



## Population biology of the largemouth bass, *Micropterus salmoides* from Goe-san lake, Korea

Ming-Ming Zhang<sup>1</sup>, Chul-Woong Oh<sup>1\*</sup>, Wan-Ok Lee<sup>2</sup> and Jong-Hun Na<sup>1</sup>

<sup>1</sup>Department of Marine Biology, Pukyong National University, Busan 608-737, South Korea

<sup>2</sup>Inland Fisheries Research Institute, Gyoenggi-do 477 815, South Korea

\*Corresponding Author email : ohcw@pknu.ac.kr

### Publication Info

Paper received:  
23 September 2011

Revised received:  
24 March 2012

Re-revised received:  
11 October 2012

Accepted:  
20 October 2012

### Abstract

The population biology of *Micropterus salmoides* were examined in Goe-san Lake from March 2010 to February 2011. The development of ovary and testis was separated into 5 stages by the criteria. The ratio of females to males increased with total length. Females were sampled in slightly larger size and greater number. Mean size and age was greater for females (255 mm total length and 2.03 years, respectively) than males (227 mm and 2.44 years, respectively). Growth was described by 3 parameter von Bertalanffy model by otoliths as  $L_t = 459.01(1 - \exp[-0.126(t+0.416)])$ . The spawning season of *M. salmoides* was from April to June, with a peak in May by the gonadosomatic indices and the monthly proportions of female and male gonad stages. Ripe females were collected during the spawning period. Mean fecundity was  $27656 \pm 1424$  oocytes every female. Fecundity was positively correlated with total length, and it was described by mean fecundity  $202.4$  Total length –  $38188$ . Higher fecundity well indicated that the largemouth bass has a flexible spawning strategy and has acclimatized well to Goe-san Lake.

### Key words

Population biology, Spawning strategy, Largemouth bass, Lake Goe-san

### Introduction

The largemouth bass (*Micropterus salmoides*), a freshwater fish native to the Midwestern and Southeastern United States, and Northeastern Mexico was imported to Korea from Louisiana in June, 1973 into three lakes located around the Korea. It has settled in and suited to live in Korea very well. They are widely spread at most of aquatic habitats in Korea (Lee *et al.*, 2008). Largemouth bass are an effective predator for shrimps, many other fish species and animal (Kerr and Grant, 2000). Shelton (2008) reported that the presence of alien predatory largemouth bass may influence abundance and habitat selection of native species, which the *Galaxias zebtratus* number was significantly lower where *M. salmoides* was present. It has been shown that largemouth bass play important ecological roles in lakes and rivers and are also important recreational angling fish for sport and eating qualities (Doadrio 2001, Waters *et al.*, 2005).

Determining the timing, location and mode of spawning as well as potential fecundity is important in

building a thorough knowledge of a species' general biology and its management requirements (King, 1995). Another aspect, as the introduced areas were different and the environmental factors varied schoolings of the freshwater bass mature earlier or later have evolved in varying spawning strategies. Several studies have shown that different environmental factors like crowded conditions of stocking or low temperature of water were able to disturb sexual cycle or inhibit spawning of *M. salmoides* (Martin *et al.*, 1999). Armour (1993) reported that natural variation in water temperature influenced the timing of reproduction and reproductive success. Parental care strategies involve tradeoffs between current and future reproduction, with selection expected to favor strategies that maximize lifetime reproductive success (Triver, 1972).

Several researchers (Lorenzoni, 2002; Beamish *et al.*, 2005 and Victoria *et al.*, 2009) paid their attention on the spawning time and the maturation size and age. Martin (1999) compared the inhibition effects of low water temperature and high stocking density on reproduction. So far, because the information on the life history of *M. salmonides* is

