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Indonesian Journal of Science & Technology

Journal homepage: http://ejournal.upi.edu/index.php/ijost/

IJoST Indonesian Journal of Science & Technology

Length-weight Relationship and Condition Factor of Trachurus Trachurus Found in The Central-East Region of The Moroccan Mediterranean

Hanae Nasri[1,*], *Souad Abdellaoui*[1,2], *Abdelouadoud Omari*[1], *Omar Kada*[1], *Abdelhafid Chafi*[1], *Belkheir Hammouti*[3], *Khalid Chaabane*[1]

[1] Laboratoire d'Amélioration des Productions Agricoles, Biotechnologie et Environnement, (LAPABE), Faculté des sciences, Mohammed Premier University, Oujda, Morocco

[2] Centre Régional de l'Institut National de Recherche Halieutique -Nador, Morocco

[2] LCAE, Faculté des sciences, Mohammed Premier University, Oujda, Morocco

Correspondence: E-mail: nasrihanae88@gmail.com, hammoutib@gmail.com

ABSTRACT

Trachurus trachurus, is a migratory, semi-pelagic species of the Carangidae family living in schools often associated with mackerel. This species is very common in the Mediterranean, and it is found on all Moroccan coasts. This study aims to determine the length-weight relationship and the condition factor (K) of Trachurus trachurus. Thus, 390 specimens were collected between August 2017 and August 2018 in the central-east region of the Moroccan Mediterranean. The parameters of the length-weight relationship were determined and analyzed by length and sex. It appears that this species has better growth in length than in weight, therefore having a negative or lower allometry. It varies according to sex, length, and season. This result shows that Trachurus trachurus in this study is not overweight in its habitat.

ARTICLE INFO

Article History:
Submitted/Received 20 Apr 2021
First revised 20 May 2021
Accepted 20 Aug 2021
First available online 22 Aug 2021
Publication date 01 Dec 2021

Keyword:
Condition factors,
Length-weight relationship,
Mediterranean,
Trachurus trachurus.

1. INTRODUCTION

The Mediterranean is a sea rich in multispecies stocks and especially in small pelagic species, with the latter representing an important halieutic potential along the Moroccan coasts. They consist of sardines (*Sardina pilchardus*) , round sardinella (*Sardinella aurita*), (*Trachurus trachurus*) and (*Trachurus medeterranus*), bogue (Boops boops), mackerel (*Scomber scombrus*), (*Scomber japonicus*) and anchovy (*Engraulis encrasicolus*) (Albo-Puigserver *et al*., 2019; Gordó-Vilaseca *et al*., 2021). The Mediterranean Sea is an almost closed intracontinental sea located between Europe, Africa and Asia, covering an area of approximately 2.5 million km^2. Its opening to the Atlantic Ocean through the Strait of Gibraltar is only 14 kilometers wide (Cardia & Lovatelli, 2007).

Trachurus trachurus has been the subject of several research studies and several geographic localities. The *Trachurus trachurus* species (Linnaeus, 1758), is sought after by fishermen because of its great economic value. It is also very popular with consumers both in its fresh and canned states due to its high nutritional value (Farabegoli *et al*., 2019). *Trachurus trachurus* is a species of the Carangidae family. It has a fusiform body and a shiny silver color. It is distinguished by a very indented caudal fin and the presence of bony scutes in the posterior part of the lateral line which accentuate its silvery luster. According to the literature, authors distinguish between three species of *Trachurus trachurus* existing in the Mediterranean Sea: *Trachurus trachurus* (Linnée, 1758), *Trachurus mediterraneus* (Steindachner, 1868) and *Trachurus picturatus* (Bowodich, 1825). Regarding its nutritional composition, *Trachurus trachurus* provides a good amount of protein and Omega 3 fatty acids, which represent 33% of total fatty acids. 100g of *Trachurus trachurus* is equivalent to 97 kcal (Morales-Medina *et al*., 2016). This species is semi pelagic, living between the surface and on the bottom in fairly large schools, they're frequently encountered on sandy bottoms at a depth between 100 and 200 m, and rarely in deeper water, up to about 1050 m (Azbaid *et al*., 2016; Lloris & Moreno, 1995). The mode of nutrition varies between juveniles and adults who feed on a wide variety of fish (*Micromesis tiuspoutassou*, *Sardina pilchardus*) as well as crustaceans (Decapods, copepods, amphipods, isopods, mysids) and squid (Stergiou & Karpouzi, 2002). They're very active predators that swim between the bottom and the surface where they climb to hunt, especially in the first part of the night, their main period of activity.

