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Short communication

Growth and reproduction of largemouth bass (*Micropterus salmoides* Lacépède, 1802) in Lake Trasimeno (Umbria, Italy)

Massimo Lorenzoni*, A.J. Martin Dörr, Rocco Erra, Giancarlo Giovinazzo, Mario Mearelli, Sabrina Selvi

Dipartimento di Biologia Animale ed Ecologia, Università degli Studi di Perugia, Via Elce di Sotto, 06100 Perugia, Italy

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Abstract

Growth and reproductive biology of largemouth bass was investigated to study aspects of its biology as well as possible effects upon other fish species as a result of its introduction to Lake Trasimeno. From April 1993 to May 1994, 182 specimens (87 males, 83 females, 12 sexually indeterminate) distributed among seven age classes were captured. The length–weight regression was $W = 0.00988\mathrm{LT}^{3.1512\pm0.027}$ (males) and $W = 0.00888\mathrm{LT}^{3.184\pm0.032}$ (females) without any significant differences between sexes. The growth of the 1+age-class is not continuous throughout the year; it slows to almost nothing in the winter. The parameters of the von Bertalanffy growth curve for length were $L_\infty = 46.88$, $K = 0.33$ and $t_0 = 0.056$ for the females and $L_\infty = 39.4$, $K = 0.42$ and $t_0 = 0.019$ for the males. The condition factor indicates that the Lake Trasimeno population is in excellent condition. Reproduction occurs mostly in May. Sexual maturity is reached at 2 years for males and 3 years for females, at lengths and weights of 22 cm and 160 g for males and 30 cm and 397 g for females, respectively. Largemouth bass has adapted well to Lake Trasimeno where physical and trophic conditions favour growth and reproduction.

Keywords: *Micropterus salmoides*; Largemouth bass; Growth; Biology; Lake Trasimeno

1. Introduction

Largemouth bass (*Micropterus salmoides* Lacépède, 1802), a fish native to the south-eastern United States, which prefers marshy environments and the shallow waters of larger lakes (Hickley et al., 1994). Because it is a premium sport fish, it has been introduced, although not always successfully, into several countries in temperate and tropical climates (Heidinger, 1976). Largemouth bass were introduced into the Italian inland waters at the end of the last century (Alessio, 1981) and spread rapidly throughout the country. It was first recorded in Lake Trasimeno at the end of the 1980s (Natali, 1989). It was introduced by sport fishermen because it is a prized catch but professional fishermen have also benefited from its presence. In 1989, largemouth bass were included in the fishing statistics with a total catch of about 170 kg, and this value has increased steadily each year. Fishing has always been one of the main economic activities of the Lake Trasimeno area having the largest nucleus of professional fishermen in inland Italy (Natali, 1989).

* Corresponding author. Tel.: +39-75-5855716; fax: +39-75-5855733.
E-mail address: lorenzon@unipg.it (M. Lorenzoni).

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However, fishing is not always well-managed mainly due to a lack of information about the biology of the fish in the lake (Lorenzoni et al., 1993).

Lake Trasimeno (central Italy, 43°9′11″ lat. N and 12°5′ long. E, F122 G.M.I) is the largest laminar lake on the Italian peninsula; tectonic in origin, it has a surface area of 126 km^2 and an average depth of 4.72 m (maximum depth 6.3 m). From a trophic point of view, Lake Trasimeno is productive and is classified as mesotrophic (Mearelli et al., 1990). The fish fauna includes 19 species, dominated by cyprinids and there are other piscivorous predators including perch (*Perca fluviatilis* L.) and pike (*Esox lucius* L.).

The aim of this study was to investigate aspects of the biology of largemouth bass. The results are compared with those of other largemouth bass populations in Italy (Zerunian, 1980; Alessio, 1981, 1983; Lorenzoni et al., 1996) and in other countries (Heidinger, 1976; Rosenblum et al., 1994; Froese and Pauly, 1998).

2. Materials and methods

Monthly samples were collected in the area called "La Valle" located between San Savino and Sant' Arcangelo from April 1993 to May 1994. Samples were collected using an electric shocker (continual pulsed current, 4 kW), collocated on a raft.

