received: 2020-02-05 DOI 10.19233/ASHN.2020.07

SPAWNING PERIOD, SIZE AT FIRST SEXUAL MATURITY AND SEX RATIO OF THE ATLANTIC HORSE MACKEREL *TRACHURUS TRACHURUS* FROM BÉNI-SAF BAY (WESTERN COAST OF ALGERIA, SOUTHWESTERN MEDITERRANEAN SEA)

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ABSTRACT

Reproduction characteristics of the Atlantic horse mackerel, Trachurus trachurus *(Linnaeus, 1758), from Béni-Saf Bay were investigated. A total of 355 specimens were sampled between November 2015 and October 2017, comprising 47.04 % males, 44.79 % females and 8.17 % undetermined. The length of individuals ranged between 7.2 and 35.4 cm, and the weight from 5.28 to 312.7g. The length at first sexual maturity was evaluated at 15.6 cm for males and 14.9 cm for females. Variations in gonado-somatic index (GSI) showed that gonads of both sexes started to develop in late February and reached sexual maturity in May-June, which marks the spawning period of the species.* T. trachurus *from Béni-Saf Bay uses nutritional reserves mainly accumulated in spring to develop their sexual products for spawning in early summer.*

Key words: Atlantic horse mackerel, *Trachurus trachurus*, reproduction, Béni-Saf Bay, Algeria

PERIODO DI RIPRODUZIONE, DIMENSIONE ALLA PRIMA MATURITÀ SESSUALE E RAPPORTO TRA SESSI NEL SUGARELLO *TRACHURUS TRACHURUS* NELLA BAIA DI BÉNI-SAF (COSTA OCCIDENTALE ALGERINA, MEDITERRANEO SUD-OCCIDENTALE)

SINTESI

Gli autori hanno studiato le caratteristiche della riproduzione del sugarello, Trachurus trachurus *(Linnaeus, 1758), proveniente dalla baia di Béni-Saf. Un totale di 355 individui sono stati campionati tra novembre 2015 e ottobre 2017, con il 47,04 % di maschi, il 44,79 % di femmine e l'8,17 % di indeterminati. La lunghezza degli individui variava da 7,2 a 35,4 cm, e il peso da 5,28 a 312,7 g. La lunghezza alla prima maturità sessuale è stata valutata a 15,6 cm per i maschi e 14,9 cm per le femmine. Le variazioni dell'indice gonado-somatico (GSI) hanno mostrato che le gonadi di entrambi i sessi hanno iniziato a svilupparsi a fine febbraio e hanno raggiunto la maturità sessuale a maggio-giugno, il che evidenzia il periodo di riproduzione della specie. I sugarelli della baia di Béni-Saf utilizzano le riserve nutrizionali accumulate principalmente in primavera per sviluppare i loro organi sessuali per la deposizione delle uova all'inizio dell'estate.*

Parole chiave: sugarello, *Trachurus trachurus*, riproduzione, baia di Béni-Saf, Algeria

INTRODUCTION

The Atlantic horse mackerel, *Trachurus trachurus* (Linnaeus, 1758), is a gregarious species of the Carangidae family. It can be found in circa-littoral bottoms and even in the higher horizon of the bathyal zone (Athanassios & Konstantinos, 2015). This species is common in shallow coastal waters off the north-eastern Atlantic, from Iceland to the Islands of Cape Verde. It is also found in the Mediterranean, the sea of Marmara and more rarely in the Black Sea (Polonsky, 1969; Arneri, 1983), in the Eastern Channel and the North Sea. *T. trachurus* is a migratory species; it lives and hunts in shoals. Usually, it migrates towards the coasts in summer and returns to offshore waters in winter; it can be found close to the bottom where it can live between 50 and 400 m depth with a capacity to adapt to brackish water (Santic *et al.*, 2003). In the Mediterranean Basin *T. trachurus* is very common (Fezzani *et al.*, 2006), living in open water and near sandy bottoms; it feeds primarily on fish such as gobies, anchovy, sardine and only on certain shellfish (Ameri, 1983; Kerstan, 1985).