The growth of *Trachurus trachurus* is rapid during the first year, and then it gradually decreases with age. The sexes are separate and the fertilization is external. Its laying period differs from one region to another; it corresponds to a migration towards the coast in spring and towards the open sea in autumn, this phenomenon is due to certain climatic factors such as salinity and temperature. In fact, a simple increase in temperature will trigger egg laying. The latter is done in parts and the eggs are pelagic. In general, the females lay eggs at a temperature between 18 and 21 ° C, with a high reproduction rate resulting in 140,000 yellow-brown spherical and smooth eggs released into the water. During hatching, the larvae barely measure 5mm. Males mature to a slightly shorter length than females, they seem to have an almost permanent sexual activity compared to the females where it occurs only in spring and summer and peaks in June-July. The males reach their first sexual maturity when they reach a length of 20-22 cm which corresponds to an age of three years. As for the females, sexual maturity is reached at an age of four years, when they measure between 26 and 30 cm. Their lifespan is very

DOI: https://doi.org/10.17509/ijost.v6i3.37923
p- ISSN 2528-1410 e- ISSN 2527-8045

long, consisting of 30 years and more, with a maximum length of 70cm.

Trachurus trachurus is mainly intended for exploitation, it occupies an important place in the fisheries of the Eastern-Central Atlantic and the Mediterranean. Each year, 140,000 tonnes of *Trachurus trachurus* are taken from the western stock. This species is caught in order to be processed into oil and flour and, since the 1970s, it has been available for human consumption. It is consumed fresh in Portugal and Spain. But almost 90% of *Trachurus trachu*rus is exported, mainly frozen, to Japan and West Africa.

The objectives of this work are the study and the illustration of the main bioecological aspects of *Trachurus trachurus* caught in the Moroccan Mediterranean coasts over a period of one year. The main growth parameters of this species such as the length, the growth, the length-weight relationship and the condition factor were studied. These biological traits, once determined, can be exploited by fisheries for their management procedures.

2. MATERIALS AND METHODS

2.1. Selection of The Species and The Study Area

The choice of the *Trachurus trachurus* species is justified by its economic importance in this region, since it's heavily consumed by the Moroccan population. Our study was carried out on commercial fishing samples unloaded at the port and then provided by National Bureau of Fishing (ONP) of Oujda.

2.2. Sampling and Laboratory Treatments

The sampling was carried out monthly. It covered almost the entire length range of *Trachurus trachurus* ranging between 7.8 and 33.8cm. Each monthly sample consists of 30 to 40 individuals. After collecting the samples, they are transported in a cooler to the laboratory of Agricultural Production Improvement, Biotechnology and Environment in Oujda's Faculty of Sciences. In total, 390 specimens of *Trachurus trachurus* were collected on a regular basis during one year from August 2017 to August 2018 in order to study their growth parameters (length-weight relationship, condition factor).

2.3. Biometric Study

2.3.1. Measurements and weighings

The following measurements were made for each individual of all the specimens collected, the total length (TL) was measured in centimeters using an ichthyometer, and the total weight (TW) was weighed in g using a 3-decimal precision balance. For each examined fish, different measurements were considered:

- Total length (TL): length of the fish from the tip of the snout to the end of the longest ray of the caudal fin.
- Fork length (FL): length of the fish from the tip of the snout to the end of the median rays of the caudal fin.
- Total Weight (TW): the entire weight of the fish before being dissected and gutted

2.3.2. Fish dissection

The dissection of the fish was carried out using a dissection kit. An incision is made in the abdominal cavity of the fish, the viscera and gonads of the dissected specimens are gently extracted and then separated. Sex identification was performed via macroscopic observation based on the morphology and the color of the gonads.

