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A Study on the Fish Community and Various Guilds to Stream Order in Geum River Watershed

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This study was conducted to evaluate fish fauna, species composition, and various guilds against stream orders along with analysis of fish community structure and diversity in Geum River watershed from 2005 to 2007. The total number of fish collected was 4,216 representing 12 families with 56 species. *Zacco platypus* was the most abundant fish species with 26% in relative abundance (RA). Korean endemic species were 24 species including *Zacco koreanus*, *Microphysogobio yaluensis*, *Gobiobotia nakdongensis*, and *Iksookimia koreensis*, etc. We also collected endangered fish species such as *G. nakdongensis*, *Liobagrus obesus*, and *Pseudopungtungia nigra*, etc., and their new distribution sites were found in the survey, providing some sites of the fish conservation and protection. Fish tolerance and trophic guilds analysis showed that the proportion of sensitive species, intermediate species, and tolerant species were 33.4%, 29.3%, and 37.3%, respectively and omnivores and insectivores were 48.1% and 38.4%, respectively. Analysis of site-base study indicated that tolerant species and omnivore species were high in some polluted tributary streams (i.e., Gap and Miho stream) and sensitive and insectivore species were low. In the functional relations, expressed as simple linear regression equations, of stream order on fish metric attributes, showed that the number of species and the number of individuals increased as the stream order increases. This phenomenon was explained by greater availability of stable water volume, rich food, and higher physical habitat capacity. Such guild compositions and stream order characteristics of the river influenced the community structures, based on species diversity, dominance and evenness index in the study. This study may be used as important data in the future for comparisons of fish fauna and compositions before and after two weir (dam) constructions in the middle of Geum River by the government.

Key words : fish distribution, fauna, tolerance and trophic guilds

INTRODUCTION

The Geum River is located central pert of South Korea and is one of four major great rivers in Korea. It is 401 km long and its watershed area is 9,859 km^2. The upper part of the river flows slowly through part of the Noryeong Mountains and is marked by extensive stream meandering, resulting in more pristine and natural conditions and low pollution (An *et al.*, 2001). On the other hand, river curves on middle and lower parts of the river influenced by urbans and point sources (An and Yang, 2007; Han *et al.*, 2010) are more gradual, partly channelized, and there is comparatively less stream meandering.

In this river, there are many tributaries, which are important influencing fish distributions, com-

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positions, and community structure as shown in previous studies (Son, 1983; Son and Byeon, 2005; An and Yang, 2007; Han *et al.*, 2010; Lee and An, 2010). Main tributary streams of Geum include Gap, Yugu, Miho, Unsan, Seokseong, and Nonsan streams. It is important to understand the influences of the tributaries in understanding fish fauna and composition in Geaum River watershed. The tributaries of Gap stream along with Daejeon and Yudung streams are located in this mid-river region, and influenced the water quality of mainstream Geum River by urban point-sources (An and Kim, 2005), fish distribution and compositions (An *et al.*, 2005), and ecological health conditions (Bae and An, 2006). In addition, Miho stream which is located in more down-river of the three tributaries, is also known as one of major sources of organic, toxic pollutions, and nutrient loading and is known as a tributary with low relative abundance of fish (Son, 1983; Son and Byeon, 2005; Lee and An, 2010) and "poor health" by biological health, based on the index of biological integrity (Lee and An, 2010). In addition to these polluted tributaries, two other tributaries of Yugu stream (An and Lee, 2007) and Bochung stream (Ryu *et al.*, 2010) on ecological health analysis and chemical water quality have been reported. Such previous studies pointed out that Gap and Miho stream are most influencial tributaries on the water quality of Geum River and the Ministry of the Environment, Korea have tried to reduce the pollution from the two streams.

One of the recent early intensive fish surveys in the all river regions is study of An *et al.* (1992) on fish fauna and distribution pattern. After that, characteristics of chemical water quality, nutrient pollutions (An and Yang, 2007), some relations of landuse pattern to water quality (Han *et al.*, 2010), and relation of fish distribution-physical habitat (Hur *et al.*, 2009b) were studied in Geum River Watershed. In addition, some fish population studies of *Pseudobagrus koreanus* (Kang, 1998) and *Zacco platypus* (Hur *et al.*, 2009a) also have been done in Geum River Watershed along with some studies of chemical water quality along the axis of the longitudinal gradients and fish composition changes. Such studies emphasized on rapid expansion of exotic species of large mouth bass, top carnivore in the system, and marked decreases of the number of endangered species and species diversity. For these reasons, continuous fish monitoring and studies are required for the river protections.

In this study, we conducted extensive fish surveys in the Guem River and its tributaries in 2005 ~2007. Our purpose of the research was to evaluate fish fauna, species composition, tolerance guilds, and trophic guilds along with analysis of fish community structure and diversity in Geum River Watershed. This study will be used as important data in the future for comparisons of fish fauna and compositions before and after two weir (dam) constructions in the middle of the Geum River by the government.

