Age and Growth estimation of forkbeard *Phycis phycis* (Linnaeus, 1766) [Actinopterygii, Gadiform, Phycidae] from the Gulf of Tunis

Ahlem ROMDHANI*, K. MAHE, J.L. DUFOUR** and M.H. KTARI***

*Laboratoire de biologie et biodiversité des populations, Faculté des sciences Tunis, Campus Universitaire El Manar II, 2092, Tunis, Tunisie. romdhani.ahlem@gmail.com

**Institut Français de Recherche pour l'exploitation de la mer (IFREMER), Pôle de Sclérochronologie, 150 Quai Gambetta, B.P. 699, 62321 Boulogne-sur-Mer, France.

ملخص

دراسة العمر و النمو عندسمك البقالو (مزداية) فى خليج تونس : يهدف هذا العمل إلى تقدير العمر و تحليل نسق النمو عند الأسمك من نوع البقالو (مزداية). تضم العينات التى تم جمعها بصفة شهرية،272سمكة في الفترة الممتدة بين سبتمبر 2007 و جوان2010 .

بينت دراسة العلاقة بين الطول و الوزن أن الوزن ينمو أكثر من الطول الكامل لدى البقالو. هذا و قد أفضى تحليل العلاقة بين طول السمكة و وزن حصاة الأذن إلى وجود تناظر بين حصاتي الأذنين اليسرى و اليمنى.

و قد تبين من خلال دراسة العلاقة بين وزن و قطر حصاة الأذن اعتمادا على عمر السمكة، أنه لا توجد فروق بين الذكور والإناث. هذا و أن دراسة العلاقة بين الطول و العمر بينت أن الإناث تبلغ43، 73صم أقصى طولا بينما لا تبلغ الذكور إلا 68 صم. أما مؤشر النمو فهو أحسن عند الإناث (Φ= 2،929) مقارنة بالذكور (Φ =2,883).

الكلمات المفاتيح: البقالو، خليج تونس، العمر، حصاة الأذن، العلاقة بين الطول و الوزن.

ABSTRACT

The age and growth of *Phycis phycis* (Linnaeus, 1766) were studied from a sample of 272 specimens collected in the Gulf of Tunis landings of the small-scale artisanal fisheries between September 2007 and June 2010.Length-weight relationships were allometrically positive for the females ($TW = 0.0083*TL^{3.0703}$), males ($TW= 0.0063*TL^{3.1471}$), and both sexes ($TW= 0.0082*TL^{3.0759}$).No significant differences were found between males and females (ANCOVA, p = 0.426). Symmetry between the right and left otolith was compared. The relation between the total length (TL) of fish and the weight of the otolith (Wo) did not show a significant difference between the right (Wo = 0.12 TL – 0.163) and left otolith (Wo = 0.11 TL – 0.124) (ANCOVA, p>0.05). The relationships between otolith radius and otolith weight with age, showed that there are no significant differences between males and females (ANCOVA, p>0.05). The growth parameters for females ($TL = 73.43 (1 - e^{-0.158 (t+1.709)})$), males ($TL = 67.51 (1 - e^{-0.168 (t+1.993)})$) and all sample ($TL = 65.73 (1 - e^{-0.135 (t+2.025)})$) were estimated. The females, with L∞ = 73.43 cm, grew faster than the males, which L∞ did not exceed 68 cm. Consequently, the index of growth performance (Φ: cm/an) of the females (Φ=2.929) was higher than that of the males (Φ=2.883).

***Keywords**: Phycis phycis*, Gulf of Tunis, age, otolith, growth.

RESUME

Age et croissance chez la mostelle de roche *Phycis phycis* (Linnaeus, 1766) [Actinoptérygiens, Gadiformes, Phycidae] dans le Golfe de Tunis : L'objectif de ce travail est l'estimation de l'âge et du rythme de croissance de *Phycis phycis* (Linnaeus, 1766) ; 272 spécimens ont été collectés à partir de la pêche commerciale dans le golfe de Tunis entre septembre 2007 et juin 2010. L'étude de la relation taille-masse indique une croissance pondérale majorante chez les mâles, les femelles ainsi que tout l'échantillon avec les sexes groupés. Cette étude ne montre pas de différence significative entre les deux sexes (ANCOVA, p = 0,426). Chez *Phycis phycis*, la relation entre la taille du poisson (Lt) et le poids de l'otolithe (Wo) ne montre pas de différence significative entre les otolithes droit (Wo = 0,12 Lt – 0,163) et gauche (Wo = 0,11 Lt – 0,124) (ANCOVA, p>0,05). Aussi, nous avons pu identifier une symétrie entre les deux otolithes sagittaux d'un même individu. Le suivi de l'évolution du poids de l'otolithe (Wo) et de son rayon (Ro) en fonction de l'âge du poisson, montre qu'il n'y a pas de différences significatives entre les mâles et les femelles (ANCOVA, p>0,05). La relation taille-âge a été étudiée pour les femelles ($Lt = 73,43 (1 – e^{-0,158 (t+1,709)})$), pour les mâles ($Lt = 67,51 (1 - e^{-0,168 (t+1,993)})$) et pour l'ensemble des individus ($Lt = 65,73 (1 - e^{-0,135 (t+2,025)})$). La longueur maximale théorique (L∞) indique que les femelles peuvent atteindre une taille de 73,43 cm alors que celle des mâles n'excède pas 68 cm. L'indice de performance de croissance (Φ) (cm/an) indique une meilleure croissance chez les femelles (Φ=2,929) que chez les mâles (Φ=2,883).