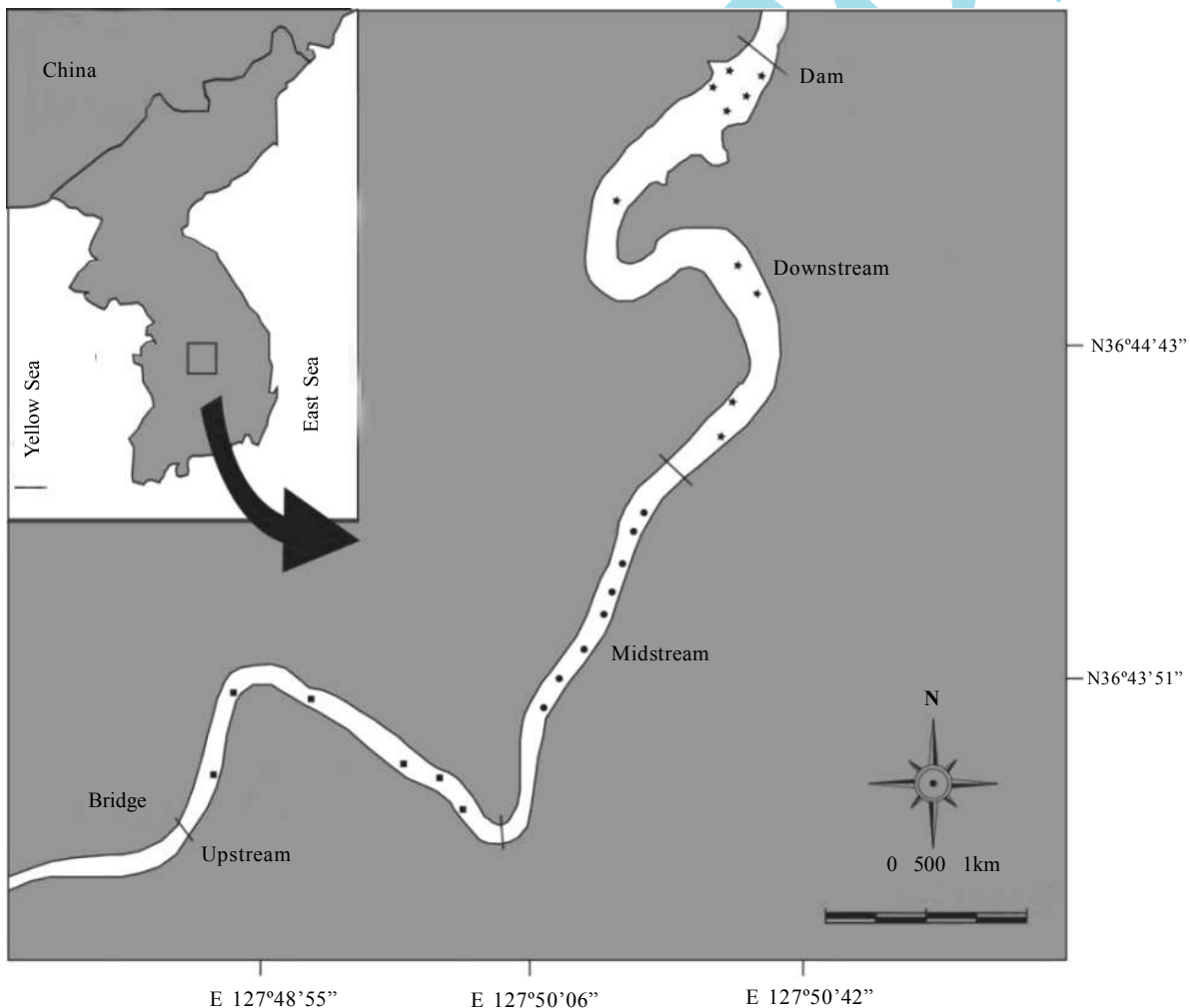
meagre, the exploitation status and assessment of appropriate management measures remain confusing in South Korea. The aim of this study was to investigate aspects of the population biology of *M. salmoides* in Goe-san lake, South Korea and the factors potentially responsible for their spawning strategies and compared with those reported in other geographic populations.

### Materials and Methods

*M. salmoides* were sampled from Goe-san lake, divided into upstream (6 stations), midstream (8 stations) and downstream (10 stations), respectively (Fig. 1).

Samples of fish were collected monthly from March to December, 2010. The sampling couldn't be done during January and February, 2011, as water in the lake was mostly frozen. In December and March, no largemouth bass was collected for the low activities at lower temperature. Fish

were sampled by fishing, as well as through gill nets (length: 20m, width: 1m, mesh size: 5.0 cm and 7.5 cm) in Goe-san lake. The water environmental factors (pH, DO, and Temperature) were measured at the site by the Potable Water Quality Analyzer and rainfall was measured by Korean Fishery Research Institutes. The fish samples were kept in insulation can with ice bags and transferred to the laboratory. In the laboratory, total length (TL) was measured to the nearest 1 mm for all fish sampled. Total weight, body weight and gonads weight were recorded with an electronic analytical balance to the nearest 0.01 g. Gonad samples of each identifiable sex and stage of development were preserved for histological examination and fecundity estimation. Macroscopically the gonads of both sexes of *M. salmoides* from Goe-san Lake and assigned reproductive stages (Stage I, Juvenile stage; Stage II, Resting stage; Stage III, Developing stage; Stage IV, Ripe stage and Stage V, Spent stage) according to the development criteria based on color, size and visibility of oocytes. The gonadosomatic



**Fig. 1** : Map showing the sampling area in Goe-san lake. (■, ●, ★, stand for sampling stations in upstream, midstream and downstream)

index (GSI) was calculated as gonads weight / (total weight - gonads weight) × 100 and HSI as (liver weight / total weight) × 100.

Ovaries of 172 ripe specimens with III and IV maturity stage, from females caught during the study period were used in order to estimate absolute and relative fecundities. The gonads were removed, weighed and then placed in Gilson's fluid for 3-4 weeks to harden eggs and dissolve ovarian membranes. The peritoneum was removed and individual eggs were released from the egg mass. The number of eggs was estimated by gravimetric method, using three pieces removed from the ovary. Fecundity was calculated by the formula given by Bagenal and Tesch (1978).

$$\text{Fecundity (F)} = W \cdot P \cdot N / W_s$$

Where W is total weight of gonad, P is weight of sample after Gilson's/weight of sample before Gilson's, N is mean number of ovary from 3 subsamples, W<sub>s</sub> is the mean weight of ovary from 3 subsamples.

