

Age and growth analysis of the chub, *Squalius squalus* (Bonaparte, 1837), in the Assino Creek (Umbria, Italy)

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ABSTRACT

Key-words:
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In this study, the population structure, growth parameters and condition of chub, *Squalius squalus*, from the Assino Creek, a tributary of the River Tiber, were investigated. A total of 1311 specimens were caught monthly from March 2008 to May 2009 by electrofishing. 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 macroscopic observation of the gonads. Age composition ranged from 0+ to 11+. Total length varied from a minimum of 4.1 cm to a maximum of 48.8 cm, for a weight of 0.5 g and 1233.0 g, respectively. Length-weight regression was $\log_{10} W = -2.201 + 3.127 \log_{10} TL$ for males and $\log_{10} W = -2.273 + 3.190 \log_{10} TL$ for females. Previous growth was determined with back-calculation from scale measurements using the non-linear Body Proportional Hypothesis. Theoretical length growth was estimated with von Bertalanffy's model. Condition was evaluated by relative weight.

In Italy there are few available data about the biology of *Squalius squalus*: the aim of this study was therefore to fill this lack of information by investigating some important aspects of the growth of the population in Assino Creek.

RÉSUMÉ

Analyse de l'âge et de la croissance du chevesne, *Squalius squalus* (Bonaparte, 1837) dans le ruisseau Assino (Ombrie, Italie)

Mots-clés :
Squalius
squalus,
relation
taille-poids,
rétro-calcul,
paramètres
de von
Bertalanffy,
poids relatif

Dans cette étude, la structure de la population, les paramètres de croissance et la condition du chevesne *Squalius squalus* du ruisseau Assino, un tributaire du Tibre, ont été analysés. Un total de 1311 individus a été capturé mensuellement de mars 2008 à mai 2009 par pêche électrique. La longueur totale ($TL \pm 0,1$ cm) et le poids ($W \pm 0,1$ g) ont été enregistrés, l'estimation de l'âge est faite par scalimétrie et le sexe est déterminé par observation macroscopique des gonades. La composition en âge va de 0+ à 11+. La longueur totale varie de 4,1 cm à 48,8 cm pour un poids de 0,5 g à 1233,0 g respectivement. La relation taille-poids est $\log_{10} W = -2,201 + 3,127 \log_{10} TL$ pour les mâles et $\log_{10} W = -2,273 + 3,190 \log_{10} TL$ pour les femelles. La croissance passée a été déterminée par rétro-calcul à partir des mesures sur écailles en utilisant le modèle non-linéaire BPH. La longueur théorique a été estimée par le modèle de von Bertalanffy. La condition a été estimée par le poids relatif.

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En Italie peu de données sont disponibles sur la biologie de *Squalius squalus* : le but de cette étude a donc été de combler ce manque d'information en étudiant quelques aspects importants de la croissance de la population du ruisseau Assino.

INTRODUCTION

The distribution area of chub, *Squalius squalus* (Bonaparte, 1837), includes the Ligurian and Tyrrhenian Sea basins from Genova to southernmost Italy, the Ionian Sea basin in southern Italy (Sini and Basento drainages), and the Adriatic basin from the Ofanto drainage area (southern Italy) to the Skadar and Ohrid basins (Kottelat and Freyhof, 2007). In Italy, the chub is one of the most common freshwater fish (Gandolfi et al., 1991), with populations so numerous that in many ecosystems it is the dominant fish species (Zerunian, 2002). Despite its wide distribution, there is little substantial information on the chub biology in Italian watercourses (Vitali and Braghieri, 1984; Bianco and Santoro, 2002). Any management strategy that aims to safeguard biodiversity can be successful only if it is based on a thorough awareness of the diffusion, ecology and biology of the fish species (Byers et al., 2002). Age and growth quantification, combined with knowledge of reproductive aspects, is vital to understanding the ecology and life history of any fish species. Growth rate information can also be used to compare dynamics among water bodies, years and fish sizes, describe trends over time, examine total mortality rates, and determine the general status of a population (Kwak et al., 2006); these are crucial aspects in fishery research and management (Summerfelt and Hall, 1987; Weatherley and Gill, 1987).