All specimens were measured for total length (TL) and standard length (SL), with an accuracy of 1 mm, and weighted (W) with an accuracy of 1 g. Sex was determined by macroscopic examination of the gonads, and gonads were weighed (W_g) with an accuracy of 0.1 g. The age of the fish was determined using the microscopic scalimetric method (Bagenal, 1978). The scales were removed from the left side of the fish, above the lateral line, near the first dorsal fin and stored in formalin (2%) for reuse in the back-calculation. The length–weight relationship $W = a\mathrm{TL}^b$ were calculated separately for the two sexes using the least squares method (Ricker, 1975). The relationship TL and SL was also calculated. Back-calculated lengths were estimated for all the specimens with readable scales. The scale radius (R_s), from the centre of ossification to the edge of the scale, and the radius of the age rings (S_t) were measured for all scales (±0.01) (Bagenal, 1978).

The relationship between the length of the specimen at capture (TL) and R_s was described using the regression $\mathrm{TL} = a + bR_s$. The result is linear and does not pass through the origin. Back-calculated lengths were estimated using the following formula: $TL_t - a = S_t/R_s(L - a)$ (Bagenal, 1978), in which a is the intercept with the axis of the abscissa of the previous regression and TL_t is the total length of the fish at age t. The comparison of the size reached at the various ages between the two sexes was compared with a t-test. To determine if there was a Lee phenomenon, a comparison was made using the t-test between the back-calculated lengths reached at the various ages of the specimens at age n with respect to the samples of the older fish $(n + i)$.

The von Bertalanffy (1938) equation was fitted to the mean back-calculated lengths: $L_t = L_\infty (1 - e^{-K(t-t_0)})$, where L_t is the theoretical total length (in cm TL) at age t; L the asymptotic length, K the coefficent of growth, t_o the theoretical age (in years) at length = 0 (Bagenal, 1978). The program Statistica for Windows (Ver. 5.1) was used to estimate growth parameters. Φ (Pauly and Munro, 1984) was calculated using the equation, $\Phi = \log(K) + 2\log(L_\infty)$.

The condition factor (CF) was calculated for each specimen using the formula of Fulton (Bagenal, 1978) $\mathrm{CF} = 100\,\mathrm{W}/\mathrm{L}^3$, expressed in g and cm TL. The comparison of the CF between sexes was done for the various age classes using t-test. The gonado-somatic index (GSI) was calculated for all sexually identified specimens, $\mathrm{GSI} = 100\,W_g/W$.

During the reproductive period, largemouth bass ovaries contain oocytes at different stages of maturity (Alessio, 1983; Rosenblum et al., 1994) so an exact egg count will be imprecise (Heidinger, 1976). Thus, the relative fertility was analysed using the regression, $W_g = a\mathrm{TL}^b$, using all female specimens captured immediately before reproduction.

3. Results

Overall 182 specimens were caught (87 males, 83 females, 12 immature), and distributed in seven age classes (Fig. 1). The maximum observed age was 7 years.

The average values for the females are slightly higher ($\mathrm{TL} = 26.43$ cm, $W = 374.21$ g, age = 2.57 years)

Fig. 1. Frequency histogram of age-classes for the whole sample.

than those for males (TL = 25.01 cm, $W = 313.33$, age = 2.44 years) but the differences were not significant for all cases using the t-test ($p > 0.05$). The relationship between SL and TL was $TL = 0.242 + 1.138SL$ ($r = 0.999$, $N = 182$, $p < 0.001$, S.E.(b) = 0.004).

The length–weight relationship estimated was $W = 0.00988TL^{3.151 \pm 0.027}$ for males ($r = 0.99$, $N = 87$, $p < 0.001$) and $W = 0.00888TL^{3.184 \pm 0.032}$ for females ($r = 0.99, N = 83, p < 0.001$). The regression coefficients did not differ significantly (t-test $p = 0.43$) with sex.

