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INVESTIGATING AGE AND GROWTH OF *CYPRINUS CARPIO* (LINNAEUS, 1758) IN SIDI SAAD RESERVOIR (CENTRAL TUNISIA)

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CYPRINUS CARPIO
SIDI SAAD RESERVOIR
LENGTH-WEIGHT RELATIONSHIP
AGE
GROWTH

ABSTRACT. – This study aims to assess the age and growth rates of the common carp, *Cyprinus carpio* (L., 1758) in Sidi Saad Reservoir in Tunisia. Sampling was conducted throughout the entire year of the experiment (January through December). A total of 2285 specimens, ranging from 12 to 58 cm in length (TL) and 24.7 to 2620 g in weight, were caught during the study period. The sample consisted of 1291 females and 994 males with total length weight (W) relationship estimated at $W = 0.0156 \times TL^{2.93}$. The monthly percentage of specimen having a terminal translucent zone indicated that circuli formed once a year, during the cold season (January). The back calculation method demonstrated the validity of using scales in the estimation of this species' age and growth. The parameters of Von Bertalanffy growth, based on the analysis of scales for 570 specimens, were estimated for each sex separately: $L_\infty = 62.20$ cm, $K = 0.151$ a^{-1}, $t_0 = -0.966$ for females, as $L_\infty = 57.98$ cm, $K = 0.165$ a^{-1}, $t_0 = -0.873$ for males and as $L_\infty = 60.05$ cm, $K = 0.157$ a^{-1}, $t_0 = -0.92$ for combined sexes. Ten age groups were identified within the common carp population in the studied reservoir.

INTRODUCTION

The common carp, *Cyprinus carpio* (Linnaeus, 1758), is one of the preeminent farmed freshwater fish in the world (Balon 1995). In Tunisia, the first introduction attempts of this species started in the 1960s (Rhouma 1975). Since the 1980s, the number of reservoirs has been in growth in the country to regulate the seasonal stream flows on one hand, and to meet the expanding water demands for agricultural and domestic uses on the other hand. This water resource expansion allowed large-scale freshwater fish introductions into reservoirs in the early 1990s, which gave rise to more fisheries compensating for the lack of marine fish landings. This farming method has had a twofold impact on rural populations, providing them with an alternative source of animal protein and increasing their income (Djemali et *al*. 2009).

The main farmed species in the Tunisian reservoirs are barbel *Barbus callensis* (Valenciennes, 1842), roach *Rutilus rubilio* (Bonaparte, 1837), rudd *Scardinius erythrophthalmus* (Linnaeus, 1758), wels catfish *Silurus glanis* (Linnaeus, 1758), eel *Anguilla Anguilla* (Linnaeus, 1758), mullets *Mugil cephalus* (Linnaeus, 1758), *Liza ramada* (Risso, 1826), and pikeperch *Sander lucioperca* (Linnaeus, 1758) (Losse *et al*. 1991, Mili *et al*. 2021a). Production has never ceased increasing in Tunisian reservoirs with 859 tons in 2003, exceeding 1350 tons in 2019, of which 37.6 % came from Sidi Saad with an annual yield of 511.14 t (DGPA 2019).

The common carp spawns naturally and perfectly adapts to Tunisian ecosystems (Losse *et al*. 1991, Djemali 2005, Mili *et al*. 2021b). Naturally, it has become the most abundant freshwater species representing 28.7 % of the total landing (DGPA 2019), mainly harvested with gill nets and trammel nets.

In order to ensure fishery management best practices, it is crucial to know the details of the age and growth of this species (Brothers 1983). Some authors worked on these variables using hard tissues, such as scales (Balon 1995, Treer *et al*. 2003, Tempero *et al*. 2006), otoliths (Vilizzi & Walker 1999, Brown & Walker 2004, Winker *et al*. 2011), vertebrae (Cochrane 1985), pectoral fin (Weber *et al*. 2010) and dorsal spiny ray (Meunier & Pascal 1981). With the exception of some studies, which focused on reproduction of the common carp (Hajlaoui *et al*. 2016), no other biological data, including age estimation, are available for the common carp populations in Tunisia.

