

Reproductive biology of horse mackerel, genus *Trachurus* Rafinesque, 1810 (Perciformes Carangidae), caught in Béni-Saf Bay, W-Mediterranean Sea (Algeria)

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ABSTRACT

This paper gives a description of reproduction of the horse mackerel (genus *Trachurus* Rafinesque, 1810) (Perciformes Carangidae) in the west-south coast of Mediterranean Sea in the Béni-Saf Bay, between November 2015 and October 2016. In total, 488 individual were sampled and 240 (49.18%) were males, 208 (42.62%) were females and 40 (8.20%) were undetermined. Length of individuals varied between 7.1 and 35.5 cm and weight from 5.09 to 343.4g. This work provides values of sizes at first sexual maturity (TL₅₀), that were estimated for males at 155 mm and females 148.5 mm, respectively. The spawning period extends from January to June and the spawning peak occurs from April to July. The factor of condition (K) increased during the sexual resting phase. This factor is weak during the period of reproduction. Coefficient of condition K seems to follow the same pattern as the GSI with high values recorded in spring (M: 3.50 and F: 4.46), (M: 3.00 and F: 3.49), in summer and (M: 1.67 and F: 2.63) in winter, and the lowest values in autumn (M: 0.54 and F: 0.69). The sex-ratio of *Trachurus*, per months, by season and by size classes, shows a dominance of males. The difference in percentage increases in favor of the males during the reproduction period, between February and July. This ratio inverts in favor of females during the rest of the year.

KEY WORDS

Horse mackerel; *Trachurus trachurus*; reproduction; Spawning period; Béni-Saf Bay.

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INTRODUCTION

The family Carangidae includes about 25 genera and 200 species distributed world-wide in the temperate and tropical seas; some of them are caught commercially and are valued as table food (Caputo et al, 1996). Data on the karyology of the Carangidae are rather scarce, though this information could be useful not only for cytotaxonomic purposes but also for genome manipulation (Amores et al., 1993). The horse mackerel (genus *Trachurus*

Rafinesque, 1810) is a gregarious fish of the Carangidae family. It can be found in circalittoral bottoms and even in the upper bathyal stage (Turki, 1987). It is characterized by a very indented caudal fin and the presence of osseous scutes in the posterior part of the lateral line which accentuate its silvery sheen (Quéro, 1984). The geographical distribution of the horse mackerel *Trachurus* covers the whole platform and slope of the European and African coasts from Norway to the Gulf of Guinea, and the Mediterranean and Black Sea.

Trachurus is a migratory fish and its movements are driven by feeding and spawning requirements (Murta et al., 2008). It can be found close to the bottom.

The study of the reproductive activity through the analysis of certain parameters such as variation of some biological indexes can help us better characterize the reproduction cycle by indicating the period and the strategy of laying of these fish. Several works have been dealing with *Trachurus* all around the world: Barraca, 1964; Letaconnoux, 1951; Ben Salem & Ktari, 1980; Arneri, 1983; Alegria, 1984; Kerstan, 1985a, 1995b; Korichi, 1988; Crim et al., 1990; Eltink, 1991; 1992; Ben Salem & Ktari, 1994; Abaunza et al., 1995; Laleye et al., 1995; Karlou-Riga & Economidis, 1996, 1997; Fezzani-Serbaji et al., 2002; Gherram, 2009; Tahari, 2011; Aydin & Erdoğan, 2018.

This paper focuses on the reproductive biology of horse mackerel (*Trachurus*) of Béni-Saf Bay with emphasis on reproduction period and size at first sexual maturity to complete gaps in life cycle of this Carangidae and better manage this resource in that part of the Algerien coast.

MATERIAL AND METHODS

Monthly samples of horse mackerel, *Trachurus*, were obtained from commercial landings in Béni-Saf port (Coast Guard checkpoint) (Fig. 1), carried out between November 2015 and October 2016. Total length (TL) was measured to the nearest millimeter, total weight (TW) and weight of the gonads (Wg) to the nearest 0.01 g. These different weights

are necessary for determining the gonado-somatic index; in addition, the sexes are determined after dissection. Fish lengths were classified in 1 cm group intervals (Fig. 2) and sex was determined macroscopically based on the morphology and the color of gonads (Mahdi et al., 2018).

