Reproductive biology of Algerian barb *Luciobarbus callensis* (Valenciennes, 1842) (Cyprinidae) in Beni Haroun dam, north-east of Algeria

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Abstract. The reproductive biology of Algerian barb, *Luciobarbus callensis* (Valenciennes, 1842) in Beni Haroun Dam (North-east of Algeria) was studied. A total of 303 fish samples (251 females and 52 males) from catches of local fishermen, were collected monthly from February 2015 to January 2016. The total length of the fishes is ranged from 16 to 47 cm. The spawning period was determined by analyzing the monthly evolution of the gonado-somatic index (GSI). The liver somatic index (LSI) and the condition factor (Kc) were calculated, and the corresponding curves were fitted. The sexes of specimens were determined macroscopically and the observed sex ratio was in favor of females during the whole cycle of study. The monthly monitoring of the gonado-somatic index (GSI) reveals that the spawning period is extended from April to June, within which LSI decreases when GSI goes up. This can be explained by the use of the liver reserves for the gonad developments.
Key words: spawning period, gonado-somatic index (GSI), liver-somatic index (LSI), condition factor (K), sex ratio.

Introduction. *Luciobarbus callensis* (Valenciennes) (synonymy of *Barbus callensis*) are an important Cyprinid fish species in the world for aquaculture purposes, due to its abundance, availability (all year round) affordability, tasteful flesh and economic value, representing 61% of world production in 2008 (Kottelat & Freyhof 2007; Gante 2011; Mimeche et al 2013; FAO 2010; Fontaine et al 2009).

The reproductive biology of fish is an essential factor in the determination of the appropriate management practice, promoting the conservation of fish species in their habitat.

Various methods are used to assess the reproductive condition in fishes, including microscopic gonadal staging, macroscopic gonadal staging, oocyte size–frequency distributions, sexes steroid measurement and gonadal indices (Lowerre-Barbieri et al 2011; West 1990).

The gonadosomatic index (GSI) expressed as a gonad mass as a percentage of total body or somatic mass is widely used simple measure of the extent of reproductive investment or gonadal development (Gunderson 1997; Cubillos & Claramunt 2009). This is due to reason that both gonad and somatic mass are highly variable in relation to individual condition, the maturational status of the gonads and environmental factors (Jons & Miranda 1997; Lambert et al 2003).

The sex ratio studies provide information on the proportion of male and female fishes in a population, as well as they indicate the dominance of sexes in population and the given basic information necessary for fish reproduction and stock size assessment (Vicentini & Araujo 2003).

Condition factor has been estimated by directly measuring physiological parameters related to the energy stores, such as tissue lipid content and reproductive status (Fechhelmet al 1995). Overall, measures of condition factor are used as a valuable tool to indicate the tissue energy reserves, with the expectation that a fish in relatively good condition should demonstrate higher growth rates, greater reproductive potential and higher survival than a lower conditioned counterpart, given comparable environmental conditions (Cone 1989).

The objectives of this study were to provide information on the biology of the *L. callensis* and describing reproductive traits of this specie, and also to analyze the sex ratio, gonado somatic index, liver somatic index and condition factor. The results of this study would assist in increasing the knowledge of the reproductive biology of *L. callensis* which is relevant in aquaculture management adequate supply and breeding.

Material and Method

Study area. The present study was carried out on the Beni Haroun Dam (the largest dam in the country), located downstream of the confluence of Oued Rhumel and Oued Endja (north-west of El-Grarem region, wilaya of Mila) to about forty kilometers north of Constantine (NAFD 2007). To the south of which are located a large urban center (Constantine, Batna, Khenchela) (Mebarki & Benabbas 2008; Mebarki 2005), covering about 3.929 ha of surface area (Tractebel 1997) (Figure 1).