This study aims to estimate the age and growth of the common carp and eventually to determine the growth model for Sidi Saad Reservoir population using the scalimetry method. The findings will help determine the age composition of the catch, which is an important parameter in stock assessment and to provide insight into the life cycle of this species in Tunisian reservoirs.

MATERIALS AND METHODS

This study was conducted in Sidi Saad Reservoir (35°22'N, 09°40'E; center of Tunisia (North Africa)) (Fig. 1), which was constructed in 1981. This reservoir is surrounded by agricultural activities and it has an average surface area of 17 km^2, a volume of 209 10^6 m^3 and a mean depth of 30 m (Soudoud 2010).

For the study purposes, biological samples were collected monthly, throughout a whole year, from January through December 2008, in Sidi Saad Reservoir, using a trammel net of 26 to 60 mm diamond mesh. A total of 2285 individuals were collected and transferred to the Laboratory of Fishery Sciences at the National Agronomic Institute of Tunisia. There, the total length (TL) to the nearest millimeter, and weight (W) to the nearest 0.1 g, were measured and the sex was determined by macroscopic observation of the gonads.

The length-weight relationship of fish was calculated for both sexes for the entire samples. The exponential equation $W = aTL^b$ (Ricker 1975), where W is weight (g), TL is total length (cm) and *a* and *b* are regression parameters, was fitted to the data. Differences of *b* values between sexes were calculated deploying covariance analysis (ANCOVA, $P > 0.01$; Zar 1999) and isometric growth was tested using a *t*-test.

For age estimation, scales were taken from above the lateral line, behind the pectoral fin from 570 individuals. They were cleaned with water and examined under the stereo binocular microscope (Fig. 2). The periodicity of ring formation in scales was then checked by calculating the increase between the last and penultimate ring (or marginal increment (MI)) using the equation:

$$MI = (R - R_n) / (R_n - R_{n-1})$$

where R, R_n, and R_{n-1} are, respectively, the radius, the radius of the last and the next-to-last growth rings. Monthly values of MI were compared using a one-way ANOVA test.

Linear regression analysis was conducted to obtain the equation between total length and scale radius (Francis 1990). Total length was then back calculated for each ring using Lee Formula (1920):

$$TL_i = a + [(TL - a) R_i / R]$$

where: TL_i = predicted total length of the fish corresponding to age or ring i; *a*: intercept of the equation $R = a + b.TL$; TL: total length of fish at capture; R_i = scale radius at age i ; R = scale radius at capture in mm.

The Von Bertalanffy growth curve was designed using the age-length key results by means of the Marquardt's algorithm for nonlinear least-squares parameter estimation (Saila *et al*. 1988). The FSAS program was used to estimate the parameters of the Von Bertalanffy growth equation (Von Bertalanffy 1938):

$$TL_t = TL_\infty [1 - e^{-K (t - t_0)}]$$
$$W_t = W_\infty [1 - e^{-K (t - t_0)}]^b$$

Where TL_t is the total length (mm) at age t, TL_∞ is the asymptotic length, K is the growth coefficient, t is age, t_0 hypothetical age at which length is zero, W_t is the weight of the fish at age t and W_∞ is the asymptotic weight (Le Cren 1951).

The index of growth performance (Φ'), which allows to compare the growth of the same species in different environments, was calculated with the equation of Pauly and Munro (1984) $\Phi' = \log(K) + 2\log(L_\infty)$; where K and L_∞ are the Von Bertalanffy growth parameters.

The value of the maximum theoretical age (Tmax), which expresses the longevity of the fish, was determined according to the formula cited by Pauly (1983):

$$Tmax = t_0 + 3 / K$$

with t_0 and K = parameters of the Von Bertalanffy equation.