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 spawning period and the strategy of these fish. Several works have dealt with *T. trachurus* (Polonsky, 1969; Sedletskaya, 1971; Macer, 1974; Arneri, 1983; Arruda, 1984; Kerstan, 1985; Korichi,1988; Eaton,1989; Hecht,1990; Ben Salem & Ktari, 1994; Abaunza *et al.*, 1995; Kerstan,1995; Karlou-Riga & Economidis, 1996, 1997; Viette *et al.*,1997; Fezzani *et al.*, 2002; Abaunza *et al.*, 2003; Šantić *et al.*, 2008; Tahari, 2011; Aydin & Karadurmuş, 2012; Carbonara *et al.*,2012; Wahbi *et al.*, 2015; Aydin & Erdoğan, 2018; Gherram *et al.*, 2018; Azzouz *et al.*, 2019; Ferreri *et al.*, 2019). The present paper focuses on the reproductive biology of *T. trachurus* of Béni-Saf Bay, with an emphasis on the reproduction period and the size at first sexual maturity to complete gaps in the life cycle of this carangid species and to better manage this resource in this Mediterranean area.

Fig. 1: Map showing the exact location where the estimated 500-cm TL female shortfin mako shark was observed on 28 June 2018.
Sl. 1: Zemljevid obravnavanega območja z označeno lokaliteto, kjer so avtorji 28. junija 2018 opazovali na 500 cm dolžine ocenjeno samico atlantskega maka.

MATERIAL AND METHODS

A total of 355 specimens of *Trachurus trachurus* were collected from Béni-Saf fishery, fished by trawlers operating between 30-130 m depth, from November 2015 to October 2016 (Fig. 1). For each individual, total length (TL) was measured to the nearest millimetre, total weight (TW) and gonads weighed to the nearest 0.01 g. Fish lengths were classified in 1 cm group intervals (Fig. 2), and sex was determined macroscopically based on the morphology and the colour of the gonads (Mahdi *et al.*, 2018).

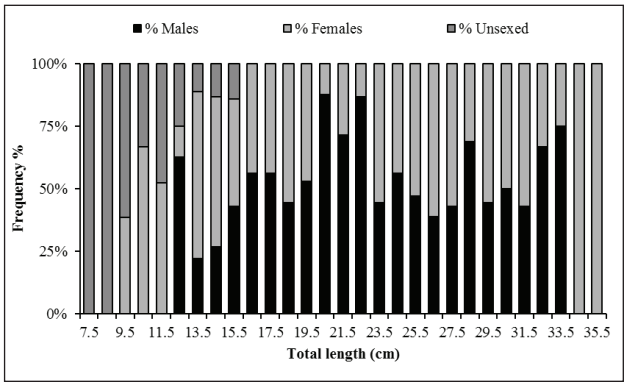

Fig. 2: *Trachurus trachurus* ***length frequency distribution of males and females caught in Béni-Saf Bay.***
Sl. 2: Porazdelitev dolžine pri samcih in samicah navadnih šnjurov, ujetih v zalivu Béni-Saf.

Sex ratio

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

SR = F / (M + F) x 100
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 both females and males, according to the equation below. The description of the reproductive cycle of this species and the determination of the spawning period were figured by tracking the monthly variations of this index.

GSI = GW / TW × 100 (Ferreri *et al.*, 2019)

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 according to the equation:

$K = \frac{TW}{TL^3} \times 1000$ (Crim *et al.*, 1990; Ferreri *et al.*, 2019)

TW: total weight,
TL: total length.

Size at first sexual maturity

The size at first sexual maturity (Lm 50 %), which corresponds to the length at which 50 % of the individuals are mature, was calculated for our specimens. When considered ripe, the gonads occupy, or almost so, the totality of the visceral cavity. For males, the testes are milky white; for the females, the ovaries are bulky and pink, with oocytes visible through the ovary walls. For each size class (1 cm) previously defined, we counted mature individuals on one hand 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. We determined the values corresponding to the sizes at first maturity from an equation (1) whose curve is sigmoid:

$P = \frac{1}{1 + e^{-(b + aTL)}}$ (1) (Wahbi *et al.*, 2015) (1)

P: proportion of mature individuals,
TL: total length in cm,

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

$Ln\left(\frac{p}{1 - p}\right) = b + aL$ (2)

RESULTS

Sex ratio

In total, 355 specimens of *Trachurus trachurus* were collected, 167 males (47.04 %), 159 females (44.79 %) and 29 unsexed (8.17 %). The length frequency distribution of the entire population is shown in (Fig. 2). Male length range was 12 to 33.5 cm; female length range was 8.8 to 35.4 cm. Male weight varied from 14.36 to 292.83 g and female weight varied from 5.28 to 312.78 g.