Age was determined by counting opaque zones in otoliths with an image processing system consisting of a computer, a video camera microscope (Zeiss DV8), and the Optical Pattern Recognition System software package of Image-Pro Plus Version 4.1. Based on the linear regression between fish length and scale radius, lengths at growth mark formation were back calculated using the Fraser-Lee equation (Francis, 1990). The growth curve was modeled using the von Bertalanffy growth equation (Hoolihan, 2006).

The total length and age at sexual maturity of *M. salmoides* from Goc-san lake were estimated using macroscopic staging of gonads. During the spawning season, collected fish were classified as immature if the gonads were estimated to belong to stage 1 and 2, and mature if belonged to stage 3 or 4. By calculating the proportions of mature fish in each 10 mm TL class and each year class, it was known that logistic curves was fitted to the data. Sizes at maturity (L<sub>50</sub>) were determined separately for each sex. If there was no significant difference between sexes, data were pooled to use. The proportion (P) of sexual mature individuals by length (L) adapting a logistic equation (King, 1995).

The differences of environmental factors among months were compared using a ANOVA test. The size-frequency distributions between sexes were compared using a Kolmogorov-Smirnov test (Sokal and Rohlf, 2002). A Chi-squared (χ<sup>2</sup>) test was chosen to analyze the difference in sex ratio. The difference of size between sexes was compared by t-test and the difference in mean GSI and HSI between sexes was test by one-way analysis of variance (ANOVA). Statistical were carried out using SPSS Version 17.0 and SYSTAT Version 9.0.

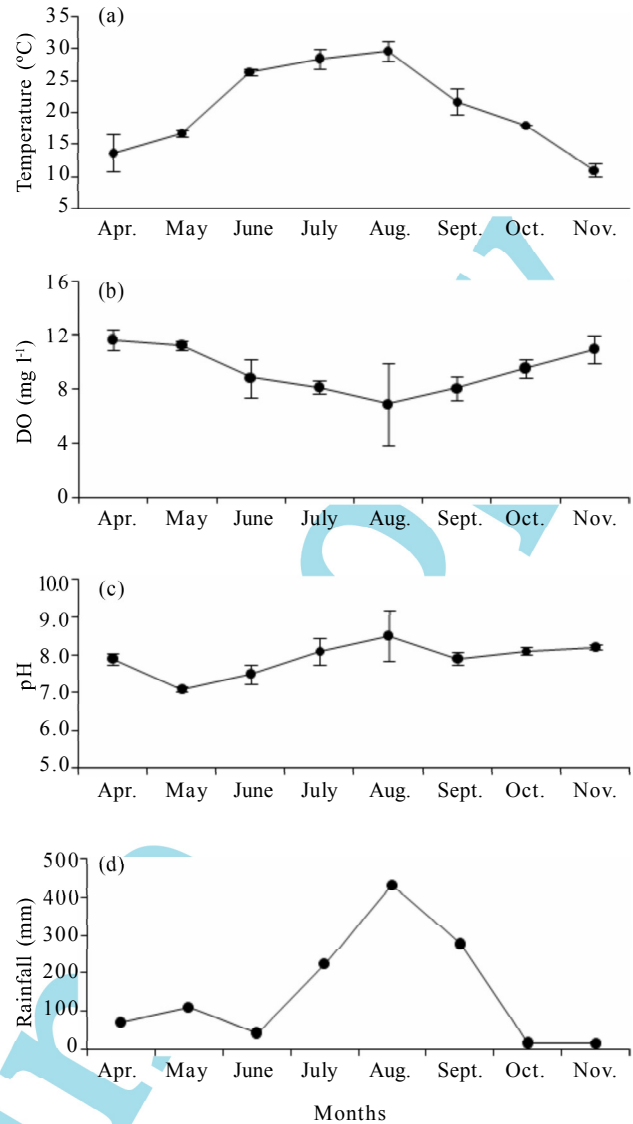


Fig. 2 : Environmental factors distribution from April to November in 2010 in Goe-san lake. (a=Water temperature; b=pH; c=DO; d= rainfall)

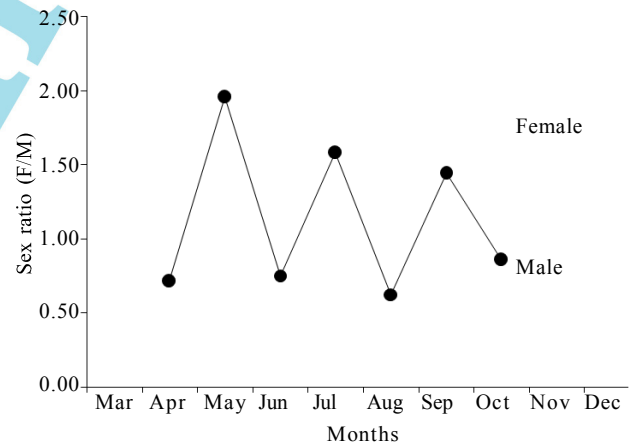


Fig. 3 : Sex ratios of *M. salmoides* from April to October in 2010 in Goe-san lake, Korea