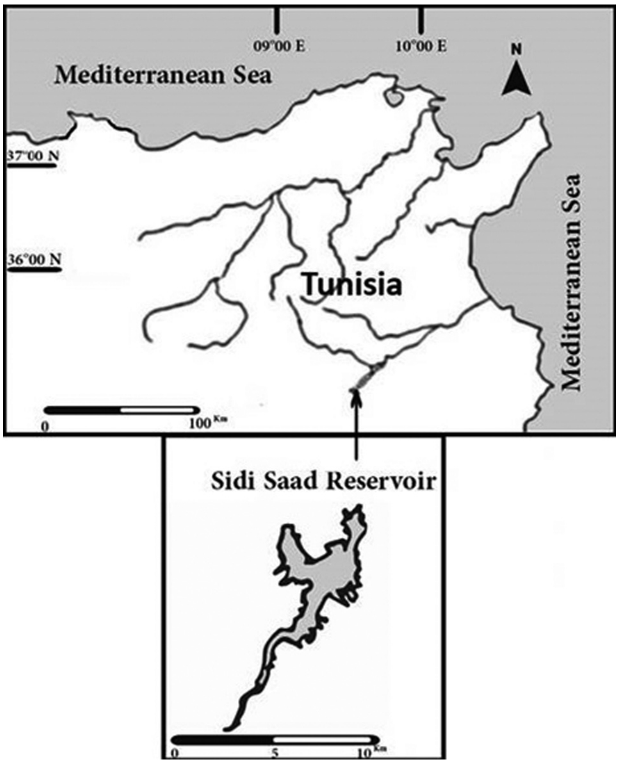

Fig.1. – Geographical position of Sidi Saad Reservoir (Tunisia).

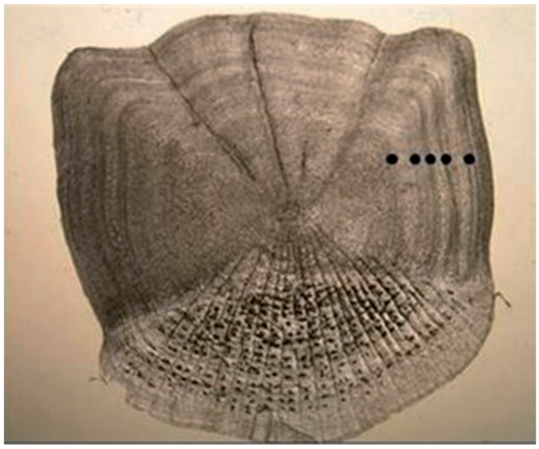

Fig. 2. – Scale from a five-year specimen of *Cyprinus carpio* from the Sidi Saad Reservoir.

RESULTS

Length-frequency distribution

The 2285 examined fish samples included 1291 (56.5 %) females and 994 (43.5 %) males. Fish varied in length from 12.3 to 58.5 cm, where the total length of females stretched from 12.3 to 58.5 cm and ranged between 12.5 and 52.0 cm (Fig. 3) for males. The length for most captured fish in this reservoir fluctuated between 15 and 41 cm (92 %) (Fig. 3).

Weight-frequency distribution

The 2285 specimens weighed between 24.7 and 2620 g. Total weight for females ranged from 24.7 to 2620 g and varied between 28.5 and 2410 g for males (Fig. 4). Most fish weighed between 50 and 450 g (79 %) (Fig. 4).

Length-weight relationship

Length-weight relationships were calculated separately for females, males and for both sexes together. The equation for females was $W = 0.0144 \times TL^{2.96}$, for males $W = 0.0184 \times TL^{2.87}$ and for the combined sexes $W = 0.0156 \times TL^{2.93}$ (Fig. 5).

The *b* value was significantly lower than the theoretical value of 3 for males ($t = 8.28$, $P < 0.05$), females ($t = 3.30$, $P < 0.05$) and combined sexes ($t = 7.00$, $P < 0.05$).

Marginal increment

Age estimation was made using scales of 570 fish samples (320 females and 250 males). The monthly change in the marginal increment (MI) using the scales was used to determine the circulus growth (Fig. 6), suggesting that the single annulus is formed in January (mean MI = 0.45 ± 0.14). The maximal mean of marginal increment ratio (MIR) was found in August (mean MI = 1.31 ± 0.45). The comparison of successive monthly mean marginal increment values using one-way ANOVA ($F = 3.867$; $P < 0.01$) revealed a significant difference in growth rates.