MATERIALS AND METHODS

1. Descriptions of sampling sites and periods

In this study, we selected 8 main-river sites and 20 tributary sites (Fig. 1), which is 2nd~6th order streams based on Strahler (1957) in Geum River for fish survey in the field and then conducted the survey from 2005 to 2007. The sites were selected

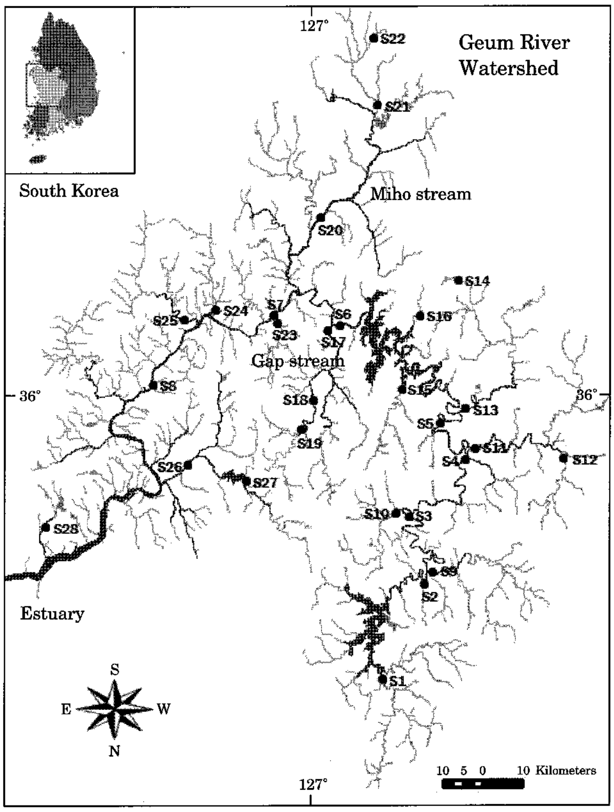

Fig. 1. Sampling sites in Geum River Watershed. Sampling sites of S1~S8 and S9~S28, indicate main-river and tributary sites, respectively.

based on major point sources, and urban along with some up-stream pristine sites. Sampling sites of main-rivers and tributaries conducted in Geum River Watershed are as follows.

1) Mainstream of Geum River (8 sites)

S1: Gamak-ri, Jinan-eup, Jinan-Gun, Jeollabuk-do (N35° 48′06″, E127° 31′02″)
S2: Yongpo-ri, Muju-eup, Muju-gun, Jeollabuk-do (N35° 59′23″, E127° 37′02″)
S3: Jeogok-ri, Jewon-myeon, Geumsan-gun, Chungcheongnam-do (N36° 6′39″, E127° 34′01″)
S4: Godang-ri, Simcheon-myeon, Yeongdong-gun, Chungcheongbuk-do (N36° 12′43″, E127° 42′27″)
S5: Jeokha-ri, Dongi-myeon, Okcheon-gun, Chungcheongbuk-do (N36° 16′01″, E127° 38′05″)
S6: Seokbong-dong, Daedeok-gu, Daejeon city (N36° 27′23″, E127° 25′36″)
S7: Naseong-ri, Nam-myeon, Yeongi-gun, Chungcheongnam-do (N36° 28′43″, E127° 16′14″)
S8: Bungang-ri, Tancheon-myeon, Gongju-si, Chungcheongnam-do (N36° 20′28″, E126° 59′13″)

2) Tributaries of Geum River (20 sites)