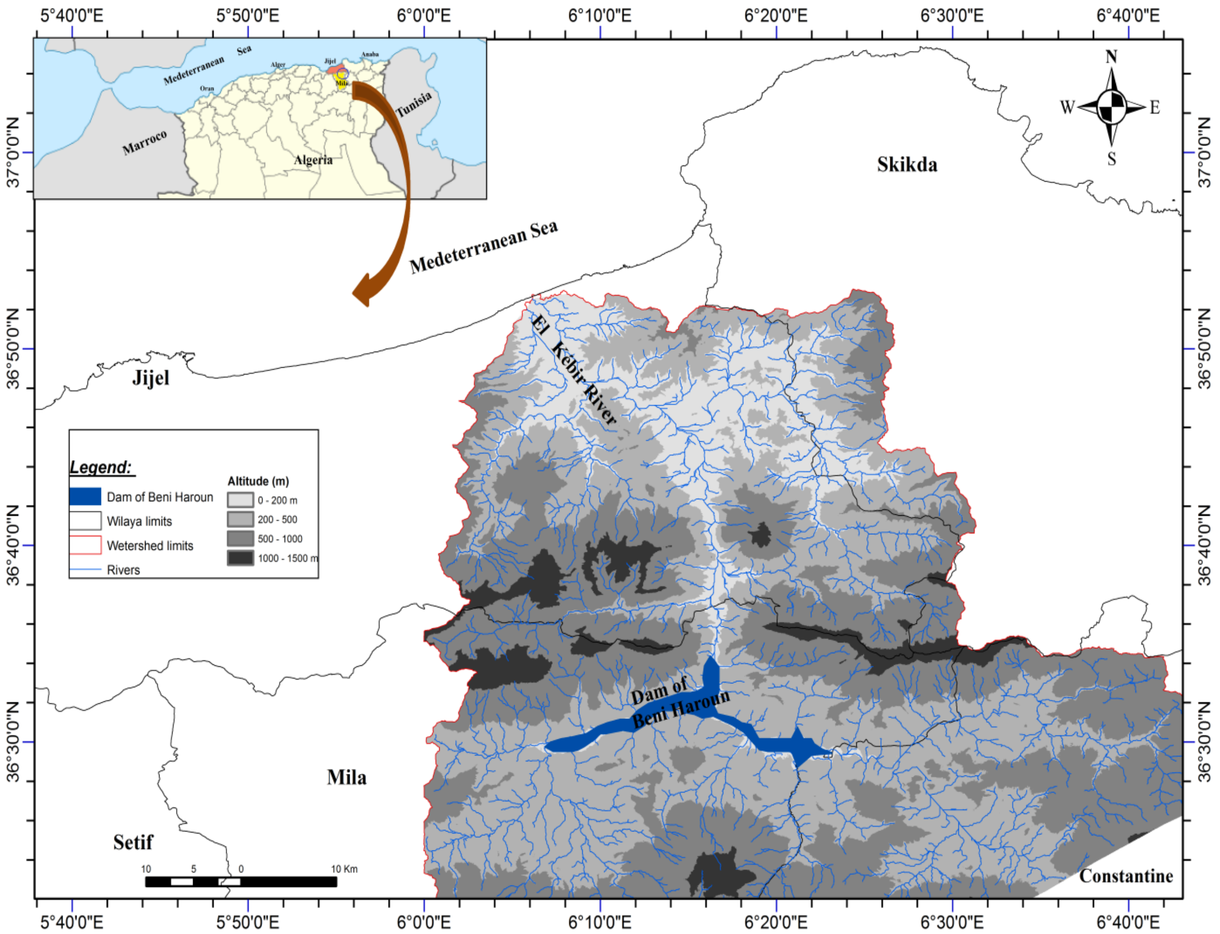


Figure 1. Map of sampling site (Dam of Beni Haroun).

Collection and sampling of specimens. The fish species were sampled using gill-nets (20, 25, 30, 35, 40 and 45 mm sides), which were recovered in the early morning. Then the specimens were transported in an insulated box containing ice chips to laboratory of Aquatic and Terrestrial Ecosystems (University Mohamed Cherif Mesaadia, Souk Ahras, Algeria). A total of 303 samples (251 females and 52 males) were collected monthly from February 2015 to January 2016.

Body measurements. Total lengths (TL, cm) were measured using a one-meter measuring board graduated in cm, since the weight was evaluated by an electronic balance accuracy of 1 g by considering the total weight (TW, g). All specimens were dissected to obtain eviscerated weight (EW, g), gonad weight (GW, g), liver weight (LW, g). Also, fish sexes (male or female) was determined by visual examination of the gonads and subsequently the mentioned parameters were recorded on a data collection sheet.

The reproductive biology was determined by sex ratio (SR), gonad somatic index (GSI), liver-somatic index (LSI) and condition factor (K).