The maximum age estimated for both sexes was ten years. The age range of the sampled fish was 1-10 years, with a majority of individuals within the 2-3 years age class (Table I).

Scale radius-body total length relationships

The relationships between the total fish length (TL) and the radius of the scale (R) in females, males and combined sexes are presented via the following equations:

– Females: $R = 0.0207TL - 0.1208$; $R^2 = 0.9521$ ($P < 0.01$);

– Males : $R = 0.0209TL - 0.1978$; $R^2 = 0.9433$ ($P < 0.01$);

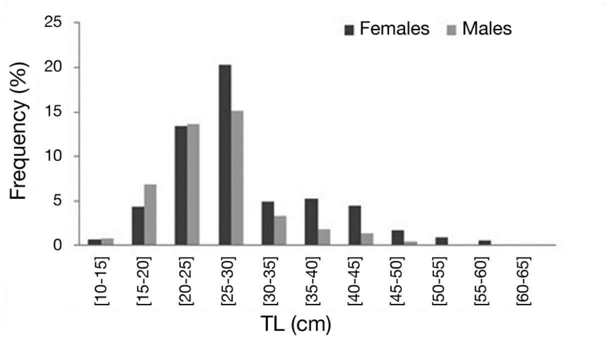

Fig 3. – Total length distribution of *Cyprinus carpio* in Sidi Saad Reservoir.

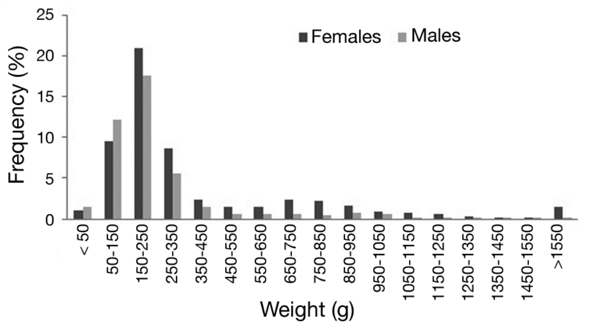

Fig. 4. – Total weight distribution of *Cyprinus carpio* in Sidi Saad Reservoir.

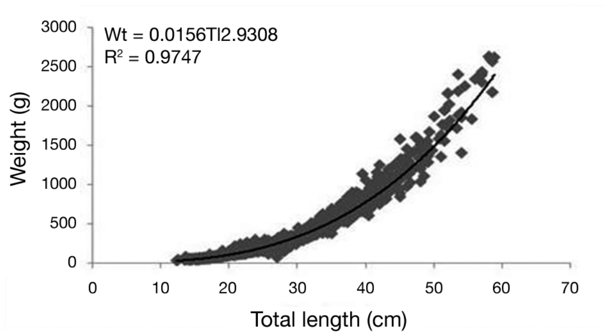

Fig. 5. – Relationships between total length and weight of *Cyprinus carpio* from the Sidi Saad Reservoir.

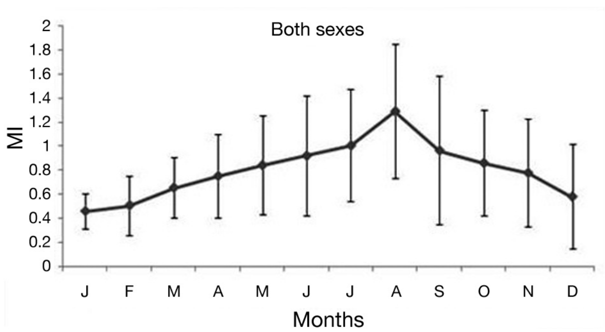

Fig. 6. – Monthly means of marginal increment (MI) of scales of *Cyprinus carpio* between January and December 2008 in the Sidi Saad Reservoir.

