Korean J. Limnol. 40 (4): 503~510 (2007)

Seasonal Dynamics of Fish Fauna and Compositions in the Gap Stream Along With Conventional Water Quality

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The purposes of the study were to analyze the seasonal effects on the fish fauna and compositions including trophic guilds and tolerance guilds. For the study, we collected fish samples twice in June as premonsoon period and early September 2007 as monsoon periods in five sampling sites of the Gap Stream, and then biological oxygen demand (BOD), nutrients (TN, TP) and suspended solids (SS) were compared with the guild data along the gradient of upstream-to-downstream. Chemical water quality, based on BOD, TP, and TN degraded gradually from the upstream to downstream reach and there were about 3 fold difference between S1 and S5. Water quality was worse in the premonsoon than the monsoon, and the heavy monsoon resulted in a dilution of the polluted river by rain water, especially, in the downstream reach. Total number of fish species, based on the catch per unit effort (CPUE), showed a distinct difference between the two seasons; 30 species were sampled in premonsoon, but 23 species were sampled in the monsoon, indicating a seasonal difference in the fish fauna. Tolerant species dominated the fish community (48.3%) in the stream, and the proportions prior to physical disturbance by the monsoon rain were evidently greater in the downstream reach than the upstream. This reflected the characteristics of urban stream polluted by nutrient enrichment as shown in the BOD and TP values. Sensitive species in the premonsoon decreased from the gradient of upstream-to-downstream reach. Such seasonal modifications in the trophic and tolerance guilds were evident. In the analysis of trophic guild and habitat guild, during the premonsoon the proportion of insectivore and riffle-benthic species were largely greater in the upstream reach than the downstream, whereas the proportions were opposite along the gradient of the stream in monsoon. Thus, the patterns of chemical water quality along the longitudinal gradients reflected the premonsoon conditions of insectivores and tolerant species, indicating that summer monsoon data of fish may not match with water quality due to large physical disturbance by flow regime. Seasonal monsoon in this region as well as the chemical pollution may act as a key role influencing the fish compositions of trophic and tolerance guilds and fauna. The data collected during the premonsoon rather than the monsoon, thus, may be better predictor for a diagnosis of stream health conditions.

Key words : fish composition, water quality, the Gap Stream, fish community, seasonal variation

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INTRODUCTION

Rapid degradations of stream water quality in the urban region are frequently associated with chemical pollutions such as nutrient enrichments of nitrogen or phosphorus (An and Park, 2002; An, 2003), and toxic chemicals such as heavy metals and pesticides (Lee *et al.*, 2007). Such chemical pollutants have been resulted in the general ecological disturbance such as decreased biodiversity (An *et al.*, 2003; Won *et al.*, 2006), reduction of sensitive species (Bae and An, 2006), and increase of tolerant species (MEK, 2000; Lee, 2001; An *et al.*, 2006) in freshwater ecosystems, so far in Korea. This phenomenon was widely reported stream researches of many developed countries (Oberdorff and Hughes, 1992; Harris, 1995; Koizumi and Matsumiya, 1997; Kovacs *et al.*, 2002).

Numerous researches of lotic ecosystems pointed out that habitat degradation is also one of the important factors influencing the biodiversity in aquatic environments as well as biological compositions and distributions (Baek and Song, 2005). Especially, accumulations of fine sands or silts in the downstream area may be a key factors influencing water volume, flow velocity, and substrate conditions, which are closely associated with fish population growth, compositions, and survival rates (Kim *et al.*, 2007). For these reasons, fish compositions and fauna are studied with habitat evaluations. In order to prevent and protect these degradations, various biological assessments and monitoring methodologies have been developed and adapted to the aquatic environments for stream restoration (An *et al.*, 2005a, b). One of the key researches in the stream monitoring is to use fish as a bioindicator in aquatic ecosystems. Recently, ecosystem health assessment methodologies using bioindicators such as attached algae (periphyton, Hwang *et al.*, 2006), macroinvertebrate (Won *et al.*, 2006), and fish (An *et al.*, 2006) have been introduced to evaluate aquatic ecosystems by the Ministry of Environment, Korea. Fish can be used as a good indicator identifying biological health and water quality conditions, and this has been shown in many previous studies of fish tissue, fish behavior, population, and fish community levels (Yeom and Adams, 2007). Especially, studies of fish community provided clues of water pollution or habitat modifications in stream ecosystems (An *et al.*, 2006).