The aim of this study was to fill this lack of information by investigating some important aspects of the *Squalius squalus* biology, such as age structure, growth and condition in the Assino Creek population. Due to the scarcity of available data on the Italian chub, the results obtained in this study about the biological characteristics of the species were compared with other European populations of chub, belonging to the genus *Squalius*.

This research is part of a larger project that aims to examine other aspects of the biology of this species, which will be treated in another paper.

STUDY SITE

The Assino Creek (43° 45' 09.99" N, 12° 22' 01.42" E) is a left tributary of the River Tiber, one of the main rivers in Italy in terms of length and area of its basin (Lorenzoni et al., 2006). The Assino Creek is 24 km long; its drainage area is 177.4 km² and its annual flow rate is about 1.8 m³.s⁻¹ (Lorenzoni et al., 2007). A Mediterranean climate, with maximum rainfall in autumn and minimum in summer, characterises this biotope, so the creek has a typical torrential regime and tends to dry up in the summer.

The creek course is fragmented by weirs that make it difficult for fish to migrate upstream. However, the stretch chosen for sampling has great importance for reproduction, as it is utilised as a spawning area by the fish that come from the River Tiber. In addition to chub, the other main species living in the stream include: Tiber barbel *Barbus tyberinus* (Bonaparte, 1839), roach *Rutilus rubilio* (Bonaparte, 1837) and South European nase *Chondrostoma genei* (Bonaparte, 1839) (Lorenzoni et al., 2007).

MATERIALS AND METHODS

Sampling was carried out monthly from March 2008 to May 2009 by electrofishing. A total of 1311 fishes were caught. Total body length (*TL*) of specimens was measured to the nearest 0.1 cm with a measuring board; individual total weight (*W*) was recorded to the nearest 0.1 g (Anderson and Neumann, 1996). On each sampling date, a randomly selected sub-sample

of specimens caught ($n = 547$) was brought back to the laboratory for scale removal and sex determination through macroscopic observation of gonads. Fish were sacrificed by administering an anaesthetic acetone chloroform (2,2,2-trichloro-2-methyl-propanol) overdose.

The scales were removed from the left side of the fish, above the lateral line, near the dorsal fin (De Vries and Frie, 1996) and stored in ethanol (33%). The fish age was determined using the microscopic scalimetric method and validated by means of length-frequency distribution (Bagenal, 1978; Britton *et al.*, 2004).

The length-weight equation was worked out through the least-squares method on logarithmic transformed data by means of the equation $W = a TL^b$ (Le Cren, 1951). This analysis was performed both on the whole sample and on the sample subdivided by sex. The relationships between the sexes were compared by analysis of covariance (ANCOVA). Standard error was calculated for the slope (b): the hypothesis of isometric growth was tested through Student's t -test, with values of $p < 0.05$ considered significant.

The previous growth of the specimens was determined by back-calculation from scale measurements. Back-calculated lengths were estimated for 201 specimens by examining four scales from each one. The scale radius (R_s), from the centre of ossification to the anterior edge of the scale along the oblique direction and the radius of the age rings (R_i) in the same direction were measured for each scale (± 0.01 mm) (Bagenal, 1978) using an image-analysis system (IAS 2000, 1994). The arithmetic mean of the four measurements was considered in the analysis. Length at age was back-calculated by means of the non-linear Body Proportional Hypothesis (non-linear BPH) (Smedstad and Holm, 1996). Back-calculated lengths at age were determined for the overall sample and separately for males and females. The differences between sexes were analysed by Multiple Analysis of Variance (MANOVA).

To determine whether Lee's phenomenon was occurring (Bagenal, 1978), an ANOVA test and a Tukey *post hoc* test were used to compare back-calculated lengths reached at various *annuli* for each age group. The older age groups (8+ to 11+) were excluded from this analysis as they were represented by a small number of specimens.

