Age and growth of the Atlantic chub mackerel
Scomber colias Gmelin, 1789 off Madeira Island

JOANA VASCONCELOS, MANUEL AFONSO DIAS & GRAÇA FARIA

The Atlantic chub mackerel, *Scomber colias* Gmelin, 1789, is one of the main fisheries resources of Madeira Island. It is caught by a small and coastal purse-seine fleet that traditionally operates around the island. From January 2002 to December 2003, monthly samples of chub mackerel were collected from landings by this commercial fishing fleet. A total of 2212 *sagitta* otoliths were extracted for age readings from 1068 males (17.4-41.7 cm total length, TL), 1066 females (18.0-41.2 cm TL) and 78 undetermined (13.0-26.8 cm TL). A single reader aged the fishes using surface-read whole otoliths aiming to build annual age-length keys. Age readings precision and reader consistency were assessed by using the average percentage error index (APE $\leq$ 1.52). Ages were validated up to 4 years using marginal analyses. Estimated mean lengths at age and length von Bertalanffy growth curve parameters, estimated by non-linear methods, showed no significant differences (p>0.05) between sexes (L_∞=50.08 cm TL, k=0.252 yr^{-1} and t_0=-1.339 yr; males and females combined). Length-weight relationships were estimated aiming to convert growth in length to growth in weight. No differences between sexes were found in length-weight parameters (P>0.05). For sexes combined, total weight (TW, g) = 0.00218.LT$^{3.40}$ and the estimated asymptotic weight, W_∞=1523.7 g.

Key words: von Bertalanffy growth parameters, length-weight relationship, otolith age reading, average percent error index, *Scomber japonicus*

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INTRODUCTION

The Atlantic chub mackerel, *Scomber colias* Gmelin, 1789 (formerly named *Scomber japonicus* Houttuyn, 1782) (Fig.1), is a cosmopolitan species inhabiting temperate and subtropical waters worldwide at depths ranging from near the surface down to 300 m (Collette & Naun 1983; Collette 1986). The chub mackerel is primarily a coastal pelagic species and, to a lesser extent, epipelagic or mesopelagic over the continental slope. *S. colias* has a very wide distribution in the Atlantic, Mediterranean and Black Sea (Collette & Naun 1983).

Until recently, all studies in the Atlantic, Mediterranean and Black Sea refer to *S. japonicus* instead of *S. colias*. However, morphologic and genetic data are in agreement with the recognition of two different species, *S. colias* in the Atlantic and *S. japonicus* in the Indo-Pacific (Scoles et al. 1998; Infante et al. 2007), classification that is now accepted (Collette 1999).

The Atlantic chub mackerel is one of the traditional fisheries resources in the Madeira archipelago. In 2008, 199 tons (€266 thousand) were landed, representing approx. 3.0 and 1.6% of the total landings in weight and value, respectively. The species is caught by a small coastal purse-

seine fleet, targeting small pelagic fish "ruama" (mainly *S. colias* and *Trachurus picturatus*), that operates, in general, off the south coast of the main island, Madeira, and occasionally off Desertas Islands (Fig. 2). It is usually marketed at a low price, contributing in a significant way to the local population's diet as fresh fish. It is also used as bait in the tuna fishery (Jesus 1992).

Despite being an important fishery resource in Madeira, information on the biology of this species in the area is relatively scarce. The only work available is Silva (1993). Most information regarding the biology of this species comes from studies conducted in other parts of the world. Age and growth studies of this species have been conducted in Argentina (Forciniti & Perrota 1988; Perrotta 1992), Canary Islands (Nespereira 1992; Lorenzo et al. 1995; Lorenzo & Pajuelo 1996; Nespereira & Pajuelo 1996), Southeast-Atlantic (Morales-Nin & Sánchez 1989), Gulf of Biscay (Lucio 1997) and Aegean Sea (Moraïtopoulou-Kassimati 1963). Studies on age and growth have

been published for *S. japonicus* from Japan (Alagarswami et al. 1969), Chile (Aguayo & Steffens 1986) and Ecuadorian waters (Morales-Nin 1988).

There are also biological synopses on *S. colias* for Gulf of Cadiz (Rodriguez-Roda 1982), Bay of Biscay (Lucio 1993), Hellenic seas (Kiparissis et al. 2000), Portugal Mainland (Martins et al. 1983; Martins 1996) and Azores (Carvalho et al. 2002), and on *S. japonicus* for the Pacific (Kramer 1969; Knaggs & Parrish 1973; Scheafer 1980) and Peru (Kotlyar & Abramov 1982).

Given the commercial importance of Atlantic chub mackerel in Madeira and the need for basic scientific knowledge for modelling population dynamics, it is relevant to study the biology of this species, including aspects such as age, growth and reproduction. Therefore, the aim of this study was to estimate age and growth parameters for the Atlantic chub mackerel applying direct methods, by interpreting and counting growth rings on *sagitta* otoliths.
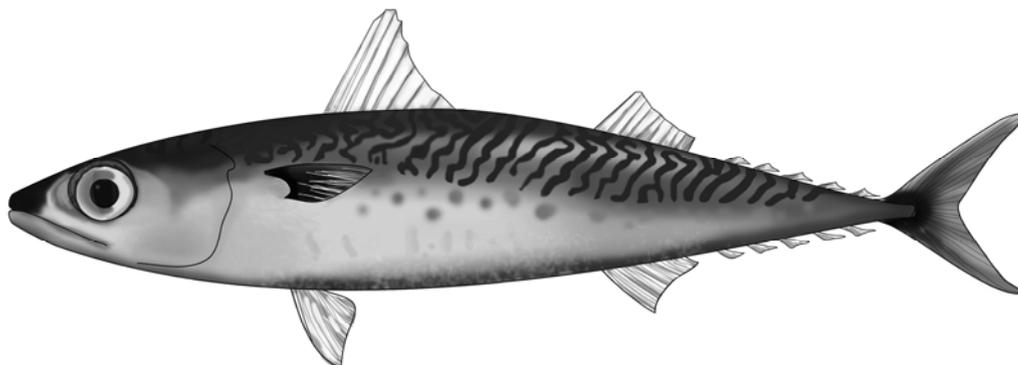

