Atlantic chub mackerel (*Scomber colias*) spawning season, size and age at first maturity in Madeira waters

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The pelagic chub mackerel, *Scomber colias* Gmelin, 1789 is one of the most important fishery resources in the Madeira Archipelago. *S. colias* is caught by a small and coastal purse-seine fleet that traditionally operates around the islands. Monthly samples of chub mackerel were taken from commercial landings, between January 2002 and December 2005. Sex and maturity were assigned by visually inspecting the gonads of 1998 males (17.4-46.0 cm total length, TL; 0-5 yr) and 2108 females (18.0-41.2 cm TL; 0-4 yr) using a five-stages macroscopic maturity scale; 99 specimens with undetermined sex (13.0-26.8 cm TL; 0 yr) were also sampled. The analysis of monthly gonadosomatic indices and maturity stages proportions showed that gonad development started slowly in July-August and increased in October-December, for males and females. Spawning took place between January-April peaking in February-March. Maturity ogives were fitted to the observed proportions of mature males and females by using non-linear methods, to estimate size and age at first maturity: 22.12 cm TL at 1.05 yr for males and 21.55 cm TL at 0.82 yr for females.

Key words: Gonadosomatic index, fisheries, Madeira Island, reproductive period

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INTRODUCTION

The pelagic chub mackerel, *Scomber colias* Gmelin, 1789 is quite wide spread around the isles of Madeira Archipelago (32º 30' - 33º 30' N; 16º 30' - 17º 30' W). *S. colias* is traditionally caught by a small coastal purse-seine fleet, targeting small pelagic fish (mainly *S. colias* and *Trachuruspicturatus*), that operates, in general, around the main island, Madeira (Figure 1). In 2011, about 234 tonnes (200 thousand €) of chub mackerel were landed representing about 5.5% and 1.8% of the total landings, in weight and value, respectively. Although it fetches a low market price, it is an important component in the diet of the local population. It is also used as bait to catch tuna fish (*Thunnus sp.*), the second most important fishery in Madeira archipelago.

Until recently all studies in the Atlantic, Mediterranean and Black Sea refer to *S. japonicus* instead of *S. colias*. However, morphologic and genetic data corroborate the existence 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 chub mackerel, like most marine fish species of commercial importance, presents a reproductive strategy characterised by being iteroparous, gonochoristic, oviparous and showing no sexual dimorphism (Murua & Saborido-Rey 2003; Gordo et al. 2008).

