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Age and Growth of Bluemouth *Helicolenus dactylopterus* (Delaroche, 1809) in the Northern Waters of Tunisia (Central Mediterranean)

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ABSTRACT

Data on age and growth of the bluemouth *Helicolenus dactylopterus* (Delaroche, 1809) from the Southern central Mediterranean Sea are provided in this paper. Ages of bluemouth rockfish (Scorpaenidae) in the northern Tunisian waters were estimated by otolith readings and verified by marginal increment analysis. A total of 513 individuals were measured, weighed and their sex was determined. The fish total length (TL) range between 8 and 30.6 cm, which corresponded to individuals between 0 to 9 years old. The otoliths showed the typical teleost fish pattern with alternated opaque and hyaline rings. Marginal increment analysis of specimens suggested that a single annulus was formed each year. The Von Bertalanffy growth function was selected as the most adequate model to fit this species' growth. Parameters of the growth curve were L_∞ =37.17cm, K=0.142year^{-1}, t_0= -1.67years. The weight-length relationship (TW= 2.2092 x10^{-5}TL$^{2.870}$) described a negative allometric growth of the species. The growth parameters obtained from the age-length relationships showed higher differences between sexes.

Keywords: *Helicolenus dactylopterus*; otoliths; age; growth; North of Tunisia

Résumé

L'âge et la croissance de la population de la rascasse de fond *Helicolenus dactylopterus* (Delaroche, 1809) a été étudié au nord de la Tunisie. Dans cette étude, 513 spécimens dont la longueur totale varie de 8 à 30,6 cm ont été examinés. Au total, 9 classes d'âges ont été déterminées par comptage des anneaux de croissance sur les otolithes. Les paramètres du modèle de Von Bertalanffy estimés sont : L_∞ = 37,17 cm, k = 0,142 an^{-1} et t_0 = -1,67 ans. Le suivi de l'allongement marginal affirme que cette espèce possède un seul cycle de croissance par an. La relation taille-poids décrie une allométrie minorante chez la rascasse de fond au nord de la Tunisie (2,2092 x10^{-5}TL^{2,870}). Cette étude a permis de montrer une différence significative du taux de croissance entre les deux sexes de cette espèce.

INTRODUCTION

The bluemouth *Helicolenus dactylopterus* (Delaroche, 1809) (Pisces: Scorpaenidae), is a deep-sea scorpion fish living in the coarse and mud-sandy bottoms of the continental shelf and slope from 20 to 1000 m (Fisher et al., 1987). Consoli et *al.* (2010) indicates that the bluemouth *H. dactylopterus* occurs in the entire Mediterranean and is widely distributed in the eastern Atlantic, from Norway south to the southern tip of Africa, and in the western Atlantic from Venezuela north to Nova Scotia. The Scorpaenidae was represented in Tunisian waters mainly by six species: *Scorpaena porcus* (Linnaeus, 1758), *Scorpaena scrofa* (Linnaeus, 1758), *Scorpaena notata* (Rafinesque, 1810), *Scorpaena elongata* (Cadenat, 1943), *Scorpaena loppei* (Cadenat, 1734), and *H. dactylopterus* (Delaroche, 1809). This teleost fish had an important economic value in Tunisia. In Tunisian waters, this species is exploited in deep-sea fisheries and it is captured especially with gillnets and it appears in the catch of bottom trawl. The study of *H. dactylopterus* population dynamics is important because the depletion of this large-size sedentary and slow-growing fish can be an index of the overexploitation of fishing grounds (Pirrera et *al.*, 2009). Besides, the investigation made on Atlantic Ocean and in many region of the Mediterranean Sea, several authors studied age and growth of *H. dactylopterus* by mean of model progression analyses and otolith reading (D'Onghia et *al.*, 1996; Massuti et *al.*, 2000; Ragonese, 1989; Ragonese and Reale, 1992; Romanelly et *al.*, 1997; Ungaro and Marano, 1995) but no age and growth data are available from the South of this area. For the Tunisian waters, there is currently no information on age and growth of bluemouth. In spite of differences in maximum age and growth parameters, all authors seem to agree that *H. dactylopterus* is a slow - growing and a long lived species (Consoli et *al.*, 2010). Sizes of this species are larger in the Atlantic Ocean, above 40cm than in the Mediterranean Sea where it reaches a maximum total length of 36cm (Massuti et *al.*, 2000; Morales-Nin, 1989).

In the present paper we estimate the age and growth patterns of bluemouth *H. dactylopterus* by means of whole otolith reading in order to contribute to the knowledge of the population dynamics of this species in the northern waters of Tunisia (central southern of the Mediterranean Sea).

MATERIAL AND METHODS

H. dactylopterus sampling was carried out from January to December 2010 in the North of Tunisian waters. Specimens were collected during several scientific bottom trawl surveys made by the research vessel of the National Institute of Marine Sciences and Technologies “Hannibal” and also from commercial landings (Fig. 1). Fishing operations were conducted between 60 and 600 m in order to collect juvenile and adults. A total of 513 fish were sampled: 138 females and 260 males.