Sex ratio. In this study, we have adopted the definition of sex ratio as the proportion of males and females in the population (Kartas & Quignard 1984).

$$\text{Proportion of females} = (F/F + M) \times 100$$
$$\text{Proportion of males} = (M/F + M) \times 100$$

Where:

F: Number of females;
M: Number of males.

Gonadosomatic index (GSI). The GSI it is one of the parameters used in reproduction studies of fish. This parameter was estimated as the ratio of gonad weight to the eviscerate weight of the body, which can encrypt the growth of gonads during the reproductive cycle (Roche et al 2003).

$$GSI = (GW/EW) \times 100$$

Where:

GW - gonad weight [g];
EW - eviscerate weight [g].

Liver somatic index. The liver is a vital organ that plays a crucial role in the processes involved in the development of genital products (Nunez 1985). The liver somatic index (LSI) was estimated as the ratio of liver weight to the eviscerate weight of the body (Bougis 1952).

$$LSI = (LW/EW) \times 100$$

Where:

LW - liver weight [g];
EW - eviscerate weight [g].

Condition factor. The condition factor (k) of the experimental fish was estimated according to the following relation (Gomiero & Braga 2005):

$$K = (W/L^{b}) \times 100$$

Where:

W – weight of fish (g);
L – total length of fish (cm);
b – slope of regression line.

The length-weight relationship was calculated using the formula of LeCren (1951):

$$W = aL^{b}$$

The formula was estimated by linear regression after logarithmic transformation of the data (Froese 2006):

$$\text{Log } W = \log a + b \log TL$$

Where:

W - body weight of fish in gram (g);
TL - total length (cm);
a – intercept;
b - slope of the regression line.

Statistical analyses were performed using the Statistica, statistical program (software version 8.0). All results are subjected to ANOVA statistical analysis, in order to compare the average GSI and LSI.

Results

Sex ratio. A total of 52 males and 251 females were observed out of 303 examined samples. Sex ratio analysis was performed by studying global sex ratio (Table 1), sex ratio by months (Figure 2) and sex ratio by length classes (Figure 3), using the heterogeneity test chi-square (X^2) with one degree of freedom, $p<0.05$.

Females were generally more abundant than males, meanwhile a significant difference between males and females throughout the year (χ^2 = 26.50; $p<0.005$) was noticed. Females were most abundant in all the four classes (χ^2 = 9.21, p = 0.03) and they also predominated in the size classes greater than 40 cm.

Table 1

Proportion of males and females in the population of *Luciobarbus callensis*

Sex	*Effectives*	*Percentage*
Males	52	20.72
Females	251	82.84

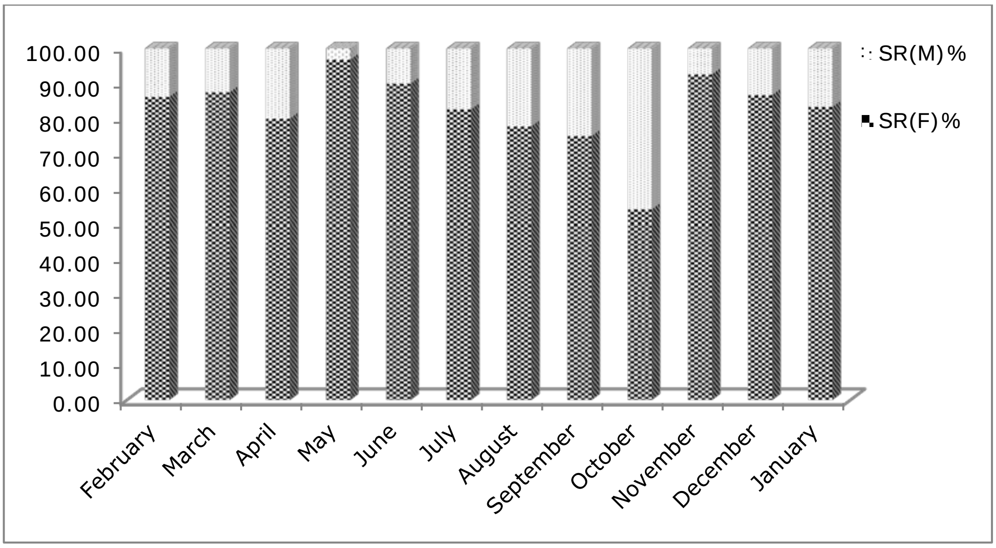


Figure 2. Monthly proportion of males and famales for *Luciobarbus callensis* specimens caught in Beni Haroun dam during the study period.

