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Growth and reproductive properties of Tench, *Tinca tinca* Linnaeus, 1758 in Trasimeno Lake (Umbria, Italy)

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ABSTRACT

Key-words: *von Bertalanffy's parameters, back calculation, reproduction, fecundity, gonadosomatic index*

Growth and some reproductive properties of native *Tinca tinca* Linnaeus, 1758 from Trasimeno Lake were investigated during 2009 and 2010. The total sample of fish (510) was composed by 126 males, 221 females and 163 immature specimens.
Total length ($TL \pm 0.1$ cm) and weight ($W \pm 0.1$ g) were recorded; age estimation was based on scalimetry and sex was determined by microscopic observation of the gonads. Age composition varied from 1+ to 11+. The TL-W relationship was $\log_{10} W = -2.235 + 3.248 \log_{10} TL$. Previous growth was determined with back-calculation from scale measurements using the Fraser-Lee method. Theoretical length growth was estimated with von Bertalanffy's model. Analysis of the gonadosomatic index (GSI) suggests that the reproductive period of the population took place from May to July. Sexual maturation occurred in both sexes at the second year of life. The mean diameter of eggs was 0.075 mm. The mean number of eggs produced by each female was 233 930 and increased with the size of the specimens.
Though it is one of the most widespread and interested species in fishing in Italian waters, tench has not been widely studied; this research deepens some biological characteristics of this species that is strongly shrinking in Italy.

RÉSUMÉ

Croissance et paramètres de reproduction de la tanche, *Tinca tinca* Linnaeus, 1758 du Lac Trasimène (Ombrie, Italie)

Mots-clés : *paramètres de von Bertalanffy, rétro-calcul, reproduction, fécondité, indice gonadosomatique*

La croissance et certains paramètres de la reproduction de *Tinca tinca* Linné, 1758 du Lac Trasimène ont été étudiés au cours de 2009 et 2010. L'échantillon total de poissons (510) se composait de 126 mâles, 221 femelles et 163 individus immatures.
La longueur totale ($TL \pm 0{,}1$ cm) et le poids ($W \pm 0{,}1$ g) ont été enregistrés ; l'estimation de l'âge a été faite par scalimétrie et le sexe a été déterminé par l'observation microscopique des gonades. La composition en âge variait de 1+ à 11+. La relation TL-W était $\log_{10} W = -2{,}235 + 3{,}248 \log_{10} TL$. La croissance a été déterminée par rétro-calcul à partir de mesures sur les écailles en utilisant la méthode de

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Fraser-Lee. La croissance en longueur théorique a été estimée avec le modèle de von Bertalanffy. L'analyse de l'indice gonadosomatique (GSI) suggère que la période de reproduction de la population a lieu de mai à juillet. La maturation sexuelle a eu lieu dans les deux sexes dès la deuxième année de vie. Le diamètre moyen des œufs était de 0,075 mm. Le nombre moyen d'œufs produits par chaque femelle était 233 930 et augmentait avec la taille des spécimens.
Bien qu'elle soit l'une des espèces les plus répandues et recherchées par la pêche dans les eaux italiennes, la tanche n'a pas été largement étudiée ; cette recherche approfondit certaines caractéristiques biologiques de cette espèce qui est en forte régression en Italie.

INTRODUCTION

Tench, *Tinca tinca* (Linnaeus, 1758), is widely distributed in Europe and Asia, and has been introduced into the America, South Africa, Australia (Rosa, 1958) and recently also in China (Wang *et al*., 2006). In Italy it is an autochthonous species: it is found throughout the peninsula, including Sicily and it has been introduced in Sardinia (Zerunian, 2004).

Its wide distribution has been favored by human translocation (Gonzalez *et al*., 2000) and because of its importance for both sport-fishing and commercially, it has traditionally been intensively reared. Nevertheless, natural propagation of this species is difficult due to some environmental and biological limiting factors (Lelek, 1987). In recent years the populations of tench are strongly shrinking in Italian range so that, previously considered as "least concern" species, is currently categorized as "near threatened" in the Italian Red List (Zerunian, 2007). This reduction is occurring mainly due to the artificialization of river beds, construction of dams and water pollution (WWF Italia, 1998). Also in Trasimeno Lake the tench population has undergone to a sharp reduction of its abundance (Lorenzoni *et al*., 2007).