2.3.3 Data processing

The collected information is grouped by month, season and sex, in order to determine various parameters such as the condition factor and the length-weight relationship.

DOI:https://doi.org/10.17509/ijost.v6i3.37923
p- ISSN 2528-1410 e- ISSN 2527-8045

2.3.4 Length-weight relationship

Knowledge of the "a and b" parameters of the length-weight relationship, particularly the value of "b", is useful in fish biology and in the management of fisheries as well as calculations related to population dynamics, biomass estimation and the assessment of halieutic stocks (Evagelopoulos *et al*., 2017; Froese *et al*., 2011).

According to Le Cren, (1851), TW is related to TL by an exponential-type relation (nonlinear) represented by the following formula: $TW = aTL^b$. This relation depends closely on the biological and physiological state of the fish as well as the habitat conditions.

TW = total weight of the fish in grams (g)

TL = total length of the fish in centimeter (cm);

a: proportionality constant

b: growth coefficient = allometric coefficient, it is always close to 3

This calculation makes it possible to learn about the proportionality of weight and length growths. Through logarithmic transformation, a linear-type relation with the following formula is obtained:

Log TW = log a + b log TL,

This transformation makes it possible to reduce the variability and to homogenize the two variables: TW and TL. The constant b is deduced from the linear regression line and the proportionality constant was determined by the following calculation: $a = e^x$, with x being the logarithmic constant of the regression curve.

The "a" and "b" parameters are characteristic factors of the environment and the species, they are calculated by the method of least squares. The b coefficient varies between 2 and 4, but is often close to 3. It expresses the relative shape of a fish's body. Three cases can arise (Froese, 2006; Froese *et al*., 2011; Le Cren, 1951):

- If b = 3, the growth is isometric and weight increase is proportional to length increase
- If b <3, the allometry is low or negative, the fish grows faster in length than in weight
- If b> 3, the allometry is high or positive, the fish grows faster in weight than in length

If weight-length data exist, individual comparisons of fish can be attempted; in this case, the condition factors that describe the state of health or fatness or the degree of well-being of the fish can be calculated. The most widely used condition factor is that of Fulton (Nash *et al*., 2006)

2.3.3 The condition factor (K)

Fulton's condition factor (K), also known as the length-weight factor, is used to determine the physiological state of a fish, including its reproductive capacity and sexual maturity as well as the influence of the environment (degree of nutrition) on the species (Costa, 2019; González-Kother *et al*., 2020). The condition factor is determined by the ratio relating the weight and the length of the fish according to the following formula:

$K = (TW/TL^3) \times 100$

The heavier a fish is for a given length, the higher its condition factor, so it is strongly correlated to the total weight of the fish. This correlation implies that the bigger the fish, the better the environmental conditions. According to Fulton:

K≥1 indicates the "well-being" of a population during the various stages of its life cycle;

K <1 means that the fish are not overweight in their habitat.

The introduction of environmental parameters, sex and season, allows to use the relative condition factor KR defined according to the following formula: $KR = TW/aTL^b$ where (b) is the allometric coefficient and (a) is a constant.

TW = total weight of the fish in grams g

TL = total length of the fish in cm

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p- ISSN 2528-1410 e- ISSN 2527-8045

3. RESULTS AND DISCUSSION

3.1. Length-Weight Relationship

The number of fish caught during the study period is 390 specimens, the total length (TL) varies between 7.8 cm for fish caught in November 2017 and 33.8 cm for female fish and 33.4 cm for male fish caught during the month of August 2018. The observed average of the total length is 18.20 cm. The minimum weight encountered is 3.78 g for a minimum length of 7.8 cm, on the other hand, the maximum weight is recorded during the month of August 2018 which coincides with the reproduction period of *Trachurus trachurus* in the study area. The maximum total weights (TW) are 310.52 g for a 33.8 cm female and 292.69 g for a 33.4 cm male. In *Trachurus trachurus*, the scatter plot resulting from the relationship between the two studied variables is well aligned for lengths inferior or equal to 22 cm, beyond this length, the scatter plot becomes more and more dispersed (**Figure 1**). This would allow us to assume the existence of another type of correlation beyond 22 cm, but logarithmic coordinates clearly show that the experimental points are grouped around the theoretical curve with the exception of some artefact values, therefore, the existence of a single regression line with an increase in the degree of correlation between the two variables from 0.9255 to 0.9928, these values thus reflect a highly significant regression which proves the close relationship between the weight and the length of *Trachurus trachurus* in study zone.