Table I. – Back-calculated total lengths by age group of the common carp in Sidi Saad reservoir. G.I: growth increment (%).

Age class (years)	Observed mean Lt	Mean back-calculated (both sexes)									
		1	2	3	4	5	6	7	8	9	10
1	15.82	14.49									
2	22.20	15.74	20.47								
3	27.35	15.97	21.57	25.01							
4	32.26	16.05	21.66	26.55	30.40						
5	36.55	16.18	21.86	26.88	31.54	34.76					
6	40.23	15.92	21.60	26.65	31.32	35.17	38.48				
7	42.99	16.06	21.87	26.92	31.78	35.79	39.29	41.70			
8	45.25	16.54	22.51	27.66	32.80	37.08	40.31	42.92	44.19		
9	47.35	16.73	22.76	28.06	32.98	37.46	40.95	43.14	45.23	47.17	
10	49.30	16.60	22.70	27.96	32.78	37.21	40.85	42.72	45.03	46.90	48.72
Total mean		16.03	21.89	26.96	31.95	36.24	39.97	42.62	44.81	47.03	48.72
G.I. (%)		30.91	20.77	16.92	12.61	9.79	6.40	5.03	4.83	3.52	

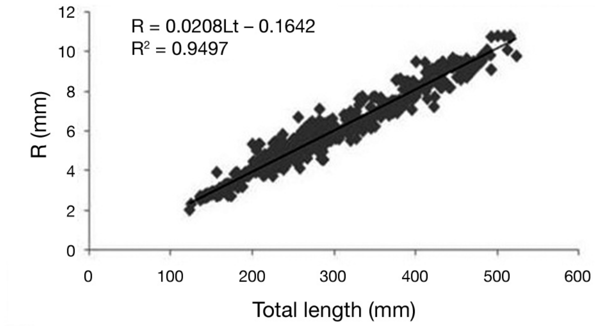

Fig. 7. – Relationships between scale radius and total length of *Cyprinus carpio* from the Sidi Saad Reservoir.

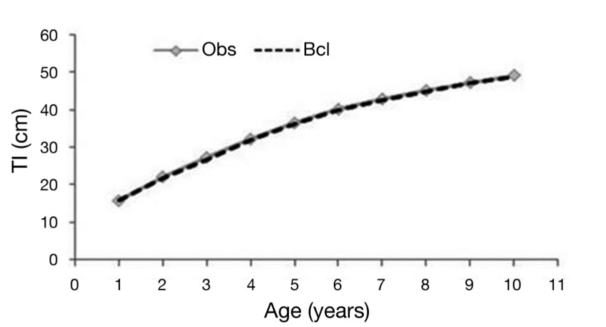

Fig. 8. – Von Bertalanffy growth curves for combined sexes of common carp *Cyprinus carpio* from Sidi Saad Reservoir. Obs., observed length; Bcl., back-calculated length.

– Combined sexes: $R = 0.0208TL - 0.1642$; $R^2 = 0.9497$ ($P < 0.01$).

These equations were obtained according to the correlation between the radius of the scale and the total length (Fig. 7).

Back-calculations

Given the strong linear correlation between the radius of the scale and the total length of the specimen, we used the scale measurement to back-calculate the total length at previous ages. The observed lengths were similar to the back-calculated length for individual age groups. The mean back-calculated length-at-age for 1 to 10-year-old specimens is listed in Table I. Growth rate was high during the first year of life for both sexes, while it slowed down after that (Fig. 8).

The Von Bertalanffy growth in length and weight

The Von Bertalanffy growth equations fitted to fish length and age data using the observed and back-calculated methods are $TL = 62.20\ (1 - e^{-0.151(t + 0.9665)})$ for females; $TL = 57.98\ (1 - e^{-0.1648\ (t + 0.8727)})$ for males and $TL = 60.05\ (1 - e^{-0.1577\ (t + 0.9205)})$ for combined sexes. For the back-calculated method, the equations are $TL = 61.71\ (1 - e^{-0.1501(t + 1.035)})$ for females; $TL = 57.82\ (1 - e^{-0.166\ (t + 0.901)})$ for males and $TL = 59.95\ (1 - e^{-0.1542\ (t + 0.9732)})$ for combined sexes.

