LENGTH - WEIGHT RELATIONSHIP AND CONDITION FACTOR OF *PHYCIS PHYCIS* (Linnaeus, 1766) AND *PHYCIS BLENNOIDES* (Brünnich, 1768) [Actinopterygii, Gadiform, Phycidae] IN THE GULF OF TUNIS

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الملخص

دراسة العلاقات بين الطول و الوزن و مؤشر اللياقة البدنية للأسماك من نوع Phycis phycis و Phycis blennoides في خليج تونس

يهدف هذا العمل إلى تحليل العلاقات بين الوزن و الطول و دراسة التغيرات الجملية و الفصلية بين الجنسين لمؤشر اللياقة البدنية للأسماك من نوع " " بالسواحل التونسية. تضم العينات التي تم جمعها بصفة شهرية، في الفترة الممتدة بين سبتمبر 2007 و أوت 2008 270 *Phycis blennoides* 213 *Phycis phycis*.

وقع تطبيق المعادلة بين الطول الكامل و الوزن الكلي على هذين النوعين و هي كالآتي $LT = a \, b$ LT.

و قد تبين أن نسق نمو الطول و الوزن متساويان بالنسبة *Phycis phycis* فإن الوزن ينمو *Phycis blennoides*. كما أفضت دراسة التغيرات الفصلية إلى أن نسق نمو الطول و الوزن متساويان خلال جميع الفصول غير أن الأسماك من نوع *Phycis blennoides* متساوية النمو خلال فصل الصيف فصل الشتاء و الخريف و فى فصل الربيع لاحظنا أن وزن هذه الأسماك ينمو أكثر من الطول الكامل.

كما يتغير معدل مؤشر اللياقة البدنية $100LT \, a^{b-3}$ = k moyenne الأشهر.

الكلمات المفاتيح: *hycis hycis*, *Phycis blennoides*, العلاقة بين الطول و الوزن, , مؤشر اللياقة البدنية.

RESUME

Relations taille-masse et facteur de condition chez *Phycis phycis* (Linnaeus, 1766) et *Phycis blennoides* (Brünnich, 1768) [Actinoptérygiens, Gadiformes, Phycidae] dans le Golfe de Tunis : La présente étude est conçue pour évaluer les relations taille-masse et déterminer le facteur de condition en fonction des sexes et des saisons chez deux espèces de Phycidae *Phycis blennoides* et *Phycis phycis*. Les échantillons ont été collectés, mensuellement, entre septembre 2007 et août 2008 à partir des apports de la pêche commerciale dans le golfe de Tunis ; un total de 270 spécimens de *P. blennoides* et de 213 *P. phycis* a été examiné.

Les coefficients de détermination « r^2 » des relations taille-masse globales sont proches de 1 ($r^2 > 0.92$, $p < 0.001$) indiquant une bonne corrélation de ces deux paramètres. L'analyse statistique globale montre que la croissance est isométrique ($t < 1,96$; $p > 0,05$) pour *P. phycis* alors qu'elle présente une allométrie majorante chez *P. blennoides*. L'étude des variations saisonnières de la relation taille-masse indique que la croissance est isométrique chez *P. phycis* quelque soit la saison. Chez *P. blennoides*, pendant les saisons estivale, automnale et hivernale, la croissance est isométrique ; cependant au printemps la croissance présente une allométrie majorante ($t > 1,96$; $p > 0,05$). Le facteur de condition calculé en fonction des sexes et des mois confirme bien ces constatations.

Mots clés: *Phycis phycis*, *Phycis blennoides*, relation taille-poids, croissance, facteur de condition.

ABSTRACT

In our study length-weight relationship are presented for 213 *Phycis phycis* and 270 *Phycis blennoides* caught between September 2007 and August 2008 and collected from trawler fishing in the Gulf of Tunis. The length-weight relationships and the condition factor were computed separately for sexes and for different seasons. The parameters of the length-weight relationship for the population as a whole are all well correlated ($r^2 > 0.92$, p <

0.001). The type of growth is isometric for *P. phycis* while it is majorant allometry for *P. blennoides*. The comparison of the regression of the weight according to the total length of males and females, of the two species, shows that the growth is therefore identical. The study of seasonal variations indicates that the slope did not differ significantly (p > 0.05) between seasons for *P. phycis*. However, it differs significantly (p < 0.05) for *P. blennoides*; during the summer season, autumn and winter, where the growth is isometric; however in the spring it presents a majorant allometry. The condition factor was calculated according to sex and months and confirmed respectively these results.

Keywords: Phycis phycis, Phycis blennoides, length- weight, growth, condition factor.

INTRODUCTION

The Gadidae fish family is represented in the Mediterranean Sea by twelve species (Fisher *et al.*, 1987), eight of which are reported to the Tunisian coasts. *Phycis phycis* (Linnaeus, 1766) and *Phycis blennoides* (Brünnich, 1768) are the most frequent species of the Tunisian coast, while the other species are sparse.