***Mots clés** : Phycis phycis*, golfe de Tunis, âge, otolithe, croissance pondérale.

INTRODUCTION

The forkbeard, *Phycis phycis* (Linnaeus, 1766), is a common fish with a wide distribution, extending in the Northeast Atlantic coast from Bay of Biscay to Mauritania, Azores, Madeira Islands and Canary Islands (Cohen *and al*., 1990 ; Whitehead *and al*.,1986 ; Fisher *and al*., 1987), the species is also known throughout the Mediterranean Sea, the Black Sea and the Adriatic.

In Tunisia, *P. phycis* is present on the northern and eastern coasts, but absent in the Gulf of Gabes (Bouhlel, 1979). *P.phycis* is a benthopelagic species, living in the hard and sandy-muddy bottoms near rocks at 100 to 650 m, but sometimes it is present at greater depths (Cohen *and al*., 1990); it is common in inshore waters between 100 m and 200 m depth (Quéro *and al*., 2003; Whitehead *and al*., 1986). Information on the age and growth of the *P.phycis* are very scarce.

Despite its wide distribution, most data on biology of this species, such as feeding, reproduction and age and growth are limited to the Atlantic Ocean, namely the Azores Islands (Morato *and al*., 1999; Costa Abecasis *and al.*, 2009), the Portuguese coasts (Mendes *and al*., 2004; Vieira *and al*., 2013), and to the Adriatic Sea (Dulčić and Kraljević, 1996; Matić-Skoko *and al*., 2011;) and the Mediterranean Sea (Morey *and al.*, 2003; Karakulak *and al.*, 2006; Valero *and al*., 2006).

In the Eastern Tunisian coasts, only one study has examined a single study focused the anisakid nematode parasites of *P. phycis* (Farjallah *and al*., 2006). Little is known on about the biology of this economically exploited species along off the Tunisian coast. Basic and biological information are required for the sustainable management of the stock. This paper aims to determine the age and growth of forkbeard from samples collected in the Gulf of Tunis (north Tunisian coasts) and to compare the present results on age and growth parameters with those reported from other geographic areas.

MATERIEL AND METHODS

A total of 272 individuals were collected monthly between September 2007 and June 2010 from the contribution of commercial fishing in the Gulf of Tunis. In the laboratory, total length (TL in cm) and total weight (TW in grams) were measured for each specimen.

The length-weight relationship was performed by the equation: $TW = a.TL^b$ (Ricker, 1975), Then, the fish otoliths are cleaned, dried, weighed (Wo, precision 0.001 mg) and are stored in paper envelopes until the date of their setting out resin.

Otoliths of *Phycis phycis* are opaque and too thick, thus the rings of growth are not clearly identifiable by simple direct lecture. So, it is necessary to carry out mean cross sections, passing through the core (*nucleus*) of the otoliths.

The right otolith were immersed in black polyester resin and cut in thin slices with a high speed cutting automatic Slicer brilliant 250® of Escil. Whole sections were viewed under a binocular magnifying glass connected to a numeric camera coupled to a computer equipped with image processing software TNPC (Digital Processing of the Calcified parts, software developed by IFREMER). The observation of annuli is carried out under reflected light. During the reading, alternations of opaque and translucent zones were checked by two readers. It was assumed that annulus formation began 1st January corresponding to the peak of the species spawning. The periodicity of ring formation in otoliths was checked by calculating increase between the last and the before last ring or marginal increment:

$$MI = R\text{-}r_n / r_n\text{-}r_{n-1}$$

Where R is otolith radius, r_n is the distance between the edge and the last growth ring and r_{n-1} is the distance between the edge and the second last growth ring.

The monthly evolution of marginal increment allows to fix the season of the annuli appearance and to know its periodicity.

Many mathematical models translating the length growth according to their ages; we propose the most used one: the model of von Bertalanffy (1938):

$$L_t = L_\infty (1 - e^{-k (t - t_0)})$$

$$W_t = W_\infty (1 - e^{-k (t - t_0)})^3 \text{ with } W_\infty = a\, L_\infty^{\,b}$$

(Ricker, 1975)

With k: the growth constant, Lt: length-at-age, L_∞: the predicted asymptotic length, W_∞: the predicted asymptotic weight, t_0: the age at zero length and W_t: the weight at age.

Moreover, indexes were developed to analyse the growth such as: Index of performance of growth Φ (in $cm.year^{-1}$) (Pauly and Munro, 1984) that allows the comparisons of the growth between different populations from the same species and between several species: $\Phi = \log(K) + 2\log(L\infty)$, where k and L_∞ are the parameters of von Bertalanffy equation.

