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# Analysis of Prey of Mandarin Fish and Large Mouth Bass and Distribution of Fish Population in Lake Paro, Korea[1a]

**Jaeyong Lee[2], Kwang yeol Lee[3], Sungchul Park[3], Jaeseok Choi[3], Hong gi Jang[2], Joon Chul Kim[4*]**

## ABSTRACT

We quantified temporal and spatial changes in the habitat for fish populations, the distribution of mandarin fish(*Siniperca scherzeri*) and an introduced species, largemouth bass(*Micropterus salmoides*) in Lake Paro and inflowing streams. The number of fish species identified in Lake Paro and the tributary streams included 10 families, 24 species and 10 families 30 species, respectively. The dominant fish species in Lake Paro were *Zacco platypus*, *Hemibarbus labeo*, *Squalidus gracilis majimae*, *S. scherzeri* and *Tridentiger brevispinis*, *Z. platypus*, *Z. koreanus*, and *S. gracilis majimae* in the inflowing streams. Although the habitat segregation for *S. scherzeri* and *M. salmoides* occurs, these two species showed the use of the fishes of the family Gobiidae as an important prey item based on IRI analysis. *S. scherzeri* and *M. salmoides* preyed mainly on *T. brevispinis*(67.4 %) and *R. brunneus*(84.0 %), respectively. The species preyed on by *S. scherzeri* and *M. salmoides* were benthic fishes that inhabit shallow water depths around the lake and have little swimming ability.

***KEY WORDS: INTRODUCED SPECIES, BENTHIC FISHES, HABITAT SEGREGATION, IRI***

## INTRODUCTION

Inland fishery resources are not only taxonomic groups in the upper trophic position to assess the health of water quality environments in the aquatic ecosystem (Drenner and Hambright, 2002), but also play an important role as food resources for humans (Byström *et al*., 2007). Inland fishery resources are an important major financial resource for fishermen and communities based on fishing. Together with the increased leisure activity time in inland waters resulting from the increase of national income and diversification of processed foods that came with a change in dietary habits, as well as new material development discovered in the fishery resources, inland fishery resources contain boundless potential to make strategic plans to promote the local and national economy.

The ecological understanding of inland waters in Korea begins with the evaluation of healthiness using organisms in aquatic ecosystems (attached algae, benthic macro-invertebrates, fish) in policies focusing on the aquatic environment with the establishment of the 'Act on Water Quality and Aquatic Ecosystem Conservation' in 2014. Local government with rich water resources and natural environments have potentially high value in terms of ecological education, economy and social/cultural aspects

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2 Environmental Technological Institute, Nature and Human Co. Ltd., Wonju 220-937, Korea
3 Research Center for Fish, Environmental Research Institute, Kangwon National University, Chuncheon 200-701, Korea
4 Dept. of Biological Science, Kangwon National Univ., Chuncheon 200-701, Korea
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* Corresponding author:Tel: +82-33-250-8526, Fax: +82-33-259-5665, E-mail: jckim@kangwon.ac.kr

through conservation and utilization of inland fishery resources. However, some areas are suffering from a drop in bio-diversity resulting from the introduction of non-native species that lead to a change in fish distribution of the aquatic ecosystem, a change in water quality, and a drop in endemic species (Drenner and Hambright, 2002; Trumpickas *et al*., 2011).

In case of Korea, the introduction of non-native species was made by the United States and Japan in the 1960s and 1970s. Non-native species were introduced as alternatives for protein sources in relation to the health of the people. However, these introduced species ended up causing severe disturbance in Korea's aquatic ecosystem mainly by the eurythermal fish that have fast growth and reproduction compared to Korea's fish fauna resources (Kamerath *et al*., 2008; Trumpickas *et al*., 2011). Introduced species such as bass (*M. salmoides*) and bluegill (*Lepomis macrochirus*) are reported to prey on Korean native species and aquatic organisms (benthic macro-invertebrates, fish, reptiles, algae, etc) (Lee *et al*., 2013; Jang *et al*., 2006; García-Berthou, 2002). García-Berthou (2002) observed the change of food sources with growth in different aquatic environments when introducing *M. salmoides* that inhabits North America. Lee *et al*. (2013) studied the preying characteristics of fish communities in the Gyeongancheon estuary area, which is a tributary of Lake Paldang and observed that 150-450 ㎜ *M. salmoides* normally fed on other fish. Jang *et al*. (2006) stated that in the case of *M. salmoides* of over 100 mm, it showed considerable predator abilities on the larva of indigenous species and that in areas *M. salmoides* inhabit, the quantity of endemic species and fish species that *M. salmoides* feed on are relatively lower. Moreover, *M. salmoides* takes an ontogenic shift that changes food sources depending on its size (or growth, and in particular, 100-225 ㎜ *M. salmoides* were found to prey mainly on shrimp, larva and insects (García-Berthou, 2002). Likewise, as *M. salmoides* displays food preying habits depending on the local food environment, it causes an imbalance of the food chain in aquatic ecosystems (Vander Zanden *et al*., 2004).