Growth was assumed to be described with the von Bertalanffy growth curve model (von Bertalanffy, 1938): $TL_t = L_\infty \{1 - \exp[-k(t - t_0)]\}$ where TL_{t_0} is total length (cm) at age t , L_∞ is theoretical maximum length (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*. 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 enables comparing growth from different populations in the same species.

In order to determine whether the specimens' growth was constant throughout the year, or whether it exhibited periods of stasis, the monthly changes in the average length and weight of specimens were evaluated. Monthly growth was analysed in the 1+, 2+ and 3+ age classes, as these comprised a large number of specimens. In this analysis specimens of the same age class caught in the same month were combined regardless of the catching year. Comparison between length and weight mean values calculated in each sampling month was made with the Tukey test.

To estimate the condition of individual fish, relative weight (W_r) (Wege and Anderson, 1978) was calculated as follows: $W_r = (W/W_s) 100$, where W is fish body weight (g) and W_s is the standard weight determined on the basis of the standard weight equation. In this study the following standard weight equation valid for chub in the River Tiber basin was used: $\log_{10} W_s = -5.001 + 2.856 \log_{10} TL + 0.067(\log_{10} TL)^2$ (Angeli *et al.*, 2010). Relative weight was calculated using both total weight (W_r) and somatic weight (W'_r). The latter index reveals the actual well-being of the population, regardless of the reproductive cycle. A value of W_r above 100 indicates that the sample is in good condition and has no feeding problems (Anderson, 1980).

Table I

Age composition of the *Squalius squalus* population in Assino Creek expressed as the number (*n*) and percentage (%) of specimens for the overall sample and number (*n*) of males and females in each age class.

Tableau I

Composition en âge de la population de *Squalius squalus* du ruisseau Assino exprimée en nombre (*n*) et pourcentage (%) de spécimens de l'échantillon total et en nombre (*n*) de mâles et femelles de chaque classe d'âge.

Age class	Overall sample		Male sample	Female sample
	<i>n</i>	%	<i>n</i>	<i>n</i>
0+	47	3.59	-	-
1+	435	33.21	11	2
2+	348	26.57	73	28
3+	282	21.53	114	29
4+	70	5.34	20	28
5+	71	5.42	22	23
6+	29	2.21	11	12
7+	12	0.92	2	7
8+	12	0.46	-	4
9+	6	0.53	-	4
10	7	0.15	-	1
11	2	0.08	-	1
All	1311		253	139

Table II

Descriptive statistics of the *Squalius squalus* population in Assino Creek for male and female samples (*n* = number of specimens): mean, minimum value (Min), maximum value (Max) and standard deviation (SD) of total length (TL in cm), total body weight (*W* in g) and age expressed in years (yr). The results of statistical comparisons of total length, weight and age between the sexes are given (*t*-test).

Tableau II

Statistiques descriptives de la population de *Squalius squalus* du ruisseau Assino pour les mâles et les femelles (*n* = nombre d'individus) : moyenne, valeur minimum (Min), valeur maximum (Max) et déviation standard (SD) de la longueur totale (TL en cm), du poids (*W* en g) et de l'âge exprimé en année (yr). Les résultats des comparaisons statistiques des longueurs totales, poids et âges entre les sexes sont indiqués (test *t*).

	Male sample <i>n</i> = 253				Female sample <i>n</i> = 139				<i>t</i> -test
	Mean	Min	Max	SD	Mean	Min	Max	SD	<i>p</i>
TL (cm)	19.38	9.30	35.80	5.74	25.26	11.50	48.80	8.32	< 0.05
W (g)	88.23	6.40	463.80	91.77	225.70	13.00	1197.70	243.17	< 0.05
Age (yr)	3.04	0.83	6.92	1.18	4.26	1.42	11.25	1.96	< 0.05

RESULTS

The chub caught ranged in total length from 4.10 to 48.80 cm (mean \pm SE = 15.51 \pm 0.22 cm) and in weight from 0.50 to 1233.33 g (mean \pm SE = 72.54 \pm 3.79 g). Twelve age classes were found, with most specimens (*n* = 435) belonging to the 1+ age class. Sex was determined in 392 specimens: 253 males and 139 females (Table I). Females were longer and heavier than males, and the differences between sexes proved to be highly significant in the Student's *t*-test with regard to the three analysed parameters (Table II).

