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Reproductive cycle of the European anchovy *Engraulis encrasicolus* (Linnaeus, 1758) (Clupeiformes Engraulidae) in the gulf of Skikda (Algerian East coasts)

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ABSTRACT A study on the sexual cycle of the European anchovy, the pelagic fish *Engraulis encrasicolus* (Linnaeus, 1758) (Clupeiformes Engraulidae), was carried out in Algerian East coasts over a year (July 2008-June 2009). Annual sex-ratio (SR) showed that females dominate with an average male sex-ratio of 39.35%. The European anchovy spawning period ranges from April to October with peaks in the warmest months, strictly dependent on temperature. The gonado-somatic index was updated monthly which allowed us to divide the entire cycle into four successive phases: (i) a phase of slow maturation which occurs between the end of winter and the beginning of spring; (ii) a phase of significant sexual activity; (iii) a phase of emission of the sexual products which corresponds to the warmest months; and, finally, (iv) a phase of sexual rest occurring in the coldest months. Monthly variation of either hepato-somatic index or mesenteric fat reserves informed us about the origin of the energetic deposits, particularly important for the development of the gonads. In both sexes, the first sexual maturity is reached at a fish total length (Lt) of 12.5 cm.

KEY WORDS Algerian East-coasts; *Engraulis encrasicolus*; reproduction; sex-ratio; first sexual maturity.

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INTRODUCTION

Reproduction and sexual behaviour of the European anchovy *Engraulis encrasicolus* (Linnaeus, 1758) (Clupeiformes Engraulidae) were the subject of many studies focusing on the connection between these items and food behaviour, plumpness of fishes and ecological factors in natural populations of this species (Fage, 1911, 1920; Dorel, 1986; Hemida, 1987; Whitehead et al., 1988; Djabali & Hamida, 1989; Pertierra, 1992; Prouzet & Metuzals-Sebedio, 1994; E.R.H., 1996; Kara, 2001; Mezedjri & Tahar, 2005, 2006; Kada et al., 2009). This work brings new information on the reproduction of *E. encrasicolus* in the Gulf of Stora, Skikda (Algerian East coasts). Sex-ratio, gonado-somatic and hepato-somatic indexes, adiposity and size at first sexual maturity were studied. Obtained results were compared with those reported in literature for several Mediterranean areas.

MATERIALS AND METHODS

The study was carried out on fishes caught by means of sliding seines in the Gulf of Stora (Algeria) during one year, from July 2008 to June 2009. Just with the unloading, a sample of 1 kg at minimum was taken at the port of Stora, monthly. On each fish a series of measures were made (Table 1) including length, by using an ichthyio-meter with meadows millimetre; total and eviscerated weights, by means of a balance with an accuracy of 0.01 g; and gonadic and hepatic weights to the nearest 0.0001 g.

Determination of maturity stages was carried out according to the method recommended by the ERH team (E.R.H., 1996), in particular, by taking into account the degree of fattening of each specimen according to an empirical four degree-scale which is a derivative of the scale of Nikolsky (1963). In literature there is a divergence on the formula for the sex-ratio. In our work we used the formula which gives sex-ratio as a percentage of males by the following relation: *SR=(Males Number/Total Number)x100*. Then, the chi-squared (χ^2) test was used to evaluate the variation of the observed values of the sex-ratio compared to the theoretical proportion of 50% (Dagnélie, 2006). We supposed as hypothesis H_0: sex-ratio = 50% and tested this hypothesis by calculating the value of χ^2_{obs} by the formula:

