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Reproductive cycle of the pelagic fish Saurel *Trachurus trachurus* (Linnaeus, 1758) (Perciformes Carangidae) Caught in the Gulf of Skikda (Algerian East Coast)

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ABSTRACT The present study focuses on the reproductive biology of the small pelagic fish Saurel *Trachurus trachurus* (Linnaeus, 1758) (Perciformes Carangidae), fished in the Gulf of Skikda on the Algerian east coast on an annual cycle from July 2014 to June 2015. The study of average sex ratio variations gave an average annual value of 49.98% in favor of males. The gonado-somatic ratio and the macroscopic examination of the gonads allowed us to locate the period of reproduction between December and April. This report highlights a sexual cycle composed of three successive phases; a slow maturation started from July to November, a phase of significant sexual activity corresponding to the laying period (December-April) and a phase of sexual rest coinciding with the month of May when the gonads recover their masses. On a monthly basis, the evolution of the hepatosomatic ratio values is similar to that observed in the gonado-somatic ones, which leads us to believe that the origin of the energy reserves of the gonads is not the liver and that Saurel is a fat" fish, i.e. lipid accumulation occurs in the muscles. The study of mesenteric reserves confirmed the origin of gonadal energetic deposits. The size of the first sexual maturity in males and females is respectively 14 cm and 13.65 cm.

KEY WORDS *Trachurus trachurus*; Algerian east coast; reproduction; sex ratio; first sexual maturity.

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INTRODUCTION

The study of the reproductive cycle of fish, including assessment of the reproductive potential is extremely useful to a better management of fisheries resources and to ensure the sustainability of these resources on the bioeconomic level.

Several studies have been devoted to various aspects of the small pelagic fish Saurel *Trachurus trachurus* (Linnaeus, 1758) (Perciformes Carangidae) (Letaconnoux, 1951; Maurin, 1954; Nikolsky, 1963; Lahaye, 1972; Macer, 1977; Fréon, 1984; Kartas & Guignard, 1984; Korichi, 1988; Wootton, 1998; Mézédjri, 2004; Mézédjri & Tahar, 2007; Robinson et al., 2008; FAO, 2013; Azzouz et al., 2015a, b, 2016, 2018).

In particular, the objective of this study is to establish a better understanding of the reproductive biology of Saurel *T. trachurus* in the Gulf of Skikda by studying the following parameters: sex Ratio, Gonado-somatic and Hepato-Somatic ratio, adiposity, size of first sexual maturity and condition factor (K) during the sexual cycle.

MATERIAL AND METHODS

The biological study consists in studying the parameters which make it possible to know the biology of our species; this study was carried out on fish caught by purse seines at the level of the Gulf of Skikda during the period stretching between July 2014 and June 2015.

Just with the unloading, at the port of Stora, a sample of 1 to 4 kg taken each month. On each fish we carried out a series of measures (Table 1). The measures of length were made by using a meter with a precision of 1 mm, the total and emptied weights by means of a precision balance with an accuracy of 0.01 g, the gonadic and hepatic weights were obtained using a balance of precision with an accuracy of 0.0001 g.

The determination of sex and maturity stages was carried out according to the method recommended by ERH team (ERH, 1996), during the evaluation of national resources campaign. It consists in the determination of the maturity stages by means of a four-stage scale.

N°	Code	Description
1	Lt	Total length
2	Wt	Total Weight
3	We	Eviscerated Weight
4	Wgon	Weight gonadic
5	Whep	Hepatic Weight
6	Adip	Adiposity
7	Sex	Identification of sex and

Table 1. Measures done on fish for the reproduction survey.

For the species such as Sardine and Saurel, grease is white and covers the internal organs. To determine the degree of fattening, we used the empirical scale with four degrees recommended by the ERH team (ERH, 1996), which is a derivative of Nikolsky scale (Nikolsky, 1963).

Sex-Ratio

In our work used the formula which gives sex-ratio as a percentage by the following relation:

SR = (Males number/Total number) x 100

Then, the chi-squared (χ^2) test was used to evaluate the variation of the actual values of the sex-ratio compared to the theoretical proportion 50% (Dagnélie, 2006). We supposed as hypothesis H0: sex-ratio = 50% and we tested this hypothesis by calculating the value $\chi 2_{obs}$.

$$\chi^2 = \left(m^2/F\right) + \left(f^2/F\right) - n$$

With: m: males number, f: females number, n = m + f, F = n/2: absolute frequency for each sex.