Trasimeno Lake (43°9′11″ N and 12°15′ E) is the fourth largest lake in Italy (124.3 km^2) and its shallowness (average depth: 4.72 m; max. depth: 6.3 m) makes it the largest laminar lake in Italy. Trasimeno is classified as an SPA of the Natura 2000 ecological network in Central Italy, according to BIOITALY (Biotopes Inventory of Italy, Italian ratification of the EU Directives HABITAT 92/43). A Mediterranean climate characterizes this biotope: its water is supplied by short intermittent streams which tend to dry up in the summer; the seasonal level of the lake is therefore quite variable. Because of these morphologic characteristics, the water temperature is almost the same as the air temperature, exceeding 30 °C in the summer; thermal stratification is usually absent (Lorenzoni *et al*., 1993). Trasimeno Lake is classified as mesotrophic (Mearelli *et al*., 1990). Aquatic macrophytes currently cover large areas of the lake, forming very dense masses, especially in shallow regions. Many phytophilic egg-layers, of which the tench is one, congregate in these areas in order to reproduce. Actually, the fish fauna of Trasimeno comprises 19 species and is dominated by cyprinids (Lorenzoni *et al*., 2010b); fish community has long been subject of man handling and the introduction of exotic species has certainly caused a severe alteration of the native faunal composition (Lorenzoni and Ghetti, 2011). Trasimeno Lake is an optimal environment for tench and, until recently, the population was one of the largest in the lake (Natali, 1993). In the '80 years, tench was the most fished species in the lake amounting to 0.01 tons ha^{-1}, that corresponded to the 30% of the total catch (Mearelli *et al*., 1990). In the next 20 years the situation has radically changed: in 2003–2004 it represented the 7,6% of total catch (La Porta *et al*., 2010) and currently the quantities are further reduced, since in 2011 the tench constituted only 3.7% of the total catch (Pompei *et al*., 2012). The remarkable decrement of tench, and other native species (Lorenzoni *et al*., 2010b), coincided with the great expansion of *Carassius auratus* (Linnaeus, 1758) (Lorenzoni *et al*., 2010a). It has been reported that the goldfish introduced into Europe affects native fish, including tench (Halačka *et al*., 2003), due to the intense competition for food and other resources. Though it is one of the most widely distributed species in Italian

waters, and among those most interested in fishing, tench has not been widely studied, indeed there are no detailed investigations on the structure and dynamics of populations and the general information reported by various authors are based on data from populations of northern Europe (Gandolfi *et al*., 1991).
The present study aims to investigate the biology of the tench, deepening some important aspects on growth, condition and reproduction in order to increase knowledge of this species of high economic value, but in worrying decline into the waters of Trasimeno Lake.

MATERIAL AND METHODS

A total of 510 specimens of tench were caught monthly from March 2009 to February 2010. Samplings were conducted by professional fishermen by means of two types of net: fyke-nets and gill-nets of different mesh size.

> GROWTH

After being caught, the fish samples were transported to the laboratory where total length (*TL*), fork length (*FL*) and standard length (*SL*) expressed in cm were measured to the nearest 1.0 mm and weight (*W* in g) was recorded with an accuracy of 0.1 g.
The following relationships were established for total sample and separated by sexes using linear regression analysis: *FL vs*. *TL* and *SL vs. TL*. Analysis of covariance (ANCOVA) was used to test differences between sexes.
The age was determined by means of the microscopic scalimetric method (Bagenal, 1978). The scales were removed from the left side of the fish, above the lateral line, near the dorsal fin (Baglinière and Le Louarn, 1987) and stored in ethanol (33%) for reuse in back-calculation.
The length-weight relationship was worked out through the least-squares method on logarithmic transformed data using the equation $W = a\,TL^b$ (Le Cren, 1951). The regressions were performed both on the whole sample and on the sample subdivided by sex. The differences between the sexes were investigated comparing the regressions by ANCOVA. Standard error was calculated for the slope (b): the hypothesis of isometric growth was tested through Student's *t*-test.
Back-calculated lengths were estimated for a subsample of 200 specimens by examining 4 scales from each one. The scale radius (S_r), from the centre of ossification to the anterior edge of the scale and the radius of the age rings (S_t) were measured along the major axis for all scales (±0.01 mm) (Bagenal, 1978) through an image-analysis system (IAS 2000); the arithmetic mean of the four measurements was considered in the analysis.
The relationship between body length and scale radius was examined through linear regression modeling: $TL = a + bS_r$ (Devries and Frie, 1996). The analysis was conducted for the overall sample and separated for sexes; the differences between males and females was tested using ANCOVA. Length at age was back-calculated following the Fraser-Lee model as $L_t = a + S_t S_r^{-1} (TL - a)$ (Bagenal and Tesch, 1985), where S_t is scale radius of *annulus t*. Back-calculated lengths at age were determined for the overall sample and separately for males and females. The differences between sexes were analyzed by Multiple Analysis of Variance (MANOVA). To investigate the occurrence of Lee's phenomenon, the back-calculated lengths reached at the various ages by the specimens at age *t* were compared with those of the older fish ($t + i$) (Bagenal, 1978) by means of the Mann-Whitney *U* test.
The theoretical growth in length was analyzed using the von Bertalanffy growth curve model (von Bertalanffy, 1938) $TL_{(t)} = L_\infty\{1 - \exp[-K(t - t_0)]\}$ where $TL_{(t)}$ is the total length (in cm) at age *t*, L_∞ is the theoretical maximum length (in cm), *K* is a constant expressing the rate of approach to L_∞ and t_0 is the theoretical age at which $TL_{(t)} = 0$. The analysis was conducted using only *TL* values back-calculated from the last *annulus* (Pompei *et al*., 2011). Back-calculated lengths for all *annuli* are commonly used in growth studies; however, in cases where a Lee Phenomenon occurs, the values of the parameters used in the equation may be over- or

under-estimated (Vaughan and Burton, 1994). The index of growth performance (ϕ') was calculated with the equation of Pauly and Munro (1984) $\phi' = \log_{10}(k) + 2\log_{10}(L_\infty)$ where k and L_∞ are the von Bertalanffy growth parameters; this index allows to compare the growth of the same species from different environments.