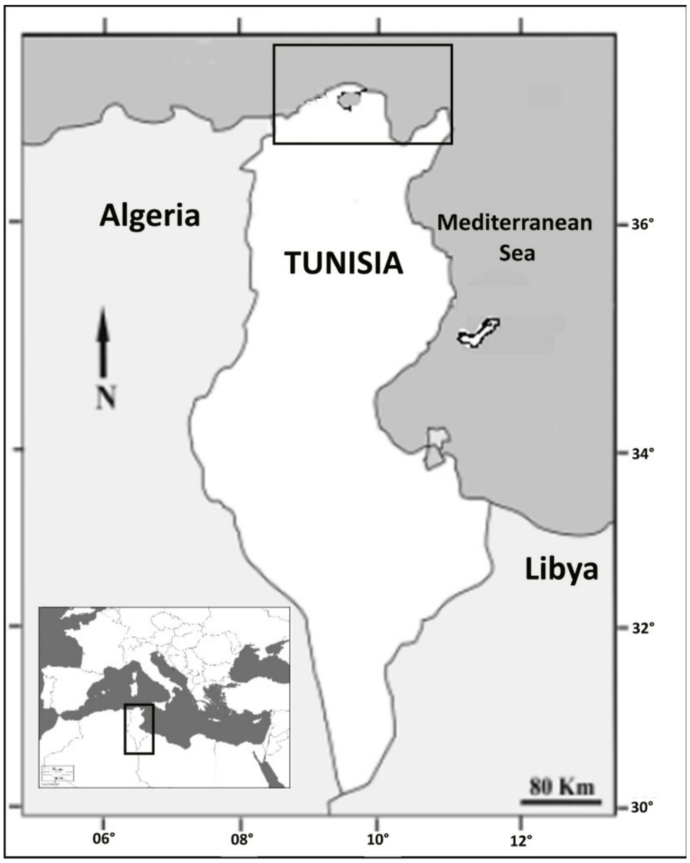

Figure 1: Map of the Tunisian coast showing study area (Central Mediterranean)

In the laboratory, each specimen (total length-TL) was measured by calliper to the nearest 0.01 cm and weighed to the nearest 0.1 g, and the sex was determined by macroscopic examination of the gonads.

Age of 509 specimens was estimated using otolith readings and interpretation of annual growth rings. Right otoliths (sagittae) were removed from the vestibular apparatus from each fish, cleaned and dried. Before observation, Sagittalotoliths were immersed in a solution of glycerine, ethanol and water for 4 hours (Consoli et *al.,* 2010). Readings were carried out with stereomicroscope under reflected light.

For each otolith, the total radius and the radius of different marks (R_1, R_2, R_3, R_4 ... R_n) were measured using an image analysis system (OPTIMAS 5.1). To determine the periodicity in the formation of the rings, the marginal increment method was applied by using the formula (Ben Abdallah-Ben Hadj Hamida et *al.*, 2016):

$$MIR = (R - Rn) / (Rn - Rn\text{-}1)$$

Once the rings were considered to be annual, each specimen was assigned to a year class, taking into account the data of capture, the annuli counts, and their formation period, as suggested by Massuti et *al.* (2000). Age was determined separately for males, females, and combined sexes including immature specimens.

The relationship between total fish length (TL) and the radius of the otolith (R) was estimated using linear regression model. A logarithmic transformation of the variables was made to reduce the variance related to size. The Von Bertalanffy growth equation was fitted to the length-at-age data obtained from otolith readings by the Quasi NEWTON non-linear method. The growth performance index Φ' was employed to compare growth rate (Munro & Pauly 1983). Additionally, growth parameters (L_∞, k, t_0) were estimated by fitting age and related length data into the theoretical growth model of Von Bertalanffy (1938):

$$L_t = L_\infty\,[1 - e^{-k\,(t - t0)}]$$

Where "L_t" is the total length at age t (years), "L_∞" is the predicted asymptotic length, "k" is the instantaneous growth coefficient, describing how rapidly this length is achieved, "t_0" is the theoretical age at zero length (years).

For estimation of growth, the mean lengths of individuals assigned to each age group were used to fit the Von Bertalanffy growth model and were determined by the method of back-calculation by using the formula:

$$L_i = \frac{aRi \times L}{aR^b}$$

Where L is the length at capture, L_i is the length of the i^{th} mark, R is the radius of the otolith and R_i is the radius of the i^{th} mark (Chemmam-Abdelkader, 2004). In addition the growth rate was calculated as:

$$Gr = \frac{(L_{i+1} - L_i)}{(L_{i+1} + L_i\,)/2}$$

Where L_i is the total length of the i^{th} annulus and L_{i+1} is the total length of the $(i+1)^{th}$ annulus.

