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GROWTH AND BIOLOGY OF PERCH (*PERCA FLUVIATILIS* L.) IN LAKE TRASIMENO (UMBRIA, ITALY)

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ABSTRACT

The growth and biology of the *Perca fluviatilis* population in Lake Trasimeno was studied by examining 940 specimens. The weight-length relationship, calculated separately for the sexes, negates the presence of an isometric growth. The growth, determined by backcalculation, was very good. The development of the perch of Lake Trasimeno was rapid, negating any hypothesis of dwarfism. In the 0+ age class, a continuous growth was observed during all the season without any lag time in the winter. Both sexes reached sexual maturity during the first year with an earlier seasonal development of the gonads in the males. Reproduction occurred in March and April. The data indicate the need to regulate the limit of perch caught in Lake Trasimeno, using equipment which avoids depleting the stock and disrupting the population structure. Some biological peculiarities were observed which distinguish the Lake Trasimeno perch population.

Keywords: *Perca fluviatilis*, growth, biology, Lake Trasimeno.

1. INTRODUCTION

The fish management in Lake Trasimeno, as is true for almost all the Italian waters, is not based on scientific criteria that could guarantee a rational use of the resources. Every study that contributes to the knowledge of the fish fauna under natural conditions is of particular importance because the information can be used to improve management efficiency.

Research on perch is also important because the Lake Trasimeno population has never been studied, even though, in the overall fishing economy, it is one of the most remunerative species and is being harvested intensively. As occurs periodically for other species, the stock decreases rapidly and the harvest consists of predominantly small fish. The professional fishermen attribute this phenomenon to the influence of pollution and to an inherited stunted growth (dwarfism), which has never been proven.

Knowledge about the Italian perch populations is scarce and fragmentary (Giovinazzo 1988; Alessio et al. 1992; Lorenzoni et al., in print). The available data refer mostly to populations of north-central Europe and therefore do not appear to be immediately transferable to the Italian situation which is at the southern limits of the species distribution in Europe (Ladiges, Vogt 1986; Gandolfi et al. 1991) and which may be characterised by some particular biological characteristics.

Therefore, the study of the growth and biology of the *Perca fluviatilis* population of Lake Trasimeno is particularly important because it may help dispel some preconceived ideas and to give some insights which would permit the empirical practices to be abandoned in the attempt to achieve a more scientific approach to harvesting the lake's natural resources.

2. MATERIAL AND METHODS

Lake Trasimeno (Fig.1) is a lake of tectonic origin situated in the Province of Perugia (central Italy: 43°9'11" N. Lat. and 12°15' E. Long.) between the Tiber and Arno River basins. It is the fourth largest lake in Italy (124.3 km^2) and the most extensive of the Italian peninsula. The shallowness (average depth = 4.72 m; max. depth = 6.3 m) characterises Lake Trasimeno as the largest laminar lake in Italy.

The catchment basin is made up of lands with low permeability and covers an area of 357.98 km^2 (Carollo 1969), about three times greater than the surface of the lake. The water is supplied by short intermittent streams which have little or no water in the summer. The average annual range of the lake level is therefore quite variable. Due to the morphologic characteristics of Lake Trasimeno, the water temperature is almost the same as the air temperature, therefore, very high in the summer; thermal stratification is usually absent. During the period 1969–1979 the average of the monthly water temperature values at the centre of the lake was 14.73°C at the surface and 14.54°C at the bottom;

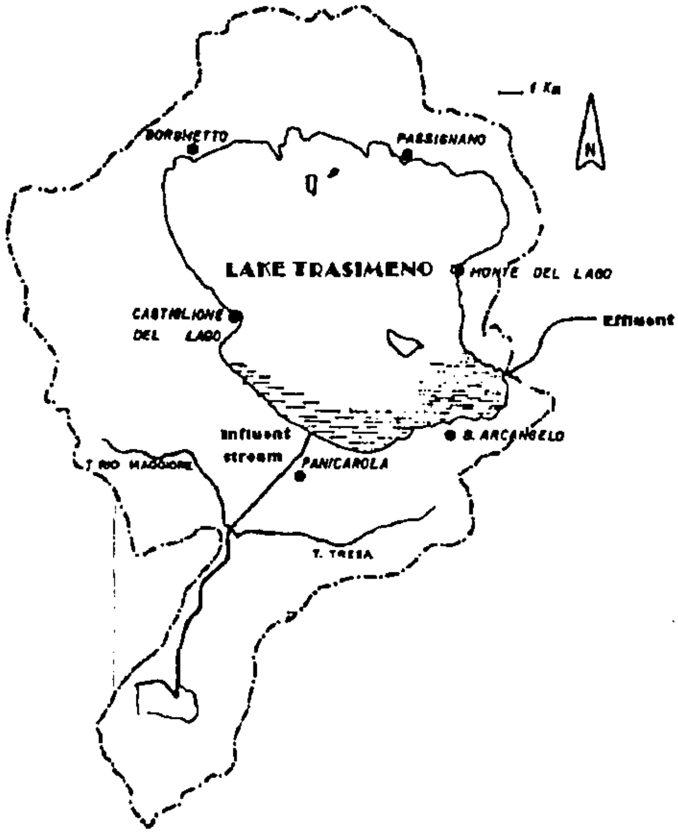

Fig. 1. Hydrographic basin of Lake Trasimeno (Taticchi 1981)

the minimum values were 4.07 and 3.00°C (January) and the maximum values 25.90 and 25.20°C (August) for the surface and bottom, respectively (Gianotti et al. 1982).