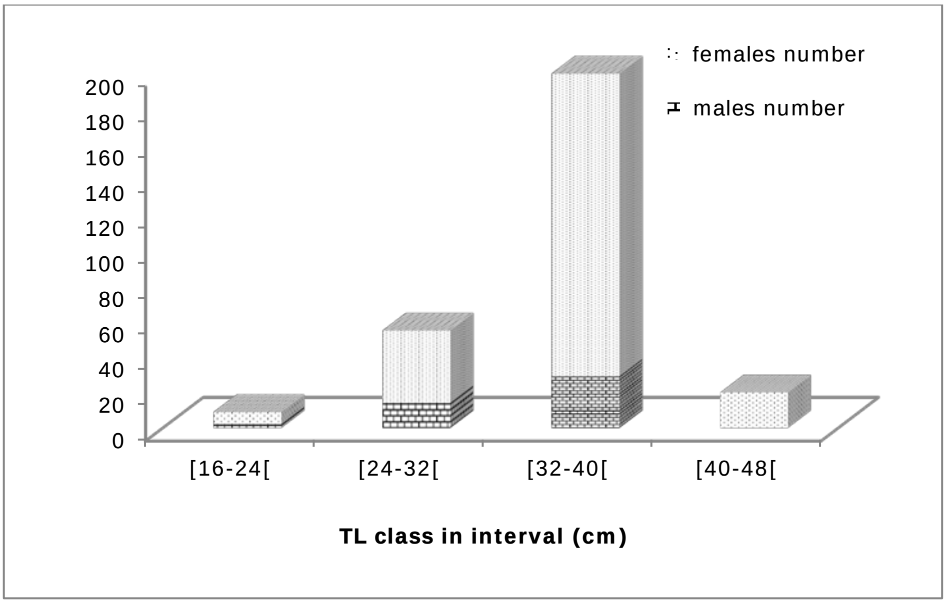


Figure 3. Proportion of males and famales in different size groups of the *Luciobarbus callensis* specimens caught in Beni Haroun dam during the study period.

Variation of gonadosomatic index (%). The highest average value of the gonadosomatic index for females (an indicator of the gonadal development state) was found in April (9.08±3.09%), since the lowest average value was recorded in August (1.19±0.62%). Whilst males reveal high values during April–June (6.07±2.26; 5.83±2.61 respectively), and the lowest GSI value was recorded during September (0.74±1.44). Here, the gonads of males has been recorded a serious regression in May (Figure 4).

The ANOVA analysis shows a significant difference in GSI of females and combined sexes (F_{obs} of females = 31.96, $P \leq 0.001$; F_{obs} of combined sexes = 30.41, $P \leq 0.001$). No significant difference was found in GSI of males population (F_{obs} of males = 2.29, P= 0.035).

