Study of the growth of *Trachurus trachurus* (Linnaeus, 1758) fished on the eastern coast of the Moroccan Mediterranean

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Abstract. *Trachurus trachurus* (Linnaeus, 1758) is a semipelagic fish common in the waters of the Moroccan Mediterranean and is of major economic importance because it occupies an important place in fish landings. The population of the eastern coast was monitored during the period from October 2017 to September 2018 using monthly sampling. This work focused on the study of the growth biology of this species. In total, 390 specimens were sampled. The total lengths of the individuals collected varied between 7.8 cm and 33.8 cm for a weight that varied from 3.78 g to 310.52 g. The study of the growth of this Carangidae and the estimation of its age are based on the reading of the otoliths. The increase in length follows the linear Von Bertalanffy model; thus, it is rapid for juveniles and decreases with age. Similar growth in length and differential growth in weight were demonstrated between the two sexes. This difference is apparent only from the fourth year onwards and remains in favour of females. The results obtained constitute a valuable contribution to a better understanding of *Trachurus trachurus* biology and to the implementation of stock assessments to ensure the sustainability of catches of this species.

1 Introduction

Pelagic species occupy an important place in global fisheries and remain among the most highly exploited species in both the Atlantic and the Mediterranean [1].

Due to its geographical position, Morocco has two maritime facades, which give it the privilege of access to a significant stock of fish. The Moroccan Atlantic coast is known for its richness in fish resources due to upwelling. This phenomenon is at the origin of high biological productivity, resulting in a high wealth of resources, with small pelagic fish in particular, such as sardines, mackerel, horse mackerel, and anchovies, representing more than 80% of catches [2].

The eastern coast of the Moroccan Mediterranean is an important area for fishing, from an ichthyological richness point of view, thus playing a major economic role. A wide variety of pelagic and demersal species are targeted for fishing. Among the pelagic species fished, *Trachurus trachurus* is widely distributed in this area and is of major economic importance because it occupies an important place in fish landings [3]. Temperature and food conditions appear to play essential roles in growth, which is generally rapid at high temperatures. It can stop in areas where the temperature decreases significantly in winter. Seasonal growth rhythms are expressed in the calcified or hard structures of fish (bony tissues, otoliths, scales, fin rays, vertebrae, etc.) by an alternation of annular zones of rapid growth and slow growth [5].

These structures appear from the initial phases of ontogenesis. The analysis of these structures allows the determination of the age of the fish and the tracing of the history of its growth [6]. Age can be determined directly by examining anatomical parts, such as otoliths (otolithometry), scales (scalimetry), and hard structures (skeletochronology), or indirectly by a statistical method based on the study of the distribution of a measurable trait (metric trait) [7].

The use of otoliths for age estimation has a great advantage compared to other structures: they are acellular in nature, are well protected because of their internal location in the skull, and do not undergo resorption or regeneration, such as scales. Otoliths provide balance in fish and ensure hearing. In addition, otoliths probably allow fish to perceive the depth where they swim [8].

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Trachurus trachurus is subject to fishing pressure from both seiners and trawlers and deserves particular attention and in-depth scientific studies to better understand its dynamics, control its biological cycle and evaluate its stock.
For this purposes, the current study aimed to estimate age by determining a technique adapted for determining the age of *Trachurus trachurus*, as well as analysing the growth in length and weight of *Trachurus trachurus* using the Von Bertalanffy model.

2 Materials and methods

2.1 Sampling protocol

The samples of *Trachurus trachurus* were obtained from catches made on the eastern coast of the Moroccan Mediterranean. Shortly after the fish were unloaded at the ports of this area (Al Hoceima, Beni Nsar, Ras kebdana), they were transported to the ONP (National Office of fishing) wholesale market in Oujda.
Where sampling is conducted on-site randomly to ensure the representativeness of the sample. Subsequently, an additional sorting is carried out to eliminate other *Trachurus* species present.
The sampling was carried out monthly throughout the study period, from October 2017 to September 2018. Each sample consisted of 30 to 40 individuals per month. In total, 390 specimens were collected.

2.2. Collection and storage of otoliths

The collection of otoliths from *Trachurus trachurus* samples was carried out according to the protocol described in Figure 1.