The weight-length relationship was calculated using the exponential equation:

$$TW = aTL^b$$

Where "TW" is the weight (g), "TL" is the total length (cm), "a" is the intercept of the regression line and represents a coefficient related to the body shape of the species, b is the regression coefficient and indicates the isometric growth when equal to 3 (Anderson and Neumann, 1996). Estimation of parameters "a" and "b" was carried out by transforming (ln) the equation by linear regression. To check the theoretical isometric (b = 3) or allometric growth (b ≠ 3) the Student's t-test was employed.

The analysis of variance (ANOVA) was used to test variability between the growths rates of both sexes. The Student's t-test test was performed to compare length increases in each age group. Differences were considered significant when the α-level (risk level) was 0.05. The curves adjustment and the variance analysis were performed using Statistica software package for Windows (8.0).

RESULTS

The total length of *H. dactylopterus* specimens ranged from 8 to 30.6 cm. The larger female and male measured 28.3 and 30.6 cm respectively. The sample was composed mainly by female (50.7%), while male and undefined sex with indistinguishable gonads that could not be sexed represent's respectively 26.9 % and 22.4%. A significant differences were observed between the mean sizes of male and female ($p<0.05$). Males attained a larger size (up to 30 cm TL) than females ($p<0.05$).

From the 513 specimen of *H. dactylopterus* sampled, 509 were used for otolith readings. The rest were either broken or difficult to interpret and were considered unreadable. The otoliths readings showed a hyaline rings that alternated with opaque rings, which can be attributed to slow and fast growth periods around an opaque nucleus (Fig. 2). The first pair of rings was wide and lay down with decreasing thickness. However, the otoliths from adult fish shows that the rings in the outer portions decreases in width, becoming very regular and equally wide. Fish total length (TL) and otolith radius (R) were closely correlated (Fig. 3). The relationship estimated for all individuals using a linear model was TL = 1.193R+1.841 (r^2=0.945).