According to the Ministry of Environment (http://www.me.go.kr), there are a total of 147 introduced fish species that were introduced in Korea and there are four introduced fish species that reproduce in the ecosystem such as *Cyprinus carpio*, *Carassius cuvieri*, *M. salmoides* and *L. macrochirus*. Among them, *L. macrochirus* and *M. salmoides* are categorized as grade 1 wild animals that disturb the ecosystem.

It is expected that unless the indiscriminate discharge of introduced species and the overfishing of predatory fish species (*Siniperca scherzeri*) can keep in check the proliferation of introduced species, the disturbance of the ecosystem will only accelerate.

As part of a basic study to provide plans to reduce the number of *M. salmoides*, which is a wild organism that disturbs the ecosystem, this study aimed at identifying each fish community within Lake Paro and its tributaries. In particular, it identified the status of habitat distribution of endemic fish species, which are important fish fauna genetic resources of Lake Paro, as well as *S. scherzeri* and *M. salmoides*, which is a wild organism that disturbs the ecosystem. Meanwhile, though there are many reports among foreign and domestic research (Jang *et al*., 2006; Pen *et al*., 1993) related to the dietary analysis of introduced species *M. salmoides*, there are very few research results on the dietary analysis of *S. scherzeri,* which is a major economical fish species in Korea. This study aimed at proving the hypothesis that "piscivorous fish species preferentially prey on fish species with poor swimming abilities" while also predicting the habitat environment of the two predatory fish species in Lake Paro through dietary analyses. It is expected that such research will be used as basic information for plans to reduce the number of non-native species in Lake Paro, while providing grounds for the need to conserve indigenous species, efficient breeding of the economic fish species of *S. scherzeri* and to explain the necessity of expanding the habitat for *S. scherzeri*.

## MATERIALS AND METHODS

### 1. Study Area

Lake Paro was made through the first dam constructed in the North Han River system that began in 1939 and ended in 1944. The total drainage area is 38.9 ㎢ and the pondage is approximately 1.018 billion tons. Lake Paro maintained a stable water environment up until 1987 and during this period, it became well known as the biggest habitat for *Siniperca scherzeri*. However, it displayed unstable aquatic ecosystems during the course of draining the lake two times (1987, 2002) for the construction of the Peace Dam (Figure 1). The only studies on fish fauna for Lake Paro and the surrounding areas include the study on fish fauna by Choi (1986) in Gandong-myeon and Hwacheon-eub of Hwacheon-gun and Yanggu-eub of Yanggu-gun, where Lake Paro is located, and the comprehensive survey within Lake Paro and its tributaries by Choi *et al*. (2004). Recently, Ahn *et al*. (2014) mentioned changes in fish communities following the generation of wetlands in relation to the restoration of the ecosystem in Yanggu-eub, which is upstream of Lake Paro.

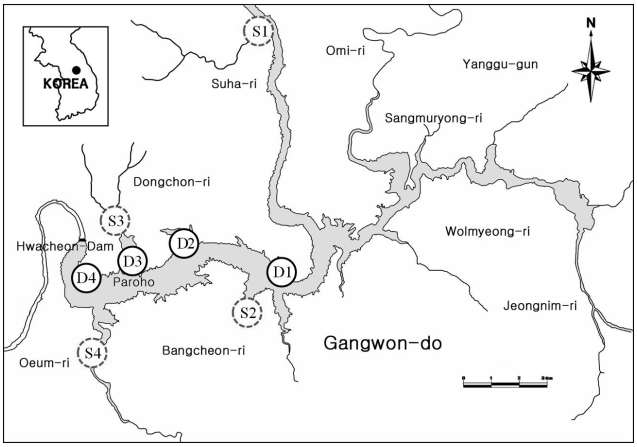


Figure 1. Map of Lake Paro with location of the sampling sites. Closed circles and dashed circles indicate Lake Paro and inflowing stream sites, respectively

## 2. Water Quality Survey

In order to identify the water quality status of the habitat environment of fish and to understand its distribution, water temperature, electric conductivity (YSI-33), dissolved oxygen concentration (YSI-85), and hydrogen ion concentrations (DENVER model 15) were measured on site as water quality items.