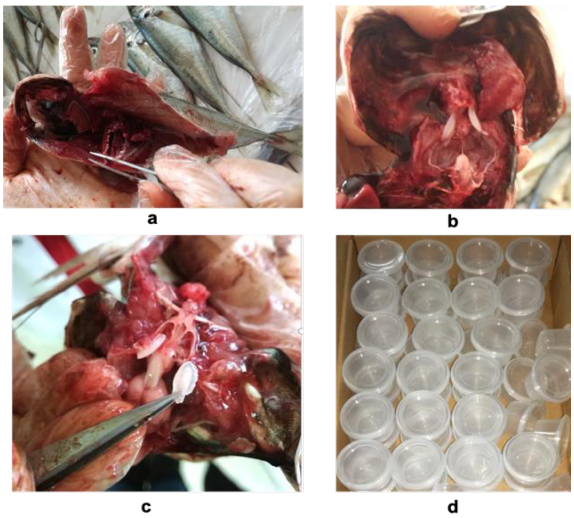

Fig. 1. Extraction and storage steps of otoliths (Sagitta) (Photo: H. NASRI, 2018) **a)** Opercula spreading and gill removal **b)** Appearance of the two otoliths (sagittae) **c)** Extraction of the otoliths **d)** Storage of the otoliths in Eppendorf tubes.

2.3 Age reading

To estimate the age of *Trachurus trachurus*, we mounted the otoliths as inclusions in "Eukitt" on plates with a black background containing numbered cells.
The observation of whole otoliths mounted on black plates was therefore carried out under a binocular magnifying glass under reflected light.
To determine fish age, we counted the number of hyaline zones corresponding to winters. In the cold season, a hyaline ring is formed, and this occurs in the hot season. The results obtained allowed us to establish age classes with corresponding average sizes; these data were used to estimate growth parameters. To achieve an accurate age estimation and minimize potential errors in otolith analysis, two readings were performed for each pair of otoliths. The age selected is the one that shows the best agreement between the two readings.

2.4 Growth parameters determination models

2.4.1 Von Bertalanffy linear growth

In ichthyology, the Von Bertalanffy model (1938) is widely used to express the growth of marine species in a given population [9]. Body length evolves as a function of age [10]. This model is one of the pillars of fisheries biology because it is used to describe the dynamics of fish populations [11].
According to Von Bertalanffy (1938) The von Bertalanffy linear growth model, also called the three-parameter model, is represented by the following formula:

$$L(t) = L_\infty * (1-\exp^{-k(t-t_0)})$$

L(t): The length of the fish at time t (age t).
L_∞: The theoretical length of very old fish, also called the asymptotic length when t tends to infinity.

K: reflects the speed of growth. The curvature parameter determines how quickly the fish reach L_∞
t_0: The theoretical age at which the fish has zero length, which is not realistic because the larvae are already a certain size at hatching. Hypothetical age t_0 is called the "initial condition parameter".
The L_∞, K and t_0 parameters can be determined graphically using LFDA (Length Frequency Data Analysis) software by applying the Von Bertalanffy equation. Thus, the data relating to lengths and corresponding ages were introduced into this data processing software.

2.4.2 Von Bertalanffy's growth in weight model

The growth in weight model expresses the individual weight of fish according to their age [12]. Von

Bertalanffy's growth in weight equation is obtained from the combination of two equations, Von Bertalanffy's linear growth equation and the length-weight relationship according to the following equation:

$$W(t)= W_\infty [1- e^{-k (t-t0)}]^{b}$$

W(t): Total weight in grams (g) at time t.
W_∞: Asymptotic weight in grams (g) corresponding to L_∞.
b: Allometric coefficient.
k: Growth coefficient.
t_0: the theoretical age at which the fish has zero length

3 Results

3.1. Age estimation

Table 1 presents the age classes with corresponding average lengths of *Trachurus trachurus*. The age-length data show an increase in length with age for both sexes, but we see that length is in favour of males for all age classes.

The lengths at the first sexual maturity of females and males, estimated at 23.5 cm and 22.5 cm, respectively, correspond to 4 years.