The condition of the specimens was evaluated using the relative condition factor (Le Cren, 1951) expressed by the formula $K' = W(aTL^b)^{-1}$, where a and b are, respectively, the intercept on the y axis and the coefficient of the regression TL-W calculated on the whole sample. Relative condition factor was also calculated using the somatic weight: $K'_s = (W - W_g)(aTL^b)^{-1}$, where W_g is the gonad weight. The trend of both parameters throughout the year was analyzed only in females, due to the low number of males captured in some months.

> *REPRODUCTION*

Sex was determined by microscopic observations of the gonads. The gonads were removed and weighed to the nearest of 0.01 g (W_g). The reproductive state of all specimens was assessed according to the Nikolsky scale (Bagenal and Tesh, 1985).

Sex ratio was investigated testing deviation from the 1:1 null hypothesis through chi-square (χ^2) analysis.

Mean size at maturity was calculated for both sexes from the percentage of mature individuals in each size class (in 1 cm TL intervals; Trippel and Harvey, 1987) using the formula $\alpha = \sum_{x=0}^{W}(x)[f(x) - f(x-1)]$ (DeMaster, 1978), where α is the mean size at maturity, x is size in cm, $f(x)$ is the proportion of fish mature at size x, and w is the maximum size in the sample.

Spawning period was determined from monthly variations of the gonadosomatic index (GSI) in females, which was calculated by the equation $\mathrm{GSI} = 100\,(W_g W^{-1})$ (Ricker, 1975).

Fecundity (F) was estimated taking three subsamples of eggs from the front, middle and back parts of each ovary at stages IV and V of gonad development. All eggs in the subsamples were counted; the total number of eggs in each ovary was proportional to the total ovary weight (Ricker, 1975). Relative Fecundity (RF) was expressed as the number of eggs produced (F) per unit of body weight (W): $RF = 1000\,(FW^{-1})$. The diameters of 10 randomly selected eggs for each mature ovary were measured using an image-analysis system (IAS 2000) (Lorenzoni *et al*., 2011). The mean value (δ in cm) of the diameters measured for each female was used in the subsequent analysis. In order to analyze how fecundity, relative fecundity and mean diameter of eggs changed with the increase of length of the females, the following regressions were calculated: $F = a\,TL^b$, $RF = a + b\,TL$ and $\delta = a + b\,TL$.

RESULTS

> *GROWTH*

The total sample of fish caught (510) in Trasimeno Lake was composed by 126 males, 221 females and 163 immature specimens. The age of fish ranged from 1 to 11 years and the second age group was dominant in the population ($n = 248$) (Table I). The sampled fish ranged in total length from 4.20 to 50.20 cm (mean $\pm SE = 25.19 \pm 0.43$) and in weight from 0.70 to 1919.40 g (mean $\pm SE = 350.44 \pm 21.34$). Females were longer and heavier than males, and the differences between sexes proved to be highly significant in the Student's t-test for both the analyzed parameters (length: $t = -2.473$, $p < 0.05$; weight: $t = -3.182$, $p < 0.05$).

The TL-FL regression was $LF = 0.141 + 0.955\,TL$ ($r^2 = 0.999$, $r = 0.999$, $p < 0.05$) for the whole sample, $LF = 0.247 + 0.950\,TL$ ($r^2 = 0.999$, $r = 0.999$, $p < 0.05$) for males and $LF = 0.124 + 0.957\,TL$ ($r^2 = 0.999$, $r = 0.999$, $p < 0.05$) TL for females. No differences emerged between sexes at ANCOVA ($F = 1.528$, $p > 0.05$).

The TL-SL relationship was found to be $LS = -0.247 + 0.849\,TL$ ($r^2 = 0.999$, $r = 0.999$, $p < 0.05$) for the whole sample and $LS = -0.0559 + 0.839\,TL$ ($r^2 = 0.999$, $r = 0.999$, $p < 0.05$)

Table I
Age and sex composition of Tinca tinca *population from Trasimeno Lake, expressed as the number of immature, males and females specimens in each age class.*

Age class	All	Immature	Males	Females
1+	31	28	2	1
2+	248	128	44	76
3+	115	7	45	63
4+	9	–	6	3
5+	25	–	12	13
6+	51	–	16	35
7+	6	–	–	6
8+	16	–	1	15
9+	5	–	–	5
10+	3	–	-	3
11+	1	–	–	1
All	**510**	**163**	**126**	**221**

and $LS = -0.344 + 0.853\,TL$ ($r^2 = 0.999$, $r = 0.999$, $p < 0.05$) for males and females, respectively. Comparison between regressions revealed no significant differences between sexes (ANCOVA: $F = 2.095$, $p > 0.05$).