Several studies describing various aspects of feeding habits have been conducted for *P. phycis* and *P. blennoides* in the Atlantic (Sorbe, 1977; Morte *et al.,* 2002; Morato *et al.*, 2001) and in the Mediterranean (Papaconstantinou & Caragistou, 1989). The reproductive biology has been studied especially in Mediterranean Sea and concerned especially the *P.blennoides* (Gallardo-Cabello & Gual-Frau, 1984; Matarrese *et al.*, 1998). Due to the low commercial interest of this family in the Tunisian coast, the catches statistics of this species were unfortunately not available. Data on biological aspects are very scare and concern only bathymetric distribution (Bouhlel, 1979) and parasitology (Farjallah *et al.*, 2006).

Fisheries management and research often require the use of biometric relationships in order to transform data collected in the field into appropriate indexes (Anderson & Gutreuter, 1983). One of the most commonly used in any analysis of fishery data is the length-weight relationship, allowing to estimate the biomass from length. It also provides information on the condition of fish, which is frequently used for interregional comparisons (Moutopoulos & Stergiou, 2002).

The present study was carried out to describe for the first time the length- weight relationship of two species *P. blennoides* and *P. phycis* in the Gulf of Tunis. The length-weight relationship and the condition factor (K) were calculated monthly and separately according to the sexes. The optimal length was also provided, and finally an interspecific comparison between the two species was established.

MATERIAL AND METHODS

Samples were collected, monthly, between September 2007 and August 2008 from the commercial fishing in the Gulf of Tunis (Fig.1). A total of 270 specimens of *P. blennoides* and 213 *P. phycis* were examined; the total length and the total weight varied from 19.5 to 55.5 cm (44 to 1779 g) and from 16.8 to 47.7 cm (30 to 967g) respectively.

In the laboratory, total length (TL) (in cm), total weights (TW), and eviscerate weights (EW) (in grams) were measured. The sexes were separated after a macroscopic determination of the gonads; when the gonads were thin and poorly developed the fish sex was considered as undetermined.

The relations between the length (TL) and weight (TW) of a fish were expressed by the equation $W = aTL^b$, where W is the total weight, TL is the total length, (a) is the coefficient related to body form and (b) is an exponent indicating isometric growth when equal to 3 and allometric growth when different to 3 (the allometry is majorant if b > 3 and minorant if b < 3) (Froese, 2006). The parameters (a) and (b) of the length–weight relationship was estimated by the least-square method, using W as the dependent variable and TL as the independent variable, $\log (W) = \log (a) + b \log (TL)$. The b-value for each species was tested by Student t-test to verify if it was significantly different from the predictions for isometric growth (b = 3). For each studied species, the comparison of slopes and intercepts of regression lines of the length-weight relationship was conducted by analyzing the covariance (ANCOVA) (Zar, 1999). For each species, we determined the length-weight relationship for males, females, all individuals grouped and according to seasons where:

Autumn: September, October and November 2007
Winter: December 2007, January and February 2008
Spring: March, April and May 2008

Fig. 1: Map of the Gulf of Tunis (the sampling area).

Summer: June, July and August 2008
The Condition Factor for was calculated according to the formula (Clark, 1928):

$$K_m = 100 \times a \times TL^{b-3}$$

We undertook a graphical comparison of length-weight relationship for assessing variation space for growth in these regions. Different equations have been developed and weight values are included only within the limits of validity of lengths for which it was calculated.

RESULTS

Structure of sampling
Among the 213 *P. phycis* individuals, 26 were undetermined, 32 males and 155 females, with a total length ranging from19.5 to 32.2 cm, from 22.5 to 55.5 cm and from 19.8 to 51.5 cm respectively (Fig. 2). Among the 270 fish of *P. blennoides*, 61 were undetermined, 25 males and 184 females with total length ranging from16.8 to 23.9 cm, from22 to 35.5 cm and from17.5 to 47.7 cm respectively (Fig. 2).
Variations of the parameters of the length-weight relationship
The coefficients of determination "r²" of the total length-weight relationship are close to 1, reflecting a good correlation between the two parameters (Table I). The slope of these regressions is not significantly different from the theoretical value 3 (p > 0.05). The relations, implying the total (TW) and eviscerate