Back-calculated lengths were estimated for 151 specimens. The relationship between TL and R_s was linear and does not pass through the origin: $TL = 42.4645 + 51.7067R_s$) ($r = 0.87, N = 151, p < 0.001$, S.E.(b) = 1.166). Female back-calculated lengths were larger than those for male (Table 1), even in the smaller age classes, and the differences in length between the sexes were significant for ages 1–3

Table 1
Average back-calculated lengths

Age	N	Length at age (cm)						
		I	II	III	IV	V	VI	VII
Females								
I	11	14.706						
II	41	15.609	21.915					
III	17	16.265	24.815	29.960				
IV	6	16.586	22.141	29.505	33.443			
V	2	15.705	23.082	27.944	33.341	38.265		
VI	0							
VII	1	14.772	23.149	29.264	32.567	37.164	40.820	42.873
Mean		15.69 ± 0.41	22.72 ± 0.44	29.67 ± 0.71	33.32 ± 1.20	37.90 ± 2.09	40.82	42.87
Males								
I	13	13.794						
II	38	15.152	21.113					
III	19	15.476	22.802	28.457				
IV	3	16.306	21.729	28.387	32.69			
Mean		15.04 ± 0.39	21.68 ± 0.43	28.45 ± 0.70	32.69			

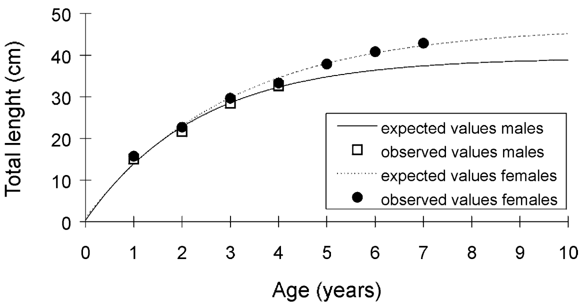

Fig. 2. Theoretical growth curve for length.

($p < 0.05$) but not for age 4 years ($p = 0.59$). In the last case, the results may be influenced by the small sample size.

The comparison between the back-calculated lengths reached at the various ages shows highly significant differences for age 1 year ($p = 0.001$) and 2 years ($p = 0.003$), in favour of the older specimens. The parameters of the von Bertalanffy growth curve were $L_\infty = 46.88$. $K = 0.33$, $t_0 = 0.056$ and $\Phi = 2.86$ for females, and $L_\infty = 39.4$ $K = 0.42$, $t_0 = -0.019$ and $\Phi = 2.81$ for males (Fig. 2). The mean CF did not differ significantly with sex (1.622 for the females

Table 2
Condition factor and comparison between sexes

Age class	Males			Females			*t*	*p*
	N	Mean	S.D.	*N*	Mean	S.D.		
0+	3	1.419	0.133					
1+	13	1.469	0.103	10	1.465	0.0825	0.11	0.91
2+	38	1.630	0.108	45	1.581	0.099	2.16	0.03
3+	22	1.629	0.136	16	1.667	0.133	0.84	0.41
4+	8	1.702	0.123	8	1.829	0.099	2.25	0.04
5+	3	1.640	0.085	3	1.829	0.123	2.18	0.09
7+				1	1.987	0.000		
Total	87	1.605	0.136	82	1.622	0.148	3547	0.850

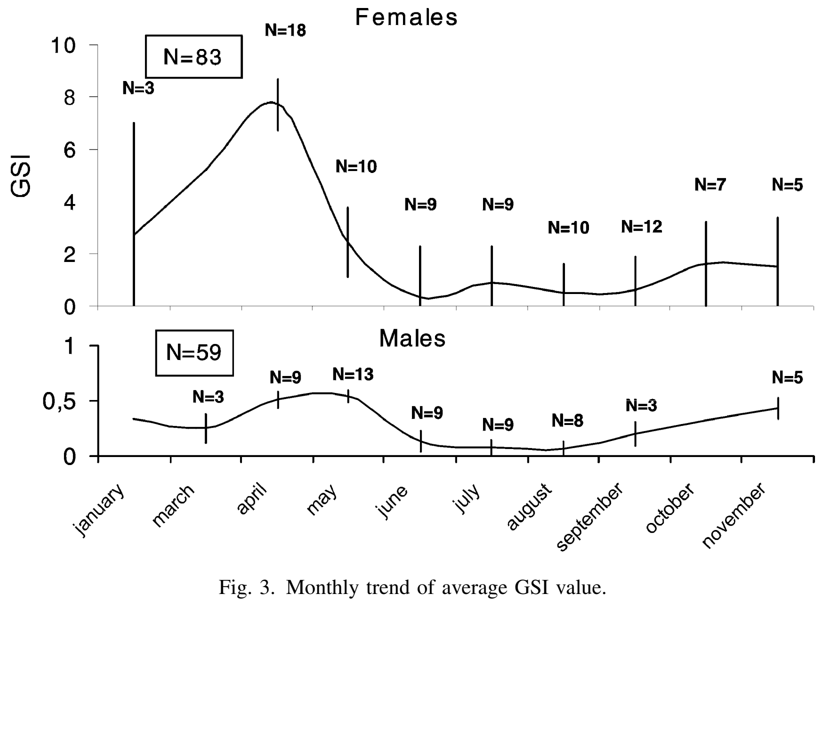

Fig. 3. Monthly trend of average GSI value.