The relationship between body weight and total length calculated on the entire sample, without distinction between the sexes, was described by the equation: $\log_{10} W = -2.235 + 3.248 \log_{10} TL$ ($r^2 = 0.992$, $r = 0.996$, $p < 0.05$). The relationship between body weight and total length was $\log_{10} W = -2.319 + 3.305 \log_{10} TL$ ($r^2 = 0.994$, $r = 0.997$, $p < 0.05$) for females and $\log_{10} W = -2.266 + 3.266 \log_{10} TL$ ($r^2 = 0.987$, $r = 0.993$, $p < 0.05$) for males. Comparison between regressions revealed statistically significant differences between sexes (ANCOVA: $F = 10.437$, $p < 0.05$), with females that can reach weights significantly greater than that of males of the same length. For each of the equations found, the regression coefficient b proved to be statistically greater than 3 at the t-test (female, male, total sample: $p < 0.05$), indicating a positive allometric growth (Ricker, 1975).

The relationship between the length of specimens at the time of capture and total radius of the scales was described by the equation: $TL = 4.908 + 61.399\,S_r$ ($r^2 = 0.930$, $r = 0.865$, $p < 0.05$) for the total sample, $TL = 9.191 + 52.669\,S_r$ ($r^2 = 0.734$; $r = 0.857$, $p < 0.05$) for males and $TL = 6.898 + 58.744\,S_r$ ($r^2 = 0.848$; $r = 0.921$, $p < 0.05$). No differences emerged between sexes (ANCOVA: $F = 0.202$; $p > 0.05$); the equation for the total sample was therefore adopted in the subsequent analyses.

The mean back-calculated lengths at various ages were determined for the overall sample (Table II) and separately for males and females. The differences between sexes were not statistically significant at Multiple Analysis of Variance (MANOVA) ($F = 1.597$; $p > 0.05$).

Comparison of the mean back-calculated lengths between specimens of age t and those of age ($t + i$) revealed the existence of Lee's phenomenon: more specifically, for the age classes 1+, 2+, and 3+ it was observed a reversed Lee's phenomenon, since the back-calculated lengths reached at the various ages showed significant differences in favor of the older specimens. By contrast, for the age classes 5+, 6+, 7+, a positive Lee's phenomenon occurred, being the length of specimens of age ($t + i$) significantly lower than those of age t (Table III).

The back-calculated lengths at various ages were used to evaluate the specimens' growth. The parameters of theoretical growth ($\pm SE$) in length were $L_\infty = 50.54 \pm 1.814$ cm, $k = 0.27 \pm 0.035$ yr^{-1}, $t_0 = 0.14 \pm 0.196$ yr. The growth performance index ϕ' was 2.845.

The mean value of condition factor ($K' \pm SE$) for the overall sample was found to be 1.012 ± 0.005, while the condition factor calculated using the somatic weight was ($K'_s \pm SE$) 0.989 ± 0.004. Comparison between sexes revealed that, regarding K', the mean value resulted slightly higher in female sample (1.010 ± 0.006) than in males (0.999 ± 0.010), but no significant difference emerged at statistical test of t-Student's ($t = 0.683$, $p > 0.05$). The condition appears to be affected by the ovary mass, since, comparing K'_s, the mean value of

Table II
Mean back-calculated total length (TL in cm) ± standard error (SE) at successive annuli *for a sub-sample (n = 200) of the* Tinca tinca *population from Trasimeno Lake. Back-calculated lengths derived from the last annulus are shown in bold.*