## 3. Fish Community Survey

Surveys on fish were carried out a total of three times (May, July, October) by selecting four sites on the inside of the lake and tributary, and the biomass, and length were measured for each individual fish species. The collection of fish was done using a casting net (mesh 6×6 ㎜) and a kicking net (mesh 5×5 ㎜), and in the spots within the lake, fyke nets (5×5 ㎜, 20×20 ㎜) and gill nets (12×12 ㎜, 40×40 ㎜) were used as tools to catch the fish. Meanwhile, the collected fish were fixed in 10 % formalin solution on site and identified and classified in a lab. In order to identify the growth (length-weight relationship) and obesity (condition factor) of *S. scherzeri* and *M. salmoides*, length and wet weight were measured (Froese, 2006; Anderson and Gutreuter, 1983; Anderson and Neumann, 1996).

Search charts and illustrated books published in Korea (Kim and Park, 2002; Kim *et al*., 2005) were used for the identification of the fish, and a classification system was prepared in accordance with Nelson (2006).

## 4. Dietary Analysis of *S. scherzeri* and *M. salmoides*

Dietary analysis analyzed the above content of the major fish species of *S. scherzeri* and *M. salmoides* to reveal the types of food they eat to use as preliminary data for predicting the ecological position and food activity locations. The above contents were checked visually by placing each individual on a petri dish or identified using a dissection microscope. When it was digested and difficult to identify, it was indicated as 'not identified'. Food organisms that could be identified after some digestion was done, size was measured by type and the number was summed up, and then a digital scale was used to measure the wet weight up to 0.1 ㎎ units. The results of analyzing the above contents were shown as the occurrence frequency (%F) of each food organism, the ration of the number of individuals (%N), and the ratio of wet weight (%W), and the index of relative importance (IRI) of food organisms were calculated using the formula by Pinkas *et al*. (1971).

# RESULTS

## 1. Environmental Factors

The range of water temperature at the survey points within the dam were 20.4～21.3 ℃, 25.9～26.3 ℃ and 18.6～18.8 ℃ in May, July and October, respectively, and

Table 1. Temporal and spatial chemical parameters in Lake Paro and its tributaries in 2014

| | In lake | | | Tributaries | | |
|---|---|---|---|---|---|---|
| | MAY | JUL | OCT | MAY | JUL | OCT |
| Water temperature(℃) | 20.8±0.5 | 26.2±0.2 | 18.7±0.1 | 20.7±2.8 | 24.6±3.4 | 16,1±3.5 |
| pH | 8.4±0.1 | 8.4±0.1 | 7.6±0.1 | 7.9±0.6 | 8.1±0.6 | 7.4±0.2 |
| Conductivity(μS·cm$^{-1}$) | 113±2.6 | 122±1.9 | 121±0.5 | 111±36.6 | 120±43.2 | 121±27.0 |
| Turbidity(NTU) | - | 1.6±0.2 | 1.4±0.4 | 5.0±3.2 | - | 1.8±1.6 |

the survey points in the tributary were 17.7～24.5 ℃, 21.0～29.1 ℃, and 13.0～19.8 ℃ (Table 1). There was a difference of 3～6 ℃ between the points in the tributaries. There was no big difference in the pH between the inside of the lake and in the tributaries, and the range was 7.3～8.7, 7.4～8.8, and 7.2～7.4 in May, July and October, respectively. Conductivity within the lake was 109～124 μ S·㎝$^{-1}$, and in the tributary it was 61～170 μ S·㎝$^{-1}$, showing a larger range of fluctuation in the tributary than in the lake. Turbidity showed ranges of 0.10～8.14 NTU (Table 1).

## 2. Seasonal Changes of Fish Communities

In this study, a total of 6,911 fish hailing from 35 species of 10 families were collected. Fish distributed within the lake totalled 2,897 among 24 species of ten families. In the survey in May, 1,237 fish of 17 species in six families, 710 fish of 13 species in five families in July, and 950 fish of 12 species in five families were found in the October survey (Figure 2). Fish distributed in the tributaries of Lake Paro numbered 4,014 among 30 species of ten families. In the survey in May, 1,444 fish of 20 species in seven families, 1,712 fish of 22 species in five families in July, and 858 fish of 14 species in five families were found in the October survey (Figure 2). The fluctuation of fish species and numbers according to seasons were similar for both within the lake and tributary, and it displayed a reverse correlation between the inside of the lake and tributaries (P<0.01).

In this study, the relative comparative abundance of the number of individuals by fish species within fish communities was high for fish in the Cyprinidae family within the lake, while in addition to the Cyprinidae family, the Gobiidae family showed a high relative abundance in the tributaries