When $\chi 2_{obs} \geq \chi 2_{1-\alpha}$ to 1 degree of freedom we rejected the null hypothesis H0 at the level α=0.05. This test is valid only for number of males or females higher than 5 (Dagnélie, 2006).

Gonado-Somatic Ratio GSR

It is calculated starting from the relationship between the weight of the gonads (Wgon) and the eviscerated weight of fish (We). We used the weight of emptied specimens in the place of the total weight to eliminate the variations due to the repletion state of the stomach. The GSR was calculated for each individual according to the following formula (Kara, 1997):

RGS = (Wgon/We) x 100

This report allowed us to follow over time the weight changes that occur in the gonads during a reproductive cycle, which allows us to understand their maturation and to determine mainly the laying period (Barnabe, 1976).

Hepato-Somatic Ratio HSR

This relationship is calculated between the hepatic weight (Whep) and eviscerated weight (We) according to the following formula (Kara, 1997):

$$RHS = (Whep/We) \times 100$$

Adiposity

Monthly variations of adiposity were assessed during the cycle of reproduction between July 2014 and June 2015. This made possible to follow the annual variations of the mesenteric greasy (ERH, 1996).

Size at First Sexual Maturity

The size of the first sexual maturity shows the legal minimum size of the fish that can be fished in order to maintain sufficient fertility to regenerate the stock. It is determined to be the size corresponding to 50% of mature individuals. It is estimated by calculation, for each size class, with an interval of 1 cm, and for each sex by considering the frequency of mature individuals in relation to the total number of the size class in question. The individuals concerned are only those caught during the Saurel breeding season, i.e. from December to April (Barnabe, 1976; Kara, 1997).

Condition Factor K

The condition factor K is an index allowing the assessment of the relative weight status of the studied individuals. According to Barnabe (1976), at equal size, fish of the same sex may have weight differences related to various factors such as feeding abundance or spawning period. It is expressed by the following relation:

$$K = \frac{p}{L^3} \times 100$$

or: P = eviscerated weight, L = total length.

In our case, we used the eviscerated weight to compensate the gonad weight fluctuations, as well as the calculated allometric no; to observe the monthly changes in K. The global allometric coefficient calculated for each sex separately was also used to observe the variations of K as a function of a given class.

RESULTS

Sex-ratio

The monthly sex-ratio evolution revealed that out of a total of 923 examined individuals, there were 462 males and 461 females, giving a sex ratio of 49.98% in favor of males. This value is not significantly different from the theoretical value SR = 50% because $\chi 2 = 2.14$ and $P > 0.05$ therefore not significant at the level of $\alpha = 5\%$.

Overall, the sex ratio was still insignificant during the entire sampling period. During the months of October and January, we noted a sex ratio in favor of males with high significance at the level $\alpha = 1\%$ ($P \leq 0.01$). Thus, in May the number of females was slightly higher than the number of males with a SR = 36.84% and $\chi 2 = 3.94$ (significant at the $\alpha = 5\%$ level; $p \leq 0.05$) (Table 2).

Monthly Variations of the Gonado-Somatic Ratio (GSR)

Fluctuations in the gonado somatic ratio in *T. trachurus* showed a difference between the mean GSR values of females which were higher than those observed in males. In females we observed a downward phase extending from July 2014 (GSR = 0.83%) to October (GSR = 0.32%), followed by a net increase, from November (GSR = 0.76%) to the month of January 2015 (4.01%). In February, the GSR values dropped significantly to reach GSR= 0.37% in May, whereas growth restarted in June (GSR = 3.83%).

In males there was a slight decrease during the months July, August and September 2014 (GSR from 0.53% to 0.28%). GSR values began to increase in October (GSR = 0.54%) up to January 2015 (GSR = 2.05%). This value was followed by a decrease in the average value during the months of February, March, April, May and June when the growth reached its maximum value (GSR = 4.59%) (Fig. 1).

