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Fish Composition and Trophic Guild Analysis as a Collection of Basic Data for Ecosystem Health Assessments in Yeongsan Lake

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The objectives of this study were to analyze fish compositions, based on trophic guilds and tolerance guilds and determine community characteristics structure at five sampling sites of Yeongsan Lake during July 2006-May 2007. Total number of species sampled was 30 species and the number was 1350. Cyprinidae (77%) and Centrarchidae (15.7%) dominated the community and then followed by Cobitidae (2.7%), Gobiidae (2.4%), Mugilidae (0.5%), and others (0.1%). The relative abundance of tolerant and omnivore species at all sites was 63% and 77% of the total, respectively, suggesting an ecological degradations in the Lake. Exotics species such as large mouth bass (Micropterus salmoides), which is a top-carnivore in the water distributed at all sampling sites, implying that ecological disturbance was severe based on previous reference of US EPA (1991). Also, we found external anomalies such as external deformities, bleeding and tumors and not found migratory fish. Analysis of fish community structure showed that species diversity index and richness index was the highest in Site 1 and the dominance index was the highest in Site 2. In this study, high proportions of tolerant species and omnivore species, widespread exotic species, and frequent observations of abnormal fish. Such problems may be directly or indirectly associated with high nutrient enrichments and the reduced flow velocity by the dam construction. The ecosystem restoration by dam removal or removal of exotic top-carnivore fish may be one of the best strategies for better lak management.

Key words : fish composition, fish community, pollution, Yeongsan Lake

INTRODUCTION

Yeongsan Lake was located in south-western part of South Korea (N 34°45′58″, E 126°29′32′) and has total length of 23.5 km, surface area of 34.6 km^2, and storage volume of 2.5×10^7 ton. The lake water is primarily used as agricultural purpose for irrigations and industrial purposes.

In the watershed of Yeongsan River, 4 multipurpose dams such as Damyang dam, Kwangju dam, Jangsung dam, Naju dam were constructed in the up-stream and Yeongsan estuary dam was also built at lower reach to obstruct influx of sea water to keep freshwater since 1981. Construction of these multipurpose dams and estuary dam, however, have been caused degradation of water quality including serious eutrophication due to contaminated inflow from several tributaries.

Previous studies of Yeongsan lake (Lee *et al.*, 1993; Park *et al.*, 2001; Yang and Choi, 2003) were most frequently associated with physicochemical water quality and hydrology. Also, there

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were numerous biological researches on phytoplankton (Kim, 2003), zooplankton (Yoo *et al.*, 1987), macroinvertebrate (Wui, 1974), and fish (Choi, 1973) and these studies were involved with various analysis of species compositions, spatiotemporal distributions, and community structures using the aquatic organisms. In particular, fish fauna, community structure, and its seasonal variabilities reported in various scales of the watershed in 1970s (Wui *et al.*, 1977) and 1980s (Choi *et al.*, 1984; Kim *et al.*, 1986; Song and Lee, 1987; Song and Lee, 1988). However, little is known about fish fauna and its compositional changes after 1990s in Yeongsan Lake. In fact, there are no recent publications on ecological differences in fish compositions and tolerance guilds between the previous and recent data.

Also, it is evident that introduced exotic species are influencial on fish species compositions of endemic species in the lake ecosystem, resulting in a modification structures of fish community and the functions of the lake. Jang *et al.* (2001) pointed out that relative abundance of exotic species in Yeongsan lake was getting higher than in any other dam lakes in Korea, and thus it is urgent to understand ecological and functional modifications on the fish distribution and compositional changes by the exotic species

This research was a good opportunity to report recent conditions of the fish fauna, compositional changes in longitudinal spaces and seasons, and characteristics of fish community structure, along with the functional variabilities of trophic and tolerance guilds. This research will provide basic biological data in cases of the dam removal or a sediment dredging from the lake bottom for the ecosystem restoration.