Previous recent studies (Bae and An, 2006) reported that water quality and fish compositions in the Gap Stream were mainly influenced by point sources of industrial complex and wastewater disposal plants in the downstream (An *et al.*, 2003). Also, many other studies on water volume for maintaining the water quality in the stream (Jung *et al.*, 2005), vegetation distributions in the riparian zone (Woo and Jung, 1988), physical habitat assessments (Bae and An, 2006), fish fauna and community (Hong, 1994; Lee, 2001), and ecological stream health (An *et al.*, 2003; Bae and An, 2006) have been reported in the Gap Stream. Such papers pointed out that individual number of fish is decreasing in the downstream rather than up-stream reach, and that stream ecosystem health, based on the biological integrity, is highly impacted in the downstream reach by the point sources. Fish fauna and compositions in such studies, however, was not extensively studied especially in terms of seasonal variations of premonsoon and monsoon. In this study, we collected fish samples in the area and then, compared to conventional water quality data such as biological oxygen demand (BOD), nutrients (TN, TP) and suspended solids (SS) along with the trophic guilds and tolerance guilds.

MATERIALS AND METHODS

1. Sampling sites and periods

Five sampling sites were selected along the gradient of the upstream to downstream in the Gap stream, a tributary of Geum River (Fig. 1). From the sampling sites, we collected fish samples twice in June as premonsoon period and early September 2007 as monsoon periods, respectively to check seasonal variation of fish fauna and compositions on summer monsoon. Generally, monsoon season is typically the period of July-August, but in 2007 heavy monsoon precipitation occurred in early September. Site 1 (S1) is surrounded by forrest area and also located some rice paddies and ordinary fields near the stream. Site 2 (S2) and Site 3 (S3) are located near the edge of the Daejeon city and also are partially covered by forrest and residental areas. Site 4 (S4) was located in the middle of metropolitan city and artificially modified the channel to strai-

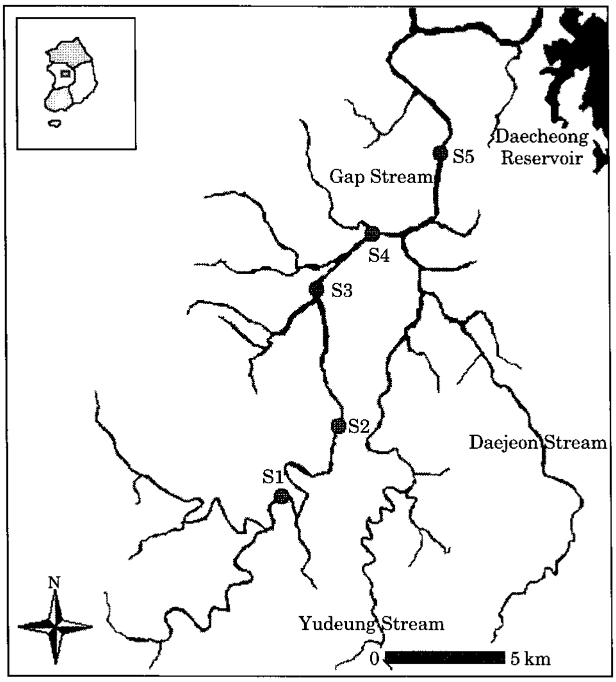

Fig. 1. The map showing sampling sites for the analysis of fish fauna and compositions in the Gap Stream.

ghten with small embankment. Site 5 (S5) was influenced by Daejeon industrial complex and wastewater treatment plants, which are located 2.5 km ahead from the site and also joining with Yudeung-stream, running through Daejeon metropolitan city just ahead of 3 km. Detail sampling sites and stream order, based on the approach of Strahler (1957), are as follows:

S1: Bongoek 2nd bridge, Bongoek-dong, Seo-gu, Daejeon city (3rd order)
S2: Gasoowon bridge, Jeonglim-dong, Seo-gu, Daejeon city (4th order)
S3: Manyeon bridge, Wolpyeong-dong, Seo-gu, Daejeon city (4th order)
S4: Daedeok bridge, Samcheon-dong, Seo-gu, Daejeon city (4th order)
S5: Gapcheon bridge, Jeonmin-dong, Daedeok-gu, Daejeon city (5th order)