(EW) weights, compared to the length show that the type of growth is isometric for *P. phycis* while it present a majorant allometry for *P. blennoides*.
The statistical analysis shows that the type of growth is isometric (p > 0.05) for the females of *P. phycis*, whereas it presents a majorant allometry for males and a minorant allometry for the undetermined individuals (t > 1.96; p > 0.05).
For *P.blennoides*, the results show that the growth is isometric for males and undetermined individuals. In the other hand, for females the weight seems growing faster than the total length (t = 2.47; p > 0.05).
The statistical comparison of the regression of the total (TW) and eviscerated (EW) weights according to the total length (TL) of males and females, of the two species, shows that there are no significant differences (ANCOVA, p > 0.05).
Seasonal variations of the parameters of the length-weight relationship
Correlation coefficients of different length-weight relationships are all highly statistically significant (p < 0.001), whatever the season. For the *P. blennoides*, during summer, autumn and winter, the growth is isometric; however in spring the growth presents a majorant allometry (Table II).
Variations of the factor of condition
For *P. phycis*, condition factor fluctuation's of females are larger than males and undetermined; while, the males of small sizes have the highest factor of condition (Fig.3). However, for *P. blennoides*, the study of variations of this factor
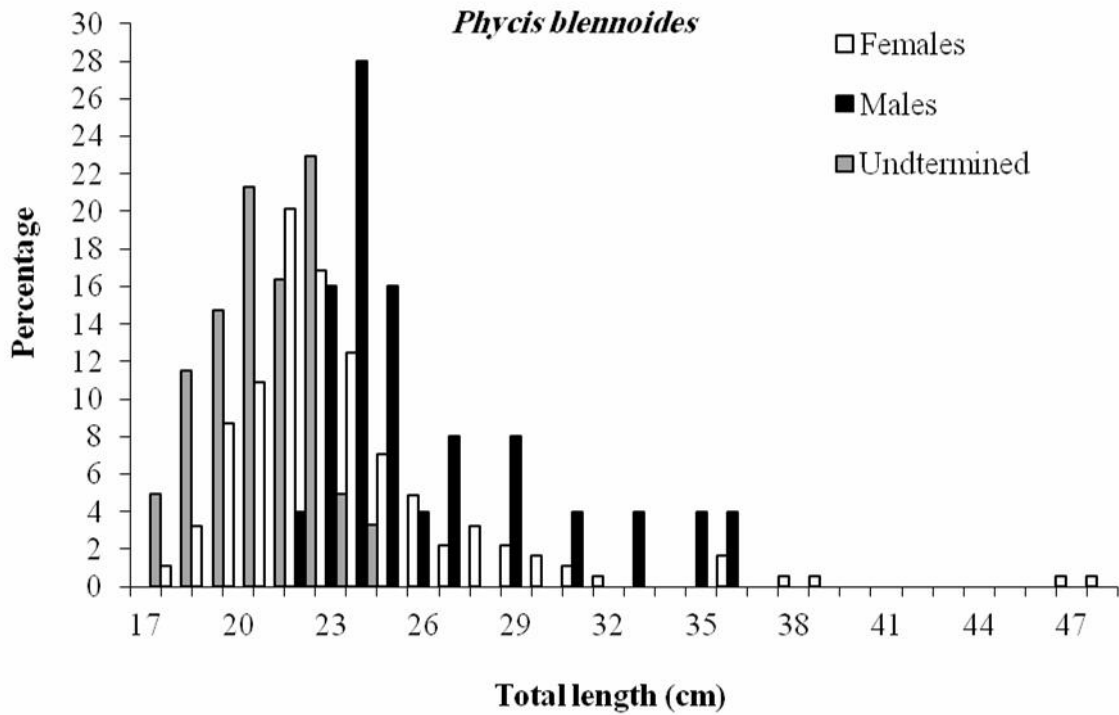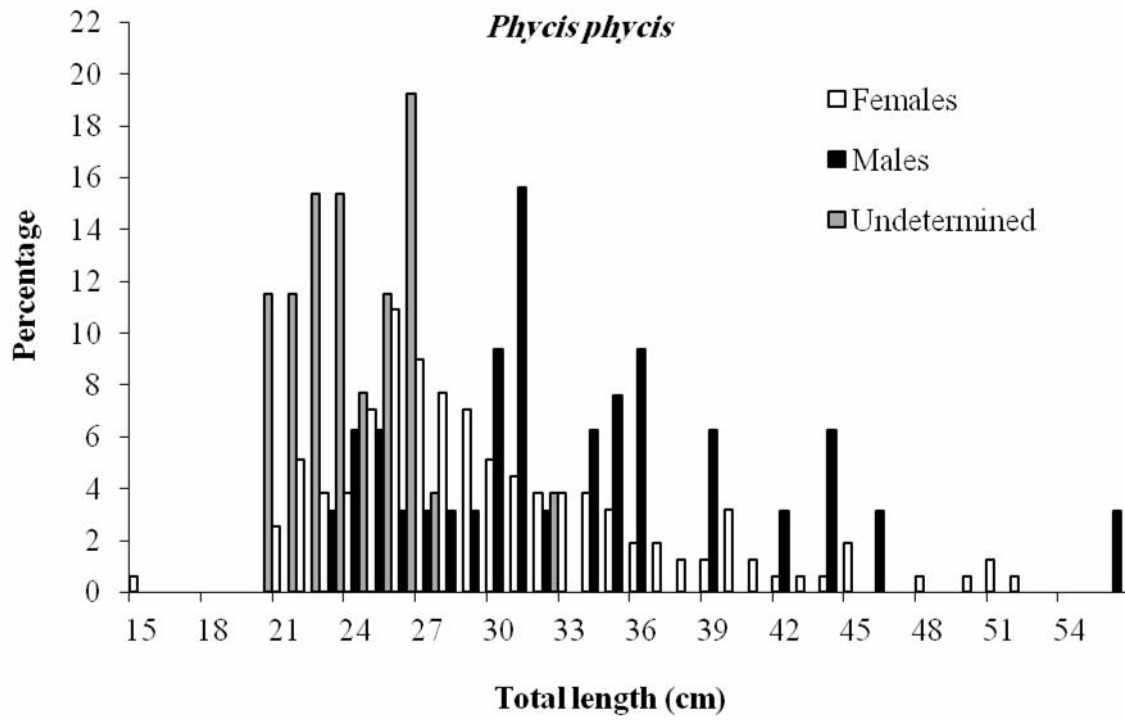
Fig. 2: Total length frequency distribution of *P.phycis* and *P.blennoides* samples from the Gulf of Tunis.