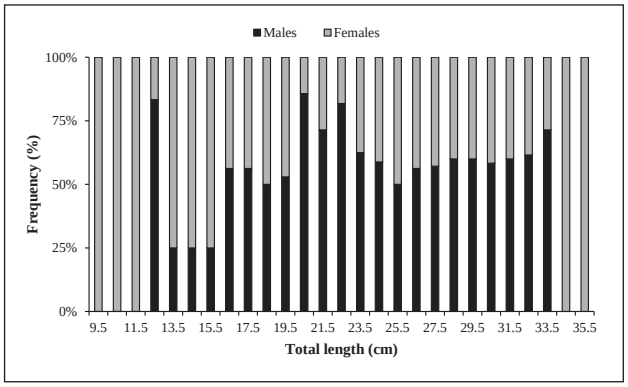

Fig. 3: Sex ratio of** Trachurus trachurus **by length size.
Sl. 3: Delež spolov pri primerkih navadnega šnjura glede na telesno dolžino.

Of the 355 individuals sampled sex ratio was in favour of males 1:0.95 and the $\chi 2$ test did not reveal any significant difference ($p<0.05$). In addition, the variations of sex ratio according to the size (Fig. 3), revealed by khi2 test significant differences in favour of females for length classes between 9.5 to 11 cm of TL ($\chi 2=11 > \chi 2_{t\,,0.05}=3.84$); beyond 16.5 cm of total length, males have the advantage but without significance (khi2). Beyond 34.5 cm of TL females are dominant.

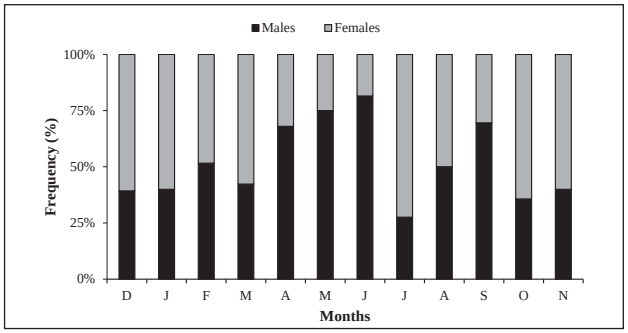

***Fig. 4: Monthly evolution of sex ratio of** Trachurus trachurus.*
Sl. 4: Delež spolov pri primerkih navadnega šnjura po mesecih.

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

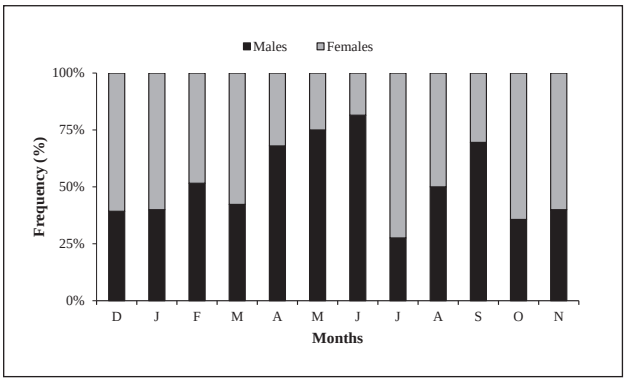

***Fig. 4: Monthly evolution of sex ratio of** Trachurus trachurus.*
Sl. 4: Delež spolov pri primerkih navadnega šnjura po mesecih.

Evolution of sex ratio related to seasons (Fig. 5) showed that females outnumbered males during the autumn-winter period, while males outnumbered females during the spring-summer period ($\chi 2=5.54 > \chi 2_{t\ ,0.05}=3.84$) corresponding to the spawning period of *T. trachurus* in Béni-Saf Bay.

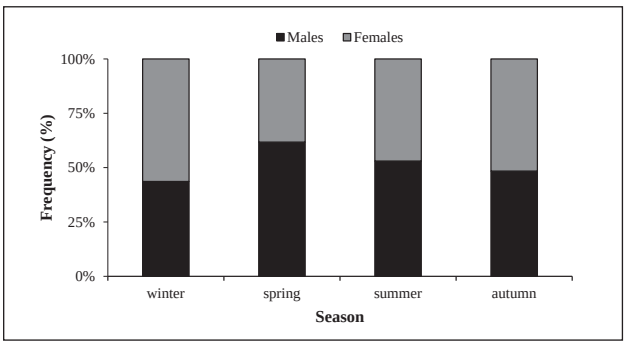

Fig. 5: Evolution of sex ratio of** Trachurus trachurus **by seasons.
Sl. 5: Delež spolov pri primerkih navadnega šnjura po sezonah.