2. Sampling methods and sampling gears

Fishes were collected from all types of their habitats including riffle, run, and pool area according to the modified method of An *et al.* (2006), based on the catch per unit effort (CPUE: Ohio EPA, 1989) and approximately 200 m stream segments were sampled at each site. The sampling time was elapsed around 60 minutes according to the quantitative sampling method (Barbour *et al.*, 1999) for fish bioassessments in lotic ecosystems. The fish samples were collected by two types of sampling gears as casting net and kick net, each size of the mesh were 5 × 5 mm and 4 × 4 mm, respectively, which are appropriate for collection of juvenile fish as well as large-size adult fish. The number of species and individuals were identified using keys of Kim and Park (2002) and classified into the order of tolerant guild as sensitive, intermediate, and tolerant species. Among collected specimens, some necessary species for detailed further identification and observation were fixed with 10% formalin solution and moved into the laboratory. Water quality data used in this study was obtained from the Ministry of Environment, Korea (http://water. nier. go.kr/weis) and the sampling sites for water quality were same as the sites collected fish. The parameters used were biological oxygen demand (BOD), total phosphorus (TP), total nitrogen (TN), and suspended solids (SS).

RESULTS AND DISCUSSION

1. Physico-chemical conditions

During the study, biological oxygen demand (BOD) increased gradually from the upstream to downstream reach and there were about 3 fold difference between S1 and S5 (Fig. 2). This result indicates that input of organic matter was greater in the point sources such as industrial complex and wastewater disposal plants. Also, there was a significant seasonal difference in the BOD between premonsoon and monsoon season; BOD was greater in the premonsoon than during the monsoon and this phenomenon occurred in all sampling sites (Fig. 2), indicating that chemical water quality is worse before the monsoon rainfall and the monsoon rain diluted the polluted river water. Total phosphorus (TP) also showed typical downstream decreases like BOD, but showed abrupt increases in the Site 5 (Fig. 2). Especially, TP values of S5 in premonsoon were 5 times greater than that of the monsoon. Total nitrogen (TN) also showed similar spatial pattern with TP. Suspended solids (SS) showed downstream increases but the gradients from the upstream to the downstream reach was greater in

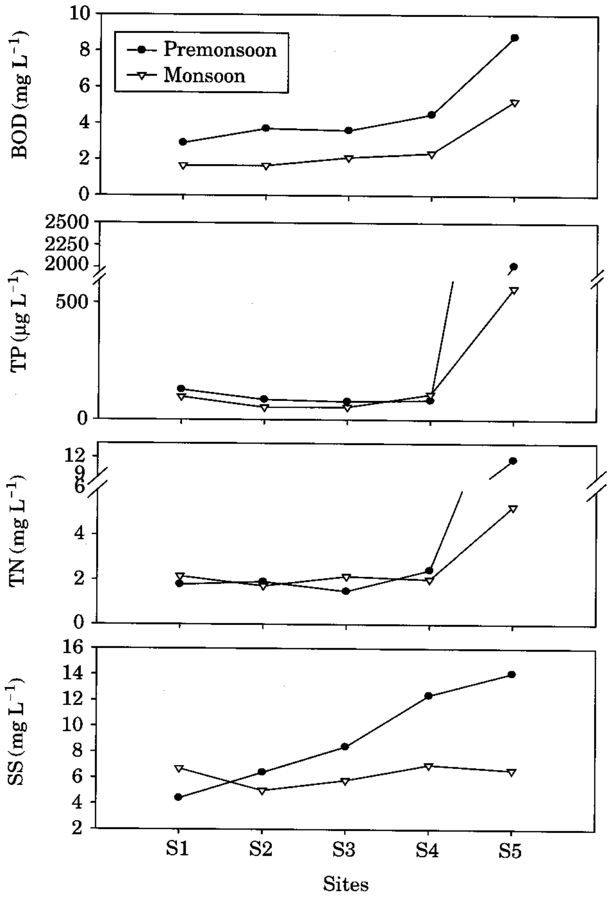

Fig. 2. Water quality at each sampling site, based on data of June as a premonsoon in 2007 and the average data of August in 2005-2006 as a monsoon period (BOD: biochemical oxygen demand, TP: total phosphorus, TN: total nitrogen, SS: suspended solids).

the premonsoon than the during monsoon (Fig. 2). These outcomes of abrupt increases of nutrients in the site 5 were attributed to nutrient-rich effluents from the wastewater disposal plants.