The comparison of the graphical representations of the length-weight relationship for *Trachurus trachurus* whose length is inferior or equal to 22 cm (**Figure 2**), and those whose length is superior to 22 cm (**Figure 3**), shows a certain difference. In fact, the correlation coefficient between the two variables reaches 0.9928 (logarithmic coordinates) for lengths inferior to 22 cm. On the other hand, the degree of correlation decreases and reaches 0.9433 when the length of the fish exceeds 22 cm. Despite this difference in the degree of association of the two variables, the regression still remains significant. Regarding sex-related variations, the graphic representations obtained show a dispersion of scatter plot from 28 cm for females (**Figure 4**), on the other hand the scatter plot of males (**Figure 5**) and indeterminate specimens (**Figure 6**) follows the trendline except for a few points found in both cases. This dispersion disappears when we switch to logarithmic coordinates for all categories of fish.

For all *Trachurus trachurus* categories in study zone (sex, size and capture period), the (b) coefficient value is equal to 2.9181. The allometry is therefore lower. The separation of the two sexes gave slightly different allometric coefficients. In fact, for males, the (b) coefficient value is 2.8294 while that of females is 2.9049 (**Table 1**).

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p- ISSN 2528-1410 e- ISSN 2527-8045

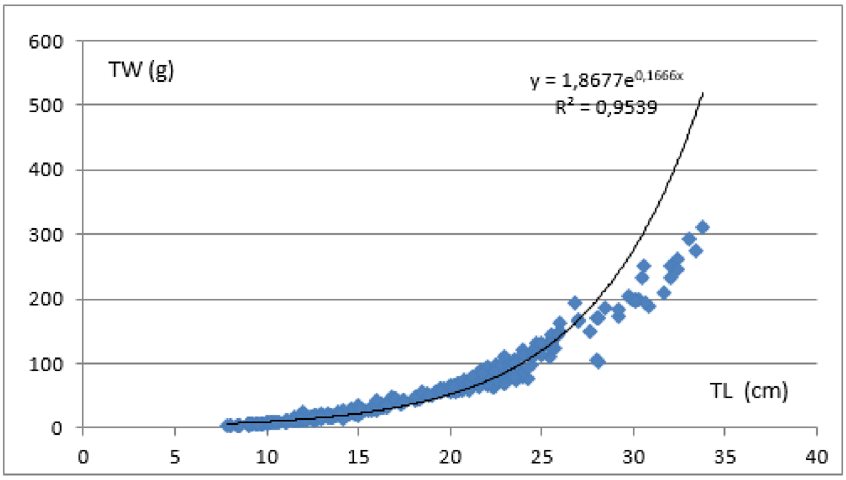

Figure 1. total length (TL) - total weight (TW) relationship for the entire population of *Trachurus trachurus*.

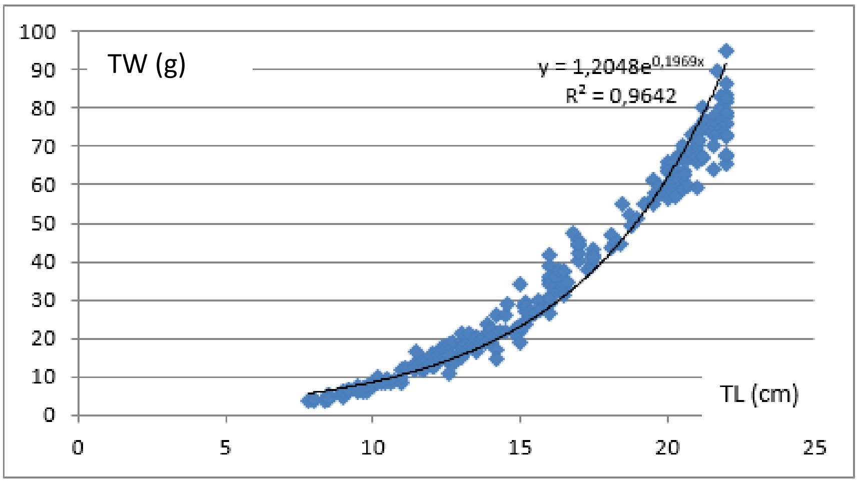

Figure 2. length-weight relationship of *Trachurus trachurus* whose length is inferior or equal to 22 cm.