Month	N males	N femeles	Sex-ratio	χ2obs	
July-2012	43	63	40.5660	3.77358491	ns
August	47	47	50.0000	0.00000000	ns
September	46	41	52.8736	0.28735632	ns
October	47	25	65.2778	6.72222222	**
November	41	44	48.2353	0.10588235	ns
December	46	37	55.4217	0.97590361	ns
January-2013	48	24	66.6667	8.00000000	**
February	37	40	48.0519	0.11688312	ns
March	35	41	46.0526	0.47368421	ns
April	30	38	44.1176	0.94117647	ns
May	21	36	36.8421	3.94736842	*
June	21	25	45.6522	0.34782609	ns
Total	462	461	49.9798	2.14099064	ns

Table 2. Monthly sex ratio changes at Saurel in the Gulf of Skikda (Algeria) with $p > \alpha = 0.05$: (ns) not significant, $p \leq \alpha = 0.05$: (*) significant, $p \leq \alpha = 0.01$: (**) highly significant.

Monthly variations of the Hepato-Somatic Ratio (HSR)

As shown in figure 2, we observed, in females, the lowest values of HRS during the month of July 2014 until December (HSR = 0.58% and 0.70%, respectively), with a maximum recorded in March (RHS = 2.04%); then again a decreasing trend from April (RHS = 1.53%), to May (HSR = 1.08%) and in June (HSR = 1.29%).

In males, variations in HSR were similar but with values slightly lower than in females. The lowest values were observed around July 2014, September, October, November and December. There was an increase in the value of the report in January 2015 (HSR = 0.90%) until reaching the maximum value in March (HSR = 1.98%), then there was a fall in HSR values in April, May and June (down to 0.89%).

Monthly Variations of Adiposity

The monthly variations of adiposity in females as in males were observed. The highest peak was recorded in the month of November (adiposity = 2.00%), then the values decreased to the lowest threshold (adiposity = 1.00%) during the breeding season. Then another peak was recorded in April in females (adiposity =1.45%) and in May for males (adiposity = 1.57%) then, again, a decreasing trend was observed (Fig. 3).

Size of the First Sexual Maturity

The evolution of the size of the first sexual maturity given by class size of the mature individuals according to the total length during the reproduction period (December/April) in *T. trachurus* where the gonads are at their maximum development, showed that the male Saurel from the Gulf of Skikda starts to participate in breeding at a size of Lt 50 = 14 cm (Fig. 4) and for the female Saurel Lt 50 = 13.65 cm (Fig. 5), so we did not observe significant difference between the size of the first sexual maturity of males and females.

Condition factor K

The average condition factor K ranged between K = 0.67 and K = 0.79 during the period under investigation, reflecting the general state of the fish as a function of physiological activities. We noted that the evolution of this index during the year was slightly stationary from July 2014 to June 2015. The highest value was recorded in March (K = 0.79) which reflects the good condition of Saurel whereas the minimum was observed in February (K = 0.67) showing a slight weight loss of fish (this is the period during which the laying takes place) (Fig. 6).

Variations in k-class size coefficients in males were slightly different from in females. The mean value recorded in males (K = 0.72) was the same value as that in females. These variations had no distinct appearance (Fig. 7)

DISCUSSION

The study of the sex-ratio variations during the period from July 2014 to June 2015 of the Saurel *T.*

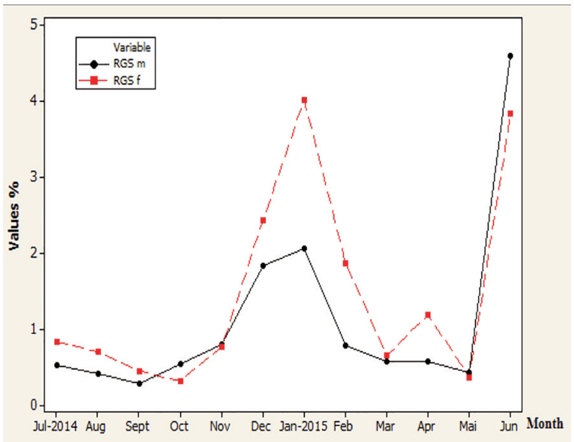

Figure 1. Monthly variations of GSR in *Trachurus trachurus*.

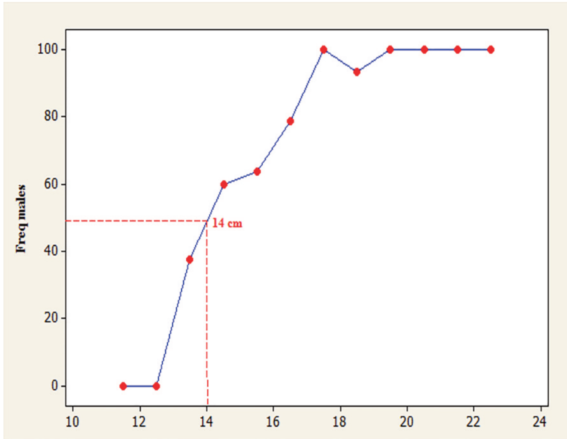

Figure 4. Size of first sexual maturity in males of *Trachurus trachurus*.

