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A REVIEW OF MEDITERRANEAN ALBACORE (*THUNNUS ALALUNGA*) BIOLOGY AND GROWTH STUDIES

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SUMMARY

*Growth parameters are used to estimate catch-at-age data which is required as an input to many stock assessment models. In the case of Mediterranean albacore stock no assessment has ever done (ICCAT, 2009). This study presents growth information based on spine section interpretation of annual time marks. A preliminary age-length key is presented for males, females and two sexes combined, based on 249 albacore (*Thunnus alalunga*, Bonn.1788) spine samples caught around the Balearic Islands and Western Mediterranean sea between June and November from 2004 thru 2006. The albacore length ranged from 52 cm to 94 cm for females and from 53 cm to 96 cm for males. Available length-weight data for 138 males and 162 females was analysed separately. New estimates presented in this study were compared with assumed biological length-weight relationship for Mediterranean albacore stock. As well, mean length by age estimates derived from the age-length-key obtained by reading fin ray section were compared with other studies that used hard parts to age Mediterranean albacore.*

RÉSUMÉ

*Des paramètres de croissance sont utilisés pour estimer les données de prise par âge requis en tant que valeur d'entrée pour de nombreux modèles d'évaluation des stocks. Dans le cas du stock de germon de la Méditerranée, aucune évaluation n'a jamais été réalisée (ICCAT 2009). Cette étude présente des informations relatives à la croissance en se fondant sur l'interprétation des sections des épines des marques annuelles. Une clé âge-taille provisoire est présentée pour les mâles, les femelles ainsi que pour les deux sexes combinés, reposant sur 249 échantillonnages d'épines de germons (*Thunnus alalunga*, Bonn, 1788) capturés dans les environs des îles Baléares et de la Méditerranée occidentale entre le mois de juin et de novembre 2004 jusqu'en 2006. La taille du germon oscillait entre 52 et 94 cm dans le cas des femelles et entre 53 et 96 cm dans le cas des mâles. Les données disponibles de longueur-poids des 138 mâles et 162 femelles ont été analysées séparément. De nouvelles estimations présentées dans cette étude ont été comparées à la relation biologique postulée longueur-poids du stock de germon de la Méditerranée. De plus, les estimations moyennes de la longueur par âge (dérivées de la clé âge-longueur) obtenues sur la base de la lecture de la section du rayon de la nageoire ont été comparées avec d'autres études qui ont recours à des pièces dures pour déterminer l'âge du germon de la Méditerranée.*

RESUMEN

*Se utilizan los parámetros de crecimiento para estimar los datos de captura por edad que se requieren como entradas para muchos modelos de evaluación de stock. En el caso del stock de atún blanco del Mediterráneo, no se ha realizado nunca una evaluación (ICCAT, 2009). Este estudio presenta información sobre crecimiento basada en la interpretación de marcas anuales de secciones de espinas. Se presenta una clave edad-longitud provisional para los machos, las hembras y ambos sexos combinados basada en 249 muestras de espinas de atún blanco (*Thunnus alalunga*, Bonn. 1788) capturado alrededor de las islas Baleares y en el Mediterráneo occidental entre junio y noviembre de 2004 hasta 2006, inclusive. La longitud del atún blanco oscilaba entre 52 cm y 94 cm para las hembras y entre 53 cm y 96 cm para los machos. Los datos disponibles de longitud-peso para 138 machos y 162 hembras fueron analizados por separado. Las nuevas estimaciones presentadas en este estudio se compararon con la relación biológica longitud-peso asumida para el stock de atún blanco del Mediterráneo.*

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Asimismo, las estimaciones de longitud media por edad derivadas de la clave edad-longitud y obtenidas mediante la lectura de secciones de rayos de aleta, se comparan con otros estudios que utilizaron partes duras para determinar la edad del atún blanco del Mediterráneo.

KEYWORDS

Mediterranean stock, albacore, length-weight relationship, age determination, spine section ageing, Thunnus alalunga

1. Introduction

Albacore, *Thunnus alalunga* (Bonnaterre, 1788) is a temperate tuna widely distributed throughout the Pacific, Indian and Atlantic Oceans, and the Mediterranean Sea.

Albacore in the Mediterranean has never been assessed and no management recommendations exist for this stock. The SCRS of ICCAT considers the existence of three separate stocks; the North and South Atlantic, separated at 5ºN and the Mediterranean Sea for management purposes (ICCAT, 2009a). According to the Performance Review Panel held in 2009 (ICCAT, 2009b), more information must be collected for the Mediterranean Albacore stock and it recommends that an assessment should be conducted at the earliest possible date. Hence, an important effort is required to characterize the life-history parameters of albacore in the Mediterranean Sea.

The averaged reported landings for the recent period 2000-2007 were 5,600 t (ICCAT, 2009) most of them caught by Italian fleets and followed to a lesser extent by the Greek and Spanish fleets. Due to incomplete Task I and Task II data from the albacore Mediterranean fisheries and to an incomplete knowledge on biological parameter this stock has never been assessed (ICCAT, 2009).

Information on the growth of albacore is important as an input biological parameter in the assessment of the stock, which is required in several steps of the population analyses. There are some published studies that investigate this population parameter and proposed a growth model estimates for albacore in the Mediterranean. These include analyses of hard part growth increment, such scales (Arena *et al*., 1980; Cefali *et al*., 1986; Megalofonou, 1990; Megalofonou *et al*., 2003) and spines (Megalofonou, 2000).

Monitoring of albacore Spanish fisheries in the western Mediterranean fishing grounds (gear, fishing effort, catch) started years ago (De la Serna, 2003) and more recently the monitoring of the sport vessels (Macías *et al*., 2010) began in this area. As a result collection of fin ray section was conducted.

The aim of this paper is to present first results on ageing based on the spine section reading, revisited the length-weight relationship by presenting analyses from the western Mediterranean area and summarized the results and conclusions on the growth parameter estimates of Mediterranean albacore stock.

2. Material and methods

2.1 Collection of data

In order to improve biological knowledge in Mediterranean albacore, sampling activities towards collecting first spine of first dorsal fin albacore from the Spanish fisheries in the western Mediterranean fishing grounds began in 2004 and continued through 2006.

The fish were caught in the western Mediterranean Sea, mainly in Spain inshore waters by sport troll (86.85%) and long liners (13.15%). On each individual the following information was recorded when possible: the fork length measurement to the lowest centimetre (FL), round weight (WR), sex was determined by visual inspection, date of captured and place of landing data. From each individual the gonads and corresponding first dorsal fin ray were collected. The sport vessels activity was monitored and samples obtained during the summer sport angling competitions along the Mediterranean ports in summer. The longline vessels were monitored by

observers on board and at landing ports. A total of 479 albacore samples were collected from the longline and sport vessels in 2004, 2005 and 2006.

Exploratory statistical test such normal Q-Q plot and box plots were used to check for possible outliers in the observations.