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

where, m: number of males; f: number of females; n = m + f; F = n/2. When $\chi^2_{obs} \geq \chi^2_{1-\alpha}$ at 1 degree of freedom we rejected the hypothesis H_0 at the level $\alpha = 0.05$. Please note that this test is valid only for number of males or females higher than 5 (Dagnélie, 2006). The gonado-somatic index (GSI) is an index expressed in percentage. It is calculated starting from the relationship between the weight of the gonads (Wgon) and the eviscerated weight of fish (We). We preferred to use 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 GSI is calculated for each individual according to the following formula (Kara, 1997): *GSI=(Wgon/We) x 100*. GSI values reflect changes in gonads weight during the reproductive cycle, thus making us possible to monitor their maturation (Barnabé, 1976). The hepato-somatic index (HSI) is expressed in percentage as well. This relationship links the hepatic weight (Whep) and the eviscerated weight (We) according to the following formula (Kara, 1997): *HSI=(Whep/We) x 100*. Its changes are connected to the variations of hepatic weight during the reproductive cycle. Monthly variations of adiposity (Adip), i.e. the mesenteric fat, were followed during the entire period (July 2008-June 2009). All the specimens caught during the reproduction period (from April to October) were distributed, according to their size, in classes of sizes with an interval of 0.5 cm. Then, we took in consideration the frequency of the mature individuals in relation to the total number of specimens belonging to each class. Size at first sexual maturity is determined as the size of 50% of the mature individuals (Barnabé, 1976; Kara, 1997). This parameter is calculated separately for each sex, and then the two sexes are compared. All calculations have been executed with the software MINITAB for analysis and statistical treatment of the data, version 16 for Windows (2010).

N°	CODE	DESCRIPTION
1	Lt	Total length
2	Wt	Total Weight
3	We	Eviscerated Weight
4	Wgon	Gonadic Weight
5	Whep	Hepatic Weight
6	Adip	Adiposity
7	Sex	Identification of sex and stage of maturity

Table 1. Measures made on fishes for the reproduction survey.

RESULTS AND DISCUSSION

Sex-ratio

On a whole of 803 examined individuals, we observed 316 males and 487 females with an average male sex-ratio of 39.35% (χ^2 = 36.41; P≤0.001). Monthly variations of sex-ratio are shown in Table 2. Broadly speaking, the sex-ratio was always in favour of females (with a male SR ranging from 18.42% to 35.62%, 0≤P≤0.05) except during September, when we noted a value of sex-ratio in favour of males (SR=71.96%, P≤0.001). SR values assessed in October 2008 and March 2009 (56.30% and 40%, respectively) were not statistically significant. Females remained dominant for 7 months, particularly during the warmest ones (from April to August), when the anchovies come closer to the Algerian coasts, where they are captured easily. This leads us to say that the Gulf of Stora may be considered as a zone of spawning of the European anchovy.

Month	No. of males	No. of females	Sex-ratio	χ2 obs
Jul-08	14	62	18.4211	30.31579 ***
Aug	50	100	33.3333	16.66667 ***
Sep	77	30	71.9626	20.64486 ***
Oct	67	52	56.3025	1.89076 ns
Nov	-	-	-	-
Dec	-	-	-	-
Jan-09	12	26	31.5789	5.15789 *
Feb	25	86	22.5225	33.52252 ***
Mar	32	48	40	3.2 ns
Apr	26	47	35.6164	6.04109 *
May	9	30	23.0769	11.30769 ***
Jun	4	6	40	0.4 ns
Total	316	487	39.3524	36.41469 ***

Table 2. Monthly variations of male sex-ratio for *Engraulis encrasicolus* from the gulf of Stora between July 2008 and June 2009. $p > \alpha = 0{,}05$: (ns) not significant, $p \leq \alpha = 0{,}05$: (*) significant, $p \leq \alpha = 0{,}001$: (***) very highly significant.