Sex ratio

It is defined as being the proportion of the male or female individuals compared to the total number of individuals. It also gives an idea on the balance of the sexes within the population. The sex-ratio generally translates the rate of femininity or masculinity of the population:

$$SR = F/(M+F) \times 100 \text{ (Kartas \& Quignard, 1984)}$$

F= number of females; M = number of males.

Gonado somatic index (GSI)

In order to understand the sexual cycle and determine the spawning period the gonado somatic index (GSI) was calculated monthly for females and males. The description of the reproductive cycle of this species and the determination of spawning period were carried by the follow-up of the monthly variations of this index.

$$GSI = GW/TW \times 100 \text{ (Htun-Han, 1978)}$$

GW: gonads weight in g; TW: total weight in g.

Coefficient of condition

The coefficient of condition K is defined by the relationship between the weight and the size of fish given by the formula:

$$K = TW/TL^3 \times 1000 \text{ (Fulton, 1940)}$$

TW: total weight; TL: total length.

Size of the first sexual maturity

The size of the first sexual maturity ($TL_{50\%}$), which corresponds to the length for which 50% of the individuals are mature, was calculated for our specimens. Considered as ripe, the individuals whose gonads occupy almost the totality of the visceral cavity: for males, the testicles are white milky, for the females, the ovaries are bulky and pinky

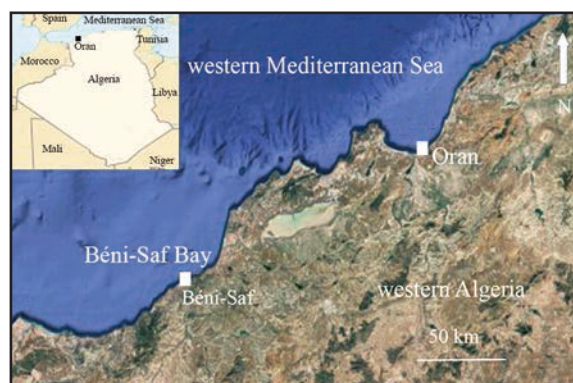


Figure 1. Geographical localization of the study area, Béni-Saf Bay, Algeria.

with visible oocytes through the wall ovaries. For each size class (1 cm) previously defined, we counted mature individuals on one side and immature individuals on the other. Consequently, we determined the relative proportions of each group in relation to the total size of each size class. Subsequently, we determined the values corresponding to the sizes at the first maturity fixed above from an equation whose curve is sigmoid:

$$P = 1 / (1 + e^{-(b + aTL)}) \quad (1) \quad (\text{Ghorbel et al., 2002})$$

P: proportion of mature individuals; TL: total length in cm.

The constants a and b are determined by the method of least squares by transforming the equation (1) into linear type:

$$\ln(P/(1-P)) = b + aL \quad (2)$$

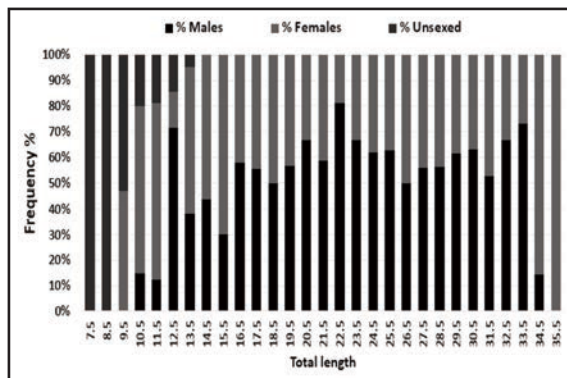


Figure 2. *Trachurus* length frequency distribution of males and females caught in Béni-Saf Bay.

RESULTS

In total, 488 specimens of *Trachurus* were collected (Fig. 2), 240 males (49.18%), 208 females (42.62%) and 40 unsexed (8.20%). The length frequency distribution of the entire population is shown in figure 2, male length range was 10.2 to 34.4 cm, female length range was 9.1 to 35.1 cm while males weight varied between 11.38 and 301.27 g and females' weight varied between 5.09 and 343.41 g.

Sex Ratio

From a 12-month sample represented by a workforce of 488 individuals, we obtained a total masculinity rate of 53.57% for a total femininity rate of 46.43% (Fig. 3).