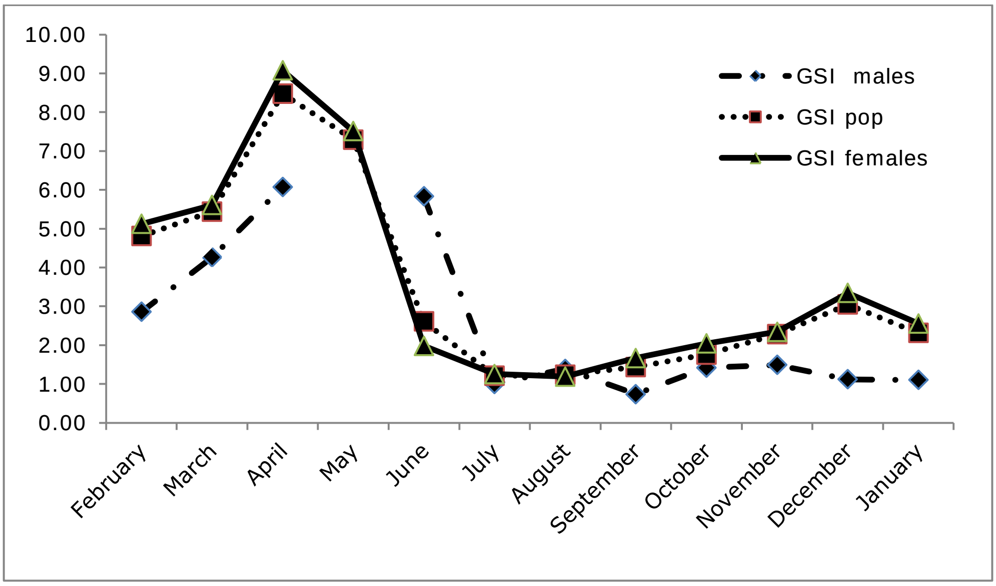


Figure 4. Gonadosomatic Index (GSI) for females and males of the *Luciobarbus callensis* specimens caught in Beni Haroun dam during the study period.

Variation of liver somatic index (%). Monitoring this index during our reproductive study shows that the average weight of the liver begins to grow from September to December for females, where the LSI reaches the highest value (2.28±0.87). From this point, the HSI drops gradually to a minimum value in August (0.46±0.28). The monthly analysis shows that LSI of males evolves in a similar way as females, showing that the important values are recorded during the winter period with a peak of 2.34±0.69 in December (Figure 5).

The ANOVA test shows a significant difference in LSI of females, combined sexes and males (F_{obs} of females = 11.79, P≤0.001; F_{obs} of combined sexes = 15.49, P≤0.001; F_{obs} of males = 12.59, P≤0.001).

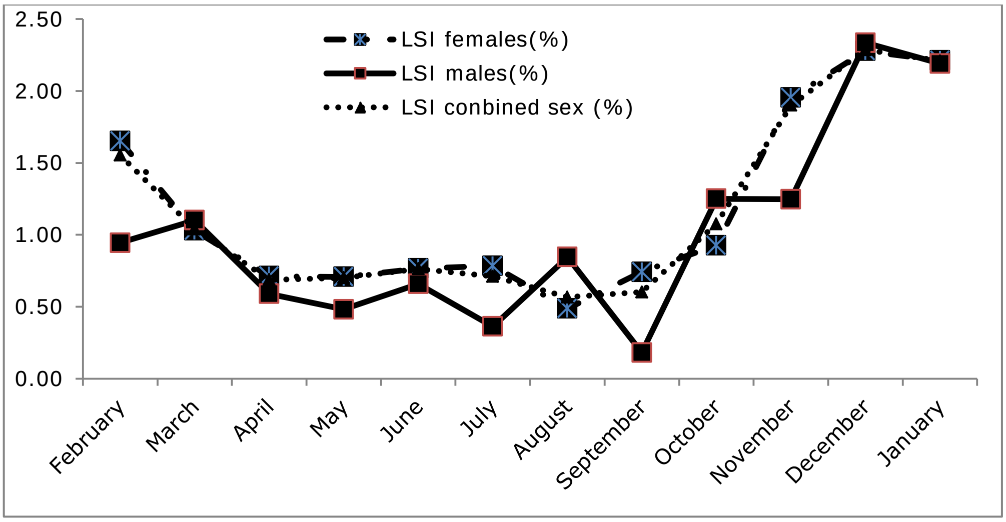


Figure 5. Liver Somatic Index (LSI) for females and males of the *Luciobarbus callensis* specimens caught in Beni Haroun dam during the study period.

Variations of the length-weight relation-ship parameters. The coefficients of determination values "r²" of the total length-weight relation-ship are respectively: 0.93, 0.92, 0.97 for both sexes, females and males, reflecting a good correlation between the two parameters (Table 2).

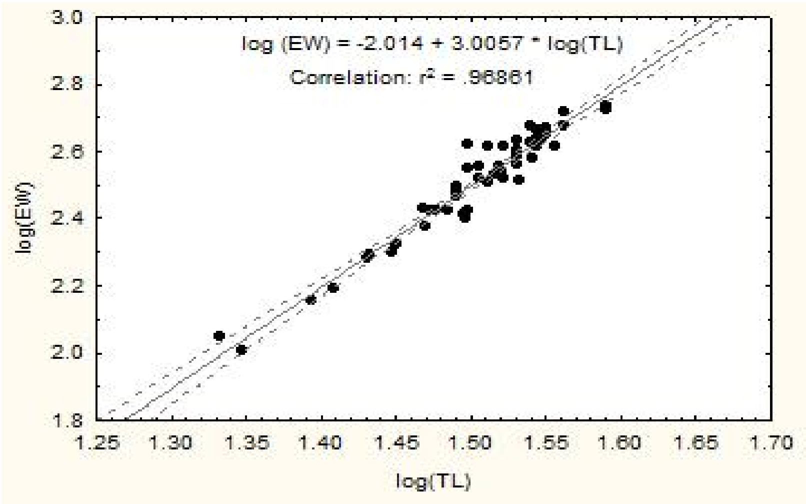
Table 2

Length-weight relationship parameters according sexes for *Luciobarbus callensis* specimens caught in Beni Haroun reservoir during the study period