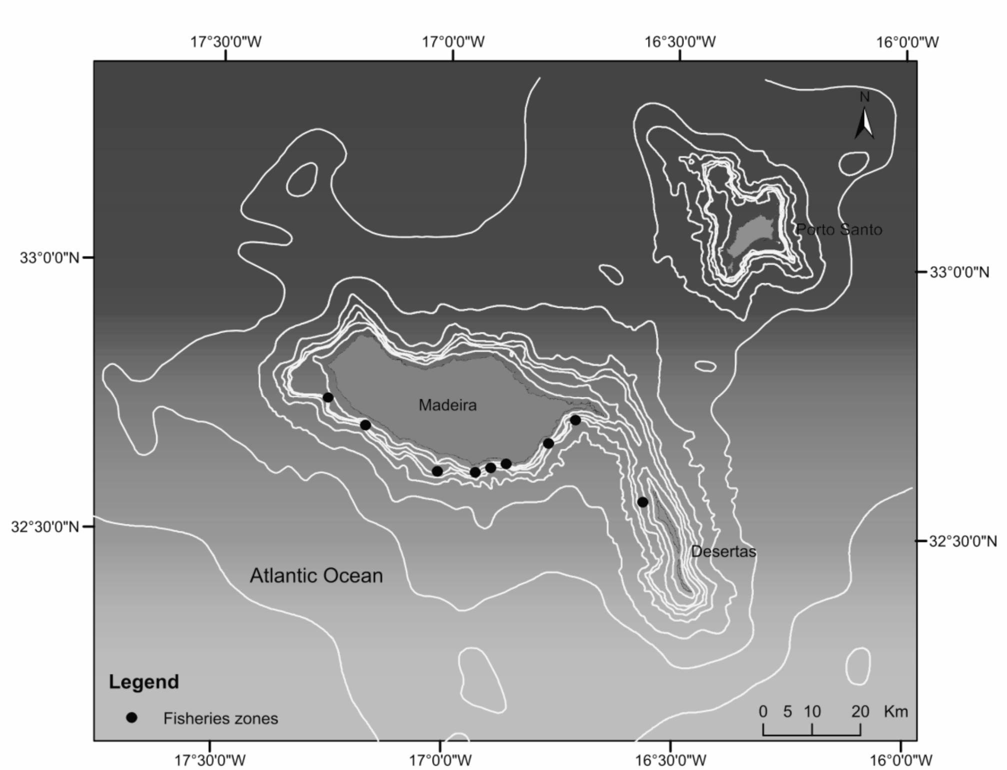

Fig. 1. Madeira archipelago map showing the location of some of the fishing zones (black dots) for *Scomber colias,* according to positional data available for 2002-2005.

Due to the chub mackerel fishery's worldwide importance, it has been the focus of several studies in the recent past. However, most of the information on the species' biology comes from studies conducted in other parts of the world. Reproductive studies were conducted on this species in Portuguese continental coastal waters (Martins et al. 1983) and Canary Islands (Lorenzo & Pajuelo 1996; Nespereira & Pajuelo 1993) and on *S. japonicus* from Japanese waters (Yamada et al. 1998; Watanabe & Yatsu 2006) and in coastal southern California, USA (Dickerson et al. 1992). There are also biological synopses on *S. colias* in the Gulf of Cadiz (Rodriguez-Roda 1982), Bay of Biscay (Lucio 1993), Hellenic seas (Kiparissis*et al*. 2000), Portugal continental coastal waters (Martins 1996) and Azores Archipelago (Carvalho et al. 2002) and on *S. japonicus* for the Pacific (Kramer 1969; Knaggs & Parrish 1973; Scheafer 1980) and Peru (Kotlyar & Abramov 1982). However, despite its regional importance, there is little information on the biology of this species in the study area. In Madeira waters, only one study on the age and growth of *S. colias* (Vasconcelos et al. 2011) and a technical report (Silva 1993) on some aspects of the reproductive biology of *S. colias*, particularly on the determination of the spawning season are available. Reliable indicators of reproductive status, such as size at maturity, spawning season and sex ratio, are fundamental elements required for the proper assessment and management of fish stocks. The objective of this paper is to present more updated data on the spawning season and to estimate size and age at first maturity for *S. colias* in this area of the Atlantic.

MATERIAL AND METHODS

Monthly samples of chub mackerel were collected between January 2002 and December 2005, by staff members of the Madeira Fisheries Laboratory (DSIP) in order to obtain biological data for *S. colias*, required by the Portuguese Fisheries Biological Data Sampling Program. The samples used were randomly selected from the commercial purse-seine fleet landings in Madeira Island. The total length of 4205 specimens was recorded to the nearest millimetre below. Individual total, gonad and liver weights were registered in grams. Sex and maturity were assigned by visually inspecting the gonads of the 4205 specimens (1998 males, 2108 females and 99 undetermined, using a five stage macroscopic maturity scale (Table 1) adapted from Holden &Raitt (1974).

The chi-square test (χ^2) was used to test for possible differences in the proportion of each sex per year (Zar 1996)

To estimate age at first maturity, age of each fish was assigned by interpreting and counting the number of growth rings, assumed as annual growth zones, on *sagitta* otoliths, using standard procedures (McCurdy et al. 2002; Morales-Nin & Panfili 2002).

Characterisation of the spawning season was made by analysing the monthly distributions of the percentage frequency of gonad maturity stages and confirmed by the evolution of the mean monthly gonadosomatic index (King 1995), calculated as GSI =Gonad weight (g)/Total weight (g) x 100; and the evolution of the monthly hepatosomatic index (Muñoz *et al*. 2005), calculated as HSI=Liver weight (g)/Total weight (g) x 100. The values presented were pooled across the three year sampling period.

The percentage of mature fish *versus* size and agewas calculated assuming that fishclassified in maturity stages 2 to 5 (Table 1) were mature. Length and age maturity ogives by sex were fitted to pooled (2002-2005) observed data collected during the first semester (spawning season).The parameters, length (TL_{50}) and age (t_{50}) at first maturity, by sex, were obtainedby fitting logistic ogivesto the proportion of sexually mature individuals by non-linear least squares analysis (King 1995; Jennings *et al*. 2001).

The percentage of mature fish at age were calculated by using an annual age-length key data available for the landings between 2002 and 2005, by dividing the number of mature fish by the total number of fish caught at each age (percentage of mature individuals by age class).