MATERIALS AND METHODS

1. Sampling periods and sites

This study was conducted three times during July 2006-May 2007 in the five sampling sites from Mongtan bridge to the estuary dam (Fig. 1). Sampling Seasons were based on flow regime. Monsoon and postmonsoon samples were collected on July 2006, and October 2006, while premonsoon samples were collected on May 2007. Sampling sites are as follows;

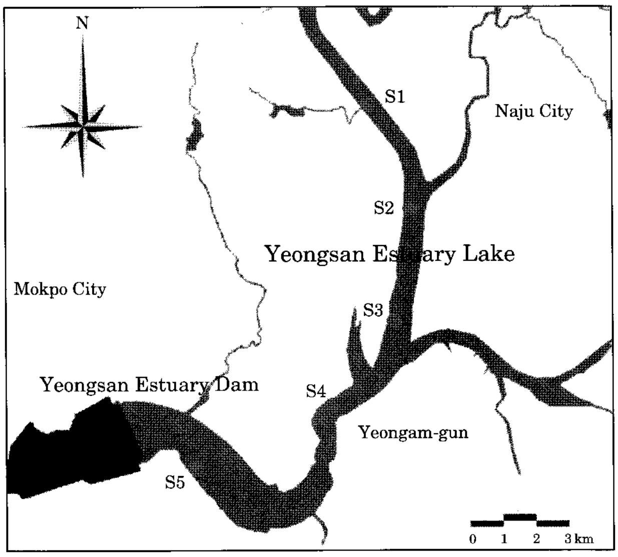

Fig. 1. The sampling sites in Yeongsan Lake.

S1 : Dangho-ri, Mongtan-myeon, Muan-gun, Jeollanam-do
S2: Bongnyong-ri, Cheonggye-myeon, Muan-gun, Jeollanam-do
S3: Uisan-ri, Illo-eup, Muan-gun, Jeollanam-do
S4: Cheongho-ri, Illo-eup, Muan-gun, Jeollanam-do
S5: Nabul-ri, Samho-eup, Yeongam-gun, Jeollanam-do

2. Fish sampling and trophic guild analyses

In Yeongsan Lake, fishes were collected based on the catch per unit of effort (CPUE; Ohio EPA, 1989) from all types of their habitats according to the approach of lake and reservoir bioassessments and biocriteria (US EPA, 1998). For the application of this evaluation methods, we sampled at the littoral zone with 0.5-4 m in water depth using casting net (mesh, 5 × 5 mm) and kick net (mesh, 4 × 4 mm) as sampling gear along with electorofishing device (12V, 24A). Casting net was mainly used at openwater around the littoral area and kick net was used at the shallow region with hydrophytes and waterweeds. At each sampling location, sampling distance was 200 m and the sampling time elapsed was 50 minutes according to the quantitative sampling method (Barbour *et al.*, 1999). Fish samples were identified using keys of Kim and Park (2002). We also classified tolerant guild as sensitive, intermediate, and tolerant species after the approach of An (2001). Among collected specimens, some necessary species for detailed further identification and observation were fixed with 10% formalin solution and moved into the laboratory. External characteristics (DELT) of all fishes were examined for deformities, erosion, lesion, and tumors in accordance with the methodology of the U.S. EPA (1993).

3. Community analysis

Community analysis in this study included community dominance index (Simpson's Dominance Index, λ; Simpson, 1949), species richness index (Margalef's species richness index, *d*; Margalef, 1958), species diversity index (Shannon-Weaver diversity index, *H'*; Shannon and Weaver, 1949) and species evenness index (Pielou's evenness index, *J'*; Pielou, 1975) for analyzing community structure. We compared index values in the study sites and then analyzed the community structure.

RESULTS AND DISCUSSION

During the study period, total number of individuals sampled was 1,350 with 10 families and 30 species (Table 1). Major dominant fish families, as a proportion of individuals, were 77% Cyprinidae (15 species) and 15.7% Centrarchidae and then followed by 2.7% Cobitidae, 2.4% Gobiidae, 0.5% Mugilidae, and 0.1% others. Among these species, only one endemic species of *Sarcocheilichthys nigripinnis morii* was collected during the study, and endangered and natural monument species were not found in the sampling sites. Overall, fish species diversity seemed to be reduced, compared to previous studies of Yeongsan Lake in 1986 (Kim *et al.*, 1986) and 1988 (Song and Lee, 1988).

Analysis of relative abundance in fish showed that five dominant species occupying more than 5% of the total were *Acheilognathus macropeterus* (28%), *Hemiculter eigenmanni* (15%), *Carassius auratus* (14%), *Micropterus salmoides* (12%), and *Carassius cuvieri* (8%; Fig. 2). Especially, predominance of large-mouth bass (*Micropterus salmoides*), as an exotic species and carnivore species, indicated potential ecological disturbances in the study area. Also, we found that all ranged-size structures observed from the juvenile to adult indicated a reproductive success in the system.

