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Research Paper.

Reproductive biology of four small pelagic fish from the Algerian basin

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Abstract

Small pelagic fish are among the main target species of commercial fisheries in the Algerian region. In this study, the reproduction of four small pelagic species in the Algerian basin was investigated. To this, 2053 individuals were sampled, including 996 individuals of *Sardina pilchardus*, 487 individuals of *Sardinella aurita*, 494 individuals of *Boops boops* and 505 individuals of *Trachurus trachurus* from the Algerian basin between July 2014 and May 2016. Sex ratio results reveal male dominance, except for *S. aurita* and *T. trachurus*. Size at first sexual maturity revealed values of 9.41, 13.79, 12.77 and 11.42 cm for *S. pilchardus*, *S. aurita*, *B. boops* and *T. trachurus*, respectively. The highest absolute fecundity was observed in *T. trachurus*, followed by *B. boops*, *S. aurita* and *S. pilchardus*.

Keywords

Sex-ratio;
Length at first maturity;
Oocyte diameter;
Absolute fecundity.

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1 INTRODUCTION

In Algeria, small pelagic fisheries are mixed, that is to say that several fleets exploit the same resource in competition and one fleet exploits several resources at the same time, making their management difficult. To ensure the sustainability of these national resources and ensure rational exploitation of these species, it is essential to determine the main biological parameters of the species including the study of reproduction and the evaluation of the exploitable biomass (Farrag, 2010).

In Algerian waters, several small pelagic species of commercial interest coexist and are present in fisheries in relatively large quantities. Among these species are two representatives of the Culpeidae family: *Sardina pilchardus* and *Sardinella aurita*, a species of the Sparidae family: Boops boops and a representative of the Carrangidae family: *Trachurus trachurus*. These species have been the subject of several researches in different regions of the Algerian coast covering different aspects of their biology, ecology and exploitation.

The aim of this study is to contribute to the knowledge of the reproduction of these four small pelagic species of the Algerian basin by abording the sex ratio, the length at first maturity and the absolute fecundity.

2 MATERIALS AND METHODS

2.1 Sampling

Sampling of the four studied species was carried out between July 2014 and May 2016 from the fishmongers of the Wilaya of Tiaret and Algiers, where fishes from the entire Algerian coast are landed. A total of 2053 individuals were sampled, distributed as follows: 996 individuals of *S. pilchardus*, 487 individuals of *S. aurita*, 494 individuals of *B. boops* and 505 individuals of *T. trachurus*. Samples were transported to the laboratory, where they were weighed and measured. Gonads from mature females (stages II, III and IV) were weighed and preserved in Gilson.

2.2 Sex-ratio

Sex and gonad maturity stage were determined macroscopically on the basis of appearance (coloration, size, shape and relative gonad size). Maturation stages were determined according to the Lamrini (1998) maturation scale, modified and reduced to five stages by Boufersaoui (2016). The sex ratio is expressed in different forms (Kartas and Quignard, 1984). It has been calculated using the following complementary expressions:

$$\%\,Female = \frac{N_f}{N_t} \times 100$$

$$\%\,Male = \frac{N_m}{N_t} \times 100$$

$$Sex - ratio = \frac{N_m}{N_f}$$

where, **Nf**: Number of females; **Nm**: Number of males and **Nt**: Number of females and males.

A comparison test $|\mathcal{E}_{cal}|$ at a risk of 5% between the theoretical (50%) and observed percentage was used to verify the results.

2.3 Length at first maturity

The length at first maturity (L50) was determined by grouping the sampled individuals during the study period according to size class. The proportion of mature individuals in each size class was then calculated. The threshold for sexual maturity is set at stage II which is the beginning of the gonad development phase (FAO, 1978).

The sigmoid function is selected for the graphical representation (Pope *et al.*, 1983) according to the equation:

$$P = \frac{1}{1 + e^{-(a+bL)}}$$

where, **P**: Proportion mature by size class, **L**: Total length, **a**: Intercept and **b**: Slope.

The parameters a and b are obtained after a logarithmic transformation of the previous expression using the method of least squares, *i.e.*:

$$-Ln\frac{100-P}{P} = a + bL$$

Based on parameters a and b of the logistic equation, the length at which 50% of individuals are sexually mature was determined L_{50} = a/b.