From a trophic point of view, Lake Trasimeno is very productive. The total N and orthophosphate phosphorous levels in the winter are such that the lake is classified mesotrophic now (Mearelli et al. 1990) even though, just a few years ago when a clean up program came into operation, the lake had poly-mesotrophic conditions (Mearelli et al. 1981).

The fish community is made up of 18 species dominated by cyprinids including tench (*Tinca tinca* L.), carp (*Cyprinus carpio* L.) and rudd (*Scardinius erythrophthalmus* L.); other common species are eel (*Anguilla anguilla* L.), perch (*Perca fluviatilis* L.) and sandsmelt (*Atherina boyeri* Risso). The population of pike (*Esox lucius* L.), once much more numerous, seems to be in progressive decline (Natali 1989). Today, fishing is still one of the main economic activities for the local population and even though the current number (170) of professional fishermen has decreased with respect to the past, it is still the highest number in Italy for the inland lakes (Natali, Gennari 1989). Perch is the most lucrative fish harvested. In 1990, according to data furnished by the professional fisherman's co-operative, 0.006 tons $\cdot$ ha^{-1} were harvested from Lake Trasimeno which was second only to tench, 0.01 tons $\cdot$ ha^{-1}.

The study was conducted for one year (May 1989–90) in collaboration with five professional fishing co-operatives operating on the lake. Monthly samples were taken. Different methods were used to sample the fish: monofilament nets (22 and 25 mm meshes), fyke nets with 2.2 m diameter opening and 3 mm mesh nets. All three system were left in the water overnight and removed the following morning. A total of 940 perch were captured and the following measurements were taken for each specimen:

Total length (TL) in cm, measured from the anterior point of the snout to the posterior edge of the superior lobe of caudal fin.

Standard length (SL) in cm, measured from the anterior point of the snout to the last scale on the caudal peduncle.

Total weight (TW) in g, measured to the nearest 0.1 g on electronic balance.

Gonad weight (GW) in g, measured to nearest 0.001 g on electronic balance.

Sex was recognised by gonad examination. Sex was not determined for all specimens, but during the very abundant monthly fish catches a randomized subsample was chosen. In this way a total of 325 males and 445 females were identified.

Age was determined by reading the scale samples (Van Utrecht, Schenkkan 1972; Bagenal, Tesch 1978) taken from the left side of the fish in an area below the lateral line and behind the pectoral fin (Bagliniere, Le Louarn 1987). The samples that were difficult to read were discarded (9 specimens).

Back-calculation was done on a subsample of 40 individuals captured in February 1990. For every specimen, four scales were removed from the same area used to determine the age. After being mounted between two glass slides, the scales were read using a micro projector. In each of the scale the distance of the focus from the various annulus (rays of annulus) and from the external edge of the scale (scale rays) was measured to the nearest 0.01 mm. Therefore, for every specimen the average of the 4 scale measurements was calculated and used in the successive analyses.

3. RESULTS

SAMPLE CHARACTERISTICS

The average standard length of the 940 specimens was about 10 cm (range 4.8–25.5 cm) with a coefficient of variation 29.55% (Tab. I). This very low value indicates that the sample was made up predominantly of individuals of homogeneous lengths, in fact, just under 50% of the specimens were between 6 and 10 cm long (Fig.2).

Table I. Statistical description of the entire sample of *Perca fluviatilis*

	SL (cm)	Weight (g)	Age (months)
Sample size	940.00	940.00	620.00
Average	10.15	23.31	20.21
Median	9.70	14.40	22.00
Mode	13.00	6.10	24.00
Geometric mean	9.72	15.10	15.14
Variance	8.98	777.24	168.31
Std. deviation	3.00	27.88	12.97
Std. error	0.10	0.91	0.52
Minimum	4.80	1.70	0.70
Maximum	25.50	351.00	82.00

The existing relationship between total length and standard length was determined by linear regression analysis:

$$TL = 0.42 + 1.136\ SL\ (r = 0.99 \text{ and } R^2 = 99.04\%)$$

The average weight of the specimens was 23.31 g with a coefficient of variation 119.6%, the range was 1.7–351.0 g (Tab. I) with the prevalent values between 0 and 50 g (Fig. 2) but 60% were between 0 and 20 g.

The age of the 931 specimens averaged about 15 months with a variation coefficient of 84.36%; most (80%) were less than 2 years old.

SEASONAL GROWTH

The seasonal growth was evaluated for the 0+ age class only because not enough specimens of the other classes were obtained that would permit statistical analysis. The data related to standard length and weight were formulated as seasonal averages, starting in June when the fries first appeared in the first take. In Fig. 3 the trend of the average seasonal values for length and weight are reported with the respective confidence limits. The data analysis showed that the length of the individuals increased steadily during the whole first year with no lag time in the winter. The weight increased accelerated from autumn to winter.

