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Article

Age and growth of the Spanish chub mackerel *Scomber colias* off southern Spain: a comparison between samples from the NE Atlantic and the SW Mediterranean

Edad y crecimiento del estornino *Scomber colias* del sur de España: una comparación entre muestras procedentes del Atlántico NE y del SW Mediterráneo

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Resumen.- Se analiza la edad y los patrones de crecimiento del estornino *Scomber colias* en aguas del sur de España, procedentes de dos áreas diferentes, costa Atlántica y Mediterráneo occidental, en el periodo comprendido entre octubre de 2003 y septiembre de 2004. La relación longitud-peso viene dada por la ecuación TW=0,0015 $TL^{3,5289}$ (r^2 = 0,99, donde TW= peso total en g, TL=longitud total en mm). La edad se determinó mediante la lectura (conteo e interpretación) de los anillos de crecimiento de otolitos *sagitta* en 221 ejemplares capturados por la flota comercial andaluza y durante las campañas oceanográficas de prospección de recursos marinos. En los otolitos, anualmente fueron depositados dos anillos, uno opaco y otro hialino. La zona opaca se formó principalmente en primavera y verano, mientras que la zona hialina se formó en otoño e invierno. La relación existente entre el radio del otolito y la longitud del pez, se describe mediante la ecuación: TL = 43,881 * $OR^{1,245}$ (r^2 = 0,93, donde OR= radio del otolito). Los parámetros de la curva ajustada de crecimiento de von Bertalanffy fueron estimados para los dos sexos de forma conjunta así como para todo el periodo de estudio (L_∞ = 43 cm, K = 0,27 para el Golfo de Cádiz, y L_∞ = 40 cm, K = 0,37 para el Mar de Alborán, donde L_∞ se define como la talla máxima teórica, y K como la rapidez con la que la curva se torna asintótica). No se han encontrado diferencias de crecimiento entre las distintas áreas de estudio, lo que sugiere que el Estrecho de Gibraltar no supone una barrera geográfica para el normal desarrollo del ciclo vital de esta especie. Por otro lado, gracias a las condiciones medioambientales similares del Mar de Alborán y del Golfo de Cádiz, el Estrecho de Gibraltar es una vía de comunicación importante que permite la existencia de un flujo larval entre el Atlántico y el Mediterráneo.

Palabras clave: Scombridae, otolito, parámetros de von Bertalanffy, Estrecho de Gibraltar

Abstract.- This paper studies the age and growth patterns of the Spanish chub mackerel *Scomber colias* off southern Spain collected from two different areas, Atlantic coast and Western Mediterranean, from October 2003 to September 2004. The length-weight relationship was given by TW=0.0015 $TL^{3.5289}$ (r^2 = 0.99, where TW= total weight in g, TL= total length in mm). Age was determined by interpreting and counting growth rings on the *sagitta* otoliths of 221 individuals caught by the commercial Andalusian fleet and during fisheries research surveys. Two rings, one opaque and one hyaline, were laid down each year on the otoliths. The opaque zone was formed during spring and summer and the hyaline one during autumn and winter. The otolith radius-length of the fish relationship was described by the equation: TL = 43.881 * $OR^{1.245}$ (r^2 = 0.93, where OR= otolith radius). The parameters of the fitted von Bertalanffy growth curve were estimated for sex combined for the whole period (L_∞ = 43 cm, K = 0.27 for the Gulf of Cadiz, and L_∞ = 40 cm, K = 0.37 for the Alboran Sea, where L_∞ is defined as the asymptotic mean length and K is the rate at which the curve approaches the asymptote). There were no differences in growth rate between the sampling areas, suggesting that the Strait of Gibraltar is not a geographical break for the life history of this species; on the contrary, thanks to the similar environmental conditions of the Alboran Sea and the Gulf of Cadiz, the Strait of Gibraltar is a communication way that allows an Atlantic-Mediterranean larval flow.

Key words: Scombridae, otolith, von Bertalanffy parameters, Strait of Gibraltar

INTRODUCTION

The Atlantic chub mackerel *Scomber colias* Gmelin, 1789, and the Atlantic mackerel *Scomber scombrus* Linnaeus, 1758, are cosmopolitan middle-size pelagic species with a wide distribution throughout the Atlantic Ocean and neighbouring seas, though the latter is more abundant at northern latitudes than the former (Collette 1986). Similar to most scombrids, mackerels are highly migratory species over the continental shelf, being mainly distributed at depths down to 250-300 m (Collette 1986, Uriarte *et al*. 2001, Villamor *et al*. 2004). Besides their economical value for several countries fisheries, both *Scomber* species occupy a key position in the trophic web of eastern Atlantic Ocean and Mediterranean Sea ecosystems, as they feed mainly on zooplankton and some small pelagic fish and they are an essential element of the diet of larger pelagic fish (*e.g.*, tuna, swordfish, and sharks) and sea mammals (*e.g.*, dolphins and seals, Zardoya *et al*. 2004).