Growth rate was not significantly different between sexes ($\chi^2 = 0.02$, $P > 0.05$). The Von Bertalanffy growth curve was fitted by length-at-age data for all individuals as shown in Fig. 7.

The observed and the back-calculated growths have similar curves which means that the index of performance for females ($\Phi = 2.766$ cm/*a*) is the same as for males ($\Phi = 2.743$ cm/*a*).

The growth in weight described by the Von Bertalanffy equation for females, males and combined sexes is presented respectively below:

– $W = 2908.55\ (1 - e^{-0.151(t + 0.9173)})^{2.9576}$; ($P < 0.05$);
– $W = 2153.7\ (1 - e^{-0.1648(t + 0.8727)})^{2.8744}$; ($P < 0.05$);
– $W = 2544.43\ (1 - e^{-0.1577\ (t + 0.9505)})^{2.9308}$; ($P < 0.05$).

The annual growth rate in weight was slightly higher for females with difference being more pronounced with age. Growth rate reached its maximum during the first year.

Longevity

The maximum longevity that the individuals of *Cyprinus carpio* can reach in Sidi Saad Reservoir is estimated at 18.9 years for females and 17.3 years for males.

DISCUSSION

The exponents of length-weight relationships for males (b = 2.8744), females (b = 2.9576) and combined sexes (b = 2.9308), estimated in Sidi Saad Reservoir, showed that the growth of the common carp was negatively allometric, slightly faster in length than in weight. Besides, no significant difference in b among sexes was observed (ANCOVA, $P > 0.01$).

These results are congruent with previous findings where negative allometric growth was noted by Gheorghe et *al*. (2011) for the Small Island (b = 2.845), Yilmaz et *al*. (2012) for the Bafra Fish Lakes (Samsun, Turkey) (b = 2.822) and Hailu (2013) for the tropical reservoir (Amerti, Ethiopia) (b = 2.923). While, isometric allometric growth of the common carp (b = 2.9017) was recorded in the Southern Caspian Sea, Iran (Sedaghat *et al*. 2013). The pattern of weight growth may fluctuate over the year depending on several factors, such as food availability, feeding rate, gonad development, or spawning period (Bagenal & Tesch 1978). The differences in b values observed for the species across the different areas may be attributed to the different trophic conditions (Chilari *et al*. 2006).

The relationship between animal length and scale radius suggests that the common carp scales continue to grow throughout life, making them a suitable structure to estimate age and investigate growth. Indeed, this structure was frequently used for the age estimation of Cyprinidae (Crivelli 1981, Fernàndez-Delgado 1990, Balon 1995, Alp & Balik 2000, Treer *et al*. 2003, Tempero *et al*. 2006, Oyugi *et al*. 2011, Saylar & Benzer 2014).

The observed lengths were similar to the back-calculated lengths for individual age groups. The results achieved through the back calculation method are up to standard and they have proved the validity of using scales to esti-

Table II. – Growth parameters of Von Bertalanffy equation (L_∞, K, t_0 and Φ') for *Cyprinus carpio* in different areas.

