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Biology of little tunny *Euthynnus alletteratus* in the Gulf of Gabes, Southern Tunisia (Central Mediterranean Sea)

Biología de la bacoreta *Euthynnus alletteratus* del Golfo de Gabes, Sur de Túnez (Mar Mediterráneo Central)

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Resumen. - Se describen algunos parámetros biológicos de la bacoreta *Euthynnus alletteratus* en el Golfo de Gabes (sur de Túnez), tales como la proporción de sexos, el Índice Gonado-Somático (IGS), el Índice Hepato-Somático (IHS), la longitud de primera madurez sexual, y la relación longitud-peso. Se analizó un total de 397 especímenes (244 hembras y 153 machos) entre los 36,7 y 97,8 cm de longitud, con un promedio $52,29 \pm 5,87$ cm. Las muestras se recolectaron mensualmente, entre enero de 2008 y diciembre de 2009. El 61% de los ejemplares fueron hembras. El periodo de desove se extiende de junio a septiembre, calculado a partir de los altos valores de IGS. Las relaciones longitud-peso revelaron que la bacoreta presenta una alometría negativa. La longitud promedio de primera madurez de las muestras tomadas en el Golfo de Gabes fue de 44,8 cm de longitud de horquilla para las hembras y 42,8 cm para los machos.

Palabras clave: Indice Gonado-Somático, longitud de primera madurez, relación longitud-peso

Abstract. - Biological features known as sex-ratio, Gonad-Somatic Index (GSI), Hepatic-Somatic Index (HSI) and size at first sexual maturity, and the length-weight relationships (LWR) were studied in little tunny, *Euthynnus alletteratus*, caught in the Gulf of Gabes (Southern Tunisia). A total of 397 little tunny (244 females and 153 males) were analysed. Fish length ranged between 36.7 and 97.8 cm, average 52.29 ± 5.87 cm. Samples were monthly fished from January 2008 to December 2009. Sixty one percent of the specimens caught were females. The high GSI suggest that the spawning period runs from June to September. Fish in spawning condition are to be observed in August since GSI reaches the peak in July. Negative allometry was found in little tunny. Fork length at first sexual maturity in males (42.8 cm) was smaller than in females (44.8 cm).

Key words: Gonad-Somatic Index, size at first sexual maturity, length-weight relationship

INTRODUCTION

Little tunny (*Euthynnus alletteratus* Rafinesque, 1810) is the only species belonging to the genus *Euthynnus* that occurs in Tunisia (Hattour 2000). This coastal species primarily occurs in Tunisia throughout the year, with frequently variation in occurrence. Large catches are recorded in May, June and July (Hattour 2000). Little tunny in Tunisia is thought to be part of the Mediterranean stock, due to lack of thorough assessment. However, Rey & Cort (1981) showed that an outer little tunny stock, different from that in the Mediterranean Sea does exist, considering the tagging results, which undoubtedly suggest possible little tunny migration into the Atlantic Ocean, from the Mediterranean Sea, through the Strait of Gibraltar.

There are several studies of biological features of little tunny (such as length at first sexual maturity, gonad-somatic index, fecundity, sex-ratio, spawning period, growth, age, length-weight relationships, length and weight frequency distributions) (Frade & Postel 1955, Landau 1965, Rodriguez-Roda 1966, 1979, Klawe *et al.* 1970, Diouf 1980, Cayre & Diouf 1983, Kahraman & Oray 2001, Kahraman 2005, Macias *et al.* 2006, Kahraman *et al.* 2008, Macias *et al.* 2009), however, scarce knowledge about little tunny exists for Tunisian coast, despite the fact its fishery importance. The only data accessible to everyone and dealing with the biology of this species in Tunisia are those of Hattour (1984, 2000, 2009) and Hajjej *et al.* (2009).

Therefore, the present study aims to analyze the biological traits of little tunny caught off the Gulf of Gabes, one of the most productive fishing areas in Tunisia (Bradai *et al.* 1995). The current data are of a great importance for better knowledge of little tunny in Tunisia.

