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Age and growth of common bream, *Abramis brama* (L.), caught at Hammam Debagh Reservoir (Guelma, northeast Algeria)

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Abstract. This study was conducted in Hammam Debagh Reservoir located in northeastern Algeria, which was first the subject of fish farming tests in 2001. The species tested included Chinese carp, royal carp, common carp, pikeperch, and common bream. The present work aimed to determine the age and growth of one of the most frequently caught species in the reservoir, common bream, *Abramis brama*. This information is essential to the knowledge of fish biology, and thereby to solving many of the problems of fish research and development. A sample of 100 common bream, *A. brama*, was caught with gillnets over a period of six months from December 2017 to May 2018. The results obtained fit well with the growth model and were similar to those published regarding other environments. Scales from a sample of 50 fish were read under an optical microscope, which permitted identifying five age groups. The value of the overall sex ratio (4.88) revealed a strong imbalance in favor of males throughout the study period. The relationship linking length-weight is of the minor allometry type with b < 3.

Keywords: Common bream, age, reservoir, growth, scale

Introduction

Common bream, *Abramis brama* (L.), is a benthic freshwater species that is distributed throughout Western and Central Europe and Asia. It was accidentally introduced into the Hammam Debagh Reservoir in 2011 along with another species known as Chinese carp. According to the Directorate of Fisheries and Fishery Resources of the Wilaya of Guelma, bream was among the most abundant fish species in the commercial harvests of 2015 and 2016, and it comprised about 20% of the catches in the reservoir.

Bream age and growth have been studied by several authors (Goldspink 1981, Kompowski 1982, Lammens 1982, Kangur 1996, Specziár et al. 1997,

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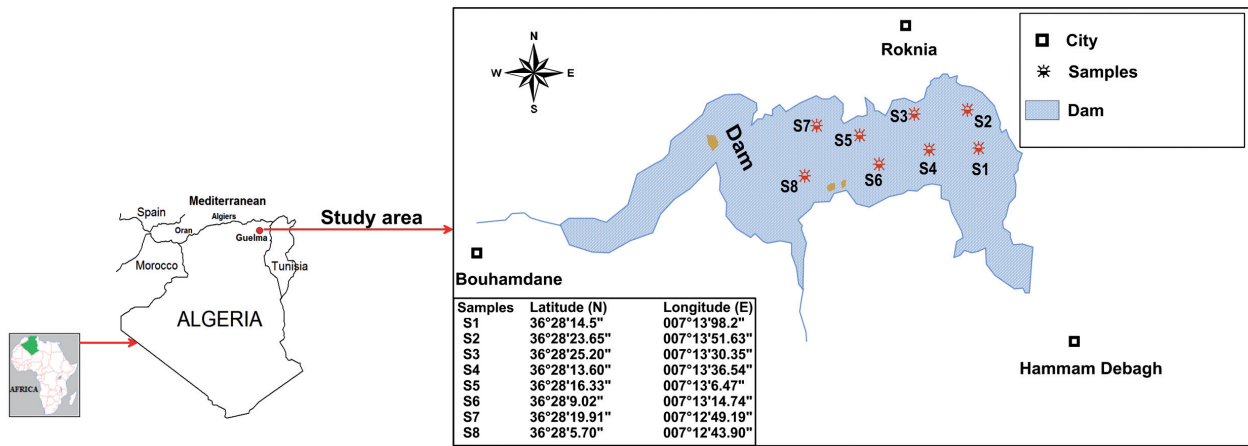
Figure 1. Location of the study area.

Matenova et al. 1998, Tierney et al. 1999, Kakareko 2001, Adakbek et al. 2003, Treer et al. 2003, Žiliukienė and Žiliukas 2011); however, no study has focused on the bream population in Algeria. Živkov et al. (1999) designated four main types of bream length growth: asymptotic standard lengths (L∞) up to 60 cm that is typical for cold, northern water basins and also stocks with a high initial growth rates; a moderate growth rate with L∞ between 60 and 80 cm; two types with asymptotic values that are too high and are biologically insignificant.