Country	Sex	L_∞	K	t_0	Φ'	References
Carmargue, France	M+F	55	0.20	–0.93	2.77	Crivelli (1981)
Guadalquivir River, Spain	M+F	79.6	0.14	0.03	2.96	Fernàndez-Delgado (1990)
Campaspe Channel, Australia	M	60	0.35	0.17	3.1	Villizi & Walker (1999)
	F	63.9	0.35	0.17	3.17	
Gölhisar Lake, Turkey	M+F	72.76	0.17	–0.44	–	Alp & Balik (2000)
	M	68.09	0.2	–0.32	–	
	F	76.72	0.149	–0.62	–	
Barmah Forest., Australia	M	48.9	0.25	–0.52	2.77	Brown *et al*. (2005)
	F	59.4	0.18	–0.61	2.8	
USA	M+F	67.9	0.28	0.01	3.12	Jackson *et al.* (2008)
Lake Gariep, South Africa	M	60.7	0.39	0.16	3.16	Winker *et al.* (2011)
	F	66.2	0.35	0.16	3.19	
Small Island	M+F	84.7	0.16	–0.81	–	Gheorghe *et al*. (2011)
Lake Naivasha, Kenya	M+F	76.7	0.53	–	–	Oyugi *et al*. (2011)
	M	61.8	0.68	–	3.41	
	F	75.5	0.75	–	3.63	
Bafra Fish Lake, Turkey	M+F	60.96	0.27	–0.80	–	Yilmaz *et al.* (2012)
	M	54.07	0.36	–0.53	–	
	F	60.96	0.27	–0.80	–	
Mogan Lake, Turkey	M+F	49.71	0.24	–0.60	–	Saylar & Benzer (2014)
	M	49.6	0.24	–1.74	–	
	F	49.06	0.25	–1.44	–	
Sidi Saad Reservoir, Tunisia	M+F	60.05	0.16	–0.92	2.75	Present Study
	M	57.98	0.16	–0.87	2.74	
	F	62.20	0.151	–0.96	2.76	

mate the common carp age and growth in the Tunisian reservoir.

Age validation and growth estimation are important parameters in the construction of age-structured population dynamic models. Therefore, there has been an increase in the use of both verification and validation methods in fish growth studies such as marginal increment analysis, centrum edge analysis and size model analysis (Panfili *et al*. 2002). To validate the periodicity of bend formation, we used MI. Like our study, most works on the common carp age and growth estimation are congruent with results showing the formation of one annulus a year in winter. This period of slow growth is associated with times of low water temperature, as recorded in our study area, in January (8.5° C) (Soudoud 2010). Similar findings have been reported for the population of the common carp due to unfavorable environmental conditions in the estuary of the Guadalquivir River in southwest Spain (Fernàndez-Delgado 1990).

The asymptotic length of the common carp from Sidi Saad Reservoir (Tunisia) is 62.20 cm for females and 57.98 cm for males. These findings are incompatible, though, with other studies (Alp & Balik 2000, Oyugi *et al*. 2011, Saylar & Benzer 2014). For combined sexes, some research works have reported similar asymptotic total length (Yilmaz *et al*. 2012). Other studies have achieved different results (Fernàndez-Delgado 1990, Alp & Balik 2000, Balik *et al*. 2006, Gheorghe *et al*. 2011) (Table II). We also noted that the difference in the growth estimation may be related to the heterogeneity of the age estimation methods, the calcified part selection and the method used to adjust the data in the growth model.

Collected data on the common carp age show inconsistency in growth rates among specimens of different areas (Turkey, France, Spain, Australia, Kenya, South Africa, and USA). This difference may also result from some environmental conditions, such as temperature, quality of food, time of capture, organic matter, stomach fullness, disease and parasitic loads (Bagenal & Tesch 1978). Similarly, this variation may be due to different stages in ontogenetic development, as well as differences in condition, sex, age, length, gonadal development of the fish (Ricker 1975), and geographic location.

The growth performance index of the common carp estimated in this study ($\Phi = 2.75$) is in line with other research studies (Table II).

In both sexes, during the first two years of life, the young common carp grows rapidly in length and weight. Growth rates, however, begin to slow down during the transition from the second to the third year of life. These results are in agreement with those of Mert & Bulut (2014), who worked on the same species.

The longevity of *Cyprinus carpio* in Sidi Saad Reservoir is estimated at 18.9 years for females and at 17.3 years for males. These findings are in harmony with those achieved by Bruslé & Quignard (2001), who have shown that the longevity of the carp varies between 15 and 20 years and, in exceptional cases, can even reach 50 years.

The pattern of exploitation for the common carp needs to be based on accurate growth information. Within this framework, this study provides insight into several key biological parameters required for age-based stock assessments and population modeling of the common carp in a Tunisian reservoir.

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