WEIGHT-LENGTH RELATIONSHIP

The weight-length relationship, $TW = aSL^b$ (in which TW is the weight of the fish in g, SL is the standard length in cm, and a and b are constants) was calculated with a least square method, separately for the sexes after log transformation of the data ($\log TW = \log a + b \log SL$) (Ricker 1975). The relationship found were $TW = 0.0092SL^{3.24\pm0.05}$ ($r = 0.99$ and $R^2 = 98.04\%$) for the males (Fig. 4) and TW

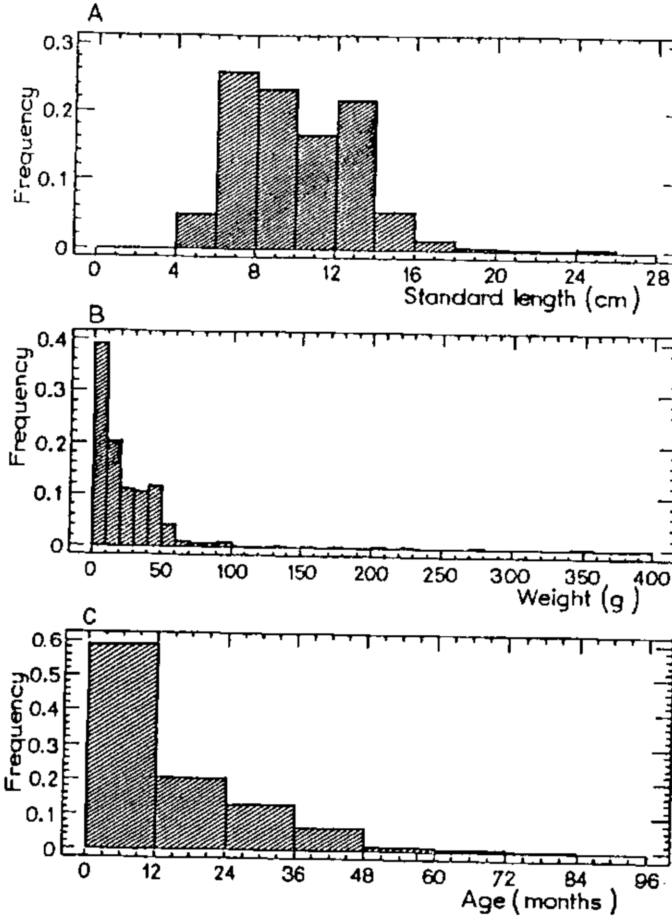

Fig. 2. Frequency histograms for *Perca fluviatilis* standards length (A), weight (B) and age (C) of the whole sample

$= 0.008SL^{3.3\pm0.05}$ (r = 0.99 and R^2 = 97.81%) for the females (Fig. 5); the differences between the males and females were not significant (t-test, P>0.05). To evaluate the growth of the perch of Lake Trasimeno more clearly the G.M. functional regressions were defined which gave a better estimate of the functional relationship between the independent variable (standard length) and the dependent variable (weight) (Ricker 1975). The entire sample was subdivided into homogeneous seasonal subsamples, regrouping the monthly values of the standard lengths and weights; this was done separately for the sexes (Tab. II). Based on the calculations, and keeping in mind that b values which significantly deviate from 3 indicate an allometric growth (Ricker 1975), the hypothesis that the males and females showed an isometric growth during all the periods considered can be excluded.

BACK-CALCULATION

Data from the scale measurements were used to determine a linear relationship between standard length and scale radius. Using regression analysis with a least

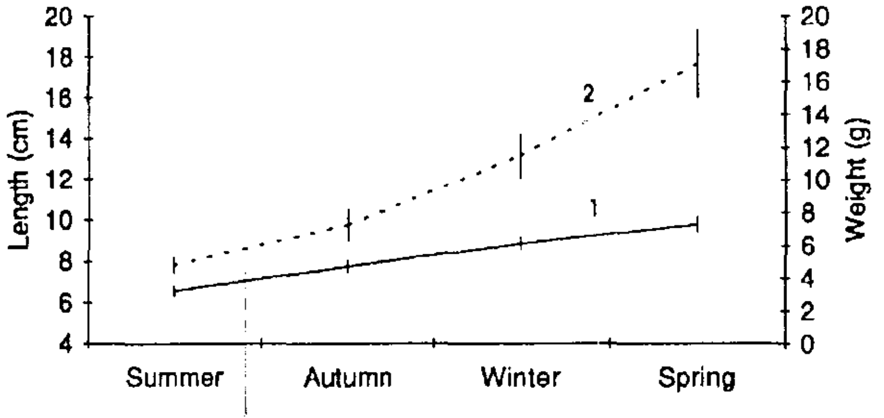

Fig. 3. Seasonal growth in length (1) and weight (2) in Class 0+ of *Perca fluviatilis*