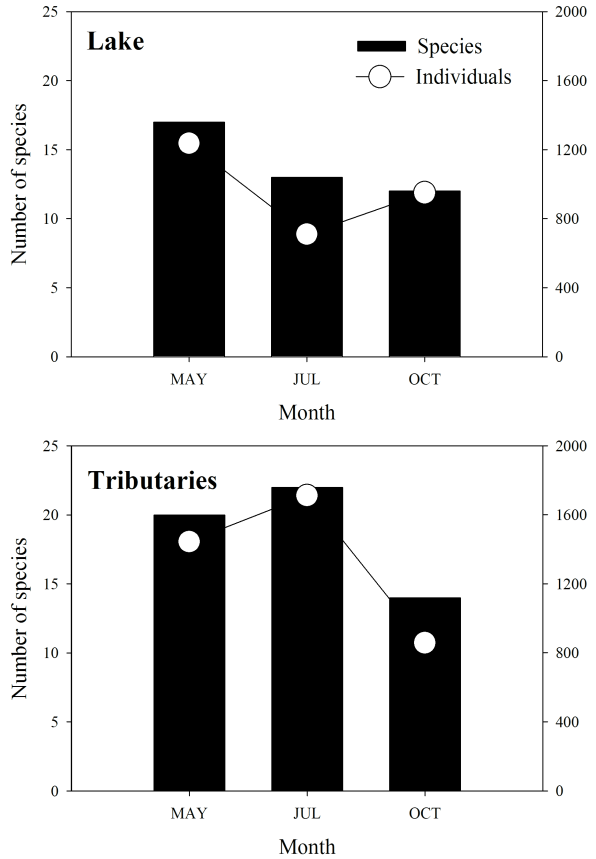


Figure 2. Seasonal changes in the number of individuals and fish species in Lake Paro and inflowing streams

(Figure 3). The relative abundance for the number of fish by species that appeared in the lake was *Z. platypus* (84.5 %), *S. gracilis majimae* (42.2 %), and *Z. platypus* (86.6 %) in May, July and October, respectively. In tributaries, *Tridentiger brevispinis* (42.4 %) showed the highest relative abundance in the May survey, while in July and October, *Z. platypus* (53.2 %) and *Z. koreanus* (30.8 %)