The development of research on rational fisheries management and exploited stock dynamics has led renewed interest in accurate age determination methods (Daget and Le Guen 1975). While Zhang et al. (2016) propose that scales are the only structure that can be used to study common bream growth, and Goldspink (1981) used the operculum to study the growth rates of *A. brama* in three eutrophic lakes in England, otoliths are widely accepted as the most appropriate structure for determining fish age (Phelps et al. 2007, Ma et al. 2011).

This work undertook to study, for the first time, the age, growth, and population conditions of bream in Hammam Debagh Reservoir where no ichthyological research has been done on this species since the reservoir was impounded or even in eastern Algeria.

Study area

Located in northeastern Algeria at 36 ° 27 ′41.78″ N, 7 ° 14′ 12.99″ E (Fig. 1) and at an altitude of 720 m, the reservoir is located 3 km upstream from the town of Hammam Debagh and about 20 km from the city of Guelma on a site rich in vegetation. The surrounding lands are exclusively agricultural. The reservoir is 430 m wide from east to west, 2,300 m long from north to south and is roughly rectangular in shape covering an area of 4.9 km^2. The depth ranges, on average, between 65 and 98 m in the vicinity of the catch tower and begins to decrease irregularly approaching the limit of the upstream zone where it reaches 2 m. The bottom of the reservoir is covered by a thick layer of black mud, which is very thin in some places and rests on a sandy-clay substrate (red and gray clay). It rises from the west east of Hill 530 to Hill 612. The length of the main course of the Wadi Bouhamdane that feeds the reservoir is 99 km. It has a slope of 0.008 (ANRH 2008) and an average altitude of 785 m (270-1281 m). The density of permanent drainage is 0.53 km^{-1}, while that of temporary drainage is 1.90 km^{-1}. The reservoir has a total capacity of 220 hm^3 that allows annual regulation of 55 to 60 hm^3. The watershed covers 1.070 km^2 that makes an inter-annual contribution of 69 hm^3. The maximum flood achieved by the project is 3.500 m^3 s^{-1}. The area is not very urbanized, and the local

population lives in traditional houses and raises cattle and sheep, and there is substantial agriculture, mainly of cereal crops, which occupies 58.1% of the surface of the basin, while olive trees occupy approximately 8%.

Material and methods

A total of 100 specimens was caught during the monthly sampling carried out between December 2017 and May 2018 at six sites (Fig. 1) using a trammel net 50 m long and just over 1 m high (internal mesh size 10 cm; external mesh size 23 cm). The samples obtained were transported to the laboratory and the following parameters were recorded for each individual: total length and standard length (TL and SL; to the nearest 0.1 cm), total weight (TW; to the nearest 0.01 g), eviscerated weight (EW; to the nearest 0.01 g). The sex and maturity stage were identified by macroscopic observations of gonads. Scales of *A. brama* were removed from the area below the pectoral fin, washed, and placed between two glass slides. Then they were photographed with a digital camera coupled with a binocular microscope (Optika Vision Lite 2.1). The von Bertalanffy equation has been used to describe *A. brama* growth (von Bertalanffy 1938):

$$TL = L\infty \ (1-e^{-k(t-t_0)}),$$

where $L\infty$ is the asymptotic mean length, k is the growth rate, and t_0 is the hypothetic age at zero length. For weight growth, the weight-age relationship that was described as linear growth with the von Bertalanffy equation that expresses the evolution of weight as a function of time:

$$TW = W\infty \ (1-e^{-k(t-t_0)})^b,$$

where TW is the average weight of fish at time t; $W\infty$ is the maximum mass corresponding to $L\infty$ (obtained from the relationship $TW = a \ TL^b$ by replacing TL by $L\infty$: $W\infty = a(L\infty)^b$, b being close to 3, this curve is a sigmoid that starts from point $t = t_0$ and is asymptotic at the right $y = W\infty$.

The commonly used length-weight relationship by Ricker (1973) was applied: $TW = a \ TL^b$,

where TW is total weight (g), TL is total length (cm), and a and b are the constants.