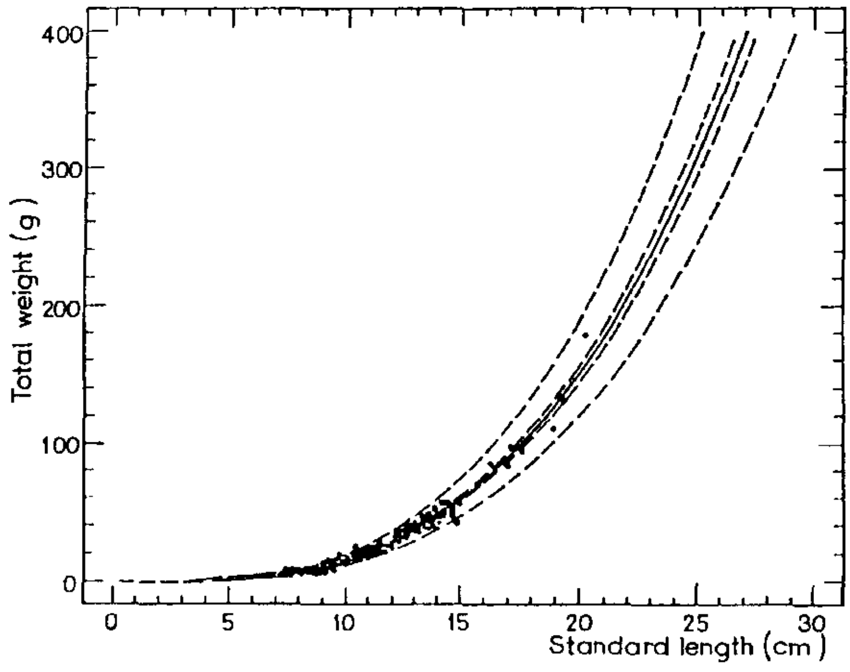

Fig. 4. Standard weight-length regression with 95% confidence and prediction limits in *Perca fluviatilis* males

squares method, the following relationship was found (in mm): SL = 39.078+33.79 R (r = 0.98 and R^2 = 96.87%). The regression line does not pass through the origin and therefore, the length of the fish at the various ages was estimated by the following, proportionally modified formula (Bagenal, Tesch 1978):

$$SL_n - a = \frac{R_n}{R}\ (SL - a)$$

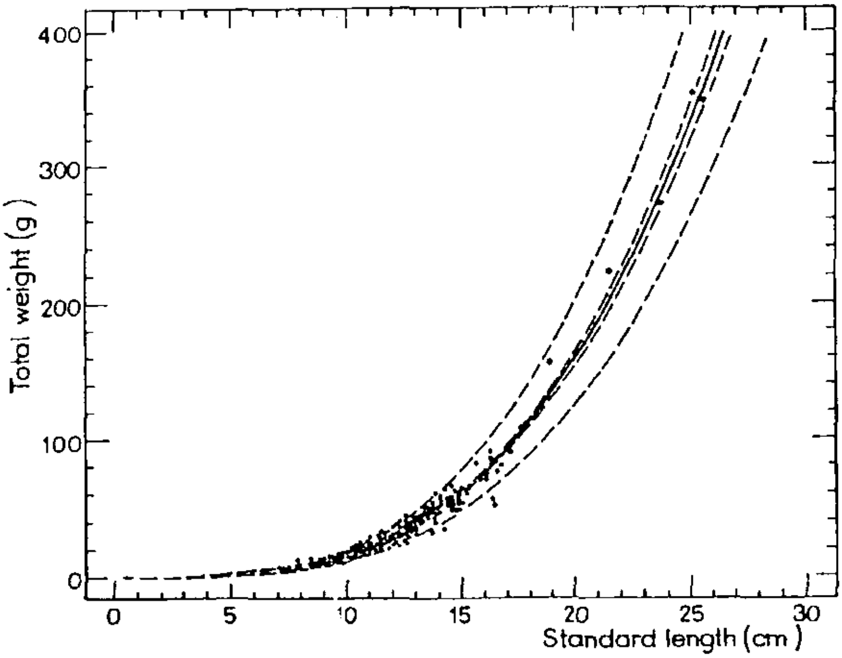

Fig. 5. Standard weight-length regression with 95% confidence and prediction limits in *Perca fluviatilis* females

Table II. Functional regressions of weight-standard lenght

Periods	*a*	*b*	95% confidence limits of *b*	R	r
			Males		
May 1989	0.0076	3.311	2.99–3.63	0.96	0.98
Summer 1989	0.0109	3.184	3.07–3.29	0.98	0.99
Autumn 1989	0.0107	3.166	3.07–3.26	0.98	0.99
Winter 1989–90	0.0074	3.315	3.10–3.52	0.98	0.99
Spring 1990	0.0081	3.295	3.18–3.41	0.96	0.98
			Females		
May 1989	0.0046	3.507	3.22–3.79	0.95	0.97
Summer 1989	0.012	3.141	3.04–3.24	0.98	0.99
Autumn 1989	0.0075	3.319	3.23–3.40	0.98	0.99
Winter 1989–90	0.0076	3.333	3.18–3.48	0.99	0.99
Spring 1990	0.009	3.265	3.17–3.36	0.96	0.98

in which: SL_n = standard length of fish when the annulus n is formed, SL = standard length of fish, R_n = radius of annulus n, R = radius of scale, a = y-intercept of regression line.

The results are reported in Tab. III. The comparison by t-test between the lengths backcalculated for the various ages with the average values shows highly significant differences ($P<0.01$) for the two-year-old specimens which were much smaller than the backcalculated values on the entire population sample. The cause could be due to differential survival of the larger individuals during the second year or to the selection for smaller fish by the fishing method (Ricker 1969; Mann 1978). No significant differences were obtained for the other age classes and therefore, the average backcalculated values appear to give a reasonable estimate of the growth in the examined population; this is also true in relationship to the higher correlation coefficient in the SL–R regression. These values were transformed by the relation TL–SL seen above, for the corresponding total lengths. These results show that the legal size of the fish (18 cm) is reached in the Lake Trasimeno during the third year.