S9: Mujoo Namdae stream, Daecha-ri, Muju-eup, Muju-gun, Jeollabuk-do (N36° 00′09″, E127° 37′30″)
S10: Bonghwang stream, Jewon-ri, Jewon-myeon, Geumsan-gun, Chungcheongnam-do (N36° 06′37″, E127° 33′06″)
S11: Chogang stream, Simcheon-ri, Simcheon-myeon, Yeongdong-gun, Chungcheongbuk-do (N36° 13′51″, E127° 43′18″)
S12: Chogang stream, Jangcheok-ri, Maegok-myeon, Yeongdong-gun, Chungcheongbuk-do (N36° 12′19″, E127° 55′54″)
S13: Bocheong stream, Godang-ri, Cheongseong-myeon, Okcheon-gun, Chungcheongbuk-do (N36° 17′44″, E127° 41′45″)
S14: Bocheong stream, Iwon-ri, Naebuk-myeon, Boeun-gun, Chungcheongbuk-do (N36° 32′26″, E127° 40′40″)
S15: Sooak stream, Jio-ri, Gunbuk-myeon, Okcheon-gun, Chungcheongbuk-do (N36° 20′05″, E127° 34′08″)
S16: Hoein stream, Jukam-ri, Hoebuk-myeon, Boeun-gun, Chungcheongbuk-do (N36° 28′00″, E127° 35′40″)
S17: Gap stream, Gujeuk-dong, Yuseong-gu, Daejeon city (N36° 26′55″, E127° 23′32″)
S18: Gap stream, Jeongnim-dong, Seo-gu, Daejeon city (N36° 18′25″, E127° 21′32″)
S19: Gap stream, Bonggok-dong, Seo-gu, Daejeon city (N36° 15′12″, E127° 19′29″)
S20: Miho stream, Sinchon-ri, Oksan-myeon, Cheongwon-gun, Chungcheongbuk-do (N36° 39′29″, E127° 23′00″)
S21: Miho stream, Ogap-ri, Chopyeong-myeon, Jincheon-gun, Chungcheongbuk-do (N36° 50′44″, E127° 30′13″)
S22: Miho stream, Cheonpyeong-ri, Samseong-myeon, Eumseong-gun, Chungcheongbuk-do (N36° 58′49″, E127° 30′02″)
S23: Yongsu stream, Seongdeok-ri, Geumnam-myeon, Yeongi-gun, Chungcheongnam-do (N36° 27′32″, E127° 16′26″)
S24: Jeongan stream, Shinkwan-dong, Gongju-si, Chungcheongnam-do (N36° 28′25″, E127° 07′38″)
S25: Yoogu stream, Dongdae-ri, Useong-myeon, Gongju-si, Chungcheongnam-do (N36° 28′07″, E127° 03′03″)
S26: Nonsan stream, Daegyo-dong, Nonsan-si, Chungcheongnam-do (N36° 12′36″, E127° 04′50″)
S27: Nonsan stream, Sinheung-ri, Yangchon-myeon, Nonsan-si, Chungcheongnam-do (N36° 10′28″, E127° 12′08″)
S28: Gilsan stream, Wongil-ri, Gisan-myeon, Seocheon-gun, Chungcheongnam-do (N36° 04′46″, E126° 44′03″)

2. Sampling approach

Fish sampling in 8 Geum River sites and 20 tributary sites followed the modified wading method (An *et al.*, 2001) after the approach of Karr (1981) and US EPA (1993). At the 28 sites, fish collections were conducted according to the method of the catch per unit of effort (CPUE), which is applied to Korean streams and rivers.

All habitat types of riffle, run, pool were included in the fish survey. When we sampled the fishes, we moved toward the upstream direction for a distance of 200 m (100 m in upstream and 100 m downstream) during 50 minutes. The gears used for fish sampling were casting net (5 × 5 mm) and kick net (4 × 4 mm). This sampling approach was based on previous our researches (An *et al.*, 2001;

An and Kim, 2005; Bae and An, 2006). All fish specimens sampled from 28 sites were preserved in 10% formalin, except for endangered species and endemic species in the river and brought to the laboratory to identify the fish taxa. Fish species classified based on the previous studies of Kim and Park (2002) and Lee and No (2006) were tolerance guilds and trophic guilds categorized as sensitive, intermediate, and tolerant species and omnivore, carnivore, and insectivore species, respectively. All fishes were examined for external deformities, erosion (skin, barbells), lesion (open sores, ulcerations), and tumors (DELT anormalies), based on the criteria of An *et al.* (2001).

RESULTS AND DISCUSSION

1. Fish fauna and habitat distribution

A total number of fish collected in 8 main-river and 20 tributary sites was 4,216 with 12 families and 56 species (Table 1). Cyprinidae was most dominant family during the study with 61% (34 species) and then, Cobitidae (4 species, 7%) was subdominant. Amblycipitidae, Osmeridae, Siluridae, Gobiidae, Bagridae, Odontobutidae, Centropomidae, and Centrarchidae were sampled in 2 species, respectively. Adrianichthyoidae, and Channidae showed only 1 species each. In the species levels, *Zacco platypus* sampled in entire sites we surveyed in this study, resulting in constancy value of 1 (100%) and showed 26% in relative abundance (RA) as most dominant species in Geum River Watershed. This result is accord with previous studies conducted by Son (1983), An *et al.* (1992), Son and Byeon (2005), An and Kim (2005), An *et al.* (2005), and Lee and An (2010). Second subdominant species was *Zacco koreanus* as 458 number of individuals (11%), and then followed by *Pseudogobio esocinus*, *Opsarichthys uncirostris amurensis*, *Acheilognathus lanceolatus*, which were shown relative abundance of >5% of the total (Table 1). Two species of *Z. platypus* and *Z. koreanus* as most two dominant species are similar shape and occurred sometimes in same habitats, but the species of *Z. koreanus* was more distributed in pristine mountain regions than *Z. koreanus*. Generally, food guilds are different between the two species; As shown in Table 1, *Z. platypus* is omnivore species, which can be distributed over the wide ranges from upstrem to downstreams, while *Z. koreanus* is known food selectivity (preference) as insectivore species, which are dominant at riffle and pool within the pristine upstream reaches. Thus, difference in the distribution of two species was probably due to greater availability of food such as aquatic insects in the upstream region.

