



## Diet shifts and delayed piscivory specialisation during the ontogenesis of the largemouth bass *Micropterus salmoides* (Lacepede, 1802) in the Nakdong River and Upo Wetlands, South Korea

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### ABSTRACT

In this study, we examined the ontogenetic changes in prey selection pattern of largemouth bass *Micropterus salmoides* (Lacepede, 1802) in accordance with habitat type. The stomach contents of largemouth bass were analysed with respect to predator size classes for two different habitats (Nakdong River main channel and the Upo Wetlands tributary) in South Korea, that differed in the diversity of potential prey items. The diversity ( $H'$ ) of invertebrate diet items in stomach of largemouth bass was found significantly different between the study sites. Small large mouth bass (<100 mm) preferred to consume decapods and mayflies in the river and wet land systems respectively. Fishes >100 mm in the river and >200 mm in the wet land system preferred fish as their prey. Results demonstrated variations in composition of prey items as influenced by habitat characteristics as well as habitat use type, contributed to the delayed ontogenetic diet shift in the largemouth bass population.

Keywords: Diversity, Habitat type, Ontogenetic change, Prey selection

### Introduction

An introduced exotic species has negative impacts on ecological functions (Fritts and Rodda, 1998; Pimentel *et al.*, 2000; Jo *et al.*, 2011; Almeida *et al.*, 2012) and poses major threats to biodiversity, ecosystem integrity, fisheries and public health (Lee, 2002). Exotic fish species also appear to impose greater pressures on endemic freshwater ecosystems and often drive native species to extinction in the new habitats (O'grady and Cowx, 2000). Therefore, investigations on interaction between exotic species and other native organisms would help to provide insight into fundamental ecological values, which can also help in formulating conservation strategies.

The largemouth bass *Micropterus salmoides* (Lacepede, 1802), is one of the most notorious exotic species in the world. Since its introduction from Japan to South Korea in 1973 (Kim and Park, 2002), many freshwater ecosystems have suffered because of this species. When largemouth bass are less than 80 mm in body length, they mainly predate invertebrates and as they grow, their diet shifts gradually to crayfish and fish in

the native habitat like North America (Olson, 1996; Post, 2003). Largemouth bass in new environments outside North America also showed similar pattern of diet shifts to native fish (Jang *et al.*, 2006; Yasuno *et al.*, 2012). When this ontogenetic diet shift is relatively discrete, a population can be divided into separate size classes based on diet diversity or habitat (Nisbet *et al.*, 1989; Osenberg *et al.*, 1994; Galarowicz *et al.*, 2006).

Largemouth bass is most commonly found in shallow lakes and rivers (Wheeler, 1978). Since largemouth bass can inhabit both lotic and lentic freshwater ecosystems, we expect that the habitat types interpreted by presence of potential prey may have influence on ontogenetic diet shift pattern of the species. Relatively few studies have been conducted to compare the diet of largemouth bass between lotic and lentic freshwater ecosystems (Ko *et al.*, 2008) and dietary studies of the species in its new habitats outside North America are scarce (Garcia-Berthou, 2002).

In the current study, we hypothesised that the difference in potential prey items with respect to types of habitat could influence the ontogenetic diet shift pattern

of largemouth bass in the new habitats. We compared diet of largemouth bass and its potential prey items between the Nakdong River main channel and its associated Upo Wetlands tributary ecosystems. The Nakdong River lies within the south-eastern corner of Korean Peninsula (35-37°N; 127-129°E). Four multi-purpose dams and one estuarine barrage regulate river flow, resulting in eutrophication (Ha *et al.*, 1998; Jeong *et al.*, 2007; Kim *et al.*, 2007). The riverbed consists primarily of sand and the riparian zone possesses low vegetative diversity (Jang *et al.*, 2001). The Upo Wetlands is connected to the main channel of the Nakdong River. In the Upo Wetlands, the riparian zone has high vegetative diversity (Kim *et al.*, 2004).