Table III. Back-calculated standard lengths (mm) for age, as well as mean values and total lengths obtained from Sl–TL relationship

Age at capture	No. of fish	Standard length (SL) at the age						
		1	2	3	4	5	6	7
1	6	94.55						
2	7	92.69	121.25					
3	10	95.57	146.37	185.19				
4	8	95.86	137.60	179.52	210.81			
5	6	100.72	147.09	179.74	211.01	234.08		
6	2	97.68	138.46	172.05	204.86	223.96	239.92	
7	1	96.35	152.37	187.36	221.79	237.37	252.67	273.44
Mean (SL)		95.87	138.97	181.41	210.83	232.20	244.17	273.44
Total length		113.11	162.07	210.28	243.70	267.98	281.57	314.83

THEORETICAL GROWTH

The theoretical growth in length was determined by the Von Bertalanffy (1938) equation:

$$SL_t = L_\infty\{1 - e[-K(t - t_0)]$$

in which: SL_t = standard theoretical length at age t, L_∞ = maximal theoretical length and represents the asymptote of the theoretical growth curve for length, K = rate with which the growth curve approaches the asymptote, t_0 = hypothetical age at which the fish has a length = 0 if it grows in conformity with that described in the Von Bertalanffy equation (D i c k i e 1978). It can therefore have positive or negative values.

To determine the theoretical growth curve, three parameters must be known: L_∞, K and t_o. The first two are obtained with the Walford method of the functional regression of SL_{+1} on SL (R i c k e r 1975), where L_∞ represents the intercept of the regression line with the bisect of the graph (Y = X) (Fig. 6), while K can be derived from the slope (k) of line from the relationship $K = -\log_e(k)$.

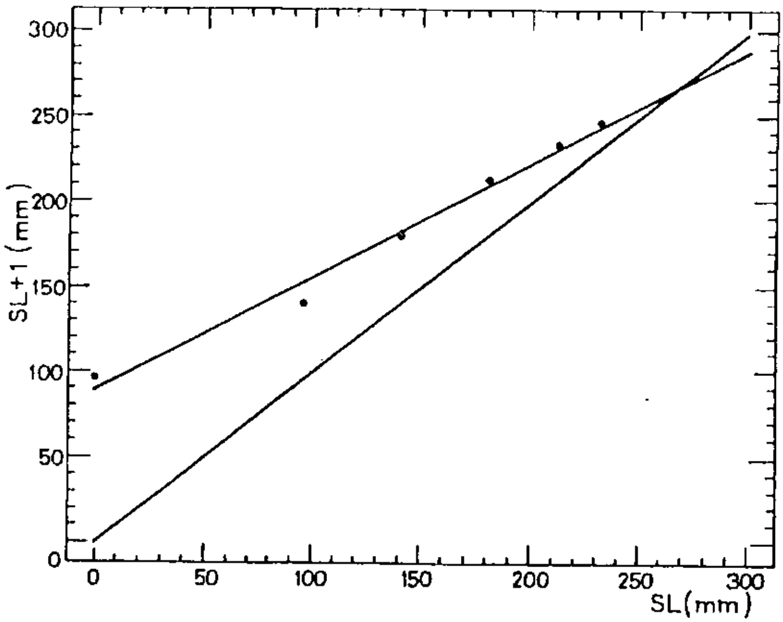

Fig. 6. Walford plot

The parameter to was calculated from the relationship $t_o = (a - \log_e L_\infty)/K$ in which a is the intercept with the ordinate axis in the equation:

$$\log_e(L_\infty - SL_t) = (\log_e L_\infty + t_o) - Kt$$

obtained by logarithmic rearrangement of the Von Bertalanffy equation (D i c k i e 1978; M a r c o n a t o et al. 1990;).

Fig. 7 shows the theoretical growth curve of length (expected values) for L_∞ = 266.78 mm, K = 0.405 and to = 0.095 and the values determined by back-calculation (observed values). The discrepancy in the 7th year is due to the observed values based on only one specimen. The observed values for one-year-old fish were also greater than the expected values, which, when combined with the indication of the Walford plot (Fig. 6) (shifting the regression curve to the left), appear to overestimate the fish in the smallest size class (0+) (R i c k e r 1975). This phenomenon can be explained most reasonably by a selection for large specimen by fishing equipment.

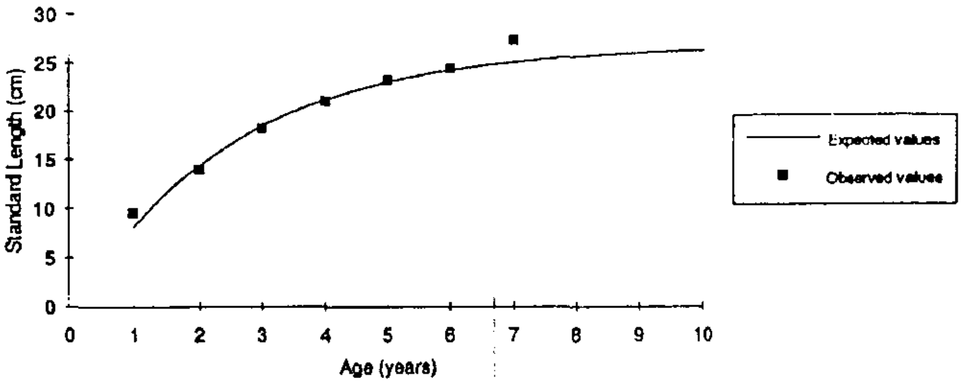

Fig. 7. *Perca fluviatilis* growth in length: a comparison of theoretical values with observed ones