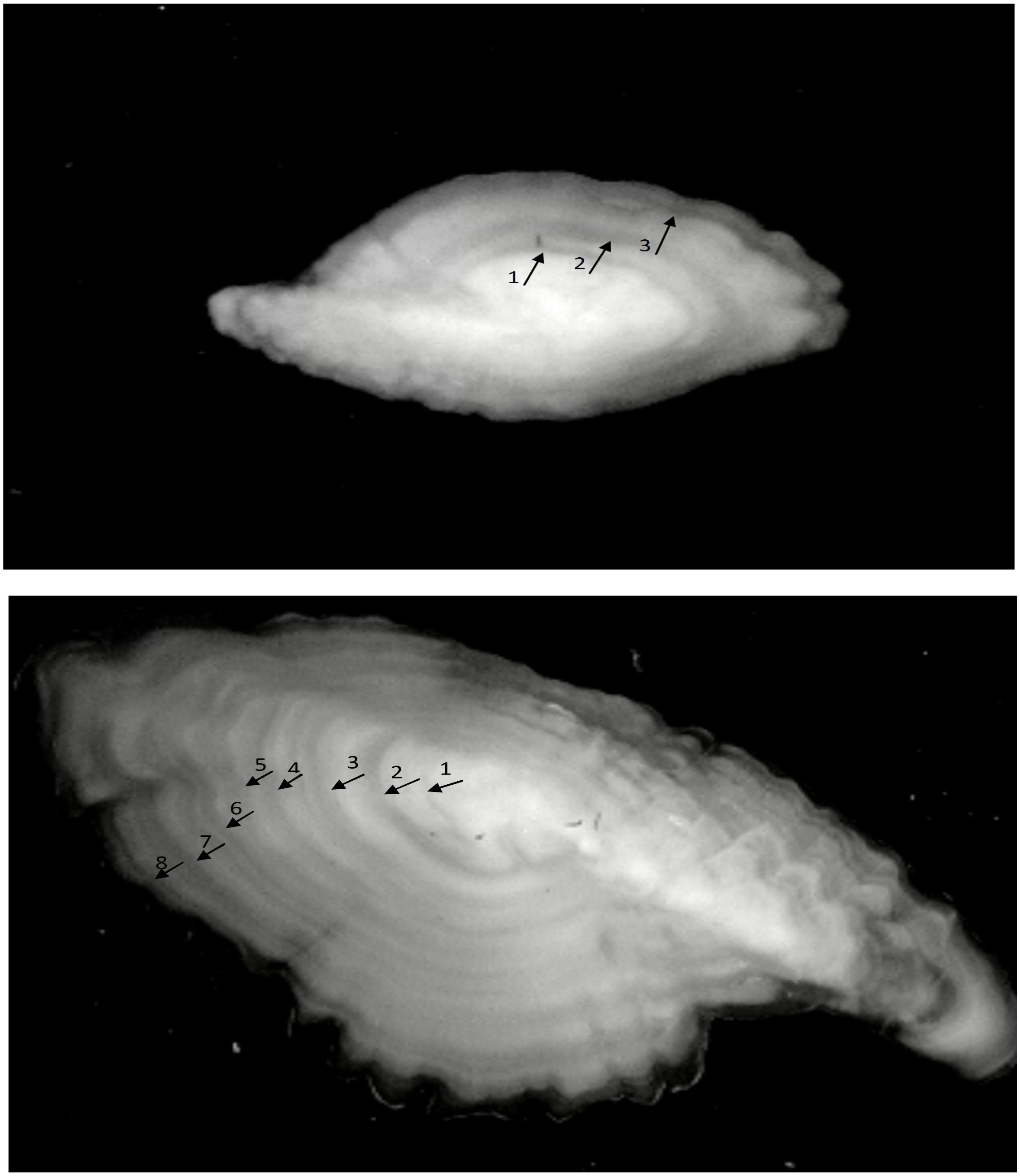

Figure 2: Sample of sagittal otolith of *Helicolenus dactylopterus*. The otoliths were estimated at age 3 and 8 years respectively (14.7 cm and 28.5 cm total length)

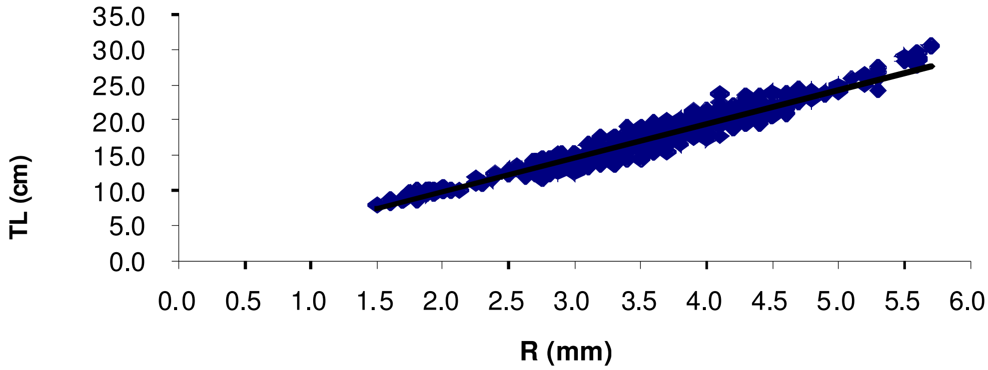

Figure 3: *Helicolenus dactylopterus* otolith radius-total length relationship in the northern Tunisian waters (N = 509)

The monthly development of opaque and hyaline marginal rings in *H. dactylopterus* otoliths showed many fluctuations throughout the year (Fig. 4). Marginal zone analysis revealed that the marginal increment (MI) dropped in November and stayed low until July (ANOVA, Tukey's post hoc, $P < 0.05$). During this period higher percentages of otoliths with hyaline marginal zones were observed. From July, the MI increased, reaching a peak in October, and then decreased. In fact, only one clearly defined peak was observed during the annual cycle, therefore one hyaline zone was deposited per year. The opaque zone was formed during summer and autumn. It was assumed that each translucent ring represented an annulus with a year's growth accounted by an opaque and its adjacent hyaline ring.

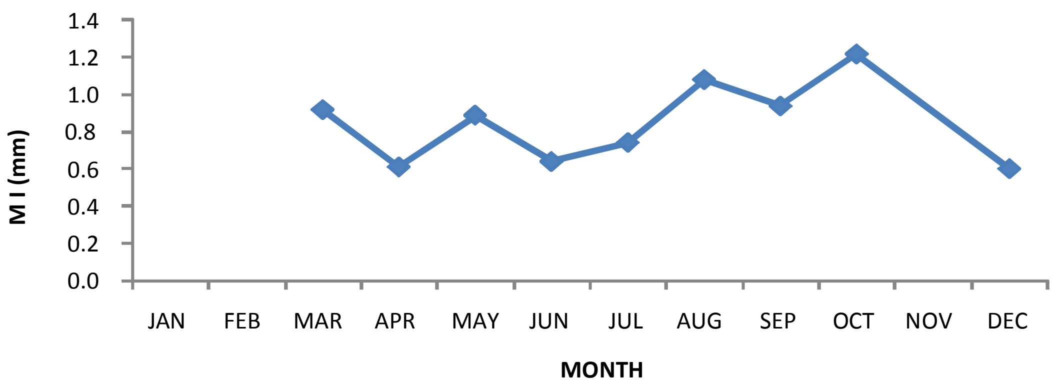

Figure 4: Monthly variation of marginal increments at the otolith of *H. dactylopterus* from the North of Tunisia