The determination of the parameters of the model (L_∞, k and to) and all the statistical analyses were conducted using the open-source statistical package "R" (http://www.r-project.org/) and the text editor chock R (http://sourceforge.net/projects/tinn-r/).2007

RESULTS

The total sample of272 individuals is composed of 38males (14%) and 205 were females (75.34%). The sex of the remaining 29 individuals could not be macroscopically determined because they had immature gonads (10.66%). Females ranged in size from 14.5 to 51.5 cm TL and males ranged from 20.9 to 55.5 cm TL (Fig.1). The mean total length of females (TL =28.95 ± 1.7 cm) was not significantly different (Mann-Witney U test; n= 243; p = 0.38) from that of males (TL =32.5 ± 2.5 cm). Immature individuals were found at TL between 19.2 and 26.6 cm (TL =23.5 ± 1.2 cm). The total weight of fish was between 45 and 1473 g (TW = 308.61 ± 7.8 g) for females, between 90 and 1779 g (TW = 431.7 ± 8.6 g) for males and between 71 and 207 g (TW = 126.35 ± 3.5 g) for undetermined sex. Mean total weight was not significantly different between sexes (Mann-Witney U test; n= 243; p = 0.51).

Length-weight relationship:

Length-weight regression parameters estimated for males, females and the whole sample are presented in table I. The statistical analysis indicate a major allometry for females ($TW= 83.10^{-4}*TL^{3.070}$), males ($TW = 63.10^{-4}*TL^{3.147}$) and for the total sample ($TW = 82.10^{-4}*TL^{3.075}$). The length-weight relationship, showed that there is no significant

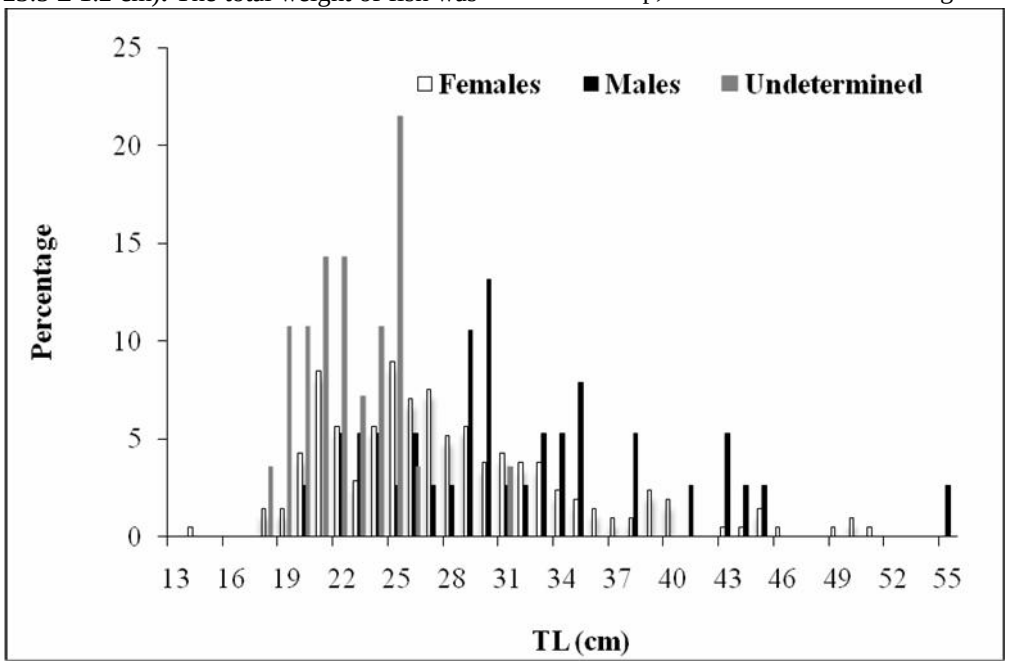

Fig 1. : Length-frequency distribution of undetermined, males and females of *Phycis phycis* from the Gulf of Tunis.

Table I. Parameters of the length-weight relationships for females, males and all individuals of *Phycis phycis* in the Gulf of Tunis.

Sex	a	b	Se (b)	n	r²	p	Growth type
Males	63.10^{-4}	3.147	0.077	38	0.978	0.00	A+
Females	83.10^{-4}	3.070	0.038	205	0.968	0.00	A+
Total	82.10^{-4}	3.075	0.034	243	0.970	0.00	A+

a: intercept, b: slope, s.e (b): standard error of b, n:sample size, r²:coefficient of determination.

difference between males and females (ANCOVA, p = 0.426) and consequently the total sample showed an isometry between length and weight.

Symmetry of otoliths and fish size relationships

Symmetry between the right and left otolith was compared. Fish total length (TL) and weight of the otolith (Wo) were closely correlated (r^2=0.913) (Fig.2). The relation between total length of fish versus weight of the right (Wo = 0.12 TL - 0.163) and left (Wo = 0.11 TL - 0.124) otolith did not show a significant difference (ANCOVA, p > 0.05).

A power relationship was estimated between total length versus otolith radius. The linear regression between the log-radius of the otolith and the log-total length of the fish indicate a good correlation between the two variables (r = 0.932) (Fig.3).