The difference in the length-weight relationship between the sexes was tested with ANCOVA, while the hypothesis of isometric growth was tested with the t-test. The growth performance index (Pauly and Munro 1984) $\varphi = \log k + 2 \log L\infty$ was calculated to compare the results obtained in this study with results published elsewhere. FISAT II (Gayanilo et al. 1996) was used to estimate the length-weight relationship and the growth parameters of the von Bertalanffy (1938) equation. The sex ratio was calculated globally as the ratio between the number of males and the number of females M/F, then it was calculated for each month and by size class.

Results

Age and growth

Common bream age was determined according to the number of scale growth streaks, and this permitted us to devise an age-length key. The age of the sampled fish ranged from 2 to 6 years, with the predominance of age groups 2 and 3 constituting 70% of the catches (Table 1).

There is a very close correlation between the total fish length (TL) and the radius scale (RS): TL = f (RS), which permitted us to relate these two parameters. The equation expressing the linear relationship between the total length (TL) and scale radius (RS) was TL = 24.83RS + 24.19 (mm) (r = 0.51; P < 0.001). The size of the fish at the appearance of the first scales was 24.19 mm. The results of the mean back-calculated lengths for each age in the total population obtained with Lee's formula are summarized in Table 2. The fish measured were divided into size classes at 5 cm intervals. These data reflect the size distribution at a given age and indicate their extreme values for each age.

Back-calculated lengths were used to calculate the von Bertalanffy parameters of $L\infty$ = 45.52 cm, k = 0.28, and t_0= -2.67. The age group 6+ (n = 2) was

Table 1
Age-length keys of *A. brama* from the Hammam Debagh Reservoir

Size classes (cm)	Age (years)					
	2+	3+	4+	5+	6+	N
13-18		1				1
18-23		2				2
23-28		10	6	2		18
28-33	1	3	8	4		16
33-38		2	2	5	1	10
38-43			1	1	1	3
N	1	18	17	12	2	50
n%	2%	36%	34%	24%	4%	100%
Total length (mean (SD))	28.5	25.95 (5.06)	30.01 (3.60)	33.29 (3.97)	37.25 (3.18)	29.59 (5.25)
Eviscerated weight (mean (SD))	208	199.05 (7.75)	224.29 (7.28)	245.41 (10.43)	417 (6.64)	22.76 (9.05)
Total weight (mean (SD))	225	220.78 (8.72)	249.59 (7.69)	288.33 (13.64)	464 (7.35)	256.6 (10.66)

Table 2
Mean (SD) total length (in cm) at the appearance of each scale growth arrest ring in the total population of *A. brama* in Hammam Debagh Reservoir

Age	TL1	TL2	TL3	TL4	TL5	TL6
2+ (N = 1)	14.83	18.31				
3+ (N = 18	14.16 (2.97)	19.29 (3.81)	24.45 (3.64)			
4+ (N = 17)	14.61 (3.76)	19.31 (3.82)	24.78 (4.11)	29.1 (3.69)		
5+ (N = 12)	14.44 (2.41)	19.4 (3.03)	22.9 (3.21)	28.44 (3.92)	31.75 (4.34)	
6+ (N = 2)	14.33 (0.7)	21.41 (2.98)	27.0 (3.51)	34.94 (4.91)	39.29 (4.74)	40.28 (4.74)
Total length mean (SD)	14.4 (3.07)	19.39 (3.49)	24.29 (3.72)	29.23 (4.02)	32.83 (5.01)	40.28 (4.74)
Number of back-calculations	50	50	49	31	14	2

not considered in the calculation of the latter. The performance index (φ) calculated was 2.76. The asymptotic length calculated from the scales (L∞$_{>♂+♀+I}$ = 45.52 cm) was perfectly consistent with the maximum length observed in the total population (TL = 41.5 cm). The parameters of the von Bertalanffy equation calculated for common bream in Hammam Debagh Reservoir were compared with those of previous works as presented in Table 3. According to von Bertalanffy's model, the equation of the linear curve was written TL = 45.52 × (1$^{-e-0.28(t+2.67)}$). Figure 2 represents the theoretical total length observed and the corresponding theoretical annual increase.