## Results and Discussion

Water temperature ranged from 11.00 to 29.67 °C (Fig. 2). It increased from April to August, and attained the peak 29.67 °C in August, then, decreased until November. The range of dissolved oxygen (DO) was 6.18-10.97 mg l<sup>-1</sup>. It's the highest with 11.60 mg l<sup>-1</sup> in April, decreased until August, then, increased until November, and reached the minimum 6.87 mg l<sup>-1</sup> in August. The pH in April was 0.8 higher than that in May. It increased from May to August, and reached the maximum 8.5 in August. The value in September was 0.6 lower than that in August, and increased slightly until November. The pH value ranged from 7.1 to 8.8. The rainfall in April was lower than that in May, but higher than that in June. From June to August, it increased and attained the peak 433 mm in August, then, decreased until November. The water temperature differed significantly among seasons (Spring: March, April and May; Summer: June, July and August; Autumn: September, October and November) ( $F = 34.715$ ,  $p < 0.05$ ). The value in spring was significantly lower than summer's, and had no difference with autumn. The DO also differed significantly among seasons (ANOVA,  $F = 9.529$ ,  $p < 0.05$ ). The DO in spring was significantly higher than that in summer and autumn (LSD,  $p < 0.05$ ), and it in summer was significantly lower than that in autumn (LSD,  $p < 0.05$ ). The pH had no significant difference among seasons ( $F = 3.304$ ,  $p > 0.05$ ), and the rainfall also had no significant difference among

**Table 1** : Correlation coefficients and significant levels among environmental factors (temperature, pH, DO and rainfall) in Goe-san lake

		Temperature	pH	DO	Rainfall
Temperature	r	1	0.209	-0.742	0.673
	p		(0.326)	(0.000)	(0.000)
pH	r		1	-0.441	0.375
	p			(0.031)	(0.071)
DO	r			1	-0.634
	p				(0.010)
Rainfall	r				1
	p				

**Table 2** : Composition for age, otolith length, total length and total weight of *M. salmoides*

Age (year)	Sample	Percentage (%)	Total length (mm)	Total weight (g)	Otolith length (mm)
0	49	23.22	127.24 ± 15.28	25.81 ± 7.25	5.10 ± 1.28
1	12	5.69	176.18 ± 24.66	66.94 ± 26.32	6.05 ± 1.14
2	60	28.44	247.16 ± 32.72	193.76 ± 85.06	7.43 ± 3.03
3	45	21.33	281.48 ± 25.45	278.52 ± 86.34	8.10 ± 2.45
4	11	5.21	324.65 ± 26.24	568.37 ± 45.29	8.93 ± 2.62
5	18	8.53	352.05 ± 44.32	1 527.35 ± 132.56	9.47 ± 2.32
6	10	4.73	391.71 ± 13.57	905.18 ± 114.52	9.96 ± 1.57
7	5	2.37	432.17 ± 7.78	1 133.46 ± 149.14	10.26 ± 1.78
8	1	0.47	478.00 ± 0.00	1 434.29 ± 103.57	11.02 ± 0.00

Values are mean of replicates ± SD

seasons ( $F = 2.964$ ,  $p > 0.05$ ). By the correlation analysis among months, the temperature was significantly correlated with DO and rainfall, and not correlated with pH. The DO was significantly correlated with other factors. The pH wasn't correlated with rainfall (Table 1).

Temperature is a very important factor (Rutherford and Houde, 1995; Stige *et al.*, 2006), which can attribute to the structure of populations. There is no study that temperature influence the reproductive and spawning of largemouth bass.

The age of the largemouth bass ranged from 0 to 8 years. The largemouth bass caught in size ranged from 115.4 to 472.0 mm in total length (TL) and from 11.68 to 1,500.05 g in total weight. Out of the 211 specimens collected, 101 (47.86%) were identified as males, ranging from 115.4 to 406.7 mm and 11.68 to 1,017.54 g, while the other 110 (52.13%) were females from ranging 122.4 to 472.0 mm and 21.90 to 1,500.05 g. Mean total length for males and females were 255.10 mm and 262.58, respectively (Table 2).

Total 211 gonads of *M. salmoides* were macroscopically examined to assess their reproductive stage of development. The sex ratio of female to male was 1.12:1. There was no significant difference ( $\chi^2 = 0.07$ ,  $df = 1$ ,  $p > 0.05$ ). Sex ratios differed between months (Fig 3). It ranged from 0.63-1.95, with the peak in May. Sex ratios differed significantly with size ( $\chi^2 = 35.44$ ,  $df = 3$ ,  $p < 0.01$ ), with the ratio of females to males increasing steadily from an 1:1 ratio less than 200 mm total length (Table 3). The size-distribution showed that both males and females were normally distributed (Anderson-Darling normally test:  $p > 0.05$ ) (Fig. 4). There was no significant difference in size composition structure between males and females (Kolmogorov-Smirnov two-sample test;  $d_{max} = 0.096$ ,  $p = 0.659$ ).