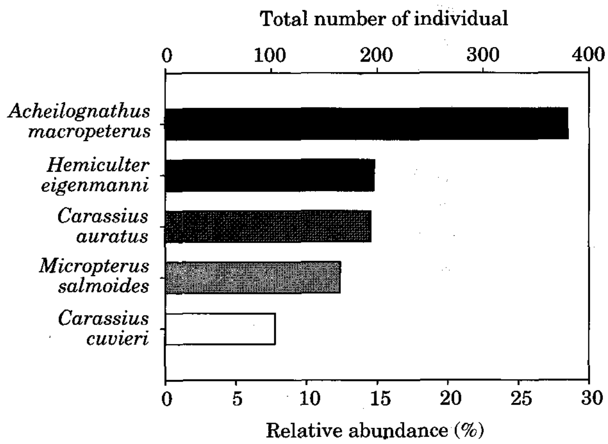

Fig. 2. The relative abundance of the fish species collected in Yeongsan Lake.

Tolerance guilds analysis showed that tolerant species dominated the community in the aquatic ecosyem. The proportion of tolerant species was 73% (850 individuals), while sensitive and intermediate species were 0% and 37% (499 individuals), respectively (Fig. 3A). The relative abundance of tolerance species showed a predominance at all sites. Barbour *et al.* (1999) pointed out that when tolerant species dominated in an aquatic ecosystem, chemical degradations occurred and organic matter pollution was frequent. We believe that the predominance of the tolerant species (>70% of the total) indicated ecological degradation in the Yeongsan Lake and if this condition is maintained, even the number of intermediate species as well as sensitive species (in spite of no sampling in this survey) will be reduced in the system as the water quality get worse.

Also, we analyzed trophic guilds for the feeding and energy interactions in the system. We found that the proportion of omnivore species, as a number of individual, was 77% (1,034 individual) and in contrast, insectivore species was only 6% (75 individuals; Fig. 3B). The proportion of the carnivore species was 14% (189 individuals) with others (such as herbivores and filter feeders) of 4%. The relative abundance of omnivore species was greater than that of any other trophic guilds such as carnivores, insectivores, and others in the Yeongsan Lake. Karr (1981) and US EPA (1993) reported that as physical and chemical degradations increase in the aquatic ecosystems, the proportion of omnivore increase among the various trophic guilds. The predominance of the

Table 1. Fish fauna and the various guilds of trophic level, tolerance and habitats in Yeongsan Lake.

Species	Tolerance guild	Trophic guild	Habitat guild	1st survey					2nd survey					3rd survey				
				S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Anguillidae																		
Anguilla japonica	IS	C	–													1		
Engraulidae																		
Coilia nasus	IS	C	–										1					
Cyprinidae																		
Abbotina rivularis	IS	O	–		6					17								
Acheilognathus macropeterus	IS	O	–		2		2	1	32	282		4	22	16	5	3	4	7
Aphyocypris chinensis	IS	O	–										1		1			2
Opsariichthys uncirostris amurensis	IS	C	–									2					2	
Rhodeus ocellatus	IS	O	–	1	1				5					3				
Sarcocheilichthys nigripinnis morii	IS	I	RB				2	5					2				5	3
Hemibarbus labeo	SS	I	–				1											
Acheilognathus rhombeus	TS	H	–						2									
Carassius auratus	TS	O	–	8	21	4			21	119	1			7	5	4		4
Carassius cuvieri	TS	O	–	1	78	1	3	4				2	2		10			3
Cyprinus carpio	TS	O	–	4	10	1	1	2	2		1		2	3		4		
Hemiculter eigenmanni	TS	O	–	10	30	21	5		17	9		5		41	43	1	1	14
Pseudorasbora parva	TS	O	–		12	1				2			3	2	9			2
Rhodeus notatus	TS	O	–	16	12													
Zacco platypus	TS	O	–	8					4					2	5			
Cobitidae																		
Cobitis lutheri	IS	I	RB						3					1				
Misgurnus mizolepis	TS	H	–	2					11					7	5	2		6
Bagridae																		
Pseudobagrus fulvidraco	IS	C	–	1			1							2				
Mugilidae																		
Chelon haematocheilus	IS	F	–				2											
Mugil cephalus	IS	F	–				2					1	2					
Adrianichthyidae																		
Oryzias sinensis	IS	F	–						1					9				
Centrarchidae																		
Lepomis macrochirus	TS	I	–			9	2				15	2		2	1	13	3	
Micropterus salmoides	TS	C	–	28	6	17	8	10	6	2	11	5	11	17	2	18	11	13
Odontobutidae																		
Odontobutis platycephala	IS	C	RB					1										
Gobiidae																		
Acanthogobius flavimanus	IS	C	–			13												
Tridentiger bifasciatus	IS	O	–			1												
Tridentiger brevispinis	IS	O	RB			12							1					
Rhinogobius brunneus	IS	I	RB											1				5
Total number of species				10	10	10	11	6	10	6	4	7	10	14	10	8	6	10
Total number of individual				79	178	80	29	23	104	431	28	21	47	113	86	46	26	59