2.4 Oocyte diameter

The measurement of oocyte diameter was carried out on eight (08) females of each species after a few days of gonad conservation in the Gilson. A total of 513478 and 475 eggs were measured for *S. pilchardus*, *B. boops* and *T. trachurus,* respectively. Observations and measurements were made with a binocular magnifier (X15) equipped with a camera connected to a computer running TSView image analysis software (V_6.2.3.5) ®.

2.5 Absolute fecundity

Absolute fecundity (F) was studied using the gravimetric sampling method from 43, 55 and 28 females for *S. pilchardus*, *B. boops* and *T. trachurus* respectively. The mature oocytes were placed in absorbent paper and different weights were taken, namely the total weight of the oocytes (Wg), the smallest possible weight of the oocytes (Wi) and the number of oocytes contained in this fragment (Ni). The operation was repeated 3 times for each female and the average W_m and Nm were calculated.

$$W_m = \frac{\sum_1^n W_i}{n}$$

$$N_m = \frac{\sum_1^n N_i W_i}{\sum_1^n W_i}$$

where, **n**: number of replicates, **Ni**: number of oocytes contained in the weight Wi, **Wm**: average weight of replicates.

Fertility was then calculated using the following formula:

$$F = \frac{N_m \times W_g}{W_m}$$

where, **F**: absolute fertility, **Nm**: average number of oocytes contained in an average weight Wm; **Wg**: total oocyte weight.

Fertility was also expressed as a function of total length (Lt), total weight (Wt) and ovary weight (Wg). Linear and power regressions were tested to establish least-squares and least-rectangles equations.

3 Results and discussion

Macroscopic observation of the gonads enabled the identification of different gonads: female (Figure 1A), male (Figure 1B), hermaphrodite (Figure 1C), immature and indeterminate (Table 1).

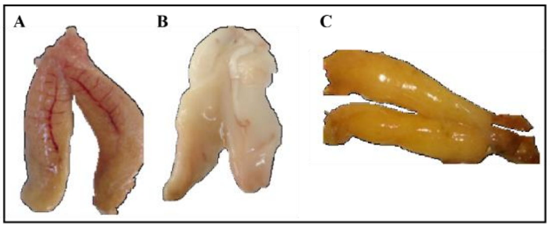

Figure 1. The different types of gonads observed. A: Female. B: Male. C: Hermaphrodite

Table 1. Distribution of species according to gonads observation

Species	N	F	M	H	IM	IND
S. pilcardus	996	345	540	-	58	3
S. aurita	487	136	234	-	95	22
B. boops	494	168	257	8	24	37
T. trachurus	505	133	240	-	77	55

N: Total number, **F**: Number of females, **M**: Number of males, **H**: Number of hermaphrodites, **IM**: Number of immature and **IND**: Number of indeterminate

The stages of sexual maturity used to study fecundity are stage II (Figure 2A), III (Figure 2B) and IV (Figure 2C).

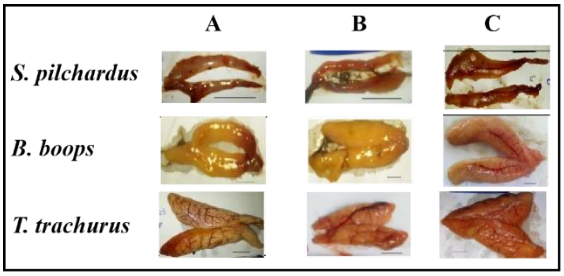

*Figure 2. Macroscopic appearance of mature ovaries used for fecundity studies. **A:** Stage II. **B:** Stage III. **C:** Stage IV. Scale bar = 1 cm.*

Table 2. Sex-ratio of the studied species

Species	*S. pilcardus*	*S. aurita*	*B. boops*	*T. trachurus*
% Female	39.05	63.24	39.53	64.34
% Male	60.95	36.76	60.47	35.66
Sex-ratio	0.64	1.72	0.65	1.80
Comparison test |Ɛcal|	NSD	SD	NSD	SD

SD: significant difference, **NSD**: non-significant difference.

