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Age, growth and mortality of the starry weever *Trachinus radiatus* Cuvier, 1829 in the Tunisian waters

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Abstract: Age, growth and mortality of the Starry weever *Trachinus radiatus* were studied for the first time from 214 individuals collected in the Gulf of Tunis between February 2014 and January 2016. The significant relationship between length-weight was observed for males (a = 0.011, b = 2.992, R^2 = 0.981, n = 77) and females (a = 0.010, b = 3.036, R^2 = 0.957, n = 109). Age was estimated by the observation of otoliths transverse thin sections. Age of individuals ranged from 1 to 15 years. The precision was measured by two age estimations from two experts and indicated a good agreement between them (PA = 85.6%, CV = 3.8% and IAPE = 4.1%). The growth parameters of the von Bertalanffy model were TL_∞ = 38.41 cm, W_∞ = 507.47 g, K = 0.3396 year^{-1}, t_0 = 0 year for males and TL_∞ = 45.46 cm, W_∞ = 914.04 g, K = 0.2136 year^{-1}, t_0 = 0 year for females. Age at first sexual maturity (t_m) of *T. radiatus* was 3.5 years, while the age at optimum length (t_{opt}) was 6.6 years. The natural mortality (M), total mortality (Z), fishing mortality (F) and exploitation (E) rates were respectively M = 0.429 yr^{-1}, Z = 0.453 yr^{-1}, F = 0.024 yr^{-1} and E = 0.053.

Résumé: *Age, croissance et mortalité de la vive à tête rayonnée* Trachinus radiatus *Cuvier, 1829 dans les eaux tunisiennes.* L'âge, la croissance et la mortalité de la vive à tête rayonnée *Trachinus radiatus* Cuvier, 1829 ont été étudiés pour la première fois à partir de 214 individus échantillonnés dans le golfe de Tunis entre février 2014 et janvier 2016. Les coefficients a et b de la relation longueur total/poids ont été déterminés pour les mâles (a = 0,011, b = 2,992, R^2 = 0,981, n = 77) et pour les femelles (a = 0,010, b = 3,036, R^2 = 0,957, n = 109). L'estimation de l'âge a été réalisée à partir des coupes transversales d'otolithes. Les âges ainsi estimés étaient compris entre 1 et 15 ans. La précision de l'estimation de l'âge a été testée et les résultats montrent une bonne reproductibilité des estimations (PA = 85,6%, CV = 3,8% et IAPE = 4,1%). Les paramètres du modèle de croissance de Bertalanffy ont été estimés pour les mâles (L_∞ = 38,41 cm, W_∞ = 507,47 g, K = 0,3396 an^{-1}, t_0 = 0 an et pour les femelles (L_∞ = 45,46 cm, W_∞ = 914,04 g, K = 0,2136 an^{-1}, t_0 = 0 an. L'âge à la première maturité sexuelle (t_m) de *T. radiatus* était de 3,5 ans, alors que l'âge à la taille optimum était de 6,6 ans. Les taux de la mortalité naturelle (M), la mortalité totale (Z), la mortalité par pêche (F) ainsi que l'exploitation (E) étaient respectivement M = 0,429 an^{-1}, Z = 0,453 an^{-1}, F = 0,024 an^{-1} et E = 0,053.

Keywords: Growth ● Age ● Mortality ● *Trachinus radiatus* ● Starry weever ● Gulf of Tunis ● South-Central Mediterranean Sea

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Introduction

The Trachinidae family comprises eight weever species distributed around the world. On the Tunisian coasts, only 4 species belonging to two genus are reported: the lesser weever *Echiichthys vipera* (Cuvier, 1829), the greater weever *Trachinus draco* Linnaeus, 1758, the spotted weever *Trachinus araneus* Cuvier, 1829 and the starry weever *Trachinus radiatus* Cuvier, 1829 (Bradai, 2000). The weevers are venomous species and several studies have been conducted, mainly on *T. draco* and *E. vipera*, to identify the nature of the venom and its toxicity (Bonnet, 2000; Geistdoerfer & Goyffon, 2004).

The starry weever, *T. radiatus*, is a fish widely distributed along the eastern coasts of the Atlantic Ocean, from Gibraltar to the Gulf of Guinea, and in all the Mediterranean coasts (Fischer et al., 1987). In Tunisia, it was reported from the Gulf of Gabes (Bradai et al., 2004) and also the northern coasts (Bradai et al., 2004). This species is found on the sandy and muddy bottoms of the continental shelf up to about 150 m but is more common between 30 and 60 m (Fischer et al., 1987).