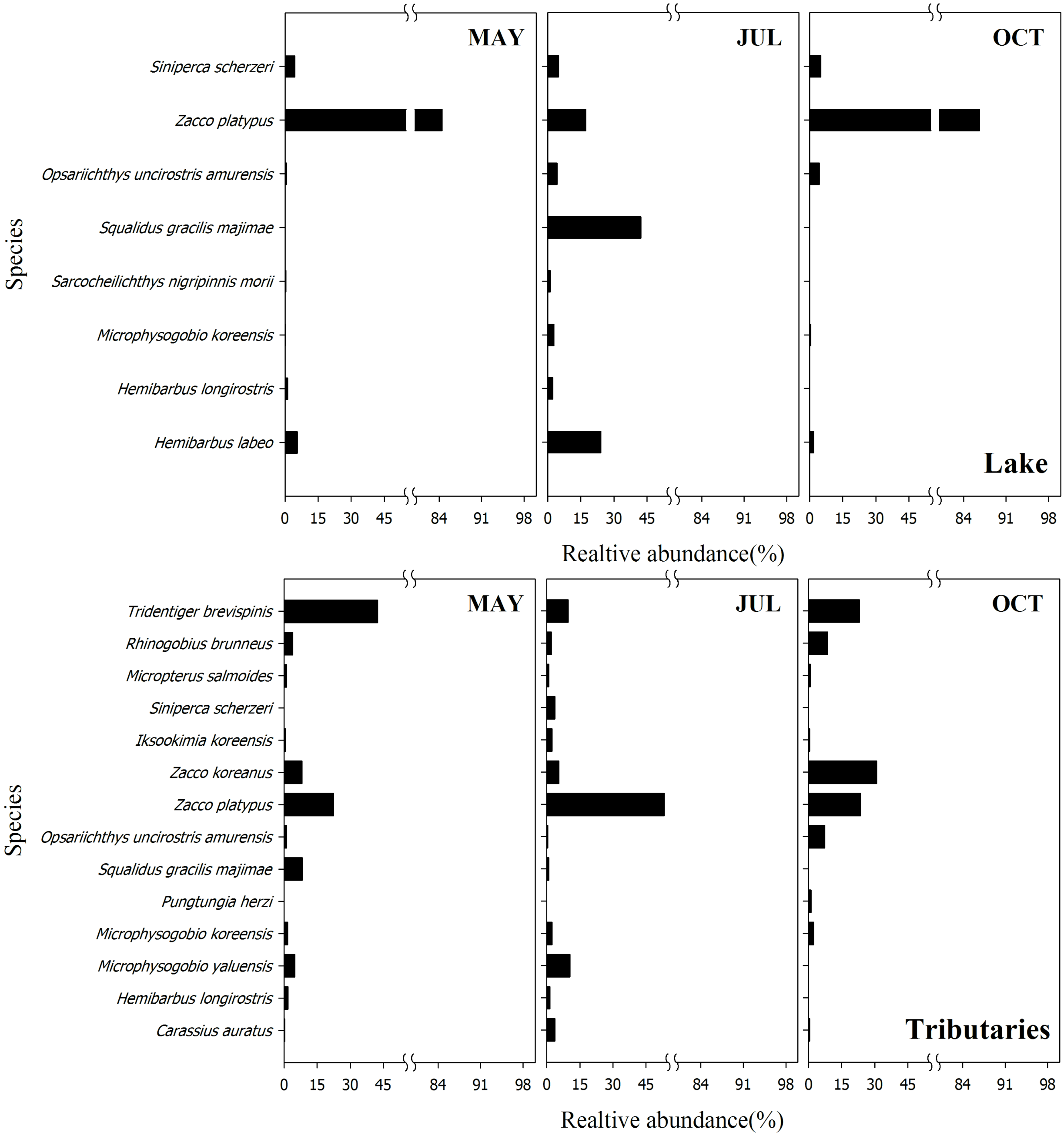


Figure 3. Relative abundance (%) of fish species in Lake Paro and inflowing streams

showed a high relative abundance, respectively. *M. salmoides*, an ecological disturbance organism designated by the Ministry of Environment, was not found within the lake in the May survey, and showed low relative abundance at 0.2 % and 0.1 % in the July and October surveys. Meanwhile, in tributaries 18 (1.3 %), 19 (1.1 %) and 7 (0.8 %) appeared in the May, July and October surveys, respectively.

### 3. Dietary Analysis

In this study, *S. scherzeri* at sizes of 142～505 ㎜ (269.0±67.8 ㎜) were found during the survey period, and in the case of *M. salmoides*, 41～438 ㎜ (166.5±79.2 ㎜)

Table 2. Stomach contents and IRI of *S. scherzeri* and *M. salmoides*. IRI abbreviates Index of relative importance

| Species and Size | Stomach contents | MAY | JUL | OCT | IRI (%) |
|---|---|---|---|---|---|
| *S. scherzeri* (142～505 ㎜, 269.0±67.8 ㎜) | *T. brevispinis* | 19 | 4 | 2 | 67.4 |
| | *Z. platypus* | - | 1 | - | 0.6 |
| | *O.uncirostris amurensis* | - | - | 1 | 0.9 |
| | *S. gracilis majimae* | - | 1 | - | 0.2 |
| | Crustacea | 3 | 1 | 3 | 7.1 |
| | Unidentified items | 14 | 3 | 3 | 23.8 |
| | Number of individuals (Empty) | 15(5) | 17(10) | 15(9) | 100.0 |
| *M. salmoides* (41～438 ㎜, 166.5±79.2 ㎜) | *T. brevispinis* | - | 1 | - | 2.7 |
| | *Z. platypus* | - | 1 | 1 | 3.3 |
| | *R. brunneus* | - | 7 | 6 | 84.0 |
| | Unidentified items | - | 3 | - | 10.0 |
| | Number of individuals (Empty) | - | 6(1) | 3(1) | 100.0 |

fish were collected (Table 2). Common food for *S. scherzeri* and *M. salmoides* were *Z. platypus* of the Cyprinidae family and *T. brevispinis* of the Gobiidae family. However, there was a clear difference in the main food sources. *S. scherzeri* and *M. salmoides* were found to prey on *T. brevispinis* (64 %) and *Rhinogobius brunneus* (84 %), respectively (Table 2). *S. scherzeri* was found to additionally prey on *S. gracilis majimae* of the Cyprinidae family and *Opsariichthys uncirostris amurensis*, as well as shrimp.

## 4. Habitat Distribution of Fish Communities

Korean native species (30.3 %) that appeared in this study were Acheilognathus gracilis, Acheilognathus yamatsutae, Coreoleuciscus splendidus, Sarcocheilichthys nigripinnis morii, S. gracilis majimae, Hemibarbus mylodon, Microphysogobio yaluensis, Microphysogobio longidorsalis, Rhynchocypris

