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# BIOLOGY AND ECOLOGY OF THE ACCIDENTALLY INTRODUCED BLEAK, *ALBURNUS ALBURNUS* (ACTINOPTERYGII: CYPRINIFORMES: CYPRINIDAE), IN KEDDARA DAM LAKE, ALGERIA

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**Background.** In this study, we present the results concerning the growth, reproduction, and trophic activities of bleak, *Alburnus alburnus* (Linnaeus, 1758), a cyprinid fish recently introduced to Algeria. We need to show that this species is adapted to local conditions. We have also characterized the biological activity of the bleak and the impact of environmental parameters on this activity.

**Materials and methods.** The fish sampling was carried out monthly from May 2008 through February 2012 in Keddara Dam Lake, from a single sampling station located in the proximity of the dam. We studied the biometric parameters of the fish, their length–weight relation, growth parameters, the reproductive and trophic activities, as well as the physical and chemical properties of the water. The data collected were processed and interpreted using selected biological indices. The climatic data were obtained from the Algerian National Office of Meteorology. The statistical analysis was performed using the R program.

**Results.** The length–weight relation of bleak represented positive allometry. The females grew less rapidly than males between 2–3 years of age. Beyond this age, females grew faster. The condition factor of females and males indicated that environmental conditions were unstable and varied between poor and good. The sex ratio was in favour of females. The reproduction activity was relatively spread over time. During the year there were many phases of sexual maturation and several spawning periods (3–4), which started from the end of January and lasted until the end of July. The last late spawning was between November and December. The sexual rest period was observed between August and September. The hepatosomatic index, in both sexes, showed no great differences. Also, the viscerosomatic index was stable. However, the repletion index was steadily increasing throughout the year. The RDA analysis analysis allows characterizing the biological activity of the bleak and the impact of environmental parameters.

**Conclusion.** We have characterized the biological and ecological variability of *Alburnus alburnus* in its new biotope and the relation of this species to the environmental parameters. This study brings new evidence for the adaptive potential of exotic species introduced in North Africa.

**Keywords:** Mediterranean, North Africa, trophic index, alien species, non-indigenous fish, reproduction, growth, bleak

## INTRODUCTION

The bleak, *Alburnus alburnus* (Linnaeus, 1758), is a lacustrine and fluvial cyprinid species widely spread in Europe and Asia (Sousa-Santos et al. 2018). It is an invertivorous, phyto-lithophylous, reolimnic, and limnophilic species (Adamczyk et al. 2017). This small sized fish was repeatedly, accidentally introduced in waters of the Iberian Peninsula (Vinyoles et al. 2007, Masó et al. 2016, Latorre et al. 2018, Sousa-Santos et al. 2018). Its first accidental introduction in Algeria (North Africa), with carps imported from Hungary, took place at the reservoir of Hamiz in 2006. Bleak was captured for the first time inside Keddara Dam Lake in May 2008. It should be emphasized that the two reservoirs are linked together through the aqueduct Hamiz–Keddara for the water transfer (Attou and Arab 2013).

Fish stock management requires information regarding abundance, distribution, biology, and ecology. The study of population dynamics has a specific purpose of describing all changes in the biological characteristics. It also explains and predicts the influence of some environmental factors (Daget and Le Guen 1975). It is very important to study

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different indices based on biological aspects such as growth, reproduction, and trophic activities to evaluate the fitness and dynamics of fish populations. Those physiological indices vary with reproductive cycles, food intake, life history, and a variety of environmental stressors (Barton et al. 2002). The knowledge of those indices allows developing some mathematical models that can serve to compare the populations of a species that are geographically distant (Belhoucine-Benyahia unpublished*).

There have been many studies of the biology and ecology of *Alburnus alburnus* (see Mathews 1971, Chappaz et al. 1987, Czeczuga 1993, Kleanthidis et al. 1999, Froese and Binohlan 2003, Koyun and Karadavut 2010, Khosravanizadeh et al. 2011, Verreycken et al. 2011, Oikonomou et al. 2012, Interesova and Chakimov 2015, Latorre et al. 2016, 2018, Masó et al. 2016, Adamczyk et al. 2017, Sousa-Santos et al. 2018). The presently reported study is, however, the first in North Africa, reporting the growth parameters and the reproductive and trophic activities of bleak at Keddara Dam Lake (Algeria). Furthermore, we characterized the ecological variability of this fish in its new biotope and the biological relation of this species to the environmental parameters.

## MATERIALS AND METHODS

**Study region.** Keddara Dam Lake (Fig. 1) is an artificial lacustrine aquatic system located in the Boumerdès Province (northern Algeria), inside a costal ridge of the Tellian Atlas Mountains, 35 km east of the city of Algiers. Keddara Dam Lake is located at the altitude of 1047 m above the sea level (36°38′58″N, 003°25′19″E). It is located in the sub-humid region with mild winters.

**Fishing technique and water sampling.** The sampling and measures were performed every month at the same station (the dam, Fig. 1) from June 2006 through February 2012. In this study, we used three gillnets, with a length of 50 m and a height of 1.5 m. These fishing nets consisted of three vertical pieces of net with different mesh sizes (7, 15, and 22 mm) tied together. In addition, we also used a trammel net, with 100 m length and 1.5 m height with four mesh sizes (13, 22, 35, and 45 mm). The water was sampled at the surface with an ordinary 1.5 L bottle.

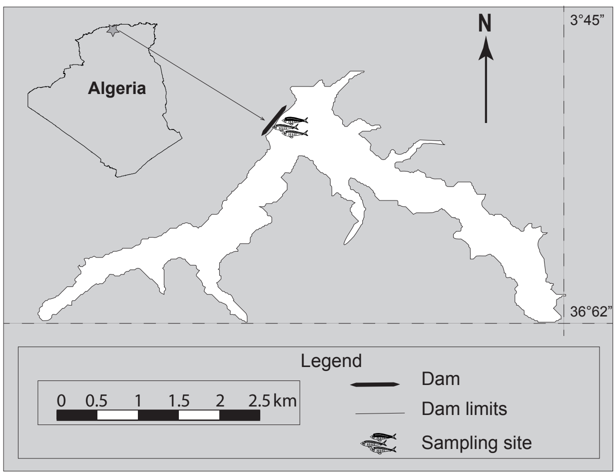


**Fig. 1.** Map of Keddara Dam Lake, northern Algeria

**Study methods.** The recorded physical and chemical properties of the water were the water temperature (°C), dissolved oxygen (mg · $L^{-1}$), pH, conductivity (µS · $cm^{-1}$), and salinity (‰), which were measured with a multi-analyser (WTW 340i) and water transparency (m) determined with the Secchi disk. The inventory of climate data was obtained from the National Office of Meteorology of Algeria (Anonymous 2013). The following parameters were considered: air temperature (°C), precipitation (mm), mean wind speed (m · $s^{-1}$), mean relative humidity (%), and insolation (days).

For individual fish, we measured the total body length ($L_t$) with an ichthyometer (cm) and determined the total body weight ($W_t$) with an ordinary balance with a precision of ±0.01 g. Viscera were weighed with a balance of $10^{-3}$ g precision. We recorded the weight of the total viscera, the gonads, the liver, and the full gastrointestinal tract separately. The age was determined by the scalimetry method. For length–weight relation we used the formula

$$W_t = aL_t^b$$

where $W_t$ is the total body weight (g), $L_t$ is the total body length (cm), while $a$ and $b$ are constants.

When the growth is isometric $b$ is equal to 3. A value below 3 means that the growth in weight is less than the growth in size, and inversely if $b$ is greater than 3 (Lévêque 2006). With a logarithmic transformation, linear equation transforms into the formula

$$\text{Log}\, W_t = b \text{Log}\, L_t + \text{Log}\, a$$

The mean comparison test, Z-score, is used to compare the mean sizes of females and males. The adjustment model is represented by the following relation

$$L_t = L_\infty \left[1 - e^{-k(t - t0)}\right]$$

where $L_\infty$ is the asymptotic size, $L_t$ is the size at age $t$, and $k$ is a constant that describes the rate of change in size and $t_0$ is the hypothetical time when the size is null.