MATERIAL AND METHODS

Random samples were taken monthly from a commercial fishery in the Gulf of Gabes, which extends from Ras Kapoudia (on parallel 35°N) to the Tunisian-Libyan border (Fig. 1), from January 2008 to December 2009. Total samples numbered 397 specimens ranging in size from 36.7 to 97.8 cm of fork length (here after expressed as L) (mean 52.29 ± 5.87 cm). Fishes were caught in various gears (purse seine, gill nets, longlines, trawls and beach seine). Specimens were measured to the nearest centimetre fork length, using a measuring board and weighed prior to dissection (total weight, Wt). Fish were sexed by macroscopic examination of the gonad (degree of opacity, consistency, oocytes or sperm occurrence as well as the overall colouring of gonads) when dissected out and subsequently weighed (We). Gonad and liver were also weighed on a digital balance with 0.01 g accuracy. The maturity stage of gonad was assessed using a developmental scale ranging from immature (stage I) to spent (stage V) (Diouf 1980).

Sex-ratio (SR) was calculated as the proportion of females. The population sexual structure was examined using a chi-squared significance test. Gonad-Somatic Index (GSI) was calculated to determine spawning periods according to the equation: $GSI = [\text{gonads weight (g)} / \text{eviscerated weight (g)}] \times 100$ (Caillier *et al.* 1986). Hepato-somatic index (HSI) was calculated as: $HSI = [\text{liver weight (g)} / \text{eviscerated weight (g)}] \times 100$ (Patzner 1980). Size at first maturity ($L_{m_{50}}$) is defined as the size at which 50% of fish were mature and was calculated as: $P = 1/[1 + \exp(-b(L - L_{m_{50}}))]$, where, P is the proportion of mature individuals (in stages III/IV, IV and V) at fork length, b is a parameter determining the slope of the maturity curve and $L_{m_{50}}$ is the fork length at which 50% of the fish are mature. Length-weight relationships were calculated by sex and by both total and eviscerated weight, according to the equation $W = aL^b$ (Ricker 1973). The value of the constants a and b was estimated from the log transformed values of length and weight *i.e.*, $\log W = \log a + b \log L$, via least square linear regression (Zar 1984). Student's *t*-test was used to determine if the coefficient b was significantly different from 3 (Teissier 1948).

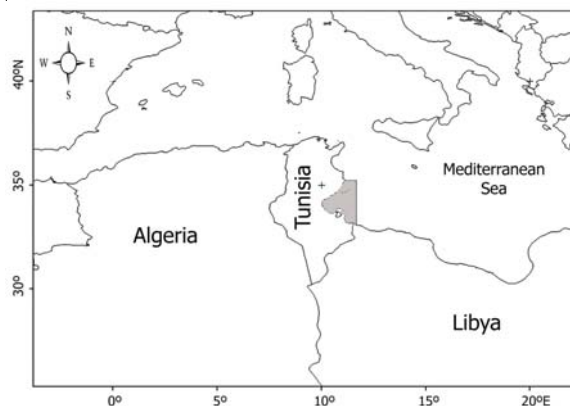


Figure 1. Map of the study area. The gray zone shows the Gulf of Gabes where the little tunny specimens were collected / Mapa de la zona de estudio. La zona gris muestra el Golfo de Gabes en donde se obtuvieron especímenes de bacoreta

RESULTS

A total of 397 specimens of *Euthynnus alletteratus* were collected during the survey. Their lengths (FL) ranged from 36.7 to 97.8 cm (mean: 52.29 ± 12.87 cm); female (N = 244) ranged 36.7 - 90.5 cm (mean: 50.53 ± 9.9 cm), while males (N = 153) ranged 37.6 - 97.8 cm (mean 54.72 ± 15.97 cm). The number of immature individuals represented 16.37% of the overall sample granted that the number is 65 specimens (immature females = 36 and immature males = 29). The sex-ratio was higher for females once again in the classes between 62 cm and 72 cm, and males became larger in number at 72 cm and more. The sex-ratio observed during 2008 and 2009 was 1:1.59 (61.46%), which significantly deviated from the expected distribution of 1:1 ($\chi^2_{\text{obs}} = 24.65 \gg \chi^2_{\text{exp}} = 3.84$; $P < 0.05$). When the fish were classified in sizes, with 2-cm length intervals, females were significantly predominant at lengths smaller than 54 cm ($\chi^2_{\text{obs}} = 6.32 \gg \chi^2_{\text{exp}} = 3.84$; $P < 0.05$), and males became larger in number in the groups between 54 cm and 62 cm length (Fig. 2).

