number of individuals				201	213	95	57	102	157	299	97	1221	

Tol. G=Tolerance guild, Tro. G=Trophic guild, Hab. G.=Habitat guild, RA=Relative abundance, TS=Tolerant species, SS=Sensitive species, IS=Intermediate species, O=Omnivores, I=Insectivores, C=Carnivores, *: Korean endemic species, †: Exotic species, I: Endangered species as 1st class, II: Endangered species as 2nd class

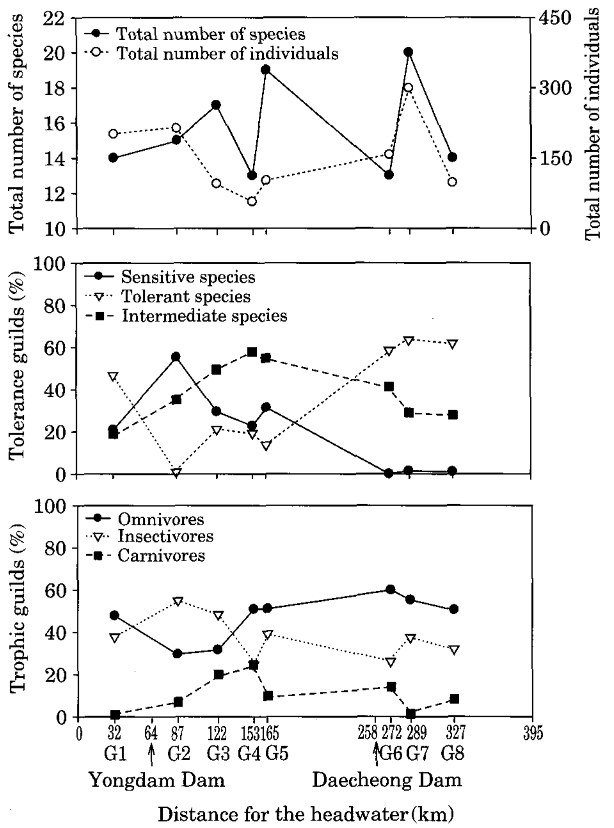

Fig. 2. Fish composition, tolerance and trophic guilds over the stream order in Geum River.

The species with high constancy in this study are similar to previous studies of fish fauna in Geum River watershed (An *et al.*, 1992).

The number of korean endemic species sampled in this Geum River study was 7 family 19 species, which is 47.5% of total 40 species (Table 1), and the number of endemic species in this study (19 species) was higher than the previous studies (An *et al.*, 1992; Kim, 1995) of Geum River (34.3%) and Korean peninsula (25.9%). Choi *et al.* (2000) pointed out that endemic species is generally distributed in mid-to-upstream region rather than the downstream, and decreased rapidly by the degradation of water quality. Such phenomenon was evident in this study; endemic species were 55% of the total at five sampling sites which are located in the upstream of Daecheong Dam, whereas they were 28% at three sites in the downstream sites of the dam. The reduced endemic species might be caused by result of habitat disturbances and degradation of water quality by industrial complex and domestic waste-water disposal plants from two tributaries of Gap Stream and Miho Stream. This fact is supported by previous studies on water quality of Geum River (An and Yang, 2007), which showed large differences in total nitrogen (TN), total phosphorus (TP), and BOD (biochemical oxygen demand) between the Geum River in the upstream (not influenced by tributary) and the downstream (influenced by tributary). Furthermore, accumulations of organic matters and sands/silts originated from the tributaries degradated the habitat quality in the downstream area (Bae and An, 2006; Lee *et al.*, 2008). For these reasons, endangered species of *Pseudopungtungia nigra* (1st class) and *Gobiobotia brevibarba* (2nd class) was only 0.5% of the total and these species were only distributed within the upstream regions, where have no big pollution sources and healthy habitats. Such species seem to be decreased in the Geum River (Choi *et al.*, 2001; Lee *et al.*, 2004).

Exotic species, *Micropterus salmoides*, which is known as large-mouth bass, were observed in two sites of S3 and S7 and the relative abundance was 0.5% (low abundance) of the total individuals in this study. However, we believe that the low occurrence (frequency) of bass was mainly attributed to partial under-estimation by special sampling technique for ecosystem health assessment evaluation (50 minutes/200 m distance). Especially, the under-estimation may be true in Yongdam and Daecheong Dams and Geum River Estuary Reservoirs, which is deep habitat and not easy in sampling by cast net and kick net. In spite of low abundance of bass, the species is carnivores and spreading speed is very fast, so this species would influence the ecosystem health in the watershed within 10~20 years.