The estimated growth parameters of the von Bertalanffy model (1938) were calculated with the R program (CRAN R)**, "fishmethods"***, and FSA**** packages. $W_t$

* Belhoucine-Benyahia F. 2012. Etude de la biologie, de la croissance et la reproduction d'un poisson téléostéen, le merlu (*Merluccius merluccius* L., 1758) et son utilisation comme indicateur biologique de la pollution par les métaux lourds (zinc, plomb, et cadmium) dans la baie d'Oran (Algérie). Thèse de Doctorat. Université d'Oran, Oran, Algeria.

** *http://www.R-project.org.*

*** *https://cran.r-project.org/web/packages/fishmethods/fishmethods.pdf.*

**** *https://mran.microsoft.com/snapshot/2016-04-24/web/packages/FSA/FSA.pdf.*

The condition factor (Ricker 1975) was defined by

$$K = W_t \cdot L_t^{-b}$$

To characterize the reproductive and trophic activities of *Alburnus alburnus*, the following biological indices were used:

- Sex-ratio (SR) defined by individuals proportions of each sex, the viscerosomatic index (VSI), which is the ratio of the weight of the total viscera to the total body weight
- The gonadosomatic index (GSI) which is the ratio of the weight of the gonads to the total body weight
- The hepatosomatic index (HSI) which is the ratio of the liver weight to the total body weight and
- The repletion index (RI), which indicates the relation between the digestive tube weight and the total weight of the individual (Roche et al. 2003, Ouakka et al. 2008).

Statistical tests, such as Student *t*-test (to compare the parameters between the sexes) and ANOVA analysis (to compare parameters between the months), were also performed to compare biological indices between sexes and months. They were performed with Rcmdr package within the R program (CRAN R).

To study the relation and the influence of the environmental parameters on the biological indices of *Alburnus alburnus* we used a redundancy analysis (RDA) (Borcard et al. 2011), which was completed by a Monte Carlo permutation test. Those analyses were performed with R language (CRAN R) using vegan package.

## RESULTS

**Environmental data.** Mean values of environmental data, represented by physicochemical variables, of the water of the dam lake and climatic variables are given in Table 1. The observed parameters show that Keddara Dam Lake is a eutrophic body of water with good water quality (Horppila and Kairesalo 1992, Lefèvre et al. 2007, Vinyoles et al. 2007, Anonymous 2014).

**Growth and condition factor.** Out of a total of 1515 individuals, there were 851 females, 389 males, and 275 of undetermined sex. The minimum size recorded was 7 cm (undetermined individuals) with 9.3 cm for females and 9 cm for males. The maximum size was 22 cm for females and 21.1 cm for males with mean values of 17.2 cm and 16.1 cm, respectively. Mean sizes between both sexes were significantly different (Z-score: $\varepsilon = 7.5 > 1.96$, $\alpha = 0.05$).

The length–weight relation is shown in Figs. 2A1, 2B1, and Table 2). Bleak in Keddara Dam Lake exhibited a major positive allometric growth ($b > 3$). The asymptotic lengths obtained for females and males differed with 5.98 cm, being the largest for females ($L_\infty = 28.9$ cm).

The von Bertalanffy model revealed a significant difference between males and females; males grew faster than females in the first age groups (2–3 years). Beyond this age, the growth rate was reversed in favour of females (Figs. 2A2, 2B2, Table 2).

The condition factor (*K*) was very variable over time with a minimum value of 0.4 $g \cdot cm^{-b}$ for both sexes and a maximum of 1.3 $g \cdot cm^{-b}$ for females and 1.4 $g \cdot cm^{-b}$ for males. The monthly variation of the mean *K* in both sexes was irregular and indicates that the investigated bleak was in poor condition ($K < 1.2$) (Barnham and Baxter 1998) (Fig. 3a). However, the annual cycle of *K* in both sexes (Fig. 3B) showed that conditions (Barnham and Baxter 1998) varied from extremely poor ($K = 0.4$ $g \cdot cm^{-b}$) to good ($K = 1.4$ $g \cdot cm^{-b}$). The Student *t*-test showed no significant differences between sexes for all months (*p*-value > 0.05, Table 3). The ANOVA analysis showed no significant difference between months for males (*p*-value > 0.05,

**Table 1**

Mean values of environmental parameters in Keddara Dam Lake, northern Algeria (2008–2012)

| Month | Physical and chemical parameters | | | | | | Climatic parameters | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_W$ [°C] | $O_2$ [$mg \cdot L^{-1}$] | Cond [$\mu S \cdot cm^{-1}$] | pH | Sal [‰] | Trsp [m] | $T_A$ [°C] | Prctp [mm] | WS [$m \cdot s^{-1}$] | RH [%] | Ins [days] |
| Jan | 13.48 | 8.20 | 1017.72 | 8.34 | 0.30 | 1.77 | 16.30 | 118.04 | 2.43 | 81.33 | 5.91 |
| Feb | 14.01 | 8.51 | 993.06 | 8.04 | 0.27 | 1.93 | 16.24 | 95.45 | 2.67 | 76.00 | 7.41 |
| Mar | 15.83 | 8.75 | 921.25 | 7.76 | 0.27 | 2.37 | 16.90 | 91.03 | 2.57 | 77.33 | 9.06 |
| Apr | 19.67 | 9.75 | 985.42 | 8.22 | 0.27 | 2.40 | 22.83 | 84.04 | 2.43 | 79.33 | 8.93 |
| May | 22.66 | 8.42 | 1082.33 | 8.28 | 0.30 | 2.50 | 29.58 | 70.48 | 2.50 | 75.00 | 10.75 |
| Jun | 25.69 | 8.88 | 1047.50 | 8.24 | 0.30 | 3.00 | 31.43 | 7.52 | 2.25 | 72.50 | 13.48 |
| Jul | 28.48 | 6.93 | 1017.39 | 8.13 | 0.33 | 3.18 | 30.80 | 4.04 | 2.48 | 70.00 | 13.81 |
| Aug | 28.38 | 6.42 | 1014.64 | 8.61 | 0.33 | 3.75 | 30.24 | 14.52 | 2.45 | 72.75 | 13.08 |
| Sep | 24.82 | 6.58 | 1085.33 | 8.47 | 0.33 | 3.18 | 27.13 | 56.48 | 2.30 | 74.25 | 9.65 |
| Oct | 20.36 | 7.07 | 1074.13 | 8.33 | 0.35 | 2.15 | 21.50 | 91.74 | 1.73 | 76.25 | 9.78 |
| Nov | 16.82 | 7.78 | 990.81 | 8.00 | 0.35 | 2.08 | 17.72 | 158.84 | 2.33 | 77.75 | 7.00 |
| Dec | 13.80 | 8.26 | 1002.73 | 8.17 | 0.35 | 1.95 | 15.63 | 123.68 | 2.05 | 79.50 | 6.68 |

$T_W$ = water temperature, $O_2$ = dissolved oxygen, Cond = conductivity, Sal = salinity, Trsp = water transparency, $T_A$ = air temperature, Prctp = precipitation, WS = mean wind speed, RH = mean relative humidity, Ins = insolation.

Table 3) but there was a significant difference for females ($p$-value < 0.05, Table 3).

**Sex ratio.** The mature specimens caught were represented by 68.63% females and 31.37% males. Mean sex ratio (F ÷ M) was thus 2.19 ÷ 1 in favour of females. The monthly mean values showed a large variation with SR the highest in February and lowest in August. The Student $t$-test showed a significant difference between sexes in all months ($p$-value < 0.05. Table 3) and the ANOVA analysis showed a significant difference between sexes ($p$-value < 0.05, Table 3).

**Gonadosomatic index (GSI).** The monthly variation of GSI in both sexes varied from 1.02% to 10.22% for females and from 0.50% to 6.22% for males. The distribution of the gonadosomatic index of females was characterized by three spawning events—the first one occurring between January and March, the second between May and August, and the last one in late November. The gonadosomatic index of males started to increase in January, April, and July (Fig. 4C). This periodicity was the same for both sexes but less pronounced in males. The reproduction activity was relatively spread over time for both females and males.