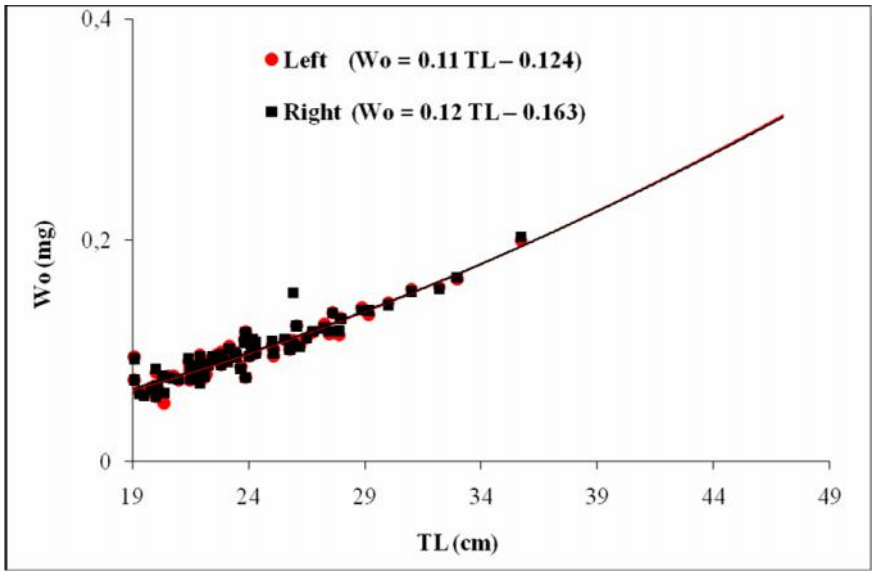

Fig 2. : Linear regression between TL/Wo of *Phycis phycis*.

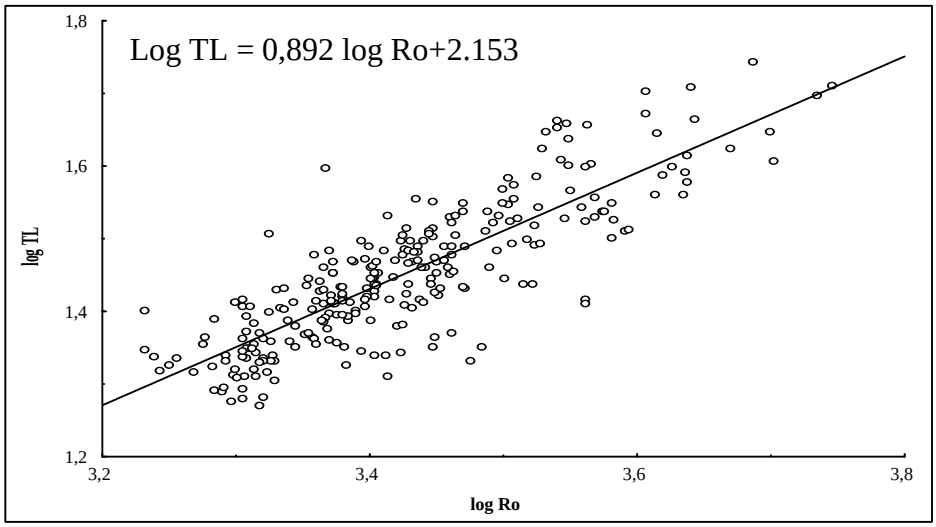

Fig 3. : Relationships between otolith radius (Ro) and total length (TL) in cm of *Phycis phycis* of the Gulf of Tunis.

Relation Age-Ro

The relationship between otolith *radius* and age showed that there are no significant differences between males, females and all individuals (Fig.4.A). Moreover, the comparison of the relation Age-Ro for males and females didn't show a significant differences between slopes and intercept (ANCOVA, $p = 0.512$).

Relation Age-Wo

The gender analyse for relationship between otolith weight (Wo) with age, did not show a significant differences between males, females and all individuals. However, the weight of the male otolith grew faster than females ones (Fig.4.B). On the other hand, the differences were statistically significant between slopes and intercepts for males and females (ANCOVA, $p = 0.0084$).