	Mean back-calculated *TL* ± *SE* at successive *annuli*										
Age class	1	2	3	4	5	6	7	8	9	10	11
1+	**12.04 ± 0.19**										
2+	12.54 ± 0.19	**18.29 ± 0.25**									
3+	14.54 ± 0.33	20.86 ± 0.43	**25.91 ± 0.41**								
4+	15.34 ± 0.33	22.30 ± 0.42	28.35 ± 0.40	**33.39 ± 0.35**							
5+	16.00 ± 0.27	22.68 ± 0.35	28.98 ± 0.33	34.32 ± 0.29	**38.86 ± 0.27**						
6+	15.65 ± 0.44	22.36 ± 0.56	28.56 ± 0.54	34.08 ± 0.48	38.26 ± 0.43	**41.35 ± 0.35**					
7+	15.13 ± 0.38	21.19 ± 0.49	27.01 ± 0.47	32.20 ± 0.42	36.44 ± 0.38	40.00 ± 0.31	**43.03 ± 0.25**				
8+	14.63 ± 0.44	20.22 ± 0.56	25.38 ± 0.54	30.23 ± 0.48	34.69 ± 0.43	38.43 ± 0.35	41.60 ± 0.28	**44.32 ± 0.28**			
9+	14.10 ± 0.98	19.45 ± 1.26	25.14 ± 1.20	29.98 ± 1.06	34.74 ± 0.97	38.93 ± 0.79	42.15 ± 0.62	44.61 ± 0.64	**45.48 ± 0.07**		
10+	14.19 ± 1.38	19.06 ± 1.78	23.00 ± 1.70	26.96 ± 1.50	30.59 ± 1.37	34.56 ± 1.12	38.08 ± 0.88	40.91 ± 0.90	43.51 ± 0.31	**46.01**	
11+	15.40 ± 1.38	20.14 ± 1.78	23.88 ± 1.70	27.51 ± 1.50	31.16 ± 1.37	35.29 ± 1.12	39.10 ± 0.88	41.99 ± 0.90	44.53 ± 0.31	46.94 –	**48.55**
Mean ± *SE*	**13.75 ± 0.15**	**20.52 ± 0.20**	**27.47 ± 0.22**	**32.96 ± 0.25**	**37.22 ± 0.30**	**39.68 ± 0.32**	**42.07 ± 0.29**	**43.95 ± 0.36**	**45.46 ± 0.86**	**46.47 ± 0.46**	**48.55**

Table III
Lee's phenomenon in the subsample of Tinca tinca *from Trasimeno Lake: comparison of back-calculated total lengths between the specimens at age t and (t + i). The results of Mann-Whitney U test are given; values of p* < 0.05 *were considered significant.*

	age *t*		age (*t* + *i*)		Mann-Whitney *U* test	
Age class	*N*	*TL* Mean ± *SE*	*N*	*TL* Mean ± *SE*	*z*	*p*
1+	51	12.04 ± 0.18	149	14.34 ± 0.16	–7.03	<0.05
2+	51	18.29 ± 0.28	98	21.69 ± 0.19	–7.86	<0.05
3+	17	25.91 ± 0.58	81	27.80 ± 0.23	–2.94	<0.05
4+	18	33.39 ± 0.39	63	32.83 ± 0.30	0.78	>0.05
5+	26	38.86 ± 0.28	37	36.07 ± 0.37	4.79	<0.05
6+	11	41.35 ± 0.47	26	38.97 ± 0.33	3.42	<0.05
7+	12	43.03 ± 0.20	14	41.25 ± 0.40	3.39	< 0.05
8+	10	44.32 ± 0.30	4	43.03 ± 0.94	1.41	> 0.05
9+	2	45.48 ± 0.07	2	44.02 ± 0.51	1.55	>0.05

females (0.968 ± 0.01) was lower than that of males (0.991 ± 0.011) and the difference proved to be significant ($t = 2.113$, $p < 0.05$). The analysis of the trend of K' and K'_s throughout the year in females (Figure 1) clearly showed that the differences between the two values are greater from May to July testifying the sharp increase in weight during the reproductive period due to the development of the ovaries. The lowest mean values for both parameters were recorded in September ($K' = 0.923 \pm 0.036$; $K'_s = 0.911 \pm 0.033$); the worst condition is therefore reached at the end of summer.

> *REPRODUCTION*

The mean size at maturity was 19.94 cm *TL* for females and 20.60 for males, that corresponds, for both sexes, to the second age class; all specimens bigger than 23 cm were mature (Table IV).

The mean value of GSI (± *SE*) calculated for the females sample throughout the year was 3.784 ± 0.284, varying from 0.011 to 15.199. The monthly variations in GSI values (Figure 2) showed a rapid increase by April, reaching the highest mean values in the months of May (8.590 ± 0.568) and June (8.914 ± 0.755); GSI decreased in July (2.234 ± 1.351) until it reached the minimum mean value in August (0.900 ± 0.036).

The number of eggs ranged from 28331 to 541506 and mean absolute fecundity (±*SE*) was 233930 ±13120. Fecundity was positively correlated with length of fish (Figure 3a) ($r^2 = 0.474$, $r = 0.688$, $p < 0.05$): longer fish showed a higher fecundity. The value of relative fecundity was 168325 ± 7202 eggs kg^{-1} of total body weight; it increased only slightly as a function of size (Figure 3b) ($r^2 = 0.010$, $r = 0.101$) and this correlation resulted not statistically significant ($p > 0.05$). The diameter of eggs varied from 0.059 to 0.090 cm with a mean value (± *SE*) of 0.075 ± 0.01 and it was independent from the size of the females: a positive relation occurred between the two parameters (Figure 3c) ($r^2 = 0.011$, $r = 0.102$), but this correlation was not statistically significant ($p > 0.05$).