Freshwater fishes were found generally to exhibit a 1:1 ratio of females to males, with some exceptions,

particularly among larger species where “females were either more abundant or larger than males” (Clarke, 1983). In the present study, a positive bias in the ratio of females to males and an increase in the proportion of males with increasing size were noticed (Table 3). The factors such as species size, depth distribution and different collecting tools and methods may account for the bias toward females in this study. It is consistent to the result in Escambia Rive (Orlando *et al.*, 1999) and Tohopekaliga in Florida (Lange *et al.*, 1994). However, opposite bias was reported (Orlando *et al.*, 1999) in Blackwater River in Florida. The possible reasons may be related with the sampling time and the geographic difference of species.

Sex ratio (F/M) showed a smaller and smaller hackle change with passing time. From April, temperature became high, and may be possibly for *M. salmoides* to act and feed, especially for male. At the same time, males matured earlier than females, therefore, males tried their best to feed more to save enough energy for reproductive and spawning (Jakobsen *et al.*, 2009). So the sex ratio was male-biased in April. In May, females started to do the similar things, and males mostly matured, so the sex ratio skewed to female. After males matured and spawned in May, they began to feed again in June, as more males were collected. Following males, females also finished some spawning and started to feed again, that was why females was higher than males collected. The spawning season was determined from April to June, mainly in May (Fig. 3). At the same time, because the fishing sporting was more and more, the stock size was smaller and smaller. Therefore, a smaller and smaller hackle curve was done.

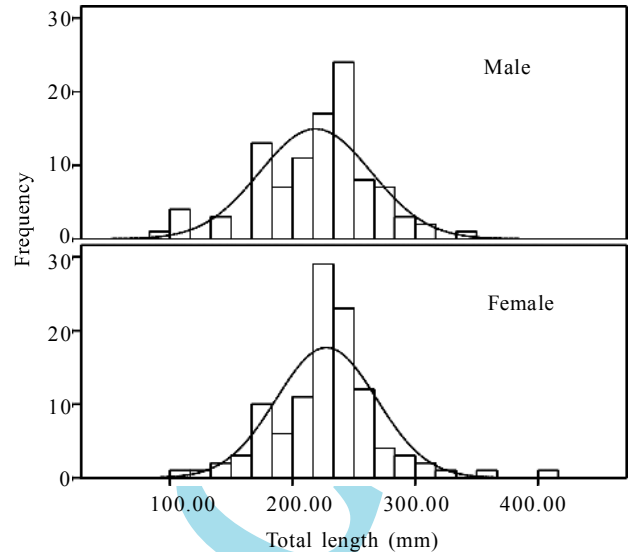
Males *M. salmoides* had a smaller size than female in Goe-san lake (t-test,  $t = -1.10$ ,  $df = 202$ ,  $p > 0.05$ ). The predominance of larger sized females is common amongst Centrarchidae. It is consistent to the reports on *M. salmoides*, which is likely the result of different growth and longevity of the sexes (Porak *et al.*, 1988; Orlando *et al.* 1999; Lange *et al.*, 1994). Porak (1988) reported largemouth bass in peninsular Florida experienced sexual dimorphic growth and females grew faster than males after approximately 200 mm in length.

GSI and HSI were examined to determine the spawning season. In female, GSI was 4.63 in April, reached peak (5.60) in May, and decreased greatly until July. The GSI of male had a similar pattern curve. The female HSI was

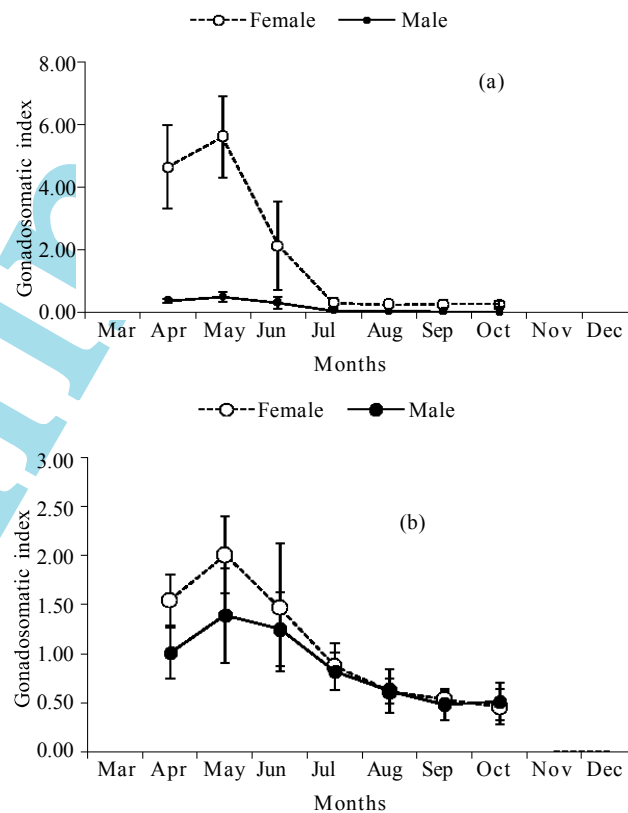
**Table 3 :** *M. salmoides* ratio of female to male in relation to size