Fig. 1. Illustration of an Atlantic chub mackerel, *Scomber colias* Gmelin, 1789, caught in Madeira Island (specimen with 23 cm total length).

MATERIAL AND METHODS

SAMPLING

Sampling was conducted on a monthly basis, between January 2002 and December 2003, by the Madeira Fisheries Laboratory (DSIP Direcção de Serviços de Investigação das Pescas) in order to obtain biological data for *Scomber colias*. This information is required by the Portuguese Fisheries Biological Data Sampling Program. All samples were randomly collected from landings by

the commercial purse-seine fleet in Madeira Island. For this analysis, data from two samples types were considered: (i) large samples, sampled on site for monthly landings length frequency (unsexed fish) estimation and, (ii) small samples, which were taken to the laboratory for further biological sampling. For these samples, individual total length (TL, mm), total weight (TW, g) and sex (male, female and undetermined) were recorded and *sagitta* otoliths were removed (ventral extraction), cleaned and stored dry in labelled vials.
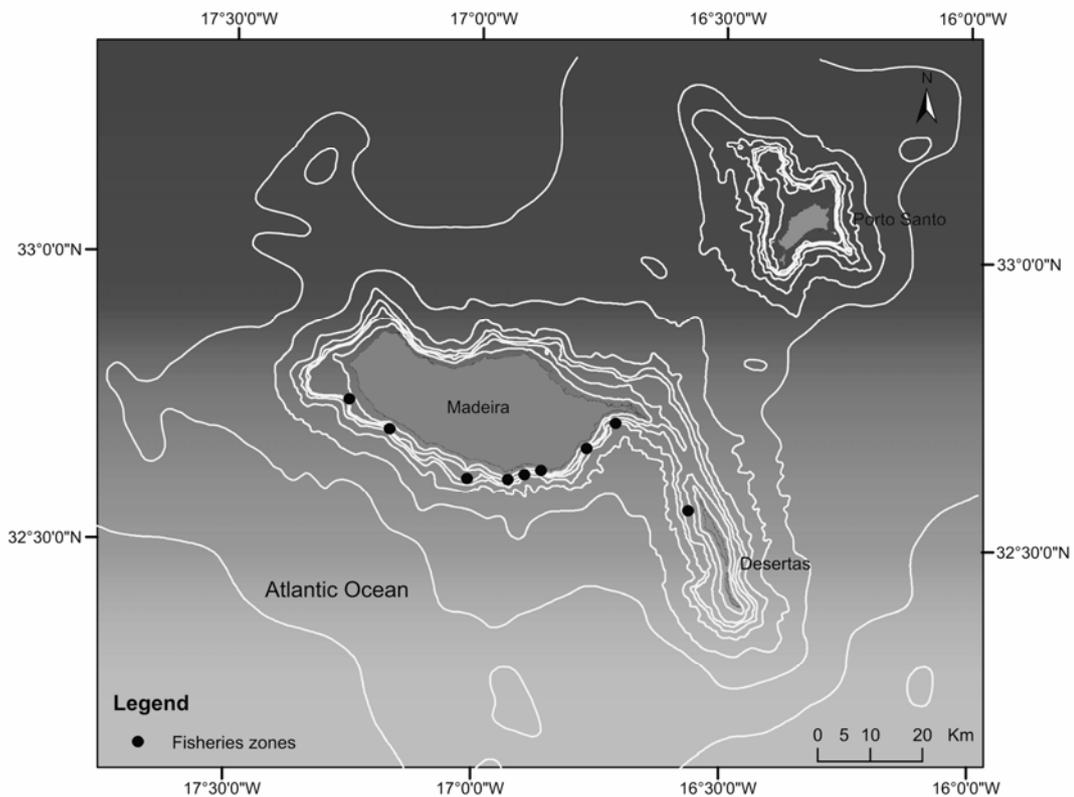
58

Fig. 2. Location of main fisheries zones (black dots) for *Scomber colias* in the Madeira archipelago according to positional data available (DSIP).

AGE DETERMINATION

A total of 2212 individuals of *Scomber colias*, 1068 males (17.4 - 41.7cm Total Length, TL), 1066 females (18.0 - 41.2 cm TL) and 78 undetermined (13.0 - 26.8 cm TL) were used for age determination in this study.

The age of each fish was assigned by interpreting and counting growth rings, assumed as annual growth zones, on *sagitta* otoliths. Whole otoliths were examined using reflected light, immersed in 70º alcohol and against a dark background, under a compound microscope Leica MZ95 (6.3x magnification). Three separate readings were performed by a single reader, and only coincidental values were considered valid. Unreadable (broken and unpaired) otoliths were excluded from the study (n = 21).