Gonado-somatic index (GSI)¶

The monthly changes of the gonado-somatic index (GSI) allowed the determination of the spawning period during an annual cycle (Fig. 6); the monthly values of this index varied between 0.47 and 5.69 for females and between 0.37 and 4.98 for males. From February, this index increases for both sexes to attain a maximum in June, after which values begin to gradually decrease until they reach their lowest value in October for males and females.

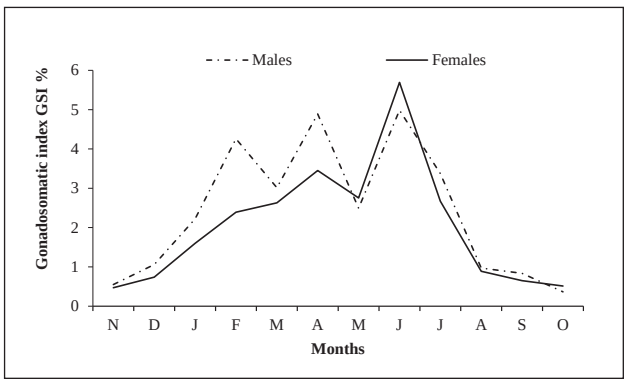

***Fig. 6: Monthly evolution of gonado-somatic index for males and females of** Trachurus trachurus.*
Sl. 6: Gonadosomatčni indeks pri samicah navadnega šnjura po mesecih.

Gonado-somatic index related to size classes

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

For males, we recorded a maximum GSI at 5.94, corresponding to a size 26.5 cm TL, and a minimum of GSI with 12.5 cm TL. For females, the GSI maximum value was recorded at 4.89 corresponding to a size of 22.5 cm TL, while the GSI minimum was recorded for a size of 13.5 cm TL.

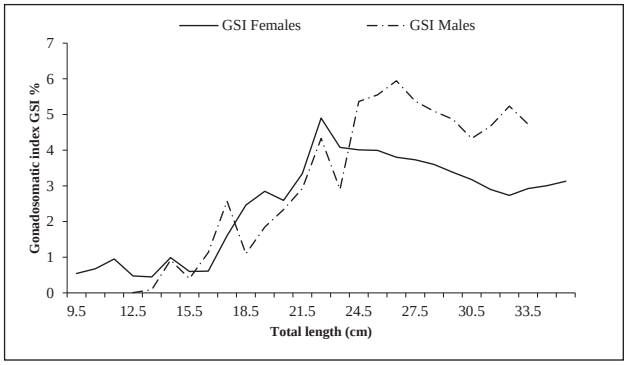

***Fig. 7: Evolution of gonado-somatic index related to total length of males and females of** Trachurus trachurus.*
Sl. 7: Gonadosomatčni indeks pri navadnem šnjuru glede na celotno dolžino samcev in samic.

Condition factor K

Evolution of the condition factor coefficient K seems to be closely related to the gonado-somatic ratio GSI, but the two indices tended to be inversely proportional. In fact, during the spawning period, the condition factor of the specimens is recorded at its lowest values (7.05) and in rest period the same factor records its highest values (8.54). The maturation of the sexual products and their emissions requires relatively high energy expenditure, and as a consequence the fish weight during spawning period is reduced (Figs. 8 and 9), corresponding to a reduction in condition factor of ~14 and 20 % for males and females, respectively.

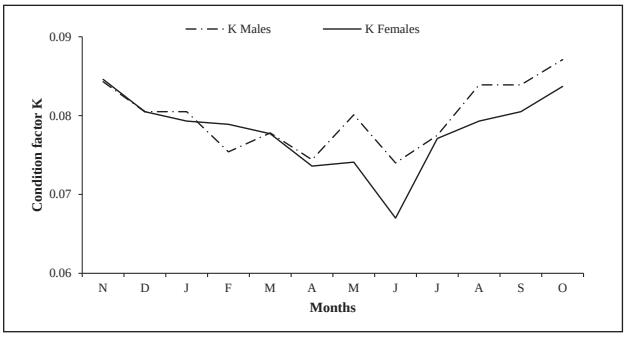

Fig. 8: Annual evolution of condition factor K of *Trachurus trachurus* ***males and females.***
Sl. 8: Letna dinamika kondicijskega faktorja K pri samcih in samicah navadnega šnjura.