SS=Sensitive species, IS=Intermediate species, TS=Tolerant species, O=Omnivore, I=Insectivore, C=Carnivore, H=Herbivore, RB=Riffle-benthic species

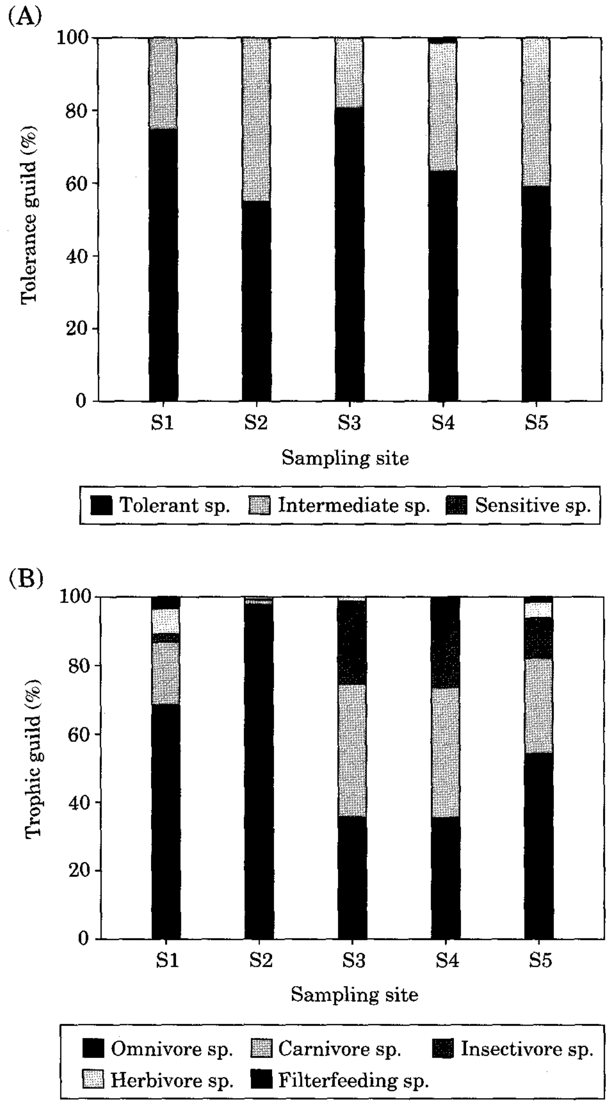

Fig. 3. Analysis of tolerance guilds and trophic guilds in Yeongsan Lake.

omnivores in the Yeongsan Lake indicated chemical water pollution and habitat degradations and this tendency was accord with the analysis of the tolerance guilds.

Our sampling in the all study sites showed that the frequency of introduced species, based on the calculation of constancy values, was 100% and the key species was large-mouth bass (*Micropterus salmoides*), which is well known carnivore species in the world and destruct endemic fish community in the world (VOOREN, 1972; Courtenay and Stauffer, 1990). The destruction of fish compositions by the large-mouth bass was evident in our ecosystem. We found that all ranged-size structures observed from the juvenile to adult indicated a reproductive success in the system. We believe that the bass settled already down in the Yeongsan Lake. Thus, the exotic species modified the fish compositions and size structures of the fish as well as rapid decreases of endemic species, resulting in functional changes in the ecosystem.