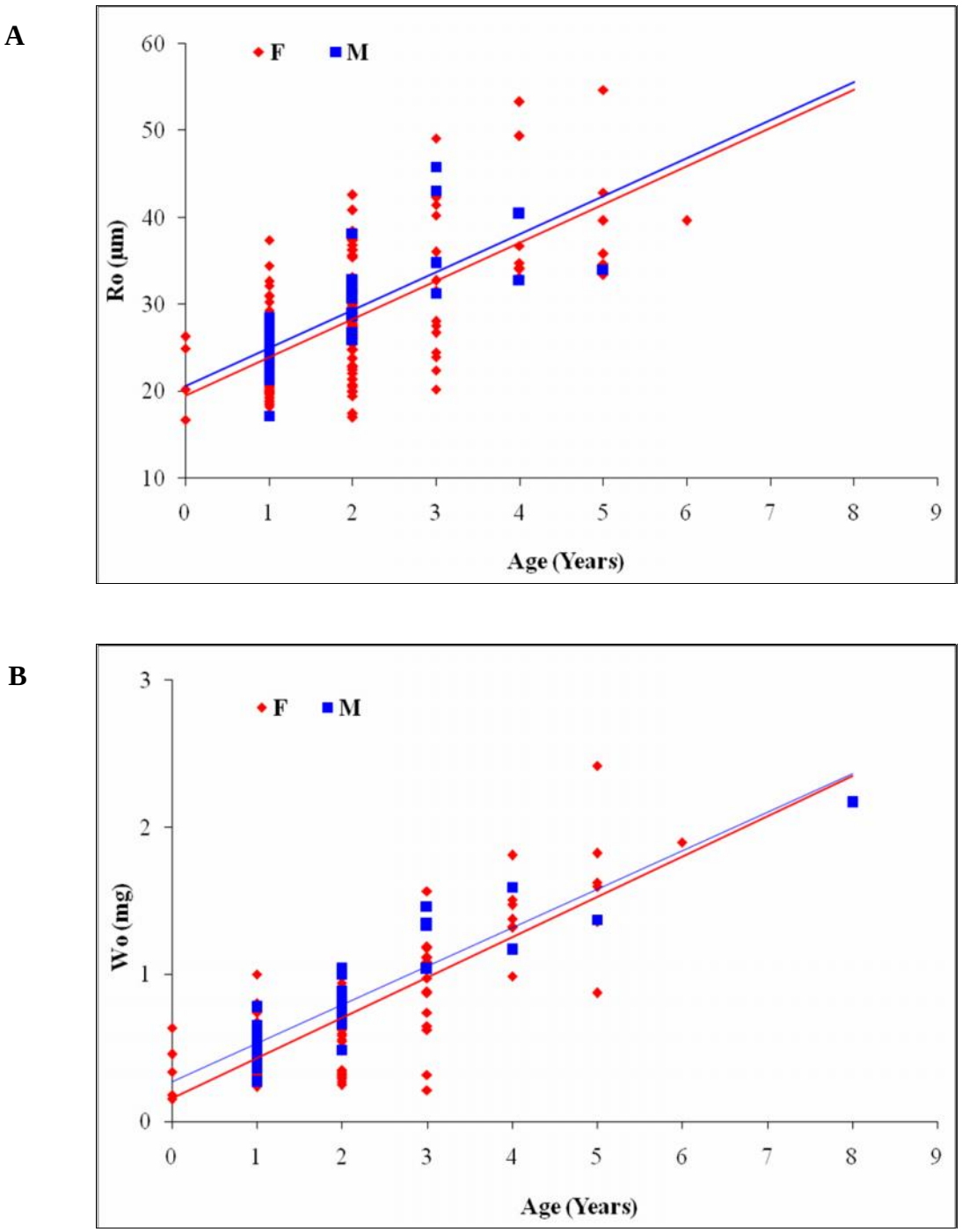

Fig 4. : Relationship between radius Ro (**A**) and weight Wo (**B**) otolith to age for *Phycis phycis* of the Gulf of Tunis.

Age and growth

All sectioned otoliths had opaque and translucent zones. These zones appeared on all axes, but were clearest in the dorsal area of the otolith. Most otoliths showed several check rings and double bands in the ventral area. The *nucleus* itself was usually delimited by a distinct translucent growth increment.This first ring considered as "demersal" check, was characteristically more distinct and less broader than subsequent translucent zones was interpreted as a transition (demersal) zone, formed as a result of a change in diet/environment from a pelagic to a demersal habit. But, we have no information to confirm this interpretation.

Marginal increments were measured for males and females. The active period of marginal increment is located between October and January. The lowest monthly mean marginal increments were recorded in May-June (Kruskal-Wallis test, p=0.39). A single *annulus* was formed per year (Fig.5).

The age-length relationship was studied from the age-length key (Table II). Estimated Ages were ranged between 0 and 8 years; the minimum observed length, corresponding to age 0 was 23 cm. The growth function indicated that the males and females grow rapidly during the first 2 years and reached a size (TL) of about 32 cm for males and 31 cm for females. The von Bertalanffy growth equations fitted to fish length and age data were: $TL = 67.51\ (1 - e^{-0.168\ (t+1.993)})$ for males and $TL = 73.43\ (1 - e^{-0.158\ (t+1.709)})$ for females.The *P. phycis* growth curves were similar for the two sexes till the3 years old (Fig.6). Consequently, the index of performance for females (Φ=2.9 cm/year) is identical with that of males (Φ=2.8 cm/year).

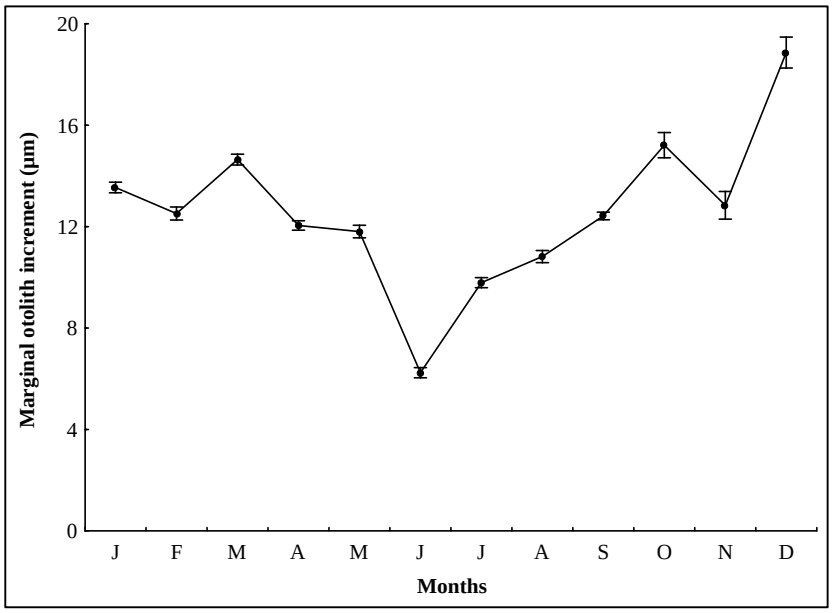

Fig 5. : Mean monthly marginal increments of otoliths for *Phycis phycis* of the Gulf of Tunis.