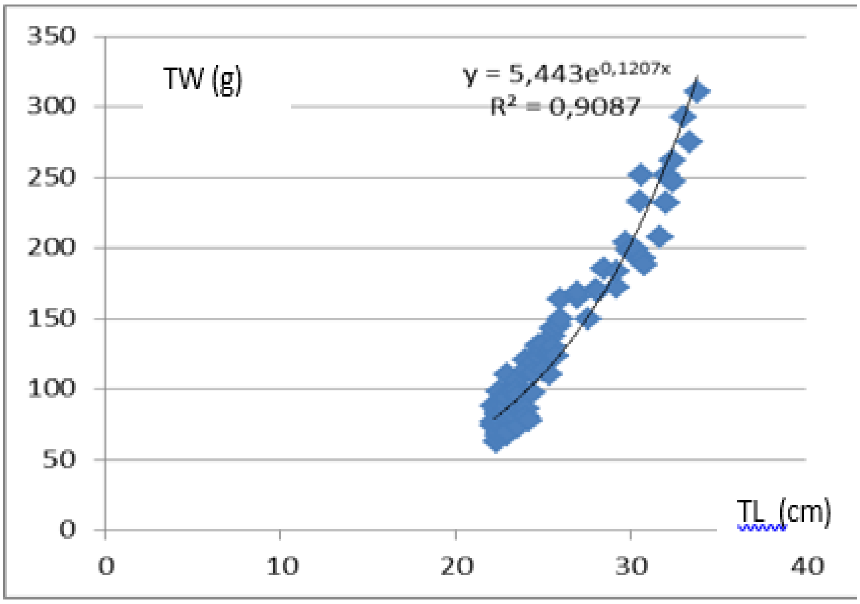

Figure 3. length-weight relationship of *Trachurus trachurus* whose length is superior to 22 cm.

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p- ISSN 2528-1410 e- ISSN 2527-8045

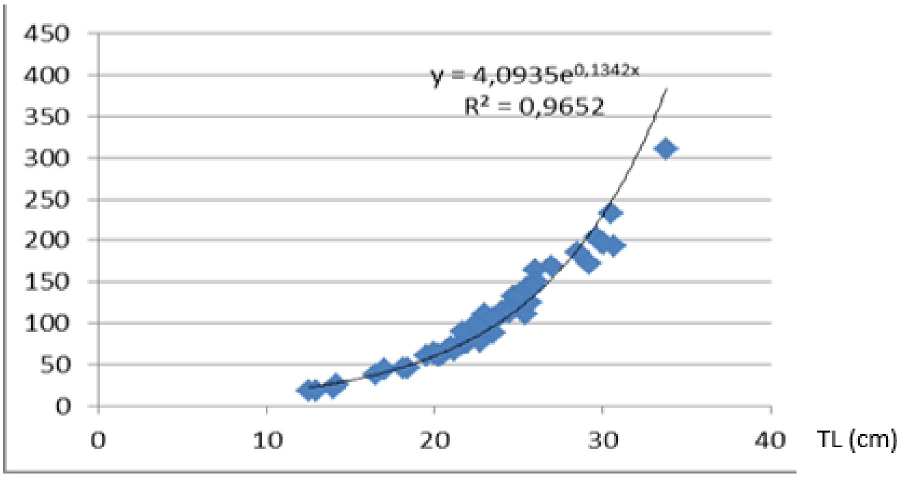

Figure 4. length-weight relationship in *Trachurus trachurus* females.