Table 1. Macroscopic sexual maturity scale, adapted from Holden & Raitt (1974), used in this study to classify *Scomber colias* females and males gonads.

Stage	Level name	Description	
		Females	**Males**
1	**Immature**	Very small and translucent ovaries, eggs	Very small testes; no sign of devel
2	**Recovery**	Ovaries in recovering condition;	Testes in recovering condition;
3	**Maturing**	Larger ovaries and eggs visible;	Larger testes,not running;
4	**Spawning**	Large transparent eggs that are released under moderate pressure;	Sperm released by a light press on the abdomen;
5	**Spent**	Ovaries shrunken with few residual eggs, much slime and often redish; resting condition.	Small, slack gonads and often re-dish; resting condition.

RESULTS

SAMPLE DESCRIPTION

The sex ratio of the whole sample did not departure significantly from 1:1 (χ^2 test, $p<0.05$), particularly taking into consideration that 2.4% of the sample was made of fish with undetermined sex (Stage 1; TL 13.0 -26.8 cm, age class 0). About 47.5% of the fishes sampled were males with a total length ranging from 17.4 to 46.0 cm and aged between 0 to 5 yr. Females outnumbered males (50.8% females against 49.2% males, in 2003; 52.1% females against 47.9% males, in 2004; 53.5% females against 46.5% males, in 2005) except in 2002 (49.2% females against 50.8% males). Female size amplitude ranged from 18.0 to 41.2 cm TL, with ages varying between 0 to 4 yr.

SPAWNING SEASON

The monthly variation of fishes caught by maturity stages, showed that although pre-spawning fishes (both male and female) were captured, mainly from December to March, ready to spawn males and females were only captured from January to April. Spent gonads were found in fish captured almost all year around, but were most frequent from April to July (Figure 2).

Looking at the monthly distribution of fish in pre-spawning, spawning and post spawning stages, there was no major difference between genders, except in spent fish caught from August to November. The gonadosomatic indices for male and female peaked in February, but did not reach more than 6% of body weight (Figure 3a). On average, mature male gonads presented higher GSI than female gonads, but only in the first quarter of the year. From March to April, both GSI indices decreased sharply with female GSI consistently higher than male GSI.

The monthly pattern of HSI indices was not as clear as GSI indices (Figure 3). HSI indices for both sexes varied between 0.8 to 1.5% of body weight and female HSI was greater than male HSI, particularly in first quarter of the year. Female and male HSI indices peaked in March and April, respectively, and steadily decreased thereafter (Figure 3b).

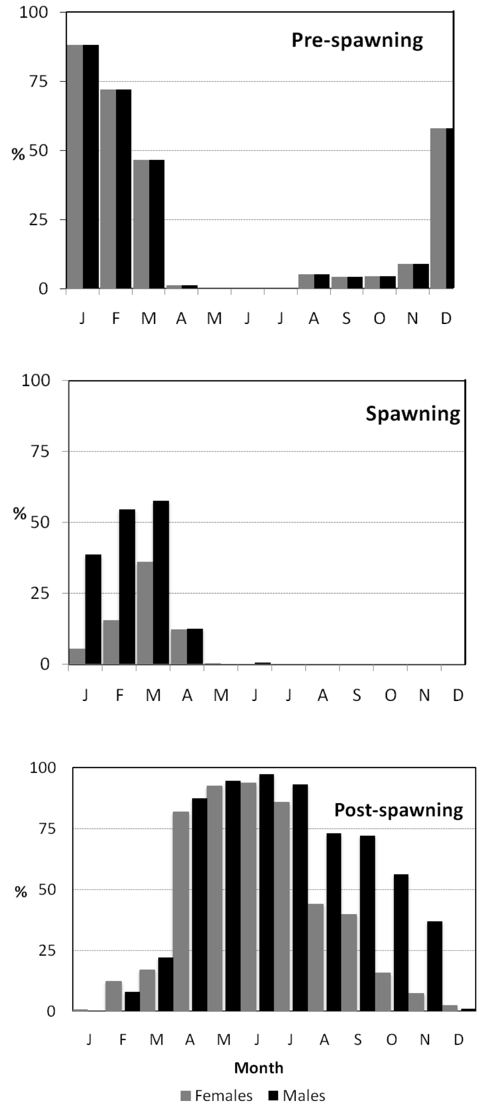

Fig. 2. Monthly percentage of females and males of *Scomber colias* with gonads in maturity stages 3 (Pre-spawning), 4 (Spawning) and 5 (Post-spawning) observed in Madeira waters in the period 2002-2005.