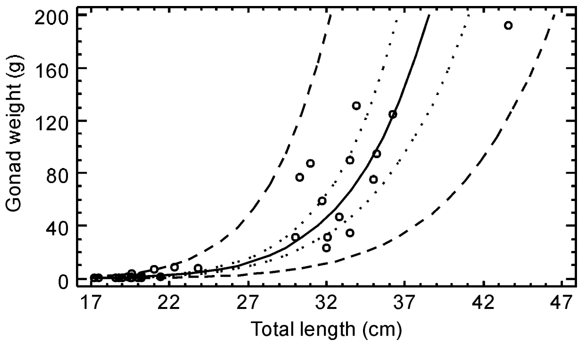

Fig. 4. TL/Wg relation in females.

and 1.605 for the males; $p = 0.47$). In general, CF increased with age for both sexes. CF differed significantly ($p < 0.05$) between sexes at age 2 and 4 years (Table 2).

The mean GSI was 2.639 for females (minimum = 0.153; maximum = 17.476) and 0.321 for males (minimum = 0.036, maximum = 0.887). GSI attained a maximum in May for males (0.544) and in April (7.71) for females which is followed by a rapid decrease in May following egg deposition (Fig. 3). From June to August, the GSI reaches to the lowest average values in both sexes. Reproduction is concentrated in May. This is confirmed by an examination of the ovaries, at the end of May, 61.54% of the females had reproduced, while at the end of June, reproduction was completed. In 1993, the average monthly water temperature was 14.71 °C in April (range 10.02–19.60), 22.79 °C in May (range 18.30–26.70) and 25.79 °C in June (range: 23.8–27.70). Macroscopic examination of the gonads showed that at second year, 71. 43% of the males and 21.05% of the females had mature gonads, while this percentage rises to 100% in the following years. The relationship between gonad weight and total length is described by the equation: $W_g = 0.001\mathrm{TL}^{7.91\pm0.43}$ ($r = 0.96$, $N = 33$, $p < 0.001$) (Fig. 4).

4. Discussion

The sample is sufficiently significant for the scope of this study even if the youngest age classes were probably under-represented because the capture method used which favoured only larger individuals (Cowx, 1990). The slope of the length–weight relationship was >3 and this agrees with other studies in which values <3 are very rare (Heidinger, 1976). The *b* value for Lake Trasimeno is higher than in other wild populations in Italy: in 4 populations of the Po basin, the value varied between 2.66 and 3.13 (Alessio, 1981), while in the Montedoglio reservoir, the value is 3.13 (Lorenzoni et al., 1996).

Data on growth of largemouth bass in Italy are scarce (Zerunian, 1980; Alessio, 1981, 1983; Lorenzoni et al., 1996). Comparison of the parameters of the von Bertalanffy growth equation in the literature (Table 3) shows that in Lake Trasimeno largemouth bass has lower L_∞ than most other populations, and that growth is quite fast with rather high K values. Growth can be judged by the Φ value which in the Lake Trasimeno is intermediate between other data reported. Sexual dimorphism in the size of largemouth bass is still debatable (Heidinger, 1976); larger females are observed only occasionally (Pardue and

Table 3
Parameters of the von Bertalanffy equation from Lake Trasimeno and other populations reported in literature

L_∞ (cm)	K(1/y)	t_0	Φ	Lake
58.9	0.160	−0.30	2.74	Lake Rebecca, USA (Froese and Pauly, 1998)
34.1	0.498	−0.07	2.76	Lake Shorenji, Japan (Froese and Pauly, 1998)
61.5	0.200	−0.11	2.88	USA (Froese and Pauly, 1998)
50.5	0.310	0.41	2.90	Lake Rebecca, USA (Froese and Pauly, 1998)
53.5	0.300		2.93	Lake Yate, New Caledonia (Froese and Pauly, 1998)
57.3	0.280	−0.23	2.80	Montedoglio Reservoir (Lorenzoni et al., 1996)
51.0	0.282	−0.13	2.87	Lake Trasimeno (Lorenzoni et al., 1996)
46.9	0.330	0.06	2.86	Lake Trasimeno, females (current study)
39.4	0.420	−0.02	2.81	Lake Trasimeno, males (current study)