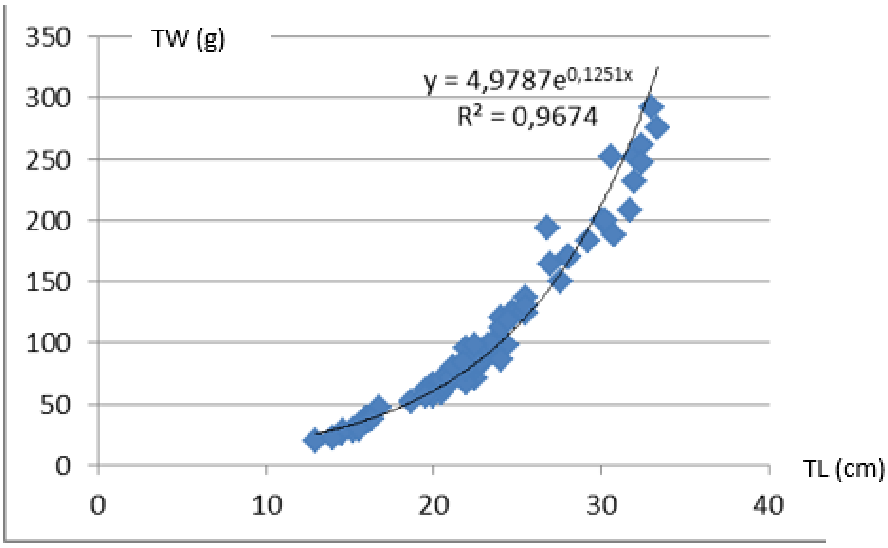

Figure 5. length-weight relationship in *Trachurus trachurus* males.

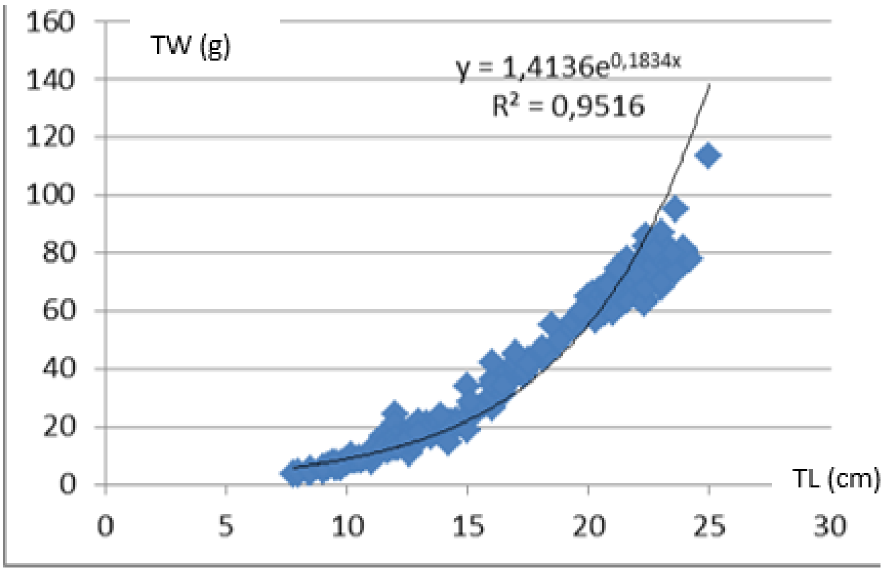

Figure 6. length-weight relationship in *Trachurus trachurus* with undetermined sex.

DOI: https://doi.org/10.17509/ijost.v6i3.37923
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It can be observed that the allometric coefficient of females is higher than that of males. This suggests that females have better growth in weight than males; due to the large increase in the weight of female gonads (ovaries) than those of males (testes), *Trachurus trachurus* females have a higher weight than males (Hajjej *et al*., 2012). Certainly, gender is one of the main factors affecting the length-weight relationship, but there are other environmental factors such as (temperature, salinity, and food availability) as well as maturity stage that significantly influence the development of the fish ((Andrade & Campos, 2002).