Analysis of 509 otoliths permitted an estimate of a maximum age of 9 years, but specimens aged more than 8 years were uncommon in this study area (Tab. 1). A large length range was recorded for each age group. Majority of samples belonged to the 2nd and 3rd class corresponding to an average of lengths between 14 cm and 20 cm. The lengths by age class are verified by marginal increment analysis. Retro-calculated total lengths at each annulus formation are presented in Table 2. The growth rate is high during the first two years and it decreases gradually with age. The parameters of the Von Bertalanffy growth curve fitted to total lengths at age estimated are summarized in table 3 (Fig. 5). The theoretical asymptotic total length (L_∞=37.17 cm) gave results higher than the largest specimen (TL=30.6 cm) in this study. The value of the growth performance index obtained for all individuals was Φ'=2.292. The mean length at estimated age class of *H. dactylopterus* suggests that there is a marked difference in growth rates between sexes (Tab. 3). Males growing is slightly faster than females and they reach a larger size ($p = 0.001<0.05$). The analyses of estimated sizes by age groups using otolithometry and verified by marginal increment analysis are in concordance with sizes obtained by Von Bertalanffy method (Tab. 4). Additionally, we recorded that the growth of *H. dactylopterus* is slow and regular in time which is a characteristic of fishes that live in deep and cool water.

Table 1: Age-length key for the population of *Helicolenus dactylopterus* in the North of Tunisia from whole otolith readings

Length class TL (cm)	Age class (years)									
	0	1	2	3	4	5	6	7	8	9
8 - 8.5	11									
9 - 9.5	39									
10 - 10.5		24								
11 - 11.5		4								
12 - 12.5		14								
13 - 13.5		29								
14 - 14.5		1	59							
15 - 15.5			27							
16 - 16.5			31	20						
17 - 17.5			12	27	4					
18 - 18.5			7	31	9					
19 - 19.5				41	4					
20 - 20.5				11	14					
21 - 21.5					23	3				
22 - 22.5					7	17				
23 - 23.5						12				
24 - 24.5						3	9			
25 - 25.5							3	1		
26 - 26.5								4		
27 - 27.5								1	1	
28 - 28.5									2	
29 - 29.5									2	1
30 - 30.5										1
Number of fish	50	72	136	130	61	35	12	6	5	2
Mean length (cm)	9.2	11.9	15.4	18.2	20.2	22.6	24.3	26.5	28.5	30.1

Table 2: Retro calculated lengths at-age for whole population of *Helicolenus dactylopterus* caught in the North of Tunisia TL, total length (cm); Avg: Average; Gr, Growth rate.

Age group	TL1	TL 2	TL 3	TL 4	TL 5	TL 6	TL 7	TL 8	TL 9
0	9.21								
I	9.16								
II	9.66	12.64							
III	9.35	12.67	15.55						
IV	8.96	11.90	14.95	17.28					
V	8.85	12.09	15.06	17.53	20.2				
VI	8.18	11.24	14.32	16.80	19	22.07			
VII	7.89	10.41	13.26	15.38	18.04	20.51	23.43		
VIII	8.84	10.75	13.42	15.97	18.39	20.76	23.10	25.90	
IX	7.33	11.30	13.68	17.39	20.30	22.95	24.54	26.66	28.51
Avg	8.74	11.62	14.32	16.72	19.15	21.57	23.69	26.28	28.51
Gr		28.29	20.78	15.48	13.52	11.9	9.35	10.37	8.15

Table 3: Computed Von Bertalanffy growth parameters of *Helicolenus dactylopterus*. L_∞ = asymptotic length; K = growth coefficient; t_0= theoretical age at zero length; Φ'= growth performance index.

Sexes	L_∞	K	t_0	Φ'	Extreme lengths (cm)
♂	39.28	0.125	-1.97	2.285	9 - 30.6
♀	36.46	0.142	-1.85	2.275	8.0 - 28.8
♂+♀	37.17	0.142	-1.67	2.292	8.0 - 30.6

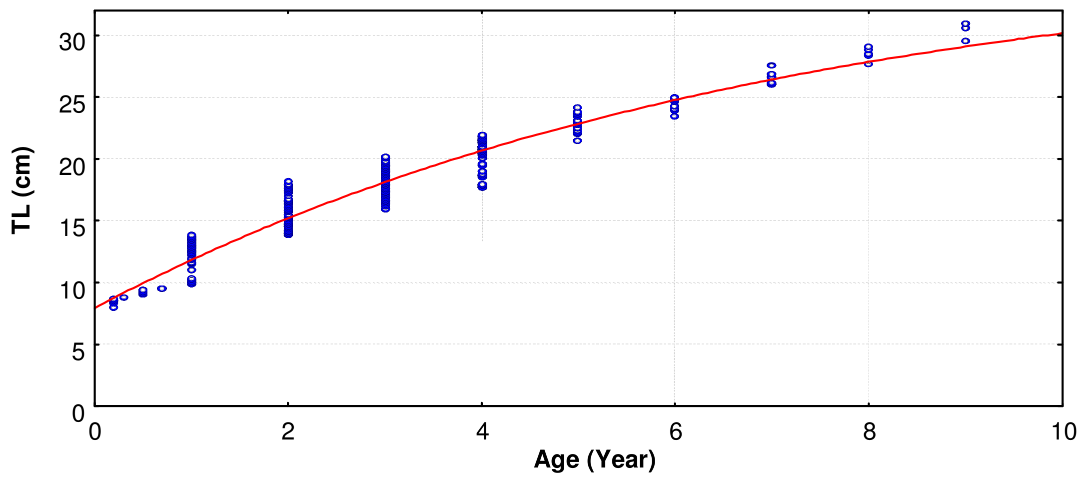

Figure 5: Bluemouth total age-at-length data fitted to Von Bertalanffy growth model