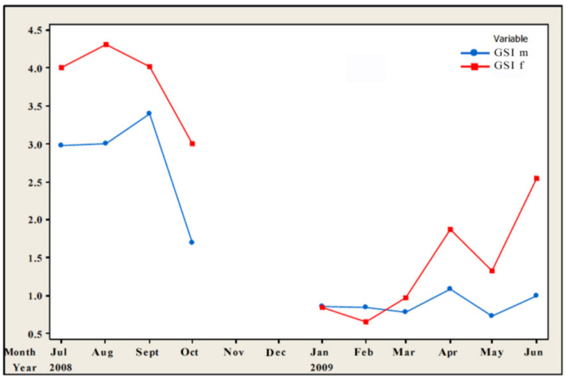
Gonado-somatic index

Graphically, monthly fluctuations of gonado-somatic index (GSI) values of *E. encrasicolus* are shown in figure 1. For females, GSI showed the highest values in summer with a maximum in August (GSI=4.31%), decreased at the beginning of autumn, the lowest values being recorded in winter with a minimum in February (0.65%), and then gradually and notably increased in spring. Males ex-hibited more or less a similar trend, with the maximum value recorded in September (3.39%) and the least in January (0.86%). Noteworthy, the increase in GSI values through the spring period (March-June) was less marked than in females. Monthly variations of the gonado-somatic index revealed that the reproduction period of the anchovy in our area spreads between April and October. This is in line with Whitehead et al. (1988) who affirm that the peak of spawning generally coincides with the warmest months, the limits of the spawning season being dependent on the temperature. Plotting the evolution of GSI values showed that the reproductive cycle of *E. encrasicolus* is characterized by four successive phases: (i) a phase of slow maturation which starts in March and continues until June; (ii) a phase of significant and intense sexual activity which occurs during the warm-est months (from June to September); (iii) a phase of decline starting in September during which the testicles and the ovaries gradually loose their mass; and finally (iv) a phase of rest, coinciding with the coldest months (from December to Feb-ruary), when fishes become sexually inactive.

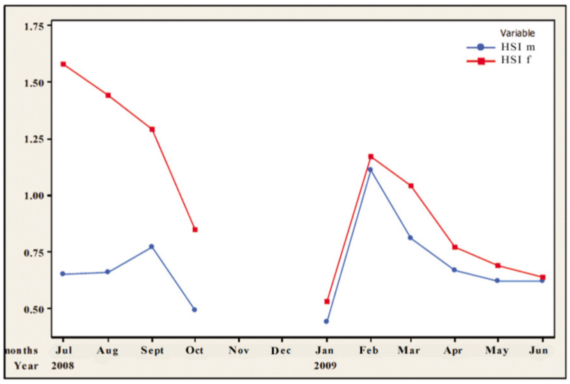
These findings once again support the hypothesis that temperature exerts a strong influence on the sexual cycle of the European anchovy, with high temperatures leading to spawning and low temperatures preventing sexual activity (Whitehead et al., 1988; Djabali & Hamida, 1989).

Hepato-somatic index

For the hepato-somatic index (Fig. 2) we observed, in females, a maximum in July (HSI=1.58%) and, then, a clear reduction up to October (0.85%), with the lowest values in January (0.53%) when it dramatically increased to reach a maximum in February (1.17%). After that, HSI gradually decreased up to June (0.64%). In males we observed the same trend, although absolute values were slightly lower than in females. HSI, compared with GSI, was less marked. During the reproduction period HSI values decreased probably due to the consumption of fat deposits, reaching a peak in winter (at the end of February) which suggests a possible storage of reserves in the liver during the sexual rest, followed by the reduction of HSI from March on, when sexual maturity begins. It is interesting to note that, especially for females, HSI and GSI values did not always show complementary trends, thus suggesting that energy reserves used to allow the development of the gonads may not be accumulated exclusively in the liver.



1



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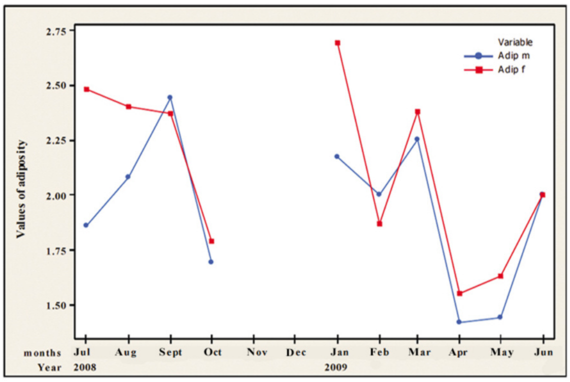