2.2 Length-weight data

Length weight data from 346 albacore was recorded. From this data set, only 138 albacore males and 162 albacore females were use in the analyses. The samples were analysed by sex and all combined. A potential model was fit to the data.

2.3 Spine preparation and age interpretation

The first fin ray, also named spine, of the first dorsal fin was collected from each specimen. Information about date, location, sex, fork length and weight was annotated. The spine was preserved in a dry state within a paper envelope and labelled. Detailed information and protocol for spine section processing was based on methodology described by Ortiz de Zárate *et al*. (2007). Two cross sections of 0.5 mm thick were cut using an ISOMED 5000 Cutter. The sections were washed in a 70% ethanol solution. They were later mounted onto labelled holders and embedded in Eukitt, a highly transparent mounting resin.

The growth bands pattern formed on the spines of albacore is a combination of translucent or hyaline band (*annulus*) or tight cluster of hyaline bands and the associated opaque band which together are assumed to represent one year of growth in this study. The hyaline band corresponds to periods of migrations or wintering, in which the metabolic cost made is reflected in growth. Ageing of specimen consists on counting the hyaline bands. Regarding the Mediterranean albacore, the pattern assumed to explain the ageing process is that described by Megalofonou (2000) who indicates that albacore spines develop only one hyaline band (*annulus*) by year at Eastern Mediterranean and considers a hyaline band plus an opaque band to be formed during one year time period. Therefore same hypothesis was applied to determine the albacore age from the Western Mediterranean samples. Age was calculated by counting consecutive growth temporal hyaline bands (*annuli*) on each spine section.

The clearest of the two sections was examined using a profile projector (model: Nikon 6C) with transmitted light at 10x – 20x magnification depending on the size of section. The diameter of each hyaline band (*annulus*) was measured and recorded with a Nikon M253 measuring table. Spine sections were read by one reader and unresolved differences in readings resulted in spine elimination. Some samples presented more than one hyaline band per year, thus the interpretation of observed pattern was difficult. Accordingly, the age determination was subject to bias caused by different pattern of hyaline bands formation.

Photographs of spine sections were taken using NIS-ELEMENTS D 3.0. software package in a Nikon SMZ 1500 stereo microscope with an objective 0,5X. The camera used is a Nikon DS-5M with a reducing lens 0,7X. Before capturing the images, parameters like calibration (3x), resolution (2560x1920) and exposure setting were defined. Photographs were captured under transmitted light. The sections chosen were those classified as good samples by reader from the point of view of identification of clear pattern subject to hypothesis applied for age determination (Megalofonou, 2000).

Normality of length distribution by sex was explored with Kolmogorov-Smirnov test. Thereafter, the hypothesis of same growth rate between male and female albacore was explored with the non-parametric Mann-Withney test (Zar, 1984). This test was applied to the mean length by age of male and female aged specimen. There was not attempt to fit a von Bertalanffy model to aging data, due to the absence of precision and bias estimates of the albacore ages derived from counting hyaline bands on the spine section. Nevertheless, the natural logarithm of mean length at age was fit to an exponential growth curve to approximate the growth curve for males and females albacore on this study.

2.4 Review of literature

Most of the information presented here is the result of a recent review of available literature describing studies related to age determination methods and growth parameter estimates of Mediterranean albacore, from both sources: ICCAT Collective Volume of Scientific Papers and other literature addressing the Mediterranean albacore ageing studies.

3. Results

3.1 Collection of data

A total of 479 albacore samples were collected from 2004 to 2006. The outcome of screening the data for outliers was that 470 out of 479 observations were selected (**Table 1**). The processed albacore samples had a length ranging from 52 cm to 96 cm and were collected from June to November during 2004, 2005 and 2006 fishing season, **Figure 1** showed the length distribution by sex and not sexed albacore sampled during the three fishing seasons of 2004, 2005 and 2006. Likewise, the length distribution of sexed albacore spine collection used for ageing was presented in **Figure 2.**

3.2 Length-weight relationship

Sampling was done from June to September in 2005 and 2006, meanwhile for 2004 fishing season there was not information recorded. Out of a total 479 albacore samples, only 300 sexed individuals ranging from 52 to 92 cm fork length and from 1,37 to 16,4 kg round weight were analysed. Samples lacking weight data or sex information were excluded from the analyses. Summary of total samples used is presented in **Table 2.** Most of the data was collected in June and July.

A significant relationship was estimated for female albacore ($r^2 = 0.912$) as well as for male albacore ($r^2 = 0.973$) and the model fit was shown in **Figure 3**.

3.3 Age determination using dorsal fin ray section

A selection of 280 spines from albacore, including 123 male albacore, 148 female albacore and 9 not sexed individual were used for age determination. Samples used are summarized in **Table 1.** Samples were taken from May to November. Most of the samples were collected in July (n=224, 80%), followed by June (n=51, 18.21%). From the 271 spines collected from sexed albacore, a total of 22 spines (8.12%) were eliminated because interpretation of hyaline band was not clear. The remaining 111 males samples and 138 females samples spines had a length size ranging from 52 cm to 96 cm. Samples were collected from June to September (**Table 1**).

The observed length distribution of male albacore fish was not normally distributed ($P<0.05$) as shown in **Figure 2**.

The cumulative age distribution by sex obtained from ageing albacore was included in **Figure 4**. Male albacore age rank from 1 to 11 years old, while female albacore were aged from 1 to 10 years old. The most abundant age groups were age 2 (n= 49, 19.68%) and age 5 (n=39, 15.66%). In agreement with this results it was concluded that the, 56.6 % of the aged albacore belonged to the age interval from 2 to 5 years old. Age length keys were derived for males, females and for the two sexes combined (**Table 3**). Likewise their mean lengths at age and standard deviations were calculated.

Significant differences were found ($P<0.05$) in the mean length at age between male and females aged albacore. Therefore from this data that had been analysed might be assumed that there was an indication of differential growth rate by sex. Although those results might be confounded by bias in the simple size or bias in the counting of growth marks (*annuli*). Moreover significant differences were found ($P<0.05$) between male and female albacore growth rate with the length distribution treated aggregated by age. Results were shown in **Table 4**. According to the p-value obtained by age group, the hypothesis of same growth rate for male and female albacore can be rejected for various age groups, as in the case of ages 1, 2 and 5 ($P<0.05$), since the probability corresponds to a 5% chance of rejecting the null hypothesis when it is true (Type I error). However, in the case of the age groups 3 and 6 the null hypothesis was not rejected ($P>0.05$). For older age groups (> 7 years and over) the number of samples is scarce to draw any conclusion.

Results from the exponential curve fit to the mean length by age were shown in **Figure 5a** for male and **Figure 5b** for female albacore respectively. The trend in the curve fit to male observations appeared to reach a value for L infinity of 100 cm, meanwhile in the case of the females fit curve, it seemed to reach a value of 90 cm for L infinity.