Age groups were assigned considering the January 1 birthday convention (e.g. Holden & Raitt 1974) and annual age-length keys built by 1 cm length class.

Mean length at age for each sex and year were calculated using the landings annual age-length composition obtained by multiplying the annual age-length keys by the annual landings length composition estimated by sex (e.g. Holden & Raitt 1974). A *t*-test was applied to compare male and female mean lengths at age (Zar 1996).

A semi-direct technique for validation of annuli formation, based on the analysis of the monthly percentage of otolith edges (Panfili & Morales-Nin 2002) was used in order to determine if one translucent and one opaque zone were formed each year.

The otolith reader's self-precision and age reproducibility was assessed using, as a measure of precision, the Average Percent Error (APE) index (Beamish & Fournier 1981). The APE (1) in aging the jth fish is, according to Beamish & Fournier (1981) as follows:

$$APE = \frac{100}{N} \sum_{j=1}^{N} \left[\frac{1}{R} \sum_{i=1}^{R} \frac{\left| X_{ij} - X_j \right|}{X_j} \right] \quad (1)$$

Where N is the number of fish aged, X_j is the average age calculated for the jth fish, X_{ij} is the ith age determination of the jth fish and R is the number of times each fish was aged. The set of determinations with a smaller index is more precise (Beamish & Fournier 1981).

GROWTH ESTIMATION

The von Bertalanffy length growth model (2) was fitted to observed annual mean length-at-age data for the period 2002-2003 (e.g. Cadima 2003), by means of the Gauss-Newton algorithm for non-linear parameter estimation using Statistica 6.0 (Statsoft 2001). The von Bertalanffy growth curves were compared between sexes by using a F-test following Zar (1996, p.139).

$$L_t = L_\infty [1 - e^{-k\,(t-t0)}] \quad (2)$$

Where L_t is the observed length (cm) at any given age (yr). L_∞ is the asymptotic mean length (cm), k is the growth coefficient (yr^{-1}), t_0 is the theoretical age at zero length (yr) and t is the fish age (yr).

Length-weight relationships (3) were obtained by least squares linear regression after logarithmic transformation of both variables using the following equation (e.g. Cadima 2003):

$$TW = q.\ TL^b \quad (3)$$

Where TW is the total weight (g), TL is the total length (cm), q is a constant (relative condition factor) and b is the allometric coefficient.

A t-test (Zar 1996) was used to test de null hypotesis H$_0$: b = 3 (isometric growth) at 5% significance level. The F-test was also applied to compare male and female length-weight relationships.

Growth in weight was estimated by using Richard's growth equation (Cadima 2003; Haddon 2001) that combines the von Bertalanffy growth in length equation (2) with the length weight relationship in equation (3), when allometry (b≠3) exists:

$$W_t = W_\infty \left[1 - e^{-k(t-t_0)} \right]^b \quad (4)$$

Where W_∞ is the mean asymptotic weight (g), W_t is the mean weight (g) at age t (yr), k is the growth coefficient (yr^{-1}), t is the individual age (yr), t_0 is the theoretical age at which weight is zero (yr) and b is the coefficient of allometry.

RESULTS

AGE DETERMINATION

Five age groups (0 to 4 yr) were obtained for Madeira Island *S. colias* 2002-2003 data, with total lengths ranging from 13 to 41 cm (Fig. 3). The identification of annual increments in *Scomber colias* was made difficult by the presence of non-periodic false rings characterised by different opacities and thickness. They were particularly common in the first year of otolith growth and, in many cases, were easily confused with the first annual zone.

Translucent and opaque otolith edges were observed in every month. However, the general pattern observed indicated the deposition of one opaque and one translucent growth zone during the year. The analysis of the border of the otolith indicated that the opaque edge begins its formation around April and the translucent by August (Fig. 4). The highest percentage of translucent border appears between November and March.
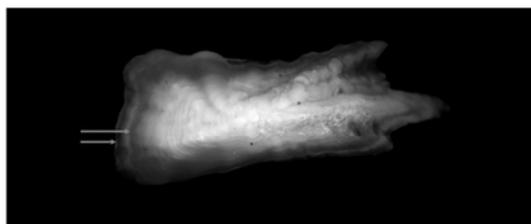
The mean lengths at age estimated for each sex and for sexes combined (all fishes) of *S. colias* in 2002 and 2003 are shown in Table 1. There were no significant differences between male and female mean lengths at age in each year (t-Student; p>0.05). Mean length at-age ranged from 20.0 to 38.5 cm between age groups 0 and 4, respectively.
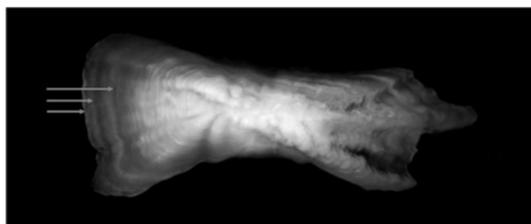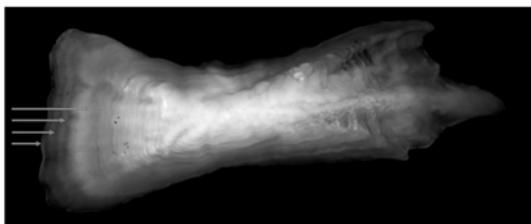
0 year
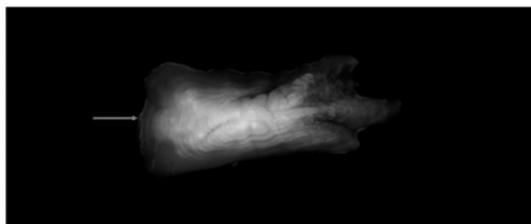
1 year

2 year

3 year

4 year

Fig. 3. Sagitta otoliths of *S. colias*, caught in 2002-03 off Madeira, representing individuals with ages 0 to 4 years (total magnification of 20X), 15.0, 19.2, 25.5, 32.5 and 37.0 cm of total length, respectively. Arrows indicate annual growth zone limits.