## Materials and methods

### Study sites and sampling

Fish samples (*M. salmoides*) were collected with castnets (mesh size 7×7 mm), scoopnets (mesh size 5×5 mm) and a fixed shore net (mesh size 10×10 mm) from the study sites, Nakdong River and Upo Wetlands (Fig. 1). All fish specimens were identified and classified according to Kim and Park (2002) and Nelson (1994). The fixed shore net was set for 24 h and the cast nets were used 20 times at each site. All the sites were sampled four times between May and November in 2008, typically once every two months.

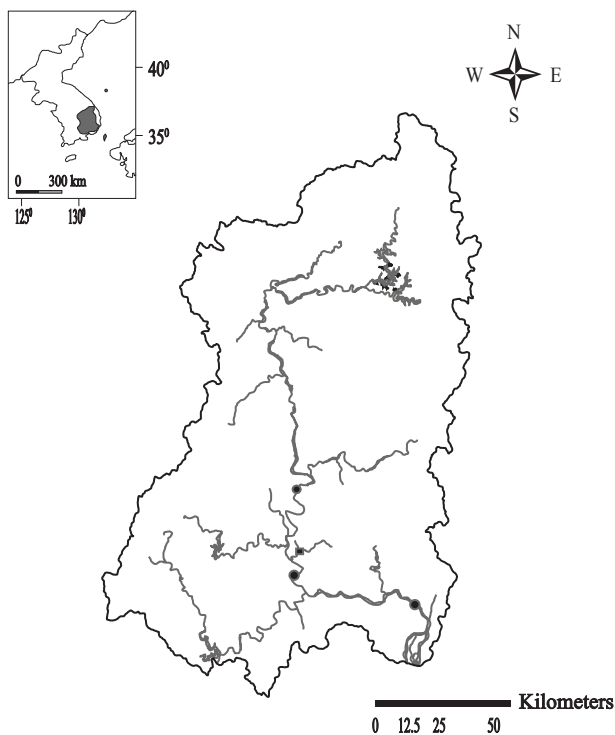


Fig. 1. Map of the study sites (Circles: Nakdong River; Square: Upo Wetlands)

### Dietary analysis

The collected fishes were anaesthetised with 0.1 g l<sup>-1</sup> ethyl 3-aminobenzoate methanesulfonate salt (Sigma-Aldrich), before examination. The total length in mm and weight in g were measured immediately and then their guts collected for stomach content analysis. Stomachs were preserved in 70% ethanol before analysis. Dietary samples from 158 largemouth bass (83 from the Nakdong River, 75 from the Upo Wetlands) were examined under a microscope (Zeiss, Stemi 1000) at magnifications of x20 to x100. The prey items were sorted to the family or order levels and enumerated. In addition, they were weighed to the nearest 0.01 mg after removing excess moisture.

### Data analyses

The diversity of potential prey items and consumed diets between two study sites were analysed using Shannon-Weaver index ( $H'$ ). Difference in species composition between the sites, index calculation and statistical analysis (student *t*-test) were performed using the PAST program (Hammer *et al.*, 2001). We performed literature survey to collect order level of potential prey invertebrates (Ministry of Environment, 2008), to compare the distribution pattern with diet consumption pattern. Potential prey items were grouped in accordance with habitat use type following Almeida *et al.* (2012) as: (i) water-column invertebrates, (ii) benthic invertebrates, (iii) water-column fishes and (iv) benthic fishes.

The index of relative importance (IRI, Pinkas *et al.*, 1971) was applied to identify the contribution of each prey item to individual largemouth bass which was calculated using the following equation:

$$IRI = (N_i + W_i) \times F_i$$

where  $N_i$  is the percentage by number of the  $i^{\text{th}}$  taxon,  $W_i$  is the percentage by weight of the  $i^{\text{th}}$  taxon, and  $F_i$  is the percentage frequency of occurrence of the  $i^{\text{th}}$  taxon.