2. Fish fauna

Total number of fish individuals, based on the catch per unit effort (CPUE), were 2,116 from five sites via premonsoon and monsoon and the total number of species was 34 during the study (Table 1). Among these species, 10 species including *Coreoleuciscus splendidus* were found to be korean endemic species (29.4% in the relative abundance, RA), which could show slightly higher than the mean RA, 23% of entire endemic species of Korea (Nam, 1996). By the analysis of premonsoon and monsoon variation to the sampling, 30 species with 1,046 individuals were sampled in premonsoon, while 23 species with 1,070 individuals were sampled (Table 1). Thus there was a distinct difference between the two seasons that indicating more species were sampled in the premonsoon than monsoon period. Also, in the upstream reach, the number of fish individual sampled was greater in the premonsoon than the monsoon, whereas, the number of individual was greater in the downstream during the monsoon. We believe that high inflow from the monsoon rainfall seemed to affect the number of species and their distributions and compositions. In the mean time, in the comparisons of endemic species between premonsoon and monsoon, 7 species were collected in the premonsoon and 6 species in monsoon that had not significant differences. Besides, endangered species and natural monument species were not found in this survey. According to fish species composition, *Zacco platypus* (41.9% in the RA) were confirmed to be the most dominant species in the fish community regardless of the seasonal variations of premonsoon (43.6%) and monsoon (40.4%; Table 1) in this survey. Relative abundance of subdominant species, *Acheilognathus lanceolatus*, averaged 11.3% and had no seasonal variation like the population of *Zacco platypus*. In premonsoon, relative abundance of *Acheilognathus lanceolatus* was 11.6%, which was a subdominant species, but the subdominant species in the monsoon was *Pseudogobio esocinus* with 14.6% (Table 1). This finding implies that heavy monsoon rain may more affect the water column species rather than benthic dweller. Benthic species such as *Pseudogobio esocinus* can hide their benthic habitat under the sand, pebble and rock, which can hardly affected under the high flow regime, resulting in the subdominance in the monsoon season. Exotic species of *Carassius cuvieri* and *Micropterus salmoides* (large-mouth bass) were observed in the site 4 and sites 1-4, respectively, implying that ecological disturbance, based on previous reference of US EPA (1991) occurred widely in the Gap Stream. Previous research (Hong, 1994; An *et al.*, 2001; Lee, 2001) pointed out that large-mouth bass as a carnivorous species, was not reported in the watershed. Thus, our observations of the exotic species indicate that this ecosystem may be vulnerable due to a rapid spreading of the exotic species and that the number of endemic fish species may be reduced unless the ecosystem

Table 1. The seasonal variation of fish fauna and compositions, based on tolerance, trophic, and habitat guilds in the Gap stream.