Table I : Length-weight relationship parameters according sexes for *P.phycis* and *P.blennoides* from the Gulf of Tunis.

	Sexes	N	a	b	se (b)	r^2	Total length (cm)			Weight (g)			test t	Growth type
							Min	Max	Mean ± se	Min	Max	Mean ± se		
P.Phycis	Males	32	0.005	3.189	0.052	0.974	22.5	55.5	33.07 ± 1.30	114	1779	449.26 ± 64.10	1.98	Allometric positive
			0.005*	3.199*	0.053*	0.973*				103*	1655*	413.90 ± 59.33*	2.03*	Allometric positive
	Females	155	0.008	3.083	0.024	0.887	19.8	51.5	30.05 ± 0.54	16	1610	341.9 ± 23.03	0.93	Isometric
			0.009*	3.024*	0.023*	0.972*				44*	1392*	313.26 ± 20.66*	0.57*	Isometric
	Undetermined	26	0.489	1.749	0.023	0.837	19.5	32.2	23.57 ± 0.55	81	207	126.15 ± 6.99	3.78	Allometric negative
			0.492*	1.723*	0.023*	0.829*				66*	194*	116.61± 6.33*	3.85*	Allometric negative
	Total	213	0.008	3.082	0.021	0.903	19.5	55.5	29.79 ± 0.48	44	1779	333.70 ± 20.09	1.19	Isometric
			0.008*	3.042*	0.021*	0.958*				16*	1655*	306.23 ± 18.22*	0.97*	Isometric
P.blennoides	Males	25	0.002	3.457	0.044	0.824	22	35.5	26.12 ± 0.75	87	749	174.20 ± 27.76	1.37	Isometric
			0.002*	3.438*	0.044*	0.828*				76*	603*	149.92 ± 22.60*	1.34*	Isometric
	Females	184	0.005	3.181	0.016	0.911	17.5	47.7	23.71 ± 0.31	48	967	128.83 ± 8.58	2.47	Allometric positive
			0.004*	3.157*	0.015*	0.943*				42*	873*	111.27 ± 7.42*	2.73*	Allometric positive
	Undetermined	61	0.003	3.327	0.017	0.800	16.8	23.9	20.25 ± 0.21	30	112	69.21 ± 2.58	1.51	Isometric
			0.005*	3.112*	0.016*	0.865*				33*	98*	62.65 ± 2.16*	0.70*	Isometric
	Total	270	0.003	3.369	0.014	0.994	16.8	47.7	23.15 ± 0.25	33	967	119.56 ± 6.65	6.04	Allometric positive
			0.004*	3.232*	0.118*	0.993*				30*	873*	103.86 ± 5.68*	4.64*	Allometric positive

N. sample size; r². coefficient of determination; a and b. length-weight parameters; se (b). standard error.* Length-weight relationship parameters (eviscerate weight).

Table II : Length-weight relationship parameters according seasons for *P.phycis* and *P.blennoides* from the Gulf of Tunis.