Feeding strategy was analysed according to Amundsen *et al.* (1996), modified from Costello (1990), to interpret data in terms of generalist and specialist feeding. The prey-specific abundance is given by the formula:

$$F_i = (N_i/N) \times 100$$

$$P_i = (\sum S_i / \sum S_{ii}) \times 100$$

where  $N_i$  is the number of predators with prey  $i$  in their stomach,  $N$  is the total number of predators with stomach contents,  $S_i$  is the stomach content (volume, weight, or number) composed of prey  $i$  and  $S_{ii}$  is the total stomach content of only those predators with prey  $i$  in their stomachs.

## Results and discussion

### Potential prey items

Data from the literature survey on invertebrate fauna in the Nakdong River and Upo Wetlands showed different species composition (Table 1). The first and second most common invertebrate orders in the Nakdong River were Diptera and Archiologochaeta, respectively, followed by Hemiptera and Ephemeroptera. Comparatively, in Upo Wetlands, Hemiptera and Odonata were the first and second most common orders, respectively. Fish fauna of the two ecosystems based on field monitoring, showed that species composition differed as expected. The first and second most common species in the Nakdong River were largemouth bass and the Korean piscivorous chub *Opsariichthys uncirostris amurensis*, respectively. In comparison, in Upo Wetlands, bluegill *Lepomis macrochirus* was the most common and largemouth bass

was the second most common fish. Notably, Gobiidae was the third most common family only in the Nakdong River.

### Diet composition

Among the 158 stomach samples, 7 empty stomachs were found (4.4%). The remaining 151 stomachs that contained prey items were used for the stomach content analysis. The gut contents of the stomach samples from the Nakdong River comprised mainly of fish by mass (85.9%) and IRI calculations provided similar results (*i.e.*, dominated by fish 68.2%). In the Upo Wetlands also fish were the most dominant prey item by mass (65.3%). However, with respect to IRI, the main prey item of largemouth bass was insect (78.5%; Table 2).

### Ontogenetic diet shift pattern in the two different types of habitats

The Costello method showed that largemouth bass adopted different feeding strategies depending on the

Table 1. List of potential food sources in the Nakdong River and Upo Wetlands

Invertebrates	NR (%)	UW (%)	HT	Fish	NR (%)	UW (%)	HT
Phylum Annelida				Phylum Chordata			
Class Hirudinea				Class Osteichthyes			
Arhynchobdellida	0.1	0.2	BT	* <i>Cyprinus carpio</i>	0.2	0.6	WT
Rhynchobdellida		0.3	BT	* <i>Carassius auratus</i>	8.4	3	WT
Class Oligochaeta				* <i>Acheilognathus lanceolatus</i>	4	<0.1	WT
Archiologochaeta	28.5	0.2	BT	* <i>Acanthorhodeus macropterus</i>	3.2		WT
Phylum Arthropoda				* <i>Pseudorasbora parva</i>	0.8	<0.1	WT
Class Crustacea				* <i>Pungtungia herzi</i>	0.8		WT
*Decapoda	<0.1	1.7	BT	* <i>Sarcocheilichthys variegates waktiyae</i>	2		WT
Isopoda		5.1	BT	** <i>Squalidus chankaensis tsuchigae</i>	8		WT
Class Insecta				* <i>Hemibarbus labeo</i>	10.8	0.6	WT
*Ephemeroptera	1	2.9	BT	* <i>Pseudogobio esocinus</i>	6.4		WT
*Odonata	<0.1	17.8	WT	** <i>Microphysogobio yaluensis</i>	0.2		WT
*Hemiptera	1.3	41.4	WT	* <i>Zacco platypus</i>	6.2		WT
*Diptera	69	9.7	BT	* <i>Opsariichthys uncirostris amurensis</i>	13.6	0.5	WT
*Trichoptera	<0.1	0.1	BT	* <i>Erythroculter erythropterus</i>	0.4	4.6	WT
*Coleoptera	<0.1	5.5	WT	* <i>Culter brevicauda</i>		0.3	WT
Phylum Mollusca				** <i>Hemiculter eigenmanni</i>		3.1	WT
Class Gastropoda				* <i>Misgurnus anguillicaudatus</i>		0.9	BT
*Mesogastropoda	<0.1	4.6	BT	* <i>M. mizolepis</i>		<0.1	BT
*Basommatophora		9.9	BT	** <i>Cobitis hankugensis</i>	0.8		BT
Class Bivalvia				* <i>Pseudobagrus fulvidraco</i>		0.1	WT
*Mytiloidea		0.2	BT	* <i>Mugil cephalus</i>	0.2		WT
*Unionida		0.1	BT	* <i>Monopterus albus</i>		0.1	BT
*Veneroidea		0.2	BT	* <i>Siniperca herzeri</i>	0.2		WT
				*▲ <i>Lepomis macrochirus</i>	5.8	73.6	WT
				*▲ <i>Micropterus salmoides</i>	18.8	12.3	WT
				* <i>Rhinogobius brunneus</i>	4.2		BT
				* <i>Tridentiger bifasciatus</i>	5.2		BT
				* <i>Channa argus</i>		<0.1	WT
Number of species	10	16		Number of species	21	16	