The monthly variation of the mean GSI in both sexes is visualised in Figs. 4B and 4C (Table 3). The ANOVA analysis revealed a significant difference in GSI between months in both sexes ($p$-value < 0.05, Table 3. The comparison of GSI values between both sexes showed that those values were higher in females than in males. This difference was due to the heavier ovary weight compared to the testis even in relation to the greater size of males compared to females. The Student $t$-test indicated a significant difference in months between sexes ($p$-value < 0.05, Table 3) except for August, September, and November.

**Table 2**

Growth parameters of *Alburnus alburnus* in Keddara Dam Lake, northern Algeria (2008–2012)

| Sex | $a$ | $b$ | $R^2$ | Relation | $L_\infty$ [mm] | $k$ (year$^{-1}$) | $t_0$ | $n$ |
|---|---|---|---|---|---|---|---|---|
| Females | 0.0024 | 3.425 | 0.935 | $W_T = 0.0024\ L_T^{3.425}$ | 288.1 | 0.20 | –1.13 | 851 |
| Males | 0.0032 | 3.311 | 0.945 | $W_T = 0.0032\ L_T^{3.311}$ | 228.35 | 0.28 | –1.14 | 389 |

$a$ = intercept, $b$ = slope, $R^2$ = coefficient of determination, $L_\infty$ = asymptotic size, $k$ = the growth rate, $t_0$ = hypothetical time when size is null, $n$ = sample size, $W_T$ = total weight, $L_T$ = total length.

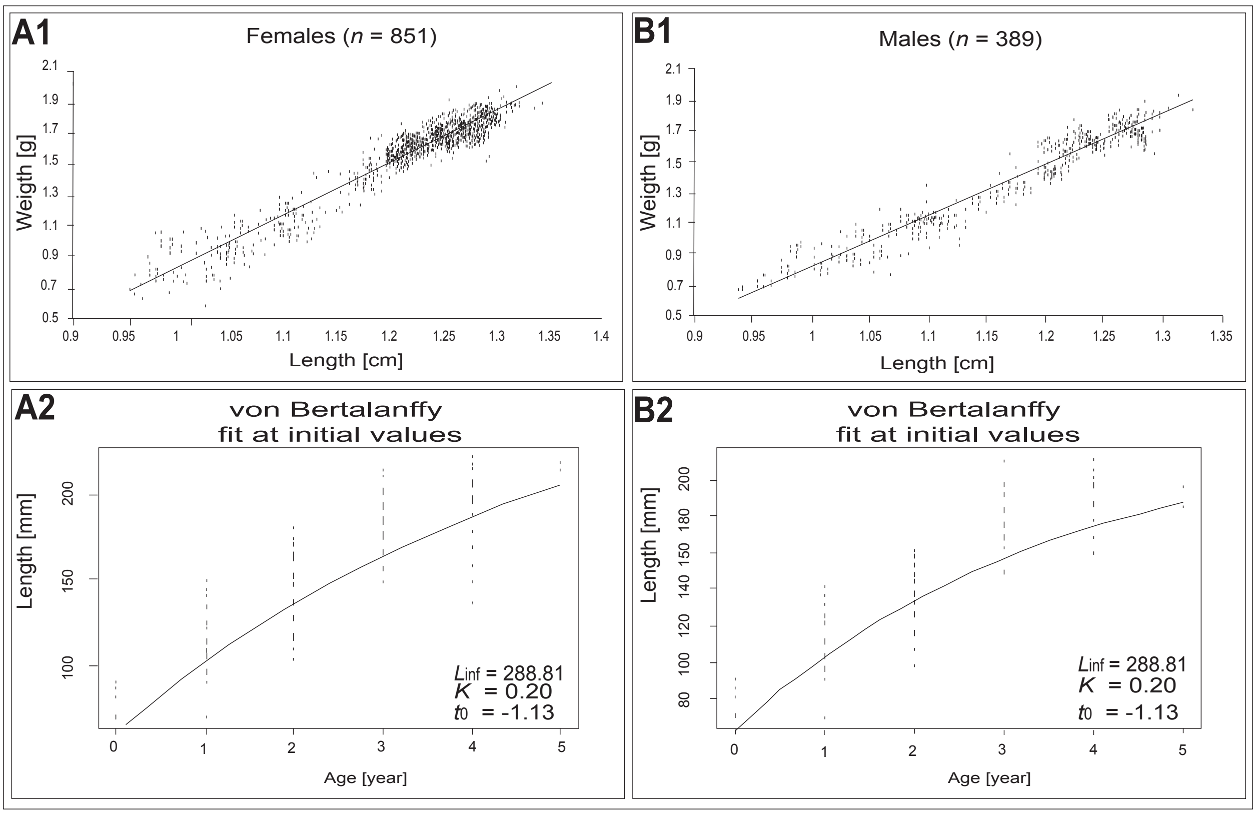


**Fig. 2.** Growth of *Alburnus alburnus* in Keddara Dam Lake, northern Algeria (2008–2012); **A1** = length–weight relation of females; **B1** = length–weight relation of males; **A2** = von Bertalanffy growth curve of females; **B2** = von Bertalanffy growth curve of males

**Hepatosomatic index (HSI).** The HSI ranged from 0.12% to 1.54% in females and from 0.11% to 1.79% in males.

The annual cycle of HSI in both sexes is presented in Figs. 5B, 7C, and in Table 3. The Student *t*-test indicated no significant differences in monthly HSI values between sexes (*p*-value > 0.05, Table 3). HSI was very variable over time and the mean HSI presented an important significant fluctuation in females (ANOVA; *p*-value < 0.05, Table 3) but was generally stationary in males (ANOVA; *p*-value > 0.05, Table 3).

**Viscerosomatic index.** VSI ranged from 3.15% to 16.05% for females and from 2.47% to 13.50% for males (Fig. 6A). Females and males started their feeding activity in September, reached a peak in February, and then descended towards August.

During the annual cycle, a significant difference was observed in VSI between sexes only in June, July, and December (Student *t*-test; *p*-value < 0.05, Table 3). The analysis revealed a significant difference of VSI between months for females (ANOVA; *p*-value < 0.05, Table 3) but not for males (*p*-value > 0.05, Table 3).

**Repletion index.** The repletion index ranged between 0.85% to 3.58% for females and from 0.32% to 4.23% for males. Although, within a year, lower values of RI were observed between May and September (Fig. 7A). The ANOVA analysis showed no significant differences in the monthly mean values of RI (*p*-value > 0.05, Table 3) for both sexes nor was there a significant difference in months between the two sexes (Student *t*-test; *p*-value > 0.05, Table 3).

**Effects of environmental parameters on bleak.** The environmental parameters explain a total of 96.95% ($RDA_1$ = 88.31% and $RDA_2$ = 8.64%) of the total variability of the biological activity (Fig. 8). According to the first axis, the biological indices had a positive correlation between them and with the dissolved oxygen and precipitation, those parameters were negatively correlated with the water temperature, insolation, pH, and salinity. The second explains only repletion index of females and wind speed, which were positively correlated. The results of the Monte Carlo permutation test (Table 4) show that the dissolved oxygen, water temperature, water transparency, pH, salinity, insolation at α = 0.05 as well as precipitation at α = 0.1 significantly explain the variability of the different biological indices. However, wind speed was non-significant (*p*-value > 0.05).

## DISCUSSION

Currently, there is a big interest in the study of the performance and adaptive strategies of invasive freshwater fish species confronted with different environmental conditions in new ecosystems (Mims et al.