The percentage of agreement between the three direct readings was 96% in 2002 and 93% in 2003. Low values for the Average Percentage Error (APE) index were obtained by the otolith age reader in 2002 (0.91) and 2003 (1.52) (APE 2002-2003=1.19) indicating high precision and consistency in age reading.

GROWTH ESTIMATION

Parameters of the von Bertalanffy length growth curves, estimated for females, males and all fishes combined, for the period 2002-2003 (Fig. 5), are presented in Table 2. No significant differences in growth parameters were found between sexes (F=-0.000012; p=0.999). The estimated von Bertanffy length growth equation for sexes combined was as follows:

$$L_t = 50.08 \left[1 - e^{-0.252(t+1.339)} \right]$$

Where L_t is the mean length (TL, cm) at age t (yr).

The estimated length-weight relationships and respective coefficients of determination (r^2) for females, males and all fishes combined, for the period 2002 - 2003, are shown in Table 3. No significant differences were found in length-weight relationship parameters between sexes (*F*=0.3504; *p*=0.7044). The length-weight relationship estimated for all fishes combined was TW = 0.00231.TL$^{3.384}$ (Fig. 6). A positive allometric growth in weight (*b*>3) was found (t=36.81, p<0.001).

Since no significant differences were found between sexes, growth in weight parameters were also estimated for sexes combined. The Richard's growth in weight equation, for sexes combined, was estimated as follows:

$$W_t = 1523.67 \left[1 - e^{-0.252(t+1.339)} \right]^{3.384}$$

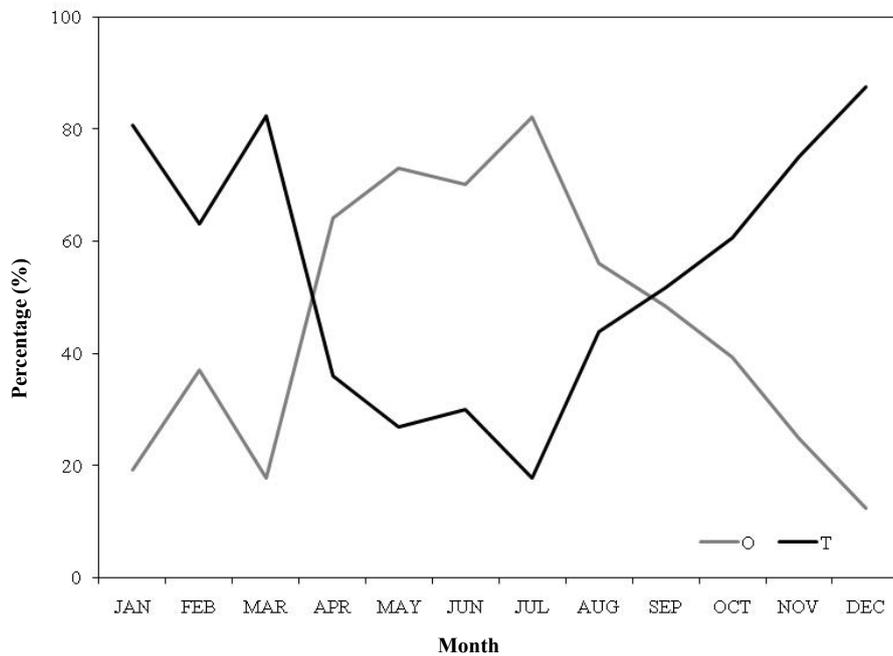Where W_t is the mean weight (g) at age t (yr).

Fig.4. Monthly percentage of the otolith edge type, opaque (O) versus translucent (T), for *Scomber colias* for males and females combined collected in the 2002-2003 off Madeira Island.
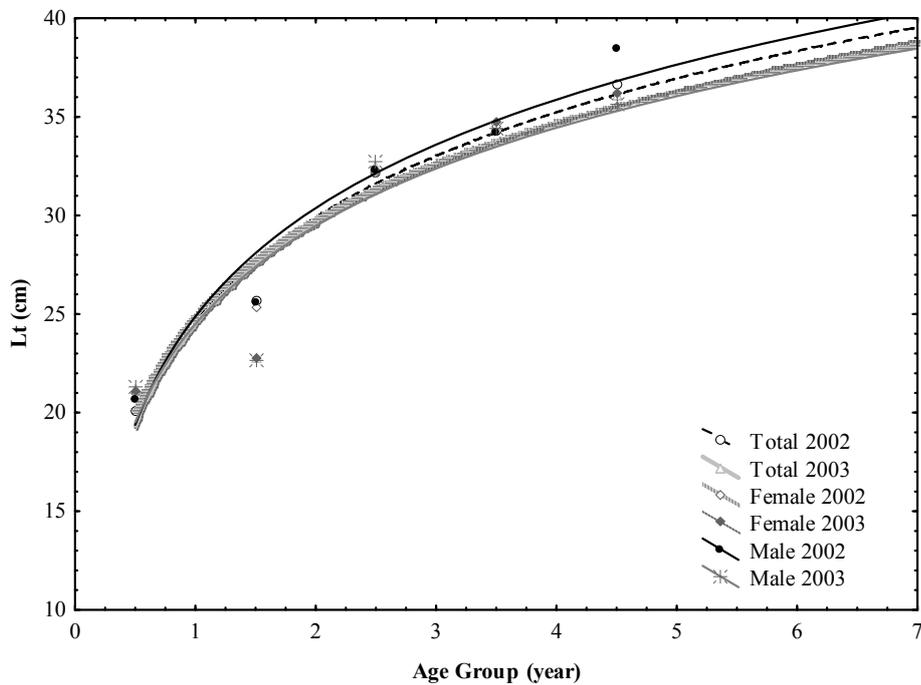