The starry weever is not targeted on the Tunisian coasts by the fleets and then its retention in the commercial catches is not frequent, making access to specimens rather difficult. In general terms, weevers are more known for their venomous dorsal spines than for their tasty flesh and are of a poor commercial value. The by-catch capture, in the Gulf of Tunis, of individuals of *T. radiatus* of respectable size and weight, suggests that the species may constitute a valuable commercial potential and a beneficial source of protein to be valued, exported for human consumption or valorized. For example, on the island of Læsø, a professional fisherman developed new products making weevers a local specialty and encouraging visitors to discover the region. Otherwise, there is very little knowledge on the biological traits of *T. radiatus* on all its area of distribution. Then, Moutopoulos & Stergiou (2002) and Morey et al. (2003) studied its weight-length relationship respectively in the Aegian Sea and the Western Mediterranean. All the others studies were conducted on starry weevers of the Gulf of Tunis and concern its demographic structure including sex-ratio, size and age frequency distribution (Hamed & Chakroun-Marzouk, 2016), its reproductive aspects such as length at first sexual maturity sexual cycle and condition (Hamed & Chakroun-Marzouk, 2016 & 2017) and its weight-length relationship (Hamed & Chakroun, 2015). Moreover, there is no information about age and mortality rate of this species. The present study constitutes a preliminary work on these life history traits of *T. radiatus* on a local and global scale. The age data are the most essential biological parameters to know in life history theory as they constitute the foundation on which fisheries management is built.

Materials and Methods

Sampling process and otolith extraction

Individuals of *T. radiatus* were sampled randomly and monthly between February 2014 and January 2016. They were caught by gill-nets and trawlers of the commercial fisheries in the Gulf of Tunis (Fig. 1). For each individual, total length (TL, ± 1 mm), standard length (SL, ± 1 mm) and total wet weight (W, ± 1 g) were measured. Individuals were sexed after a macroscopic observation of their gonads. Sagittal otoliths were extracted from the brain cavity of each specimen, cleaned and stored dry in Eppendorf tubes for further treatment.

Study of the somatic growth

Weight-length relationships (W-TL) were expressed by the commonly used exponential equation of Ricker (1975):

Figure 1. *Trachinus radiatus.* Sampling station.

$$W = a \times TL^b \quad (1)$$

In order to estimate the parameters of the weight-length relationship, its base-10 logarithm was fitted to data using a least squares regression:

$$\log W = \log a + b \times \log TL \quad (2)$$

where a is the intercept and b is the slope of the log-transformed relation (Ricker, 1975). The ANCOVA analysis was applied to test significant difference in weight-length relationships between sexes. The b value variation was tested with a one sample t-test at a 0.05 significance level to verify if it was significantly different from 3.

Otolith observation and validation procedures

Since there was no previous investigation on the growth of *T. radiatus*, calibration of the ageing method was needed. Several processing methods (whole, burnt and sectioned otolith) were used in order to ensure the highest resolution pattern of growth rings. Finally, the transverse thin of the otolith has been the most successful technique to age the starry weever making the growth rings the most visible. For that purpose, the otoliths were embedded in epoxy resin and transverse sections of 0.4 mm thickness were made through the core (or *nucleus*) using a high speed precision saw. Then, slices were examined, under transmitted light, using a compound stereoscope, with a 10x magnification, connected to a video camera and an image-analysis system using TNPC software (digital processing of calcified structures, www.tnpc.fr developed by IFREMER). Growth increments were counted following the ventral otolith radius from the nucleus to the otolith edge (Fig. 2). Each otolith was analysed by two readers to estimate aging precision which is defined as the reproducibility of repeated measurements on a given otolith, whether or not measurements are accurate (Chilton & Beamish, 1982). Precision was evaluated from the index of average percent error (IAPE), the percentage of agreement (PA) and the coefficient of variation (CV). To calculate IAPE, the following formula presented by Beamish & Fournier (1981) was used:

Figure 2. *Trachinus radiatus.* Transverse section of a sagittal otolith under transmitted light with assigned growth zones (black circles).

$$IAPEj(\%) = 100 \times \frac{1}{R} \sum_{i=1}^{R} \frac{|x_{ij} + x_j|}{x_j} \quad (3)$$

where x_{ij} is the ith age determination of the jth fish, x_j is the average age calculated for the jth fish and R is the number of times each fish was aged.