Species	Tolerance guild	Trophic guild	Habitat guild	S1		S2		S3		S4		S5		Seasonal total				Total	
				Pr	Mo	Pr	Mo	Pr	Mo	Pr	Mo	Pr	Mo	Pr	RA (%)	Mo	RA (%)	#	RA (%)
1 *Odontobutis platycephala*	S	C	RB	10		3						1		14	1.34	0	0.00	14	0.66
2 *Hemibarbus longirostris*	S	I	–		17		2	22	38	6	6		1	28	2.68	64	5.98	92	4.35
3 *Zacco temminckii*	S	I	–	8						1				9	0.86	0	0.00	9	0.43
4 *Coreoleuciscus splendidus**	S	I	RB	10		3		15	4		4	1	1	29	2.77	9	0.84	38	1.80
5 *Iksookimia koreensis**	S	I	RB	54		15	1	6	8					75	7.17	9	0.84	84	3.97
6 *Pseudobagrus koreanus*	S	I	RB	4		5			5					9	0.86	5	0.47	14	0.66
7 *Pungtungia herzi*	S	I	RB	45	13	29	8	3	11	3	6		1	80	7.65	39	3.64	119	5.62
8 *Acheilognathus lanceolatus*	S	O	–		7	116	31	4	31	1	47		2	121	11.57	118	11.03	239	11.29
9 *Acheilognathus yamatsuate**	S	O	–					1						1	0.10	0	0.00	1	0.05
10 *Erythroculter wrythropterus*	I	C	–									1		1	0.10	0	0.00	1	0.05
11 *Opsariichthys uncirostris amurensis*	I	C	–		1		5	1	31	1	21		25	2	0.19	83	7.76	85	4.02
12 *Pseudobagrus fulvidraco*	I	C	–						6					0	0.00	6	0.56	6	0.28
13 *Odontobutis interrupta**	I	C	RB						9					0	0.00	9	0.84	9	0.43
14 *Acheilognathus rhombeus*	I	H	–					1			6			1	0.10	6	0.56	7	0.33
15 *Gnathopogon strigatus*	I	I	–						5		4	13	5	13	1.24	14	1.31	27	1.28
16 *Pseudogobio esocinus*	I	I	–	1	7	3	3	4	30	19	76	3	40	30	2.87	156	14.58	186	8.79
17 *Sarcocheilichthys nigripinnis morii**	I	I	–								2			0	0.00	2	0.19	2	0.09
18 *Squalidus gracilis majimae**	I	I	–	1										1	0.10	0	0.00	1	0.05
19 *Cobitis lutheri*	I	I	RB	1				1	1					2	0.19	1	0.09	3	0.14
20 *Rhinogobius brunneus*	I	I	RB	34	7	7	2	4	4	4	4	9	3	58	5.54	20	1.87	78	3.69
21 *Tridentiger brevispinis*	I	I	RB	6				1					1	7	0.67	1	0.09	8	0.38
22 *Acheilognathus koreensis**	I	O	–	6										6	0.57	0	0.00	6	0.28
23 *Acheilognathus macropeterus*	I	O	–			1	3	6	1		2			7	0.67	6	0.56	13	0.61
24 *Rhodeus uyekii**	I	O	–	2										2	0.19	0	0.00	2	0.09
25 *Squalidus japonicus coreanus**	I	O	–		1								4	0	0.00	5	0.47	5	0.24
26 *Microphysogobio yaluensis**	I	O	RB	4		19	7	10	3		1			33	3.15	11	1.03	44	2.08
27 *Micropterus salmoides*	T	C	–		5		11	1	3	1	2			2	0.19	21	1.96	23	1.09
28 *Silurus asotus*	T	C	–									3		3	0.29	0	0.00	3	0.14
29 *Misgurnus mizolepis*	T	H	–	9				1						10	0.96	0	0.00	10	0.47
30 *Hemibarbus labeo*	T	I	–				1	1	9	8	8	17	28	26	2.49	46	4.30	72	3.40
31 *Carassius auratus*	T	O	–					4		7		4		15	1.43	0	0.00	15	0.71
32 *Carassius cuvieri*	T	O	–							4				4	0.38	0	0.00	4	0.19
33 *Pseudorasbora parva*	T	O	–		1		1			1	5			1	0.10	7	0.65	8	0.38
34 *Zacco platypus*	T	O	–	61	80	143	58	157	146	82	56	13	92	456	43.59	432	40.37	888	41.97
Total number of species				16	10	11	13	19	18	13	16	10	12	30		23		34	
Total number of individual				256	139	344	133	243	345	138	250	65	203	1046	100	1070	100	2116	100

*: Endemic species, Tolerance guild (S: Sensitive, I: Intermediate, T: Tolerance), Trophic guild (I: Insectivore, O: Omnivore, C: Carnivore, H: Herbivore), Habitat guild (RB: Riffle Benthic), Pr: Premonsoon, Mo: Monsoon, #: total individual number, RA: Relative abundance.