GONADOSOMATIC INDEX

The gonadosomatic (GSI) index represents the percentage ratio between total weight (TW) and the gonad weight (GW):

$$GSI = 100 \frac{GW}{TW}$$

Useful information is derived about the seasonal development of the gonads, as well as the duration of the reproductive period. In the case of perch in Lake Trasimeno, the GSI was independent of the individual total weights. Therefore the data was analyzed without considering the different age classes.

Fig. 8 shows the average annual GSI trends in the two sexes. The gonad development began in September in both sexes. In the males, the GSI reached the maximum of 5.68% already in October and maintained the high level until February. It then decreased progressively until the minimum was reached in the successive months. In the females the annual maximum of 13.85 was recorded in February with a rather rapid gonad development after December; the GSI progressively decreased after February and reached its minimum after April. Therefore, reproduction occurs between March and April. This was confirmed by examining the ovaries: at the end of February only 8% of the females had already spawned, by March, 55% and by the end of April, 100%.

In general, sexual maturity is reached in the first year in both the males and females, although the complete reproductive potential is probably realized in the following year, particularly in the females.

CONDITION FACTOR

The condition factor was calculated separately for the sexes using the formula:

$$K = 100 \frac{W}{SL^3}$$

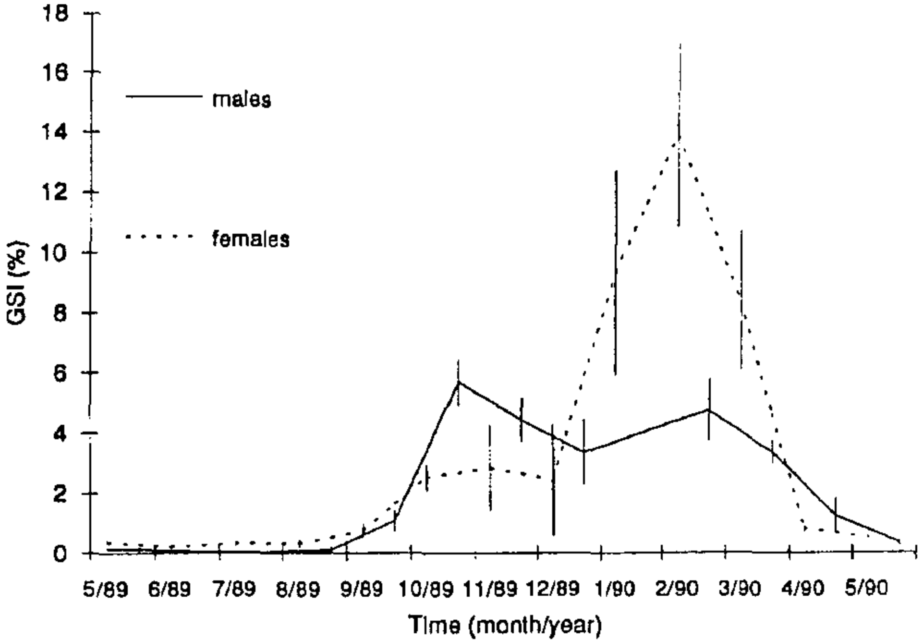

Fig. 8. Annual trend of GSI

in which W is weight expressed in grams and SL is the standard length in cm. Calculated in this way, K represents the individual deviations from the hypothetically ideal fish having isometric growth (Weatherley 1972) and permits the comparison between individuals, populations and different sexes (Ricker 1975).

To evaluate the influence of the reproductive cycle on condition, the K value was determined for each sex in two ways: considering the specimens including gonad weight (total weight) and without the ovary or testicle weights (somatic weight). In the both cases, the average annual K values were greater in the females with highly significant differences with the t-test ($P<0.01$). The average annual K values calculated on somatic weight were 1.58 and 1.64 in the males and females, respectively, while the values calculated on total weight were 1.61 and 1.68, respectively.

In Figs. 9 and 10, the average monthly values of the condition factor are reported with the confidence limits.

The trends did not show substantial differences between the sexes. In June the condition factor of the specimens with gonads showed a relative maximum in both sexes. This maximum was followed by a progressive decrease in the average values until the absolute minimum was reached in November in the males and in December in the females. These values increased in both sexes with an absolute maximum in February; the best condition for both sexes occurred in the pre-reproductive period, February, and in the spring, May and June, when reproduction finished. The maximum condition in February was due, in part, to the contribution of the gonads which were fully developed in this period in both sexes.