DISCUSION

In spite of the sampling effort, samples were not representative for the entire population size structure with small individuals (<14.9 cm TL) as well as individuals larger than 55.5 cm TL being scare, as a result of the long line size selectivity and the natural scarceness of larger individuals in the populations.

The weight-length relationships parameters for *P.phycis* from different areas are given in table III. The slope coefficient varied between 3.001 and 3.500 showing that the type of growth is a positive allometry for both males and females. The weight-length relationship is a practical index of the condition of fish (Mouine *and al.*, 2010). Changes in fish shape, physiological changes, hydrological environmental conditions, different food availability during life and biological span, growth increment or break in growth can all influence the growth exponent b (Torcu-Koc *and al.*, 2004).

Age estimation in fishes is complicated by the phenomenon of "stacking" of growth zones towards the otolith margin, particularly in older fish; in many cases age determination is difficult because whole otoliths are so thick that light does not pass through (Buxton and Clarke, 1991). The otoliths of *P. phycis* have a ring pattern common to teleost fishes. Marginal increment analysis demonstrated that one *annulus*, consisting of one opaque zone and one hyaline zone, is formed annually. These rings are believed to be deposited during periods of fast and slow growth, respectively. Seasonal growth cycles might be related to physiological changes produced by the influence of temperature, feeding habits and reproductive cycle (Morales-Nin and Ralston, 1990). The von Bertalanffy growth model reveals the reduction of somatic growth and the formation of the hyaline zone during May and June. The high correlation found between TL and otolith *radius* indicates that otoliths are a useful structure for estimating the age and for indicating the past growth history of Forkbeard. The use of the von Bertallanfy

Table II. Age-length key for females and males of *Phycis phycis* of the Gulf of Tunis.

Age	1		2		3		4		5		6		8	
Sex	F	M	F	M	F	M	F	M	F	M	F	M	F	M
Length (cm)														
15														
19	4													
20	3													
21	7	1	2											
22	15		3		1									
23	8	2	3		1									
24	4	1	2	1										
25	10	2	2											
26	17	1	2											
27	12	2	3											
28	15	1												
29	7	1	4											
30	3	2	6	2	3									
31	3	3	5	2										
32	2		7	1										
33			6	1	2									
34	1		7	2										
35			4	2			1							
36	1		1	3	2									
37	1				2									
38					2									
39			1		1	1		1						
40	1		1		2		1							
41			1				2							
42						1	1							
44					1	1		1						
45									1	1				
46						1	1		2					
47									1					
50							1							
51									1		1			
52									1					
56														1
Mean (cm)	25.63	27.01	30.13	32.47	34.41	42.6	41.98	41.45	47.61	45	50.5			55.5
s.e	0.35	0.80	0.60	0.87	1.45	1.60	1.85	2.85	1.24	-	-			-
N	114	16	60	14	17	4	7	2	6	1	1			1

model to describe growth has been criticized for several reasons (Booth, 1997). These include the use of parameters that have a little biological meaning (Schnute, 1981) and the absence of parameters that take into account seasonal changes in growth rate (Pauly, 1980; Moreau, 1987). Nevertheless, the von Bertallanfy growth model has been used extensively to describe the growth of Forkberad. The growth model provides a simple description of growth which can be compared between species and group of species (Booth, 1997).

The von Bertalanffy parameters estimated for the Forkbeard showed that it has a relatively slow growth reaching 8 years old. Although the maximum TL

Table III. Parameters of the length-weight relationship of *Phycis phycis* by authors and study area.

Authors	Localities		N	min	max	a. (10^{-4})	b	s.e. (b)	r^2
Papaconstantinou *and al.* (1989)	Kastellorizo area		270	18	52	0.01	3.001	-	-
Dulčić and Kraljević (1996)	Eastern Adriatic (Croatian waters)		58	26.2	56.4	0.002	3.5	0.108	0.97
Morato *and al.* (2001)	Azores, north-eastern Atlantic		42	11.1	59.5	69	3.13	0.044	0.99
Morey *and al.* (2003)	Western Mediterranean		96	10.6	48.4	45	3.26	0.098	0.98
Mendes *and al.* (2004)	Portuguese west coast		45	17.2	50.5	64	3.14	-	0.97
Karakulak *and al.* (2006)	North Aegean Sea (Turkey)		59	13.7	44.5	52	3.18	0.045	0.98
Vieira *and al*. (2013)	Portuguese continental waters	Males	317	-	-	42	3.25	-	0.99
		Females	368	-	-	49	3.22	-	0.98
Present study	Gulf of Tunis	Males	38	20.9	55.5	63	3.147	0.077	0.97
		Females	205	14.5	51.5	83	3.070	0.038	0.96
		All sample	243	14.5	55.5	82	3.075	0.034	0.97

n: simple size; min and max: minimum and maximum total length (TL); a and b: parameters of the relationship; s.e (b): standard error of the slope b; r^2: coefficient of determination.