For the evaluation of CV and PA the following expressions proposed by Kimura & Lyons (1991) and Campana (2001) were used:

$$PA = \frac{\sum |n_{diff} \leq 1|}{n} \quad (4)$$

$$CV_j(\%) = 100 \times \frac{\sqrt{\sum_{i=1}^{R} \frac{(x_{ij} - x_j)^2}{R-1}}}{x_j} \quad (5)$$

where R is the number of times each fish is aged, X_{ij} the i(th) age determination of the j(th) fish, X_j is the mean age calculated for the j(th) fish, and n_{diff} is the difference in age determination between the two readings.

To validate indirectly the periodicity of the growth increment formation, the monthly mean marginal increment (MI) was calculated with the following formula:

$$Mi = \frac{R_0 - R_n}{R_n - R_{n-1}} \quad (6)$$

where R_0: otolith radius (mm), R_n: radius of the last growth ring (mm) and R_{n-1}: radius of the penultimate growth increment (mm).

Once the annual basis for growth increment deposition was confirmed the counts were converted into ages assuming 1 January as birthday.

Growth model estimation

The model of von Bertalanffy (1938) was adopted and then the growth of the starry weever in terms of length and weight was described by the following equations:

$$TL_t = TL_\infty \times (1 - e^{-K \times (t-t_0)}) \quad (7)$$

$$W_t = W_\infty \times (1 - e^{-K(t-t_0)})^3 \quad (8)$$

$$W_\infty = a \times TL_\infty^b \quad (9)$$

where TL_t and W_t are the total length and weight at age t, TL_∞ and W_∞ are respectively the asymptotic length and weight, K is the rate at which the asymptotic length is reached and t_0 is the theoretical age (in years) at zero length. The t_0 value has no biological significance (Knight, 1968); to adjust these models, t_0 value has been fixed to zero. The von Bertalanffy growth equations were calculated for males and females separately and for the whole sample to allow further biogeographical comparisons.

The growth performance index Φ' of Munro & Pauly (1983) was calculated using the following equation:

$$\Phi' = \log K + 2TL_\infty \quad (10)$$

Age at first sexual maturity (t_m) and age at optimum length (t_{opt})

Ages t_m and t_{opt} represent respectively the average age at which fish in a given population are mature for the first time and the average age at which fish reach the optimal length. They were calculated, using the inverse of the growth function of von Bertalanffy (Froese & Binohlan, 2000), with the following equations:

$$t_m = t_0 - \text{Ln}(1 - TM_{50}/L_\infty)/K \quad (11)$$

$$t_{opt} = t_0 - \text{Ln}(1 - L_{opt}/L_\infty)/K \quad (12)$$

where t_0, L_∞ and K are the parameters of the von Bertalanffy growth model; TL_{50} is the size at the first sexual maturity and L_{opt} is the optimal length. TL_{50} and L_{opt} were taken from Hamed & Chakroun-Marzouk (2017).

Mortality and exploitation rates

As recommended by Then et al. (2015), who evaluated the predictive performance of empirical estimators of natural mortality, both growth and longevity based methods were used to evaluate the following respective instantaneous rate of natural mortality $M = 4.118\ K^{0.73}\ L_\infty$ and $M = 4.899\ t_{max}$ - 0.916 with K and L_∞ the estimated von Bertalanffy growth curve parameters and t_{max} the maximum observed age. It was the mean value of the two former evaluation of M that was taken in consideration.

The estimation of fishing mortality was F = Z – M, where Z is the total instantaneous mortality rate. The rate of total mortality (Z) was obtained using the length converted catch curve of Pauly (1983), excluding points not aligned on the linearized curve. Exploitation ratio (E) was calculated using the expression (Gulland, 1971): E = F/Z.

Statistical analyses

All the statistical analyses were carried out using the open-source statistical package "R" (R Core Team, 2016). Differences were considered significant at $p < 0.05$.

Results

A sample of 214 specimens was collected for this study; it was composed of 77 males (36.0%), 109 females (50.9%) and 28 unsexed individuals (13.1%). Total length (TL) of the whole sample ranged from 11.0 to 50.7 cm. Total length range for males, females and unsexed individuals were respectively from 17.8 to 43.4 cm, from 16.5 to 50.7 cm and from 11.0 to 36.0 cm. Females attained larger sizes than males. The TL-SL relationship

$$TL = 1.099 \times SL + 2.919,\ n = 214 \quad (13)$$

showed a significant correlation of the two parameters ($P < 0.001$).