Overall, in our sample, there is a convergence

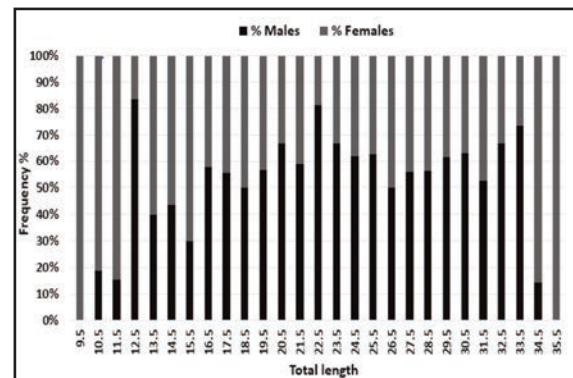


Figure 3. Sex ratio by length size of *Trachurus* caught in Béni-Saf Bay.

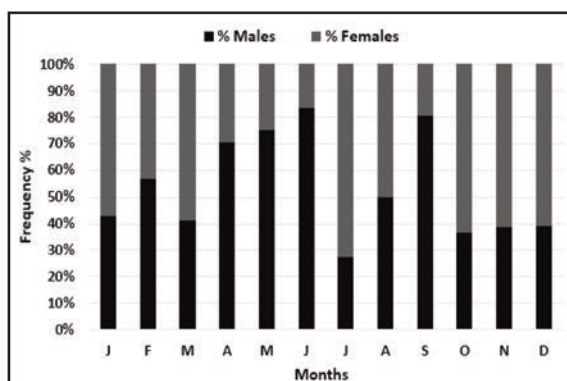


Figure 4. Monthly evolution of Sex ratio of *Trachurus* caught in Béni-Saf Bay.

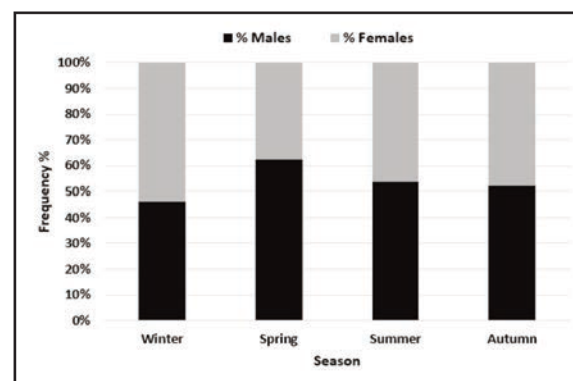


Figure 5. Evolution of Sex ratio by seasons of *Trachurus* caught in Béni-Saf Bay.

between the two sexes ratio with a slight favor of males. In addition, the variations in sex ratio according to size is in favor of females whose total length is less than 16.5. In sizes between 16.5 and 35.5 cm, males outnumbered females, except for size 34.5 cm and 35.5 cm, where females outnumbered males.

Monthly variations of sex-ratio (Fig. 4) reveal that females dominate during the months of January, March, July, October, November and December. And males dominate during February, April, May, June, and September, with a numerical equality in August.

Evolution of sex-ratio related to seasons (Fig. 5) showed that females dominate in winter period while males dominate in spring-summer-autumn period.

Gonado Somatic Index (GSI)

The monthly evolution of the gonado-somatic index (GSI) can help us to determine the spawning

period during an annual cycle (Fig. 6), the monthly values of this index varied between 0.43 and 5.87 for females while it varied between 0.30 and 5.08 for males. From January, this index increases for both sexes to attain its maximum in June, after which they begin to gradually decline until they reach their lowest value in October for males and in November for females. This pattern marks an intense sexual activity until early summer in June where this index decreases gradually to reach its lowest values in autumn, marking it as the post spawning period.