Monthly variation in mean Gonad-Somatic Index (GSI) of females and males occurred between July and October, although less variation was found in the HSI (Fig. 3); for females, GSI showed a pronounced growth reaching a peak in July (3.88), decreasing from September to October, and reaching a minimum value in January (0.032). For males, GSI had a peak also in July (3.45) and a minimum value in November (0.028). The HSI reached a maximum value in May for males (2.33) and females (2.65). The HSI showed slight variations during other months (Fig. 3). These results were also supported by the macroscopic maturing stage

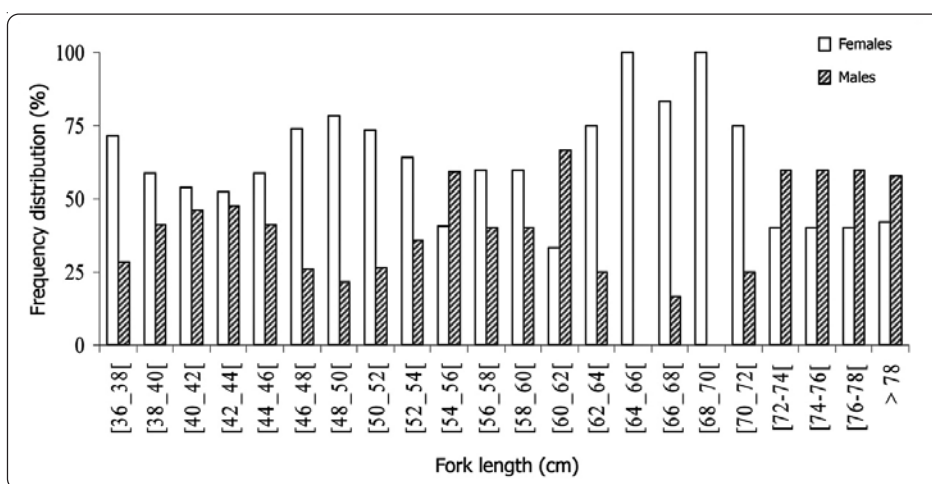


Figure 2. Frequency distribution of fork length by sex in *Euthynnus alletteratus* / Distribución de la frecuencia de la longitud de horquilla por sexo en *Euthynnus alletteratus*