All weight-length regression values were found to be highly significant ($p < 0.001$):

Males:

$$W = 0.011 \times TL^{2.992},\ R^2 = 0.981,\ n = 77,\ p < 0.001 \quad (14)$$

Females:

$$W = 0.010 \times TL^{3.036},\ R^2 = 0.957,\ n = 109,\ p < 0.001 \quad (15)$$

Total:

$$W = 0.009 \times TL^{3.035},\ R^2 = 0.976,\ n = 214,\ p < 0.001 \quad (16)$$

Student t-test showed that the *b* values obtained for males, females and the total sample did not deviate significantly from 3 ($p > 0.05$) indicating an isometric growth. There was no significant difference in weight-length relationships between males and females (ANCOVA, $p < 0.05$).

Each annual growth increment, on transverse sections of otoliths, was represented by a thick and a thin growth zones corresponding respectively to rapid and slow growth (Fig. 2). The distance measured between the successive growth increments of same nature decreased from the otolith core towards the outer margin. The annual periodicity of growth zones was established by the marginal increment analysis of the otoliths (Fig. 3). Irrespective of the number of growth zones in the otoliths, one mode was observed during a twelve months period.

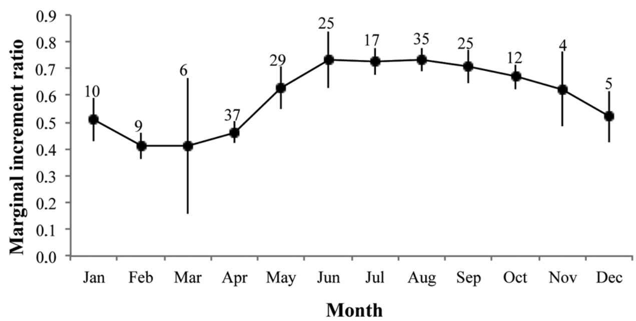

Figure 3. *Trachinus radiatus.* Monthly trend of marginal increment ratio (mm per month; mean ± SD) on otolith transverse section in the Gulf of Tunis (N = 214).

The age readings on the sagittal otoliths was validated and the results showed a relatively good agreement between readers (PA = 85.6%, CV = 3.8% and IAPE = 4.1%). The estimated ages of the total sample ranged from 1 to 15 years. Then the reading of the otoliths of *T. radiatus* allowed us to individualize 15 age groups. Age group 0 has not been indexed. Both sexes reach age 15. Age group 5 is the most represented in males, females and the total sample.

The estimated parameters of the von Bertalanffy growth model in length and weight are presented, in table 1 and figure 4, for the total sample and sexes separately. Females grew to heavier asymptotic weight (W_∞) and greater length

Table 1. *Trachinus radiatus.* Parameters of the von Bertalanffy growth models in length and weight of the Gulf of Tunis (Total = males, females and immatures).

Sex	N	TL_∞ (cm)	W_∞ (g)	K ($year^{-1}$)	Φ' ($cm.year^{-1}$)
Males	77	38.41	507.47	0.340	2.700
Females	109	45.46	914.04	0.214	2.645
Total	214	41.54	665.83	0.258	2.648

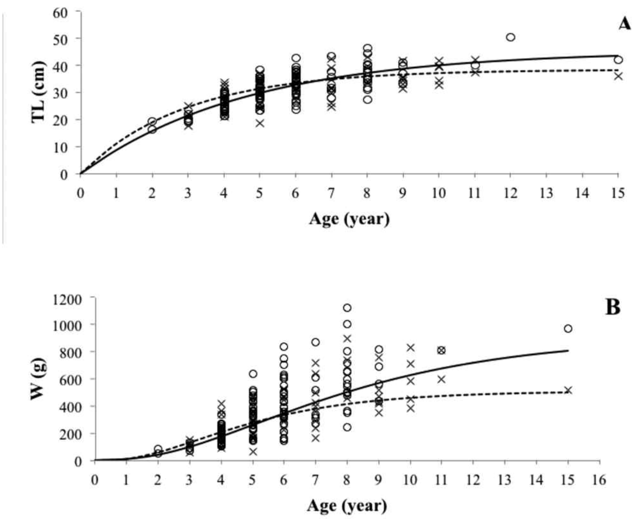

Figure 4. *Trachinus radiatus.* Von Bertalanffy growth curves. A. Length/Age. **B.** Weight/Age of females (black line) and males (dotted line) with observed data (females (o) and males (x)).