NR: Nakdong River; UW: Upo Wetlands; RA: Relative abundance %; HT: Habitat use type; WT: Water-column type; BT: Benthic type; \*\*: Korean endemicspecies; ▲: Exotic species; \*: Potential food sources referred by Ko *et al.* (2008)

Table 2. Results of stomach content analysis of *Micropterus salmoides* from the Nakdong River and Upo Wetlands

Prey organisms	NR				UW			
	Prey no.	Prey no. %	Prey weight %	IRI (%)	Prey no.	Prey no. %	Prey weight %	IRI (%)
Plantae	3	0.5	0.2	0.1	4	0.3	0.8	0.1
Animalia								
Phylum Annelida								
Class Hirudinea					3	0.2	0.5	<0.1
Class Oligochaeta					1	0.1	0.1	<0.1
Phylum Arthropoda								
Class Crustacea								
Decapoda	39	6.7	9.5	18.9	3	0.2	0.7	0.1
Branchiopoda	323	55.4	0.1	8.5	548	35.3	2.3	14.5
Class Insecta								
Ephemeroptera	50	8.6	0.8	2.4	105	6.8	12.3	16.1
Odonata (adult)	8	1.4	1.3	0.5	14	0.9	2.5	0.5
Hemiptera	3	0.5	0.9	0.3	571	36.8	7.5	42.1
Diptera	34	5.8	0.4	1.3	264	17.0	4.9	19.7
Trichoptera					8	0.5	0.3	0.1
Phylum Chordata								
Class Osteichthyes								
Cypriniformes								
Cyprinidae	29	5.0	11.1	8.2	3	0.2	11.4	0.9
Cobitidae	1	0.2	3.8	0.2				
Perciformes								
Centrarchidae	14	2.4	3.1	0.6	7	0.5	52.2	4.1
Gobiidae	49	8.4	46.3	50.1				
Channidae	1	0.2	15.5	0.8				
Unidentified fish	15	2.6	5.9	6.0	3	0.2	1.7	0.1
Fish egg	1	0.2	0.2	<0.1				
Unidentified particles	13	2.2	1.0	2.2	19	1.2	2.9	1.7
Total	583	100	100	100	1553	100	100	100

NR: Nakdong River; UW: Upo Wetlands

size class. This was clear when stomach contents were compared based on habitat differences. In the Nakdong River, small largemouth bass (<100 mm) preferred to consume Decapods, while those larger than 100 mm in body length (*i.e.* 100-149, 150-199 and over 200 mm) exhibited a clear specialisation for fish. Decapods were the second most common prey item in the intermediate-sized predator individuals (*i.e.* 100-149 and 150-199 mm, Fig. 2a); whereas, the size of specialisation for fish was larger in the wetland. Individuals smaller than 100 mm preferred mayflies, while fish consumption was apparent when the predators were over 200 mm. The 100-149 and 150-199 mm size classes were characterised by mixed feeding strategies between specialisation and generalisation (Fig. 2b).