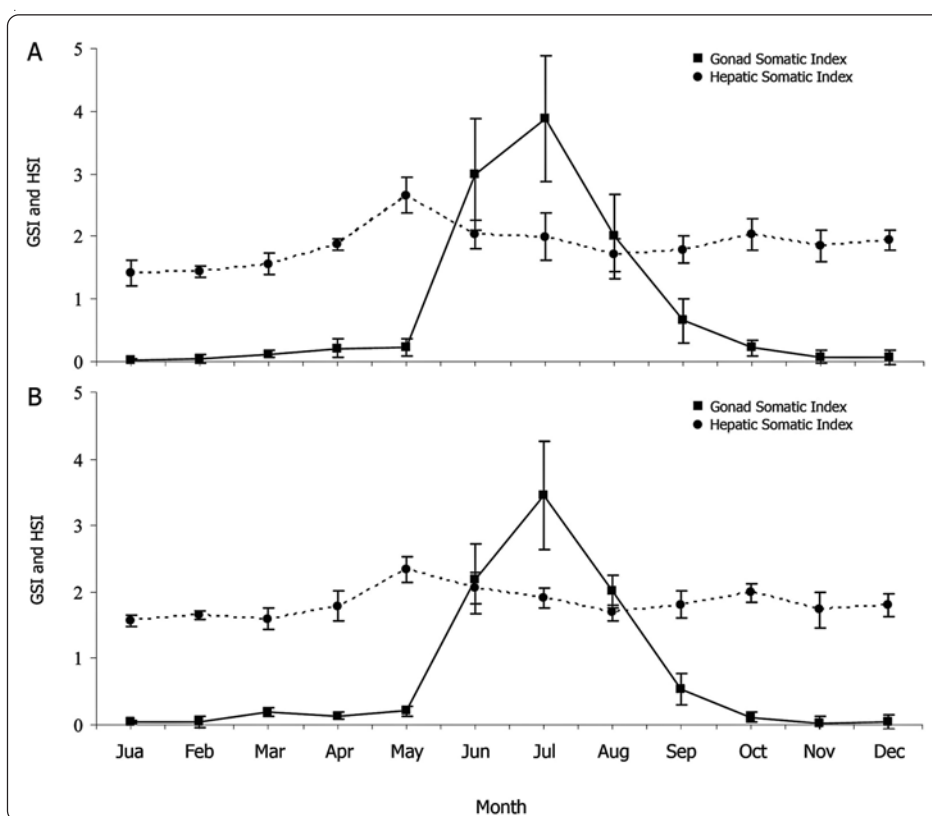


Figure 3. *Euthynnus alletteratus* mean monthly Gonad-Somatic Index and Hepatic-Somatic Index for A) females and B) males. Vertical bars indicate confidence interval (\pm 95% CI) / Valores promedio mensuales del Índice Gonado-Somático e Índice Hepato-Somático de las A) hembras y B) machos de *Euthynnus alletteratus*. Las barras verticales indican el intervalo de confianza (\pm 95% IC)

analysis, that showed mature females and males were common between May and October, with a peak in July (Fig. 4).

The linear regression of total weight (Wt) as a function of eviscerated weight (We) for combined sexes showed a very high correlation coefficient ($We = 0.8906Wt + 26.71$; $r^2 = 0.996$) suggesting a perfect correlation between the two parameters. The a factor and the allometry coefficient b of the relationships between fork length (L) and total weight (Wt) or eviscerated weight (We) of the all specimens of *Euthynnus alletteratus* (Table 1, Fig. 5). For females, males and combined sexes, the exponent of the length-weight relationship is significantly lower than the

3 value ($t \gg 1.96$, $P < 0.05$) indicating a negative allometric growth. The weight of Gulf of Gabes little tunny increases proportionally slower than size. During the spawning period, the allometry coefficient b for the length-total weight was 2.82 for males and 2.86 for combined sexes. These values were significantly lower than 3, therefore showing a negative allometry ($P < 0.05$). Females have a b value not significantly different from 3, indicating an isometric allometry ($b = 2.975$, $t = 0.74$, $P > 0.05$).

For the population, 50% of the males and females attained first maturity at 42.8 and 44.8 cm FL respectively (Fig. 6) indicating that the males generally mature at relatively smaller sizes than the females.

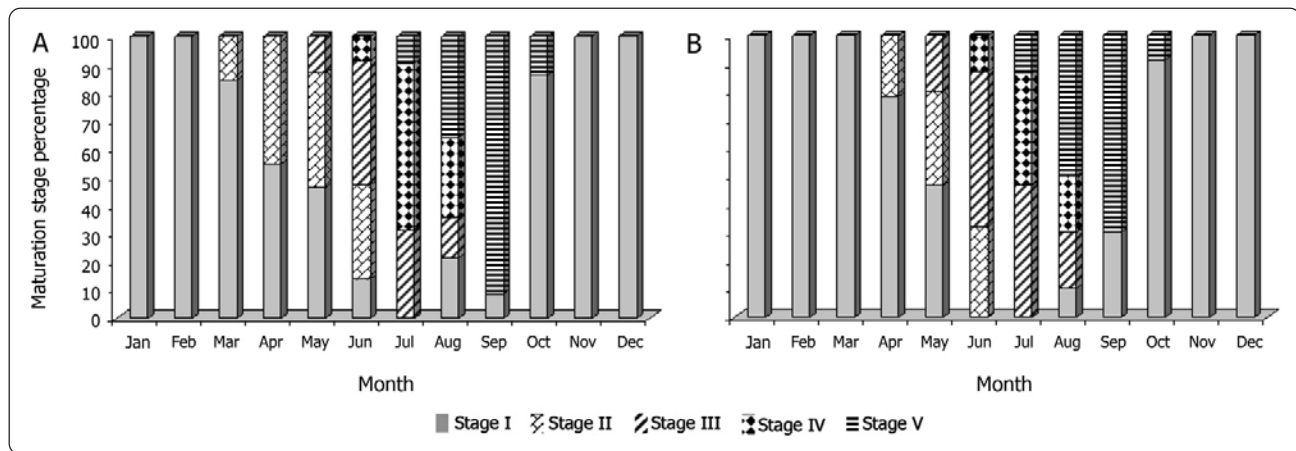


Figure 4. Proportion of *Euthynnus alletteratus* by maturity stage and month from A) females and B) males / Valores promedio mensuales de la fase reproductora en A) hembras y B) machos de *Euthynnus alletteratus*