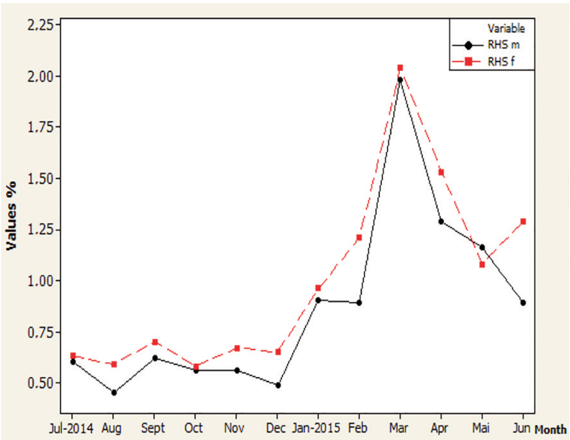

Figure 2. Monthly variations of HSR in *Trachurus trachurus*.

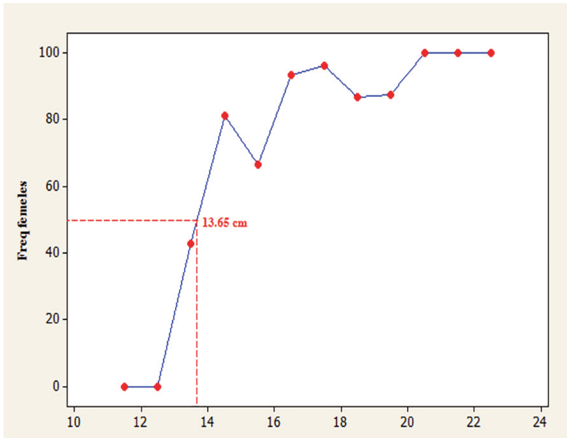

Figure 5. Size of first sexual maturity in females of *Trachurus trachurus*.

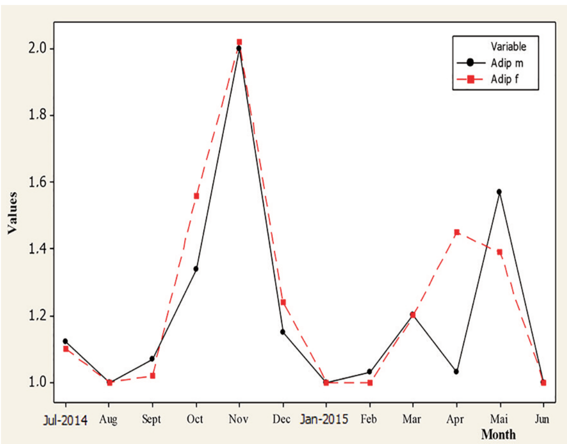

Figure 3. Monthly variations of adiposity in *Trachurus trachurus*.

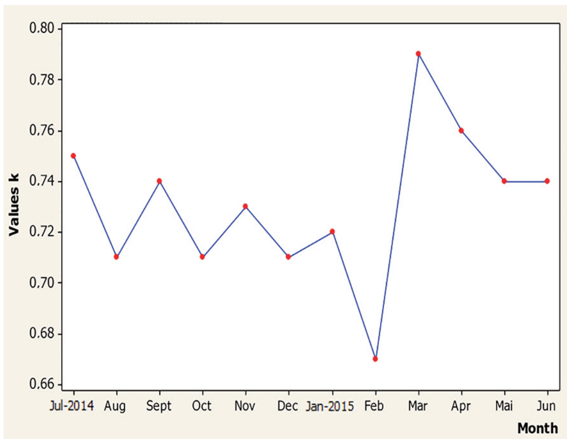

Figure 6. Monthly variations of K in *Trachurus trachurus*.