Scomber colias is exploited from the south of Africa to the south of Iberian Peninsula. In the North West Africa region, the chub mackerel fishery is targeted by the Moroccan coastal purse seiners, by the pelagic trawlers that operate under the Morocco-Russian Federation fishing agreement and other vessels chartered by Moroccan operators, and by several pelagic trawlers from different countries (Russian Federation, Ukraine, European Union and others), and it is also considered as bycatch by the Senegalese artisanal fleet (FAO 2008). In the Azores, artisanal fleet includes this species as one of its main target but is considered as bycatch in the longline demersal fishery operating offshore areas and is also used as bait for the tuna longline and handline fisheries (Carvalho *et al*. 2002). In the Canary Islands, the chub mackerel supports an important commercial fishery (Lorenzo *et al*. 1995, Lorenzo & Pajuelo 1996). In the Mediterranean and Black Sea, a major proportion of the *S. colias* is taken by Turkey fleets (Sever *et al*. 2006) but is also a species of high commercial interest in other places as the Hellenic seas (Kiparissis *et al*. 2000). Although annual landings of chub mackerel have decreased during the last few years in the Azores and the Mediterranean (Carvalho *et al*. 2002, Sever *et al*. 2006), the capture of this species has seen an increasing trend since 1991 in the Northwest Africa region, being the second most important species (following *Sardina pilchardus*) landed in Morocco in 2006 (FAO 2008). This increment has been also observed in the Andalusian ports (Spanish Institute of Oceanography database).

On the other hand, *Scomber scombrus*, is restricted to the North Atlantic Ocean and adjacent seas (Scoles *et al*. 1996, Nesbø *et al*. 2000), from the south of the Iberian Peninsula to the north of Norway (Villamor *et al*. 2004), and supports valuable fisheries (handlines, purse seines, trawls and gillnets) of great importance in several European countries (ICES 2004) whose catches have also increased in recent years (ICES 2001).

Because of the worldwide importance of the chub mackerel fishery, it has been the focus of several studies in the recent past. Many authors have been studied different aspects of the fishery and biology of this species in the south-western Atlantic (Lorenzo 1992, Lorenzo *et al*. 1995, Lorenzo & Pajuelo 1996, Carvalho *et al*. 2002, Martins 2007) and in the Mediterranean (Bas 1959, 1960, Kiparissis *et al*. 2000, Perrota *et al*. 2005). However scarce information is available on chub mackerel from the waters off southern Spain. Rodríguez-Roda (1982) analysed aspects of the biology of this species in the Gulf of Cadiz and his study has constituted the only information available on the biology of *Scomber colias* in this area. Knowledge of the rate of growth is essential for studies of population dynamics and stock assessment, and it is usually based on age determination of random samples of the population. The objective of the study is to compare age and growth of two closed populations of the Atlantic chub mackerel, separated by the Strait of Gibraltar, one from the Gulf of Cadiz (Atlantic southern coast of Spain) and the other one from the Alboran Sea (Mediterranean southern coast of Spain), because the Strait of Gibraltar has been considered as an important natural barrier in populational terms (Murta *et al*. 2008) and as a breakpoint area to gene flow (Lo Brutto *et al*. 2004, Rubín *et al*. 1997, 2006) between two marine biogeographical provinces, the Mediterranean Sea and the Northeast Atlantic, which may influence on the biological characteristics of the fish.

MATERIALS AND METHODS

Scomber colias monthly samples were obtained from commercial catches landed by Andalusian fleets (purse seine 88%, trawl 10% and artisanal 2%) in the ports of the Gulf of Cadiz (Sanlucar de Barrameda, Puerto de Santa Maria, Cadiz) in the NE Atlantic (36ºN, 7º20’-5º50’W), and in the ports of the Alboran Sea (Algeciras, Estepona, Marbella, Malaga and Almeria) in the SW Mediterranean (36ºN, 5º50’-2º11’W) (Fig. 1). In addition, some samples were taken using a trawl net during the annual surveys in those areas. Specialists determined if mackerels were *Scomber colias* (the space between posterior end of first dorsal fin groove and origin of second dorsal fin is approximately equal in length to groove; first dorsal fin spines: 9-10) or *S. scombrus* (the space between first dorsal fin groove and second dorsal