Table 1. Average lengths of *Trachurus trachurus* samples according to age and sex

	Fish age classes					
	1	2	3	4	5	6
L(t)Males (cm)	18	19.5	21.72	23.6	27.5	30.97
L(t) Females (cm)	15.34	18.62	21.52	23.5	26.67	29.75

3.2 Determination of the von Bertalanffy linear growth parameters

The Von Bertalanffy model was used to estimate the linear growth parameters of *Trachurus trachurus*. $L\infty$, k and t_0 are the parameters to be determined for males and females. The ELEFEN method described in the LFDA (Length Frequency Data Analysis), software makes it possible to use size and age data to estimate growth parameters (Table 2).

The growth curves are shown graphically in Figure 2. The $L\infty$ values of the two sexes of *Trachurus trachurus* are very close: 38.39 cm for males and 38.56 cm for females. The growth constant (k) of females was slightly greater than that of males. This result highlights the similar growth in length rate between the two sexes.

Table 2. Parameters of the von Bertalanffy linear growth equation for *Trachurus trachurus*

	Parameters		
Sex	L_∞	K	t_0
Male	38.39	0.22	-0.95
Female	38.56	0.23	-0.9
	Equation		
Male	$Lt = 38.39*[1 – e^{-0,22 (t +0,95)}]$		
Female	$Lt = 38.56*[1 – e^{-0,23 (t +0,9}]$		

In general, fish growth follows an asymptotic function, as described by the Von Bertalanffy model. In our case, the theoretical graph obtained by this model is close to our observed values (Figure 2).

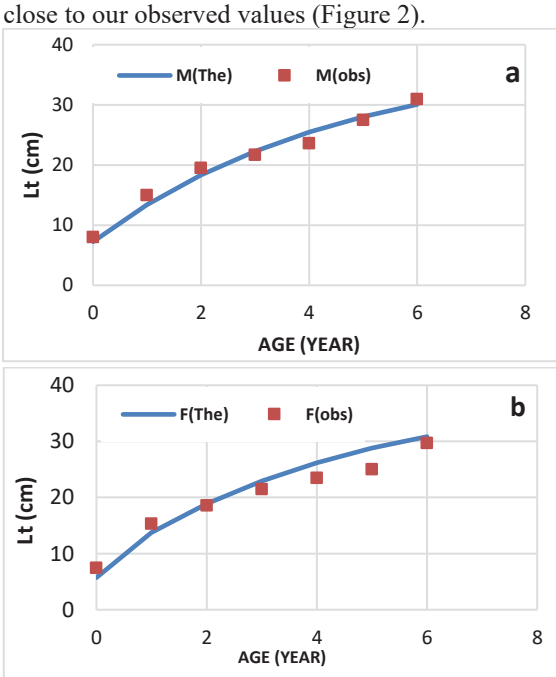

Fig. 2. Linear growth graphs (theoretical (The) and observed (obs)) of *Trachurus trachurus*; a: males (M), b: females (F).

This result also indicates that our sample is representative of the size range of Trachurus trachurus studied. Figure 2 allowed us to compare the growth of the two sexes. This comparison revealed that the growth of Trachurus trachurus males was similar to that of females.

3.3 Von Bertalanffy's growth in weight

For each sex, the asymptotic length $L\infty$ is substituted into the length-weight relationship equation to obtain the asymptotic weight $W\infty$. Table 3 shows the von Bertalanffy growth in weight formulas, while the growth in weight graph of Trachurus trachurus is shown in Figure 3.

Figure 3 shows the theoretical growth in weight graphs; males and females show similar growth in weight until the age of 4 years, and beyond this age, we see a divergence between the two sexes in favour of females.