Length-weight relationship

The negative allometry for *A. brama* in the study area for combined sexes (r = 0.83; P < 0.001) and males (r = 0.86; P < 0.001) were observed (Table 4). For females, isometric growth was recorded (r = 0.90; P < 0.001). The slopes (b-values) of the length-weight relationship or the eviscerated size-weight relationship did not differ between the sexes (ANCOVA

Table 3

Comparison of growth parameters for *A. brama* in Hamman Debagh Reservoir with those determined by other authors

Place and source	t (year)	Asymptotic standard length in cm (L∞)	Curvature parameter (k)	Overall growth performance (Φ)
Hammam Debagh Reservoir (Guettaf et al. 2018)	6	45.52	0.28	2.76
Croatian Danube (Treer et al. 2003)	16	57.7	0.087	5.67
Lake Balaton (Specziar et al. 1997)	10	50.1	0.083	5.34
103 populations (Živkov et al. 1999)	10	62.3	0.0986	5.95
Curonian Lagoon (Stankus et al. 2006)	15	71.6	0.576	2.591
Lake Rubikiai (Žiliukienė et al. 2011)	13	65.7	0.085	2.565
Average lengths reference (Hartvich and Kubečka 1989)	11	44.5	0.153	5.71

covariance analysis, F = 2.43 and F = 2.45 respectively, P > 0.05).

Weight growth

The weight growth equation for both sexes was $W = 6106.986[1-e^{-0.28(t+2.67)}]^{2.463}$. The asymptotic weight in the total population of W∞ = 6106.986 g was greater than the maximum observed weight (We = 527 g).

Sex ratio

Of the 100 individuals examined, 83 were male and 17 were female, which represents a strong, significant imbalance in favor of the males. The ratio of males to females was 4.88. Statistical tests showed that the difference between males and females was highly significant. Except in February, males were more numerous and dominant than females throughout the study period, especially in April and May, the months that coincided with the spawning period (Table 5). It was difficult to determine whether the difference between males and females was because of the migration of females to the bottom, i.e., to the spawning grounds of the reservoir, or to the selectivity of the fishing gear. This could also have resulted from both phenomena.
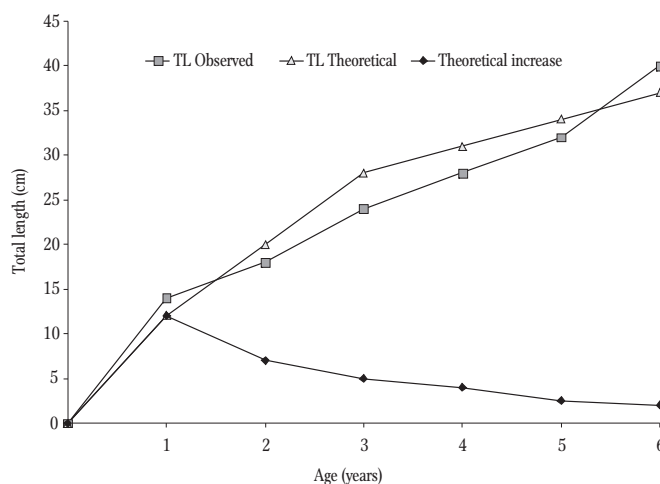

Figure 2. Observed and theoretical linear growth and theoretical annual increase calculated for the total population of *A. brama* in Hammam Debagh Reservoir.

Discussion

Age determinations are essential fish biology knowledge, and they contribute to solving many problems concerning fish research and development (Carlander 1956, Lagler 1956). It is through the study of fish age and mortality that the importance of various age classes in a population is discovered. This knowledge can be used to make forecasts of the magnitude of possible catches and to suggest what changes should be made to regulations. In this study,

Table 4

Parameters of the *A. brama* length-weight relationship in Hammam Debagh Reservoir