Sexes	*N*	*a*	*b*	*r^2*	*Total length (TL) (cm)*			*Eviscerate weight (EW) (g)*		
					Min	*Max*	*Mean±SE*	*Min*	*Max*	*Mean±SE*
Males	52	-2.02	3.00	0.97	21.5	39	32.08±3.70	102	543	341.12±108.30
Females	251	-2.24	3.17	0.92	16.5	47.5	34.29±4.22	37	1090	449.49±168.39
Both sexes	303	-2.25	3.17	0.93	16.5	47.5	34.01±4.22	37	1090	431.37±164.73

N - sample number; r² - coefficient of determination; a and b. -Length-weight parameters; SE - standard error.

The relationships between TL and EW (dependent variable) showed a best fit between length and weight (regression analysis p<0.05). These parameters were estimated separately for total specimens, males and females (Figure 6).



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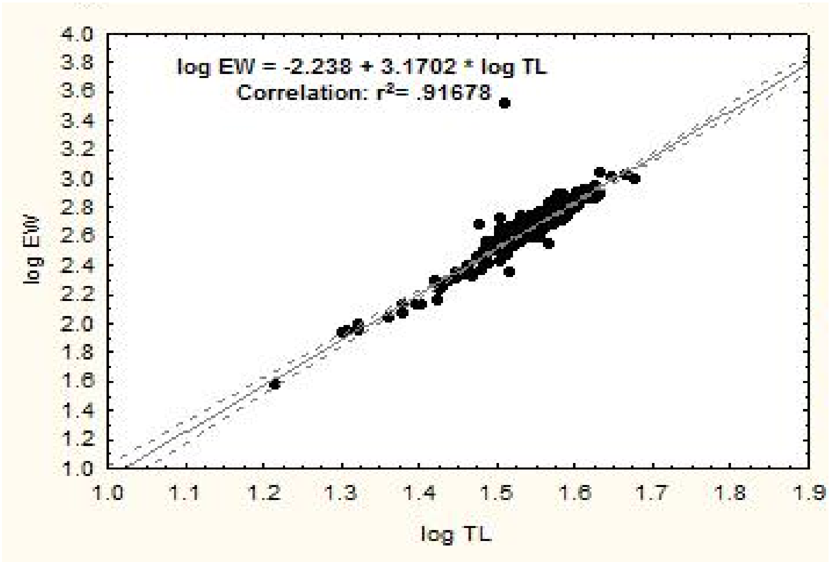

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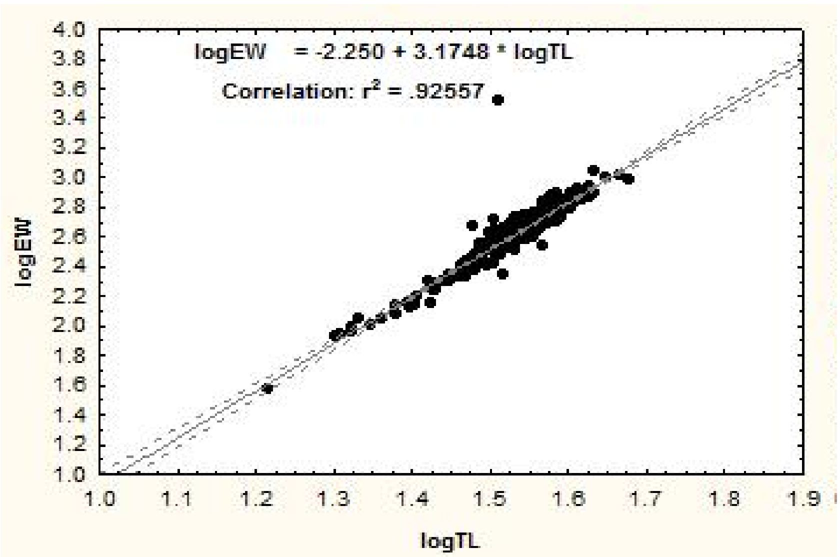

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Figure 6. Length-weight relationship for male (a), female (b) and both sexes (c) of *Luciobarbus callensis* specimens in Beni Haroun dam.