DISCUSSION

Tench is well adapted to the shallow, vegetation-rich environment of Lake Trasimeno: the high productivity of the lake can supports an abundant fish population by providing the basis of the fish diet (Lorenzoni *et al.* 2007). The growth of tench is evidence of these favorable environmental conditions. The regression coefficient of the *TL*/*W* relationship was well above 3;

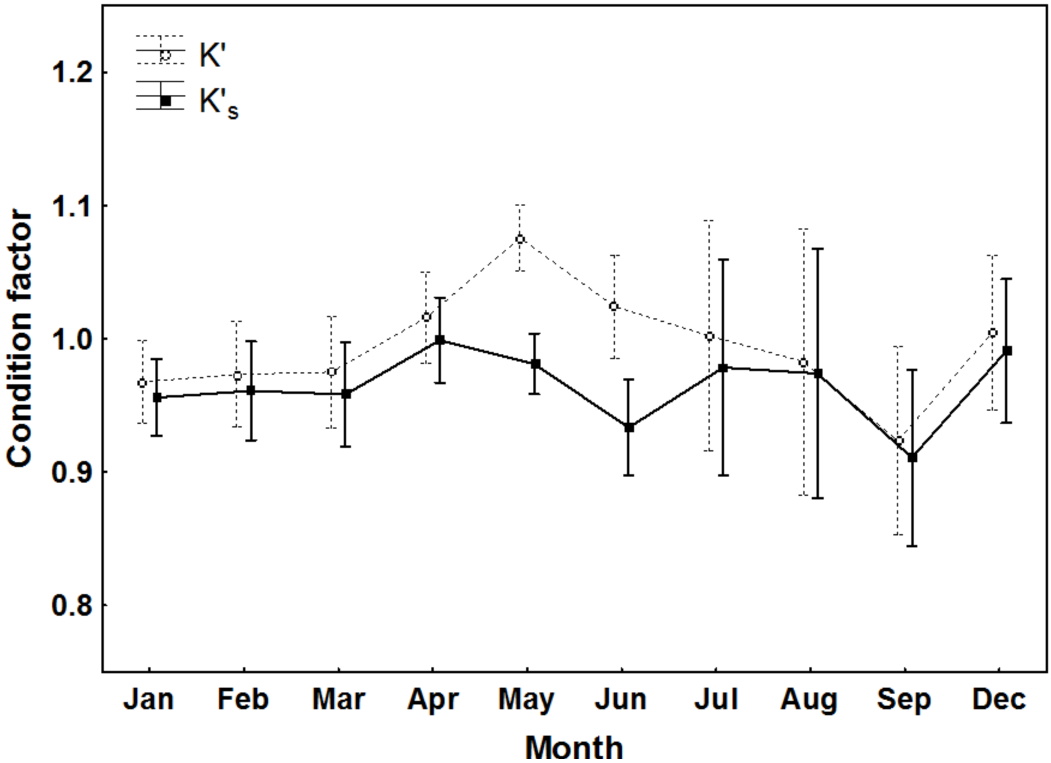

Figure 1
Monthly variation in condition in female sample of Tinca tinca *population from Trasimeno Lake. The solid line indicates condition factor calculated using total body weight (K′) and the dotted line indicates condition factor calculated using the somatic weight (K'_s). Vertical bars indicate 95% confidence intervals.*

Table IV
Proportion of mature males and females for each size and age class in Tinca tinca *population from Trasimeno Lake.*

Size class	% Mature males	% Mature females
<15	all immature	
15.1–16	0.00	12.50
16.1–17	6.06	8.82
17.1–18	14.71	23.68
18.1–19	13.33	29.73
19.1–20	26.32	30.00
20.1–21	51.52	65.22
21.1–22	63.64	66.67
22.1–23	64.29	68.75
> 23.1	all mature	

the value calculated for the whole sample was similar to (Altindag *et al*., 2002), or higher than those reported in the literature (O'maoileidigh and Bracken, 1989; Wright and Giles, 1991; Altindag *et al*., 1998; Sinis *et al*., 1999; Miranda *et al*., 2006; Alaş and Ak, 2007; Balık *et al*., 2009; Erguden and Goksu, 2009; Erguden and Goksu, 2010; Innal, 2010). The tench in Trasimeno Lake can reach the length of 50.54 cm and the rate of growth was high (0.27 yr^{-1}); also the growth performance index testifies the quality of the growth, being its value the higher reported in literature for other populations (Wright and Giles, 1991; Balık *et al*., 2009; Froese and Pauly, 2011).