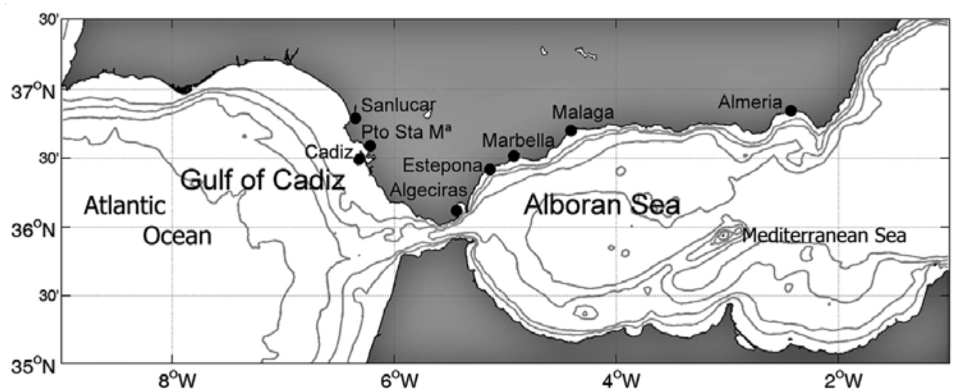

Figure 1. Locations of the study area. In the Gulf of Cadiz, the sampling were from Sanlucar de Barrameda, Puerto de Santa Maria and Cadiz. In the Alboran Sea, the sampling were from Algeciras, Estepona, Marbella, Malaga and Almeria / Localizaciones del área de estudio. En el Golfo de Cádiz, las muestras fueron obtenidas en Sanlúcar de Barrameda, Puerto de Santa María y Cádiz. Las muestras procedentes del Mar de Alborán, provenían de Algeciras, Estepona, Marbella, Málaga y Almería

fin is clearly greater, approximately 1.5 times, than length of groove; first dorsal fin spines: 11-13) following Collette & Nauen (1983) before the analysis. Chub mackerels were sampled between October 2003 and September 2004. A total of 729 fish were analyzed (363 from the Gulf of Cadiz and 373 from the Alboran Sea).

Specimens were measured for total length (TL) to the nearest 1 mm, and the total weight (TW) was recorded to the nearest 0.01 g. Each specimen was sexed by macroscopic observation of the gonads. The parameters of the length-weight relationships were estimated by linear regression analysis on log-transformed data.

Sagittal otoliths from 221 specimens were used for age determination. Whole otoliths were mounted on a blackened background, concave side up, covered with resin (Eukitt) and examined with a stereo microscope using reflected light. Two experienced readers aged the otoliths and each otolith was read twice, on two separate occasions. The readings for a given otolith were accepted only if both readers agree, and whenever there was a discrepancy between the four readings, the age data were excluded from the study. The criteria used to determine age were: (1) the date of birth was considered to be 1 January according with the reproduction season (winter) related in other studies (Bas 1960, Lorenzo 1992), (2) each year a translucent and an opaque growth band are deposited on the otolith agreeing with other studies (Rodríguez-Roda 1982, Lorenzo 1992, Carvalho *et al.* 2002, Perrota *et al.* 2005), and (3) the age of the fish corresponds to the number of complete translucent bands (n). Monthly proportions of opaque and translucent bands along the edge of the otoliths were examined in order to validate the annual periodicity of band formation. The fact that the formation of the rings was regular implied that the otoliths could, therefore, be used to determine growth. Besides the number of annuli on each otolith, the otolith radius (OR) (distance from the focus to the otolith posterior end) as well as the type of marginal formation were recorded. The measurements were determined using image analysis (Program Visilog 6 + TNPC 3.2, described by IFREMER). The back-calculation method reconstructs the size of individuals at a younger age, based on growth recorded in their calcified structures (Casselman 1987). An age-length key was elaborated. Whole length distributions by age were used to estimate the growth rate of chub mackerel. The total length distribution by age class was fitted to the von Bertalanffy equation, $L_t=L_\infty[1-\exp(-k(t-t_0))]$, where L_t is the mean fish length at age t; L_∞, K and t_0 are the parameters that determine the shape of the growth curve. L_∞ is defined as the asymptotic mean length; K the rate at which the curve approaches the asymptote and t_0 the age at which mean length is zero. All the parameters were calculated using the subroutine Analysis of length-at-age data of the FISAT II software (Gayanillo *et al.* 1993). Growth curves were compared with other studies by the phi-prima test (Φ') following Munro & Pauly (1983) where $\Phi' = \log_{10} K + 2 \log_{10} L_\infty$. A nested ANOVA was used to detect differences in growth between both areas of study following Sokal & Rohlf (1995).