The relationship between body weight and total length proved to be $\log_{10} W = -2.273 + 3.190 \log_{10} TL$ ($r^2 = 0.990$, $r = 0.995$, $p = 0.000$) for females and $\log_{10} W = -2.201 + 3.127 \log_{10} TL$ ($r^2 = 0.986$, $r = 0.993$, $p = 0.000$) for males. Comparison between regressions did not reveal any statistically significant differences between sexes (ANCOVA: $F = 1.573$, $p = 0.211$). The relationship between body weight and total length calculated

on the entire sample, without distinction between the sexes, was described by the equation: $\log_{10} W = -2.148 + 3.098 \log_{10} TL$ ($r^2 = 0.985$, $r = 0.992$, $p = 0.000$). For each of the equations found, the regression coefficient b proved to be statistically greater than 3 in the t -test (female: $p = 0.000$; male: $p = 0.000$; total sample: $p = 0.000$), indicating a positive allometric growth.

The relationship between scale radius and total length was calculated for the overall sample as $\log_{10} TL_c = 1.721 + 0.873 \log_{10} R_s$ ($r^2 = 0.960$, $r = 0.980$, $p = 0.000$); for males as $\log_{10} TL_c = 1.720 + 0.874 \log_{10} R_s$ ($r^2 = 0.935$, $r = 0.967$, $p = 0.000$); and for females as $\log_{10} TL_c = 1.728 + 0.882 \log_{10} R_s$ ($r^2 = 0.949$, $r = 0.974$, $p = 0.000$). No differences emerged between sexes in ANCOVA ($p = 0.498$); 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 III) and separately for males and females. The differences between sexes were not statistically significant in Multiple Analysis of Variance (MANOVA) ($p = 0.790$).

Comparison of the mean back-calculated lengths between specimens of age t and those of age $(t + 1)$ did not reveal the existence of Lee's phenomenon. The back-calculated lengths reached at previous various ages showed significant differences only for the age of 1 year in the ANOVA test ($p = 0.020$) (Table III); however, there was no clear increasing or decreasing trend in the back-calculated lengths in older specimens. This was confirmed by the Tukey *post hoc* test: there were no statistically significant differences in mean back-calculated lengths for the first *annulus* between the age 1+ and all the other cohorts ($p > 0.05$).

The back-calculated lengths at various ages were used to evaluate the specimens' growth. The parameters of theoretical growth in length were $L_\infty = 63.908$ cm, $k = 0.123$ yr⁻¹, $t_0 = 0.160$ yr; the growth performance index ϕ' was 2.701.

The monthly trend analysis in length and weight of the 1+ and 2+ age classes is shown in Figure 1. In the 1+ age class, growth was fairly rapid from January to early spring, with a sharp slowdown in February. Between June and September, a period of particularly rapid growth was observed, with differences in both length and weight that proved statistically significant among all successive summer months. Regarding the 2+ age class, length and weight increased continuously in all seasons, albeit in a slightly different way from one period to another. From January to early spring, growth was quite rapid, especially between February and April regarding weight and between February and March regarding length. Subsequently, at the beginning of the spawning season (March–May), length growth slowed down slightly, while weight continued to increase rapidly. In summer, the growth rate increased again, accelerating sharply between July and August; in autumn and early winter growth slowed and then increased again after late February, more so regarding weight than length, in the 3+ age class.