2. Korean endemic species

We collected Korean endemic species of 24 species including *Zacco koreanus*, *Microphysogobio yaluensis*, *Gobiobotia nakdongensis*, and *Iksookimia koreensis*, *etc.*, and this was 42.8% of the total in the Geum River Watershed. Thus, this value of relative abundance (42.8%) was greater than the 22.5% (Nam, 1996) in total Korean peninsula region, and also was similar to previous fish study of Geum River (Jeon and Byeon, 1999). The slight difference may be come from differences of sampling efforts (CPUE) and the number of sampling sites, so the difference is ignored. This results indicated that species compositions, in the view of Korean endemic species, did not change over the eight year period, so the ecosystem of Geum River may be well maintained since the period. Previous some studies on fish distribution showed that greater number and abundance of Korean endemic species may indicate healthier ecosystem conditions, but this evidence are not proved yet because some species are tolerant guilds, which may survive under low water quality.

3. Legal protected species

Legal protected species designated by the Ministry of Environment, Korea were collected in the survey; *Gobiobotia nakdongensis* and *Liobagrus obesus* as an endangered fish species - I (EFS-I) were observed in Site 24 and Site 11, respectively. Also, *Pseudopungtungia nigra* as a EFS-I, was collected from total 5 sites (S2, S5, S9, S11, S12) of 2 main-rivers and 3 tributaries. Two species of *Gobiobotia brevibarba* and *Gobiobotia macrocephala* designated as an endangered fish species-II (EFS-II) were observed at 5 sites (S2, S3, S9, S11, S12) of 2 main-rivers and 3 tributaries and one site of Site 11 (S11), respectively. Based on these results, S2 in the main-river and S11 in the tributary had common species of EFS-I and EFS-II. For this reason, this area should be continuously monitored for a conservation of the endangered species and also should be protected from

Table 1. Fish compositions and various guilds in Geum River watershed.

Species	Tol. G	Tro. G	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	Total	RA(%)
Zacco platypus	TS	O	81	10	9	4	12	78	134	34	42	53	11	32	17	28	30	26	15	40	25	147	86	21	80	49	33	7	5	3	1112	26.38
*Zacco koreanus**	SS	I	33	96	15	5	21				40	10	22	58	2	81	31				44										458	10.86
Pseudogobio esocinus	IS	I	1	1	11		5	16	38	10	9	2	8	4	9	1	11		19	6	1	7	29	18	3	20	3	16	14		262	6.21
Opsarichthys uncirostris amurensis	IS	C	1		4	5		1	3	6		14					2		6			4	16		1	8		145	20	17	253	6.00
Acheilognathus lanceolatus	SS	O			3	15	7	4	11	7		17	1		4		81		8	4		10	3		10	26		6		1	218	5.17
*Microphysogobio yaluensis**	IS	O	30		1		3		2		33	2	18	8	1	23	1			1	4	16	2	19	6		5				175	4.15
Pseudorasbora parva	TS	O						7	5	2		2						1	101	3		6	5	23						1	156	3.70
Rhinogobius brunneus	IS	I	13						11			3	1	1	17	2	36	37	1			3	5	1	8			1		3	143	3.39
*Acheilognathus koreensis**	IS	O		56	15	1	26					3	4		3		13				6										127	3.01
Gnathopogon strigatus	IS	I						1	9	2						2	7		8				2	84	2	3	4			1	125	2.96
*Odontobutis interrupta**	IS	C			2	2	4	21	10	1		10				5	1	4	2	12	4	11	7	1	3	11	8		2	1	122	2.89
Pungtungia herzi	SS	I	4	13	12	8	6		2		11		9	15	2	2	1				16		2		2	1	13				119	2.82
Carassius auratus	TS	O						2	2			8					1		1		4	4		79	1						102	2.42
Hamibarbus longirostris	SS	I	15		3		2	1	2	14	2	2		8		2	5		1		3	8	6		2	2	9	10	3		100	2.37
Hamibarbus labeo	TS	I						1	44	13									3	5			2				1	2		1	72	1.71
*Odontobutis platycephala**	SS	C	1	11	6	4	4				3		5	4	4	7	1				6				1						57	1.35
*Squalidus gracilis majimae**	IS	I				1			3	1						1			2		20	20	1					1			50	1.19
Rhynchocypris oxycephalus	SS	I																49													49	1.16
*Pseudobagrus koreanus**	SS	I	5	10					10		3			2								1	6				8				45	1.07
Tridentiger brevispinis	IS	I						22	1										4			1	11	1	5						45	1.07
Misgurnus anguillicaudatus	TS	H	12				1			4		3								2		1	1	1		4		1	4	10	44	1.04
*Coreoleuciscus splendidus**	SS	I	1	4	1		3				6		7	10	5																37	0.88
Misgurnus mizolepis	TS	H		1		2		1	1			4						2	1	5	1	1	4		3	5	3				34	0.81
*Iksookimia koreensis**	SS	I	2				1				2		2		4	4	4	4			2				2						27	0.64
*Rhodeus uyekii**	IS	O		1													7				6				9	1					24	0.57
Rhodeus notatus	IS	O								1										1					14		8				24	0.57
*Acheilognathus yamatsuatea**	SS	O		4		7	2						2							2					7						24	0.57
*Gobiobotia nakdongensis**	SS	I																								23					23	0.55
*Pseudopungtungia nigra**	SS	I		1			1				13		2	5																	22	0.52
Micropterus salmoides•	TS	C			5					1		2					2			9		1		1						1	22	0.52
*Acanthorhodeus gracilis**	IS	O							9								4			4						4					21	0.50
*Coreoperca herzi**	SS	C		2	2	2	1				2	1	5	2																	17	0.40
*Gobiobotia brevibarba**	SS	I		1	4						2		1	9																	17	0.40
*Squalidus japonicus coreanus**	IS	O			1		1	2					2		1				2								6				15	0.36
*Liobagrus mediadiposalis**	SS	I	2											4	7																13	0.31
Silurus asotus	TS	C											1					2				1				5					9	0.21
Carassius cuvieri•	TS	O																	6				1			1					8	0.19
Acanthorhodeus macropterus	IS	O								1									5									1			7	0.17
Oryzias sinensis	TS	O																												5	5	0.12
Cyprinus carpio	TS	O			1							1														2			1		5	0.12