Sex	N	r	Mean ± SD	Length-weight relations	Allometry
Males	83	0.86	236.02 ± 10.65	TL= 0.05 EW2.46	Negative allometry
			260.36 ±11.78	TL = 0.05 TW2.45	
Females	17	0.90	169.82 ± 10.05	TL = 0.03 EW 2.56	Isometric growth
			211.11 ± 11.71	TL = 0.03 TW 2.56	
Total	100	0.83	225.61 ± 10.82	TL = 0.05 EW 2.46	Negative allometry
			255.01 ± 11.99	TL = 0.05 TW 2.46	

TL – total length, EW – eviscerated weight, TW – total weight

Table 5

Monthly evolution of the sex ratio (SR) of the *A. brama* population in Hammam Debagh Reservoir

Month	Males	Females	SR	χ^2_{obs}	P-value
December	14	1	14	11.26 S	0.00
February	2	5	0.4	1.28C	0.31
March	28	9	3.11	9.75 S	0.00
April	21	1	21	18.18 S	0.00
May	18	1	18	15.21S	0.00

the scale striations were well marked and spaced, which facilitated reading them microscopically and determining the five age groups (Table 1). The identification of five age groups in the study sample caught indicated that the bream birth date was June 2012, and that these fish had been released into the reservoir as six-month-old juvenile specimens, and similar stocking operations were conducted in 2013, 2014, and 2015. Since bream generally reaches sexual maturity at the age of four years (Backiel and Zawisza 1968), the first recruitment in reservoir waters was in 2016 followed by a second in 2017.

In the present study, the fish length at which scales first form that was determined empirically was 24.19 mm in the Hammam Debagh Reservoir, which was close to the 20 mm length reported by Vasnetsov et al. (1957) and Kennedy and Fitzmaurice (1968). Fish growth depends on multiple factors that are related to three groups of factors: hereditary, dietary, and environmental (other than food, that include dissolved salts, latitude, insolation, geological nature of the soil, temperature). Temperature, in particular, clearly influenced the rate of food conversion, either as energy for vital life processes or as fish flesh.

Noteworthy among studies that focus on nutritional and growth issues is Kesteven (1946) who calculated the maintenance feed ration (which is ratio of the weight of food consumed daily that ensures the weight of a fish is maintained) at approximately 2%. Marciak (1972) found a positive correlation between growth rates and invertebrate biomass of mud. Stankus (2006) reports that the growth rate of *A. brama* is related to latitude and compared growth rates of *A. brama* in different water bodies and found that growth decreased with increasing latitude. Growth was influenced not only by the geographical location of the water body, but also by the abundance of food. Kakareko (2001) and Stankus (2006) indicated that growth rates of *A. brama* depended on the abundance of benthic organisms.

The growth rates of the bream in the Hammam Debagh Reservoir of Φ = 2.76 and L∞ = 45.52 cm obtained in the current study were significantly lower than in previous studies (Table 4). Low growth rates could be linked to the high bream density and the scarcity of zoobenthos. Whereas Živkov et al. (1999) report a relatively higher *A. brama* growth rate of Φ = 5.95 and L∞ = 62.3 cm, and Treer et al. (2003) also

report a particularly high *A. brama* growth rate of Φ = 5.67 and L∞ = 57.7 cm in the Danube in Croatia.

These results indicate that beside benthic organism abundance, many other factors, such as temperature and latitude, influence the growth of the common bream populating the Hammam Debagh Reservoir. Thus, it cannot be assumed that the stock or productivity of the reservoir can be properly estimated based solely on quantitative analyses of benthos or plankton.

Parameters *a* and *b* of the length-weight relationship are very sensitive to the number of monthly samples and the size composition of each sample (Fréon 1988). Thus, the relationship between length and weight in both sexes was very well correlated at r = 0.90 for females (Fig. 3) nad r = 0.86 for males (Fig. 4). Figure 5 indicates that regardless of the size of the species, the scatterplot is not dispersed, which suggests that the length-weight relationship is governed by the same correlation for all sizes. The allomeric coefficient value in both sexes combined of *b* = 2.46 was lower than values obtained in previous work conducted in different regions, for example, for the same bream species *b* = 2.884 (Dauba and Biró 1992) in Hungary, *b* = 3.020 (Kompowski 1982) in Poland, *b* = 3.175 (Verreycken et al. 2011) in Belgium, *b* = 3.250 (Tarkan et al. 2006) in Turkey, and *b* = 3.207 (Huo et al. 2011) in China. This minor allometry indicates that growth in length was faster than growth in weight. The rate of weight increase also decreased gradually with age (Fig. 6). It is important during the first years of fish life when bream gains weight more quickly.