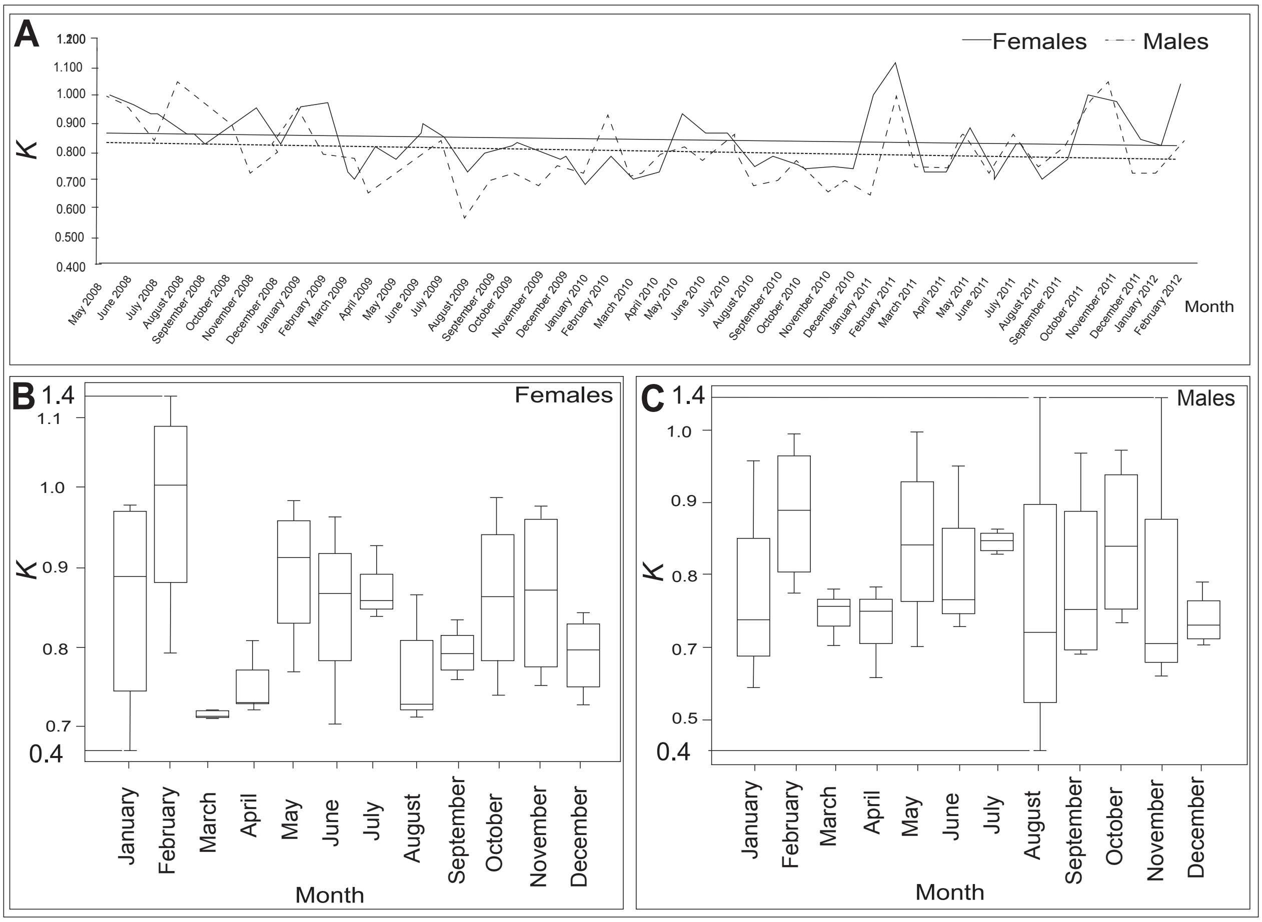


**Fig. 3.** Monthly variations of the condition factor (*K*) for both sexes of *Alburnus alburnus* in Keddara Dam Lake, northern Algeria (2008–2012); **A** = monthly distributions; **B–C** = boxplots of annual cycle of *K*

**Table 3**

Statistically processed annual biological parameters of *Alburnus alburnus* in Keddara Dam Lake, northern Algeria (2008–2012)

| Parameter | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | ANOVA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $K_F$ | Mean | 0.857 | 0.978 | 0.715 | 0.752 | 0.894 | 0.850 | 0.869 | 0.760 | 0.792 | 0.863 | 0.869 | 0.790 | 0.030 |
| | SD | 0.143 | 0.139 | 0.005 | 0.047 | 0.093 | 0.107 | 0.041 | 0.072 | 0.031 | 0.106 | 0.110 | 0.050 | |
| $K_M$ | Mean | 0.767 | 0.883 | 0.741 | 0.731 | 0.841 | 0.802 | 0.844 | 0.759 | 0.789 | 0.844 | 0.775 | 0.738 | 0.751 |
| | SD | 0.133 | 0.098 | 0.033 | 0.064 | 0.121 | 0.099 | 0.015 | 0.204 | 0.128 | 0.109 | 0.175 | 0.037 | |
| STP | | 0.392 | 0.312 | 0.302 | 0.678 | 0.517 | 0.539 | 0.317 | 0.998 | 0.966 | 0.806 | 0.404 | 0.157 | |
| SRF | Mean | 77.833 | 81.238 | 79.723 | 77.033 | 63.705 | 64.375 | 76.198 | 60.425 | 64.265 | 64.773 | 70.385 | 70.298 | 0.024 |
| | SD | 8.013 | 8.164 | 17.581 | 3.424 | 8.367 | 7.444 | 12.317 | 7.859 | 9.423 | 3.664 | 9.379 | 8.566 | |
| SRM | Mean | 22.168 | 18.763 | 20.277 | 22.967 | 36.295 | 35.625 | 23.803 | 39.578 | 35.735 | 35.228 | 29.615 | 29.703 | 0.024 |
| | SD | 8.013 | 8.164 | 17.581 | 3.424 | 8.367 | 7.444 | 12.317 | 7.862 | 9.423 | 3.664 | 9.379 | 8.566 | |
| STP | | 0.000 | 0.000 | 0.014 | 0.000 | 0.004 | 0.002 | 0.001 | 0.010 | 0.005 | 0.000 | 0.001 | 0.001 | |
| $GSI_F$ | Mean | 6.547 | 8.094 | 7.774 | 8.674 | 4.779 | 6.106 | 5.652 | 2.085 | 3.075 | 4.962 | 4.741 | 5.736 | 0.000 |
| | SD | 1.351 | 2.579 | 0.554 | 0.895 | 1.548 | 1.824 | 0.909 | 0.906 | 1.280 | 1.010 | 1.763 | 1.071 | |
| $GSI_M$ | Mean | 4.332 | 4.207 | 4.168 | 4.022 | 2.512 | 2.199 | 2.553 | 1.032 | 1.503 | 2.570 | 2.178 | 2.618 | 0.000 |
| | SD | 0.405 | 1.520 | 1.112 | 2.138 | 0.849 | 0.433 | 1.067 | 0.291 | 0.737 | 1.025 | 0.494 | 0.495 | |
| STP | | 0.041 | 0.049 | 0.016 | 0.048 | 0.016 | 0.020 | 0.005 | 0.099 | 0.089 | 0.016 | 0.057 | 0.005 | |
| $HSI_F$ | Mean | 0.606 | 1.071 | 0.168 | 0.325 | 0.536 | 0.623 | 0.704 | 0.557 | 0.471 | 0.461 | 0.415 | 0.643 | 0.005 |
| | SD | 0.057 | 0.586 | 0.047 | 0.235 | 0.248 | 0.166 | 0.300 | 0.165 | 0.075 | 0.163 | 0.087 | 0.071 | |
| $HSI_M$ | Mean | 0.651 | 0.889 | 0.622 | 0.542 | 0.553 | 0.718 | 0.520 | 0.508 | 0.330 | 0.467 | 0.400 | 0.576 | 0.800 |
| | SD | 0.239 | 0.697 | 0.690 | 0.436 | 0.109 | 0.503 | 0.280 | 0.055 | 0.145 | 0.178 | 0.227 | 0.366 | |
| STP | | 0.732 | 0.703 | 0.372 | 0.502 | 0.903 | 0.740 | 0.404 | 0.600 | 0.152 | 0.962 | 0.906 | 0.743 | |
| $VSI_F$ | Mean | 11.783 | 14.208 | 11.911 | 12.498 | 10.775 | 12.180 | 10.634 | 6.400 | 9.522 | 10.558 | 10.671 | 11.588 | 0.031 |
| | SD | 1.628 | 2.715 | 0.205 | 0.964 | 2.530 | 1.664 | 1.254 | 2.759 | 3.395 | 3.923 | 3.249 | 1.735 | |
| $VSI_M$ | Mean | 10.012 | 9.719 | 8.624 | 8.767 | 6.903 | 6.237 | 7.528 | 4.687 | 6.403 | 8.515 | 8.285 | 8.336 | 0.115 |
| | SD | 0.993 | 3.417 | 1.466 | 4.033 | 2.031 | 1.708 | 1.192 | 1.404 | 3.164 | 1.437 | 3.596 | 1.426 | |
| STP | | 0.123 | 0.088 | 0.058 | 0.247 | 0.056 | 0.002 | 0.012 | 0.325 | 0.228 | 0.386 | 0.363 | 0.029 | |
| $RI_F$ | Mean | 2.521 | 2.096 | 2.020 | 2.014 | 1.738 | 1.848 | 2.006 | 1.594 | 1.972 | 2.074 | 2.087 | 2.525 | 0.930 |
| | SD | 1.140 | 0.188 | 0.925 | 1.177 | 0.704 | 0.937 | 1.129 | 0.796 | 0.628 | 0.205 | 0.735 | 0.758 | |
| $RI_M$ | Mean | 3.409 | 2.561 | 2.251 | 1.740 | 1.719 | 1.716 | 2.026 | 1.079 | 1.313 | 2.123 | 2.528 | 2.451 | 0.143 |
| | SD | 0.914 | 1.508 | 0.559 | 1.144 | 0.684 | 0.900 | 1.733 | 0.374 | 0.668 | 0.611 | 0.879 | 0.936 | |
| STP | | 0.272 | 0.583 | 0.735 | 0.787 | 0.970 | 0.845 | 0.986 | 0.302 | 0.201 | 0.887 | 0.472 | 0.906 | |