The growth in length of *Trachurus trachurus* is greater than its growth in weight. The separation of the different lengths into two groups shows that the values of (b) vary when the size of the fish is lower or higher than 22 cm. In fact, the (b) coefficient value is 2.9419 for *Trachurus trachurus* whose length is inferior or equal to 22 cm, on the other hand the value of (b) is equal to 3.1914 for *Trachurus trachurus* whose length is superior to 22 cm, the allometry is therefore important for this length category, *Trachurus trachurus* has an allometric-type growth in favor of the total weight of the body. This is explained by the fact that these *Trachurus trachurus* are all sexually mature, this physiological state generally leads to metabolic activities in the gonads at the expense of body weight, that is to say a reorientation of the energy allocation of the metabolism to gonadal activity (Bhatta *et al*., 2012).

The variability of the b coefficient observed during this study explains that it depends closely on biotic and abiotic factors. Length-weight relationship parameters are an essential tool for comparing different populations of the same species living in similar or different ecosystems (Imsland and Jonassen, 2003; Lugert *et al*., 2016; Mehanna *et al*., 2018).

Table 1. Regression equations for the relationship between total weight (g) and total length (cm) in *Trachurus trachurus* from the Mediterranean zone X (r: correlation coefficient; N: number of fish and R^2: coefficient of determination).

Lengths	Regression line equations	r	N	R^2
All lengths	$TW = 0.011473675 \times TL^{2.9181}$	0.9255	390	0.9539
	$Log (TW) = 2.9181 \times Log (TL) – 4.6477$	0.9928		
Lt ≤ 22cm	$TW = 0.009048104 \times TL^{2.9419}$	0.9255	280	0.9609
	$Log (TW) = 2.9419 \times Log (TL) – 4.7052$	0.9928		
Lt > 22 cm	$TW = 0.00391007 \times TL^{3.1914}$	0.9561	110	0.8899
	$Log (TW) = 3.1914 \times Log (TL) – 5.5442$	0.9433		
Males	$TW = 0.013172816 \times TL^{2.8294}$	0.9563	90	0.9798
	$Log (TW) = 2.8294 \times Log (TL) – 4.3296$	0.9898		
Females	$TW = 0.010568261 \times TL^{2.9049}$	0.9531	55	0.9816
	$Log (TW) = 2.9049 \times Log (TL) – 4.5499$	0.9907		
Undetermined	$TW = 0.011682071 \times TL^{2.8354}$	0.9767	245	0.9816
	$Log (TW) = 2.8354 \times Log (TL) – 4.4497$	0.9907		

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p- ISSN 2528-1410 e- ISSN 2527-8045

3.2. Condition Factor K

Fulton's condition factor (K) is used to estimate seasonal changes in fatness under the influence of external (environment) or internal (physiological) factors (Costa, 2019).

The evolution of this factor makes it possible to deduce a strategy in the use of energy inputs. In fact, K has a positive correlation with lipid density (fish weight). The latter being used during fasting, reproduction and maturation periods (Robinson *et al*., 2008). It decreases after reproduction. This factor is used to calculate and process the biological data of *Trachurus trachurus* populations.

The condition factor is equal to 0.99 for the entire studied population (**Table 2**). The determination and the comparison of this factor showed variations inferior to 1 between the different categories of *Trachurus trachurus*. Moreover, the condition factor oscillated between the different lengths. The minimum value is obtained in fish whose length is superior to 22 cm and said value is equal to 0.77. This can be explained by the maturity stage of this category of fish where energy inputs are used for the development of the gonads. In fact, several studies point out that reserves are invested in the sexual development and that gonadal development increasingly compresses the digestive tract of fish and can lower the condition factor (Aristizabal, 2007; do Cormo Silva *et al*., 2019; Williams *et al*., 2017). These low values observed could be explained by reproduction. The condition factor is slightly higher in females with Kf = 0.88> Km = 0.86. But the condition factor observed in the population does show a higher growth in length compared to the growth in weight. And this value is inferior to 1 which clearly shows that the studied *Trachurus trachurus* is not overweight in its habitat. The use of the condition factor by integrating the “a” and “b” parameters of the length-weight relationship gives relatively higher values compared to those obtained by the formula using the cube of fish length.