Table 3. Growth in weight equations for *Trachurus trachurus* according to sex

T trachurus	**Growth in weight equation**
Males	$W(t) = 291.11\ [1-e^{-0.22(t+0.95)}]^{2.82}$
Females	$W(t)= 319.99\ [1-e^{-0.23(t+0.90)}]^{2.90}$

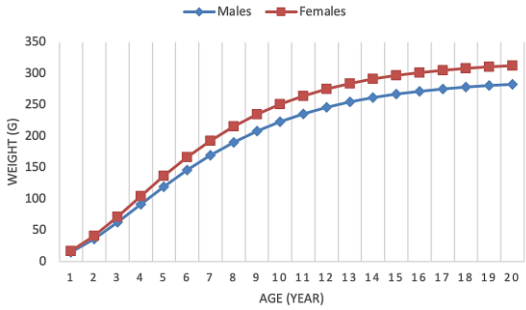

Fig. 3. Theoretical growth in weight of *Trachurus trachurus* according to the von Bertalanffy model

4 Discussion

L(t) lengths of *Trachurus trachurus* samples vary between 7.8 cm and 33.8 cm for a weight that varies between 3.78 g and 310.52 g. In general, we note that the range of lengths and weights in the present study cover a large part of the *Trachurus trachurus* population. Based on the comparison of these values with other values obtained in different areas in the Atlantic and Mediterranean Seas, the results show significant intervals of lengths varying between 7.2 cm and 43.6 cm and intervals of weight varying between 5.28 g and 736.3 g [12, 13]. Several factors influence the length frequency distribution of a population, such as growth, mortality, fishing gear selectivity and, above all, the sampling strategy used [14]. In the present work, the linear growth of *Trachurus trachurus* was studied according to the Von Bertalanffy model. This model was applied for the two sexes separated and yielded values closer to those observed. The growth rate relative to each sex decreases with age and then stabilises as the fish length approaches the asymptotic length. The adjustment of the growth parameters to the Von Bertalanffy growth model showed very similar K values for both sexes, while the increase in weight favoured females, especially for the oldest fish. This difference can be explained by the difference in metabolism between the two sexes. The results of the growth parameters obtained in this work were compared to other results obtained in different geographical areas. According to some previous studies since 2002 (Table 4), the asymptotic length oscillates between a minimum value of 23.8 and a maximum value of 43.9. In the Mediterranean basin, our results are close to those obtained by [15, 16]. On the other hand, the estimated asymptotic length (L∞) remains higher than those obtained by [17, 18].

Table 4. Growth parameters of *T. trachurus* in various regions (F: females, M: males)

Author	L∞ (cm)	K (year-^{1})	t_0 (year)
Present study	F: 38.78 M: 38.39	F: 0.23 M: 0.22	F: -0.9 M: -0.95
[15]	37.68	0.23	-0.30
[17]	F: 23.8 M: 24.70	F: 0.86 M: 0.86	F: -0.97 M: -1.87
[19]	43.9	0.1	-0.32
[20]	F: 30 M: 30	F: 0.61 M: 0.68	F: -0.51 M: -0.60
[21]	37.66	0.22	-1.016

According to Sparre and Venema (1996) [22], two categories of fish exist: the first reaches its asymptotic length very quickly in one or two years and has a high K value. The second curve presents a growth curve characterised by a low value of K and reaches its asymptotic length only after many years, as is the case for *Trachurus trachurus*. Thus, the variability between the values of growth parameters observed within the same species could be explained by the availability of prey resources in the areas of its distribution. Likewise, successive cohorts can develop differently depending on the prevailing hydroclimatic and environmental conditions of each zone, thus inducing variable growth performance. In addition, variations in the values of growth parameters recorded in different areas are probably due to the methodological approaches used, sampling procedures from catches (commercial or survey data), and fluctuations in physicochemical parameters in the environment [23]. A slight temperature change can influence growth; indeed, an inversely proportional relationship has been shown between asymptotic length and ambient temperature [24]. Also, sexe is one of the main factors affecting the height-weight relationship, but there are other environmental factors such as, salinity, and food availability, as well as the stage of maturity that significantly influence their development [25]

5 Conclusion

Trachurus trachurus is among the significant species for the fishing sector in the Moroccan Mediterranean, where it is exploited all along the Mediterranean coast mainly by coastal fishing. The objective of this study is to review the biological aspects, particularly the study of growth, to estimate the biological parameters that will serve as a basis for the evaluation of *Trachurus trachurus* stock and the management of this fishery. The present study showed that the adjustment of growth parameters to the von Bertalanffy growth model highlights similar growth in length and differential growth in weight between the two sexes. This difference is apparent only from the fourth year onwards and remains in favour of females.

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