Table 1. Continued.

Species	Tol. G	Tro. G	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	Total	RA (%)
*Sarcocheilichthys nigripinnis morii**	IS	I							1												1		2								4	0.09
Pseudobagrus fulvidraco	IS	C																								3					3	0.07
*Gobiobotia macrocephala**	SS	I											2																		2	0.05
Acheilognathus rhombeus	IS	O																		1					1						2	0.05
Squaliobarbus curriculus	IS	O																											1	1	2	0.05
*Silurus microdorsalis**	SS	C		2																											2	0.05
Abbottina rivularis	IS	O							1													1									2	0.05
Hypomesus nipponensis	SS	H																				2									2	0.05
Siniperca scherzeri	SS	C				1	1																								2	0.05
Channa argus	TS	C																			1										1	0.02
*Microphysogobio jeoni**	IS	I																								1					1	0.02
Lepomis macrochirus•	TS	I																				1									1	0.02
Plecoglossus altivelis altivelis	SS	H													1																1	0.02
Cobitis lutheri	IS	I													1																1	0.02
*Sarcocheilichthys variegatus wakiyae**	SS	I					1																								1	0.02
*Liobagrus obesus**	SS	I											1																		1	0.02
Number of individuals			201	213	95	57	102	157	299	97	168	137	104	162	78	158	238	125	185	95	144	246	191	249	160	169	101	190	50	45	4216	100.00
Number of species			14	15	17	13	19	13	20	14	13	17	19	14	15	12	18	8	17	14	16	20	19	11	19	18	12	10	8	12	56	

Tol. G=Tolerance Guild, Tro. G=Trophic Guild, SS=Sensitive species, IS=Intermediate species, TS=Tolerant species, O=Omnivore, I=Insectivore, C=Carnivore, H=Herbivore, RA: Relative abundance (%), *: Endemic species, •: Exotic species

artificial disturbances such habitat destruction or water pollution in order to extinct the endangered species in Geum River. Especially, the distribution regions in the species of *Gobiobotia nakdongensis* are known as sand depositional area of Imjin River, Han River, and Nakdong River, but the presence of this species in Geum River was obscure due to no sampling records so far (Chae, 2004). However, we found the species of *Gobiobotia nakdongensis* (total numer of individual=23) in our survey, and the distribution site was limited in the Jungan stream (S24). This region also should be protected from the pollution source and habitat disturbance by the Ministry of Environment, Korea or Gongju City. In the mean time, *Liobagrus obesus* as an EFS-I, distributed in inlet of Daechugn Reservoir which is located in Simcheon-myeon, Yeongdong-gun, Chungcheongbuk-do. Son and Byeon (2004) reported that *L. obesus* does not distribute in Chogang stream anymore, but we found the species in Chogang stream. However, the total number of individuals was only one in the site, indicating a low population number, so the conservation and protection are required to get rid of the extinction in the stream.

4. Fish composition analysis of tolerance guilds

Fish tolerance guilds analysis showed that the proportion of sensitive species (SS), intermediate species (IS), and tolerant species (TS) was 33.4%, 29.3%, and 37.3%, respectively, indicating not too polluted or pristine in the over all sites by the tolerance diagnosis criteria suggested by Barbour *et al.* (1999). According to the comparisons of main-rivers vs tributaries in the tolerance guilds, the proportion of SS and TS in the main-rivers, was 32.4% and 38.2%, respectively, while the proportion in the tributaries was 37.2% and 48.0%, respectively. The higher proportion of tolerant guilds were found in Gap stream (S17, S18), Miho stream (S20~S22), and Younsu stream (S23), which are known as already highly nutrient polluted by nitrogen and phosphorus as well as toxic pollutions. In these tributary streams, the proportion of tolerant guilds was >50% during the study period. Thus, tolerant species more dominated the community in the tributary than in the main-river sites, indicating that tributaries may be more polluted and disturbed in habitats, than the main-rivers. Also, as shown in Fig. 2, the tolerant species along the main axis of the river from S1 to S8