In addition, another symptom of environmental degradations in the Yeongsan Lake was found in the analysis of external anormalies in fish individuals. Major fishes shown external anormalies in the sampling sites was *Carassius auratus, Cyprinus carpio*, and *Hemiculter eigenmanni*. We found that these fishes were morphologically abnormals with external vertebral deformities, tumors, and fin erosions. External examinations showed that fish abnormalities were composed of 58% for a lesion, 11% for caudal and dorsal fins, 5% for deformity and fin erosion, respectively, and 9% for skin tumors in the diseased fishes. We believe that these symptoms in the fish seemed to be associated with degradations of chemical water quality and biological factors like virus or bacterial infection, which is correlated with lake eutrophication by nitrogen and phosphorus (US EPA, 1993)

In the Yeongsan Lake, fish community analyses, based on species diversity index, evenness index, and dominance index, are shown in Table 2. Species diversity index, as a degree of relative balance in the species and individuals of fish community, was highest (0.84) in the Site 1 and lowest (0.63) in the Site 2. Community richness index was similar to the patterns of species diversity index; the value was highest (2.32) in the Site 1 and lowest (1.53) in the Site 2. Evenness index, as a degree of homogeneous conditions in the distributions of species and individuals, was highest (0.90) in the Site 4 and lowest (0.66) in the Site 2. Dominance index showed that Site 2 was highest (0.35) and lowest (0.19) in the Site 1. Previous studies of Choi *et al.* (2003) and Choi *et al.* (2004) pointed out that artificial reservoirs generally have characteristics of high predominance in a specific fish species along with low species diversity and evenness indices. Such tendency in the the Yeongsan Lake, however, was not shown; values of species diversity index and evenness index were high and dominance index was low (Choi *et al.*, 2005). We believe that dis-

Table 2. Community analysis, based on the species richness index, community evenness index, species diversity index, and community dominance index in the sampling sites.

Sampling site		S	N	*d*	*J′*	*H′*	Lambda′
1st survey	S1	10	79	2.060	0.793	0.793	0.207
	S2	10	178	1.737	0.759	0.759	0.249
	S3	10	80	2.054	0.814	0.814	0.178
	S4	11	29	2.970	0.902	0.940	0.144
	S5	6	23	1.595	0.828	0.644	0.278
2nd survey	S1	11	104	2.153	0.815	0.849	0.182
	S2	6	431	0.824	0.497	0.387	0.506
	S3	4	28	0.900	0.678	0.408	0.444
	S4	7	21	1.971	0.933	0.789	0.179
	S5	10	47	2.338	0.718	0.718	0.287
3rd survey	S1	14	113	2.750	0.772	0.885	0.191
	S2	10	86	2.020	0.732	0.732	0.289
	S3	8	46	1.828	0.784	0.708	0.255
	S4	6	26	1.535	0.860	0.669	0.260
	S5	10	59	2.207	0.905	0.905	0.149

S=Total number of native species, N=Total number of individual, *d*=Margalef's species richness index, *J′*=Pielou's evenness index, *H′*(log)=Shannon-Weaver diversity index, and Lambda'=Simpson's Dominance Index

tinct disparity in the community structures, compared to other freshwater reservoirs, may be resulted from estuary reservoirs with high salinity and high turbidity, compared to other freshwater lakes.

In conclusion, analysis of fish fauna and compositions in the Yeongsan Lake suggested that tolerance species and omnivore species dominated the fish community, and exotic species of large -mouth bass were widely distributed in all sampling sites. Also, external abnormality of fish such as skin lesion, deformity of vertebrae and fin erosion, and skin tumors was frequently observed in the fishes sampled. We believe that these symptoms in the fish seemed to be associated with degradations of chemical water quality and biological factors like virus or bacterial infection. Now, previous research results on water quality in the Yeongsan Lake (Joo and Park, 1991; Kang and An, 2006) support our hypothesis of chemical degradations. In fact, trophic state, based on nutrients of nitrogen and phosphorus, were classified as eutrophic-hypertrophic conditions, based the chemical criteria of the Ministry of Environment, Korea (MEK, 2004, 2005). Evidently, analysis of fish compositions in the tolerance guilds and trophic guilds suggested that ecological health in the lake is rapidly degradated. Therefore, reductions of chemical inputs, habitat restoration by bottom dredging, or the removal of the estuary dam along with an elimination of exotic species (large-mouth bass) may be effective strategies for better ecosystem management and conservations in the Yeongsan Lake.

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