ANOVA = ANOVA *p*-value for all months combined, STP = Student *t*-test *p*-value of males and females , $K_F$ = condition factor of females. $K_M$ = condition factor of males, SRF = sex-ratio of females, SRM = sex-ratio of males, $GSI_F$ = gonadosomatic index of females, $GSI_M$ = gonadosomatic index of males, $HSI_F$ = hepatosomatic index of females, $HSI_M$ = hepatosomatic index of males, $VSI_F$ = viscerosomatic index of females, $VSI_M$ = viscerosomatic index of males, $RI_F$ = repletion index of females, $RI_M$ = repletion index of males.

2010). The study of bleak, *Alburnus alburnus*, a cyprinid fish, in the North-African dam reservoir (Keddara Dam Lake, Algeria) allowed us to provide some new elements on its ecology by characterizing its new habitat, its biology by the study of the growth, reproduction and trophic activity, as well as its biogeography by providing ~~a~~ new evidence about its distribution. This species was imported from Hungary (personal information from the Ministry of Fisheries and Fisheries Resources and the National Centre Research and Development for Fisheries and Aquaculture, Algeria) and it was able to adapt to the local conditions colonizing Keddara Dam Lake and other Algerian bodies of water of different bioclimatic conditions. In the Mediterranean regions of Algeria, we have the wet regions (Bougous and Guenetra dam lakes), the sub-wet regions (Hamiz and Cap-Djenet dam lakes), and the semi-arid regions (Ghrib, Aïn Zada, M'hamed Benaouda Ouizert, and Bouhanifia dam lakes). In the semi-arid steppic region, however, we have only Bakhadda Dam Lake (Attou and Arab 2013, Attou unpublished*). Keddara Dam Lake provides good water quality for the survival of cyprinid fishes.

In this study, the value of *b* in the length–weight relation was higher than 3, indicating that the weight increases faster than size. The *b* value, obtained at Keddara Dam Lake was higher than that obtained in Spain (Leunda et al. 2006, Miranda et al. 2006), in Belgium (Verreycken et al. 2011), in Greece (Kleanthidis et al. 1999, Koutrakis and Tsikliras 2003), in France (Chappaz et al. 1987, Argillier et al. 2002), in Bulgaria (Raikova-Petrova et al. 2009), in Poland (Kompowski 2000), and in Turkey (Erdoğan and Torcu Koç 2017). This indicates a good ponderal growth of *Alburnus alburnus* in Keddara Dam Lake in Algeria. However, in England and for females Mathews (1971), recorded that *b* was slightly higher than that observed by us at Keddara. The *b* parameter of the length–weight relations of fishes is affected by a number of factors, including environmental conditions (such as temperature and salinity), sex, gonad maturity, health, season, habitat, nutrition, area, degree of stomach fullness, differences in the length range of the caught specimen, and the fishing gear used (Tesch 1971, Froese 2006).

Also, there were differences in growth between sexes. The males grow more rapidly than the females during

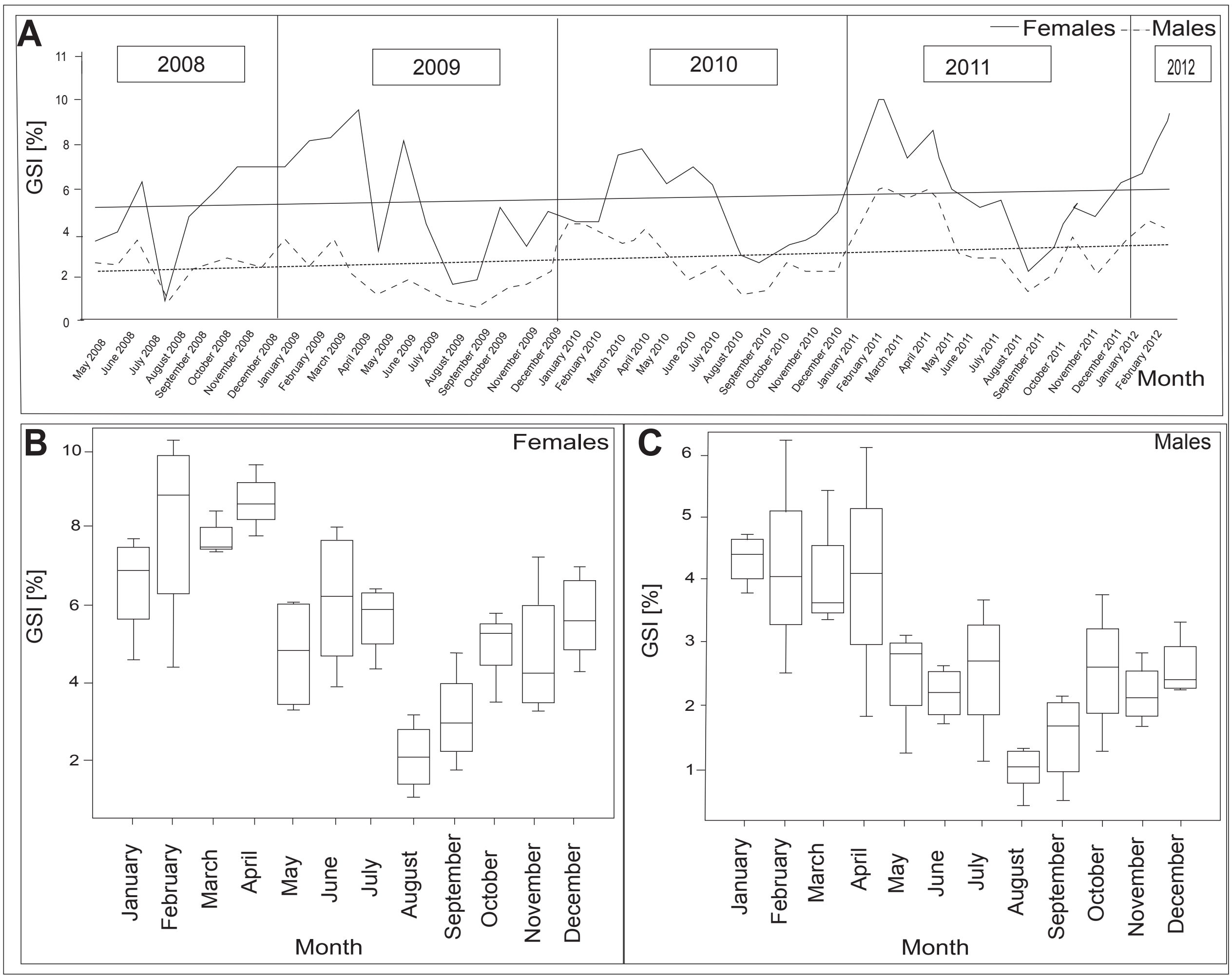


**Fig. 4.** Monthly variations of the gonadosomatic index (GSI) in both sexes of *Alburnus alburnus* in Keddara Dam Lake, northern Algeria (2008–2012); **A** = monthly distributions; **B–C** = boxplots of annual cycle life

* Attou F. 2014. Dynamique de population et ecobiologie d'*Alburnus alburnus* ( poisson Cyprinidae) dans le lac de barrage de Keddara (W. Boumerdes). Thèse de Doctorat, University of Science and Technology – Houari Boumediene, Algiers, Algeria.

the first years, after this age (2 years and more), and the growth rate is inversed in favour of the females. In Poland and Bulgaria, the body length and weight of females were bigger than those of males of the same age (Kompowski 2000, Georgiev et al. 2015).