#### *Ontogenetic diet specialisation in selecting fish as main prey item*

The results of this study showed different pattern of ontogenetic diet specialisation in selecting fish as main prey item in accordance with type of habitat. Especially,

we observed delay of ontogenetic diet shift in the wetland habitat. Previously, the only two non-native regions where this difference in diet shift has been observed are South Africa and Spain (Hickley *et al.*, 1994; Garcia-Berthou, 2002; Wasserman *et al.*, 2011). In South Africa, largemouth bass utilised invertebrate prey at low fish prey abundances (Hickley *et al.*, 1994) and therefore, fed opportunistically on migrant fish when these were available (Wasserman *et al.*, 2011). In Spain, Garcia-Berthou (2002) gave an explanation that predation on crayfish instead of fish probably implies a change to a more benthic microhabitat and different foraging behaviour.

Upo Wetlands had more of potential invertebrate prey items than potential fish prey items (Table 3). However, in the Nakdong River, we found that the diet shift pattern based on size classes was similar to that in North America (Post, 2003). Jang *et al.* (2006) studied the diet of largemouth bass in South Korea and obtained similar results to the present study in Nakdong River.

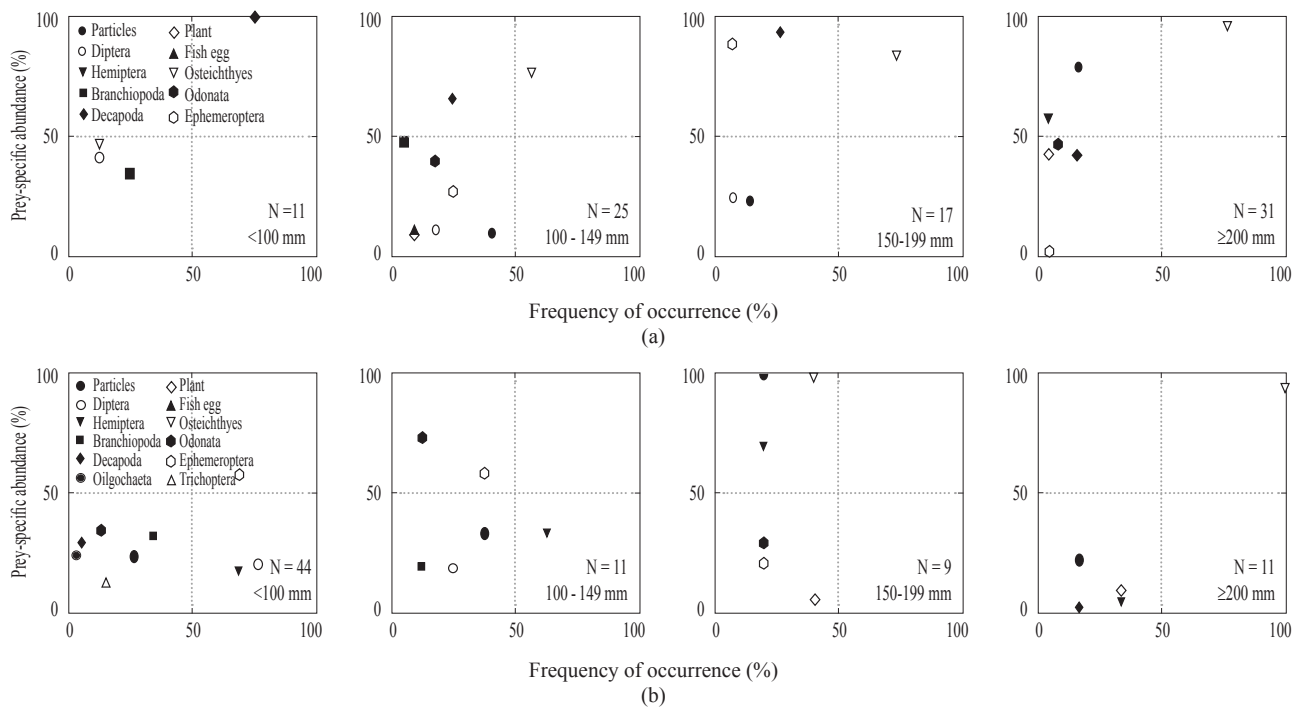


Fig. 2. Plots of feeding strategies for *Micropterus salmoides* on the basis of the Costello (1990) method modified by Amundsen *et al.* (1996) for (a) Nakdong River, (b) Upo Wetlands

The Nakdong River had a lower diversity of invertebrate prey than the Upo Wetlands, while the diversity of potential prey fish, including preferred prey fish like Gobiidae, was high in the river. In this regard, differences in the diversity between potential prey invertebrates and fish could be responsible for delay in the ontogenetic diet shift.

Gobiidae are generally regarded as one of the most vulnerable prey species to largemouth bass, likely second only to crayfish (Tsunoda *et al.*, 2010). Generally, crayfish are benthic invertebrates and one of the important prey species for largemouth bass in North America (Wheeler and Allen, 2003; Braun and Walser, 2011). According to the IRI values in this study, Gobiidae was the most important prey item in the Nakdong River (Table 2). In the Upo Wetlands, however, Gobiidae were absent. Benthic potential prey fishes also occurred in the Upo Wetlands (*i.e.*, *Misgurnus anguillicaudatus* Cantor 1842, *Misgurnus mizolepis* Gunther 1888 and *Monopterus albus* Zuiew 1793; Table 1). However, the burrowing