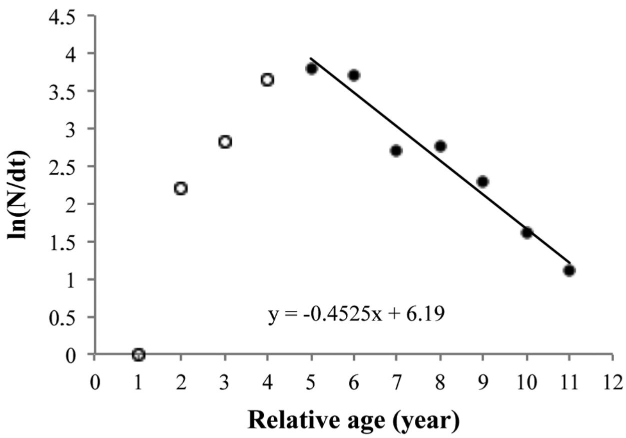

Figure 5. *Trachinus radiatus.* Length-converted catch curve from the Gulf of Tunis. The initial data points (o) were not used in the regression.

(TL_∞) than males. Males attained their asymptotic length with a better rate.

Age at first sexual maturity (t_m) of *T. radiatus* was estimated at 3.5 years, while the age at optimum length (t_{opt}) was 6.6 years.

The instantaneous rates of natural mortality (M) was 0.410 $year^{-1}$ using the longevity based method and 0.447 $year^{-1}$ using the growth based method; the mean value of M was 0.429 $year^{-1}$. Otherwise, total mortality (Z) extracted from the length converted catch curve shown in Figure 5 was 0.453 $year^{-1}$. Following estimation of Z and M, the fishing mortality (F) estimated by substraction was 0.024 $year^{-1}$. The evaluated exploitation ratio (E) of *T. radiatus* in the Gulf of Tunis was 0.053.

Discussion

The maximum total length previously recorded of the starry weever is 50.0 cm (Fisher et al., 1987); in the Gulf of Tunis, the sampling effort covered the full length range of the species as the recorded size interval of the sample was between 11.0 and 50.7 cm; however, size structure was different in the Balearic Islands (TL = 16.5-47.0 cm; Morey et al., 2003) and in the Aegean Sea (TL = 15.4-40.4 cm; Moutopoulos & Stergiou, 2002).

The weight-length relationships of males and females of *T. radiatus* were not significantly different; but for another congeneric species of the same area, *T. draco* or the greater weever, a significant difference was found between the W-TL relationships of the two sexes (Hamed & Chakroun-Marzouk, 2015). Although dissimilar patterns were observed for weight-length relationships of *T. radiatus* from different areas (Fig. 6); the lowest *b* value (2.897, n = 24) was reported by Moutopoulos & Stergiou (2002) in the Aegean Sea and the highest *b* value (3.206, n = 52) was noted by Morey et al. (2003) in the Balearic Islands. In the Gulf of Tunis, the *b* value of the somatic growth (3.035, n = 214) was between the two previous ones. Several factors could explain the differences observed across studies, among them the number of individuals examined and the length-classes composition of the sample. However, the growth coefficient *b* of *T. radiatus* seems to show a longitudinal trend in the Mediterranean Sea with highest values in the western part and lowest values in the eastern part. Spatial variability of the somatic growth rates of many organisms is known to be a product of environmental conditions, genotype and to the potential

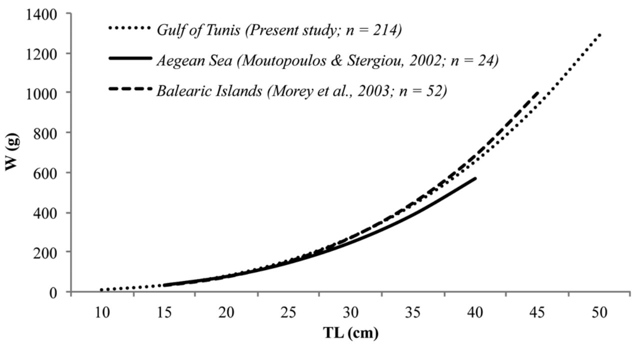

Figure 6. *Trachinus radiatus*. Comparison of the W-TL relationships from different regions.

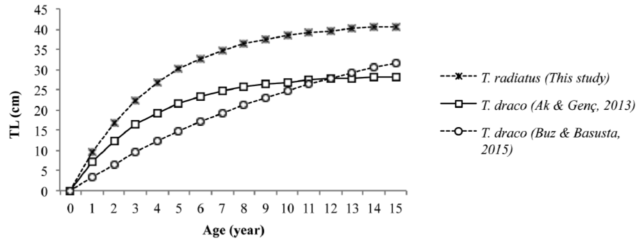

Figure 7. *Trachinus radiatus*. Comparison of the von Bertalanffy growth curve from the Gulf of Tunis with those of *Trachinus draco* from different areas.

importance of interactions between these two factors (Garvey et al., 2003; Curtis & Shima, 2005; Bevacqua et al., 2010). Temperature and food availability are the main environmental factors to have a significant effect on growth rates of fish (Pauly, 2010).