The W_r mean value (\pm SE) calculated for the overall sample was 92.170 ± 0.417 , while the somatic relative weight (W'_r) was 85.744 ± 0.464 . Comparison between sexes revealed that mean values of both parameters were higher in females ($W_r = 90.063 \pm 0.808$; $W'_r = 86.951 \pm 0.765$) than in males ($W_r = 88.113 \pm 0.604$; $W'_r = 85.034 \pm 0.579$). Upon statistical testing (Student's t -test), the differences between sexes proved to be significant regarding W'_r ($t = 4.017$, $p = 0.046$), but not W_r ($t = 3.735$, $p = 0.054$).

The monthly trend of W_r and W'_r in both sexes (Figure 2) shows that in the winter the average values are well below 100; relative weight increased markedly from March, with both indexes reaching their highest mean values in April. From April to June, the condition clearly deteriorated and, after a slight improvement in July in females, low average values for both W_r and W'_r were recorded in August.

DISCUSSION

The *S. squalus* population of Assino Creek displayed a balanced age structure, mostly made up of young individuals; the 0+ age class was poorly represented, probably owing to the selectivity of the sampling tools. Lifespan proved to be over 11 years, according to the typical

Table III
Mean back-calculated total length (TL in cm) ± standard error (SE) at successive annuli for a sub-sample (n = 201) of the Squalius squalus population in Assino Creek. The results of the ANOVA test used to compare back-calculated lengths reached at various annuli for each age group are given. The older age groups (8+ to 11+) were excluded from this analysis as they were represented by a small number of specimens. Back-calculated lengths derived from the last annulus are shown in bold.

Tableau III

Longueur totale moyenne rétrocalculée (TL en cm) ± erreur-standard (SE) aux annuli successifs pour le sous-échantillon (n = 201) de la population de *Squalius squalus* du ruisseau Assino. Les résultats d'une ANOVA comparant les longueurs rétrocalculées correspondant aux différents annuli sont donnés par groupe d'âge. Les groupes d'âge 8+ à 11+ sont exclus de l'analyse en raison de leurs faibles effectifs. Les longueurs rétrocalculées correspondant au dernier annulus sont en gras.

Age class	n	Mean back-calculated TL ± SE at successive annuli													
		1	2	3	4	5	6	7	8	9	10	11			
1+	44	6.36 ± 1.26													
2+	61	5.55 ± 1.42	12.38 ± 0.21												
3+	36	6.16 ± 1.75	12.95 ± 0.27	18.98 ± 0.24											
4+	16	6.34 ± 1.50	13.46 ± 0.52	20.19 ± 0.51	24.70 ± 0.51										
5+	22	6.71 ± 1.70	12.77 ± 0.44	19.09 ± 0.44	24.63 ± 0.45	29.06 ± 0.37									
6+	9	6.30 ± 1.25	13.11 ± 0.65	18.84 ± 0.75	23.45 ± 0.72	28.47 ± 0.74	32.42 ± 0.48								
7+	6	6.90 ± 1.67	12.71 ± 1.14	18.22 ± 0.96	23.29 ± 0.66	29.17 ± 0.64	33.18 ± 0.43	35.63 ± 0.36							
8+	3	6.16 ± 0.51	12.90 ± 1.89	17.39 ± 1.76	23.10 ± 1.46	27.95 ± 0.96	32.20 ± 0.21	36.19 ± 0.71	39.47 ± 0.92						
9+	2	6.96 ± 1.10	14.20 ± 1.48	20.42 ± 1.24	25.16 ± 0.36	29.48 ± 0.17	33.12 ± 0.18	36.67 ± 0.68	39.89 ± 0.86	42.20 ± 0.63					
10	1	6.45	12.54	18.62	23.89	28.01	31.61	35.01	38.83	41.78	45.19				
11	1	6.03	9.71	15.33	19.41	23.24	27.16	31.31	35.68	39.13	43.33	47.11			
Mean ± SE	20	6.13 ± 0.11	12.74 ± 0.15	19.09 ± 0.20	24.18 ± 0.27	28.74 ± 0.29	32.39 ± 0.35	35.54 ± 0.44	38.96 ± 0.69	41.33 ± 0.78	44.26 ± 0.93	47.11			
Anova		p = 0.020	p = 0.334	p = 0.149	p = 0.258	p = 0.682	p = 0.290	-	-	-	-	-	-	-	-