RESULTS

Of the total number of chub mackerel examined in the Gulf of Cadiz, 169 were females, 142 were males and 52 indeterminate. The range of the total lengths of the fish sampled in this area was 16.4-43.0 cm [mean length = 26.7 ± 5.6 (sd) cm]. In the Alboran Sea, 185 females, 128 males and 60 indeterminate were analyzed. Fish ranged in size from 17.2 to 40.0 cm [mean length = 26.8 ± 3.7 (sd) cm]. There were no significant differences in TL between sexes (ANOVA $F_{(1, 582)}$ = 3.09, P = 0.079) or sampling areas (ANOVA $F_{(1, 728)}$ = 0.15, P = 0.701). Regression between total length and weight was $TW = 0.0015\ TL^{3.5289}$ (r^2 = 0.99) for the Gulf of Cadiz and $TW = 0.0014\ TL^{3.5369}$ (r^2 = 0.97) for the Alboran Sea. The comparison of the weight-length regressions lines did not show differences between sexes (neither in intercept $F_{(1, 582)}$ = 2.44, P = 0.119; nor in slope, $F_{(1, 582)}$ = 0.25, P = 0.617), nor sampling areas (neither in intercept $F_{(1, 728}$ = 2.56, P = 0.109; nor in slope, $F_{(1, 728)}$ = 1.61, P = 0.204), so data can be pooled. The relation for the entire sample is given by equation $TW = 0.0015\ TL^{3.51}$ (r^2 = 0.99).

The otoliths showed a seasonal variation in the formation of hyaline and opaque zones during the period of the study (Fig. 2). Analysis of the border of the otolith showed a general pattern where two rings, one opaque and one hyaline, were deposited during the period of one year. Opaque bands begin to form at the beginning of spring (March and April), ending during late summer (September or October), while translucent bands predominate during the remaining months of the year. Formation of the rings was regular and the otoliths could, therefore, be used to determine growth. The relationship between otolith radius (OR) and fish length was established. The TL and OR regression lines did not differ between sexes (neither in intercept $F_{(1, 147)}$ = 1.66, P = 0.199; nor in slope, $F_{(1, 147)}$ = 0.89, P = 0.348), or sampling areas (neither in intercept $F_{(1, 220)}$ = 0.30, P = 0.858; nor in slope, $F_{(1, 220)}$ = 0.7, P = 0.789), so data were pooled. The relation is given by the equation $TL = 43.881 * OR^{1.245}$ (r = 0.93) (Fig. 3). The proportion between fish growth and otolith size increase were closely correlated, allowing the use of back-calculation for determinate length.

Full agreement was obtained in the readings of 221 otoliths performed by two readers (66% of success). Chub mackerels aged I to VII years were present in the samples (Table 1). The parameters of the von Bertalanffy equation for the pooled data of both sexes from each sampling area were estimated: the theoretical maximum length value, 43 cm in the Gulf of Cadiz and 40 cm in Alboran Sea, was fixed to the size of the largest fish sampled in each area. The phi-prima (Φ') test estimations present similar values:

Gulf of Cadiz:

L_∞ = 43 cm, K = 0.27 yr^{-1}, t_0 =-1.1 yr and Φ'= 2.698

Alboran Sea:

L_∞ = 40 cm, K = 0.37 yr^{-1}, t_0 =-0.1 yr Φ' =2.772

The von Bertalanffy growth curve is shown in Fig. 4, where the simulated VBFG curve fits well to the measured values. The nested ANOVA showed no differences in growth between chub mackerel from the Gulf of Cadiz and from Alboran Sea ($F_{(1, 728)}$ = 2.23, P = 0.428).

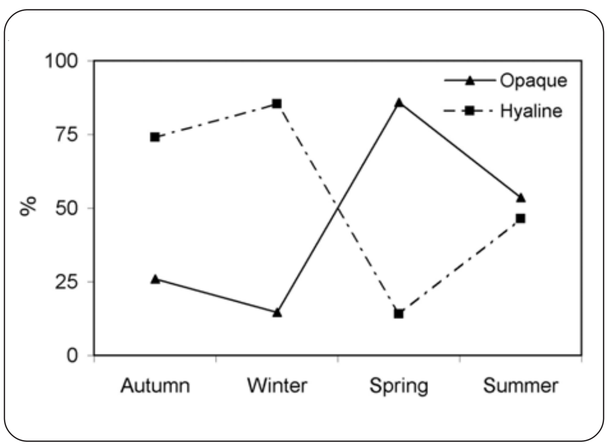

Figure 2. Mean seasonal percentage of otoliths of *Scomber colias* off the Andalusian coast with opaque and hyaline edges / Porcentaje medio trimestral de otolitos de borde opaco y borde hialino para *Scomber colias* en la costa andaluza