Although biased in favor of younger age classes, the population structure is though continuous and life span proved to be over 11 years, according to the typical species longevity

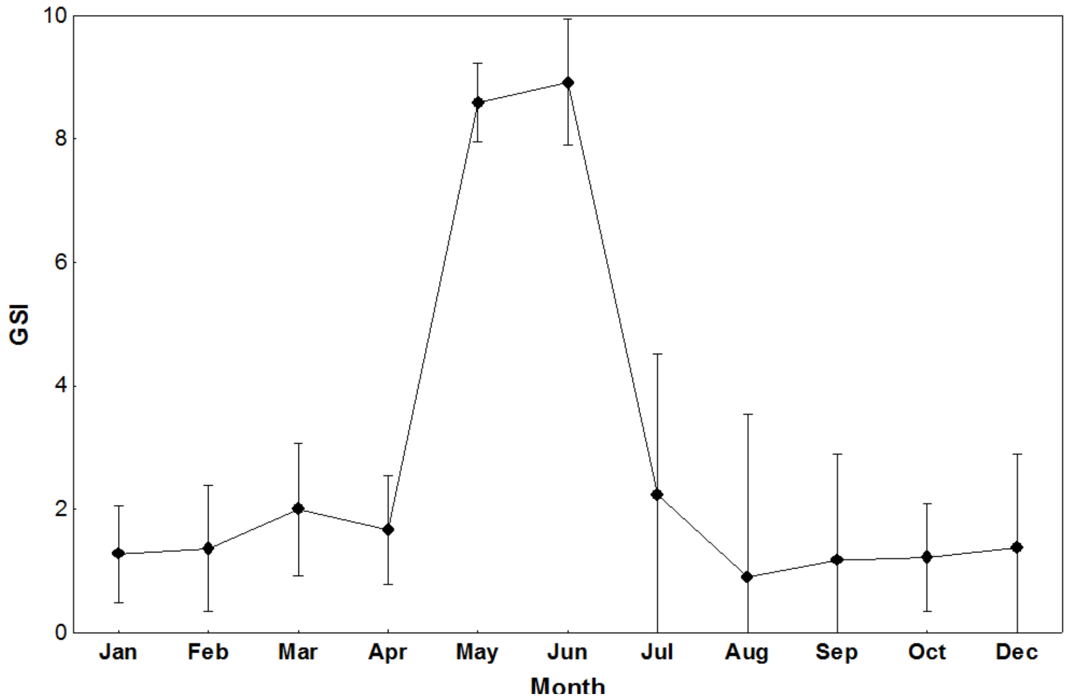

Figure 2
Monthly variations in mean GSI values and female sample of Tinca tinca *from Trasimeno Lake. Vertical bars indicate 95% confidence intervals.*

(Gandolfi *et al*., 1991). However, the maximum age found in Trasimeno Lake was well higher than those reported in literature for other environments (Wright and Giles, 1991; Altindag *et al*., 2002; Benzer and Yılmaz, 2007; Balık *et al*., 2009; Gürbüz, 2011; Erguden and Goksu, 2010; Vetlugina, 1992).

As regard the wellbeing of fishes, females proved to be in better condition than males, but this result seemed to be affected by the ovary mass; indeed, when the somatic weight was considered in the calculation of condition factor, it was greater in males than females with statistically significant differences. The monthly trend analysis of K' and K'_s reveals not only how condition varied during the year, but also provides some information on the reproductive investment of females identifying the reproductive period, since after the month of April the K' grew rapidly, attesting an increase in ovarian mass and simultaneously the K'_s decreased until June: during spawning the somatic condition of females was subjected to a real worsening. The occurrence of reproduction in the months of May and June was also confirmed by the analysis of GSI throughout the year, however some specimens spawned their eggs until July. The spawning season appears to be similar to that observed by some authors in Greece (Neophitou, 1993) and Russia (Berg, 1963), while several other authors reported a longer breeding time (Nikolsky, 1963; Poncin *et al*., 1987; Linhart and Billard, 1995; Yılmaz, 2002; Benzer and Yılmaz, 2007; Gürbüz, 2011). The temperatures of the water in Trasimeno Lake are highly variable, strongly influenced by the atmospheric temperature. The length of the reproductive period may be influenced by the rapid heating in spring and by the achievement of very high temperatures in summer, as in July the water exceeded 30 °C. In agreement to the mean size of maturation found in this research, tenches below 21 cm should not be fished in Trasimeno Lake. The Regional Regulation of professional and sporting fishing (DGR 121-2011) assessed the legal size at 25 cm: this is greater than the size at which specimens attain the first reproduction, but is probably too close for safeguarding the species. However, tench in Trasimeno Lake showed a good reproductive potential: both absolute and relative fecundity were found well higher than reported in the above studies. Fecundity was significantly correlated to fish length, but with the growth of specimens didn't occur the tendency to improve

