Short communication

Growth and reproduction of largemouth bass
(Micropterus salmoides Lacépède, 1802) in Lake Trasimeno (Umbria, 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 $W = 0.00988LT^{3.1512±0.027}$ (males) and $W = 0.00888LT^{3.184±0.032}$ (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. © 2002 Elsevier Science B.V. All rights reserved.

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).
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.J) is the largest laminar lake
on the Italian peninsula; tectonic in origin, it has a sur-
face area of 126 km² 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 popu-
lations in Italy (Zerunian, 1980; Alessio, 1981, 1983;
Lorenzoni et al., 1996) and in other countries
(Heidinger, 1976; Rosenblum et al., 1994; Froese

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 (Wg) 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 \( W = aTL^b \) 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 speci-
mens 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 (\( S_i \)) 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 regres-
sion \( TL = a + bR_s \). The result is linear and does not
pass through the origin. Back-calculated lengths were
estimated using the following formula:
\( TL_a = TL - \frac{S_i}{R_s} \) (Bagenal, 1978), in which \( a \) is the in-
tercept with the axis of the abscissa of the previous
regression and \( TL_a \) 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 phenom-
enon, a comparison was made using the t-test between
the back-calculated lengths reached at the various ages
of the specimens at age \( n + i \).

The von Bertalanffy (1938) equation was fitted
to the mean back-calculated lengths:
\( L_t = L_\infty \left(1 - e^{-K(t-t_0)}\right) \), where \( L_t \) is the theoretical total length
(in cm TL) at age \( t \); \( L_\infty \) the asymptotic length, \( K \) the
coefficient of growth, \( t_0 \) the theoretical age (in years)
at length = 0 (Bagenal, 1978). The program Statistica
for Windows (Ver. 5.1) was used to estimate growth
parameters. \( \Phi \) (Pauly and Munro, 1984) was calcu-
lated 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)
\( CF = 100W/L^3 \), expressed in g and cm TL. The com-
parison 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, \( GSI = 100 \frac{W_g}{W} \).

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,
\( W_g = aTL^b \), 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
(TL = 26.43 cm, \( W = 374.21 \) g, age = 2.57 years)
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 $R$, was linear and does not pass through the origin: $TL = 42.4645 + 51.7067R$, ($r = 0.87, N = 151, p < 0.001$, 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

![Figure 1](image_url)  
**Fig. 1.** Frequency histogram of age-classes for the whole sample.

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>Length at age (cm)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
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<tbody>
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<td></td>
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<td>Females</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>I</td>
<td>11</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>II</td>
<td>41</td>
<td>15.609</td>
<td>21.915</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>17</td>
<td>16.265</td>
<td>24.815</td>
<td>29.960</td>
<td></td>
<td></td>
<td></td>
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<td>IV</td>
<td>6</td>
<td>16.586</td>
<td>22.141</td>
<td>29.505</td>
<td>33.443</td>
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<td>V</td>
<td>2</td>
<td>15.705</td>
<td>23.082</td>
<td>27.944</td>
<td>33.341</td>
<td>38.265</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>0</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>VII</td>
<td>1</td>
<td>14.772</td>
<td>23.149</td>
<td>29.264</td>
<td>32.567</td>
<td>37.164</td>
<td>40.820</td>
<td>42.873</td>
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<tr>
<td>Mean</td>
<td></td>
<td>15.69 ± 0.41</td>
<td>22.72 ± 0.44</td>
<td>29.67 ± 0.71</td>
<td>33.32 ± 1.20</td>
<td>37.90 ± 2.09</td>
<td>40.82</td>
<td>42.87</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>Length at age (cm)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>13</td>
<td>13.794</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>38</td>
<td>15.152</td>
<td>21.113</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>19</td>
<td>15.476</td>
<td>22.802</td>
<td>28.457</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>3</td>
<td>16.306</td>
<td>21.729</td>
<td>28.387</td>
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<tr>
<td>Mean</td>
<td></td>
<td>15.04 ± 0.39</td>
<td>21.68 ± 0.43</td>
<td>28.45 ± 0.70</td>
<td>32.69</td>
<td></td>
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</tr>
</tbody>
</table>
(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>
<thead>
<tr>
<th>Age class</th>
<th>Males</th>
<th>Females</th>
</tr>
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<tbody>
<tr>
<td>N</td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>0+</td>
<td>3</td>
<td>1.419</td>
</tr>
<tr>
<td>1+</td>
<td>13</td>
<td>1.469</td>
</tr>
<tr>
<td>2+</td>
<td>38</td>
<td>1.630</td>
</tr>
<tr>
<td>3+</td>
<td>22</td>
<td>1.629</td>
</tr>
<tr>
<td>4+</td>
<td>8</td>
<td>1.702</td>
</tr>
<tr>
<td>5+</td>
<td>3</td>
<td>1.640</td>
</tr>
<tr>
<td>Total</td>
<td>87</td>
<td>1.605</td>
</tr>
</tbody>
</table>

Fig. 3. Monthly trend of average GSI value.
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: \( W_g = 0.001 T L^{0.91 \pm 0.43} \quad (r = 0.96, \quad N = 33, \quad p < 0.001) \) (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 \( L_{\infty} \) than most other populations, and that growth is quite fast with rather high \( K \) values. Growth can be judged by the \( \Phi \) 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>
<thead>
<tr>
<th>( L_{\infty} ) (cm)</th>
<th>( K (1/y) )</th>
<th>( t_0 )</th>
<th>( \Phi )</th>
<th>Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>58.9</td>
<td>0.160</td>
<td>-0.30</td>
<td>2.74</td>
<td>Lake Rebecca, USA (Froese and Pauly, 1998)</td>
</tr>
<tr>
<td>34.1</td>
<td>0.498</td>
<td>-0.07</td>
<td>2.76</td>
<td>Lake Shorenji, Japan (Froese and Pauly, 1998)</td>
</tr>
<tr>
<td>61.5</td>
<td>0.200</td>
<td>-0.11</td>
<td>2.88</td>
<td>USA (Froese and Pauly, 1998)</td>
</tr>
<tr>
<td>50.5</td>
<td>0.310</td>
<td>0.41</td>
<td>2.90</td>
<td>Lake Rebecca, USA (Froese and Pauly, 1998)</td>
</tr>
<tr>
<td>53.5</td>
<td>0.300</td>
<td></td>
<td>2.93</td>
<td>Lake Yate, New Caledonia (Froese and Pauly, 1998)</td>
</tr>
<tr>
<td>57.3</td>
<td>0.280</td>
<td>-0.23</td>
<td>2.80</td>
<td>Montedoglio Reservoir (Lorenzoni et al., 1996)</td>
</tr>
<tr>
<td>51.0</td>
<td>0.282</td>
<td>-0.13</td>
<td>2.87</td>
<td>Lake Trasimeno (Lorenzoni et al., 1996)</td>
</tr>
<tr>
<td>46.9</td>
<td>0.330</td>
<td>0.06</td>
<td>2.86</td>
<td>Lake Trasimeno, females (current study)</td>
</tr>
<tr>
<td>39.4</td>
<td>0.420</td>
<td>-0.02</td>
<td>2.81</td>
<td>Lake Trasimeno, males (current study)</td>
</tr>
</tbody>
</table>
In Lake Trasimeno, the comparison between the sexes showed that the females were bigger than the males at all ages. Females had higher $L_\infty$ than males. In the latter, the growth was faster, the 95% of $L_\infty$ (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 $0.0068 \pm 0.00127$ for females ($r = 0.51$) and $0.0012 \pm 0.0013$ 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, just 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