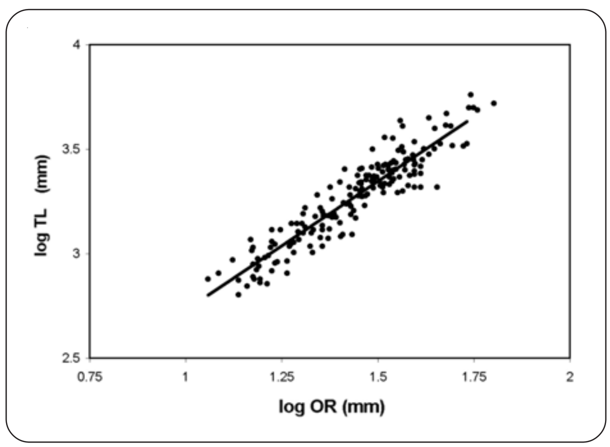

Figure 3. Relationship between the otolith radius and the total body length (both in logarithms) of *Scomber colias* off the Andalusian coast / Relación entre el radio del otolito y la longitud total del pez (ambos en logaritmos) para *Scomber colias* en la costa andaluza

Table 1. Length and age correspondence of the chub mackerel *Scomber colias* in two sampling areas. 0 to VII indicate the fish age in years / Correspondencia entre longitud y edad del estornino *Scomber colias* en dos áreas de estudio. 0 a VII indica la edad de los peces en años

Length (cm)	Age classes														
	Gulf of Cadiz								Alboran Sea						
	0	I	II	III	IV	V	VI	VII	0	I	II	III	IV	V	VI
16.0-16.9		2													
17.0-17.9		7								8					
18.0-18.9	1	4								4					
19.0-19.9	2	5								2					
20.0-20.9	4	6	1						1	1					
21.0-21.9		7	1						1	1	1				
22.0-22.9		2	1	1						2	1				
23.0-23.9	1	3	4	1					1	1	1				
24.0-24.9	1	4	2	1						2					
25.0-25.9		2	4							3	2		1		
26.0-26.9			4	1						6	6	1			
27.0-27.9		3	5	2						2	4				
28.0-28.9		1	5	1							6	1			
29.0-29.9		2	3	3						1	8			1	
30.0-30.9			5	3						3	6				
31.0-30.9										1	6	1			
32.0-32.9										1	5				
33.0-33.9		1		3	2						1				
34.0-34.9					1					1	1	1			
35.0-35.9				1									1		
36.0-36.9						1									
37.0-37.9															
38.0-38.9					1		1								
39.0-39.9					3										
40.0-40.9															1
41.0-41.9							1								
42.0-42.9															
43.0-43.9								1							
n	9	49	35	17	7	1	2	1	3	39	48	4	2	1	1
Mean Length	20.7	21.6	26.7	29.2	36.9	36.4	39.9	43.0	22.0	23.6	28.9	29.9	30.1	29.1	40.0

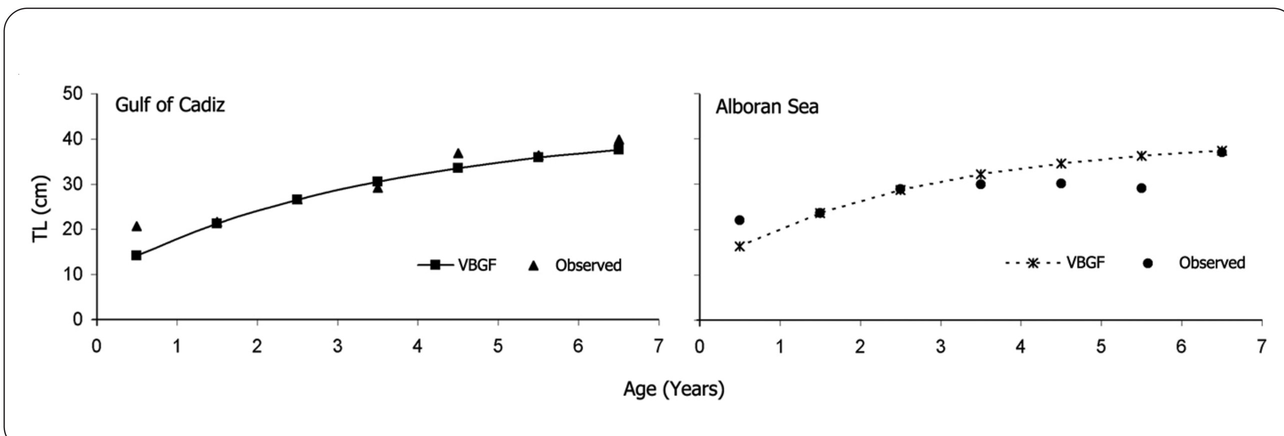

Figure 4. The von Bertalanffy growth curve of *Scomber colias* off the Andalusian coast obtained from back-calculated mean length at age. The mean of the observed points and the theoretical points (estimated by VBGF) are represented / Curva de crecimiento de von Bertalanffy para *Scomber colias* en la costa andaluza, obtenida a partir del retrocálculo talla-edad. Se representa la media de los valores observados y los valores estimados a partir de la ecuación de VBGF