Sex-ratio related to the size classes

To investigate the role of small specimens and their contribution to the renewal of the resource, we related GSI to length of individuals (Fig. 7) and it was established that GSI increased simultaneously

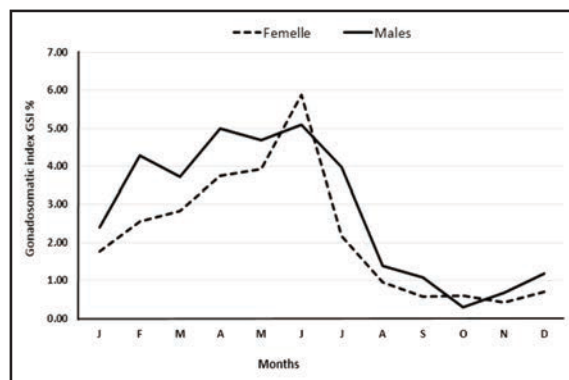


Figure 6. Monthly evolution of GSI for males and females of *Trachurus* caught in Béni-Saf Bay.

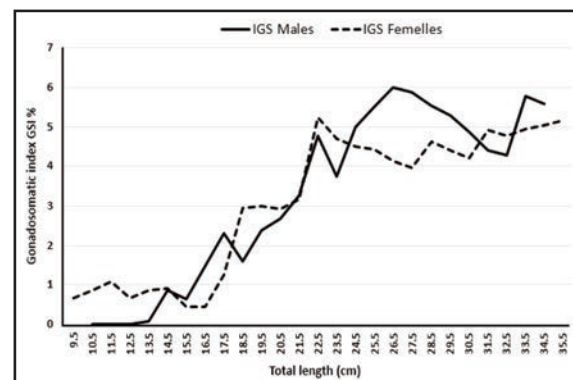


Figure 7. Evolution of GSI related to total length of males and females of *Trachurus* caught in Béni-Saf Bay.

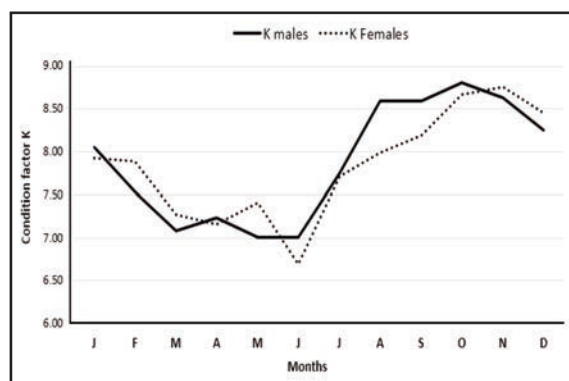


Figure 8. Annually evolution of condition factor K of *Trachurus* males and females caught in Béni-Saf Bay.

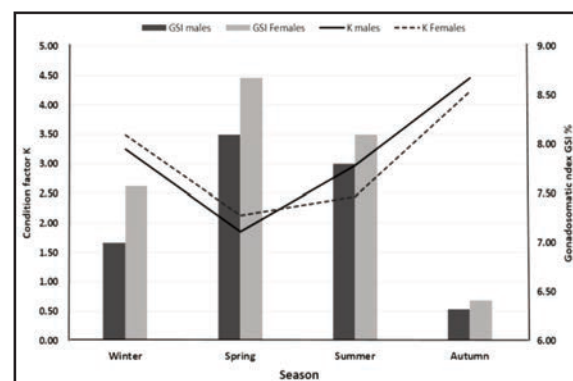


Figure 9. Seasonal evolution of condition factor K and GSI of *Trachurus* males and females caught in Béni-Saf Bay.

in females and males. For males, we recorded a maximum of GSI at 5.995 corresponding to a size 27.5 cm and a minimum of GSI at 0.004 according to 12.5 cm. For females, the GSI maximum value was recorded at 5.23 corresponding to a size of 22.5 cm while the GSI minimal value was recorded for 16.5 cm.

Condition Factor *K*

The changes observed in the condition factor coefficient seem to be closely but inversely related to the gonado-somatic ratio (GSI), where the two indices are inversely proportional. In fact, during the spawning period the condition factor of the specimens was recorded at its lowest values (7.01 for females and 6.70 for males) and in rest period the same factor records its highest values (8.81 for females and 8.76 for males). The maturation of the sexual products and their emissions requires relatively high energy expenditure, and by consequence the reduction of fish weight during spawning period (Fig. 8)

Size at First Maturity

The analysis of the proportions of the mature horse mackerels (genus *Trachurus*) shows that no individual, whatever his sex, is mature with a size lower than 105 mm, as all the individuals observed are mature with a size total higher (TL) than 225 mm. Length at first maturity was estimated as 155 mm for males and 148.5 mm for females (Fig. 10).