Table 4: Sizes (cm) of *H. dactylopterus* by age groups estimated using different methods

Method	Age (year)								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Otolithometry	11.9	15.4	18.2	20.2	22.6	24.3	26.5	28.5	30.1
back-calculation	8.7	11.6	14.3	16.7	19.2	21.6	23.7	26.3	28.5
Von Bertalanffy	11.8	15.2	18.1	20.7	22.9	24.8	26.4	27.8	29.1

Regarding the estimate of von Bertalanffy growth parameters a low estimate of k together with a high L_∞, indicates that *H. dactylopterus* is slow-growing and long-lived. Asymptotic total weight of *H. dactylopterus* from the northern region of Tunisia is estimated as 855.3g while it was about 806.9g using eviscerated weight. Weight of *H. dactylopterus* by age group calculated is summarized in table 5.

The larger female and male measured 28.3 and 30.6 cm respectively. Significant differences between male and female average sizes ($p<0.05$) were observed. Length frequency distribution of *H. dactylopterus* indicates the presence of different cohorts (Fig. 6). The total average sample length is 16.7cm. The structure of samples showed nine modes corresponding to the nine age classes deduced by otolithometry method.

The morphometric relationship between total length (TL), fork length (FL) and standard length (SL) were determined for whole population (Tab. 6). The analysis of the equations between lengths showed a strong relationship as demonstrated by the high values of R^2. The relationship between the total length and the standard length showed a positive allometry, however it was negative between the total length and fork length. The total weight-length and the eviscerated weight-length relationships estimated for *H. dactylopterus* in the study area are summarized in table 6. Weights did not increased isometrically with size, since the values of b have a significant difference from the value 3.0, as confirmed by the Students t-test. The allometry was negative indicating that the weights grow slowlier than the cube of the total length.

Table 5: Weight (g) of *H. dactylopterus* by age group calculated. TW: total weight, EW eviscerated weight

Age (year)	1	2	3	4	5	6	7	8	9
TW	23.4	51.4	89.5	135	185.6	238.7	292.4	345.2	395.9
EW	21.7	48	83.6	126.4	174	224	274.6	324. 4	372.2

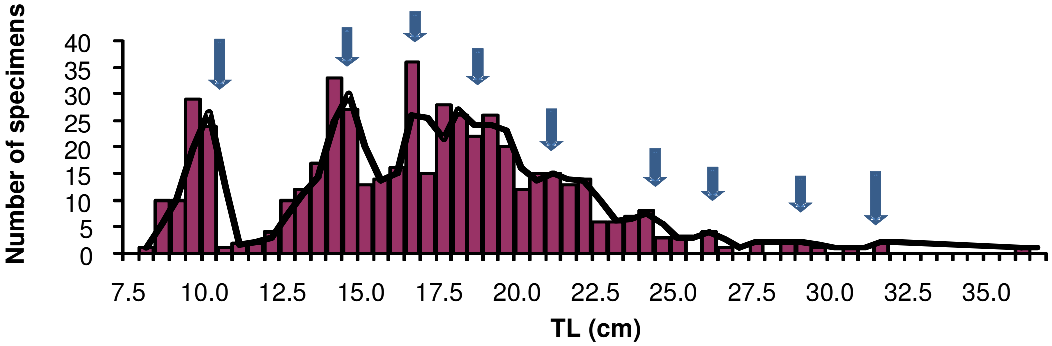

Figure 6: Length frequency distribution of *Helicolenus dactylopterus* in the northern Tunisian waters (N = 513)

Table 6: Morphometric relationships between total lengths (TL), fork length (FL), standard length (SL) and Length-weight relationships of *H. dactylopterus* in Tunisian waters. TW: total weight, EW eviscerated weight, N: Number of individual, R^2: Determination coefficient

Relationships	N	R^2	Allometry	Student's t-test
TL= 1.021 SL-0.123	513	0.996	+	7.866 (p<0.05)
TL= 0.981 FL+0.109	513	0.995	-	7.552 (p<0.05)
TW = 2.2092 x10^{-5} TL $^{2.870}$	513	0.990	-	10.206 (p<0.05)
EW = 2.2068 x10^{-5} TL $^{2.841}$	513	0.989	-	10.820 (p<0.05)

DISCUSSION

In this study, otoliths appear to be a valid method for ageing *H. dactylopterus*. Similar results have been obtained by Isidro (1984) and Massuti et *al.* (2000). The high percentage of opaque rings in summer and autumn, attributed to a fast growth period, could be due to temporal variations in food resources and their influence on the feeding and activity patterns of the species. Presumptuous the annual periodicity of otolith growth rings, our data suggest that *H. dactylopterus* is a long-lived species, with numerous age-classes in the population. Additionally a high percentage of the sample studied consisted of fish between 9 and 21 cm TL, corresponding to young recruits and juveniles from 1 to 4 years of age. This abundance of small fish in the samples might be due to the method of capture. The pattern of increment deposition was similar to that described by other authors (e.g. Massuti et *al*., 2000; Sequeira et *al*., 2009.