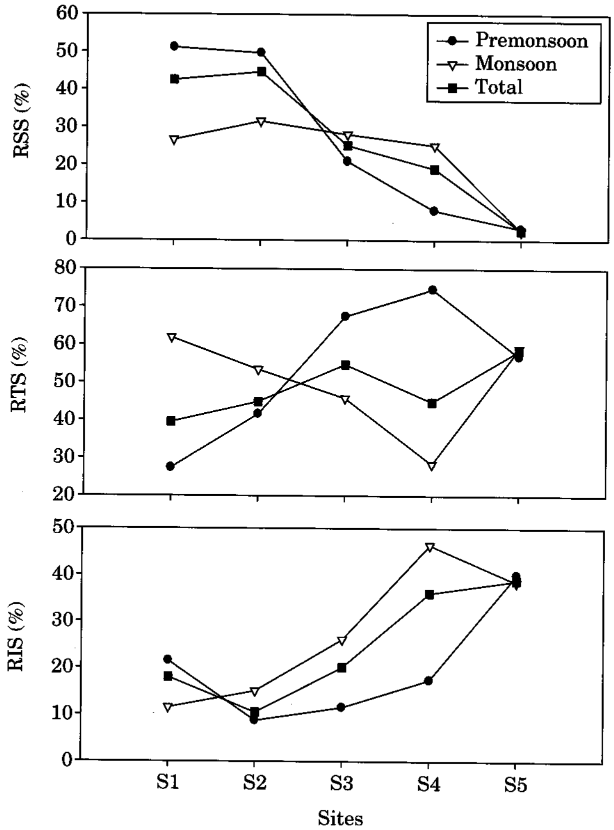

Fig. 3. Seasonal variations of tolerance guilds, based on the number of individual (RSS: relative sensitive species, RTS: relative tolerant species, and RIS: relative intermediate species).

conservations and protections are maintained.

3. Seasonal variations of tolerance guilds and trophic guilds

According to the analysis of tolerance guild, relative proportion of tolerant species was 48.3% (1,023 individuals) during the survey, whereas the proportion of sensitive species was 28.8% (610 individuals; Fig. 3). Thus, dominance of tolerant species was evident and this reflected the characteristics of urban stream polluted by nutrient enrichment. Sensitive species showed in premonsoon were tend to decrease along with the current from upstream (S1) to downstream (S5) gradually (Fig. 3). But the proportion of sensitive species in the monsoon ranged between 25 and 35% in each site and spatial variation was lower in the monsoon than the premonsoon (Fig. 3). In the site 4, the proportion of sensitive species was greater in the monsoon than premonsoon, indicating that the fish composition was largely modified by the monsoon flow regime. In contrast, there was no seasonal variation of sensitive species in the site 5 and the values were minimum among the sampling sites. This condition was accord with high proportions of tolerant species (>60%) such as *Carassius auratus, Zacco platypus*, and *Hemibarbus labeo* (Table 1). These conditions seem to be closely associated with high BOD (>6 mg L^{-1}) and nutrient enrichment of nitrogen (>4 mg L^{-1} as TN) and phosphorus (>500 µg L^{-1} as TP; Fig. 2).

Greater oxygen demands and nutrients in the downstream reach were evidently due to excessive nutrient inputs from the point sources of industrial complex and wastewater disposal plants. Simultaneously, other hazard chemicals may be also responsible for the reduced sensitive species and high proportions of tolerant species in the donstream sites. This implication may be supported by previous GC-FID profiling dataset and Ames tests analyzed from the downstream location (Expo-Apartment complex area, Jeonmin-dong) in 1999 (Kim *et al.*, 2001). According to this study, the number of chemical peaks, based on acetonitrile fraction, was more than 3 fold greater in the downstream (mean=38.7) than the upstream region (12.1), and the Ames tests using S9 mixture showed positive reactions in the downstream but not in the upstream. Also, Kim *et al.* (2001) found 1-5 fold greater toxicity in the upstream station based on Microtox toxicity tests using a methanol fraction, and two time greater PAHs (ethylacetate fraction) in the downstream (70.6 ng L^{-1}) than the upstream (36.9 ng L^{-1}). The proportion of tolerant species had tendency to increase along the gradient of upstream to downstream, whereas the trend in the monsoon was opposite (Fig. 3). However, there were no significant seasonal changes of tolerant species in the site 5, indicating that the dominance of tolerant species regardless of season in the site. Except the site 5, monsoon flow largely contributed the compositional changes. In other words, fish composition was mixed up by heavy amount of inflow via the monsoon, so that characteristics of fish distribution between upstream and downstream became ambiguous to configure the locational specificity of stream in monsoon period. Temporal analysis of intermediated species showed that in both seasons of premonsoon and monsoon the downstream had higher values than the upstre-