The growth parameters obtained in the presently reported study appeared to be closer to those of Turkey (Koyun and Karadavut 2010), Germany (Spratte and Hartmann 1998), and the United Kingdom (Froese and Binohlan 2003). By contrast, we have noticed a faster growth compared to Greece (Politou unpublished*). Moreover, in the Iberian Peninsula (Masó et al. 2016, Latorre et al. 2018) and in the Danube River in Serbia (Lujić et al. 2013), the growth rates were lower than those obtained in Keddara Dam Lake.

The condition factor ($K$) of the females and the males varied from poor ($0.4\ g \cdot cm^{-b}$) to good ($1.4\ g \cdot cm^{-b}$) for the survival of the species (Barnham and Baxter 1998). The highest values of the condition factor were found in February, being generally higher just prior to spawning season and lower after spawning with no difference between sexes as seen in Figs. 4A, 4B. The difference in values in both sexes may be attributed to the metabolism during maturation, spawning, and the changes in nutritional activity or in the environmental conditions (Lavergne et al. 2013, Aera et al. 2014).

In Çaygören Dam Lake in Turkey (Erdoğan and Torcu Koç 2017) the monthly mean condition factors varied between 1.6 and 1.9 and substantially exceeded the condition factor in Keddara Dam Lake ($0.4–1.4\ g \cdot cm^{-b}$). This variation was due to the geographic location and environmental conditions such as temperature, salinity, pH, dissolved oxygen, Secchi disk visibility depth, and the water system (Ongun-Sevindik et al. 2010, Çelik 2013). Also, the highest condition factor values were obtained in the Iberian Peninsula (Latorre et al. 2018), the Danube in Serbia (Lujić et al. 2013), and Pilica in Poland (Mann and Penczak 1984). The differences in those values are due to the variation in latitude and ecosystem type (Latorre et al. 2018).

In our study, the sex ratio was in favour of the females and this is consistent with the data observed by other authors (Raikova-Petrova et al. 2009, Georgiev et al. 2015, Erdoğan and Torcu Koç 2017). This numeric dominance was attributed, according to and Zaugg (unpublished**), to the rapid growth and early maturity of the females and higher mortality of the males. However, in the Iberian

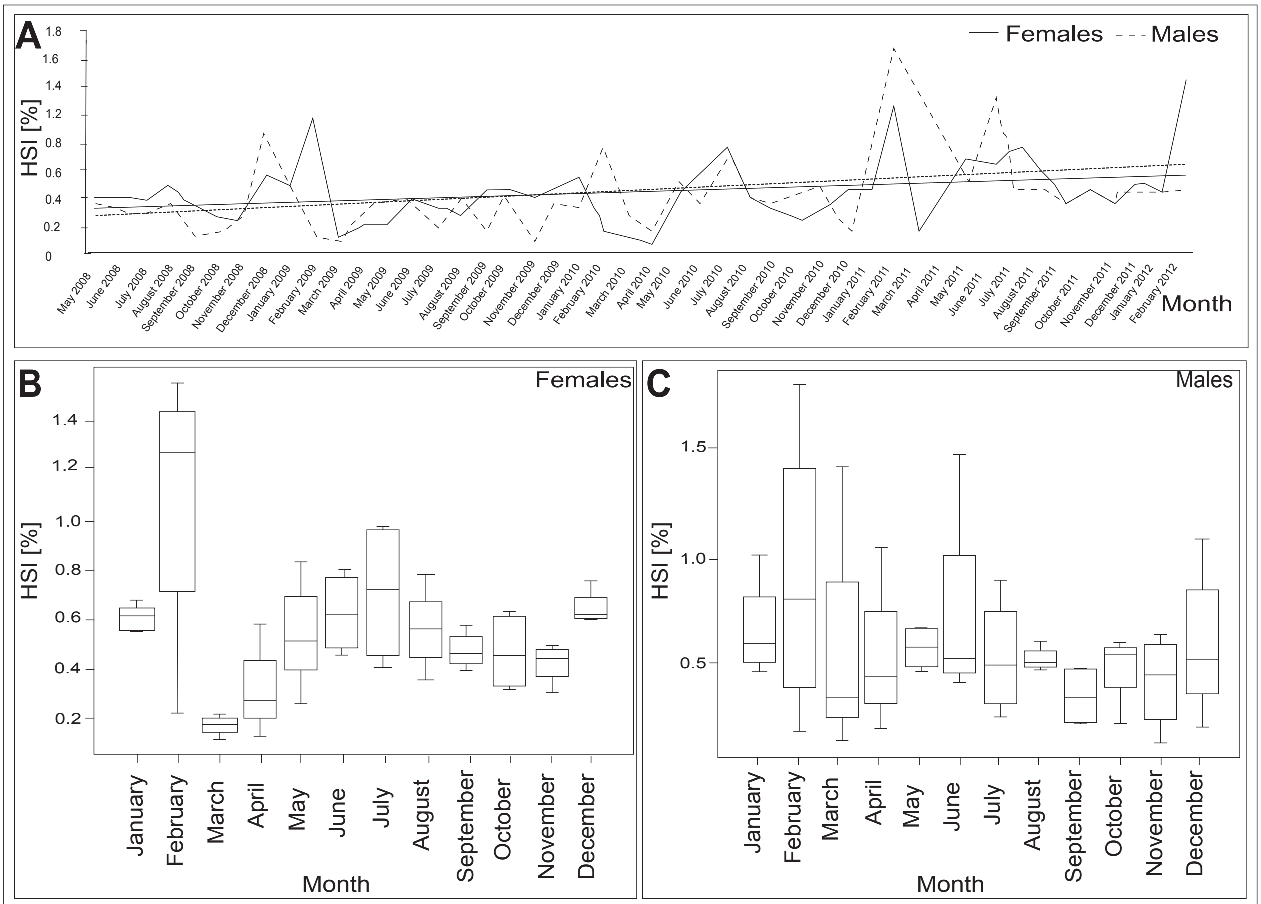


**Fig. 5.** Monthly variations of the hepatosomatic index (HSI) in both sexes of *Alburnus alburnus* in Keddara Dam Lake, northern Algeria (2008–2012); **A** = monthly distributions; **B–C** = boxplots of annual cycle life

* Politou C.Y. 1993. Viología kai dynaμikí tou psarioú *Alburnus alburnus* (L. 1758) sti líμni Koróneia. [Biology and dynamics of the fish *Alburnus alburnus* (L. 1758) in Lake Koronia.] Doctorate thesis, University of Thessaloniki, Thessaloniki, Greece. [In Greek.]

** Zaugg B. 1987. Quelques aspects de dynamique des populations de biologie générale et de biométrie du gardon *(Rutilus rutilus L.)* dans 4 lacs du plateau suisse. Thèse de Doctorat. Université de Neuchâtel, Switzerland.

Peninsula (Masó et al. 2016, Latorre et al. 2018) and in the Danube River in Serbia (Lujić et al. 2013), the entire bleak population was dominated by males. According to these authors, this was due to the period of sampling and the behaviour of the males, especially in the period of spawning, which significantly increases their probability of capture. In addition, the fishing devices are not able to catch fish and the phenomenon of the hermaphroditism influenced by various environmental factors (social factors, the temperature in particular).