The present work has shown the first results on age and growth traits of *T. radiatus* on a worldwide scale. Aging the starry weever by the interpretation of growth increments on slices is a valid method because the monthly analyse of the marginal increments validated the hypothesis of an annual periodicity of growth increment deposition. Indeed, the thick growth zone (opaque zone) is deposited from May to October and the thin growth zone (translucent zone) from November to March. Also the low values of the average percent error and the coefficient of variation and the high value of the percentage of agreement indicate that the sectioning technique of otoliths of the starry weever is a valid approach for age estimation. However, Ak & Genç (2013) and Buz & Basusta (2015) used the whole otolith for the age determination of a congeneric species *T. draco*, but for the starry weever of the Gulf of Tunis, it was very difficult to observe the growth increments on the edge of the whole otolith for old fish. Then the technique used in the present study to determine the age, namely the transverse otolith section, could be an increasing ageing precision factor between studies.

The estimates of the von Bertalanffy model of growth presented in the present paper are, until now, the only available results in the literature for *T. radiatus*. Indeed, only three age and growth studies have been performed but for its congeneric species, *T. draco* in the Kattegat (Bagge, 2004), in the eastern Black Sea (Ak & Genç, 2013) and in Iskenderun Bay (Buz & Basusta, 2015). The growth of *T. radiatus* appears to be much higher than *T. draco* one (Fig. 7). In the Gulf of Tunis, females of *T. radiatus* grew to heavier asymptotic weight (W_∞) and greater maximum theoretical length (TL_∞) than males. The same trend was observed for *T. draco* in the Iskenderun Bay (males, TL_∞ = 40.27 cm; females; TL_∞ = 43.99 cm), in the Kattegat (males, TL_∞ = 35.10 cm; females, TL_∞ = 38.30 cm) and in eastern Black Sea (males, TL_∞ = 29.31 cm; females, TL_∞ = 32.62 cm). The parameters TL_∞ and K are highly related, the last one being larger for smaller values of TL_∞; this dependency among parameters causes problems in model fitting and interpretation (Ogle, 2013). Moreover, the values of these estimated parameters may be influenced by the size and number of the individuals in the sample. Indeed, the fish sampled did not include enough older specimens at the end of their growth and this may explain the inferiority of TL_∞ with respect to the maximum observed length (Sparre & Venema, 1996). The growth coefficient of *T. radiatus* (K = 0.26, Gulf of Tunis) is superior to that of *T. draco* in Kattegat (K = 0.16, Bagge, 2004) and Iskenderun Bay (K = 0.08, Buz & Basusta, 2015) but a little inferior to that of *T. draco* in the Black Sea (K = 0.28, Ak & Genç, 2013). However, it was found misleading taking into account only a single parameter for growth comparisons and growth performance indices have been rather recommended as tools for this (Pauly, 1979). Comparisons of overall fish growth performance have been employed to identify populations that, in nature at least, have the highest growth performance, and to select species with aquaculture potential or for transfers and introduction (Moreau et al., 1986). The growth performance index (Φ') of *T. radiatus* of the Gulf of Tunis (2.65) was either better than the *T. draco* one in the Kattegat (2.32), the eastern Black Sea (2.36) and even the Iskenderun Bay (2.22). Growth is a very complex process as it depends mainly on environmental factors and genetic properties (Morita et al., 2001). Magnussen (2007) has highlighted how an abundant food supply and a high temperature have favored the intraspecific growth performance of 14 fish species. Either, different species or even single individuals in the same environmental conditions could present a different adaptive answer due to their physiological plasticity (Wootton, 1992). According to Wetjen (2012) inter- and intraspecific latitudinal differences as well as seasonal differences in growth probably depend mostly on variations of food availability, food quality, and the feeding intensity; the author states that as numerous species migrate and change their diet during different life stages, it would be instructive to observe these seasonal and ontogenetic changes for a better understanding of their production dynamics.

Fifteen age groups have been identified for the total sample of *T. radiatus* in the Gulf of Tunis. Age group 5 was always dominant with respective percentages of 22% for the total sample, 26.4% for males and 25% for females. No comparison could be made on this subject for this species due to the lack of other studies. The corresponding age at first sexual maturity (t_m) of the starry weever was 3.5 years, while the age at optimum length (t_{opt}) was 6.6 years. Size and age at sexual maturity are strongly correlated with growth, maximum size and longevity of species (Froese & Binohlan, 2000).