Fig. 5. von Bertalanffy growth curves adjusted to mean length at age data for females, males and sexes combined of *Scomber colias* caught in 2002-2003 off Madeira Island.

Table 1. Annual mean lengths at age (L_t) for *Scomber colias* estimated by sex and for sexes combined (all fishes), in 2002 and 2003. Fish caught off Madeira Island by the local purse-seine fleet (TL = total length; n= sample size).

Age group (year)	TL (cm)	2002						2003					
		Females		Males		All fishes		Females		Males		All fishes	
		n	L_t	n	L_t	n	L_t	n	L_t	n	L_t	n	L_t
0	17.4 - 27.5	101	20.96	99	20.67	269	20.10	5	20.05	5	21.32	10	21.21
1	19.7 - 33.4	56	25.38	49	25.57	106	25.64	211	22.78	194	22.70	411	22.73
2	23.5 - 38.9	339	32.18	354	32.31	693	32.24	118	32.29	138	32.75	256	32.56
3	27.0 - 40.7	68	34.52	81	34.19	149	34.32	141	34.76	121	34.39	262	34.54
4	32.5 - 41.7	1	35.50	1	38.50	2	36.64	19	36.20	14	35.62	33	36.05

Table 2. von Bertalanffy growth parameters (asymptotic length, L_∞; growth coefficient, k and theoretical age at zero length, t_0), sample size (n) and coefficient of determination (r^2), estimated by sex and for sexes combined (all fishes) for *Scomber colias*, caught off Madeira Island in 2003-2003.

Year	Sex	n	L_∞ (cm)	k (yr^{-1})	t_0 (yr)	r^2
	Females	1059	56.49	0.188	-1.703	0.944
2002-2003	Males	1056	50.20	0.245	-1.436	0.936
	All fishes	2115	50.08	0.252	-1.339	0.947

Table 3. Asymtotic weight (W_∞) and length weight relationship parameters (relative condition factor, q and allometric coefficient (b), estimated by sex and for sexes combined (all fishes), for *Scomber colias* caugth off Madeira Island in 2002-2003. r^2= coefficient of determination.

Year	Sex	n	W_∞ (g)	q	b	r^2
	Females	1051	1921	0.00218	3.401	0.9779
2002-2003	Males	1063	1258	0.00233	3.381	0.9716
	All fishes	2191	1524	0.00231	3.384	0.9796
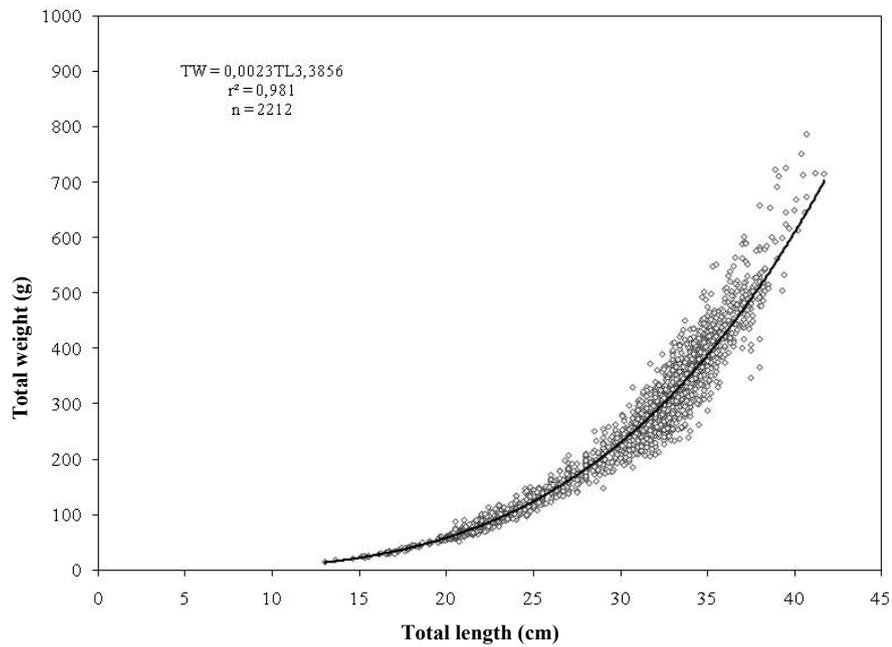
Fig. 6. Length-weight relationship estimated for *Scomber colias* (all fishes combined) caught in 2002-2003 off Madeira Island.
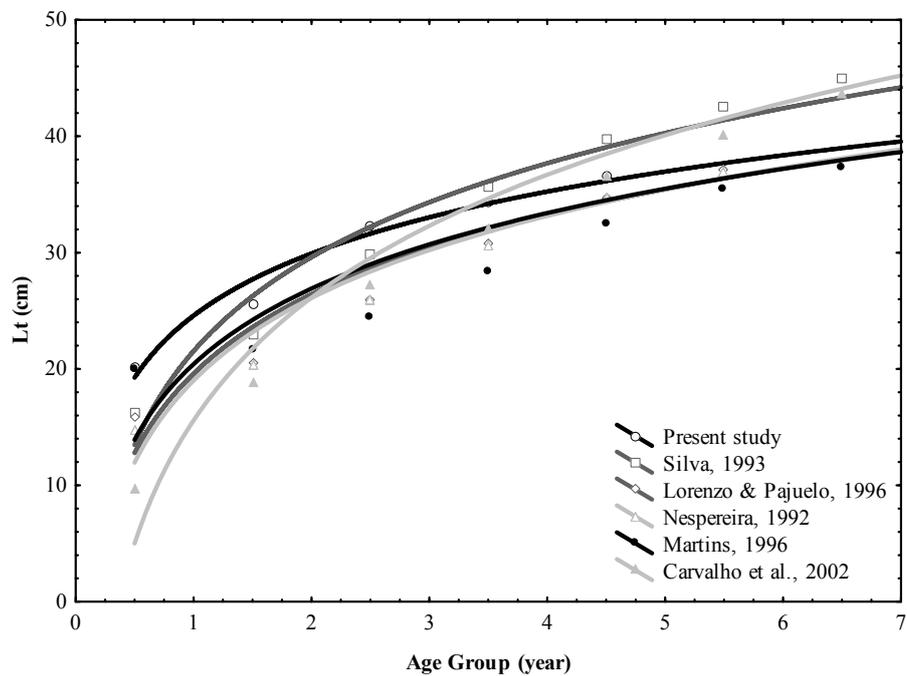