Total length (mm)	♀	♂	N	♀:♂
≤ 200	7	7	14	1:1
200-300	101	92	193	1.09:1
300-400	19	15	34	1.27:1
≥ 400	2	1	3	2:1

greatly higher than that of male from April to July, and slightly higher from July to October. The spawning period was also determined between April and June, and main spawning time was May. There was a significant difference in the

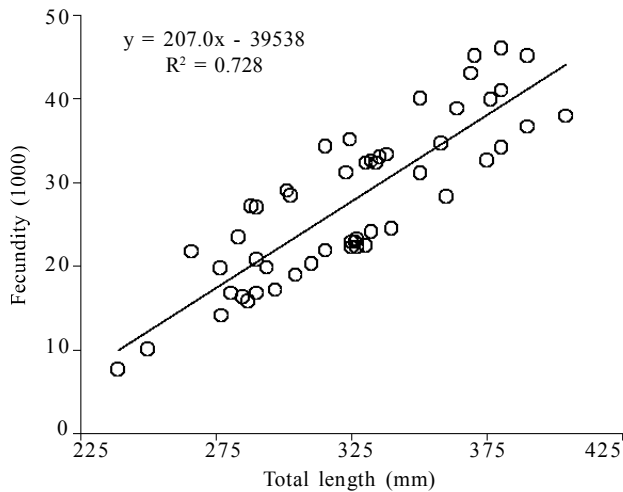


**Fig. 4 :** Total length distribution of male and female of *M. salmoides*

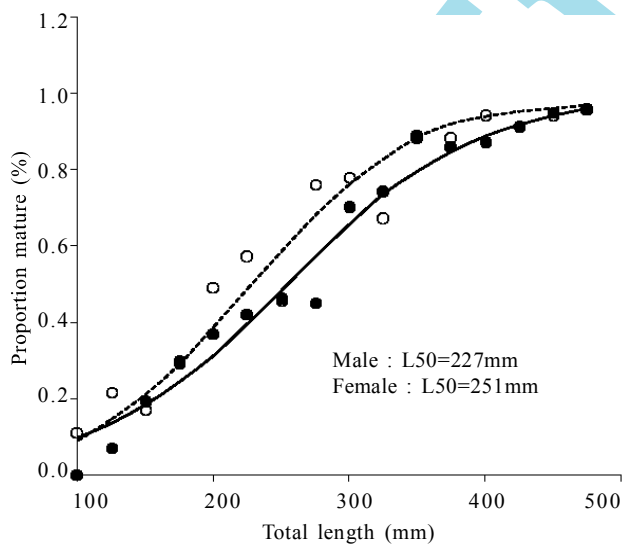


**Fig. 5 :** Gonadosomatic index (mean % GSI ± SE) and hepatosomatic index (mean % HSI ± SE) for female and male *M. salmoides* in Goe-san lake, Korea

mean GSI of both sexes between months (ANOVA, Female:  $F = 39.65$ ,  $df = 1, 6$ ,  $p < 0.01$ ; Male:  $F = 17.28$ ,  $df = 1, 6$ ,  $p < 0.01$ ) (Fig. 5A). The pattern of HSI was similar with that of GSI (Fig. 5B). The peaks also occurred in May. The female HSI was greatly higher than that of male from April to July, and similar from July to October. The spawning season was also determined in May. Significant differences between testis stages (ANOVA,  $F = 214.8$ ,  $df = 4, 100$ ,  $p < 0.01$ ) and ovary stages (ANOVA,  $F = 187.6$ ,  $df = 4, 109$ ,  $p < 0.01$ ) were found, respectively. There was a significant difference in the mean HSI between months (ANOVA, Female:  $F = 17.6$ ,  $df = 1, 6$ ,  $p < 0.01$ ; Male:  $F = 30.4$ ,  $df = 1, 6$ ,  $p < 0.01$ ). The monthly variation of GSI was significantly correlated with HSI for both sexes (Female:  $r = 0.882$ ,  $p < 0.01$ ; Male:  $r = 0.669$ ,  $p < 0.01$ ).



**Fig. 6 :** Relationship between fecundity and total length (mm) for stage 3 and 4 female *M. salmoides* in Goe-san lake, Korea



**Fig. 7 :** Reproductive maturity total length with fitted logistic curves for male and female *M. salmoides*. The logistic curve for males is represented by a dashed line and for female by a solid line

Most of the fish living in the temperate zone exhibit an annual reproductive cycle. Reproduction, or more precisely hatching, occurs when food is available for the fry in the wild. Therefore, reproduction is closely related to environment. Harris (1986) also postulated that falling water temperatures and decreasing photoperiod were main cues in the onset of spermatogenesis and oocyte maturation in *M. novemaculeata*, with flooding acting as the proximal factor. In this study, *M. salmoides* spawned mainly from April to June, mainly in May determined by GSI and HSI. According to the investigation of environment factors, during this period, the temperature increased and it is possibly temperate for photo-planktons and zooplanktons to grow. The fry and larval of *M. salmoides* can get enough food, which could be related to the biomass of zooplankton during this period.