Species	Seasons	N	a	B	r²	Total Length (cm)			Weight (g)			test t	Growth type
						Min	Max	Mean ± se	Min	Max	Mean ± se		
P.phycis	Winter	44	0.0092*	3.005*	0.954*	19.50	51.30	28.09 ± 1.27	66*	1392*	276.45 ± 44.76*	0.049*	Isometric
			0.0098	3.020	0.942				81	1610	310.84 ± 50.51	0.17	Isometric
	Spring	84	0.0084*	3.053*	0.986*	20.5	51.5	30.65 ± 0.73	81*	1367*	338.95 ± 27.97*	1.329*	Isometric
			0.0095	3.038	0.974				90	1473	367.97 ± 30.29	0.72	Isometric
	Summer	33	0.0071*	3.091*	0.973*	21.90	40.20	30.54 ± 0.95	99*	658*	305.51 ± 30.19*	0.984*	Isometric
			0.0072	3.110	0.972				108	733	334.22 ± 33.56	1.16	Isometric
	Autumn	52	0.0106*	2.951*	0.916*	14.50	55.50	29.30 ± 0.94	44*	1655*	276.53 ± 41.83*	0.387*	Isometric
			0.0053	3.162	0.873				16	1779	294.71 ± 46.30	0.65	Isometric
	Annual	213	0.008	3.082	0.903	19.5	55.5	29.79 ± 0.48	44	1779	333.70 ± 20.09	1.19	Isometric
			0.008*	3.042*	0.958*				16*	1655*	306.23 ± 18.22*	0.97*	Isometric
P.blennoides	Winter	93	0.0106*	2.872*	0.894*	16.8	36.1	21.63 ± 0.28	33*	373*	76.50 ± 4.05*	1.239*	Isometric
			0.0072	3.028	0.850				30	414	84.45 ± 4.61	0.21	Isometric
	Spring	109	0.0032*	3.262*	0.915*	17.7	47.7	23.37 ± 0.40	44*	873*	109.45 ± 10.77*	2.729*	Allometric positive
			0.0029	3.356	0.884				51	967	130.67 ± 12.96	3.03	Allometric positive
	Summer	31	0.0047*	3.154*	0.953*	19.4	35.7	27.75 ± 0.81	58*	494*	133.25 ± 19.00*	1.188*	Isometric
			0.0067	3.080	0.963				69	534	149.19 ± 20.30	0.71	Isometric
	Autumn	37	0.0049*	3.122*	0.982*	16.9	39	25.01 ± 0.85	36*	491*	131.54 ± 16.78*	1.73*	Isometric
			0.0062	3.090	0.982				43	539	150.27 ± 19.02	1.27	Isometric
	Annual	270	0.003	3.369	0.994	16.8	47.7	23.15 ± 0.25	33	967	119.56 ± 6.65	6.04	Allometric positive
			0.004*	3.232*	0.993*				30*	873*	103.86 ± 5.68*	4.64*	Allometric positive

N. sample size; r². coefficient of determination; a and b. length-weight parameters; se. standard error.* Length-weight relationship parameters (eviscerate weight).
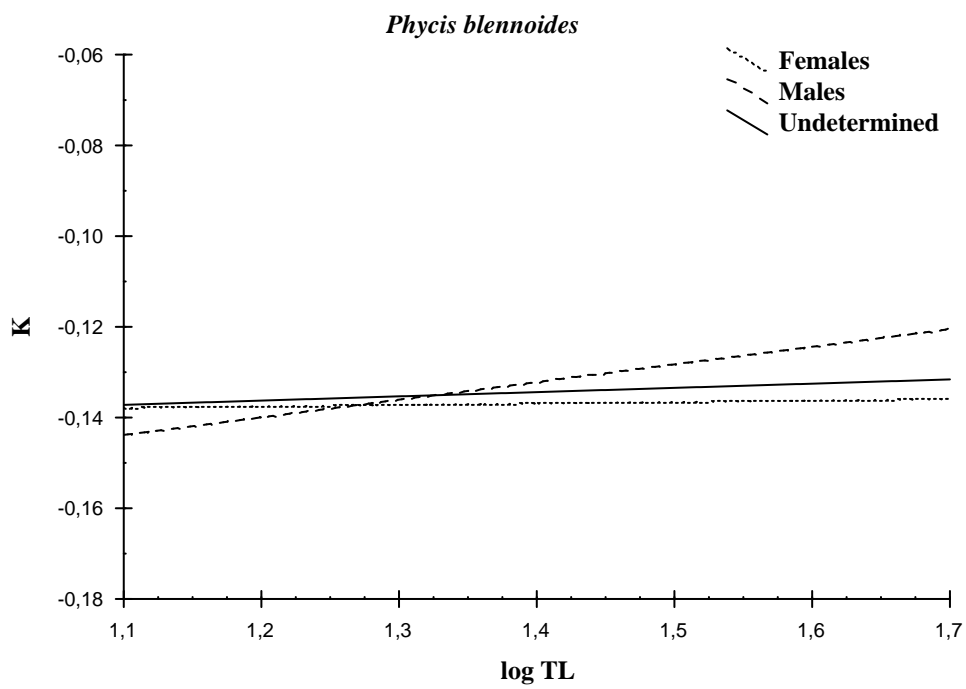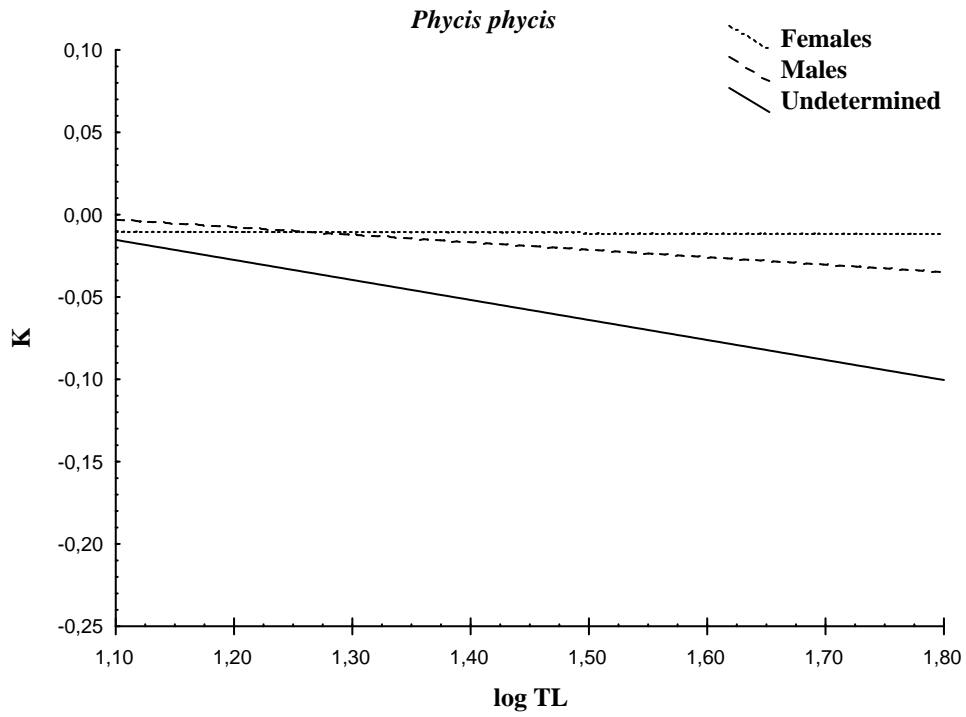
Fig. 3: Condition factor variations of *P.phycis* and *P.blennoides* from the Gulf of Tunis according to the sexes.