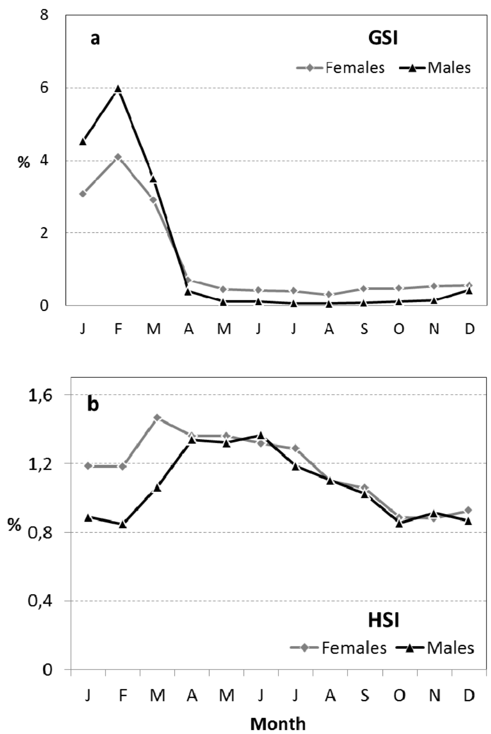

Fig. 3. Monthly evolution of the gonadosomatic (GSI) (a) and hepatosomatic (HIS) (b) indices obtained for females and males of *Scomber colias* caught in Madeira waters in the period 2002-2005.

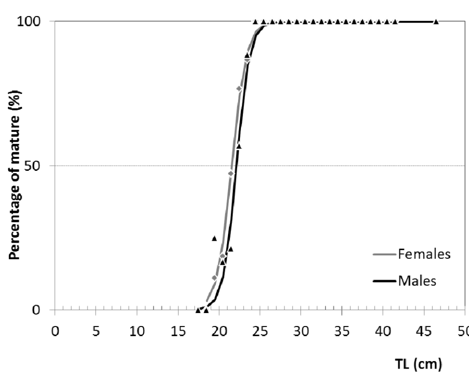

Fig. 4. Length maturity ogives obtained for females and males of *Scomber colias* caught off Madeira archipelago between 2002 and 2005.

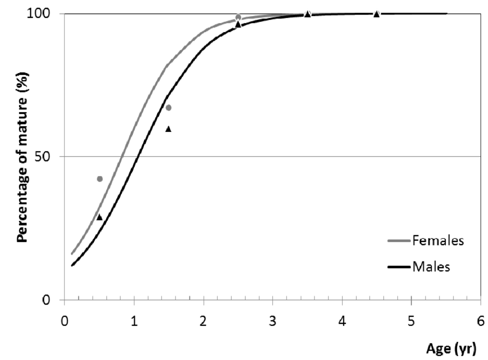

Fig. 5. Age maturity ogives obtained for females and males of *Scomber colias* caught off Madeira arquipelago in the period 2002-2005.

MATURITY OGIVES

The length and age at first maturity for malesand females were estimated to be 22.1 cm TL at 1.05 yr of age and 21.6 cm TL at 0.82 yr, respectively.The smallest mature fish sampled during the considered sampling period was a male with 19.7 cm TL.

DISCUSSION

In general, pelagic fish spawn in areas with substantial biological production to ensure adequate adultand larval feeding (Blaxter & Hunter 1982; Caramantin-Soriano et al. 2009). Furthermore, one of the main triggers of spawning activities in chub mackerel is water temperature (15 - 20ºC; Collete & Nauen 1983).The results indicate that the reproductive period for the Atlantic chub mackerel in Madeira waters occurs mainly in the first four months of the year, with maximum activity in February and March. These results concur with data previously obtained in this geographic area and reported by Silva (1993). The maximum values of the mean GSI observed in *S. colias* were found to be surprisingly low (about 6%) in relation to other species. Actually, values of 10% for mean GSI are common during the reproductive period (Macer 1974; Viette et al. 1997). Moreover, the mean GSI during the first trimester reached higher values in males than in females contrary to what is considered to be the norm (Macer 1974).