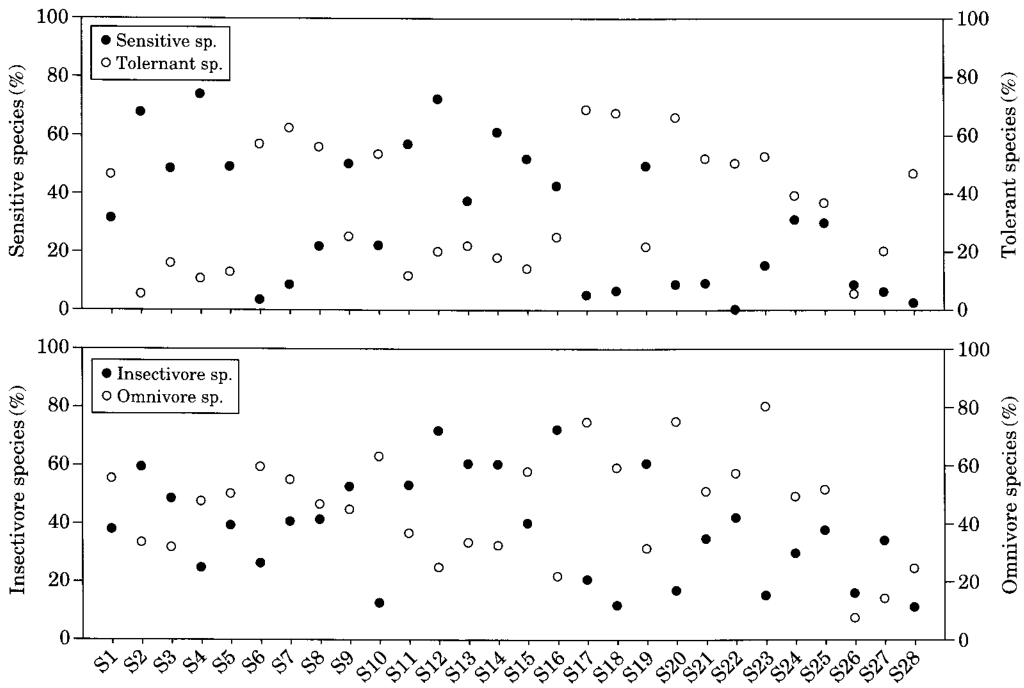

Fig. 2. Tolerance guild and trophic guilds in the sampling sites of Geum River Watershed from 2005 to 2007.

showed large increase in S6, which is directly influenced by the polluted tributary of Gap stream, whereas the proportion of sensitive species decreased in the site. Such compositional change was a direct results of pollution by tributary inflow. In fact, tolerant species were >68% in the tributary of Gap stream where large wastewater disposal plants and industrial complex are located, indicating a influence of the pollution on the fish tolerance guild composition. Also, sensitive species were not found in S22 where is an upstream site of Miho stream which is directly influenced by agricultural and industrial wastewater treatment plants. On the other hand, sensitive species were most abundant in the S4 where has no point-source and mainly surrounded by forests. In this site, sensitive fishes such as *Acheilognathus lanceolatus*, *Pungtungia herzi*, and *Acheilognathus yamatsuatea* were 26.3%, 14%, and 12.3%, respectively, resulting >50% in total abundance of sensitive species.

5. Fish composition analysis of trophic guilds

According to trophic guild analysis in 28 sites of the Geum River, the proportion of omnivore species (OS) and insectivore species (IS), based on the number of individuals, was 48.1% and 38.4%, respectively, indicating that omnivore species were more dominant. Previous studies of trophic guilds (Barbour *et al.*, 1999; An *et al.*, 2001; An and Kim, 2005; An *et al.*, 2005) suggested that the proportion of omnivore fish tended to increase in streams and rivers when water quality is eutrophied and had greater organic matters, and omnivores had reverse relations with insectivore in regression analysis. This outcome indicates that the waterbody of Geum River, in the aspect of trophic guilds, is not pristine condition. The comparisons of main-rivers vs tributaries in the tolerance guilds showed that the proportion of IS and OS in the main-rivers, was 41.3% and 48.5%, respectively, while the proportion in the tributaries was 37.2% and 48.0%, respectively. Thus, the main-rivers were better as shown in tolerance guild analysis.