Variation of indices of fish condition. The Figure 7 shows the monthly condition factor for females of *L. callensis* specimens in Beni Haroun dam. The highest condition factor value was recorded in March (2.43), since the lowest value was observed in October (0.02) (Figure 7). The K values for male samples were generally higher than those of the females. The K values for female and male were 0.70 and 1.16, respectively (Figure 8).

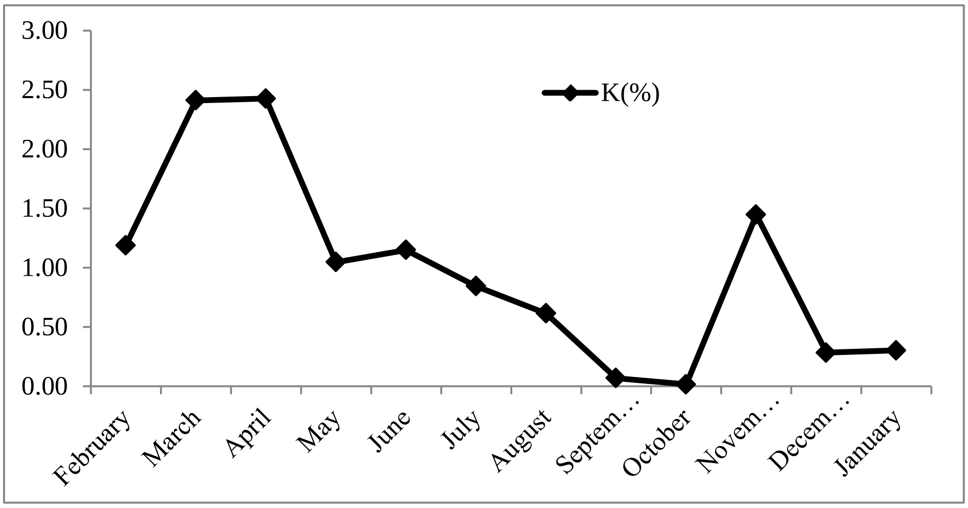

Figure 7. Monthly condition factor for female of *Luciobarbus callensis* in Beni Haroun dam.

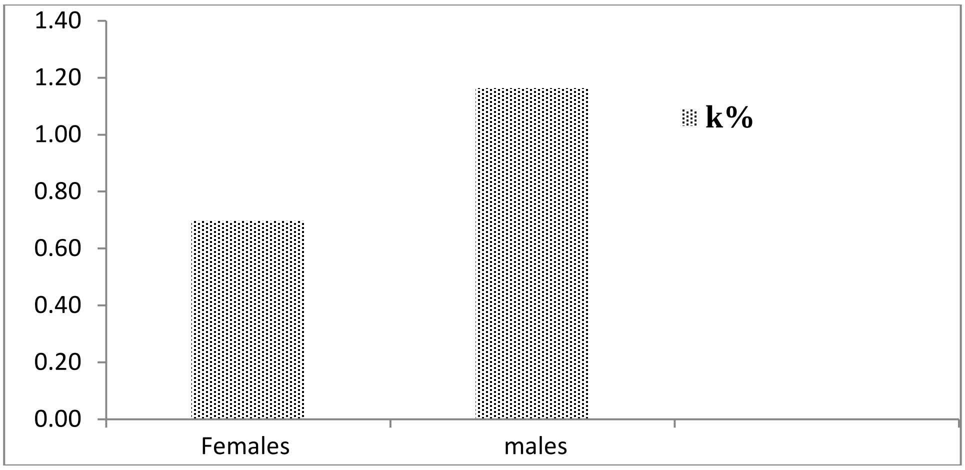

Figure 8. Mean condition factor for males and females *Luciobarbus callensis* in Beni Haroun dam.