Table 1. Regression parameters (a , b , r^2) of the length-weight relationships of *Euthynnus alletteratus* in the Gulf of Gabes. (t test; t : stadigraph, +: $P < 0.05$), F: females, M: males / Parámetros de regresión (a , b , r^2) de las proporciones longitud-peso de *Euthynnus alletteratus* en el Golfo de Gabes (prueba de t ; t : estadígrafo, +: $P < 0,05$), F: hembras, M: machos

Equations	Sex	a	b	sd (b)	r^2	t	Significance	Allometry
$Wt=aL^b$	F	0.0212	2.9183	0.0321	0.9753	2.4635	+	Negative
	M	0.0301	2.8296	0.0298	0.9835	5.4439	+	Negative
	F+M	0.0261	2.8645	0.0188	0.9807	6.1807	+	Negative
$We=aL^b$	F	0.0233	2.8669	0.0331	0.8895	2.8443	+	Negative
	M	0.0302	2.8036	0.0305	0.9848	6.5999	+	Negative
	F+M	0.0267	2.8329	0.0245	0.9460	4.5254	+	Negative

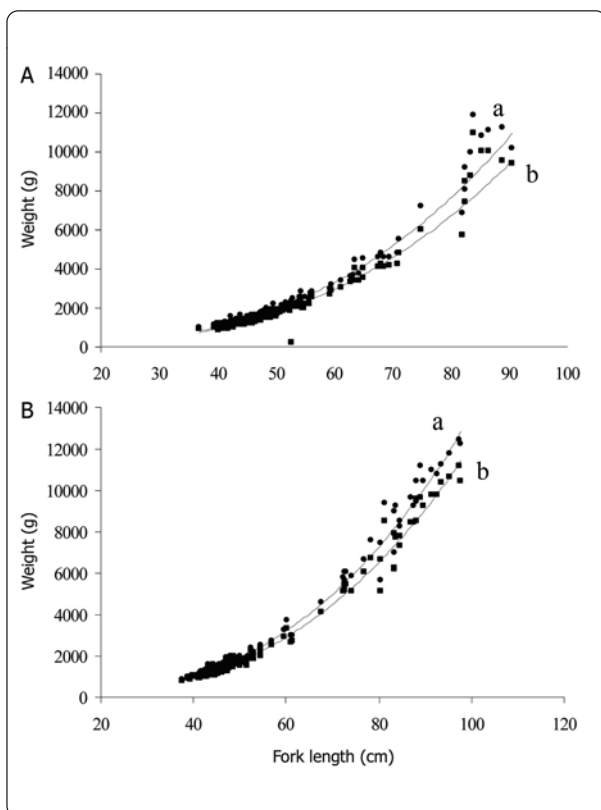


Figure 5. Relationship between fork length with (a) total weight and (b) eviscerated weight of *Euthynnus alletteratus* A) females and B) males from the Gulf of Gabes / Relación entre longitud a horquilla con (a) peso total y (b) peso eviscerado en A) hembras y B) machos de *Euthynnus alletteratus* desde el Golfo de Gabes

DISCUSSION

According to our knowledge, there is no study reporting biological parameters of *Euthynnus alletteratus* focused only in the Gulf of Gabes. Based on the mean monthly GSI change, it is clear that the little tunny spawning season in this area is from June to September, with a peak in July coinciding with the rise in water temperature. This fact is confirmed by the macroscopic evaluation of the gonad maturity stage. In fact, this spawning season is based on the presence of large numbers of males and females in stages III-V (mature-spent) of maturity in the June-September samples, coupled with the very high GSI values recorded during this period. Furthermore, no specimens were found to be mature from November to February. This conclusion is closely related to the results obtained by Hattour (2000) in all the Tunisian coasts. Similar results were found by several authors (Rodriguez-Roda 1979, Cayre & Diouf 1983). On the other hand, Landau (1965) showed that the spawning period starts early; between May