In **Figures 6a and 6b,** were included a selection of photographs taken corresponding to both sexes: males and female and to age groups from 1 to 3 years old and for 4 and 5 years old, respectively. It is clear in all the age groups the resorption localized in the inner part of the spine section. This tissue phenomena adds complexity to

the ageing process by masking the first hyaline band (*annuli*). In the female albacore sample aged 5 years old, the formation of double hyaline band is clear, which adds diversity to the interpretation of annual growth marks.

4. Discussion

Comparison of the sex combined length-weight relationship fit in this study and the length-weight (Megalofonou, 2000) considered for the Mediterranean stock (ICCAT Manual, 2006-2009) were presented in **Figure 7**, It was observed that for albacore of size over 70 cm length the new relationship fit converts into larger weight albacore than the assumed relationship for this stock, which represents an impact into the populations analyses. The differences can be solved with further effort to increase the sample size by time and spatial strata in order to cover the entire population targeted by the diverse gears year round in the Mediterranean albacore fishing grounds.

Concerning the length distribution by sex, it is noticeable the small number of males of length class bin 1 cm between 67 and 73 cm (**Figure 2**).This might be caused by a sampling bias due to not applying a random sampling design and targeting the largest available albacore from the catch during the spawning season in the fishing area around the Balearic Is. (Garcia *et al.*, 2002)

According to findings by (Arena, 1991), albacore of 2 years old with 62 cm length is sexually mature. The largest proportion of albacore samples analysed were in agreement with this hypothesis and can be considered adult specimen which were caught in the spawning area located off Balearic Islands (Garcia *et al*.2002).

The sex-ratio found in this study is quite different from the sex-ratio reported by Megalofonou (1990; 2003) presented in (**Table 5**). Nevertheless, the fishing areas and season are different, as well as time lag between studies

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Assuming the ageing results obtained, albacore caught in this area represented the oldest aged specimen in the Mediterranean Sea (**Table 5**). Also it would be worthwhile to increase the number of spine samples by sex to obtained separate growth estimates for males and females albacore accordingly with the very preliminary results obtained in this study which indicated a differential growth rate between males and females albacore. It is obvious by observing the age-length key (**Table 5**) results (*i.e*. albacore of 83 cm length was aged 5, 7 and 10 age group) that those estimates should be taken with caution since the growth theory of one hyaline band per year needs further validation study as well as the calibration between trained readers. The identification of *annulus* carried out in this study by considering one single hyaline band per year is displayed in the images captured and shown in **Figure 6a** and **6b** for individuals considered to belong to ages 1, 2 and 3 groups male and female and ages 4 and 5 male and female, respectively. Those samples were aged by counting each hyaline band highlighted in the corresponding images. It is noticeable that both males and females present the same pattern of *annuli* formation. However, as point out by Campana (2001), in the absence of an absolute form of age validation, the periodicity of *annulus* formation and location of the first *annulus* should be identified.

Moreover, most of the growth studies in the Mediterranean Sea (**Table 5**) were based on scales reading (Arena *et al.*, 1980, Cefali *et al*., 1986, Megalofonou, 1990; Megalofonou *et al.*, 2003). Those authors found that the scales methodology underestimated the age in larger fish.

Nevertheless, the results discussed provide a starting point of discussion to be considered for the data preparatory meeting of Mediterranean albacore. As mentioned, several research issues remained to be fulfilled for a comprehensive age and growth parameters estimation of Mediterranean albacore stock.

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Table 1. Number of albacore sampled and in brackets number of spines read from the western Mediterranean (2004-2006). (1= males, 2= females, 3= not sexed).

	Month							
Year/ Sex	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*Total*
2004		1( )	28 (28)					29 (28)
1			11 (11)					11 (11)
2			17 (17)					17 (17)
3		1( )						1 (1)
2005	1( )	1( )	158 (105)		17 ( )			177 (105)
1			68 (53)		6 ( )			74 (53)
2			82 (51)		11 ( )			93 (51)
3	1 ( )	1 ( )	8 ( )					10 ( )
2006		53 (50)	197 (92)	3 (1)	6 (3)	1 ( )	4 (1)	264 (147)
1		26 (24)	80 (33)	2 (1)	2 (1)	1 ( )	2 ( )	113 (59)
2		27 (26)	83 (52)	1 ( )	4 (2)			115 (80)
3			34 (7)				2 (1)	36 (8)
Total	1( )	55 (51)	383 (224)	3 (1)	23 (3)	1 ( )	4 (1)	470 (280)

Table 2. Number of albacore round weight observations by sex from the Mediterranean Sea (2005-2006). In brackets mean fork length (cm) and mean weight (kg). (1= male, 2= female).

	Month				
Year/ Sex	*6*	*7*	*8*	*9*	*Total*
2005		59 (70.25 - 7.13)		17 (62.88 - 4.96)	76 (68.61 - 6.65)
1		22 (70.46 - 7.04)		6 (61 - 4.42)	28 (68.43 - 6.48)
2		37 (70.14 - 7.19)		11 (63.91 - 5.26)	48 (68.71 - 6.75)
2006	53 (71.91 - 8.02)	163 (68.28 - 6.56)	2 (58 - 3.85)	6 (63.67 - 5.28)	224 (68.92 - 6.85)
1	26 (70.65 - 7.45)	80 (69.08 - 6.78)	2 (58 - 3.85)	2 (66.5 - 6.14)	110 (69.20 - 6.87)
2	27 (73.11 - 8.56)	83 (67.51 - 6.35)		4 (62.25 - 4.85)	114 (68.65 - 6.82)
Total	53 (71.91 - 8.02)	222 (68.80 - 6.71)	2 (58 - 3.85)	23 (63.09 - 5.04)	300 (68.84 - 6.80)

Table 3. Age length key for the western Mediterranean Sea (2004-2006). (M= male, F= female, T= total).

Age	*1*		*2*		*3*		*4*		*5*		*6*		*7*		*8*		*9*		*10*		*11*		*T*
Length	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	
50																							
51																							
52		1																					1
53	1	2																					3
54	2																						2
55	3																						3
56	2	3																					5
57						1																	1
58			3	1																			4
59		3		1	2	1																	7
60		2	4	1	1	1																	9
61		1	5	2		1																	9
62		1	2	4	1																		8
63		1	3	3	1																		8
64			3	2		2																	7
65			1	1	1	3																	6
66			3	2		1		1															7
67			1	3		1		4															9
68				3	2			1		1													7
69				1		1		3															5
70						1		6	1	3													11
71								8		2													10
72							1	1		3		2											7
73						1		4		2		1											8
74									4	3	2												9
75								1	4	6	1	1											13
76										3	1	2	1										7
77									1			2		1									4
78							1		5		1	3		2									12
79												5	2	1		2							10
80											2		1		1								4
81											3	2	3		1								9
82											1			1	3		1						6
83									1				1							1			3
84											1		2	1	1	1	2						8
85												1					2	1	1				5
86											1				1			1	1				4
87															1		1						2
88															1								1
89													1		1				1				3
90																	2	1	1				4
91															1		1						2
92																	1		1		1		3
93														1									1
94																1							1
95																							
96																			1				1
97																							
98																							
T																							249

Table 4. Albacore mean fork length (FL) and U Mann-Whitney test probability by age. (Test not corrected for ties).