Hester, 1967; Alessio, 1981). In Lake Trasimeno, the comparison between the sexes showed that the females were bigger than the males at all ages. Females had higher L_∞ than males. In the latter, the growth was faster, the 95% of L_∞ (Craig, 1978) was attained by 7 years of age in males and 9 years of age in females. The legal size for keeping largemouth bass is 20 cm, and is reached by the end of the second year in both sexes.

An earlier study (Lorenzoni et al., 1996), in which no back-calculated data were used, showed that largemouth bass from Lake Trasimeno grew more slowly, as demonstrated by the lowest value of *K*. This contrasting observation could have been due to an overestimation caused by the so-called ''Inverse Lee phenomenon'' in the back-calculation which is generally due to a predation phenomena and/or competition among the young, causing a selective mortality unfavourable to the smallest specimens (Bagenal, 1978). In Lake Trasimeno, the *t*-test showed a statistically significant difference between I and II age classes and the rest of the sample. There may be a differential mortality in the population giving larger individuals an advantage. This is fairly common in largemouth bass particularly during the first winter of life (King et al., 1979; Shelton et al., 1979; Timmons et al., 1980; Ludsin and DeVries, 1997).

CF is the individual deviation from the hypothetical ideal fish having a isometric growth (Weatherley, 1972); it permits a comparison between individuals, populations and different sexes (Ricker, 1975). In Lake Trasimeno, largemouth bass are collocated at the highest condition level in the scale proposed by Bennet (1971) in Heidinger (1976). In particular, the CF value increases with age and in the third year both sexes pass from an ''medium'' condition to a ''very fat'' condition.

In Lake Trasimeno, GSI depended on the size of the individual: the regression between GSI and weight had a slope of 0.0068 ± 0.00127 for females ($r = 0.51$) and 0.0012 ± 0.00013 for males ($r = 0.54$). In each case, the GSI trend during the year was calculated without considering the different age classes. The annual trend of GSI is as described by Alessio (1983) for other Italian populations. The maximum monthly GSI for the females occurred in April, immediately before reproduction, with ovary development particularly rapid between January and April. The maximum average GSI value for females is 7.71, falls within the range of 7–10 (Heidinger, 1976). The increase in testicular weight occurred more slowly and begun in autumn. The maximum monthly GSI values for males was reached in April and May (0.54) and was lower than that described by Alessio (1983) and Rosenblum et al. (1994). The GSI trend in both sexes rapidly decreases in June and no gradual decline was observed over the summer period as described by Rosenblum et al. (1994) for fish in Florida. It should be noted that egg deposition tends to be more prolonged in the more southern areas of distribution (Heidinger, 1976). In contrast, the results indicate that reproduction in Lake Trasimeno is concentrated in a rather brief period, mostly in May, with only a small part in June. Reproduction occurs when water temperatures were close to 20 °C or above.

Sexual maturity was reached at age 2 years for males and 3 years for females and at sizes 22 cm and 160 g and 30 cm and 397 g, respectively. The minimum length limit of 20 cm therefore is too small for the protection of the species; in fact, at this size the species has not started to spawn.

The results clearly indicate that the largemouth bass has acclimated well in Lake Trasimeno, having found environmental and trophic conditions that are favourable to its development. Once acclimated, an exotic species can create serious problems for fish species already present (Holcik, 1991). In Lake Trasimeno, the largemouth bass does not seem to be characterised by exclusively piscivorous feeding and there is an overlap in the diets of largemouth bass and pike (Lorenzoni et al., 1999). This is cause for concern because the pike population in Lake Trasimeno had already been declining for several years before largemouth bass were introduced (Natali, 1989).

References

Alessio, G., 1981. Ricerche sul persico trota *Micropterus salmoides* (Lacep.) nel bacino medio-superiore del F.Po (Pisces Centrarchidae). Natura 72, 197–220.

Alessio, G., 1983. Le black-bass, *Micropterus salmoides* (Lacep.), dans les eaux italiennes. Un antagoniste du Brochet? Bull. Fr. Piscic. 292, 1–17.