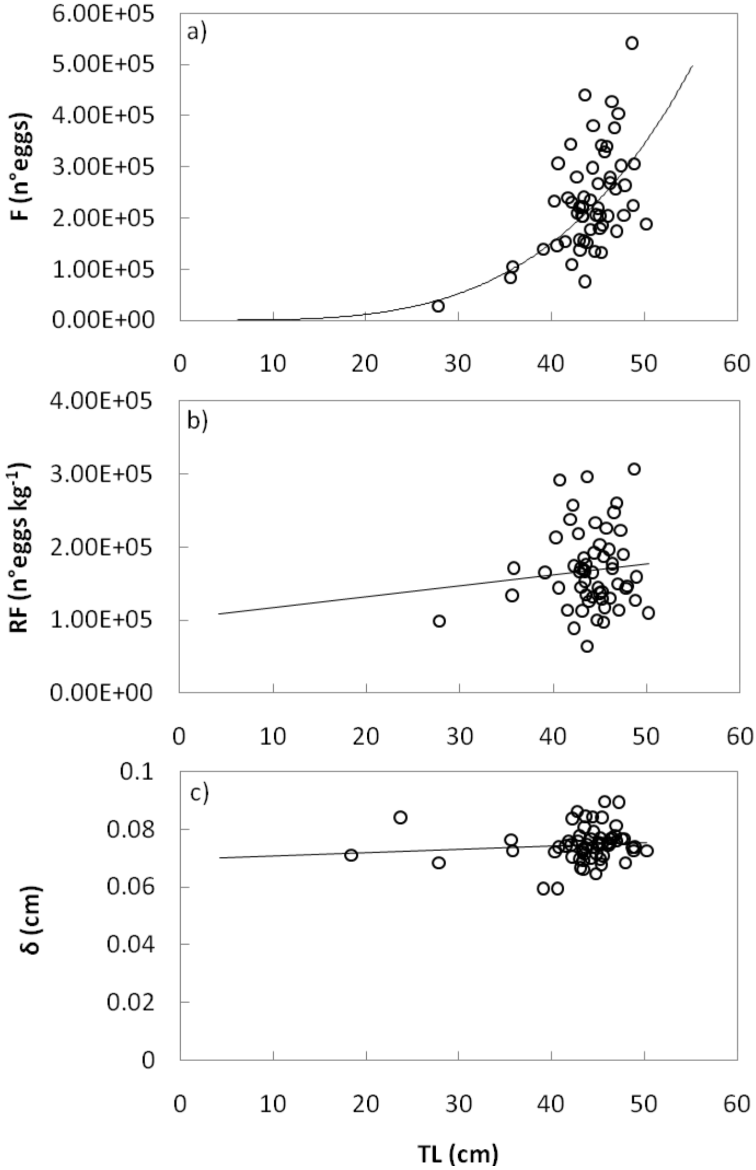

Figure 3
Correlation between (a) egg number (F), (b) relative fecundity (RF), (c) eggs diameter δ in cm) with total length (TL in cm) in Tinca tinca *females from Trasimeno Lake.*

the quality of the eggs at the expense to the quantity: the diameter of eggs, indeed, was quite homogeneous in all size classes and, consequently, also the relative fecundity values.

The reproductive strategy, along with the balanced population structure and the growth values, indicated that Trasimeno Lake is a favorable environment for tench, in which the species have good condition and chance to survival.

But the decline of population that occurred in recent years could be justified by a series of causes that act together. The research, indeed, has shown that the tench population of Trasimeno Lake seemed to verify selective mortality phenomena relating to the size of the specimens, but that affected the age groups in a differential way. In the youngest age classes an inverse Lee's phenomenon occurred to testify that mortality affected the smallest individuals. This can be explained by the existence of very intense intraspecific interactions among the younger specimens which favors those of larger size (Lorenzoni *et al*., 2002a). Is to be verified whether this phenomenon may be due also to the competition for food resources with the *Carassius auratus* (Lorenzoni *et al*., 2007). Otherwise, it could be the predation acting more strongly on small specimens (Ricker 1975); however, fish assemblage, with regard to predators, is not substantially changed in recent years. The latest introduction is the Large-mouth Bass, *Micropterus salmoides* (Lacepedè, 1802), but it does not seem to prefer the tench among its preys (Lorenzoni *et al*., 2002b) and does not appear to have abundances such to affect the population dynamics of tench in the Trasimeno lake. Thus, is not to be excluded that the predatory pressure on the smaller specimens is performed by cormorants *Phalacocrorax carbo*. It is extremely difficult to quantify the impact of cormorants, as well as other ichthyophagous, on natural fish stocks (Dekker and De Leeuw, 2003), but the abundance of cormorants colonies in Trasimeno Lake are increasing (Cucchia, 2004) and numerous studies have found that the main prey species of cormorants are cyprinids (Santoul *et al*., 2004; Volponi *et al*., 2005), especially young tench in the shallow waterbodies (Suter, 1997), like Trasimeno is. On the contrary, the larger specimens seemed to be disadvantaged in the older age classes as testified by the positive Lee's phenomenon. This could imply that slower-growing members of the year-class escaped fishing-related or natural mortality better than faster-growing members did (Devries and Frie, 1996). Lee's phenomenon may also be due to non-random sampling of the stock; for example, if sampling tends to select the larger members (Bagenal, 1978). In Trasimeno Lake the occurrence of Lee's phenomenon in the older age classes is probably due to excessive fishing effort, which acts on the larger specimens. In effect, the tench population may have been subject to an excessive yield, as also evidenced by the scarcity of older specimens. The professional fishing indeed is of primary role in Trasimeno Lake, since it is still an important economic activity and the local community of professional fishermen is one of the most numerous of all the Italian inland waters (Natali and Gennari, 1989).

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