Table 3. Length at first sexual maturity of the studied species compared to others from different regions

Species	L_{50} (cm)	Region	Reference	Species	L_{50} (cm)	Region	Reference
S. pilchardus	**9.41**	**Algerian basin**	**Present study**	***S. aurita***	**13.79**	**Algerian basin**	**Present study**
	12.2	Oran Bay	Bouchereau, (1981)		♀14.1	Bou-Ismail Bay	Bouaziz *et al.* (2001)
	♀ 12.6 ♂11.9	Bou-Ismail Bay	Mouhoub, (1986)		♀ 14.14 ♂13.64 13.93	Algiers	Bouaziz (2007)
	♀ 11.5 ♂11.28	East Algerian coast	Bouhali *et al.*, (2015)		♀ 13.9 ♂13.64 13.78	Annaba Golf	Belouahem, (2010)
	11.3	Tunis Golf	Khemiri, (2006)		♀ 13.5 ♂12.5	Tunisia	Gaamour et *al.* (2001)
B. boops	**12.77**	**Algerian basin**	**Present study**	***T. trachurus***	**11.42**	**Algerian basin**	**Present study**
	17.1	Oran Bay	Kherraz, (2010)		♀ 14.2 ♂ 13.5	Bou-Ismail Bay	Korichi, (1988)
	♀ 14.6 ♂13 13.6	Bou-Ismail Bay	Benina, (2015)		♀ 25.4 ♂ 22.3	North East Atlantic	Kerstan, (1985)

3.1 Sex-ratio

The sex-ratio of the studied species is shown in Table 2. The populations of *S. pilcardus* and *B. boops* show a trend in favor of males. Unlike *S. aurita* and *T. trachurus* where the female ratio slightly exceeds the male ratio. Application of the reduced difference test gives a non-significant difference ($|Ɛ_{cal}| < 1.96$) only for *S. aurita* and *T. trachurus*. Thus, we can conclude that the *B. boops* and *S. pilcardus* stocks are made up of as many males as females.

3.2 Length at first maturity

Length at first sexual maturity is 9.41, 13.79, 12.77 and 11.42 cm for *S. pilchardus*, *S. aurita*, *B. boops* and *T. trachurus,* respectively (Table 3). Length at first sexual maturity varies from year to year and from zone to zone. This inter-annual variability is due to the temporal variability of the spawning initiation date (early or late spawning, depending on the year) and the corresponding annual recruitment (Abad and Giraldez, 1993). L50 may also vary according to sex.

The results obtained in the present study for *S. pilchardus* are lower than those obtained by other researchers (Table 3). For *S. aurita*, the results are similar to those obtained in the Algerian and Tunisian regions. The L_{50} values obtained for *T. trachurus* are close to those found by Kerstan (1985) in the North-East Atlantic. For *B. boops*, our results are higher than those calculated by authors who have worked on this species, whatever the region studied.

Abed and Giraldez (1993) explain that variations in length at first maturity are apparently attributable to the different strategies developed by fish in different environments for better adaptation to environmental conditions such as temperature.

3.3 Oocyte diameter

The frequency distribution histograms of oocyte diameters showed distinct batches of oocytes. The modal value of the first batch (01) of oocytes represents the reserve stock. The upper diameter of these eggs is 189±11.76 μm, 356.5±16.17 μm and 337±21.36 μm for *S. pilcardus*, *T. trachurus* and *B. boops,* respectively, and corresponds to the mesh size of the filter chosen to eliminate reserve eggs. The remaining oocytes (batches 2, 3, 4 and 5) are mature eggs likely to be laid within the year and can therefore be used to estimate fecundity.

According to Mellinger (2002), the heterogeneity and multimodal distribution of oocyte diameters indicate a continuous recruitment of vitellogenic oocytes, which are not all released at the same time. Reproduction in the three species studied, even in *S. aurita* according to Bouaziz (2007), is asynchronous, fractionated, with mature oocytes emitted in small quantities over a long period of time, followed by very rapid recovery of the ovary. This asynchronous reproduction is characteristic of partial reproducers (Holden and Rait, 1974).