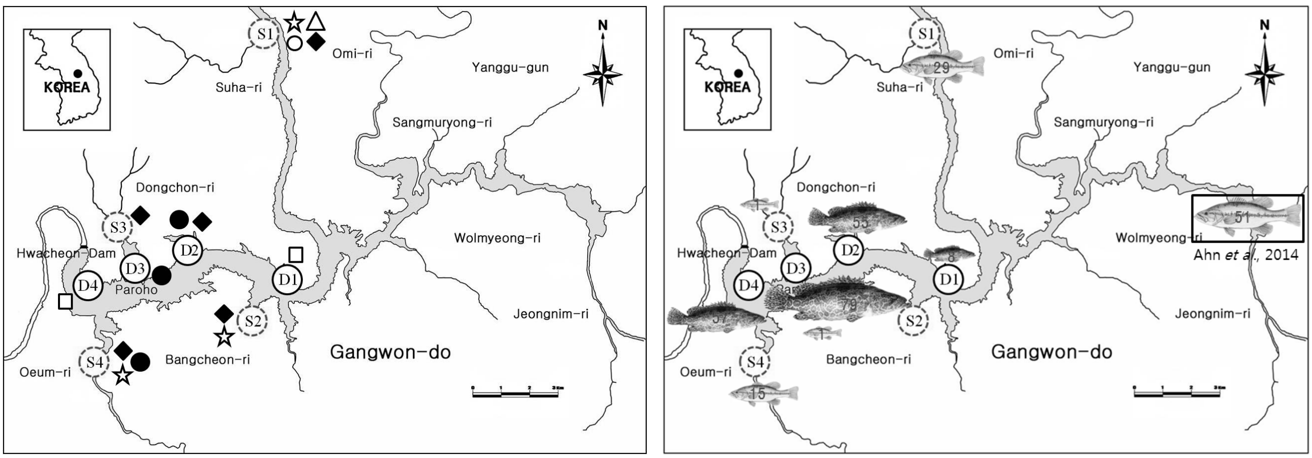


Figure 4. Distribution of native fish species (upper panel) and *S. scherzeri* and *M. salmoides* (lower panel) around Lake Paro. Symbols indicate sites where native species occurred: ◆ *Z. koreanus*, *I. koreensis*, △ *A. gracilis*, *A. yamatsutae*, *H. mylodon*, ○ *C. splendidus*, *M. longidorsalis*, *R. kumgangensis*, □ *S. nigripinnis morii*, ● *S. gracilis majimae* and ☆; *M. yaluensis*. The number of individuals of largemouth bass (*M. salmoides*) in Yanggu-eup area is from the Ahn *et al*. (2014)

Table 3. Seasonal variation of length-weight relationship and condition factor among fish species

| Species | Length-weight relationship | | | Condition factor | | |
|---|---|---|---|---|---|---|
| | MAY | JUL | OCT | MAY | JUL | OCT |
| *S. scherzeri* | 3.33 | 3.13 | 3.03 | 0.0005 | 0.0007 | 0.0001 |
| *M. salmoides* | 3.11 | 2.94 | 2.12 | 0.0027 | -0.0007 | -0.0036 |
| *Z. platypus* | 2.85 | 2.79 | 3.08 | -0.0015 | -0.0023 | 0.0010 |
| *O. uncirostris amurensis* | 3.21 | 3.11 | 3.07 | 0.0010 | 0.0004 | 0.0006 |
| *T. brevispinis* | 2.52 | 2.66 | 2.89 | -0.0165 | -0.0115 | -0.0033 |
| *R. brunneus* | 3.10 | 2.06 | 2.82 | 0.0024 | -0.0441 | -0.0074 |

kumgangensis, Z. koreanus, and Iksookimia koreensis for a total of 11 species, and among them, natural monument (no. 259), H. mylodon was collected only at the S1 point (Figure 4).

Four non-native species, such as *C. carpio* (Israeli type), *C. cuvieri*, *M. salmoides* and *L. macrochirus* were found, and the number of species that appeared by period showed dominance rates of 11.5～12.0 %.

*S. scherzeri* is normally distributed within the lake and they normally inhabit points near the dam. Meanwhile, *M. salmoides* normally appears in the stagnant waters of the estuary where Lake Paro and the tributaries (S1, S4) meet. Therefore, the habitation of *S. scherzeri* and *M. salmoides* was clearly separated (Figure 4).

### 5. Growth Rate and Obesity Analysis

Table 3 shows the growth rate and obesity of predatory fish species and their food organisms. By identifying the slope of the growth rate and obesity of *S. scherzeri* and *M. salmoides*, it is possible to predict the food and habitat environment of two species with similar ecological positions. In Lake Paro, the condition factor of growth rate of *S. scherzeri* in May, July and October were +3.110, +3.130 and +3.026, respectively, and they showed a state of stable growth (Table 3). Meanwhile, the condition factor of *M. salmoides* in May was +3.331, showing good growth, but in July and October they were -2.907 and -2.115, and thus, it was found that the habitat environment and food environment conditions were not very good (Table 3). In the case of food organisms, compared to planktonic fish species (*Z. platypus*, *O. uncirostris amurensis*), the growth rate of benthic fish species (*T. brevispinis*, *R. brunneus*) was lower, and obesity was also found to have a negative value (Table 3).

## DISCUSSION

Fluctuations of fish communities in artificial lakes display temporal and spatial changes. In particular, it is related to the environmental changes of habitats and the distribution of non-native species (Pen *et al*., 1993; Jang *et al*., 2006; Lee *et al*., 2013). Furthermore, artificial lakes in Korea show large fluctuations in water levels depending on changes in the climatic environment or the season, so the connection between the lake and tributaries may have an impact on the distribution of fish communities (Kim *et al*., 2000; Ahn *et al*., 2014).