The seasonal evolution of the condition factor (**Figure 7**) shows that the maximum values of K are recorded during the winter and the spring periods, the periods which coincide with the presence of abundant food and gonadal development. The minimum value recorded during the summer can be explained by the significant decrease in gonad weight during this period. Therefore, the seasonal effect on the condition. This difference can be explained by the fact that the condition factor varies not only according to food availability, but also according to the season, the sex, the length, and the age of the fish factor is highly significant.

Table 2. Condition factor K of the different fish categories.

Trachurus trachurus characteristics	K= $(W/L^3) \times 100$	KR = W / aL^b
All lengths	0.99	1.09
Lt < or = 22cm	0.94	1.22
Lt > 22 cm	0.77	1.07
Males	0.86	1.12
Females	0.88	1.12
Undetermined	0.92	1.24

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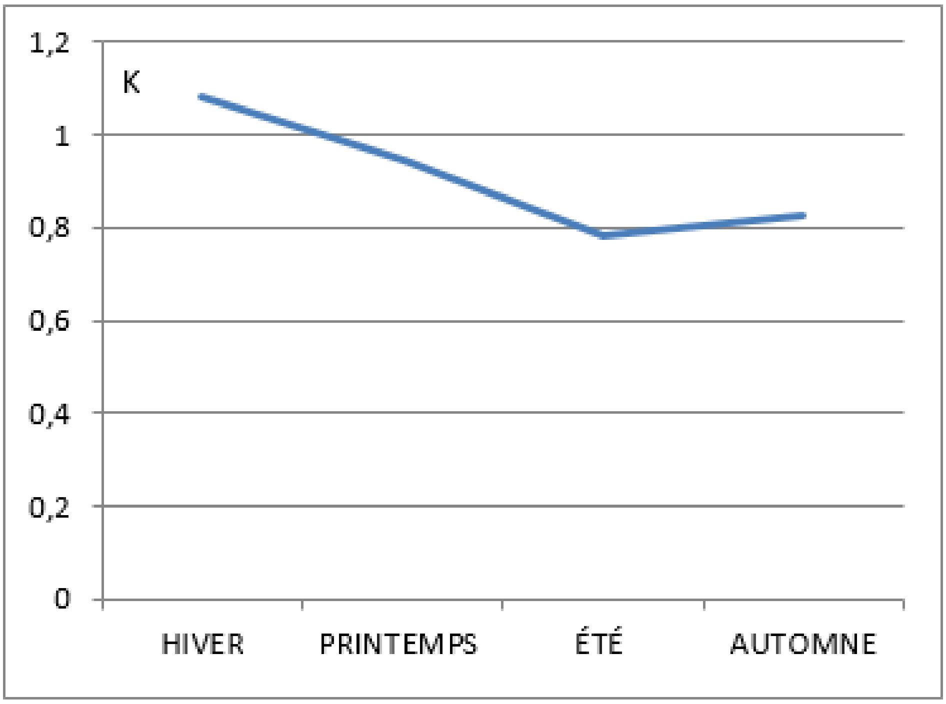

Figure 7. Seasonal variation of the condition factor K in *Trachurus trachurus*.

4. CONCLUSION

The study of growth parameters of *Trachurus trachurus* in zone X clearly shows that the allometric coefficient is inferior to 3 and varies slightly depending on the sex and the length of the fish. The condition factor of the studied population of *Trachurus trachurus* is inferior to 1, revealing that *Trachurus trachurus* does not adapt well to its habitat where the physicochemical and biological conditions (diet) necessary for its development are unfavorable. These results clearly show that the "state of well-being" of the population of this species would therefore not be well expressed in the *Trachurus trachurus* ecosystem of study zone during this period. These results contribute to the development of an information base concerning the biology of *Trachurus trachurus* in zone X. They mainly provide a database on the length-weight relationships and condition factors of this Carangidae. Additionally, they allow researchers and natural resources managers to adopt good policies in fishery management as well as the conservation of *Trachurus trachurus* populations.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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DOI: https://doi.org/10.17509/ijost.v6i3.37923
p- ISSN 2528-1410 e- ISSN 2527-8045