In this study, in absence of information on the captures, empirical methods were used to evaluate the stock status of *T. radiatus*. All natural mortality estimation methods have been recently revised by Then et al. (2015) to evaluate the predictive performance of empirical estimators of natural mortality rate; the methods based on longevity and the growth parameters were recommended as better performer of M. The instantaneous rate of natural mortality (M = 0.429 $year^{-1}$) of *T. radiatus* stock is a little bit lower than the instantaneous rate of total mortality (Z = 0.453 $year^{-1}$). The resulting instantaneous rate of fishing mortality is then very insignificant (F = 0.024 $year^{-1}$). In fact, *T. radiatus* being a by-catch species, it can be expected that fishing pressure exerted on its stock is almost null. In terms of populations dynamic the starry weever stock is at its unexploited equilibrium level in the Gulf of Tunis.

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References

Ak O. & Genç Y. 2013. Growth and reproduction of the greater weever (*Trachinus draco* L., 1758) along the eastern coast of the Black Sea. *Journal of Black Sea/Mediterranean Environment*, **19**: 95-110.

Bagge O. 2004. The biology of the greater weever (*Trachinus draco*) in the commercial fishery of the Kattegat. *ICES Journal of Marine Science*, **61**: 933-943.
Doi: 10.1016/j.icesjms.2004.07.020

Beamish R.J. & Fournier D.A. 1981. A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries and Aquatic Sciences*, **38**: 982-983.

Bevacqua D., Melià P., Follesa M.C., De Leo G.A., Gatto M. & Cau A. 2010. Body growth and mortality of the spiny lobster Palinurus elephas within and outside a small marine protected area. *Fisheries Research*, **106**: 543-549.

Bonnet M.S. 2000. The toxicology of *Trachinus vipera*: The lesser weeverfish. *British Homeopathic Journal*, **89**: 84-88.

Bradai M.N. 2000. Diversité du peuplement ichtyque et contribution à la connaissance des Sparidés du golfe de Gabès. PhD thesis, Faculty of Sciences of Sfax. 600 pp.

Bradai M.N., Quignard J.P., Bouain A., Jarboui O., Ouannes-Ghorbel A., Ben Abdallah L., Zaouali J. & Ben Salem S. 2004. Ichtyofaune autochtone et exotique des côtes tunisiennes: recensement et biogéographie. *Cybium*, **28**: 315-328.

Buz K. & Basusta N. 2015. Age and growth of the greater weever, *Trachinus draco* (Linnaeus, 1758) inhabiting Iskenderun Bay, North-eastern Mediterranean Sea. *Cahiers de Biologie Marine*, **56**: 289-295.
Doi: 10.21411/CBM.A.CDD104C5

Campana S.E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. *Journal of fish biology*, **59**: 197-242.
Doi: 10.1006/jfbi.2001.1668

Chilton D.E. & Beamish R.J. 1982. Age determination methods for fishes studies by the groudfish program at the Pacific Biological Station. *Canadian Special Publication of Fisheries and Aquatic Sciences*, **60**: 102.

Curtis T.D. & Shima J.S. 2005. Geographic and sex□specific variation in growth of yellow□eyed mullet, *Aldrichetta forsteri*, from estuaries around New Zealand. *New Zealand Journal of Marine and Freshwater Research*, **39**: 1277-1285.
Doi: 10.1080/00288330.2005.9517392

Fischer W., Bauchot M.L. & Schneider M. 1987. Fiches FAO d'identification des espèces pour les besoins de la pêche. (Révision 1). Méditerranée et mer Noire. Zone de pêche 37. Volume II. Vertébrés. Publication préparée par la FAO, résultat d'un accord entre la FAO et la Commission des Communautés Européennes (Projet GCP/INT/422/EEC) financée conjointement par ces deux organisations. Rome, FAO, Vol. 2, pp. 761-1530.

Froese R. & Binohlan C. 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. *Journal of Fish Biology*, **56**: 758-773. Doi: 10.1006/jfbi.1999.1194

Garvey J.E., Devries D.R., Wright R.A. & Miner J.G. 2003. Energetic adaptations along a broad latitudinal gradient: implications for widely distributed assemblages. *Bioscience*, **53**: 141-150.
Doi : 10.1641/0006-3568(2003)053[0141:EAAABL]2.0.CO;2

Geistdoerfer P. & Goyffon M. 2004. Animaux aquatiques dangereux. *EMC - Toxicologie Pathologie*, **1**: 35-62.

Gulland J.A. 1971. *The fish resources of the ocean*. West Byfleet, UK: Fishing News (Books) Ltd: 255 pp.