Fig. 7. von Bertalanffy growth curves obtained for sexes combined of *Scomber colias* in the present and other studies, in the continental Portuguese coast (Martins 1996), Madeira Island (Silva 1993), Azores Archipelago (Carvalho et al. 2002) and Canary Islands (Nespereira 1992; Lorenzo & Pajuelo 1996).

64

DISCUSSION

AGE DETERMINATION

The otolith rings were often difficult to interpret due to false marks. The same difficulties were also found using otoliths of *S. colias* in previous studies (Morales-Nin 1988). These false rings are particularly common in the first year of growth and, in many cases, were easily confused with the first annual growth zone (Wright et al. 2002).

In this study the range of ages obtained (0 to 4 yr) was narrower than those observed previously for the chub mackerel in Madeira Island (Silva 1993; 6 yr), Hellenic seas (Kiparissis et al. 2000; 6 yr), Portugal mainland (Martins 1996; 12 yr), Canaries (Lorenzo et al. 1995; Lorenzo & Pajuelo 1996; 7 yr), Azores (Carvalho et al. 2002; 13 yr), Southeast Africa (Morales-Nin & Sánchez 1989; 8 yr), Argentina (Forciniti & Perrota 1988, Perrota 1992; 10 yr) and Bay of Biscay (Lucio 1997; 7 yr). In the Gulf of Cadiz, Rodriguez-Roda (1982) aged fish up to 2 years. In Peru (Kotlyar & Abramov 1982; 6 yr), Chile (Aguayo & Steffens 1986; 9 yr), Japan (Alagarswami et al. 1969; 6 yr) and in the Pacific (Kramer 1969; 9 yr; Knaggs & Parrish 1973; 8 yr). The ages estimated for *S. japonicus* were also higher than the obtained in this study. The oldest age group in the annual catch composition of *S. colias* in Madeira, between 2002 and 2008, varied between 4 and 6 yr (DSIP unpublished data). Apart from the presence of false rings and problems identifying the first growth ring, the alternative pattern of opaque and translucent rings was easily distinguishable on the otoliths of chub mackerel used in this study. Two rings, one opaque and one translucent, were laid down each year on the otoliths. The opaque zones were mainly formed during the spring and summer months, from April to September, and the translucent one during the autumn and winter months, when the spawning of the species occurs.

Very similar results on the evolution of the type of edge were obtained by other authors. In the Canaries (Lorenzo et al. 1995; Lorenzo & Pajuelo 1996) and Hellenic seas (Kiparissis et al. 2000), the opaque zones of *S. colias* were formed between March and September and translucent bands during the remaining months of the year. In Mar del Plata (Argentina), the opaque edge reaches maximum values in February and translucent between November and December (Forciniti & Perrotta 1988). Alagarswami et al. (1969) and Aguayo & Steffens (1986) also mention the formation of the *annulus* during the winter for *S. japonicus*.

By comparing mean lengths at age 0 to 4 yr estimated in this study with those obtained by Silva (1993), we obtained a similar mean length at age 1 but different results for all the remaining ages (Student t test, p <0.05). The enforcement of a minimum landing size of 20 cm for *S. colias* in Madeira may have contributed to a lack of small individuals in the samples and, consequently, to the overestimation of the mean length calculated for the age group 0.