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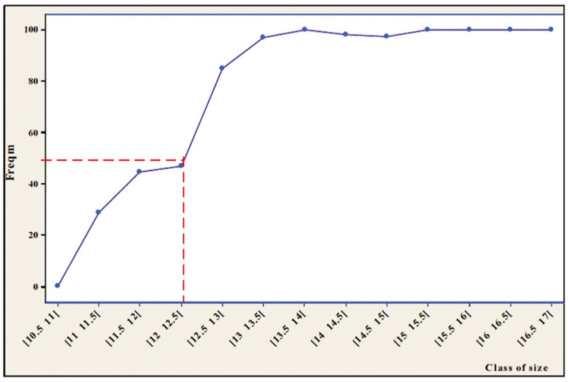

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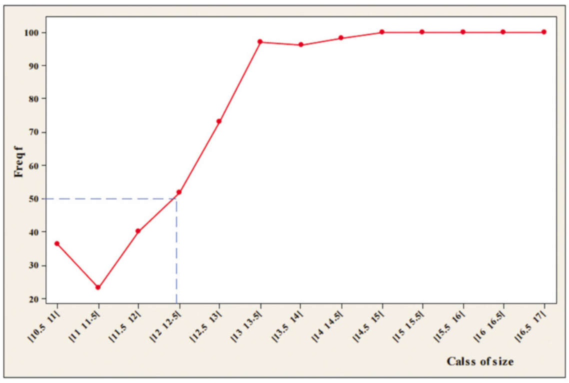

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Figure 1. Monthly variations of GSI in *Engraulis encrasicolus* from the gulf of Stora.
Figure 2. Monthly variations of the HSI for *E. encrasicolus* from the gulf of Stora.
Figure 3. Monthly variations of adiposity for *E. encrasicolus* from the gulf of Stora.
Figure 4. Size at first sexual maturity in females of *E. encrasicolus* from the gulf of Stora.
Figure 5. Size at first sexual maturity in males of *E. encrasicolus* from the gulf of Stora.

Djabali & Hamida (1989) during a study on the European anchovy, carried out between 1983 and 1984, concluded that the liver didn't have any role in the maturation process of the sexual products; this implies that the two parameters (GSI and HSI) should be studied together.

Adiposity

Changes in mesenteric deposits in *E. encrasicolus* are shown in figure 3. The maximum values were recorded in September (males) and January (females) while, in both sexes, the lowest ones were in April.

Taking into account that the highest values were observed in winter (during the sexual rest) and the lowest ones in the warmest months, these findings confirm the hypothesis, maintained by Djabali & Hamida (1989), that gonadic reserves may origin mainly from mesenteric fat deposits.

Size at first sexual maturity

The size at the first sexual maturity (Lt) is roughly the same for both sexes and corresponds to 12.5 cm (Figs. 4, 5). As can be seen, our data are in line with most of the Lt values available for *E. encrasicolus* populations in the Mediterranean (Table 3), suggesting that, in the areas analysed, there are not big differences in environmental factors, particularly water temperatures, population density and food availability, while Lt = 6.5 cm reported for the lagoon of Nador (Morocco) might be possibily due to disturbing issues including high fishing pressures.

In conclusion, the present study not only gave information on any biological aspects of *Engraulis encrasicolus* from the guld of Skikda (Algerian East-coasts), which up to now were deficient, but also contributed to provide a preliminary base for monitoring the changes in biological indexes connected to the reproduction cycle of this species in order to ensure its sustainable management in the Mediterranean area.

Lt (cm)	Sex	Locality	Author
13.0	Males	Golf of Biscay	Dorel, 1986
13.0	Females	Golf of Biscay	Dorel, 1986
11.2	Males	Bay of Algiers	Djabali & Hamida, 1989
11.6	Females	Bay of Algiers	Djabali & Hamida, 1989
11.5	Indefinite	Coast of Catalonia	Pertierra, 1992
12.5	Both sexes	Golf of Stora (Skikda)	Mezedjri & Tahar, 2005; 2006
12.5	Both sexes	Golf of Stora (Skikda)	present paper
06.5	Both sexes	the lagoon of Nador (Morocco)	Kada et al., 2009

Table 3. Size at first sexual maturity of *Engraulis encrasicolus* in some regions of the Mediterranean Sea.

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