The highest proportion of IS was observed in Whein stream (S16) where showed 72% of the trophic guilds, and the dominant insectivore species were *Rhynchocypris oxycephalus* (49 as the number of individual, 39.2%) and *Rhinogobius brunneus* (37 as the number of individual, 29.6%). Thus, this stream was considered well conserved the ecosystem. In contrast, the highest proportion of OS was observed in Youngsu stream (S23)

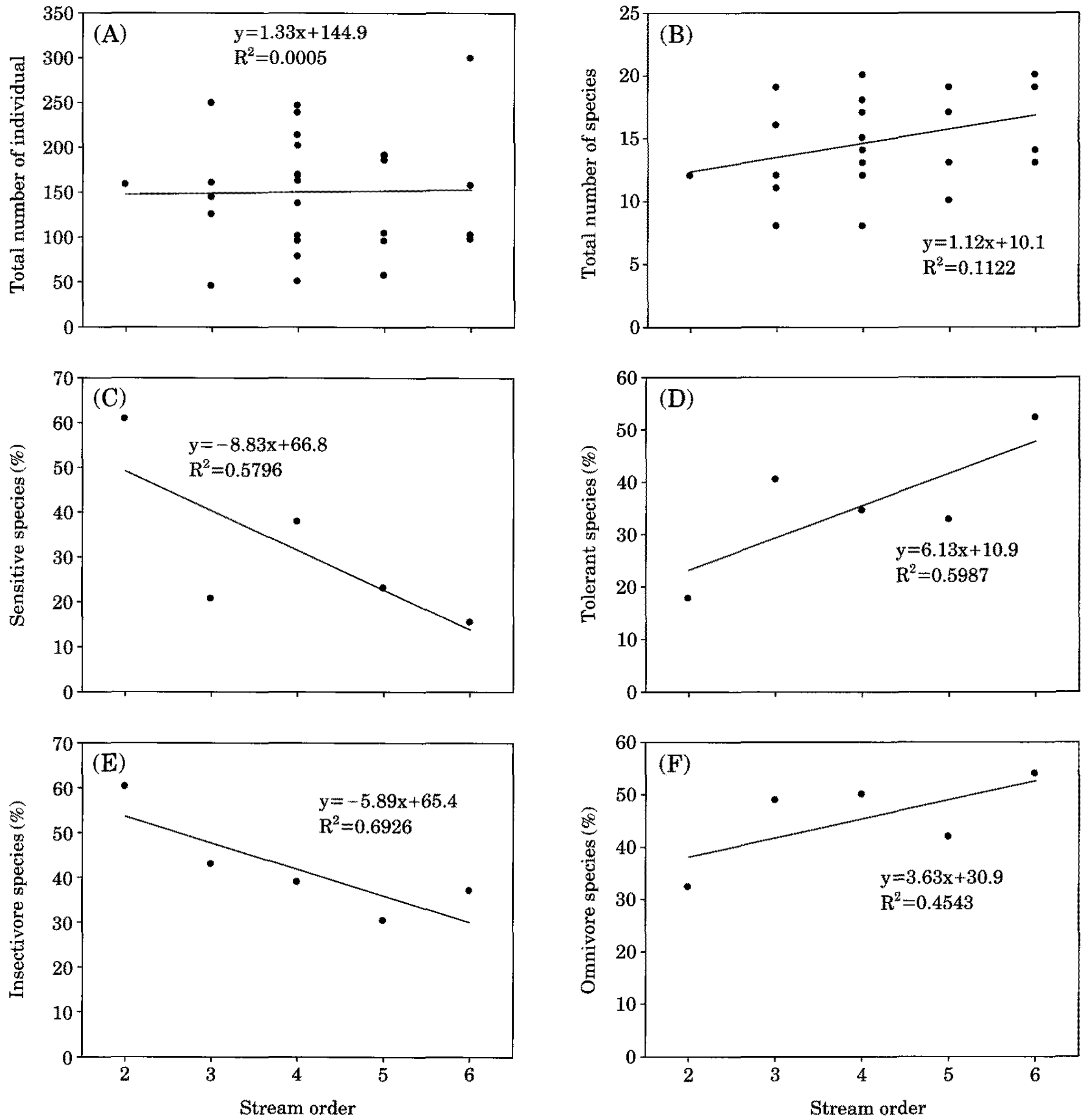

Fig. 3. Regression analysis of total number of fish species, total number of individuals, the proportions of sensitive species, tolerant species, insectivore species, and omnivore species against stream order in Geum River Watershed.

where showed 80% of the trophic guilds, and the dominant omnivore species was *Zacco platypus* (80 as the number of individual, 50%). In the mean time, in Nonsan stream, carnivore species of *Opsarichites bidden* dominated the community by 73.6%, and thus the trophic connection in the food web may be unbalanced conditions by a predominance of one carnivore species (Fig. 2). Also, the omnivores along the main axis of the river from Site 1 to Site 8 showed large increase in Site 6, which is directly influenced by the polluted tributary of Gap stream, whereas insectivores decreased in the same site. Such compositional change was a direct results of pollution by tributary inflow as shown in tolerance guild analysis. Our result is accord with previous reports (Karr, 1981; US EPA, 1991) that proportions of omnivores increases as organic and nutrient pollutions enhance in the lotic ecosystems.