In studies of population dynamics, it is always necessary to know the sex ratio since it is indeed the number of females in the population that determines the number of future recruits. Up to four periods with specific sex ratios can generally be distinguished in breeding populations (Živkov 1980, Yankov and Zivkov 1988). Males dominate the youngest age groups (period A) because they mature earlier. The next period (B) has balanced sex ratios, while females dominate the older age groups (period C) because of their longer life cycle. There are only females
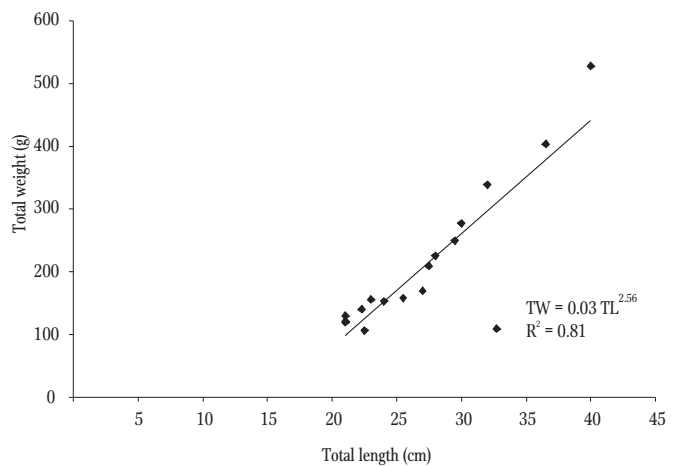

Figure 3. Standard length-weight relationship (a) and total length-weight relationship (b) of *A. brama* females in Hammam Debagh Reservoir.
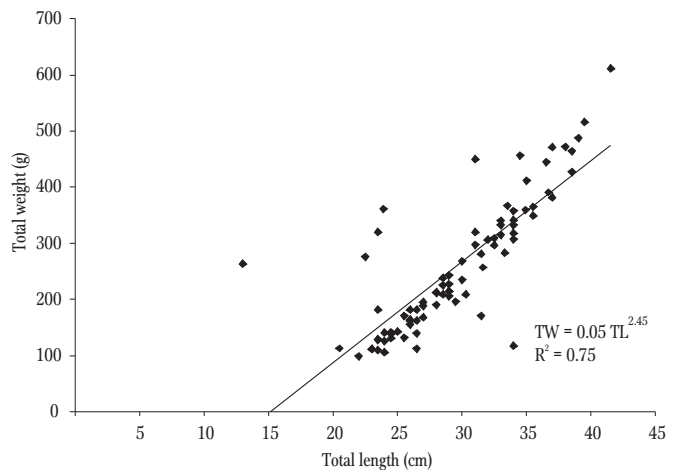

Figure 4. Standard length-weight relationship (a) and total length-weight relationship (b) of *A. brama* males in Hammam Debagh Reservoir.