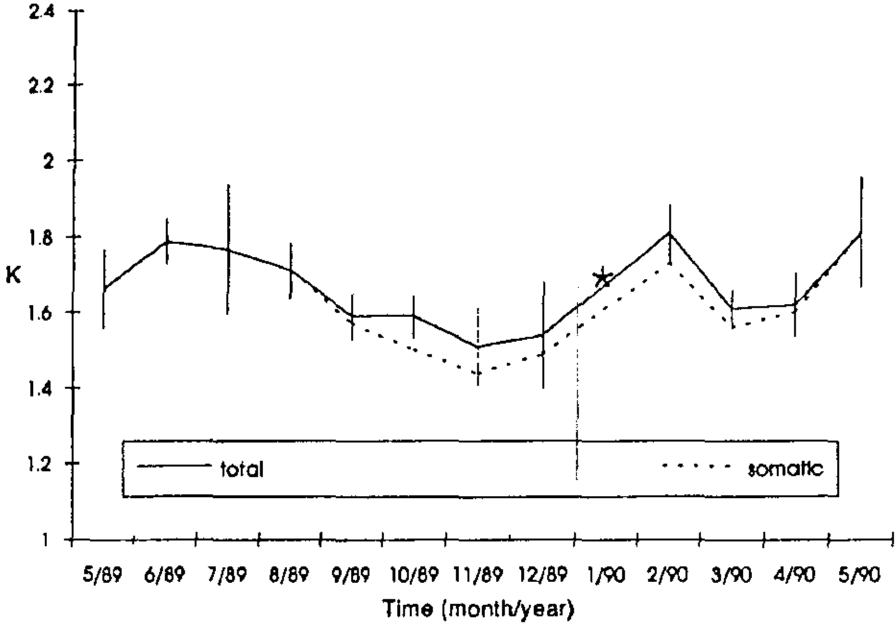

Fig. 9. Annual course of the condition factor K in *Perca fluviatilis* males. The asterisk indicates the absence of an average monthly value due to the lack of a sufficient number of specimens

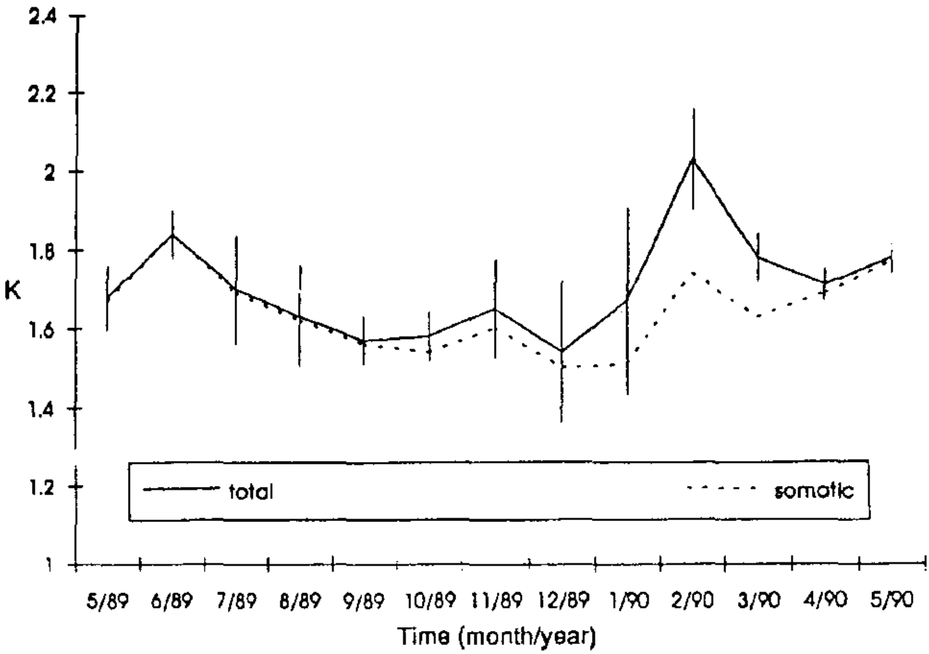

Fig. 10. Annual course of the condition factor K in *Perca fluviatilis* females

In fact, although February was a period of better condition in the specimens without ovaries or testicles, the absolute maximum occurred in June. This appears to be the greatest difference between specimens with or without gonads. The rest of the trends were very similar; the figures show that the gonad development began by September and reproduction was almost finished by April. In fact, it is primarily in this period that the greatest differences were recorded in the calculated condition on the somatic weight and that calculated on total weight; for the rest of the year the two K values were almost identical for both sexes.

SEX RATIO

The sex ratio in the entire sample was 1:1.375 in favour of the females. Dividing the sample into age classes, notable differences were seen (Tab. IV). The sex ratio is almost one during the first year but becomes unbalanced in the successive years. The males were more abundant in the fourth year, while the females were more numerous in all other age classes.

Table IV. Sex ratio

	Males	Females	Ratio
Age class			
0+	203	196	1:0.96
1+	52	132	1:2.54
2+	95	73	1:0.77
3+	23	35	1:1.50
4+	4	41	1:10.5
5+	0	3	
6+	0	1	
Total	325	445	1:1.375

4. DISCUSSION

Comparing these results with the data reported in the literature for the other European localities (Craig 1974; Thorpe 1977; Hoestland 1980) and those in Italy (Giovinazzo 1988; Gandolfi et al. 1991; Alessio et al. 1992) the population of *Perca fluviatilis* of Lake Trasimeno is among the better growing populations. This fact seems to be confirmed by Tesch (1955) who, studying numerous European populations of perch, characterised five different types of growth. The situation in Lake Trasimeno appears to be 'very good' with respect to the standards of Tesch, in fact, total length was greater than 20 cm after three years. The theoretical growth curve shows that 95% of the theoretical maximum length was already reached by seven years with a rapid development (Taylor 1959; Craig 1978). The lack of a static period during the winter in the young 0+ class explains the very good growth and rapid development (Gandolfi et al. 1991).