2. Analysis of community index

Analytical results of fish community in Geum River watershed are shown in Table 2. During the study period, community dominance index was averaged 0.19, which is low, and the species evenness index was averaged 0.74. This outcomes indicate that no specific species did not dominate in the community, even though the highest dominance of *Zacco platypus*. In contrast, species diversity index and species richness index were averaged 2.03 and 3.00, respectively. These results indicate that structure of fish community is stable in the Geum River watershed. Species diversity index,

Table 2. Community analyses, based on the richness index (d), evenness index (J'), diversity index (H'), and dominance index (λ) in the Geum River.

Site	G1	G2	G3	G4	G5	G6	G7	G8
TNS	14	15	17	13	19	13	20	14
TNI	201	213	95	57	102	157	299	97
d	2.45	2.61	3.51	2.97	3.89	2.37	3.33	2.84
J'	0.70	0.62	0.88	0.88	0.80	0.64	0.65	0.77
H'	1.85	1.68	2.49	2.25	2.36	1.63	1.96	2.04
λ	0.22	0.28	0.09	0.12	0.13	0.29	0.24	0.18

TNS=Total number of species, TNI=Total number of individuals, d=Margalef's species richness index, J'=Pielou's species evenness index, H'=Shannon and Weaver's species diversity index, λ=Simpson's community dominance index

however, was low in Site G6 (1.63) where is influenced by habitat destruction according to the dam construction and industrial complex and domestic wastewater disposal plants of Gap Stream tributary, and massive accumulations of organic matter and sands/silts were observed on the river bed. This condition may resulted in unstable fish community structure (Bang *et al.*, 1995; An *et al.*, 2005; Son and Byeon, 2005).

3. Analysis of ecological indicator characteristics

According to the tolerance guild analysis, sensitive species (SS) which is easily disappeared by degree of water pollutions was 19.5% (Relative Abundance, RA), whereas tolerant species (TS), usually increased species number and distribution range along with water quality and habitat deteriorations was 39.6% (RA) and intermediate species (IS) was 35.1% in this study. Thus, TS was dominant in the tolerance guild analysis. From analysis of site characteristics derived from individual proportion, SS had a tendency to decrease along the gradient from up to downstream reach except G1. However, TS showed an opposite result compared to SS, tend to increase following the current from up to downstream and it was also increased suddenly from G6 after Daecheong Dam area. IS was increased until G5 but decreased from G6 along with increase of TS (Fig. 2).

Among sampled 14 species in G1, located the most headwater reach among the sampling sites (32 km from the headwater), TS was presented only 3 species but *Zacco platypus* was dominant over 40% so that affected to the TS dominance. In case of G2 (87 km from the headwater), representative SS, *Zacco temminckii* was dominant over 45% so that presented the highest SS as 55.4% in the entire sampling sites. G3 ~ G5 had a tendency to increase TS ratio but relatively high ratio of SS and IS was dominant over 50%. At G6 (272 km from the headwater), the location after Daecheong Dam (258 km from the headwater), SS was not appeared at all but TS was dominant over 55%. In the G7 ~ G8, TS was over 60% as dominant species, indicating variance of tolerance guilds had been occurred along with physical and chemical deterioration by various pollutants after Daecheong Dam area in the watershed (Barbour *et al.*, 1999).

According to the trophic guild analysis, omnivores were 47.3% (Relative Abundance, RA), whereas insectivores and carnivores were 39.3% (RA) and 7.7% (RA), respectively. Herbivores was not appeared at all. From analysis of site characteristics by Proportion of individuals, omnivores were dominant in the trophic guild analysis other than G2 ~ G3, at all sites (Fig. 2).

Omnivores were dominant in the G1 because of the dominance of omnivore species, *Zacco platypus*, as similar as the result of tolerance guilds. In the G2, it was appeared 54.9% (RA), the highest proportion of insectivore. However, insectivores were going to decreasing from G3 (122 km from the headwater) and was 24.6% as same as carnivores with the dominant omnivores over 50% in G4 (153 km from the headwater). From G5 (165 km from the headwater) to downstream reach, it was appeared in the order of omnivore, insectivore, and carnivore without much difference.