in the fourth period (D). The occurrence and duration of the four periods depend on population growth rates and age at first maturity. In this study, our results indicated that there was a strong imbalance in favor of males in the sex ratio of the Hammam Debagh Reservoir common bream population throughout the study period except in February when females dominated (Table 5). So period A dominated and included the age groups caught (2-6 years). Indeed, the geographical distribution of individuals could have been related to hydrological conditions, plankton composition and abundance,
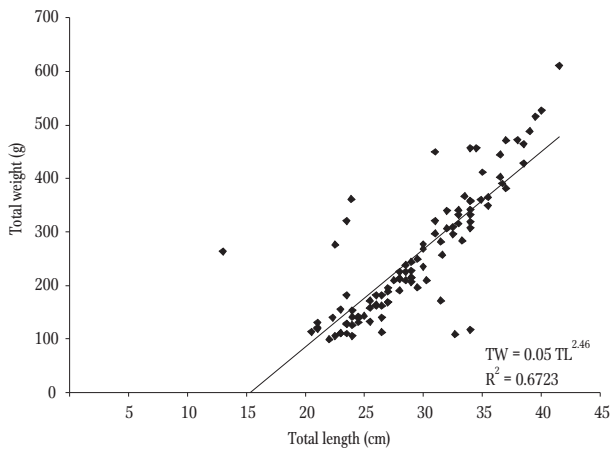
Figure 5. Standard length-weight relationship (a) and total length-weight relationship (b) in both sexes of *A. brama* in Hammam Debagh Reservoir.
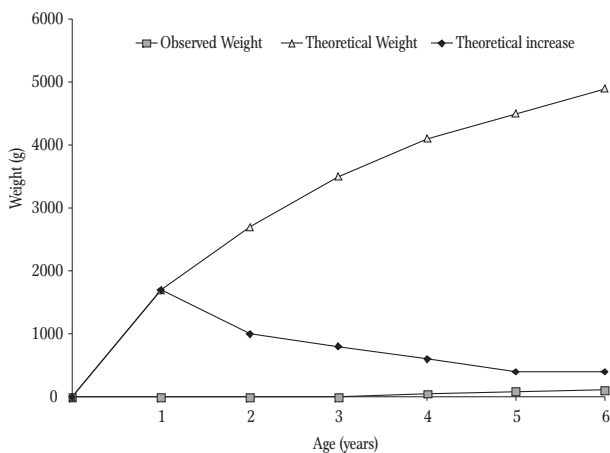

Figure 6. Observed and theoretical weight growth and theoretical annual increase calculated for the total population of *A. brama* in Hammam Debagh Reservoir.

and the migratory nature of common bream (Fréon 1988). Other factors could have also influenced changes in demographic structure, such as the first period of sexual maturity, which could have occured later and lasted longer. Males dominate most bream populations (Table 6) and sometimes consistently, as was the case in Hammam Debagh Reservoir where the number of males was 4.88 times greater than that of females, and they can be from 1.2 to 8.5 times more numerous than females (Karakumskoe Reservoir, Sokolova 1990, Rimov Reservoir, Kubečka 1990, Lake Kotokel, Kupchinskii 1984). Some authors explain this strong sex ratio imbalance by the

fact that males stay longer at spawning sites (Kupchinski 1984).

Conclusions

In addition to changes in its original habitat, the large spatial and temporal variations of various natural biotic and abiotic factors had a great impact on the growth rate of the common bream in Hammam Debagh Reservoir.

Age estimations using growth arrest rings facilitated distinguishing 5 age groups from 2 to 6 years; the one-year-old individuals escaped the fishing gear because of their small size.

The values of the parameters of the Von Bertalanffy linear growth model, and the overall growth performance index (Φ) calculated in this study were relatively low compared to results obtained in previous work in different regions of Europe and Asia. Despite this, Von Bertalanffy's model was perfectly applicable to the growth of *A. brama* from the Hammam Debagh Reservoir. The asymptotic length obtained was close to the size of the largest specimen caught.

Allometry coefficient *b* values that express the relative shape of a fish's body, was less than 3, so the ANCOVA covariance analysis showed that there was no significant difference between the two sexes. This minor allometry indicates that growth in length was faster than growth in weight. The asymptotic weight obtained was greater than the weight of the largest specimen caught.

Although there is a lack of information on the ichthyofauna of the Hammam Debagh Reservoir, we believe that the relatively low growth rate of common bream in this area can be explained by the difference in temperature and the limited food supply. Such information suggests there are good conditions, but this must be confirmed by detailed research.

Table 6

Sex-ratio (SR) variations according to *A. brama* size in Hammam Debagh Reservoir

Size classes	Males	Females	SR	χ^2_{obs}	P-value
13-18	1	0	-	-	-
18-23	4	6	0.66	0.4C	0.33
23-28	20	4	5	10.66S	0.00
28-33	27	5	5.4	15.12S	0.00
33-38	21	1	21	18.18S	0.00
38-43	6	1	6	3.57C	0.07

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