Bagenal, T.B., 1978. Fish Production in Fresh Waters. Blackwell Scientific Publications, Oxford.

Cowx, I.G., 1990. Developments in Electric Fishing. Blackwell Scientific Publications, Oxford.

Craig, F.J., 1978. A note on ageing in fish with special reference to the perch, *Perca fluviatilis* L. Verh. int. Ver. Limnol. 20, 2060–2064.

Froese, R., Pauly, D., 1998. Fish Base 98: concepts, design and data sources. ICLARM, Manila.

Heidinger, R.C., 1976. Synopsis of biological data on the largemouth bass *Micropterus salmoides* (Lacépède) 1802. Fish. Synopsis 115, 1–85.

Hickley, P., North, R., Muchiri, S.M., Harper, D.M., 1994. The diet of largemouth bass, *Micropterus salmoides*, in Lake Navaisha, Kenya. J. Fish Biol. 44, 607–619.

Holcik, J., 1991. Fish introdution in Europe with particular reference to its central and eastern part. Can. J. Fish. aquat. Sci. 48 (suppl.1), 13–23.

King, T.A., Davies, W.D., Shelton, W.L., 1979. Fishing and natural mortality: effects on the initial year class of largemouth bass in West Point Reservoir, Alabama-Georgia. Trans. Am. Fish. Soc. 108, 150–155.

Lorenzoni, M., Giovinazzo, G., Mearelli, M., Natali, M., 1993. Growth and biology of perch (*Perca fluviatilis* L.) in Lake Trasimeno (Umbria, Italy). Pol. Arch. Hydrobiol. 40, 313–328.

Lorenzoni, M., Carosi, A., Dörr, A.J.M., Giovinazzo, G., Petesse, M.L., Mearelli, M., 1996. Accrescimento di *Micropterus salmoides* (Lacépède) nel lago Trasimeno e nell'invaso di Montedoglio. Atti VI Convegno Aiiad, pp. 177–188.

Lorenzoni, M., Dörr, A.J.M., Erra, R., Giovinazzo, G., Selvi, S., Mearelli, M., 1999. Sovrapposizione alimentare fra *Esox lucius* L. e *Micropterus salmoides* Lac. nel lago Trasimeno. Quad. ETP 28, 179–183.

Ludsin, S.A., DeVries, D.R., 1997. First-year recruitment of largemouth bass: the interdependency of early life stages. Ecol. Appl. 7, 1024–1038.

Mearelli, M., Lorenzoni, M., Mantilacci, L., 1990. Il lago Trasimeno. Riv. Idrobiol. 29, 353-390.

Natali, M., 1989. La fauna ittica del lago Trasimeno: aggiornamento al 1988. Riv. Idrobiol. 28, 33–42.

Pardue, G.B., Hester, F.E., 1967. Variation in the growth rate of know-age largemouth bass (*Micropterus salmoides* Lacépède) under experimental conditions. Proc. Southeastern Assoc. Game fish Comm. 20, 300–310.

Pauly, D., Munro, J.L., 1984. Once more on the comparison of growth in fish and invertebrates. ICLARM Fishbyte 1 (2), 21–22.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. 191, 1–382.

Rosenblum, P.M., Brandt, T.M., Mayes, K.B., Hutson, P., 1994. Annual cycles of growth and reproduction in hatchery-reared Florida largemouth bass, *Micropterus salmoides floridanus*, raised on forage or pelleted diets. J. Fish Biol. 44, 1045–1059.

Shelton, W.L., Davis, W.D., King, T.A., Timmons, T.J., 1979. Variation in the growth of the initial year class of largemouth bass in West Point Reservoir, Alabama and Georgia. Trans. Am. Fish. Soc. 108, 142–149.

Timmons, T.J., Shelton, W.L., Davies, W.D., 1980. Differential growth of largemouth bass in West Point reservoir, Alabama and Georgia. Trans. Am. Fish. Soc. 109, 176–186.

von Bertalanffy, L., 1938. A quantitative theory of organic growth. Hum. Biol. 10, 181–243.

Weatherley, A.H., 1972. Growth and ecology of fish population. Academic Press, London.

Zerunian, S., 1980. Accrescimento in condizioni naturali ed intensive del persico trota (*Micropterus salmoides*) nel basso Lazio. Riv. It. Piscic. Ittiopatol. 15, 13–16.