Fluctuation and distribution according to the season for fish communities showed clear differences among fish species that used the lake or tributaries as their habitat (Figure 2).

In case of *Z. platypus*, according to the relative abundance according to the number of individuals, it is distributed within the lake in May, but after spawning in July, it grows in tributaries, and then returns back to the lake in October (Figure 3). This is judged to be due to the movement among habitats for spawning and the growth of fish species in their life cycles.

In particular, in the Korean lentic ecosystem, a longitudinal connection with tributaries is judged to be related to the distribution of various endemic fish species. In this study, a total of eleven (30.3 %) indigenous species were confirmed (Figure 4) and it is actually higher than the rate of Korean native species of 25.9 % (Kim, 1995). In this study, the distribution of indigenous fish species were in the Lake Paro tributaries and surrounding areas, and it was found that in addition to *S. nigripinnis morii*, ten indigenous fish species were distributed focusing on S1 (app. 91 %). S1 was known to be a habitat for *Brachymystax lenok tsinlingensis* (natural monument) and *H. mylodon* (natural monument) in the past, but in this study, only the habitation of *H. mylodon* was confirmed. However, S1 receives considerable impact from the fluctuation of water levels of Lake Paro and an old concrete bridge passes over the river, which can act to hinder the movement of fish. Moreover, the ecological disturbance fish species of *M. salmoides* frequently appeared in the S1 estuary (Figure 4). *M. salmoides* is also a cause for the considerable decrease in the numbers of indigenous fish species (Weidel *et al*., 2007). The dominance rate of indigenous species that appeared in Lake Paro was 34.4 % in 2003 and 35.0 % in 2006, and in this study, it was reduced slightly to 30.3 % (Choi *et al*., 2004). Meanwhile, the dominance rate of *Z. platypus* increased up to 86.6 % in this study compared to 78.7 % when first published by Choi *et al*. (2004) in the past.

In this study, the spatial distribution of *S. scherzeri* and *M. salmoides*, which display similar ecological status and preying properties, showed clear differences (Figure 4). Kim *et al*. (2013) reported that the distribution features of *M. salmoides* that inhabit medium to large artificial lakes in Korea do not depend on the water quality environment, but in fact are related to the physical habitat environment, available food quantity, and relations with competing organisms. In this study, *S. scherzeri* was usually distributed in the lake around the dam and in the case of *M. salmoides*, it displayed the geographical distribution features of inhabiting the embayment area of the lake, which is also the estuary or lentic part of the tributary (Figure 4). Among the points where a frequent appearance of *M. salmoides*, S4 forms a lentic area around the constructed dam by flowing into Lake Paro and passing the river. S1 also includes the sector where there is a pond at a depth of less than 2 m between Lake Paro and tributaries when the water level of Lake Paro rises. Both points have floating artificial structures and there are fallen trees or aquatic plants within and around the stream channel, and therefore, it is used as a habitat and hiding area for *M. salmoides* (Lyons, 1993; Sammons *et al*., 2003).

In this study, meanwhile, among the factors that determine the distribution features of *M. salmoides*, it is judged that the impact of water temperature is also important (Lyons, 1993). In this study, the water temperature in sites where *M. salmoides* appear falls in the range of 19.8 ℃～29.1 ℃ and compared to other sites where almost no *M. salmoides* appeared (within lake, 22.4±3.4 ℃; tributaries, 18.5±3.5 ℃), it was 2.8 ℃～6.3 ℃ higher (Lyons, 1993). When considering the fact that *M. salmoides* is usually found in higher temperatures than *S. scherzeri*, the difference of tolerance for water temperature between the two species is presumed to be an important factor for the two species to live in different habitats.

The gradual increase of water temperature due to changes in the climatic environment causes an increase of introduced fish species and can result in the localized extinction of indigenous fish species and cold water fish species in the aquatic ecosystem, as well as changes in the ecological status of indigenous species and a drop in numbers, while amplifying the effects on ecological disturbance (Vander Zanden *et al*., 2004; Eaton and Scheller, 1996; Kang *et al*., 2013). Among introduced species, in the case of *M. salmoides*, tolerance against water temperature is high and it is aggressive and tends to protect its eggs and larva, while also having a low death rate. Furthermore, *M. salmoides* grows to 50 % of its maximum size within three years after hatching (Rodriguez-Sánchez *et al*., 2009). As a result, the fast growth of *M. salmoides* and the lack of a competing indigenous fish species against the relatively newly non-native fish species can be the cause for the flourishing of introduced fish species in the lentic ecosystem. The distribution and spread of *M. salmoides* in Lake Paro became known in the last ten years, and up until 1986, there was a high appearance of the predatory fish species, *S. scherzeri*. Meanwhile, at this time, the appearance of *M. salmoides* was not yet confirmed. From 2002, however, *M. salmoides* was spotted and with the overfishing of *S. scherzeri*, the number of *M. salmoides* that accounted for 0.01 % and 0.03 % in 2003 and 2004, respectively, rapidly rose up to 3.03 % in 2005, while the dominance of *S. scherzeri* dwindled down to 0.03 % (Choi *et al*., 2004; Hwacheon-Gun, 2006).