Several studies on this species suggest that the growth increment including one opaque zone with the adjacent translucent zone can be considered as equivalent to one year of life (Abecasis et *al*., 2006; Consoli et *al*., 2010; Massuti et *al*., 2000; Ragonese and Reale, 1992; Romanelly et *al*., 1997). This calcified structure was chosen because it has a good legibility and regularity of its growth mark patterns and it gives good results of observation (Chemmam-Abdelkader, 2004).

The growth parameters obtained in this study showed some differences compared with those reported from other Mediterranean areas (Tab. 7); however, the Φ' values obtained are similar (Consoli et *al*., 2010: D'Onghia et *al.* 1996; Kelly et *al*., 1999; Mamie et *al*., 2007; Massuti et *al.* 2000; Peirano & Tunesi 1986; Ragonese and Reale 1992; Ungaro and Marano 1995). The variability of the growth parameters could be due to differences in the range of sizes sampled, the methodology applied and the characteristics of the study areas. As suggested by Pirrera et *al.* (2009), the estimation of growth parameters is strongly affected by sampling gear as well as by bias of age estimation. On the other hand, asymptotic sizes found by Abecasis et *al.* (2006), Sequeira et *al.* (2009) and Paul and Horn (2009) are higher compared to our results. It is clear that there could be some differences between growth characteristics from one area to another for reasons of food availability, hydrographical and climatic conditions, and fishing mortality rates. Additionally, the differences can be explained by the spatial and temporal variability, as well as the sampling period.

Moreover, we report differences in *H. dactylopterus* length between populations in the Mediterranean Sea. It could be due to the different fishing pressure in the study areas, to the maximum sampling depth, and also to the fishing gear employed. In fact, according to Massuti et *al.* (2001), smaller sized individuals are concentrated at shallow depths while larger ones prefer deeper areas, showing a clear preference for rocky bottoms, which are not very accessible to trawling, and thus they can escape or avoid the net. On the other hand, many authors (Abecasis et *al*., 2006; Allain and Lorance, 2000; Kelly et *al*., 1999; White et *al*., 19 9 8) estimated

Table 7: Growth parameters for *Helicolenus dactylopterus*, reported by several authors in different areas. L∞ = asymptotic length; K = growth coefficient; Φ'= growth performance index

L∞ (cm)	K ($year^{-1}$)	T_0 (year)	Sexe	Φ'	N	TL range (cm)	Area	Authors
31.0 37.2	0.09 0.06	-3.0 -4	F M	1.94 1.92		10-38 10-38	Northeast Atlantic	Kelly et *al.* (1999)
29.9	-0.13	-1.75	M+F	2.06	938	2-30	Balearic Sea (Mediterranean)	Massuti et *al.* (2000)
30	0.1	-2.86	M+F	1.95	1455	3-36	Alborán Sea (Mediterranean)	
56.52 59.06	0.07 0.07	-1.13 -0.21	F M	2.28 2.39	230 330	13-41 14-46	Azorian waters	Abecasis et *al.* (2006)
28.2	0.12	2.10	M+F	1.98		5-26	Northwest Atlantic	Mamie et *al.* (2007)
45.50	0.05	4.01	M+F	2.01	901	5-36	Portuguese waters	Sequeira et *al.* (2009)
46.97	0.08	-2.2	M+F		152	11.2-47.9	Azorian waters	Montiero et *al.*, 1991
26.1	0.14	-1.92	M+F	1.98	498	3-27	Tyrrhenian Sea (Meditarranean)	Consoli et *al.* (2010)
70.7	0.05	-0.41	M+F	2.35	300	4-28	Ligurian Sea (Meditarranean)	Peirano and Tunesi (1986)
39.2	0.13	-1.46	M+F	2.29	585		Sicilian Channel (Meditarranean)	Ragonese and Reale (1992)
30	0.16	-0.02	M+F	2.158	1412	2.5-24.5	Southern Tyrrhenian Sea (Meditarranean)	Pirrera et *al.*, 2009
30.7	0.16	-0.9	M+F	2.167	410	3-24	Ionian Sea (Meditarranean)	D'Onghia et al., 1996
29.9	0.19	-0.85	M+F	2.23			Adriatic Sea (Meditarranean)	Ungaro and Marano (1995)
36.46 39.28 37.17	0.14 0.12 0.14	-1.85 -1.97 -1.67	F M M+F	2.275 2.285 2.292	513	9-30,6 8,3-28.8 8.3 - 30.6	Tunisian waters (Mediterranean)	Present work