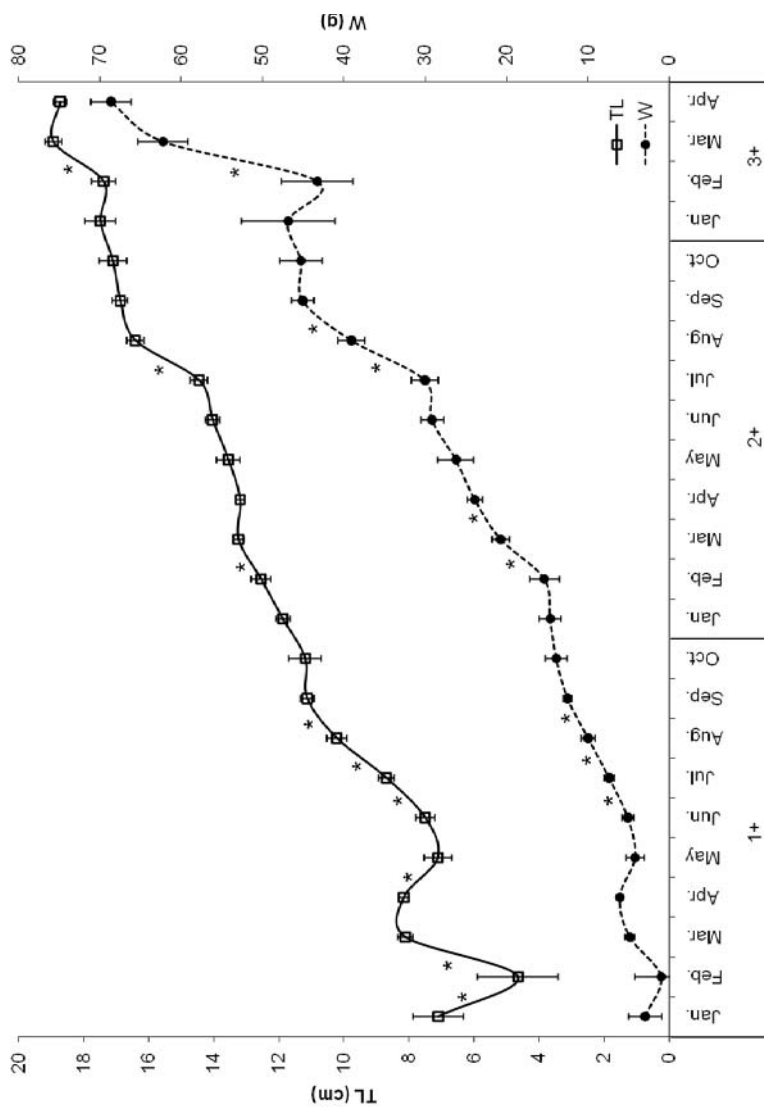


Figure 1

Monthly growth in length (TL in cm) and weight (W in g) of the *Squalius squalus* population in Assino Creek. The analysis includes the 1+, 2+, and 3+ age classes. Asterisks indicate significant differences in the Tukey test ($p < 0.05$) among successive months. The values represent the mean of total length and weight for each month; vertical bars indicate 95% confidence intervals.

Figure 1

Croissance mensuelle en longueur (TL en cm) et en poids (W en g) de la population de *Squalius squalus* du ruisseau Assino. L'analyse prend en compte les classes d'âge 1+, 2+ et 3+. Les astérisques indiquent les différences significatives selon le test de Tukey ($p < 0,05$) entre deux mois successifs. Les points représentent la longueur totale et le poids moyens pour chaque mois, les barres verticales les intervalles de confiance à 95 %.