Hamed O. & Chakroun-Marzouk N. 2015. Croissances pondérales de *Trachinus draco* Linnaeus, 1758 et *Trachinus radiatus* Cuvier, 1829 du golfe de Tunis. Actes des 6èmes rencontres de l'ichtyologie en France. Paris. 72 pp.

Hamed O. & Chakroun N. 2016. *Caractérisation des Trachinidae du golfe de Tunis: Caractéristiques morphométriques, structure démographique et croissance*. Editions universitaires européennes. 120 pp.

Hamed O. & Chakroun-Marzouk N. 2016. First investigation on the reproductive traits of *Trachinus radiatus* Cuvier, 1829. *Rapports de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée*, **41**: 457.

Hamed O. & Chakroun-Marzouk N. 2017. Aspects of the reproductive biology of *Trachinus radiatus* Cuvier, 1829 (Pisces: Trachinidae) in the Gulf of Tunis. *Cahiers de Biologie Marine*, **58**: 435-441. Doi : 10.21411/CBM.A.B4E2CB7

Kimura D.K. & Lyons J.L. 1991. Between-reader bias and variability in the age determination process. *Fishery Bulletin*, **89**: 53-60.

Knight W. 1968. Asymptotic growth: an example of non sens disguised as mathematics. *Journal of the Fisheries Research Board of Canada*, **25**: 1303-1307.

Magnussen E. 2007. Interpopulation comparison of growth patterns of 14 fish species on Faroe Bank: are all fishes on the bank fast growing? *Journal of Fish Biology*, **71**: 453-475. Doi: 10.1111/j.1095-8649.2007.01502.x

Moreau J., Bambino C. & Pauly D. 1986. A comparison of four indices of overall fish growth performance, based on 100 *Tilapia* population (Family Cichlidae). In: *The first Asian Fisheries Forum* (J.L. Maclean, L.B. Dizon and L.V. hosillo (eds). pp. 201-206. Asian Fisheries Society: Manila, Philippines.

Morey G., Moranta J., Massutı E., Grau A., Linde M., Riera F. & Morales-Nin B. 2003. Weight-length relationships of littoral to lower slope fishes from the western Mediterranean. *Fisheries Research*, **62**: 89-96. Doi: 10.1016/S0165-7836(02)00250-3

Morita S.H.H., Morita K. & Sakano H. 2001. Growth of chum salmon (*Oncorhynchus keta*) correlated with sea-surface salinity in the North Pacific. *ICES Journal of Marine Science*, **58**: 1335-1339. Doi: 10.1006/jmsc.2001.1116

Moutopoulos D.K. & Stergiou K.I. 2002. Length-weight and length-length relationships of fish species from Aegean Sea (Greece). *Journal of Applied Ichthyology*, **18**: 200-203. Doi: 10.1046/j.1439-0426.2002.00281.x

Munro J.L. & Pauly D. 1983. A simple method for comparing growth of fishes and invertebrates. *Fishbyte*, **1**: 5-6.

Ogle D. 2013. *FishR Vignette-Von Bertalanffy growth Model-Extra*. Ashland, USA: Northland College. 54 pp.

Pauly D. 1979. Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula. *Berlin Institute Meereskunde*, **63**: 156.

Pauly D. 1983. Length-converted catch curves: a powerful tool for fisheries research in the tropics (part 1). *Fishbyte*, **1**: 9-13.

Pauly D. 2010. Gasping fish and panting squids: oxygen, temperature and the growth of water-breathing animals. In: *Excellence in ecology. Book* 22 (O. Kinne ed), pp. 89-100. International Ecology Institute: Oldendorf/Luhe.

Ricker W.E. 1975. Computation and interpretation of the biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*, **191**: 1-382.

R Core Team 2016. R: A language and environment for statistical computing. Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Sparre P. & Venema S.C. 1996. Introduction à l'évaluation des stocks de poissons tropicaux. Première partie. *Document Technique. FAO*, **306**: 1-401.

Then A.Y., Hoenig J.M., Hall N.G. & Hewitt D.A. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. *ICES Journal of Marine Science*, **72**: 82-92.

Von Bertalanffy L. 1938. A quantitative theory of organic growth (inquiries on growth laws. II). *Human biology,* **10**: 181-213.

Wetjen M. 2012. Growth production of two notothenioid fish species from different geographical regions of the Antarctica. Master thesis in the framework of the International Degree Course of Industrial and Environmental Biology M.Sc. at the University of Applied Sciences in Bremen. 119 pp.

Wootton R.J. 1992. *Fish ecology*. Blackwell: Glasgow. 203 pp.