Age (years)	*Number of samples*		*Mean fork length*		*Standard deviation*		*P value*
	Male	Female	Male	Female	Male	Female	
1	8	14	54.8	57.8	1.0	3.5	0.042
2	25	24	62.2	64.0	2.6	3.1	0.038
3	8	14	63.0	64.6	3.7	4.4	0.402
4	2	29	75.0	70.2	4.2	2.2	0.052
5	16	23	76.0	73.1	2.9	2.3	0.004
6	13	19	79.4	77.6	3.8	3.2	0.147
7	11	7	81.5	81.6	3.4	5.6	0.596
8	11	4	84.7	84.0	3.7	7.1	0.489
9	10	3	87.0	87.0	3.5	2.6	0.937
10	6	1	89.7	83.0	4.0		
11	1		92.0				

Table 5. Summary of albacore growth studies using hard parts in the Mediterranean Sea (2004-2006).

	Arena (1980)	*Megalofonou (1990)*	*Megalofonou (2000)*			*Megalofonou (2003)*	*Present study*		
Zone	Tyrrhenian Sea	Aegean Sea	Aegean Sea and Gulf of Taranto			Aegean Sea	Western Mediterranean		
Method	Scales	Scales	First dorsal fin ray			Scales	First dorsal fin ray		
Sample size	122	219	1087			446	249		
Length range (cm)	32 – 88	54.8 – 82	57 – 92			55.5 – 89	52 - 96		
Sex ratio (M:F)		2. 1 :1				2: 1	1 : 1.16		
Age	Undetermined	Undetermined	Males	Females	Combined	Undetermined	Males	Females	Sex combined
0	38.3 (19)								
1	45 (1)	56.5 (4)		59.5 (2)	59.5 (2)	56.6 (4)	54.8 (8)	57.8 (14)	56.7 (22)
2	66.3 (7)	64.5 (83)	65.9 (91)	65.1 (117)	65.8 (280)	65.4 (139)	62.2 (25)	63.9 (24)	63.0 (49)
3	75.4 (75)	68.8 (78)	70 (219)	68.1 (123)	69.8 (520)	69.4 (201)	63.0 (8)	64.6 (14)	64.1 (22)
4	78.1 (20)	73 (39)	74.9 (109)	72.1 (25)	74.4 (195)	74.3 (81)	75.0 (2)	70.2 (29)	70.5 (31)
5		77 (5)	79.1(38)	76.3 (5)	79.3 (72)	78.2 (16)	76.0 (16)	73.1 (23)	74.3 (39)
6		79 (1)	81.1 (7)	79.4 (2)	81.2 (13)	82.8 (5)	79.4 (13)	77.6 (19)	78.3 (32)
7			89 (1)		85.5 (4)		81.5 (11)	81.6 (7)	81.6 (18)
8					92 (1)		84.7 (11)	84.0 (4)	84.5 (15)
9							87.0 (10)	87.0 (3)	87.0 (13)
10							89.7 (6)	83.0 (1)	88.7 (7)
11							92.0 (1)		92 (1)

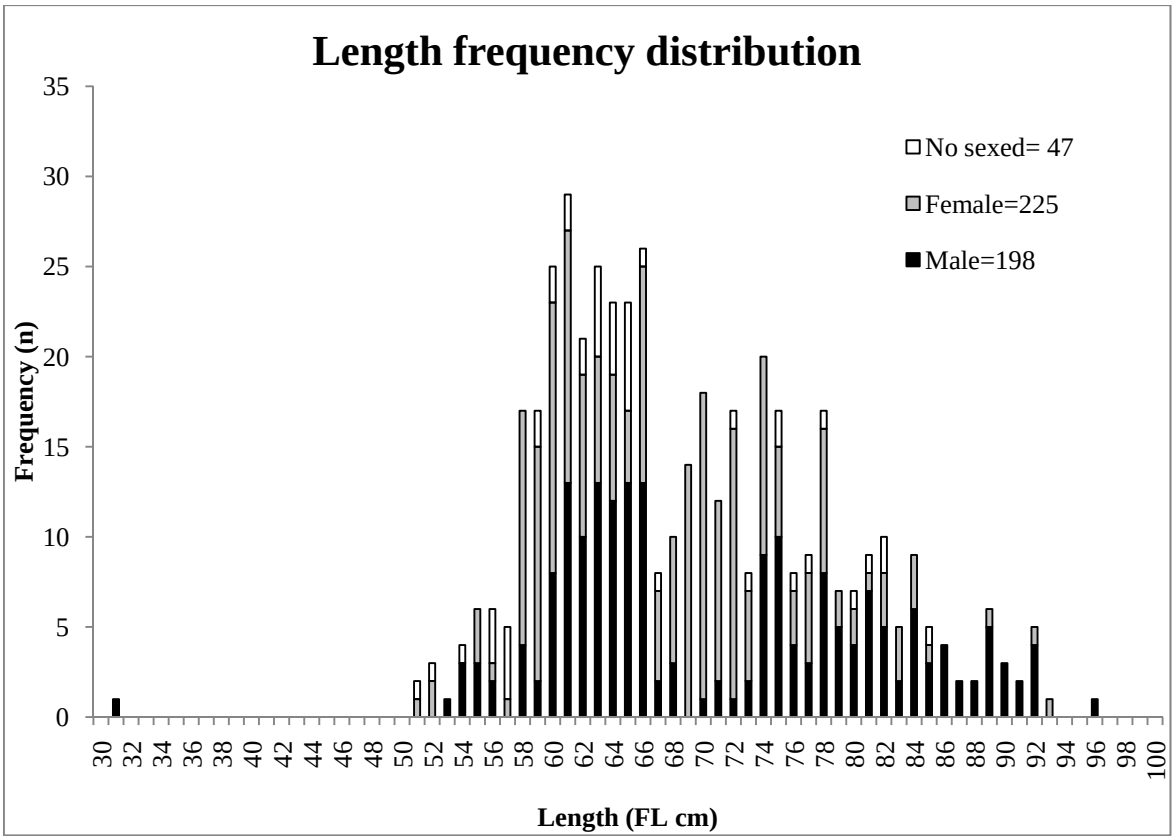

Figure 1. Length distribution of albacore from the western Mediterranean Sea (2004-2006).