Discussion

The positive allometry of the total length – total weight relationship has been previously observed in *Scomber colias* in other studies (Rodríguez-Roda 1982, Kiparissis 2000, Bayhan 2007). Although irregular spacing of annuli or when these, especially in older fish, become extremely thin and closely spaced near the edge of the otolith often made age interpretation difficult (Carvalho *et al.* 2002), the observation and interpretation of the otoliths for the chub mackerel is considered to be adequate and consistent for assigning age of this species and previous studies have used otoliths to age *Scomber colias* (Rodríguez-Roda 1982, Kiparissis *et al.* 2000, Perrota *et al*. 2005, Martins 2007). Two rings, one opaque and one hyaline, were laid down each year on the otoliths (Rodríguez-Roda 1982, Lorenzo 1992, Carvalho *et al.* 2002, Perrota *et al.* 2005). The opaque zone was mainly formed during the spring and summer months while hyaline bands were formed during the autumn and winter months according with other studies. The same period of fast growth has been observed in the Hellenic Seas (Kiparissis *et al.* 2000), in the NW Mediterranean (Perrota *et al*. 2005), in the Azores (Carvalho *et al*. 2002) and in the Canary Islands (Lorenzo *et al*. 1995). Due to their annual periodicity opaque and translucent bands are appropriate for assigning age.

Rodríguez-Roda (1982) found only young chub mackerel from the Gulf of Cadiz, but the analysis of the otoliths in our study concluded that *Scomber colias* from the Andalusian coast is a moderately long-lived species with longevity of 7 years, as Tuggac (1957) in Marmara Sea and Lorenzo *et al*. (1995) in the Canary Islands found (Table 2). Carvalho *et al*. (2002) reported a chub mackerel aged 13 in Azores (L_∞ = 57.5 cm) but their length-age key showed individuals of a TL 40-49 cm aged 6-7 years that agree with our results. Growth of *Scomber colias* is rapid during the first year of life; with growth rates similar in both sampling areas, reaching 50% of the asymptotic length in the Gulf of Cadiz and 59% of L_∞ in Alboran Sea. This growth also was very high during the first year of life in other studies (Lorenzo *et al.* 1995, Kiparissis *et al.* 2000, Perrota *et al*. 2005). The values of the growth parameters in the present study are very similar to those reported for the same species in other locations of the Mediterranean (Tuggac 1957, Kiparissis *et al*. 2000, Bayhan 2007) and the Atlantic coasts (Krivospitchenko 1986, Lorenzo *et al*. 1995).

The phi-prime test estimates (Φ') provide an indication of estimation reliability, since it has been suggested that phi-prime values are similar for the same species and genera (Moreau 1986, Bellido *et al*. 2000). The results obtained in the present study (2.77 for Alboran Sea and 2.69 for Gulf of Cadiz) were similar to those found in other areas of the *Scomber colias* distribution range: Marmara Sea (Tuggac 1957), NW Mediterranean (Perrota *et al*. 2005), Azores (Carvalho *et al*. 2002), Canary Islands (Lorenzo *et al.* 1995), and Morocco (Krivospitchenko 1986).

Chub mackerel is characterized by the absence of geographical differentiation in growth between the two sampling areas in our study. This result has been also observed in the same areas with other fish species such as *Pagellus acarne* (Velasco *et al*. 2010), *Engraulis encrasicolus*, *Trachurus trachurus* or *Mullus surmuletus* (unpubl. data, Spanish Institute of Oceanography database 2010), which suggest that the Strait of Gibraltar is not a geographical break for the life history of these species; on the contrary, probably there are similar environmental conditions in the Alboran Sea and the Gulf of Cadiz, instead the Strait of Gibraltar would be a communication way that allows an Atlantic-Mediterranean larval flow.

Table 2. Values of the growth parameters for *Scomber colias* according to different studies / Valores de los parámetros de crecimiento para *Scomber colias* según diferentes estudios