The fecundity of *M. salmoides* was examined in maturing and ripe fish sampled between April and July. The observed fecundity varied between 7,568 eggs at 239 mm total length and 44,226 eggs at 324 mm total length. There were significantly positive relationships between fecundity and total length ( $n = 51$ ,  $r = 0.772$ ,  $P < 0.01$ ) (Fig. 6).

Fecundity is potentially affected by changes in abundance. Although direct estimates of fecundity as a function of population size are comparatively rare, there is substantial information on changes in body size of fish as a function of abundance (Jakobsen et al., 2009). In many exploited stocks, the spawning stock has become progressively more male-biased through the loss of large, old spawners that are disproportionately female (Marshall et al., 2006). In this study, the spawning stock was female-biased. It may be the large loss of male during the past exploited activities or the gear selective for more females. The highly fecundity of *M. salmoides* fecundity also well indicated that the largemouth bass has a flexible spawning strategy and has acclimatized well to Goe-san lake.

The age of the largemouth bass studied ranged from 0 to 8 years, and the age groups 2 and 3 were the dominant groups. The von Bertalanffy growth equation was determined from the back-calculated standard length at age for combined sex of largemouth bass. The estimated parameters of  $L_{50}$ ,  $K$ ,  $t_0$  were 459.1, 0.126 and -0.416.

Logistic curves for length at maturity were separated by sex. The estimated  $L_{50}$  of female *M. salmoides* (255 mm TL) was larger than males (227 mm TL). The relationship between the proportion of sexual mature and total length by sexes was calculated by fitting a logistic function (Fig. 7).

Males began to mature at smaller sizes and approached 100% maturity over a larger range of size classes than females. However, both females and males were

estimated to reach 100% maturity at similar sizes (475 mm TL). The estimated age at 50% maturity of female and male was 2.44 and 2.03 years, respectively. By calculation, the age at sexual maturity was 2.03 for male and 2.44 for female, respectively.

Female *M. salmoides* reached sexual maturity at size of 255 mm, and was larger than male at size of 227 mm. The maturation of males at smaller sizes than that of females is consistent with findings of previous studies (Orlando *et al.*, 1999; Olaf and Thomas, 1999) and has been suggested to be likely due to different growth rates between the sexes. Male and female *M. salmoides* 50% sexual maturity was at 2.03 and 2.44 years. It was similar to the result of Olaf (1999). Typical of many teleosts, the onset of sexual maturity in male and female *M. salmoides* coincided with an overall decrease in growth rates (Walsh *et al.*, 2000) and is likely due to energy being invested in reproduction other than somatic growth. Further studies are required to definitively determine the causal mechanisms influencing spawning and recruitment in *M. salmoides* populations, including the effects of environmental flows.

This research demonstrated that *M. salmoides* exhibited a relatively higher fecundity and longer spawning period. Therefore, its spawning strategy is highly flexible. The variation in the timing and periodicity was shown to be related with the latitude location, environmental factors including mainly temperature and rainfalls as well as the age and size structure of the population. Nonetheless, the data of fecundity is also limited, and the climate is changing. Therefore, more systematic investigations should be done in more areas.

### Acknowledgments

This study project was provided by Inland Fisheries Research Institute, National Fisheries Research & Development Institute (NFRDI) and Marine Ecology laboratory, Pukyong National University. We would like to thank them for assistance and guidance.