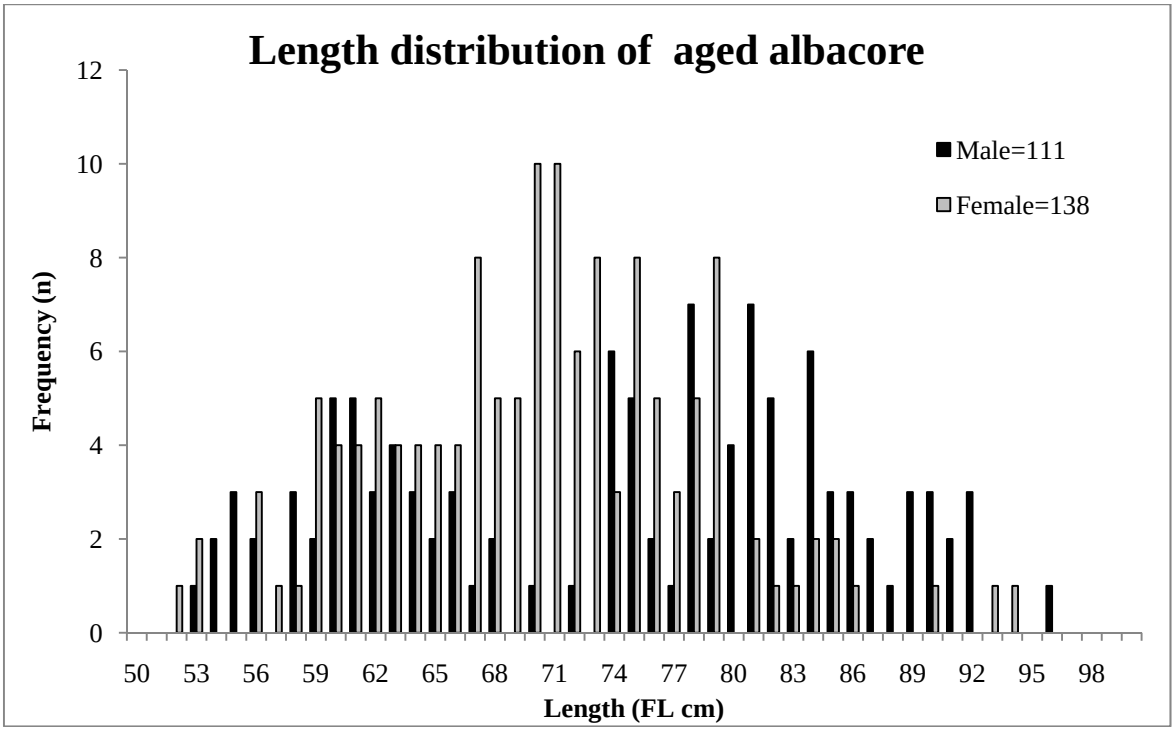

Figure 2. Length distribution of aged albacore from the western Mediterranean Sea (2004-2006).

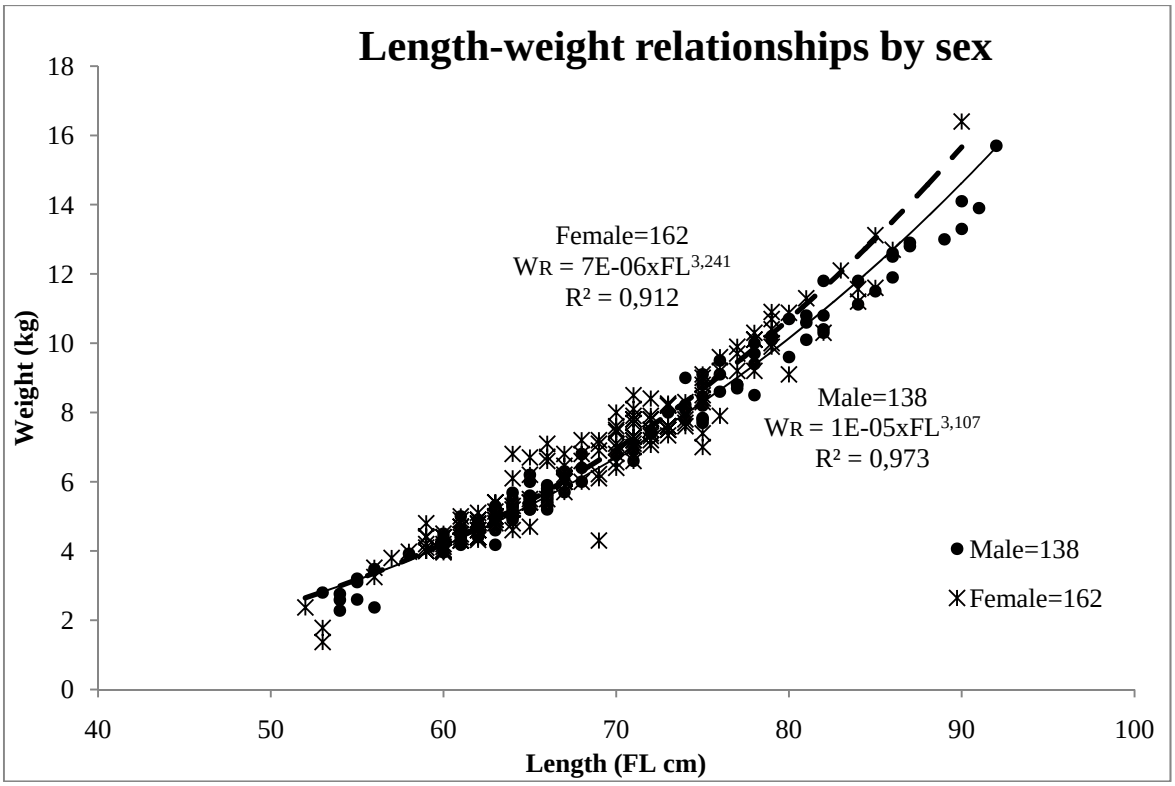

Figure 3. Estimated length-weight relationship by sex from the western Mediterranean Sea (2005-2006).