Reference	Area	Position	L_∞(cm)	*K*	T_0	Φ'	Length
Lorenzo *et al*. (1995)	Canary Islands	27-29ºN	49.2	0.21	-1.40	2.706	TL
Lorenzo & Pajuelo (1996)	Canary Islands	27-29ºN	49.5	0.23	-	2.751	TL
Krivospitchenko (1979)	Morocco		44.1	0.32	-0.83	2.800	TL
Kiparissis *et al*. (2000)	Hellenic Seas	34-38ºN	47.59	0.15	-2.18	2.542	TL
Present study	Gulf of Cadiz	35-36ºN	43	0.27	-1.10	2.698	TL
Present study	SW Mediterranean	35-36ºN	40	0.37	-0.91	2.772	TL
Carvalho *et al*. (2002)	Azores	37-40ºN	57.52	0.20	-1.09	2.823	TL
Bayhan (2007)	Aegean Sea	38ºN	29.87	0.20	-0.36	2.250	FL
Perrota *et al*. (2005)	Catalan Sea	40º-43ºN	39.75	0.29	-1.41	2.674	TL
Tuggac (1957)	Marmara Sea	40ºN	33.00	0.47	-	2.710	TL

TL: total length, FL: fork length

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Literature cited

Bas C. 1959. Consideraciones acerca del crecimiento de la caballa (*Scomber japonicus*) en el Mediterráneo español. Parte I. Investigaciones Pesqueras 14: 65-113.

Bas C. 1960. Consideraciones acerca del crecimiento de la caballa (*Scomber japonicus*) en el Mediterráneo español. Parte II. Investigaciones Pesqueras 16: 33-90.

Bayhan B. 2007. Growth characteristics of the chub mackerel (*Scomber japonicus* Houttuyn, 1782) in Izmir Bay (Aegean Sea, Turkiye). Journal of Animal Veterinary Advances 6: 627-634.

Bellido JM, GJ Pierce, JL Romero & M Millán. 2000. Use of frequency analysis methods to estimate growth of anchovy (*Engraulis encrasicolus* L. 1758) in the Gulf of Cadiz (SW Spain). Fisheries Research 48: 107-115.

Carvalho N, RG Perrotta & E Isidro. 2002. Age, growth and maturity in chub mackerel (*Scomber japonicus* Houttuyn, 1782) from the Azores. Arquipélago Ciências Biológicas e Marinhas 19: 93-99.

Casselman JM. 1987. Determination of age and growth. In: Weatherley AH & HS Gill. (eds). The biology of fish growth, pp. 209-242. Academic Press, New York.

Collette BB. 1986. Scombridae. In: Whitehead PJP, ML Bauchot, JC Hureau, J Nielsen & E Tortonese (eds). Fishes of the North-eastern Atlantic and the Mediterranean, pp. 981-997. UNESCO, Paris.

Collette BB & CE Nauen. 1983. FAO Species Catalogue. Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fisheries Synopsis 125(2): 1-137.

FAO. 2008. Report of the FAO working group. Workshop on the assessment of small pelagic fish off northwest Africa. Agadir, Morocco, 17-26 April 2007. FAO Fisheries Report 849: 1-248.

Gayanillo FC, P Sparre & D Pauly. 1993. The FISAT user's guide. FAO-ICLARM Stock assessment tools. FAO Computerized Information Series / Fisheries 99: 1-126.

ICES. 2001. Report of the Working Group on the Assessment of mackerel, horse mackerel, sardine and anchovy. ICES Document CM 2001/ACFM: 06: 1-456.

ICES. 2004. Report of the Working Group on the Assessment of mackerel, horse mackerel, sardine and anchovy. ICES Document CM 2004/ACFM 08: 1-472.

Kiparissis S, G Tserpes & N Tsimenidi. 2000. Aspects on the demography of Chub Mackerel (*Scomber japonicus* Houttuyn, 1782) in the Hellenic Seas. Belgian Journal of Zoology 130: 3-7.

Krivospitchenko SG. 1979. Mackerel (*Scomber japonicus*) of the Saharan littoral region. Meeting of the Ad Hoc Working Group on West African Coastal Pelagic Fish from Mauritania to Liberia (26gr N to 5gr N), Dakar (Senegal), 19 Jun 1978, pp. 125-128. FAO Fisheries Department, Rome.

Krivospitchenko S. 1986. Evaluation of the Sahara-Mauritanian stocks of chub mackerel (*Scomber japonicus*). FAO COPACE/PACE/Series-86/37.

Lo Brutto S, M Arculeo & N Parrinello. 2004. Congruence in genetic markers used to describe Mediterranean and Atlantic populations of European hake (*Merluccius merluccius* L. 1758). Journal of Applied Ichthyology 20(2): 81-86. <doi: 10.1046/j.1439-0426.2003.00514.x>

Lorenzo JM. 1992. Crecimiento de la caballa *Scomber japonicus* Houttuyn, 1782 en aguas del Archipiélago Canario. PhD thesis, University of La Laguna, Tenerife, 199 pp.

Lorenzo JMN & JMG Pajuelo. 1996. Determinación del crecimiento de la caballa (*Scomber japonicus* Houttuyn, 1782) de las islas Canarias a través del análisis de las frecuencias de tallas. Boletín del Instituto Español de Oceanografía 12: 83-90.