### References

- Armour, C.L.: Evaluating temperature regimes for protection of smallmouth bass. Resource Publication 191, US Department of Interior Fish and Wildlife Service, Washington (1993).
- Bagenal, T.B. and F.W. Tesch: Age and growth. In: Methods for assessment of fish production in fresh waters (Eds.: T. Bagenal 3<sup>rd</sup> Edn.), IBP Handbook No. 3, Blackwell Scientific Publications, pp. 101-136 (1978).
- Beamish, C.A., A.J. Booth and N. Deacon: Age, growth and reproduction of largemouth bass, *Micropterus salmoides* in Lake Manyame, Zimbabwe. *Afr. Zool.*, **40**, 63-69 (2005).
- Clarke, T.A.: Sex ratios and sexual differences in size among mesopelagic fishes from the central Pacific Ocean. *Mar. Biol.*, **73**, 203-209 (1983).
- Doadrio, I.: Atlas y Libro Rojo de los Peces Continentales de España. Dirección General de Conservación de la Naturaleza, Museo Natural de Ciencias Naturales, Madrid (2001).
- Francis, R.I.C.C.: Back-calculation of fish length: A critical review. *J. Fish. Biol.*, **6**, 883-902 (1990).
- Harris, J.H.: Reproductive of the Australian bass, *Macquaria novemaculeata* (Perciformes: Percichthyidae) in the Sydney Basin. *Aust. J. Mar. Freshw. Res.*, **46**, 219-234 (1986).
- Hoolihan, J.P.: Age and growth of Indo-Pacific sailfin, *Istiophorus platypterus*, from the Arabian Gulf. *Fish. Res.*, **78**, 89-95 (2006).
- Jakobsen, T., M.J. Fogarty, B.A. Megry and E. Moksness: Fish reproductive biology. In: Implications for assessment and management. Wiley-Blackwell, pp. 48-91 (2009).
- Kerr, S.J. and R.E. Grant: Largemouth bass. In: "Ecological impacts of fish introductions: Evaluating the risk" fish and wild-fish branch. Ontario Ministry of National Resources, Ontario, pp. 301-324 (2000).
- King, M.: Population dynamics. In: Fisheries biology, assessment and management. Blackwell Science, Oxford, pp. 79-197 (1995).
- Lange, T. R., H.E. Royals and L.L. Connor: Mercury accumulation in largemouth bass, *Micropterus salmoides*, in a Florida Lake. *Arch. Environ. Contain. Toxicol.*, **27**, 466-471 (1994).
- Lee, W.O., I.R. Lee, H.Y. Song and I.C. Bang: Genetic differentiation of the largemouth bass, *Micropterus salmoides*, from the major rivers and reservoirs in Korea assessed by AFLP. *Korean J. Limnol.*, **41**, 395-401 (2008).
- Lorenzoni, M., A.J. Dörr, R. Erra, G. Giovanazzo, M. Mearelli and S. Selvi: Growth and reproduction of largemouth bass, *Micropterus salmoides*, (Lacépède, 1802) in Lake Trasimeno (Umbria, Italy). *Fish. Res.*, **56**, 89-95 (2002).
- Marshall, C.T., C.L. Needle, A. Thorsen, O.S. Kjesbu and Yarina: Systematic bias in estimates of reproductive potential of an atlantic cod stock: Implications for stock-recruit theory and management. *Can. J. Fish. Aqu. Sci.*, **63**, 980-994 (2006).
- Martin, M., V. Goubier, J.M. Exbrayat and S. Kamvira: Effect of environmental factors on oocyte maturation and spawning delay or inhibition, in black-bass, *Micropterus salmoides*: Synthesis of two years experiments. *Pol. Arch. Hydrobiol.*, **46**, 63-70 (1999).
- Olaf, L.F. and Thomas Hecht: A successful population of largemouth bass in a subtropical lake in Mozambique. *Environ. Biol. Fishes*, **54**, 53-66 (1999).
- Orlando, E.F., N.D. Denslow, L.C. Folmar and L.J. Guillette: A comparison of the reproductive physiology of largemouth bass, *Micropterus salmoides*, collected from the Escambia and Blackwater Rivers in Florida. *Environ. Hlth. Perspect.*, **107**, 199-204 (1999).
- Porak, W., W.S. Coleman and S. Crawford: Age, growth and mortality of Florida largemouth bass utilizing otoliths. *Proc. Annu. Conf. S.E. Assoc. Fish. Wild Agen.*, **40**, 206-215 (1988).
- Rutherford, E.S. and E.D. Houde: The influence of temperature on cohort-specific growth, survival, and recruitment of striped bass, larvae in Chesapeake Bay. *Fish. Bull.*, **93**, 315-332 (1995).
- Shelton, J.M., J.A. Day and C.L. Griffiths: Influence of largemouth bass, *Micropterus salmoides*, on abundance and habitat selection of Cape galaxias, *Galaxias zebratus*, in a mountain stream in the Cape Floristic Region, South Africa. *Afr. J. Aquat. Sci.*, **33**, 201-210 (2008).
- Sokal, R.R. and F.J. Rohlf: Biometry. In: The Principles and Practice of Statistics in Biological Research. WH Freeman, Company, New York, pp. 1-887 (2002).
- Stige, L.C., G. Ottersen, K. Brander, K.S. Chan and N.C. Stenseth: Cod and climate: Effect of the North Atlantic oscillation on recruitment in the North Atlantic. *Mar. Ecol. Prog. Ser.*, **325**, 227-241 (2006).
- Trivers, R.L.: Parental investment and sexual selection. In: Sexual

- Selection and the Descent of Man (*Eds.*: B. Campbell). Heinemann Press, London, pp. 136-179 (1972).
- Victoria, R.S., E. Lourdes, R.R. Amadora and Ramona: Largemouth bass, *Micropterus salmoides*, growth and reproduction in Primera de Palos' lake (Huelva, Spain). *Folia. Zool.*, **58**, 436-446 (2009).
- Walsh, M.G., K.A. Bjorgo, and J.J. Isely: Effects of implantation method and temperature on mortality and loss of simulated transmitters in hybrid striped bass. *Trans. Am. Fish. Soc.*, **129**, 539-544 (2000).
- Waters, S., R.L. Noble and J.E. Hightower: Fishing and natural mortality of adult largemouth bass in a tropical reservoir. *Trans. Am. Fish. Soc.*, **134**, 563-571 (2005).

Online Copy