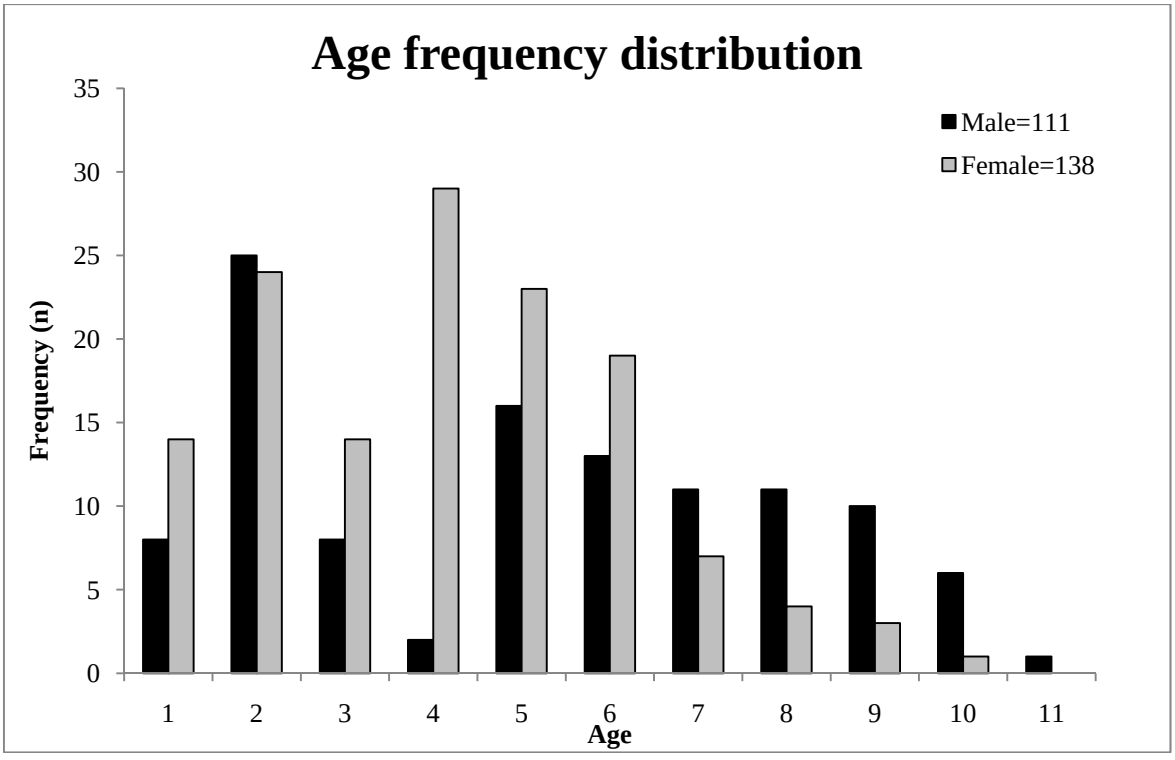

Figure 4. Albacore age frequency distribution by sex obtained from spine reading. Western Mediterranean Sea samples (2004-2006).

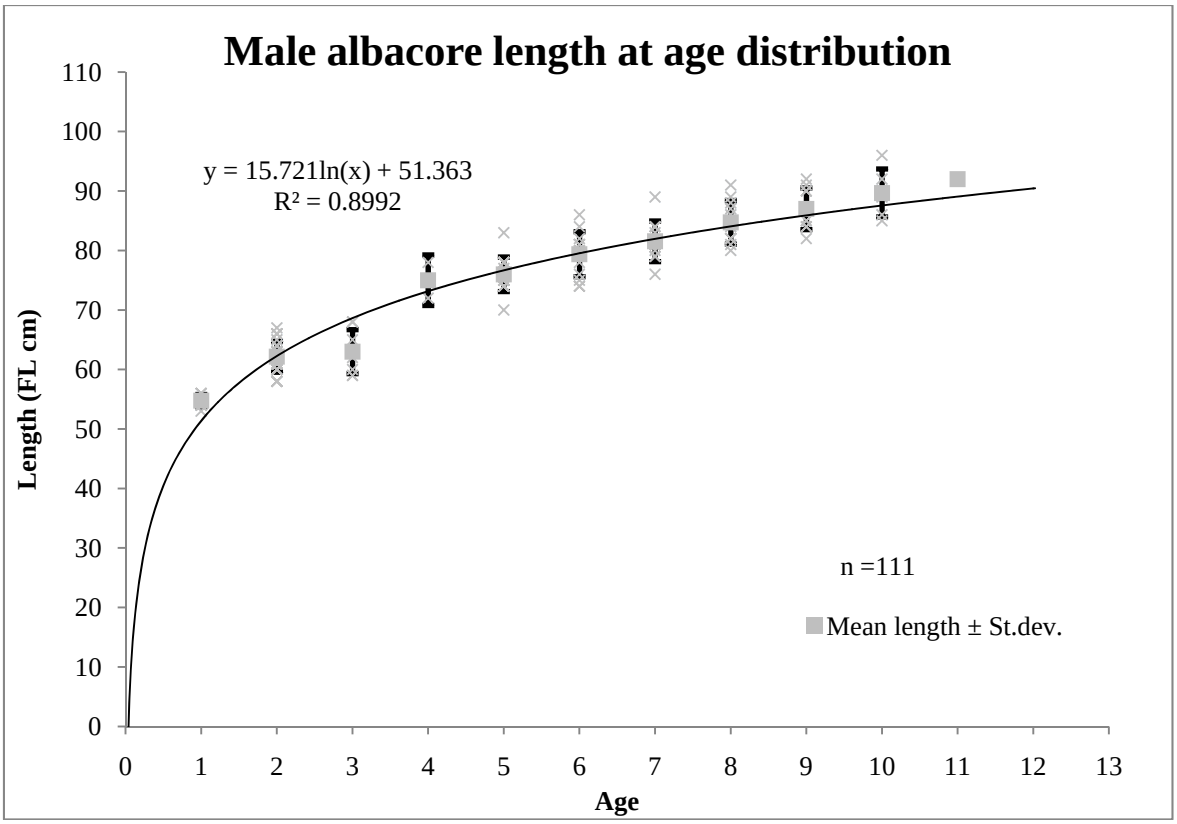

Figure 5a. Male albacore mean length (± St. dev.) observations by age group from western Mediterranean samples (2004-2006).