AVERAGE PERCENTAGE ERROR (APE) INDEX

In general, there was a high agreement in the three direct readings carried out by the same reader, discordant readings were relatively few. As the *APE* indices obtained were very low (≤1.52), we can assume that the readings are acceptable and that the reader achieved a high precision standard in readings. Low values of *APE* indicate high precision in age determinations (Beamish & Fournier 1981; Campana 2001), but do not imply that the estimated age is correct (accuracy), as precision relates to reproducibility and is not a measure of accuracy (Beamish & Mcfarlane 1983). Lorenzo & Pajuelo (1996) aged Atlantic chub mackerel from 0 to 7 yr in the Canaries and obtained an *APE* index of 3.8%, higher than those estimated in the present study. This could be due to the aging of fish older than 4 yr.

GROWTH ESTIMATION

Chub mackerel growth rates are very similar between males and females, as observed in other regions throughout the species distribution range (Kiparissis et al. 2000). In most studies, *S. colias* exhibit a very high growth rate during its first year (Schaefer 1980; Perrota 1992; Kiparissis et al. 2000). In this study, fish length reached 40.14% of its asymptotic length in the first year, indicating that this population has one of the highest growth rates during the first year. Silva (1993), studying the population in the same geographic area, verified a growth of only 32.6% during the first year. The referred author had ac-

cess to a larger number of small specimens (13 to 20 cm) than those used in the present work, which allowed for a better estimation of mean lengths at age 0. Yet, the growth rate estimated were similar to that observed in the Canary Islands (Lorenzo et al. 1995; Lorenzo & Pajuelo 1996) and relatively higher than the value obtained in the Azores (Carvalho et al. 2002) and Hellenic seas (Kiparissis et al. 2000), where this species reached 32.9 and 38.7% of its asymptotic length, respectively, during the first year of life. The highest growth rate reported for the Atlantic chub mackerel was in Argentina (Perrota 1992) where it reached 50% of the asymptotic length during the first year of life. Similar results were obtained by Alagarswami et al. (1969) for *S. japonicus* in Japan.

The lack of individuals older than 4 yr and the possible overestimation of mean length at age 0 may have influenced the estimation of mean asymptotic length (L_∞), making the estimation of body growth coefficient (k) more dependent on L_∞. The lack of older individuals may have led to an overestimation of the L_∞ and, consequently, to an underestimation of k. However, the overestimation of mean length at age 0 may partially compensates this effect.

Growth parameters can vary from stock to stock, i.e., they can exhibit different values throughout its distribution (e.g. Villamor et al. 2004). However, the mean asymptotic length value ($L_\infty = 50.08$ cm) estimated in this study, was similar to that reported previously for *S. colias* off the Madeira archipelago (Silva 1993) and Canary Islands (Nespereira 1992), and numerically lower than values estimated in the Portuguese continental waters (Martins 1996), Canaries (Lorenzo & Pajuelo 1996; Nespereira & Pajuelo 1996), Azores (Carvalho et al. 2002) and Southeast-Atlantic (Morales & Sánchez 1989). Kiparissis et al. (2000) and Westhaus-Ekau & Ekau (1982) obtained a mean asymptotic length value lower than the estimated in this study (Table 4). In Chile (Aguayo & Steffens 1986) and in the Pacific (Knaggs & Parrish 1973) the mean asymptotic length values estimated for *S. japonicus* were also lower than values obtained in this study.

The growth in length parameters estimated was compared to those obtained by other authors using the Pauly's growth performance index

$[\phi' = \log_{10}(k) + 2\log_{10}(L_\infty)]$ (Pauly 1997). The index, calculated for 2002-2003 ($\phi' = 2.80$) was very similar to the value obtained for mackerel in the Azores (Carvalho et al. 2002) but different from all the other studies (Table 4). Despite the similarity between the two studies there are no statistical criteria for deciding if ϕ' values differ or not significantly.

When a body part grows faster or slower than another it is referred as allometric growth (Jones 2002). The allometric coefficients obtained for females ($b = 3.40$), males ($b = 3.38$) and all individuals ($b = 3.38$) revealed an allometric growth, which implies an increase in weight not proportional to the increase in individual growth ($b \neq 3$). In the Portuguese coast (Martins et al. 1983; Martins 1996), Canary Islands (Nespereira 1992; Lorenzo & Pajuelo 1996), Azores (Carvalho et al. 2002), Gulf of Cadiz (Rodriguez-Roda 1982), Hellenic seas (Kiparissis et al. 2002), Argentina (Perrota 1992) and Bay of Biscay (Lucio 1993, 1997), the resultant parameters of the weight-length relation are in agreement with the values reported for *S. colias* off Madeira. Only Moraïtopoulou-Kassimati (1963), studying the population in the Aegean Sea, determined an isometric growth ($b=3$). Finally, in Peru (Kotlyar & Abramov 1982) and in the Pacific (Knaggs & Parrish 1973), *S. japonicus* also showed an allometric growth (Table 5).

The asymptotic weight estimated in this work ($W_\infty = 1523.7$ g) was higher than those estimated by Silva (1993) for *S. colias* present in Madeira Island ($W_\infty = 1327.0$ g), Martins et al. (1983), off the Portuguese mainland coast ($W_\infty = 1498.18$ g), Forciniti & Perrota (1988), for Argentina ($W_\infty = 865.52$ g) and Aguayo & Steffens (1986), for *S. japonicus* from northern Chile ($W_\infty = 1292.2$ g).

66

Table 4. Von Bertalanffy length growth parameters (L∞, k and t_0) estimated for *Scomber colias* (sexes combined), from direct reading of otoliths in the present study and by other authors. n = sample size; r^2 = coefficient of determination; Φ' is the Pauly's growth performance index used for growth parameters comparisons.