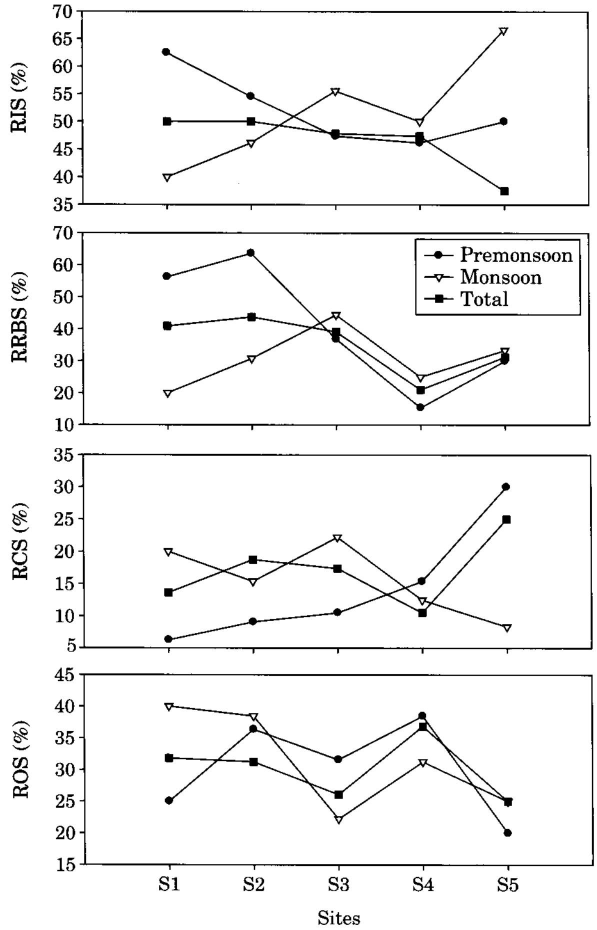

Fig. 4. Seasonal variations of trophic guilds and habitat guilds, based on the total number of species (RIS: relative insectivore species, RRBS: relative riffle-benthic species, RCS: relative carnivore species, and ROS: relative omnivore species).

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Analysis of trophic guilds showed that during the premonsoon the proportion of insectivore and riffle-benthic species were largely greater in the upstream sites than the downstream (Fig. 4). During the monsoon, in contrast, the proportions of insectivore and riffle-benthic species had greater increasing trend in the downstream reach than the upstream (Fig. 4). As our chemical dataset of BOD, TP, TN and SS (Fig. 2), the water quality showed a typical degradation trend toward the downstream reach. Thus, the pattern of chemical water quality along the longitudinal gradients reflected the premonsoon conditions of the insectivores and tolerant species, indicating that summer monsoon data of fish may not match with water quality due to large physical disturbance by flow regime. The proportions of carnivores were more dominated in the downstream than the upstream in the premonsoon, but the pattern during the monsoon was the opposite.

Our overall data suggest that conventional chemical water quality, based on nutrients of TP and TN and BOD, degraded as the stream water goes to the downstream. The degradation was associated with high population density, greater depositions of sediments from the upstream, and large point sources in the downstream reach. These conditions prior to the heavy monsoon rain set fish distributions and compositions of trophic conditions, based on insectivores and omnivores, and of tolerance guilds, based on tolerant species and sensitive species. High flow during the monsoon, however, modified the fish distributions and compositions in the Gap stream. Seasonal monsoon in this region, thus, may act as a key role influencing the fish composition and fauna. These circumstances may not reflect well the conditions of water chemistry, so the data collected during the premonsoon may be better predictor for a diagnosis of stream health conditions.

ACKNOWLEDGEMENTS

This research is supported by the grant "Assessment model developments of biological, chemical, and physical habitat in the level of fish individual and community in aquatic ecosystems and their optimum stressor analysis", the Ministry of Environment, Korea in 2007.

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(Manuscript received 25 October 2007,
Revision accepted 10 December 2007)