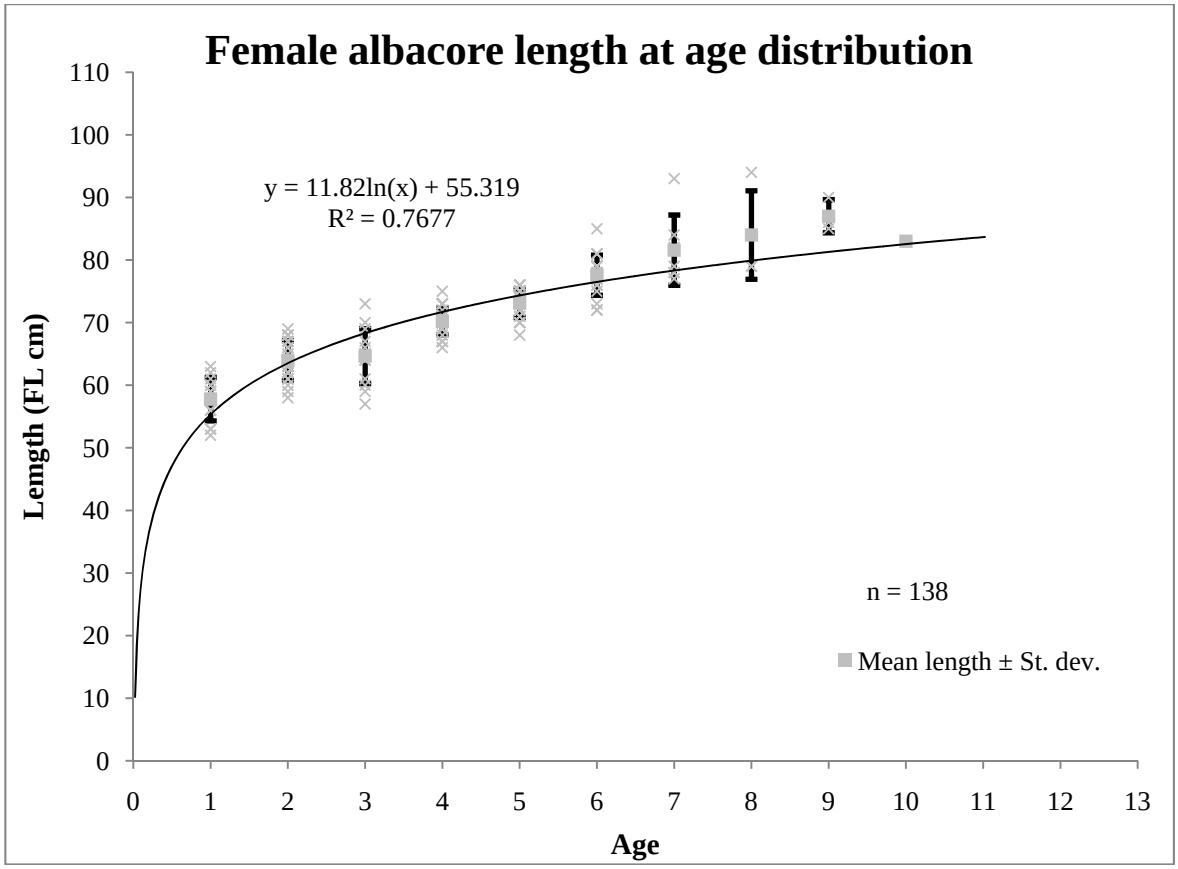

Figure 5b. Female albacore mean length (± St. dev.) of observations by age group from western Mediterranean samples (2004-2006).

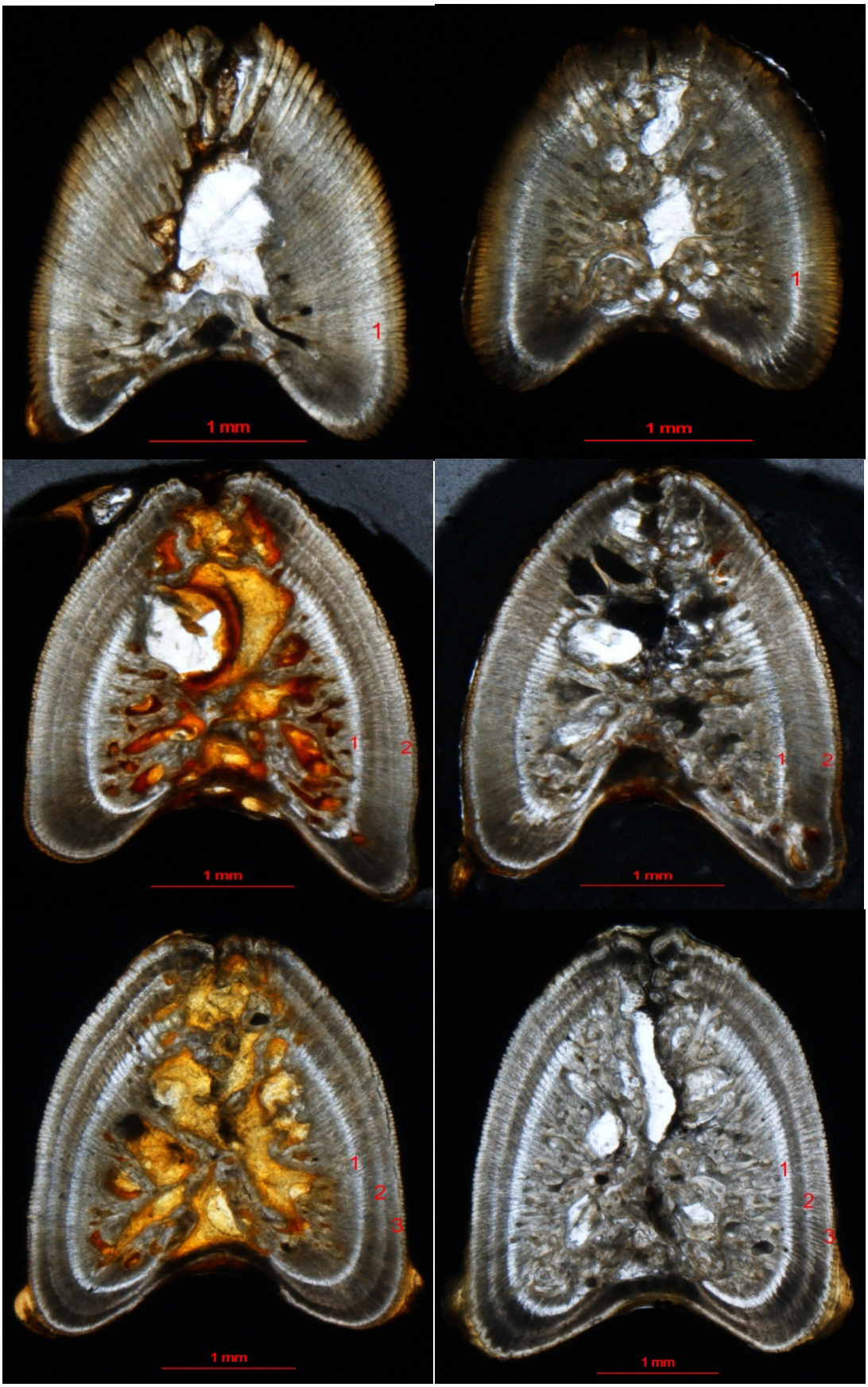

Figure 6a. Left column top to bottom. Male albacore age 1 (FL = 53 cm), age 2 (FL = 64 cm) and age 3 (FL = 60 cm). Right column top to bottom. Female albacore age 1 (FL = 53 cm), age 2 (FL = 63 cm) and age 3 (FL = 61 cm).