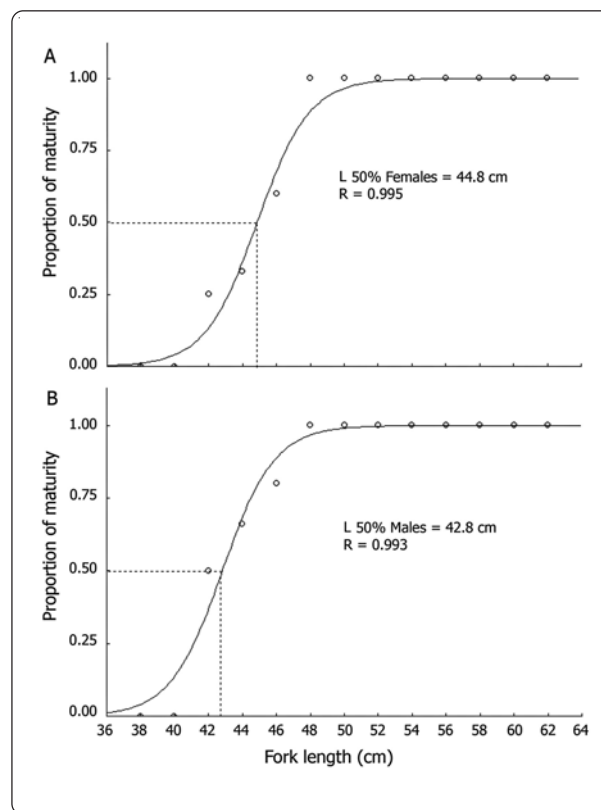


Figure 6. Proportion of mature female (A) and male (B) little tunny in the Gulf of Gabes by fork length classes (L), during 2008 and 2009. Dotted lines show length at 50% maturity, R: coefficient of correlation / Proporción de hembras maduras (A) y machos (B) de bacoreta en el Golfo de Gabes según su longitud a horquilla (L) durante 2008 y 2009. Las líneas de puntos muestran la talla de madurez del 50%, R: coeficiente de correlación

and September. In eastern and western Atlantic, little tunny spawning has been reported to occur from about April to November (Collette & Nauen 1983), which is a much more extended period than the interval reported in this study. For males and females, the minimum HSI value, obtained when GSI is highest (June-September), suggests that the liver experiences a weight loss, which may indicate the metabolisation of the hepatic reserves for gonad maturation. Indeed, the accumulation and storage of fat within the liver in the course of ovary maturation is a known phenomenon for many fish species (Bailey 1952, Smith 1957).

Different mortality, growth, sex reversal, seasons, fishing gear and methods influence the sex-ratio variation (Wenner 1972, Wu *et al.* 2001). The size-combined sex-ratio of the *Euthynnus alletteratus* caught in the Gulf of Gabes significantly deviates from the expected 1:1 ratio, with a female percentage of 61.14%. This suggests that

there is a difference in the availability of both sexes for the fishery. This may be because of a spatial segregation of sexes or because of different behaviour in relation to the gear (Mendonça *et al.* 2006). Except in June, at the beginning of the reproduction period, females outnumber males throughout the year. This result is similar to that found by Hajjej *et al.* (2009) for the same species in Tunisian waters in general. The increment of males with high GSI value during this period can be due to the tough competition strategy between males, resulting in the selection of the fittest for reproduction (Sousa *et al.* 2003). The dominance of females has been proven by Kahraman *et al.* (2008) in eastern Mediterranean and Valeiras *et al.* (2008) in western Mediterranean Sea. However, the sex-ratio was for males in Tunisian waters (Hattour 2000) and in eastern Atlantic Ocean (Gaykov & Bokhanov 2008). This change in the sex-ratio could be due to differences in fishing gear and methods used (Wu *et al.* 2001). The sex-ratio analysis by length indicates an alternation of dominance between females and males, with female dominance in most of the size classes, except between 54 and 62 cm, and in the size classes larger than 74 cm, where males are predominant. The same phenomenon of male preponderance in the larger size classes has also been reported for other tuna species, such as yellowfin tuna *Thunnus albacares* (Sun *et al.* 2005), albacore tuna *Thunnus alalunga* (Wu & Kuo 1993, Ramon & Bailey 1996), Atlantic bluefin tuna *Thunnus thynnus* (Clay 1991), and bigeye tuna *Thunnus obesus* (Nikaido *et al.* 1991).