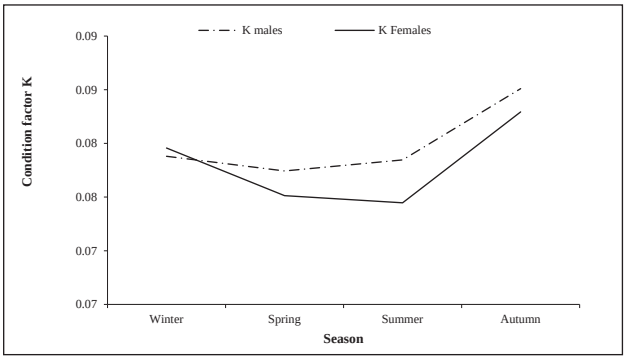

Fig. 9: Seasonal evolution of condition factor K of *Trachurus trachurus* ***males and females.***
Sl. 9: Sezonska dinamika kondicijskega faktorja K pri samcih in samicah pri primerkih navadnega šnjura.

Size at first sexual maturity

The proportion of mature individuals in each size class (Fig. 10) showed that first maturity was attained at 14.9 cm TL where 50 % of the females were mature, whereas 50% of males attained this proportion at 15.6 cm TL.

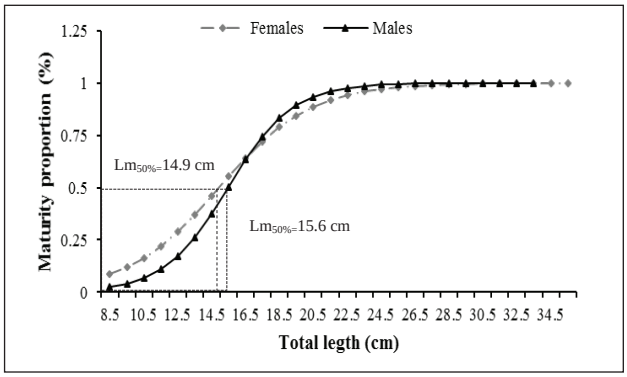

Fig. 10: Length at sexual maturity of males and females of *Trachurus trachurus****.***
Sl. 10: Dolžina, pri kateri samci in samice navadnega šnjura dosežejo spolno zrelost.

DISCUSSION

The sex ratio is slightly in favour of the males. The evolution of this index does not have phrenological regularity and is close to 1 for the March-June period, whereas females dominate in July. The Atlantic mackerel is a pelagic fish living in dense fish benches. It is possible that certain fish populations are predominantly males or females. According to Carbonara *et al*. (2012) and Wahbi *et al*. (2015) fluctuations of the sex ratio are due to ethologic phenomena (stray species, demographic segregations) responsible for the overdispersion and segregated distribution of the sexes. The difficulty in interpreting the fluctuations of this ratio is due to several factors, such as the behaviour of the species, the spawning period and mortality, sampling procedure, aggregation of the of the same sex individuals, etc. The change in weight of the ovaries and the testes during the cycle of maturation shows that the gonads develop at stage II, increased at stage III then regress at stage IV. The weight of the testes is higher than that of the ovaries during this last phase; this could indicate intense expulsion of the sexual products of females.

The monthly evolution of GSI follows a similar pattern for the two sexes, the spawning starting at the beginning of February to continue until July. The period of reproduction (Tab. 1) extends from February to July with a peak in June, while in central Algerian waters (Bousmail Bay), the reproduction is during summer and at its maximum in July-August. In ccertain areas (Spain, Portugal, France and Morocco) *T. trachurus* has an early spawning period beginning in spring with a maximum around March and all

Tab. 1: The spawning period and length at first maturity obtained for *Trachurus trachurus* ***by various authors.***
Tab. 1: Obdobje drstitve in dolžina, ko šnjur *Trachurus trachurus* ***doseže spolno zrelost po različnih avtorjih.***