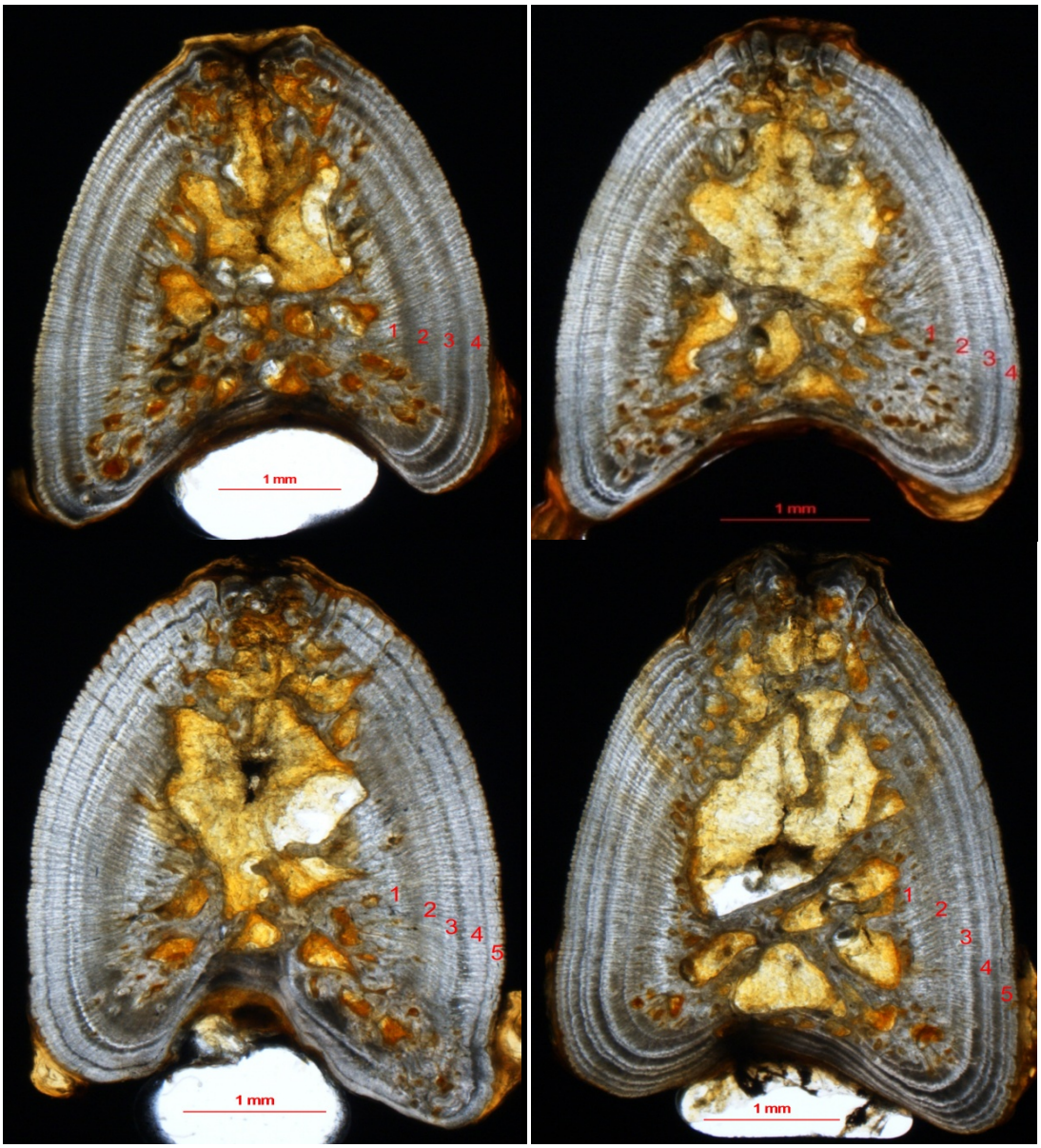

Figure 6b. Left column top to bottom. Male albacore age 4 (FL = 78 cm) and age 5 (FL = 75 cm). Right column top to bottom. Female albacore age 4 (FL = 67 cm) and age 5 (FL = 75 cm).

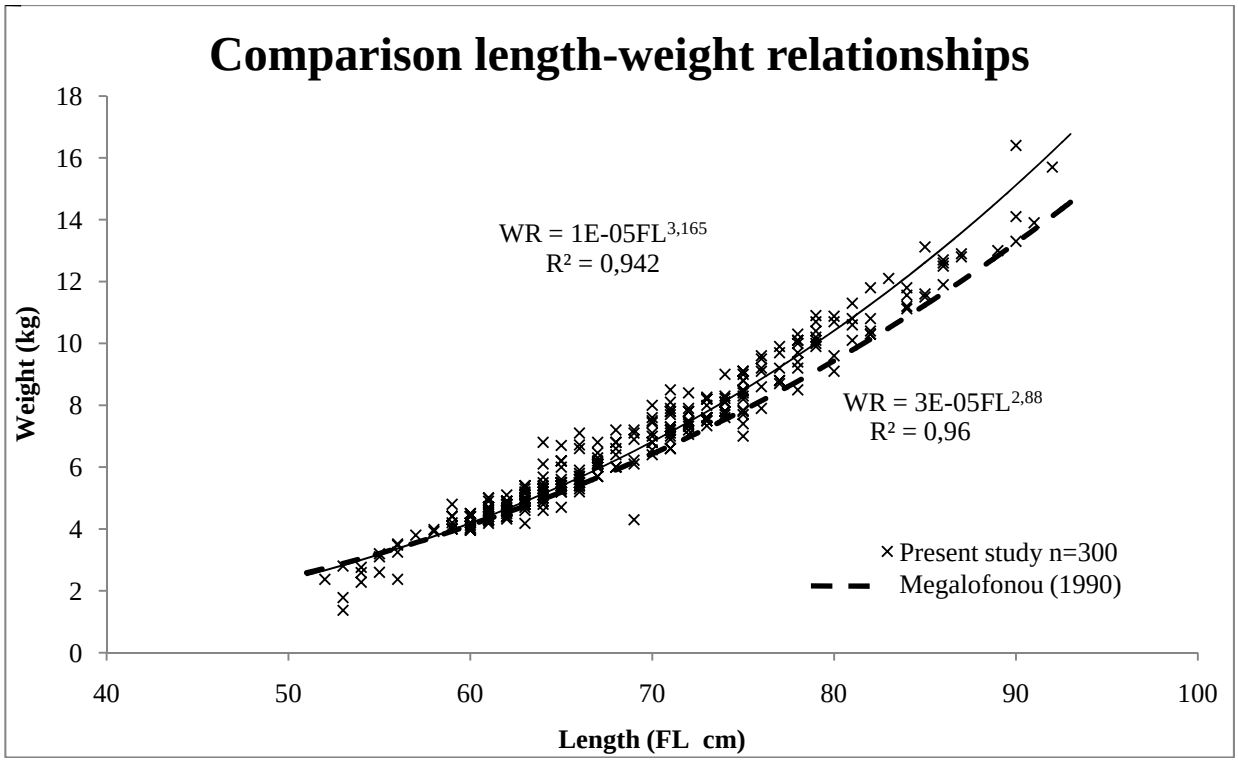

Figure 7. Comparison between the length-weight in the present study and the length-weight relationship accepted for the Mediterranean albacore stock (Source: ICCAT).