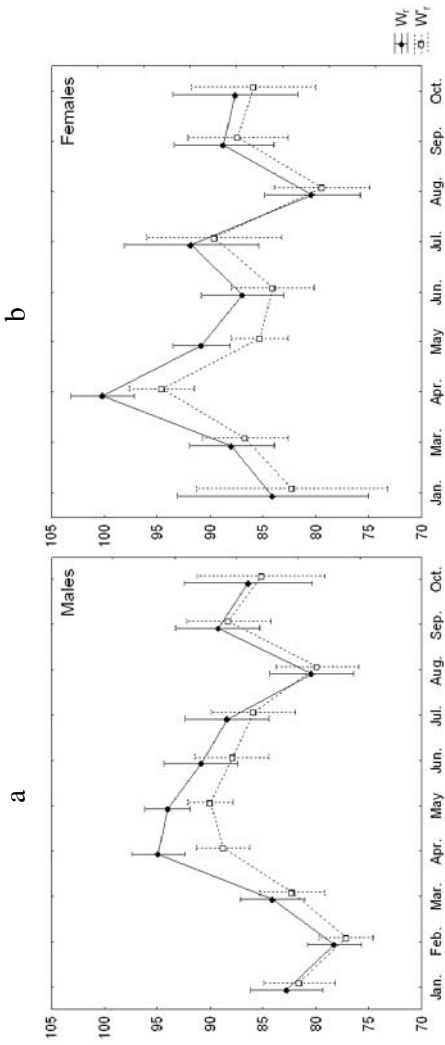


Figure 2 Monthly variation in relative weight in male (a) and female (b) samples of the *Squalius squalus* population in Assino Creek. The solid line indicates relative weight calculated using total body weight (W_t) and the dotted line indicates relative weight calculated using the somatic weight (W_s). Vertical bars indicate 95% confidence intervals.

Figure 2 Variations mensuelles du poids relatif des mâles (a) et des femelles (b) des échantillons de *Squalius squalus* du ruisseau Assino. Le trait plein indique le poids relatif calculé en utilisant le poids total (W_t) et la ligne pointillée le poids relatif calculé en utilisant le poids somatique (W_s). Les barres verticales indiquent les intervalles de confiance à 95 %.

species longevity (Gandolfi *et al.*, 1991). However, chubs that had lived through more than six winters were not very abundant; this could be due either to mortality linked to achievement of sexual maturity or to high fishing pressure that selectively targets larger specimens. The latter hypothesis is highly unlikely, since the importance of this species to anglers has decreased significantly in recent years. Rather, the lack of older specimens seems to be mainly related to the population's reproductive behaviour. It is possible that older specimens migrate from the River Tiber and populate the creek only in the reproductive period. Moreover, the older specimens are all females; this is also consistent with the *S. squalus* characteristics, in which females live longer, predominating in the > 6-year age groups (Gandolfi *et al.*, 1991). The present study confirmed this pattern and is in line with those of other authors (Öztaş and Solak, 1988; Altındağ, 1996; Ekmekçi, 1996; Erdoğan *et al.*, 2002; Koç *et al.*, 2007).

The slope (b) value of the length-weight relationship calculated for the overall sample was 3.098; this indicates allometric growth in which length increases less than proportionally to other dimensions (Ricker, 1975). The available data analysis in the literature shows that the value of b for other European chub populations can vary from 2.49 to 3.86 (Koç *et al.*, 2007; Bostanci and Polat, 2009; Froese and Pauly, 2010). Geographic location, environmental conditions, different amounts of food available, life span or growth increment, and disease and parasite loads can affect the length-weight relationship (Ricker, 1975).

Back-calculation revealed that the formation of the *annulus* in the scales takes place around April–May, in concomitance with the reproductive period.

On the whole, growth can be considered to be fast. The parameter k of the von Bertalanffy equation, which describes the growth rate, was 0.123 yr^{-1} , in line with the value reported in other European populations ($k = 0.1 \text{ yr}^{-1}$) (Froese and Pauly, 2010). Although the growth rate was similar, the specimens examined in the present study reached a theoretical maximum length of 63.91 cm, which is greater than other European populations (Mann, 1976; Koç *et al.*, 2007; Sen and Saygin, 2008; Bostanci and Polat, 2009; Froese and Pauly, 2010). The Φ' value was 2.701, greater than both values reported in the literature for populations of Central and Southern Europe ($\Phi' = 2.20$) (Froese and Pauly, 2010) and that obtained from research on 106 populations of chub in the River Tiber basin ($\Phi' = 2.63$) (unpublished data).