DISCUSSION

During the study period, sex-ratio is slightly in favor of the males, the evolution of this index does not have a phenological regularity the fluctuations of the sex-ratio. The difficulty in interpreting the fluctuations of this ratio are due to several factors such as the behavior of the species, spawning period and mortality, sampling procedure, and aggregation of the of the same sex individuals. During the period of peak spawning, males outnumber females. This is probably due to a behavioural difference between the sexes (Polonsky & Tormosova, 1969).

The sexual cycle and spawning period of *Trachurus* fish in the Atlantic coasts have been the sub-

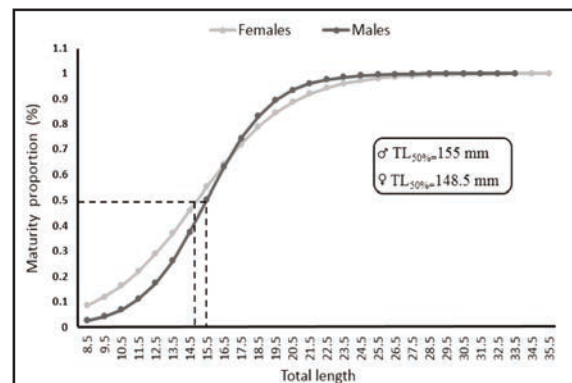


Figure 10. Ogive of sexual maturity of males and females of *Trachurus* of Béni-Saf Bay.

ject of several studies (Table 1). In fact, Arruda (1984) noted that the reproduction period of this fish extends from the beginning of November to May on the west Portuguese coasts and also between April and December in Matosinhos Bay. On the other hand, Arruda (1984) showed that *Trachurus* living in the Portuguese coast (Southern coast) spawns throughout the year. Studies on the reproduction of *Trachurus* carried out in the East and the Center-East of the Atlantic showed that the period of the reproduction of this species is not synchronous while passing from one region to another. In contrast, at the North Sea and English Channel coasts, Macer (1974) has shown that the spawning period of *Trachurus* fish is very prolonged during the year and takes place from March to August, while it is shorter in west of the British Isles and takes place from March to June according to Eaton (1989), and from February to May according to Abaunza et al (1995) in North-west of Spain Galician and Cantabrian shelf. Despite the difference in the timing of prematurity, maturation and sexual rest, the spawning period of *Trachurus* in the North-west Atlantic (Abaunza et al., 2003) coincides with that of Present study in Béni-Saf Bay (February-June).

In the Mediterranean coasts, the spawning period varies between 4 and 6 months. Šantić et al (2008) noted the reproduction period of this fish starting from December to May on the Italian east coasts (Adriatic Sea).

In addition, according to Karlou & Economidis (1997) on the coast of Greece, *Trachurus* fish reproduce between December and April. Studies car-

References	Study area	Spawning period	TL _{50%} (cm)
Letaconnoux, 1951	Gulf of Gascogne		19 (shore) 23 (offshore)
Andreu & Rodriguez-Roda, 1951	(NW Mediterranean Sea) Catalonia		15.5
Lozano Cabo, 1952	N/NW coast of Spain		21.1
Planas & Vives, 1953	(NW Mediterranean Sea) Catalonia		16
Gail, 1954	North Africa		15
Barraca, 1964	Portugal		19
Polonsky, 1969	North Sea and English Channel		20–24
Sahrhage, 1970	North Sea		18–19
Sedletskaia, 1971	North Africa		16–23
Macer, 1974	North Sea and English Channel	March to August	20–24
Ameri, 1983	Adriatic Sea		15 - 18
Alegria, 1984	Adriatic Sea		16
Kerstan, 1984	NE Atlantic (British water)		24.2-24.6
Arruda, 1984	Portuguese coast	Western coast	November to May
		Matosinhos Bay	April to December
		Southern coast	Whole year
Kerstan, 1985	British & Celtic Sea		24.2-24.6
Korichi, 1988	Bousmail bay Algeria		-
Kerstan, 1995	Southwest coast of Ireland		19.8 M - 25 F
	Northern Biscay		19.4 M - 24.6 F
	South of Biscay		19 M - 25.3 F
Eaton, 1989	W British Isles	March to July	
Lucio & Martin, 1989	South of Bay Biscay		
Hecht, 1990	South-eastern coast of South Africa	June to November	
Borges & Gordo, 1991	Portuguese Coast		22.5
Abaunza et al., 1995	North-western of Spain Galician and Cantabrian Shelf	February to May	20.9 M
			21.9 F
Karlou-Riga & Economidis, 1996	Aegean Sea		22
Karlou-Riga and Economidis, 1997	Saronikos Gulf (Greece)	December to April	
Viette et al., 1997	Italy- Gulf of Trieste	May to August	15.6 M 16 F
Abaunza et al., 2003	North-western Atlantic	February to August	16-25
Šantić et al., 2008	E Adriatic Sea	December to May	
Tahari, 2011	Oran Bay (Algeria)	October to March	
Aydin & Karadurmuş, 2012	Ordu Black Sea (Turkey)	May to August	