Discussion. To determine the reproduction characteristics of *L. callensis* population inhabiting Beni Haroun dam, various parameters such as sex ratio, reproduction period and condition factor were investigated. According to sexes, this study indicates that females were the dominant sexes in all length classes. The results of sex ratio of different sizes showed absence of males above 39 cm. This indicates that females grow to a larger size than males. However, Ould Rouis et al (2012) found that the sex ratio in length class between 26 and 46 cm would be in favor of females (the study of *L. callensis* in the Hamiz reservoir; Algeria). Bouhbouh (2002) in Morocco reported the predominance of males in spring period to precociousness of sexual maturity according to Phillipart (1972).

Using the gonado somatic index values in determining the spawning season for *L. callensis* population of Beni Haroun dam showed a marked individual variation in the pattern of monthly GSI values, ranging from 9.08-1.19 and 6.07-0.74 for females and males respectively.

Examination relating to the monthly evolution of the gonado-somatic index (GSI) leads to divide the sexual cycle of *L. callensis* into three phases:

-The rapid maturation phase which begins in February (R.G.S. = 5.12) and continues to April, where the GSI reaches at its maximum level (9.08);
- The spawning phase which begins in April and lasts until June, during which the GSI decreases (1.98);
- The sexual resting phase which begins after laying and lasts from June until January with a low GSI value (1.19 to 3.34). Overall, the spawning in Beni Haroun dam started in April, similar to what have been found in several local and Mediterranean regions (El-Harrach River(Morsi et al 2015), Hamiz reservoir (Ould Rouis et al 2012) and between April and May for Allal El Fassi reservoir (Bouhbouh 2002)) (Table 3).

Table 3

Spawning period of *Luciobarbus callensis* reported in other previous studies

Regions and references	*Spawning*
Present study	Started in April
El-Harrach River (Morsi et al 2015)	Started in April
Hamiz reservoir (Algeria) (Ould Rouis et al 2012)	Started in April
Allal El Fassi reservoir (Morocco) (Bouhbouh 2002)	Between April and May

In this study, the obtained values of GSI values showed that females exhibited higher GSI values than males in all months. According to Encina & Granado-Lorencio (1997), the development of gonadosomatic index of female becomes important, because the ovarian tissue contained much more energy than testis. Hogg (1976) revealed that this difference is due to the weight of the eggs.

Liver somatic index (LSI) had a clear inverse seasonal pattern to GSI for males and females. As reported by Bertin (1958), the liver plays an essential role in the storage and mobilization of energy substances necessary for the development of genital products, suggesting that there was a mobilization of reserves for gonad development and high energy investment in reproduction (Merayo 1996; Murua & Motos 2006).

The seasonal physiological statue and changes in body composition can be obviously indicated by studying of the variation in condition factor or other related indices of body energy content used in barbells (Encina & Granado-Lorencio 1997).

Knowledge of spawning pattern and reproductive strategy is a basic requirement for the improvement of fish stock management (Marshall et al 2003). Also, the monthly variations of female condition factors are related to the fluctuations of sexual cycle. The highest values of condition factor were generally observed in March and April. Whilst, the increased condition factor in March and April could be due to gonadal developments. Similar pattern was found in other barbel species (Rodríguez-Ruiz & Granado-Lorencio 1992; Herrera & Fernández-Delgado 1992; Torralva et al 1997; Ould-Rouis et al 2012; Mimeche et al 2013). Further, during summer (final phases of spawning), females appear a decrease in somatic condition value. These droughts produce unfavorable conditions for fish survival and result in a depletion of stored energy. The temporal variation in somatic condition (factor K) reflected the effects of both environmental seasonality and the reproductive cycle of the species (Mimeche et al 2013). Similar repletion was observed by Encina & Granado-Lorencio (1997); Oliva-Paternaetal (2003); Mimeche et al (2013), reporting a spawning activity and a high metabolic demands. Mean condition factor (K) recorded in this study for male fish species were higher indicating that males were in good condition. This could be due to the fact that females expended a lot of metabolic energy that could have been used for gonadal development.

Conclusions. This study could contribute to a valuable knowledge of reproductive biology required for fisheries management and aquaculture of *L. callensis*. High gonado somatic indices were recorded in April to June of the spawning period. Additionally, liver somatic index (LSI) had a clear inverse seasonal pattern to GSI reported for the development and the high energy investment in reproduction. The obtained condition factor values (K) for the females of *L. callensis* indicate a bad condition, and therefore an unhealthy status of females with less tissue energy reserves and depressed reproductive potential was observed.

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