Lorenzo JMN, JMG Pajuelo & AG Ramos. 1995. Growth of the chub mackerel *Scomber japonicus* (Pisces: Scombridae) off the Canary Island. Scientia Marina 59: 287-591.

Martins MM. 2007. Growth variability in Atlantic mackerel (*Scomber scombrus*) and Spanish mackerel (*Scomber japonicus*) off Portugal. ICES Journal of Marine Sciences 64: 1-6.

Moreau J, C Bambino & DA Pauly. 1986. A comparison of four indices of overall growth performance based on 100 tilapia populations (Fam. Cichlidae). In: Mackean JL, LB Dizon & LV Hosillos (eds). The first Asian fisheries forum, pp. 201-206. Asian Fisheries Society, Selangor.

Munro JL & D Pauly. 1983. A simple method for comparing the growth of fishes and invertebrates. Fishbyte 1: 5-6.

Murta AG, AL Pinto & P Abaunza. 2008. Stock identification of horse mackerel (*Trachurus trachurus*) through the analysis of body shape. Fisheries Research 89: 152–158.

Nesbø CL, EK Rueness, SA Iversen, DW Skagen & KS Jakobsen. 2000. Phylogeography and population history of Atlantic mackerel (*Scomber scombrus* L.): a genealogical approach reveals genetic structuring among the eastern Atlantic stocks. Proceedings of the Royal Society of London B 267: 281-292.

Perrota RG, N Carvalho & E Isidro. 2005. Comparative study on growth of chub mackerel (*Scomber japonicus* Houttuyn, 1782) from three different regions: NW Mediterranean, NE and SW Atlantic. Revista de Investigación y Desarrollo Pesquero 17: 67-79.

Rodríguez-Roda J. 1982. Biología de la caballa (o estornino), *Scomber* (*Pneumatophorus*) *japonicus* Houttuyn (1782) del Golfo de Cadiz. Investigaciones Pesqueras 46: 143-159.

Rubín JP, N Cano, P Arrate, J García Lafuente, J Escánez, M Vargas, JC Alonso-Santos & F Fernández. 1997. El ictioplancton, el mesozooplancton y la hidrología en el golfo de Cádiz, estrecho de Gibraltar y sector noroeste del mar de Alborán, en julio de 1994. Informes Técnicos, Instituto Español de Oceanografía 167: 1-44.

Rubín JP, P Mafalda Jr & C Sampaio de Souza. 2006. Efectos de los cambios interanuales en las masas de agua sobre la comunidad de larvas de peces en el estrecho de Gibraltar y la zona noroeste del mar de Alborán (frontera atlántico-mediterránea). Boletín del Instituto Español de Oceanografía 22(1-4): 13-22.

Scoles DR, BB Collette & JE Graves. 1996. Global phylogeography of mackerels of the genus *Scomber*. Fisheries Bulletin 96: 823-842.

Sever TM, B Bayhan, M Bilecenoglu & S Mavili. 2006. Diet composition of the juvenile chub mackerel (*Scomber japonicus*) in the Aegean Sea (Izmir Bay, Turkey). Journal of Applied Ichthyology 22: 145-148.

Sokal RR & FJ Rohlf. 1995. Biometry. The principles and practice of statistics in biological research, 887 pp. WH Freeman, San Francisco.

Tuggac M. 1957. On the biology of the *Scomber colias* Gmelin. Studies and Reviews, General Fisheries Council for the Mediterranean 4: 145-159.

Uriarte A, P Alvarez, S Iversen, J Molloy, B Villamor, MM Martins & S Myklevoll. 2001. Spatial pattern of migration and recruitment of North East Atlantic mackerel. ICES C.M. 2001/O:17: 1-40.

Velasco EM, N Jiménez-Tenorio, J Del Arbol, MA Bruzón, J Baro & I Sobrino. 2010. Age, growth and reproduction of the axillary seabream, *Pagellus acarne* (Risso, 1827), in the Atlantic and Mediterranean waters off southern Spain. Journal of the Marine Biological Association of the United Kingdom. [on line] <doi:10.1017/S0025315410000305>.<http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=7837418>

Villamor B, P Abaunza & AC Fariña. 2004. Growth variability of mackerel (*Scomber scombrus*) off north and northwest Spain and a comparative review of the growth patterns in the northeast Atlantic. Fisheries Research 69: 107-121.

Zardoya R, R Castilho, C Grande, L Favre-Krey, S Caetano, S Marcato, G Krey & T Patarnello. 2004. Differential population structuring of two closely related fish species, the mackerel (*Scomber scombrus*) and the chub mackerel (*Scomber japonicus*), in the Mediterranean Sea. Molecular Ecology 13: 1785-1798.

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