Back-calculated growth analysis and $TL-W$ regression comparison between males and females allowed excluding the presence of sexual dimorphism in growth. Mean value comparison of back-calculated total lengths for all *annuli* at various ages did not reveal the existence of a Lee's phenomenon or an inverse Lee's phenomenon. Comparison among the mean back-calculated lengths at the first *annulus* revealed growth variability; however, it is possible to exclude the existence of selective size-related mortality phenomena due to predation and/or competition, or to sampling tool selectivity. Rather, these variations may be attributed to the great unpredictability of environmental parameters in the Assino Creek, especially flow and temperature, which influence the availability of resources during the winter, and which can cause variations in growth from one year to another.

The monthly trend analysis in length and weight revealed that, in the 1+ and 2+ age classes, growth did not take place at a uniform rate throughout the year; a stasis is evident in the cold months, while faster growth occurs in the spring and summer that in the 2+, in addition to being favoured by the temperature increase and resource abundance, can be caused by gonad development, since some individuals may have already reached sexual maturity at two years (unpublished data).

The relative weight mean value of specimens was distinctly below 100. When W_r values are well below 100 for an individual or size group, problems may exist regarding food supply or feeding conditions (Anderson and Neumann, 1996). Females proved to be in better condition than males, but the differences were not statistically significant. This condition seems to be affected by the gonad weight; indeed, when only the somatic weight was considered in the calculation of the relative weight (W'_r), it was always greater in females than in males, and the difference proved to be statistically significant. The monthly trend analysis of W_r and W'_r reveals not only how condition varied during the year, but also provides some information on the reproductive investment of females and males. The trends clearly showed that specimens

of both sexes reached their best condition in April; this testifies to the improvement of conditions due to the gonad mass growth but also that specimens tend to accumulate a large amount of reserves in order to get through the reproductive period. In the spawning period (April–July) we observed a rapid decrease in W_r in females; this depended not only on the complete emptying of the ovaries, but also on a real worsening of the fish's well-being, as shown by somatic relative weight W'_r . A similar trend was also observed in males, but the decrease in W'_r was postponed until the end of the breeding season; indeed, in spring, the reproductive effort seems to impact less on males than on females. The reproductive period is quite long for both sexes, lasting from April to July. Reproductive investment is very high in females, but males also allocate a substantial proportion of their biomass to gonad development. Our analysis indicates that the most critical periods for survival are winter (January and February) and August. This is probably due to a combination of circumstances: lack of food and low temperatures in winter, and, in August, high energy investment in the just-concluded reproduction and reduced water flows.

The upper course of the river Tiber, of which Assino is a tributary, is characterised by extreme unpredictability of environmental factors that, as is typical of Mediterranean basins (Gasith and Resh, 1999), represents a severe limiting factor for fish. Native fish inhabiting these streams possess several life-history and behavioural attributes to cope with seasonal flow variability (Pires *et al.*, 1999). The chub is therefore characterised by a great ecological adaptability which enables the species to live in very different environments and adapt to harsh conditions. The results of the present study confirm its ability to adjust some biological traits in response to ecological conditions: the early achievement of sexual maturity, the high reproductive investment and the extended reproductive period testify to the capability of the species in resource allocation between reproduction and growth depending on environmental pressures. In other water bodies of North Italy, characterised by less unpredictable environmental conditions, indeed, chub shows a different strategy: in the river Po (Vitali and Braghieri, 1984) and in Suviana and Brasimone (Trisolini *et al.*, 1991) lakes it displays a higher growth rate combined with a delayed sexual maturity and a shorter reproductive period.

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