6. Influence of stream order on fish abundance

For the analysis of influence of stream order on fish abundance, we categorized the stream and rivers as 2nd order stream (1), 3rd order streams

(5), 4th oder stream (12), 5th order stream (6) and 6th order stream (4). As shown in Fig. 1, main-rivers of Geum River were consisted of 4~6th order streams and tributaries were made of 2nd ~5th order streams. Fig. 3 shows the functional relations, expressed as simple linear regression equations, of stream order on fish metric attributes. Regression analysis of stream order against the number of species (Fig. 3) indicated that the number of species in the watershed increased as the stream order increases ($y=1.12x+10.1$, $R^2=0.1122$; $p<0.05$) and the number of individuals increased slightly with stream orders ($y=1.33x+144.9$, $R^2=0.0005$: $p<0.05$). Such phenomenon was explained by greater availability of stable water volume, rich food, and higher physical habitat capacity. In contrast, as the stream sizes (order) increase, relative abundances of sensitive species and insectivore species decreased in the watershed, while tolerant species and omnivore species increased during the study period (Fig. 3). Barbour *et al.* (1999) who developed "Rapid Bioassessment Protocol (RBP)" using fish assemblage hypothesized that generally as the stream orders increase, inputs of organic pollutants, nutrients, and toxic chemicals to the river increase, so simplification of species compositions and predominance of tolerant species and omnivore species are general along the river from the up-stream to downstream. Our results are accord with the hypothesis, so the largest compositional changes in the trophic guilds occurred immediately after the input of polluted tributary waters (i.e., Gap stream).

Table 2. Fish community structure analysis, based on species richness index (d), evenness index (J'), species diversity index (H'), and dominance index (λ) in Geum River Watershed.

Site	Stream order	S	N	λ	*d*	*H'*	*J'*
S1	4	14	201	0.16	2.45	0.80	0.30
S2	4	15	213	0.21	2.61	0.73	0.27
S3	5	17	95	−0.08	3.51	1.08	0.38
S4	5	13	57	−0.10	2.97	0.98	0.38
S5	6	19	102	−0.05	3.89	1.02	0.35
S6	6	13	157	0.22	2.37	0.71	0.28
S7	6	20	299	0.18	3.33	0.85	0.28
S8	6	14	97	0.04	2.84	0.89	0.34
S9	4	13	168	0.10	2.34	0.68	0.26
S10	4	17	137	0.07	3.25	0.93	0.33
S11	5	19	104	−0.07	3.88	1.08	0.37
S12	4	14	162	0.10	2.56	0.89	0.34
S13	4	15	78	−0.06	3.21	1.00	0.37
S14	2	12	158	0.25	2.17	0.68	0.27
S15	4	18	238	0.10	3.11	0.91	0.32
S16	3	8	125	0.22	1.45	0.63	0.30
S17	5	17	185	0.23	3.06	0.77	0.27
S18	4	14	95	0.07	2.85	0.88	0.33
S19	3	16	144	0.05	3.02	0.94	0.34
S20	4	20	246	0.29	3.45	0.72	0.24
S21	5	19	191	0.14	3.43	0.87	0.30
S22	3	11	249	0.20	1.81	0.72	0.30
S23	3	19	160	0.16	3.55	0.86	0.29
S24	4	18	169	0.04	3.31	0.98	0.34
S25	4	12	101	0.04	2.38	0.93	0.38
S26	5	10	190	0.55	1.72	0.42	0.18
S27	4	8	50	0.10	1.79	0.70	0.34
S28	3	12	45	−0.05	2.89	0.82	0.33
Total number of individuals		56	4216	0.09	6.59	2.92	0.73

S=total number of native species, N=total number of individual, λ=Simpson's dominance index *d*=Margalef's species richness index, *H'*=Shannon-Weaver diversity index, and *J'*=Pielou's evenness index

7. Fish community structure analysis

Overall, fish community structure was analyzed by four index of species dominance index, diversity index, species richness index, and evenness index. The community analysis showed that species dominance index, diversity index, species richness index, and evenness index were 0.09 (range: −0.10~0.55), 2.92 (range; 0.42~1.08), 6.59 (range: 1.45~3.89), and 0.73 (0.18~0.38), respectively (Table 2). The species dominance index was highest (0.55) in the Site 26, whereas at this site, species diversity index and evenness index were lowest (0.42 and 0.18, respectively) during the study. The highest dominance in this site was attributed to highest occurrence of *Opsarichthys uncirostris amurensis* (76%, 145 as a total number of individuals), indicating a predominance of single species, which is carnivore. Under the circumstances, other species may not compete the species, resulting in degradation of fish community structure by the dominant species. In the up-river zone (S3) where is located in non-point source and is surrpunded by forests, species diversity index and evenness index were highest (1.08 and 0.38, respectively) in the study period along with high values in richness index (3.51) and low dominance index (−0.08). Also, in the Site 11 species diversity index was highest (1.08) with S3, and values of evenness index and evenness index were relatively high, indicating a stable fish community stability. Also, species diversity index was largely decreased in Site 6 which is directly influenced by the wastewater disposal plant and industrial complex of Gap stream, indicating an influence of chemicals on the species diversity.

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