higher bluemouth longevity in the Atlantic Ocean. The difference of longevity between specimens from Atlantic Ocean and Mediterranean Sea could be due to the different age reading methodologies as those authors used thin-sectioning whereas we used whole otoliths. *H. dactylopterus* can attain more than 30 years of age, it is a long-lived species (Massuti et *al*., 2000). Data related to the life span of this fish are influenced by methods used for estimation such as whole otolith readings or sliced (Abecais et *al*., 2006) and length-frequency distribution analysis. D'Onghia et *al.* (1992) indicated that the length and age of *H. dactylopterus* is well correlated to bathymetric distribution. The differences of maximum age estimates are very important for management because the exploitation of the species is correlated to its life history (Denney et *al*., 2002). According to Pirrera et *al*., (2009), the blue-mouth rockfish are vulnerable to overfishing because of their biological characteristics (long life, large size, late maturity, slow growth and low mortality rate) and are strongly exploited by trawling fishing. The length at age analyzed in this research suggests that the population is made up almost exclusively of juvenile individuals (0-4 years), this result was similar to that obtained by Pirrera et *al*., (2009). The larger animals (up to 20 cm TL) can reach up to 9 years of age. D'Onghia et *al.* (1996) indicated that the estimation of growth parameters through frequency distribution underestimates the growth rate of younger fish and allows only the few earlier age groups to be identified. Additionally, these authors affirms that recruit reach the edge of the continental shelf during spring and move toward bathyal grounds as they grow. The growth performance index (Φ') values, with coefficient of variation of only 16% indicate that the growth potential in the different areas of the Mediterranean and Atlantic are quite comparable.

Additionally, the differences in the values of growth parameters obtained between sexes might indicate that sexual development and life strategy affect the growth rate of this species. Same observation was reported by Massuti et *al.* (2000) indicating that males grow larger than females. The reproductive effort, considering the bioenergetic constraints of the energy budget of the organisms, implies reduced growth rates of females (Gunderson, 1997). The viviparity of *H. dactylopterus*, in conjunction with the development of a gelatinous matrix within the ovary to cover the fertilized eggs (Washington et *al*., 1984), the low fecundity of this species, and the relatively large eggs Massuti et *al.* (2000) imply that females have a higher energetic cost during reproduction than males, and these factors could form the basis of differences in growth between sexes.

The length-weight relationship describes a negative allometric growth for *H. dactylopterus* in the study area, in contrast with other studies made in the Mediterranean Sea (Tab. 8) where the results reported an isometric growth (Consoli et *al*., 2010; Massuti et *al*., 2000).

Table 8: Length-weight relationships parameters for *Helicolenus dactylopterus*, reported by several authors in different areas. a: intercept of the curve; b: coefficient of allometry; R^2: Determination coefficient

Study area	Sex	a	b	R^2	
Ionian Sea (Meditarranean)	♂+♀	0.000012	3.06	0.987	D'Onghia et *al.* (1996)
	♀	0.000025	2.92	0.963	
	♂	0.000010	3.07	0.994	
Azorian waters (Portugal)	♂+♀	1.04×10^{-2}	3.14	0.997	Monteiro et *al.* (1991)
Turkey waters (Mediterranean)	♂ ♀	0.0141 0.0135	3.088 3.084	0.97 0.98	Demirhan and Akbulut (2015)
Tyrrhenian Sea (Mediterranean)	♂+♀	0.016	2.99	0.99	Consoli et *al.* (2010)
Northeast Atlantic	♂+♀	0.22	2.92		Kelly et *al.* (1999)
Balearic Sea (Mediterranean)	♂+♀	2×10^{-5}	2.98	0.99	Massuti et *al.* (2000)
Alborán Sea (Mediterranean)	♂+♀	1.3×10^{-5}	3.02	0.99	
Tunisian waters (Mediterranean)	♂+♀	2.2092×10^{-5}	2.870	0.99	Present work

Finally, the growth parameters obtained in this study are reasonable because the theoretical maximum length is larger than the size of the biggest fish sampled, with the correlation found between total length and otolith radius suggesting the potential use of otoliths for estimating the age and growth of *H. dactylopterus*. On the other hand, along the northern Tunisian waters, *H. dactylopterus* is mainly caught by trawlers which do not catch very small size of individuals (<8cm). Furthermore, this species seems to be overexploited. The overexploitation of *H. dactylopterus* in the study area was caused by low growth and absence of very large individuals.

This study provides new information on the biology of the bluemouth *H. dactylopterus* in the north sea of Tunisia, contributing to the knowledge required by resource management . Nevertheless , more research effort should be done in order to study reproductive biology which may be considered for decision-making on possible ecologically based management strategies of the species' fisheries in the study area.

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