According to the analysis of tolerance and trophic guilds based on the stream order (Fig. 3), G1 and G2 were 4th order stream, just before confluence of the Mujunamdae Stream, which were dominant with sensitive (38.7%) and insectivore species (46.6%). G3 and G4, 5th order stream before the confluence of the Cho River were sud-

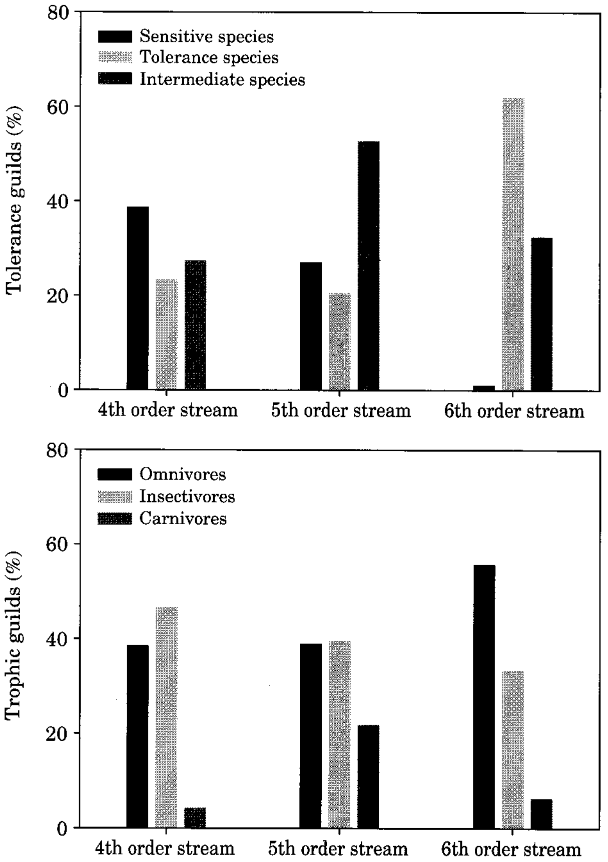

Fig. 3. Compositional changes of tolerance and trophic guilds with stream order.

denly increased intermediate species (21.7%) and appeared with similar proportion of omnivores (38.8%), insectivores (39.1%), and carnivores (21.7%). 6th order stream, G5~G8 were appeared less than 1% of sensitive species and were dominant as tolerant (52.6%) and omnivore species (55.7%). Thus, it was well represented characteristics of the Geum River watershed that degradation of water quality and habitat destruction were occurred along the gradient of up to downstream reaches.

4. Comparison to the previous researches

Using dataset of fish composition in previous researches (Choi *et al.*, 1977; An *et al.*, 1992) and this sampling, we comparatively analyzed the fish species composition of Geum River mainstream before and after Daecheong Dam construction. Though there were some differences between site numbers and sampling methods, it was sampled 24 family and 89 species in Choi *et al.* (1977) before the Daecheong Dam construction and 18 family 70 species in An *et al.* (1992) and 9 family 40 species in this study after the Daecheong Dam construction. Thus, differences of species composition was obvious before and after Daecheong Dam construction in this analysis.

After the construction of Daecheong Dam, the species number was decreased rapidly and especially, *Hamibarbus mylodon* seemed to be disappeared since the previous report (Choi *et al.*, 1977) and was not sampled in this survey. This species was originally distributed in the Han and Geum River and known as almost exterminated in the Geum River watershed so that selected this species in the Geum River as natural monument No. 239. Endangered protected species, *Liobagrus obesus* (1st class) and *Gobiobotia macrocephala* (2nd class) were reported in the previous research (An *et al.*, 1992) but they were not sampled in this study. In addition, exotic ecological disrupter, *Micropterus salmoides* was sampled in mid to upstream of the Geum River.

Consequently, it may consider biological factors as well as chemical water pollution and physical habitat disturbance were also caused deterioration of aquatic ecosystem health so that may influence the simplification of biodiversity. Hence, it was necessary for long-term stream ecosystem monitoring to predict and manage those ecological changes.

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