Study	Species	Geographic area	n	TL Range (cm)	Age Range (year)	Methods	L_∞ (cm)	k (yr)	$t_{0(yr^{-1})}$	r^2	Φ'
Present study	*S. colias*	Madeira Island	2115	17.4-41.7	0-4	Otoliths direct reading	50.08	0.252	-1.339	0.947	2.80
Silva 1993	*S. colias*	Madeira Island	1715	13-45	0-6	Otoliths direct reading	49.684	0.315	0.00654	0.998	2.89
Martins 1996	*S. colias*	Portuguese continental coast	883	16-54	0-7	Otoliths direct reading	58.52	0.1035	-3.681	0.990	2.55
Martins et al. 1983	*S. colias*	Portuguese continental coast	533			Backcalculation	53.83	0.1735	-2.026	-	
Carvalho et al. 2002	*S. colias*	Azores archipelago	349	9.8-56.57	0-13	Otoliths direct reading	57.52	0.201	-1.093	0.970	2.82
Lorenzo & Pajuelo 1996	*S. colias*	Canary Islands	470	13,7-42,1	0-7	Otoliths direct reading	52.4	0.19	-1.61	0.957	2.72
Nespereira & Pajuelo, 1996	*S. colias*	Canary Islands	3858	13-48	0-5	Indirect estimation	49.50	0.23			2.75
Lorenzo et al. 1995	*S. colias*	Canary Islands	548	-	1-7	Backcalculation	49.2	0.21	-1.40	0.97	
Nespereira 1992	*S. colias*	Canary Islands	878		1-6	Otoliths direct reading	50.69	0.208	-1.45		2.73
Nespereira 1992	*S. colias*	Canary Islands	-	-	1-5	Backcalculation	49.22	0.210	-1.40	-	
Nespereira 1992	*S. colias*	Canary Islands		4-48	-	Indirect estimation	49.22	0.22			2.73
Kiparissis et al. 2000	*S. colias*	Hellenic Seas	1138	9.1-31.0	0-5	Otoliths direct reading	47.596	0.154	-2.177	0.988	2.54
Morales-Nin & Sánchez 1989	*S. colias*	Southeast Africa (area ICSEAF, Division 1.5)	76	37-57	4-8	Otoliths direct reading	88.75	0.04	-12.21	-	2.50
Westhaus-Ekau & Ekau 1982	*S. colias*	Azores archipelago	-	-	-	Otoliths direct reading	44.737	0.2447	-1.0006	-	2.69
Forciniti & Perrota 1988	*S. colias*	Argentina	379	-	1-8	Backcalculation	43.79	0.3425	-0.1308		
Perrotta 1992	*S. colias*	Argentina	232	-	0-10	Backcalculation	44.51	0.32	-1.3379	-	2.80
Perrotta 1992	*S. colias*	Argentina	1580	-	0-10	Indirect estimation	44.89	0.31	-1.3660		2.80
Morales-Nin 1988	*S. japonicus*	Equatorian waters	1.464.090	11-38	-	Indirect estimation	39.60	0.391			2.79
Aguayo & Steffens 1986	*S. japonicus*	Chile	1085	12-41	1-8	Otoliths direct reading	44.37	0.164	-1.543	-	2.51
Knaggs & Parrish 1973	*S. japonicus*	Pacíf (California)	1205	-	1-8	Otoliths direct reading	43.61	0.2444	-3.0222	-	2.67
Alagarswami et al. 1969	*S. japonicus*	Japan	187	12.8-40.6 FL	1-6	Backcalculation	41.26	0.26	-1.69		

Table 5. Length-weight relationship parameters (condition factor, *q* and allometric coefficient, *b*) for *Scomber colias* (sexes combined) obtained in the present study and by other authors. n = sample size; r^2 = coefficient of determination.

Study	Species	Local	n	q	b	r^2
Present Study	*S. colias*	Madeira Island	2129	0.00231	3.384	0.9796
Silva 1993	*S. colias*	Madeira Island	2969	0.08535	3.2924	0.999
Carvalho et al. 2002	*S. colias*	Azores	187	0.0049	3.2612	0.973
Martins 1996	*S. colias*	Portugal	3761	0.00278	3.330	0.946
Martins et al. 1983	*S. colias*	Portugal	553	0.00365	3.2427	0.999
Lorenzo & Pajuelo 1996	*S. colias*	Canary Island	1142	0.00294	3.30905	0.977
Nespereira 1992	*S. colias*	Canary Island	4010	0.00347	3.25917	-
Kiparissis *et al.* 2000	*S. colias*	Hellenic seas	1138	9.65×10^{-7}	3.5	-
Lucio 1997	*S. colias*	Bay of Biscay	485	0.002437	3.376	0.995
Lucio 1993	*S. colias*	Bay of Biscay	393	9.35×10^{-7}	3.393	0.996
Perrotta 1992	*S. colias*	Argentina	330	$8.89.10^{-7}$	3.40	0.980
Rodriguez-Roda 1982	*S. colias*	Gulf of Cadiz	672	2.0387×10^{-6}	3.3004	-
Moraïtopoulou-Kassimati, 1963	*S. colias*	Aegean Sea	-	0.01	3	-
Knaggs & Parrish 1973	*S. japonicus*	Pacífic	1232	1.366×10^{-6}	3.39358	0.994
Kotlyar & Abramov 1982	*S. japonicus*	Peru	3058	0.00826	3.1203	-

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69

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