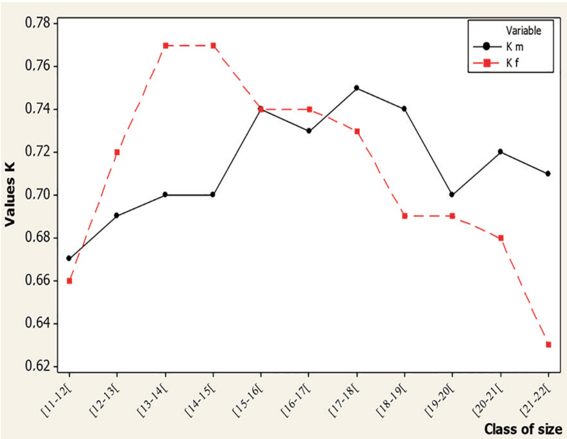

Figure 7. K Variations by Sex and Size classes in *Trachurus trachurus*.

trachurus of the Gulf of Skikda gave an average annual value of 49.98% in favor of the males, so overall, the males and the females were presented by almost equal proportions. Male sex ratio values were dominant in summer and fall, while females were dominant in winter and spring when breeding occurs.

Monitoring the monthly changes in GSR provides information on the periods of sexual activity and allowed us to establish that the saurel breeding season in our region occurs between December and April. GSR levels of females were higher than those of males because of the large size of the ovaries.

The values obtained for the evolution of the GSR showed that the studied sexual cycle comprises three phases: 1) slow maturation phase extending from the month of July and going on until the month of November when the GSR reaches the lowest values; 2) a phase of intense sexual activity from December to April, which is the period of laying where the RGS reaches the maximum; and 3) a phase of sexual rest that coincides with the month of May when the testicles and the ovaries recover their mass.

The peak observed in June 2015 was probably related to climate change and the high temperature recorded during the summer of 2015, so a breeding phase in Saurel was, probably, triggered.

The study of the monthly variations of the HSR showed that the necessary energy for the maturity of the gonads comes from the lipid reserves stored at the level of the liver. In both sexes one has the same pace but with slightly lower values in the males. In general, during the maturation period, we had the lowest values of HSR followed by an increased peak of HSR during the breeding season. Therefore, these HSR variations showed an evolution almost similar to that of the GSR with maximum and minimum values reached at the same time, which suggests that the species is a fatty fish for which lipid accumulation occurs in the muscles (Bertin, 1958), and the liver does not intervene in the transfer of energy reserves (Djabahi & Hamida, 1989). As the liver plays no part in the process of maturation of sexual products, this implies that the two parameters (GSR, HSR) should be studied together and not separately, so these two indices are to be considered a good indicator of the metabolic state and energy reserves of fish.

With regard to mesenteric fat stores, values generally fluctuated throughout the sexual cycle in Saurel, there was a maximum peak implying an accumulation of reserves during the period of sexual rest and, still, maturation was followed by very low fat levels during the reproduction period, which confirms the origin of gonadal reserves (Djabali & Hamida, 1989).

The study of the size of the first sexual maturity based on the frequency of the mature individuals as a function of the total length (Lt 50) for which 50% of the individuals of the population are able to reproduce, made it possible to assess that for the males of *T. trachurus* the size of the first sexual maturity in the Gulf of Skikda during the studied period, July 2014–June 2015, is estimated as Lt 50 = 14 cm for males and Lt 50 = 13.65 cm for females.

The monthly evolution of this coefficient (K) in the Saurel *T. trachurus* of the Algerian east coast is slightly stationary throughout the sexual cycle, the lowest value showing a slight weight loss noted during the month of February which coincides perfectly with the period of laying where the reserves energy is consumed, followed by an increase in the value of K in the month of March, where the fish quickly recover their weight during the sexual rest period.

CONCLUSIONS

The biological study of the reproduction of Saurel samples taken from the Gulf of Skikda (Algerian east coast) during the year July 2014 to June 2015 shows that: the reproduction of horse mackerel *T. trachurus* takes place once a year, apparently from December to April. The study of the sex-ratio shows that the males dominate (SR = 49.98%) The values obtained on the evolution of the Gonado-Somatic Ratio show that the sexual cycle studied passes by three successive phases, a phase of slow maturation, a phase of intense sexual activity and a phase of sexual rest. Variations of the Hepato-Somatic Ratio leads us to believe that the origin of the energetic reserves of the gonads is not the liver but, rather the muscles. The size of the first sexual maturity is reached at a length of 14 cm in males and females 13.65 cm. The monthly change in the condition factor (K) shows that our Saurel fish makes its energy reserves available during the breeding season and stores them during sexual rest.

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