Authors	Area		Lm50% (cm)	Spawning period
Polonsky, 1969	North Sea and English Channel		20 - 24 *	-
Sedletskaya, 1971	North Africa		16 - 23	-
Macer, 1974	North Sea and English Channel		20 - 24	March to August
Arneri, 1983	Adriatic		15 - 18	-
Arruda, 1984	Portuguese coast	Western coast	16 - 19 M 21 - 24 F	November to May
		Matosinhos Bay		April to December
		Southern coast		Whole year
Kerstan, 1985	North -East Atlantic (British water)		24.2 - 24.6	-
Korichi, 1988	Algiers Bay (Bou-Ismail bay)		14.2 *	-
Eaton, 1989	West of the British Isles			March to July
Hecht, 1990	South-East coast of South Africa		32 - 33	June to November
Abaunza *et al.*, 1995	North-west of Spain Galician and Cantabrian shelf		20.9 M 21.9 F	February to May
Kerstan,1 995	Southwest coast of Irland		19.8 M 25 F	-
	Northern biscary		19.4 M 24.6 F	-
	South of biscary		19 M 25.3 F	-
Karlou-Riga & Economidis, 1996	Aegean Sea		22	-
Karlou-Riga & Economidis, 1997	Saronikos Gulf (Greece)		-	December to April
Viette et al.,1997	Italy Gulf of Trieste		15.6 M 16 F	May to August
Abaunza et al., 2003	Northwest Atlantic		16 - 25	February to August
Šantić et al., 2008	Eastern Adriatic Sea		-	December to May
Tahari, 2011	Oran Bay (Algeria)		-	October to March
Aydin & Karadurmuş, 2012	Ordu Black Sea (Turkey)		-	May to August
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	
Aydin & Erdoğan, 2018	Northern Aegean Sea between (Turkey)		13 F	April to August
Gherram et al., 2018	Oran Bay (Algeria)		18.42 M 18.28 F	January to May
Azzouz et al., 2019	Gulf of Skikda (Algeria)		14 M 13.65 F	December-April
Ferreri et al., 2019	Central Mediterranean Sea: Strait of Sicily: Tyrrhenian Sea		16.1 17.6	-
Present study	Béni-Saf Bay		15.6 cm M 14.9 F	February to July

the authors attribute this to the temperature of the medium. An increase in the temperatures beyond 11 °C conditions the development of the eggs (Villamor *et al*., 1997; Wahbi *et al*., 2015). Our study shows that *Trachurus trachurus* females reached their sexual maturity at 14.9 cm, earlier than males, which attain this maturity at 15.6 cm TL.

To indicate the importance of our results regarding size at first sexual maturity (Lm 50%), the comparative study sets out with different research groups (Tab. 1). Firstly, it is clear that our (Lm 50%) value was much higher than those reported by Aydin & Erdoğan (2018, Northern Aegean Sea near Turkey) and Azzouz *et al*. (2019, Gulf of Skikda, Algeria). On the other hand, the obtained (Lm 50%) value comported fairly well with Viette *et al*. (1997, Italy, Gulf of Trieste), Arneri (1983, Algeria; 1983, Adriatic), and Korichi (1988, Algiers Bay). We found no significant differences compared with research groups of Arruda (1984, Portuguese coast), Abaunza *et al*. (2003, Northwest Atlantic) and Ferreri *et al*. (2019, central Mediterranean Sea), etc. (see Tab. 1).

T. trachurus from Béni-Saf Bay reaches sexual maturity at an earlier size, and this suggests that the fish has changed its sexuality strategy to ensure its sustainability. The species changes the size of its first sexual maturity and reproduces very early.

ACKNOWLEDGMENTS

The authors are grateful to coast guards of Béni-Saf for their precious help and also grateful to the reviewers who improved the manuscript with their helpful advices and directives.

OBDOBJE DRSTENJA, SPOLNA ZRELOST IN SPOLNI DELEŽ ŠNJUROV *TRACHURUS TRACHURUS* IZ ZALIVA BÉNI-SAF BAY (ZAHODNA OBALA ALŽIRIJE, JUGOZAHODNO SREDOZEMSKO MORJE)

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POVZETEK

Avtorji so raziskovali razmnoževalne posebnosti pri navadnem šnjuru, Trachurus trachurus *(Linnaeus, 1758), iz zaliva Béni-Saf. V obdobju med novembrom 2015 in oktobrom 2017 so analizirali skupno 355 primerkov, od katerih je bilo 47,04 % samcev, 44,79 % samic in 8,17 % nedoločenih primerkov. Šnjuri so merili med 7,2 in 35,4 cm v dolžino in tehtali od 5,28 do 312,7 g. Spolno zreli samci so merili v dolžino 15,6 cm, spolno zrele samice pa so dosegle 14,9 cm v dolžino. Spremembe v gonadosomatskem indeksu (GSI) so pokazale, da se gonade pri obeh spolih pričnejo razvijati konec februarja, spolno dozorijo pa v maju in juniju, kar opredeljuje obdobje drstenja pri vrsti. Primerki* T. trachurus *iz zaliva Béni-Saf porabljajo prehranske rezerve, pridobljene spomladi, za razvoj spolnih produktov za zgodnje poletni drst.*

Ključne besede: navadni šnjur, *Trachurus trachurus*, razmnoževanje, Béni-Saf Bay, Alžirija

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