The monthly variation of the gonadosomatic index in both sexes led us to conclude that the reproduction of *Alburnus alburnus* in Keddara Dam Lake continues all year long. Spawning starts in February until the end of July and resumes again at the beginning of August. A reproductive resting period occurred between the end of August and September and then the cycle started again from October onwards. The last late spawning was observed between November and December. In each sample, we noticed the presence of eggs and larva during almost every month of the year. In our site of study the temperature of water varied from 11 to 30°C. We compared our results with the other study sites, which present lower temperatures with those recorded in Keddara Dam Lake.

Latorre et al. (2018), in the Iberian Peninsula, mentioned a range in the body weight from 0.65 to 53.74 g and in ovary weight from 0.22 to 6.69 g, these values are much lower than those observed in Keddara Dam Lake (body weight 2.95–96 g and ovary weight 0.1–16.63 g). Also, the GSI in the Meuse River, Belgium (Rinchard and Kestemont 1996) was with 18%, slightly higher than in Keddara Dam Lake (17.32). The previous values were both higher than those in the Saône River (15%) (Latorre et al. 2018) and much higher than those registered (mean of 5%) in Çaygören Dam Lake in Turkey (Erdoğan and Torcu Koç 2017).

According to Kompowski (2000) in Międzyodrze waters (Oder River, Poland), the spawning of bleak was extended in time, this was due to three major thermal power stations which increase the water temperature which normally range from 2 to 23°C and is by 6–8°C higher in power-plant water discharge canals (Pilecka-Rapacz et al. 2015).

However, in the water bodies of central Europe, in the Beek River, spawning occurs mainly in June (Kugel 1942 in Kompowski 2000, Krzykawski 1968 in Kompowski 2000). However, it can begin in May and last through August in Konin Lakes (Wilkońska and Żuromska 1977 in Kompowski 2000) in which the temperature varies from 3.3 to 29.9°C (Stawecki et al. 2007). Also, in Turkey, in the Çaygören Dam Lake (Erdoğan and Torcu Koç 2017), the spawning period of this species was determined to last from April through August, knowing that the water temperature varied from 4.6 to 27.6°C.

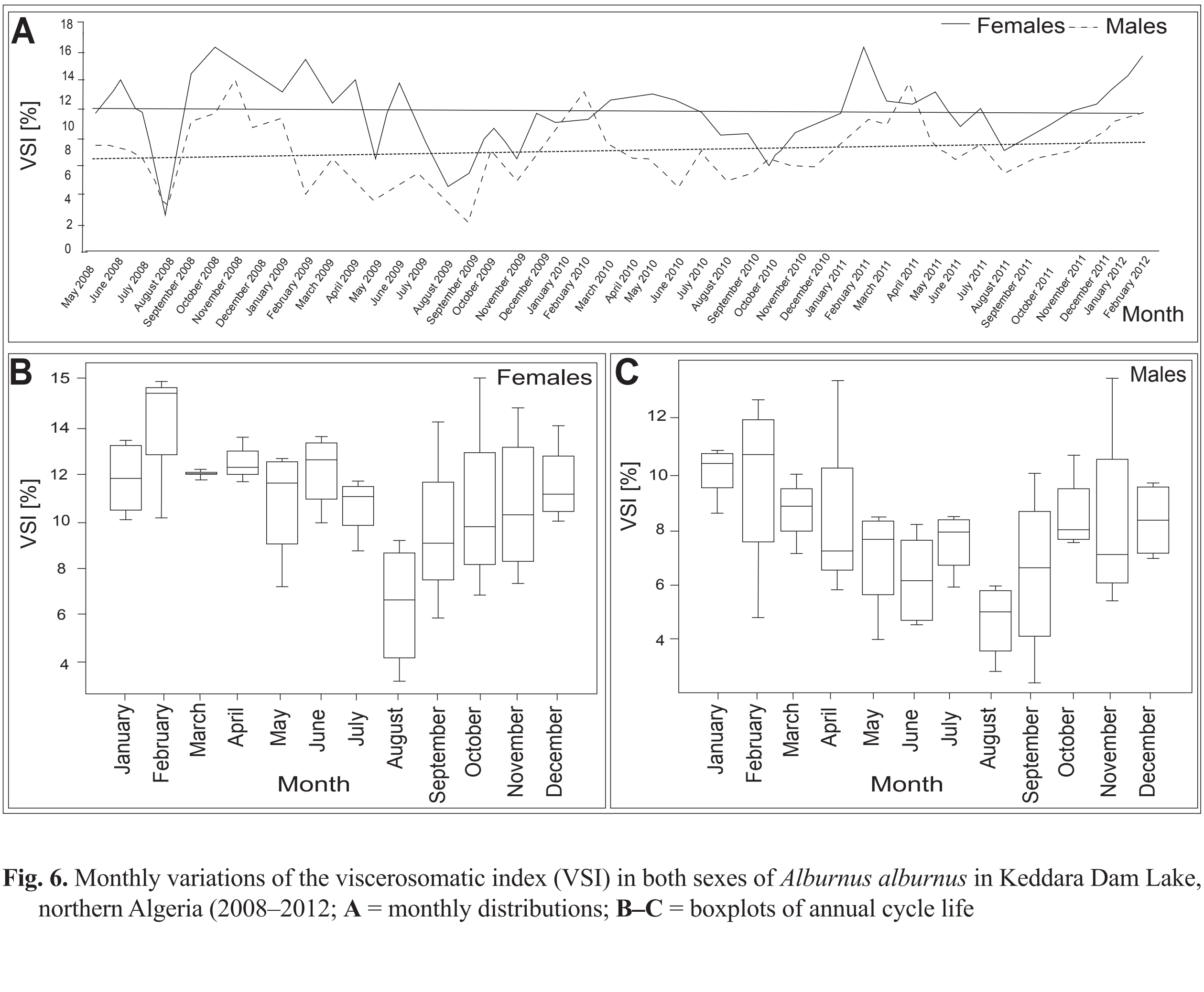


**Fig. 6.** Monthly variations of the viscerosomatic index (VSI) in both sexes of *Alburnus alburnus* in Keddara Dam Lake, northern Algeria (2008–2012; **A** = monthly distributions; **B–C** = boxplots of annual cycle life

Indeed, the water temperature is the most important factor in determining the spawning period of bleak. The sexual maturation and the spawning of bleak need high temperatures. When the temperature increases, the gonadosomatic index decreases (Phillippart and Vranken 1983) which explains the negative correlation between those factors in our results.

Moreover, the results of the presently reported study corroborate in observations of fish spawning behaviour and reproductive development, such as described by Bíró (1980) where bleak adopts multiple spawning strategies, with up to three batches of eggs produced by individual fish, and by Nunn et al. (2002, 2007) in the lower River Trent (England) where it was also observed that bleak spawn more than once annually.

A decrease in the hepatosomatic index indicates that the hepatic reserves have been used at the end of the sexual maturation period and the lowest HSI values are observed at the end of this period. Its decrease reflects the intense transfer of hepatic reserves to the gonads (Le Bec 1983). Indeed, we observed an inverse variation of both parameters GSI and HSI. In our results, no great differences were visible between the recorded values of the hepatosomatic index over time. Also, the statistical test confirmed that there were no significant differences between sexes and between the months. This result can be explained by the existence of another source of reserve noticed in the body cavity, highlights the existence of a very important fat mass that surrounds the fish stomach. This mass changed inversely proportional over time to the development of the sexual organs. Therefore we concluded that alongside the partial intervention of the liver as an energy source for reproduction, there is another source, represented by the fat present around the stomach of the bleak. A similar phenomenon has been known in fatty fish such as sardinella where lipids are deposited in the muscles within or between the muscle fibres (Bertin 1958 in Bouaziz unpublished*). So, the liver does not experience significant variations in weight and volume during the sexual cycle (Bouaziz unpublished*).

The trophic indices viscerosomatic index and repletion index are respectively stationary and increasing in time. The low values of these indices in Keddara Dam Lake could be explained by the diminution in recorded trophic resources and climatic perturbations (Hadou-Sanoun unpublished**).