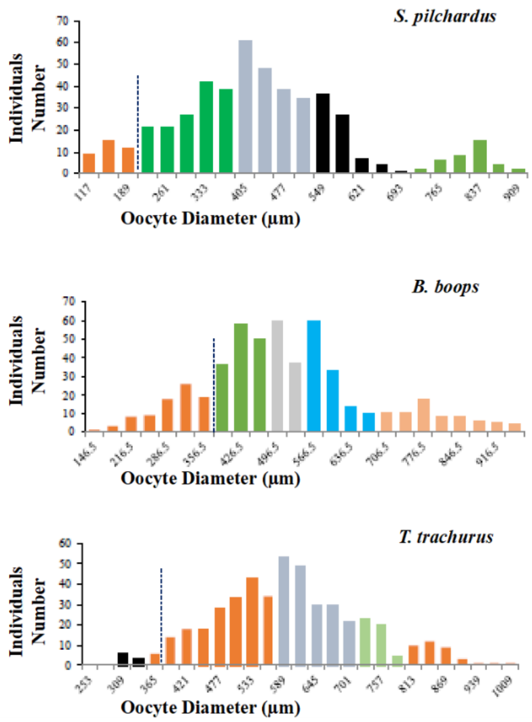

Figure 3. Histogram of oocyte diameter frequencies for the three studied species

3.4 Absolute fecundity

Absolute fecundity was carried out on individuals with length ranging from 11.7 to 18 cm and with weights varying from 10.5 to 47.58 g for *S. pilchardus*, as for *B. boops*, the estimate was made on individuals of length between 19.4 to 29.5 cm, with weights from 71.5 to 239.35 g, while *T. trachurus* was represented by females ranging in length from 18.7 to 32.5 cm, with weights from 54.94 to 307.75 g.

The average number of oocytes emitted per female is 6856±1614 oocytes for S. pilchardus, 34349±6468 oocytes for *B. Boops* and 38392±12395 oocytes for *T. trachurus* (Table 4).

Table 4. Extreme and mean values of oocytes emitted by females for the four species.

Species	Absolute fecundity		
	Minimal	Maximal	Mean±s.d.
S. pilcardus	421	35787	6856±1614
B. boops	9973	119153	34349±6468
T. trachurus	2544	136812	38392±12395
S. aurita (Bouaziz, 2007)	11680	40348	25001±2413

Table 5 shows that the correlation between fertility and the various parameters relating to individual height and weight, as well as gonad weight, is significant, especially for gonad weight. Thus, it appears that the power-type model fits the observed data better, and it follows that the power-type is the best model for expressing absolute fecundity as a function of total height, total weight and gonad weight in females of the studied species.

4 Conclusion

Macroscopic determination of sex and maturity stage presents difficulties, especially for young individuals where gonads are difficult to identify due to their size. For these reasons, and because the macroscopic scale of sexual development is based on external gonadal characteristics that can be ambiguous, the study of the microscopic scale is necessary and provides a more reliable methods to follow the evolution of ovarian development.

Table 5. Relationships between absolute fecundity and the different parameters in the studied species

Species		Linear relationship			Power relationship		
		$F=aL_T+b$	**$F=aW_T+b$**	**$F=aW_g+b$**	**$F=aL_T^b$**	**$F=aW_T^b$**	**$F=aW_g^b$**
S. pilcardus	MC	$876.9L_T–6690$	$123.7W_T+3105$	$17592W_g–4626$	$14.68L_T^{2.232}$	$668.5W_T^{0.68}$	$11490W_g^{0.977}$
	MR	$1055.44L_T–9278.46$	$199.84W_T+824.11$	$12494.68W_g–5092.25$	$2.76L_T^{1.289}$	$0.87W_T^{5.876}$	$0.68W_g^{9.098}$
	R	0.83	0.618	0.848	0.809	0.781	0.915
B. boops	MC	$2313L_T–16679$	$84.7W_T+26627$	$4871W_g+16247$	$430.9L_T^{1.409}$	$7590W_T^{0.33}$	$12122W_g^{0.739}$
	MR	$3106.64L_T–35717.87$	$102.13W_T+23639.71$	$535894W_g+11929.87$	$1.88L_T^{4.566}$	$0.4W_T^{8.566}$	$0.64W_g^{-674}$
	R	0.744	0.83	0.91	0.748	0.82	0.93
T. trachurus	MC	$6024L_T–12082$	$6024W_T–12082$	$8224W_g–10787$	$0.03L_T^{4.208}$	$0.03W_g^{4.21}$	$6690W_g^{0.997}$
	MR	$6964.84L_T–145738.6$	$385.86W_T–27705.92$	$8650.79W_g–14413.5$	$4.5L_T^{-4.45}$	$1.53W_g^{2.613}$	$1.03W_g^{8.742}$
	R	0.724	0.896	0.95	0.745	0.91	0.966

a, b: coefficients of the equations, **R**: Correlation coefficients

- **Conflict interest**

The authors confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. Also, there are no funding was received for this work.

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