indicates a better condition for individuals of larger sizes of males. In contrast, females have the same well being whatever the size (Fig. 3).

The study of monthly variation of condition factor shows a better condition between January and August for *P. phycis* (Fig. 4). While, during September, October and November the condition decreases. However for *P. blennoides*, changes in the condition factor are increased during March to August (Fig. 4). During the rest of year, all individuals have the same condition.
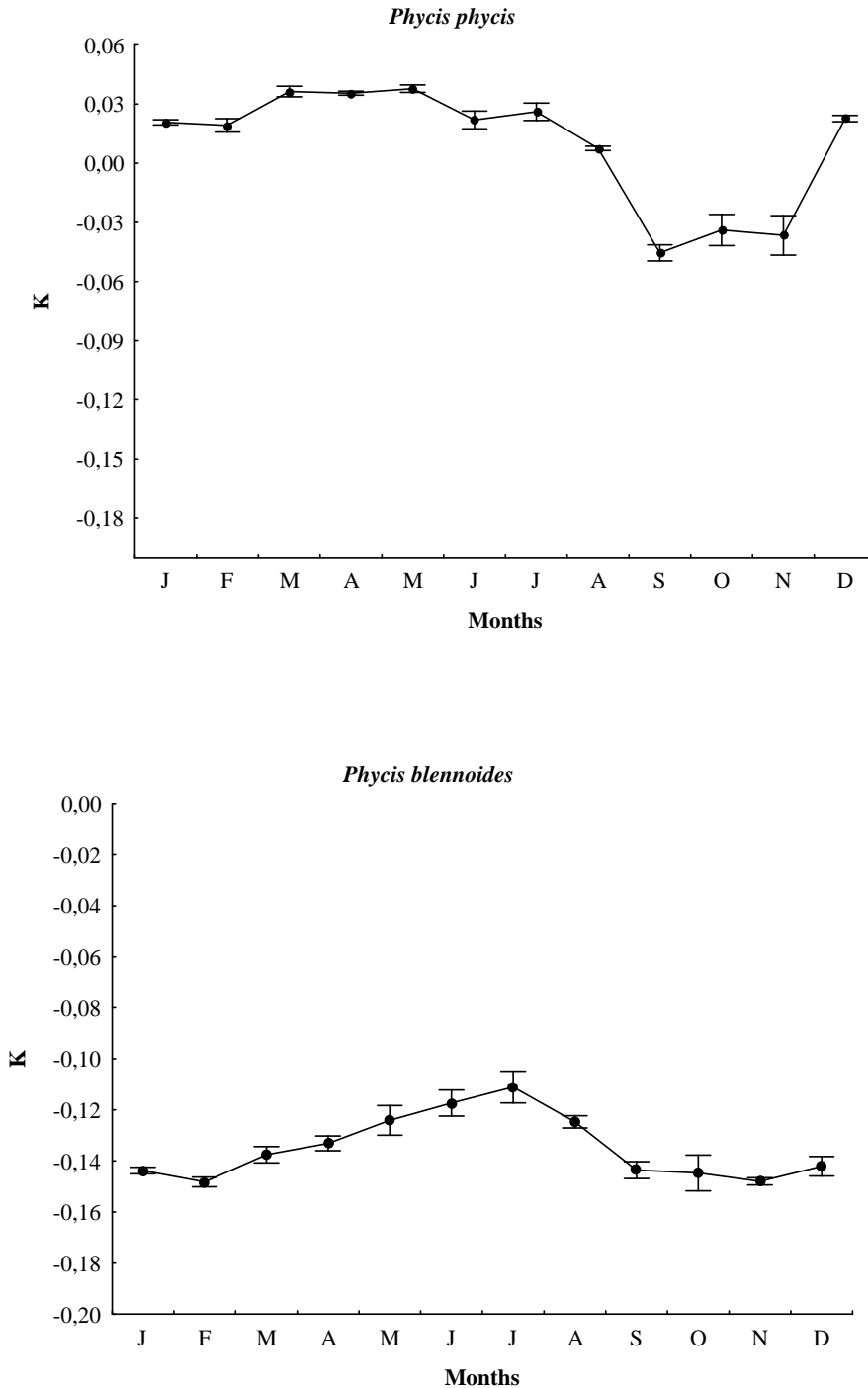