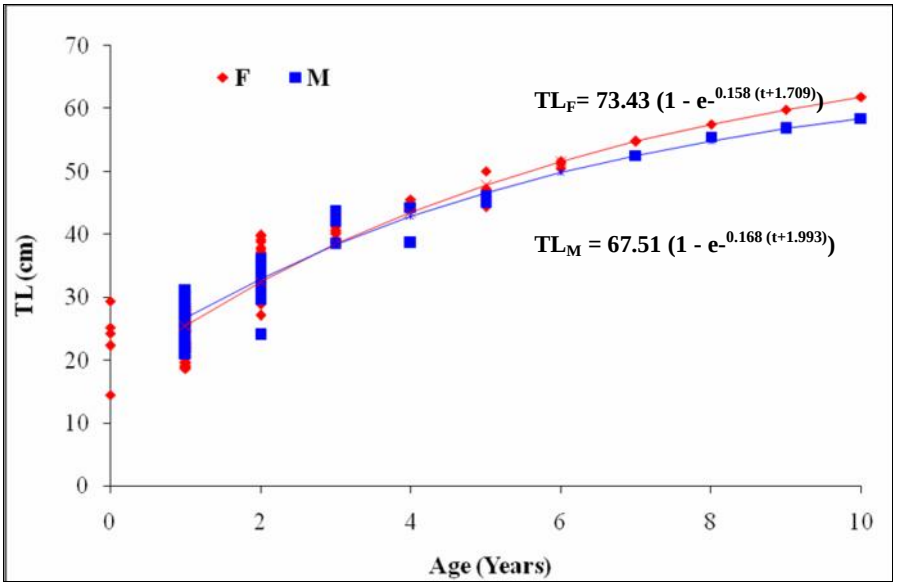

Fig 6. : The von Bertalanffy curve estimated for the males (M) and females (F) of *Phycis phycis* of the Gulf of Tunis.

recorded in the present study was 55.5 cm, the historical record of 74 cm TL (Pinho, 2003) is close to the estimated L_∞ of 65.73 cm. The Forkbeard did not show dimorphism in growth, even though differences in growth between sexes are a common feature among related gadidae such as *Phycis blennoides* (Casas and Piñeiro, 2000). In addition, when we compare the parameters obtained by this study with those of literature in different geographic areas, we become aware of large differences in L_∞,k and t_0(Table IV). The historical records prior to this study were: 79.6 cm (Costa Abecassis *and al.*, 2009) and 74.14 cm (Vieira *and al.*, 2013). They were different to the L_{∞} estimated for combined sexes (65.73 cm). The maximum age observed in this study is very different from that reported for the Portuguese continental waters, where the maximum age reported was 18 years old.

Table IV. Biogeographic comparison of von Bertalanffy growth function parameters and growth performance index (Φ) of *Phycis phycis*.

Authors	Localities	Sex	TL_∞ (cm)	k (year^{-1})	t_0 (year)	N
Costa Abecassis *and al.* (2009)	Azorean archipelago, North Atlantic	All sample	79.60	0.09	1.88	477
		Males	85.30	0.08	2.31	241
		Females	80.50	0.09	1.53	227
Mati´c-Skoko *and al*. (2011)	South-eastern Adriatic Sea (Elafiti Islands)	Males	75.18	0.15	0.70	254
		Females	59.08	0.24	0.33	385
Vieira *and al*. (2013)	Portuguese continental waters	All sample	74.14	0.10	2.09	687
		Males	74.84	0.10	2.00	318
		Females	75.56	0.10	2.19	369
Present study	Gulf of Tunis	All sample	65.73	0.135	2.02	272
		Males	67.51	0.168	1.99	38
		Females	73.43	0.158	1.71	205

TL∞: asymptotic length; k: growth coefficient; t_0: theoretical age at zero length; N: sample size.

BIBLIOGRAPHY

Bouhlel M., 1979 - Les Gadidés des côtes Tunisiennes : Systématique, Répartitionet associations écologiques. *Bull. Inst. Natn. Scient. Tech. Océanogr. Pêche Salammbô*., 6: 5-40.

Booth A. J., 1997 – On the life history of the lesser gurnard (Scorpaeni-formes : Triglidae) inhabiting the Agulhas Bank, South Africa. *J. Fish. Biol*., 51: 1155-1173.

Buxton C. D. & Clarke J. R., 1991 – The biology of the white mussel cracker *Sparadon durbanensis* (Pisces: Sparidae) on the Eastern Cape Coast, South Africa. S. Afr. *J. Mar. Sci*., 10: 285-296.

Casas J.M & Piñeiro C., 2000 - Growth and age estimation of greater fork-beard (Phycis blennoides Brünnich, 1768) in the north and northwest of the Iberian Peninsula (Ices Division VIIIc and IXa). *Fish. Res*., 47: 19-25.

Cohen D.M., Inada T., Iwamoto T., & Scialabba N., 1990 - FAO species catalogue. Vol. 10. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. FAO Fish. Synop., 10 (125), 442 pp.

Costa Abecasis A.R., Canha A., Reis D., Ruio Pinho M., & Gil-Pereira J., 2009 - Age and growth of the forkbeard *Phycis phycis* (Gadidae) from the Azorean archipelago, North Atlantic. *J. Mar. Biol. Ass. U. K*., 89 (3): 629–633.

Dulčić J., & Kraljević M., 1996 - Weight–length relationships for 40 fish species in the eastern Adriatic (Croatian waters). *Fish. Res*., 28: 243-251.