According to this study, the smallest female and male mature specimens observed were 38.7 cm and 39.4 cm respectively, being slightly shorter than the values reported earlier by Hattour (2000), who indicated that females of 40 cm began to mature, while males began to mature at 41 cm. Diouf (1980) determined that specimens at 60 cm of length were fully mature in Senegal. This size is significantly larger than the 49.2 cm found in this study, and the 49 cm from the Tunisian waters (Hattour 2000). It is interesting to note that macroscopic staging is not recommended to be the most appropriate method to estimate maturity because mature but post-spawning or resting females may be misclassified as immature (Schaefer 2001).

In Tunisian waters, 50% maturity is reached by age two at size of 42.9 cm for females and 39.7 cm for males (Hattour 2000). Chur (1973) estimated maturity length at 50% for little tunny in the Gulf of Guinea to be 44 cm for males and 42 cm for females. Our estimated length at 50% maturity was 42.8 cm FL and 44.8 cm FL for males and

females respectively, which is substantially lower than the estimates for southern Spain: 56 cm FL (Rodriguez-Roda 1966). Natural fish stocks are complex mixtures of genotypes, responding differently to fishing pressure, which somewhat erodes natural genetic diversity in order to select the genotypes that are better able to withstand the impacts, and the change in size at maturity is one of the more worrisome genetic changes (Walters & Martell 2004). From the present study, it is evident that females *E. alletteratus* reach sexual maturity at a larger size than the males, similar to the report on the same species from Tunisian waters (Hattour 2000). This could ensure that the fish have more accommodative capacity for increased egg production. It is also evident from the present study, that males mature at smaller sizes than females. This could suggest either that at some stage the males grow more slowly than the females, or that the males mature earlier than the females.

The difference in size at maturity between this work and Hattour (2000), thus, may reflect the effects of decades of fishing pressure upon *E. alletteratus* in Tunisian waters. The current fishing pressure is apparently planned seeing as little tunny was recently described as a priority species by the Scientific Advisory Committee of CGPM (FAO 2009). Further, according to Walker & Ellis (1998), the negative effects of exploitation, may be counteracted by compensatory mechanisms such as density dependent changes in fecundity, age or size at maturation.

In this study, the relationships established using eviscerated or total fish weights showed always an allometric growth (negative allometry). This conclusion is similar in the Aegean Sea (Kahraman & Oray 2001), in the eastern Mediterranean Sea (Kahraman 2005), in the north-eastern Mediterranean (Kahraman *et al.* 2008) and in the south-east of Spain (Macias *et al.* 2006) for the same species. The relatively low values of b ($b < 3$) can be attributed to the combination of one or more of the following factors, such as temperature, salinity, stage of maturity, or food abundance (Andrade & Campos 2002). The b values for both weights (total and eviscerated weight) for the combined sexes found in this study are much lower than those obtained by Hattour (1984, 2000, 2009) for the Tunisian coasts. These differences are probably related to the different size structure of little tunny population included in the length-weight relationship analysis, or with interannual changes in the nutritional condition of the organisms (Isajlovic *et al.* 2009). Furthermore, when the monthly b values were analysed on the spawning period (June-September) it was observed that the b values for

males and both sexes were significantly different from three, which supports the trend observed during the global study period. However the *b* value, for females, was relatively higher, indicating an isometric growth may be due to the significant increase in the studied ovarian weight. This increase in female weight during the spawning period is obviously linked to the reproduction process (Bottari 2004).

The contribution of this study lays in the description of some characteristics of the reproductive biology of *Euthynnus alletteratus* in the Gulf of Gabes. The information obtained could be of use in the development of fishery management strategies for this species.

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