Fig. 4: Condition factor variations of *P.phycis* and *P.blennoides* from the Gulf of Tunis, according to the months.

DISCUSSION

The comparison of the *Phycis* length-weight relationship in this work and those previously reported by other authors showed a spatial variation among regions (Table III and Fig. 5). Comparison of length-weight relationships of *P. phycis* indicates that the value of the slope b varies between 2.431 and 3.133 showing different types of growth.

Weight differences between populations of *P. phycis* from different maritime sectors are negligible below the size of 25 cm. Beyond that, relative weight growth in Tunisian coasts is the lowest and the size has the same range as that of the Turkish coasts (Karakulak *et al*., 2006). This growth is slightly higher in the Portuguese coasts (Mendes *et al*., 2004) and Croatia (Morato *et al*., 2001), but it is much more pronounced in the Balearic Islands (Morey *et al*., 2003) and the Adriatic (Dulčić and Kraljević, 1996) (Fig. 5A).

For *P. blennoides*, the growth is lowest in the North Aegean sea (Papaconstantinou *et al*., 1993) and the Balearic Islands (Morey *et al*., 2003); followed by Gulf of Cadiz (Torres *et al*., 2012), the Tunisian coasts and finally by the Portuguese coasts (Mendes *et al*., 2004) (Fig.5B).

The analysis of length-weight relationship in the Gulf of Tunis shows that the type of growth is isometric for *P. phycis*, whereas it shows a majorant allometry for *P. blennoides*. This dissimilarity of the type of growth can be explained by the body forms specific for each species. *P. blennoides* has an elongate form; however *P. phycis* is relatively higher; and this could be related to the environmental behaviour of the two species.

However, according to the sexes, this study indicates a majorant allometry only for females of *P. blennoides* and males of *P. phycis*. The examination of seasonal length-weight relationship revealed always isometric growth for *P. phycis*. However, the growth shows a majorant allometry in spring and an isometry for *P. blennoides* in the other seasons.

The monthly variations of condition factor are related to the fluctuations of sexual cycle, for the two species. Indeed, the higher values of condition factor are recorded during the sexual resting.

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

	Authors	Localities	N	min	max	a. (10⁻⁴)	b	s.e. (b)	r²
Phycis blennoides	Papaconstantinou *et al.* (1993)	North Aegean Sea (Greece)	532	6.4	46.4	0.026	3.19	-	0.97
	Pérez and Contreras (1995)	North-eastern Atlantic	178			33	3.23	-	
	Merella *et al.* (1997)	Balearic Islands	343	5.5	53.8	26	3.27	-	0.99
	Morey *et al.* (2003)	Western Mediterranean	189	4	42	69	2.97	0.215	0.96
	Filiz and Bilge (2004)	Northern Aegean Sea, (Turkey)	12	12.3	15	17	3.55	-	0.89
	Mendes *et al.* (2004)	Portuguese west coasts	39	17.3	55.5	156	2.84	-	0.94
	Torres *et al.* (2012)	Gulf of Cadiz	51	8.6	47.8	72	3.006	-	0.97
	Present study	Gulf of Tunis	270	16.8	47.7	30	3.36	0.014	0.99
Phycis phycis	Dulčić and Kraljević (1996)	Eastern Adriatic (Croatian waters)	58	26.2	56.4	0.002	3,5	0.108	0.97
	Morato *et al.* (2001)	Azores, north-eastern Atlantic	42	11.1	59.5	69	3,13	0.044	0.99
	Morey *et al.* (2003)	Western Mediterranean	96	10.6	48.4	45	3,26	0.098	0.98
	Mendes *et al.* (2004)	Portuguese west coasts	45	17.2	50.5	64	3,14	-	0.97
	Karakulak *et al.* (2006)	North Aegean Sea, Turkey	59	13.7	44.5	52	3,18	0.045	0.98
	Present study	Gulf of Tunisia	213	19.5	55.5	80	3.08	0.021	0.90