The availability of food in large amounts and favourable conditions may cause an increase in the

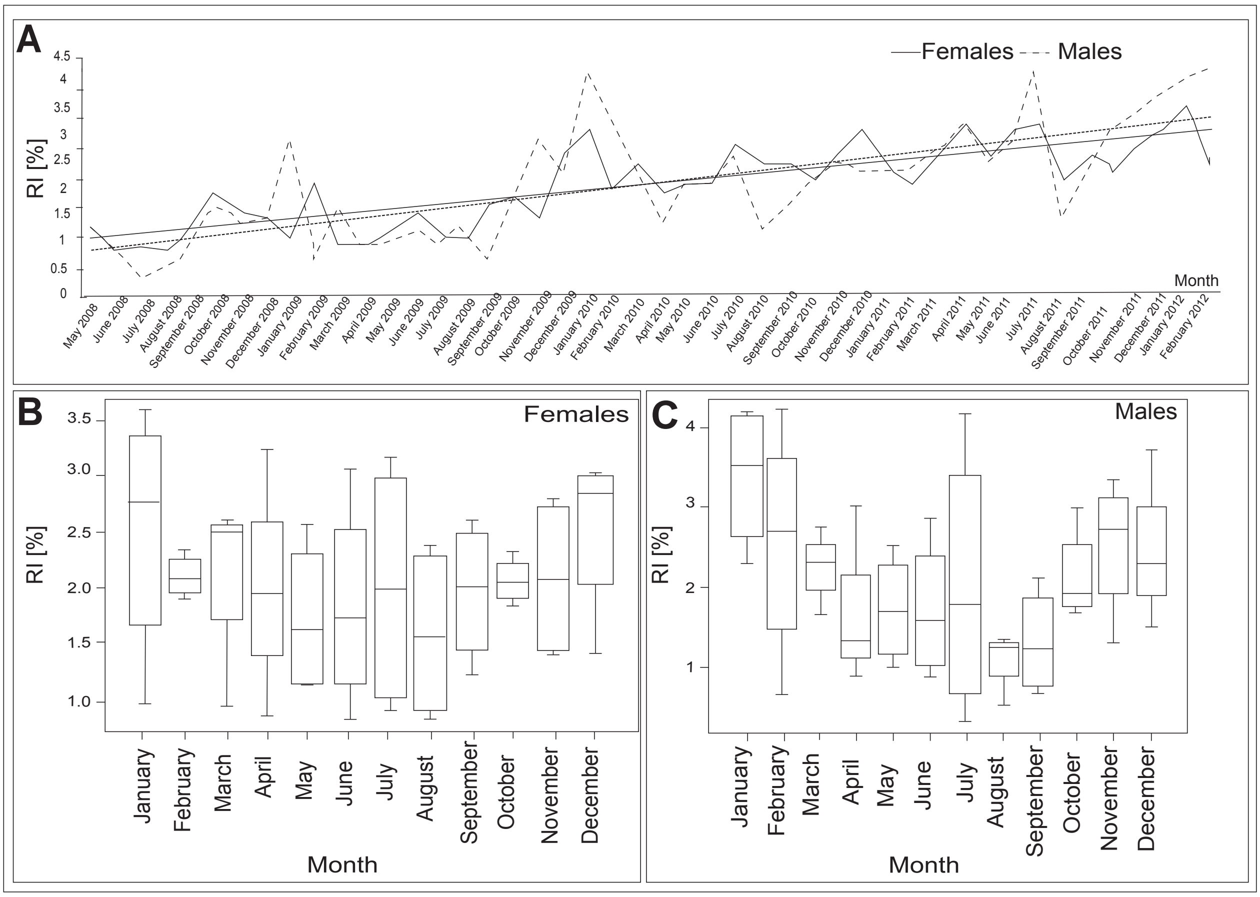


**Fig. 7.** Monthly variations of the repletion index (RI) in both sexes of *Alburnus alburnus* in Keddara Dam Lake, northern Algeria (2008–2012); **A** = monthly distributions; **B–C** = boxplots of annual cycle life

* Bouaziz A. 2007. La sardinelle (*Sardinella aurita*, Valenciennes, 1847) des côtes algériennes: distribution, biologie et estimation des biomasses. Thèse de Doctorat, University of Science and Technology – Houari Boumediene, Algiers, Algeria.

** Hadou-Sanoun G. 2013. Etude écologique et biologique d'un poisson Cyprinidé du genre *Barbus* (*Barbus setivimensis* et *Barbus antinorii*) dans le barrage de Keddara (W. Boumerdes). Thèse de Doctorat, University of Science and Technology – Houari Boumediene, Algiers, Algeria.

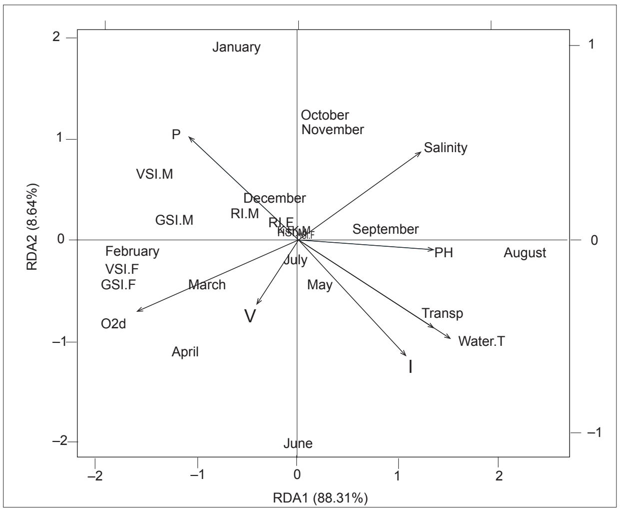


**Fig. 8.** Redundancy analysis (RDA) showing the influence of the environmental parameters of Keddara Dam Lake, northern Algeria, on the biological indices of *Alburnus alburnus*; $T_W$ = water temperature, $O_2$ = dissolved oxygen, pH = pH of water, Sal = salinity of water, Trsp = water transparency, Prctp = precipitation, WS = mean wind speed, Ins = insolation, $GSI_F$ = gonadosomatic index of females, $GSI_M$ = gonadosomatic index of males, $HSI_F$ = hepatosomatic index of females, $HSI_M$ = hepatosomatic index of males, $VSI_F$ = viscerosomatic index of females, $VSI_M$ = viscerosomatic index of males, $RI_F$ = repletion index of females, $RI_M$ = repletion index of males, $K_F$ = condition factor of females, $K_M$ = condition factor of males

**Table 4**

Statistical effect of the significant and non-significant environmental factors on the Keddara Dam Lake, northern Algeria, according to the RDA analysis

| Parameter | Df | AIC | *F*-value | *p*-value |
|---|---|---|---|---|
| $O_2$ [mg·L$^{-1}$] | 1 | 21.268 | 15.1367 | 0.005 |
| $T_W$ [°C] | 1 | 24.669 | 8.9330 | 0.005 |
| Trsp [m] | 1 | 23.295 | 11.2299 | 0.010 |
| pH | 1 | 25.896 | 7.0933 | 0.010 |
| Sal [‰] | 1 | 27.243 | 5.2780 | 0.020 |
| Ins [days] | 1 | 28.314 | 3.9742 | 0.035 |
| Prctp [mm] | 1 | 28.401 | 3.8729 | 0.060 |
| WS [m·s$^{-1}$] | 1 | 31.698 | 0.5404 | 0.520 |

$T_W$ = water temperature, $O_2$ = dissolved oxygen, pH = pH of water, Sal = salinity, Trsp = water transparency, Prctp = precipitation, WS = mean wind speed, Ins = insolation.

HSI value. An increase in the daily weight of the body is related to the increase in the HSI value.

The effect of environmental conditions on biological indices was confirmed by the RDA analysis (Tables 1 and 4).

Each fish species has evolved in response to a unique set of selective pressures, hence the species often differ in their life-history strategies; each life-history strategy is a set of developmental adaptation that allows a species to achieve evolutionary success (DeMartini and Sikkel 2006).

The bleak's trophic and reproductive activities are strongly regulated by physicochemical parameters of the water and weather conditions in particular high temperature. This would improve evolution capacities of this species in North Africa.

This research work is the first in Algeria and brings new data relevant for foraging strategies. The bleak presents a highly important species as a source of socio-economic activity, sold on the local markets under the name of sardine of dams. But, this invasive and predatory species (Attou and Arab 2013), poses risk to ecosystems. It is extremely important to extend its study on other regions in Algeria.

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