Upon identifying the index of the relative importance

(IRI) of food organisms, *S. scherzeri* and *M. salmoides* did not show signs of overlapping food sources (Table 2). The main food sources of these two fish species were *R. brunneus* and *T. brevispinis*, and these are benthic fish species that live on the surface or floor of substrates such as inside the lake and the estuary of tributaries.

In this study, in addition to the clear separation of habitats between *S. scherzeri* and *M. salmoides*, it was also found that there was a difference in food sources. This is judged to be caused by *S. scherzeri* and *M. salmoides* being active in different habitats and feeding activities. While *M. salmoides* are usually captured in areas near stagnant rivers with a depth of less than 2 m, *S. scherzeri* are usually captured within lakes at a depth of more than 2 m. The major food organisms of these two fish species are *R. brunneus* and *T. brevispinis*, and they have different vertical distribution features. In the case of *R. brunneus*, it normally lives around the river, while *T. brevispinis* lives within the lake. Therefore, *S. scherzeri* and *M. salmoides* are judged to prey on food within their own range of activities. In this study, it is judged that the predatory fish species *S. scherzeri* and *M. salmoides*, which have similar ecological positions, avoid competition through differences in the scope of activities within their habitat and difference in food that they prey on (Pen *et al*., 1993; Lorenzzoni *et al*., 2002).

In this study, the difference of areas where *S. scherzeri* and *M. salmoides* are normally distributed have clear differences, and rather than preying on floating fish of the Cyprinidae family, both species prefer to prey on benthic fish species that barely move (Figure 4; Table 2). Such results show slight differences from past research results (Lee *et al*., 2012; Jang *et al*., 2006). Lee *et al*. (2012) reported that in the case of *S. scherzeri* found between Imjingang and Seomjingang, over 90 % of what was found in their stomachs were fish and the collected fish species were almost all floating fish species. It was also different with the report by Jang *et al*. (2006) that *M. salmoides* usually prey on *C. auratus* of the Cyprinidae family as food sources. Likewise, the difference of food sources that appeared among researchers in the lentic ecosystems of other regions are deemed to be the result of reflecting different food environments according to the region. Also, both fish species selected benthic fish species over floating fish species at Lake Paro, and this is judged to be because from the predator's perspective, these food sources can be preyed upon more efficiently while minimizing energy consumption (Vander Zanden *et al*., 2006).

The result of avoiding an overlap in habitat and food by *S. scherzeri* and *M. salmoides* also shows clear differences through growth and obesity, which can predict the growth state (or food environment) that appears in the two species (Table 3). In the case of *M. salmoides*, while it showed low growth (2.12～2.94) and negative obesity in surveys after May (3.33), *S. scherzeri* showed high growth during the same survey period (3.03～3.13) as well as positive obesity (Table 3). *M. salmoides* displayed good growth in May and this period is consistent with the period in which most of the fish move to the tributaries for spawning. According to this study, the distribution regions where *M. salmoides* normally lives are concentrated in the embayment tributaries within the lake (Figure 4).

The relationship with the growth state of food organisms should also be given attention (Table 3). *R. brunneus* (growth scale, 2.057～3.099) and *T. brevispinis* (growth scale, 2.522～2.887) that *S. scherzeri* and *M. salmoides* normally prey on as food sources, respectively, show low growth. Despite this, while *S. scherzeri* did not show a large fluctuation in growth during the survey period and maintained good status, *M. salmoides* displayed a continuous drop in its growth after May. This is because the space in which *M. salmoides* inhabits showed limited activity ranges compared to that of *S. scherzeri* as it was pushed out to the tributary, and because it mostly depends on *R. brunneus* (84.0 %) that has low growth as its main food source (Table 2, Table 3).

Frequent draughts resulting from the recent rapid climate changes and the construction of physical structures within water channels for flood control are presumed to have formed aquatic environmental conditions (decreased water level, higher water temperature, increase residence time) in which eurythermal fish species such as *M. salmoides* can breed (Eaton and Scheller, 1996; Kang *et al*., 2013). Therefore, it is necessary to identify a clearer trophic level and habitat environment for introduced species (Vander Zanden *et al*., 2004) and by constructing a food chain through stable isotope analysis and tracking energy flows, it must be applied to the Lake Paro fish fauna resource habitat establishment, resource preservation, and management. This study is expected to provide important information when establishing and implementing plans to reduce the population of *M. salmoides* at Lake Paro in the future.

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