N. sample 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; r². coefficient of determination.
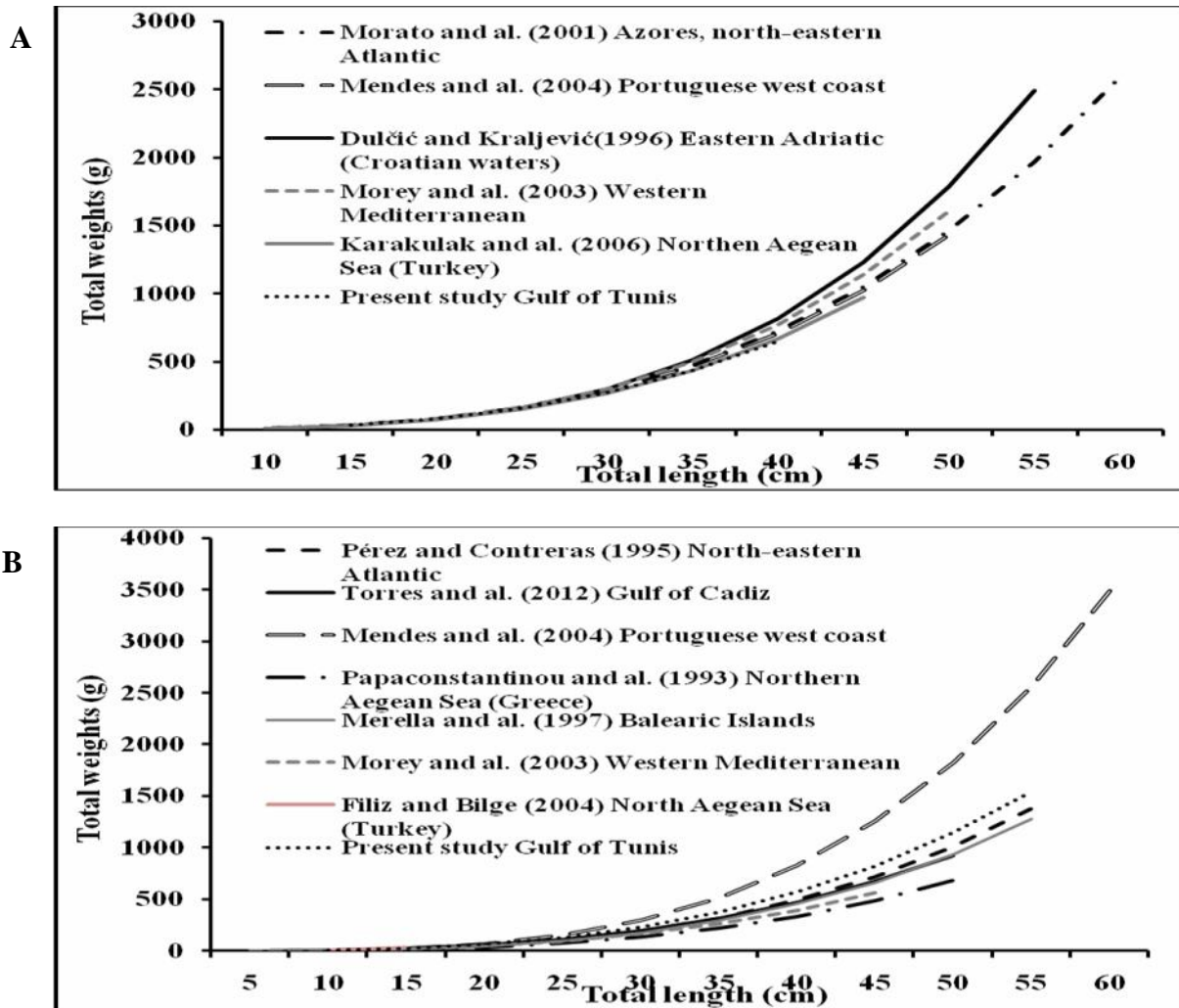
Fig. 5: Comparison of the length-weight relationship of *P. phycis* (A) and *P. blennoides* (B) from different regions.

These differences can be attributed to the combination of one or several factors such as the difference in the number of specimens examined and the size range of species (Moutopoulos & Stergiou, 2002). Petrakis and Stergiou (1995) suggest that the use of length-weight relationships should be strictly limited to the size range used for estimating parameters of linear regressions. However, these variations are particularly reflecting specific conditions of each environmental medium such as temperature, salinity of sea water, availability of food and changes in maturity stages.

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