behaviour of these species would pose difficulty for largemouth bass to consume. Therefore, the habitat use (*e.g.* benthic or water-column) of the prey is also important for largemouth bass in selecting their prey items. These situations provide evidence for the hypothesis that different habitat types, including potential prey items, influence the pattern of specialisation on fish in largemouth bass.

The results of this study suggest possible approaches to the management of largemouth bass populations in order to minimise their impact on the native species in the two different types of habitat. When largemouth bass is introduced to an ecosystem having relatively low diversity of potential prey items, such as Nakdong River main channel, largemouth bass individuals over 100 mm total length need to be considered. Whereas, large sized largemouth bass (*i.e.* over 200 mm total length) are suitable for ecosystems having high diversity of potential prey items as in Upo Wetlands. The diversity of potential

Table 3. Shannon-Weaver index (*H'*) for potential food source and diet items

		NR	UW	
Potential food source items	Invertebrate	0.69	1.66	t = -8.0629, df = 170.74, p<0.001
	Fish	2.34	0.79	t = 12.194, df = 153.55, p<0.001
Diet items in gut contents of largemouth bass	Invertebrate	0.99	1.32	t = -6.3193, df = 597.8, p<0.001
	Fish	1.54	1.04	t = 3.2878, df = 49.814, p<0.005

NR: Nakdong River; UW: Upo Wetlands

prey items as well as habitat use type of potential prey items were identified as important aspects contributing to diet shifts in largemouth bass.

Elimination of individual largemouth bass should be based on the observed patterns of population dynamics and juvenile removal is fundamental to population management. Nevertheless, decision makers should be concerned about types of new habitat ecosystems to control introduced exotic species, when more effective conservation is possible. Additional experimental studies, extended over every types of habitat, are necessary to develop a firm management strategy.

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