Farjallah S., Ben Salimane B., Bilel H., Amor N., & Khaled S., 2006 - Anisakid parasites of two forkbeards (*Phycis blennoides* and *Phycis phycis*) from the eastern Mediterranean coasts in Tunisia. *Parasitol. Res*., 100: 11–17.

Fisher W., Schneider M., & Bauchot M.L., 1987 - Fiches FAO d'Identification des espèces pour les besoins de la pêche (Révision 1). Méditerranée et mer Noire. Zone de pêche 37. Vol. II. Vertébrés, FAO, Rome, pp.1530.

Karakulak F.S., Erk H., & Bilgin B., 2006 - Length–weight relationships for 47 coastal fish species from the northen Aegean Sea, Turkey. *J. Appl. Ichtyol*., 22: 274-278.

Matić-Skoko S., Ferri J., Škeljo F., Bartulović V., Glavić K., & Glamuzina B., 2011 - Age, growth and validation of otolith morphometrics as predictors of age in the forkbeard, *phycis phycis* (Gadidae). *Fish. Res*., 112: 52-58.

Mendes B., Fonseca P., & Campos A., 2004 - Weight–length relationships for 46 fish species of the Portuguese west coast. *Journal of Applied Ichtyology*. 20, 355-361.

Morales-Nin B., & Ralston S., 1990. – Age and growth of *Lutjanus kasmira* (Forskal) [sci] in Hawaiian waters. *J. Fish. Biol*., 36: 191-203.

Morato T., Solà E., Grós M.P., & Menezez G., 1999 - Diets of forkbeard (*Phycis phycis*) and conger eel (*Conger conger*) off the Azores during spring of 1996 and 1997. *Arquipélago. Life and Marine Scienc*G. *es*., 17A: 51-64.

Morato T., Afonso P., Lourinho P., Barreiros J.P., Santos R.S.,& Nash R.D.M., 2001- Length–weight relationships for 47 coastal fish species of the Azores, north-eastern Atlantic. *Fish. Res*., 50: 297-302 pp.

Morey G., Moranto J., Massuti E., Grau A., Linde M., Riera F., & Morales-Nin B., 2003 - Weight–length relationships of littoral to lower slope fishes from the western Mediterranean. *Fish. Res.*,62: 89-96.

Moreau J., 1987 – Mathematical and biological expression of growth in fishes: recent trends and further developments. *In* Age and growth of fish (R. C. Summerfelt and G. E. Hall, eds.), p. 81-113. Iowa State Univ. Press, Ames, IA.

Mouine N., Ktari M.H.,& Chakroun-Marzouk N., 2010 - Age and growth of *Diplodus vulgaris* (Sparidae) in the Gulf of Tunis. *Cybium*., 34 (1): 37-45.

Papaconstantinou C.,& Caragistou E., 1989- Feeding interaction between two sympatric species *Pagrus pagrus* and *Phycis phycis* around Kastellorizo Island (Dodecanese, Greece). *Fish. Res*., 7: 329-342.

Pauly D., 1980 – on the interrelationships between natural mortality, growth parameters, and mean enviromental temperature in 175 fish stocks. *J. Cons. Int. Explor. Mer*., 39: 175-195.

Pauly D., & Munro J.L., 1984 - Once more on the comparison of growth in fish and invertebrates. *ICLARM Fishbyte*., 2 (1): 21.

Pinho M. R., 2003 – Abundance estimation and management of Azorean demersal species. PhD thesis. Department of Oceanography and Fisheries, University of the Azores, Horta, Portugal.

Quéro J.C., Porché P., & Vayne J.J., 2003 - Guide des poissons de l'Atlantique européen, Delachaux and Nieslé. 465 p.

R Development Core Team, 2007. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URLhttp://www.R-project.org.

Ricker W.E., 1975 - Computation and interpretation of the biological statistics of fish populations. *Bull. Fish. Res. Board. Canada*., 191: 1-382.

Schnute J., 1981 – A versalite growth model with statistically stable parameters. Canadian J. *Fsh. Aqua. Scien*.. 38: 1128-1140.

TNPC 5.0 : Traitement Numérique des Pièces Calcifiées, URL http://www.tnpc.fr.

Torcu-Koc H., Türker-Cakir D.,& Dulčić J., 2004 - Age, Growth and mortality of the Comber, Serranus Cabrilla (Serranidae) in the Edremit Bay (New Aegean Sea, Turkey). *Cybium*., 28 (1): 19-25.

Valero A., Paniagua M.I., HierroI., Díaz V., Valderrama M.J., Benítez R., & Adroher F.J., 2006 -Anisakid parasites of two forkbeards (*Phycis blennoides* and *Phycis phycis*) from the Mediterranean coasts of A ndalucía (Southern Spain). *Parasitol. Inter*., 55: 1-5.

Vieira A. R., Neves A., Sequeira V., Paiva R. B. & Gordo L. S., 2013 – Age and growth of forkbeard, *Phycis phycis* in Portuguese continental waters. *J. Mar. Biol. Ass. U. K*., 94: 623-630.

Von Bertalanffy., 1938 -A quantitative theory of organic growth (inquires on growth Laws II). *Hum. Biol*., 10(2): 181-213.

Whitehead P.J.P., Bauchot M.L., Hureau J.C., Nielson J., & Tortonese T., 1986 -Fishes of the North-eastern Atlantic and the Mediterranean. UNESCO, Paris., Vol.I-III: 1473 p.