Table 1/1. Spawning period and length at first maturity obtained by various authors for *Trachurus*.

References	Study area	Spawning period	TL _{50%} (cm)
Carbonara et al., 2012	Central-western Mediterranean Sea		GSA 10 17.8 M 18.9 F GSA 18 17.8 M 18.9 F GSA 19 17.8 M 18.9 F
Gherram et al., 2018	Oran Bay (Algeria)	January to May	18.42 M 18.28 F
Aydin & Erdoğan, 2018	Northern Aegean Sea (Turkey)	April to August	13 F
Azzouz et al., 2019	Gulf of Skikda (Algeria)	December-April	14 M - 13.65 F
Ferreri et al., 2019	Central Mediterranean Sea	Strait of Sicily Tyrrhenian Sea	16.1
			17.6
Present study	Béni-Saf Bay	January to July	15.5 cm M
			14.85 cm F

Table 1/2. Spawning period and length at first maturity obtained by various authors for *Trachurus trachurus*.

ried out on the west-southern coast of the Mediterranean Sea showed that the spawning period of this species is not regular when moving from one region to another. According to Tahari (2011), in Oran Bay the *Trachurus* fish reproduce between October and March. And in a clear difference, Gherram et al (2018) have shown the *Trachurus* fish living in the same area (Oran Bay) spawning between January to May. On the other hand, according to Azzouz et al. (2019), this fish reproduces between December and April in Skikda Bay.

Our study in Béni-Saf Bay indicates that the spawning period of *Trachurus* is the longest during the year and the monthly evolution of GSI follows a similar pattern for the two sexes. The spawning starts at the beginning of January and continues until June. On the contrary, it is shorter (from May to August) in northern Italy (according to Veet et al., 1997) and also in the Black Sea in Turkey (according to Aydin & Karadurmuş, 2012).

Our study shows that *Trachurus* females reached their sexual maturity at 148.5 mm, earlier than males which attain this maturity at 155 mm. The comparison of our results and those obtained in other geographical areas (Table 1) showed that *Trachurus* of Béni-Saf Bay reaches sexual maturity at earlier size than other regions (Table 1), which makes it possible

to think that the fish changed its sexual strategy by maturing earlier in order to ensure its sustainability which is in accordance with Korichi (1988) in central Algerian waters and Gherram et al. (2018) in Oran Bay. In central Mediterranean basin (Adriatic Sea), this length seems to be attained lately between 15 and 18 cm (Arneri, 1983; Alegria-Hernandez, 1984), while in Atlantic Ocean this length is more importantly (Table 1) comprised between 19 and 33 cm (Letaconnoux, 1951; Kerstan, 1985, 1995a, b).

CONCLUSIONS

Through this study, we tried to understand the reproductive behavior of mackerel in the Gulf of Béni Saf.

The results of our study on the reproduction of *Trachurus* of Béni-Saf Bay enable us to supplement the work already made on this species in the Mediterranean Sea allowing a better management of the exploitable resource. Our findings can be a useful tool for scientists, administrators and professionals of the fisheries sector to regulate fishing establishment and update of minimum landing sizes of captures of these species. In addition, there remain many points to be elucidated concerning

the fisheries of this species in the Mediterranean basin and Algerian waters especially and which can be the subject of future research.

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