No significant differences were observed between the sexes when the length-weight curves were compared. The regression coefficients were calculated from all the data for an entire year or were divided into seasonal sub samples; the calculated coefficients were greater than 3 in 11 of the 12 cases. These results exclude the presence of any inherited stunted growth (dwarfism). However, the population of perch of Lake Trasimeno is poorly structured by age having a strong prevalence of young in the population. Almost 60% of the captured specimens were less than one year old and more than 90% did not exceed three years and had not reached legal size. The reason for this imbalance in the population could be attributed to a high natural mortality or to an excessive fish catch. The second hypothesis is more probable considering the fact that the current management model tends to maximize profits without taking into account the necessity to establish an optimal equilibrium between stock and harvested fish.

This study indicates the necessity to regulate the catch and reconsider the equipment used in order to avoid depleting the stock and disrupting the population structure.

Regarding the biological aspects, sexual maturity is reached earlier than that reported in the literature; in fact, in Lake Trasimeno, both sexes were already mature in the first year, while generally the first reproduction occurs during the first or second year in males and a little later, in the first or second years, in the females (Thorpe 1977). This could be a consequence of a rather rapid growth that occurs in Lake Trasimeno where the age of the first reproduction appears to be determined more by size than by age (Alm 1953; Craig 1978). However, the interaction of other factors cannot be excluded. In France, for example, a relationship between climate and sexual maturity has been reported, with the southern population reproducing at a younger age (Hoestland 1980); it has also been suggested that eutrophication, which favours high growth rates can be, in some cases, the cause of precocious sexual maturity (Hartman 1974).

The annual GSI trend of perch in Lake Trasimeno shows that the maximum gonad development occurs much earlier in males, a situation perfectly in line with that reported by various authors for other European populations (Le Cren 1951; Craig 1974): The maximum GSI values reached in the sexes during the year (5.68 and 13.85 in males and females, respectively) place the Lake Trasimeno population in an intermediate position within the European context, with lower values respect to the more common values (8% in the males and 20% in females) (Thorpe 1977). A slightly earlier reproductive period was also observed in Lake Trasimeno with respect to other Italian and European populations; this is probably due to the more favourable climatic conditions of a more southern latitude of the lake.

The annual trends of the condition factor did not show substantial differences between the sexes. The minimum values in both sexes were concentrated in autumn (September-December); the reproductive cycle influences the condition, resulting in high values in the pre-reproductive period followed a decrease after the spawn. The average annual values of the condition factor of perch of Lake Trasimeno (1.58 and 1.64 for the males and females, respectively for somatic weight) show significant differences between the sexes. These values did not appear to be excessively high with respect to the other European and American populations (Thorpe 1977). It can be noted, that the condition factor is influenced by the size of the specimens (Weatherley 1972) and therefore, the overall situation of Lake Trasimeno could be penalized by the prevalence of individuals from the younger age classes.

The sex ratio, 1:1.375, appears slightly imbalanced with the females generally more abundant than the males in the older age classes but fall within the norm in that the males undergo a higher mortality due to natural causes (Alm 1953).

The performed analyses have shown some interesting characteristics which highlight the uniqueness of the Lake Trasimeno population and provide stimuli for further research. More information is needed about the biology of one of the most southern populations of perch. This study has only begun to gather information about the characteristics of this species with particular reference to the Italian population.

5. SUMMARY

The growth and biology of the *Perca fluviatilis* population in Lake Trasimeno was studied by examining 940 specimens. The length-weight relationships found were $TW = 0.0092SL^{3.24\pm0.05}$ for the males and $TW = 0.008SL^{3.3\pm0.05}$ for the females; no significant differences were observed between the sexes and deviations from an isometric growth were observed in 11 out of 12 cases in which the regression coefficient was greater than 3. The development of perch of Lake Trasimeno was rapid and the growth, determined by back-calculation, was very good, in fact the total length was over 20 cm after three years. These results exclude the presence of any inherited stunted growth (dwarfism). In the 0+ age class, a continual growth was observed during all the seasons without any lag time in the winter.

Both sexes reached sexual maturity during the first year; with an earlier seasonal development of the gonads in the males. Gonad development began in September in both sexes; in the males the GSI reached the maximum of 5.68 already in October and maintained the high level until February, while in the females the annual maximum of 13.85 was recorded in February with a rather rapid development after December. Reproduction occurred in March and April.

The annual average of the condition factors calculated on somatic weights were 1.58 and 1.64 in the males and females, respectively, while the values calculated on total weights were 1.61 and 1.68, respectively; in both cases the differences in the sexes were highly significant with t-test.

The data indicate the need to regulate the number of perch caught in Lake Trasimeno, the type of equipment used which would avoid depleting the stock and disrupting the population structure. Some biological peculiarities were observed which distinguish the Lake Trasimeno perch population. Further research is needed to increase the knowledge about perch in Lake Trasimeno.

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