Based on results obtained in this study and by other authors, *S. colias* exhibits temporal sexual maturation differences throughout the Atlantic Ocean. In the Canary Island spawning occurs during winter with maximum activity in December and January (Nespereira 1992; Nespereira & Pajuelo 1993; Lorenzo & Pajuelo 1996), whereas in Portuguese continental coastal waters, spawning activity was reported by-Martins et al. (1983) and Martins (1996) to occur between February/March and May/June. In Azorean waters, spawning occurred slightly later, mainly from March to July/August (Westhaus-Ekau & Ekau 1982; Carvalho et al. 2002). The Atlantic chub mackerel found in Mar del Plata (Forciniti & Perrota 1988) and in the Bay of Biscay (Lucio 1993, 1997) spawn during the spring and summer seasons, similar to the population found in Portuguese continental waters. In Buenos Aires (Argentina), the reproductive peak period occurred in November (Perrota 1992). Spawning of *S. japonicus* in Sea of Cortez occurs most frequently between November and April (Esqueda-Escarcega 1995). Based on these and the present results, it seems that mass spawning is favoured by spring warming, causing slight discrepancies in the duration and/or peak of spawning in different geographical areas.

Regarding the age at first maturity, the utility of this value should be viewed with caution. Earlier work has shown that very similar estimates of age at first maturity can be obtained for different distributions of the proportion mature at age (Trippel & Harvey 1991). Age and total length at sexual maturity values estimated in this study were lower than those estimated for *S. colias* in Portuguese continental coastal-waters (Martins et al., 1983); Azores (Carvalho et al. 2002); Bay of Biscay (Lucio 1993) and South Africa (Crawford 1981) but higher than values obtained in the Canary Islands (Nespereira 1992; Nespereira & Pajuelo 1993; Lorenzo & Pajuelo 1996) (Tables 2 and 3).

According to Kramer (1969), the population of *S. japonicus* from the pacific spawns only at age 2. For the same area, Knaggs & Parrish (1973) refer that males mature earlier than females, at just 1 yr of age. In Peru, the chub mackerel reaches maturity in the first and second year of life corresponding to 18-19 cm TL (Kotlyar & Abramov 1982). In Madeira archipelago, previous estimations of Lm50 in 2003 (males =23.53 cm TL; females = 25.65 cm TL) were also higher than those obtained in the present study (Graça Faria and Adriana Alves, pers. comn). Net selectivity is commonly associated with the capture of a greater proportion of larger versus smaller individuals of a

Table 2. Size at first maturity (Lm50) estimated for females (F) and males (M) of *Scomber colias* in the present study and by other authors.

Study	**Local**	**Lm50 (cm)**	
		F	**M**
Present Study	Madeira Island	21.55	22.12
Carvalho et al. (2002)	Azores Archipelago	27.78	
Lorenzo & Pajuelo (1996)	Canary Island	19.9	19.8
Lucio (1997)	Bay of Biscay	29.0	30.80
Martins (1996)	Portuguese continental coast	27	
Nespereira&Pajuelo (1993)	Canary Island	19.9	19.85
Nespereira (1992)	Canary Island	19.9	19.85
Silva (1993)	Canary Island	23.0	22.0

Table 3. Age at first maturity (Tm50) estimated for females (F) and males (M) of *Scomber colias* in the present study and by other authors.

Study	**Local**	**Tm50 (year)**	
		F	**M**
Present Study	Madeira Island	0.82	1.05
Martins (1996)	Portuguese continental coast	3	
Carvalho et al. (2002)	Azores Archipelago	2.23	
Lucio (1997)	Bay of Biscay	4	
Crawford (1981)	South Africa	3	

cohort. These larger members tend to achieve sexual maturity earlier in life than slow-growing cohort members (Trippel et al.1995). Hence, a greater proportion mature at age would be estimated than occurs naturally in the population and bias is especially pronounced in the younger, recruiting age groups. According to ICES (1994), commercial samples from large-mesh gear are particularly suspect for maturity ogive construction.

Maturity indices based on a visual macroscopic inspection of the gonads are sometimes uncertain. This is partly because the criteria may be arbitrary. Comparison of results of visual and histological examination of the gonads is needed because young immature fish may be misclassified as mature. This could lead to positive bias in the estimation of proportion mature at age ranging from 10-30% (Trippel et al. 1995). Sampling of fish from the spawning aggregation could also introduce positive bias in the proportion mature. Further consideration and confirmation of accurate identification of maturity is recommended for sampling times both during spawning and others periods.

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