Preliminary observation on sexual maturity of chub mackerel (*Scomber colias*) in the Northern Iberian Atlantic waters (ICES Divisions 27.8.c and 27.9.a.N)

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ABSTRACT

A study of the reproductive biology of the Atlantic chub mackerel (*Scomber colias*) has been performed in Northern Iberian Atlantic waters (ICES Divisions 27.8.c and 27.9.a.N) based on samples of 14538 specimens (11-50 cm total length) from commercial landings and scientific surveys from 2011-2019.

The spawning period was defined based on the monthly prevalence of active females (maturity stages 3, 4 and 5 according to Walsh maturity scale) and temporal variability of females gonado- and hepatosomatic indices (GSI/HSI). Length and age maturity ogives were also estimated for males and females pooling all sampled years together.

The spawning period occurred from March to July, with a peak in June. In the 27.8.c area, the GSI, HSI and prevalence of active females increased from March to June and then GSI and prevalence decreased abruptly. In the 27.9.a.N, the peak of spawning was observed earlier (April-May) and with lower intensity than in 27.8.c, but sampling in 27.9.a area was limited to the northern zone (Spanish waters) and are not conclusive.

L_{50} and A_{50} values estimated with annual data were 22.9 cm and 1.6 years old respectively for both sexes combined, similar to the values estimated with data only from the spawning period: 22.7 cm and 1.5 years old respectively for both sexes combined. Our results were compared with those from previous studies in the NE Atlantic.

KEY WORDS

Scombridae, Atlantic Ocean, spawning period, maturity ogives

1. INTRODUCTION

Atlantic chub mackerel, *Scomber colias*, is a middle size pelagic species distributed on both sides of the Atlantic Ocean. In the Eastern Atlantic it is mostly captured in African waters (FAO, 2020), although landings of this species have increased recently in Atlantic waters of the Iberian Peninsula, likely associated to the increase of its abundance (ICES, 2020).

ICES recommends the analytical assessment of this potential new European stock (ICES, 2020); for that purpose, knowledge of its reproductive biology is necessary as well as estimation of reproductive parameters like maturity at length or age.

The aim of this study is to improve the knowledge of the reproductive biology of the Atlantic chub mackerel and to present updated information on spawning period and maturity ogives that can be used for analytical stock assessment.

2. MATERIAL & METHODS

2.1. Sampling

A total of 14538 *S. colias* from Northern Iberian Atlantic waters (ICES Div. 27.8.c and 27.9.a.N) with a length range of 11-50 cm, were collected and sampled between 2011 and 2019 from both, commercial landings (10545 specimens) in Spanish fish markets (Santander, A Coruña and Vigo), and scientific acoustic pelagic surveys "PELACUS" (Massé *et al*., 2018) (3162 specimens) and the demersal trawl surveys "DEMERSALES" (831 specimens) delivered by the IEO on board of the R/V "Miguel Oliver" during March-April and September-October, respectively (Fig. 1).

Total length (TL) (1 cm), total and gutted weight (1 g) and gonad and liver weight (0.1 g) were recorded. Sex and macroscopic sexual maturity stage of males and females were determined according to the Walsh Maturity Scale (Walsh et *al.*, 1990). Otoliths were removed and aged following standardized criteria (ICES, 2016b).

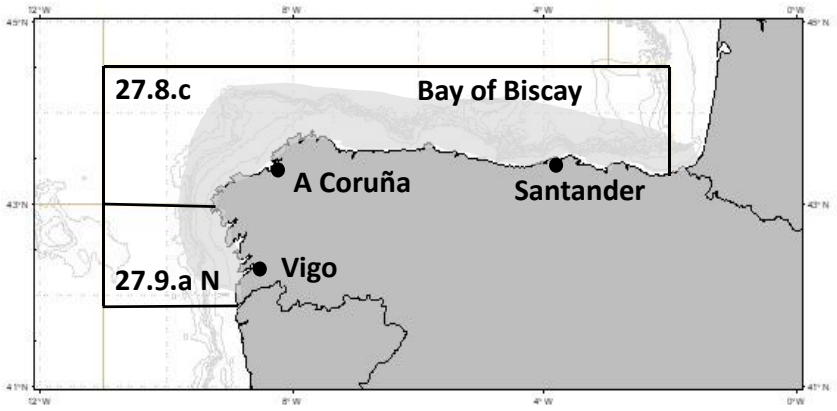

Figure 1. Area of study (gray shading) corresponding to the area covered (ICES Div. 27.8.c and 27.9.a.N) by the scientific surveys PELACUS and DEMERSALES, and where the commercial fleet operates, highlighting the fishing harbours sampled.

2.2. Spawning period

Spawning period was determined from the analysis of the monthly variation of the percentage of active females (maturity stages 3, 4 and 5) and the mean gonado- and hepatosomatic indices (GSI/HSI). Immature individuals were not included in the analysis to avoid biased results due to sampling origin or recruitment times. Individual GSI and HSI of active females were calculated as:

$$GSI = W_o / W_g \times 100; \qquad HSI = W_L / W_g \times 100$$

where W_o *= ovary weight (g); Wg = gutted weight (g) and* W_L *= liver weight (g)*

2.3. Maturity ogives

Maturity ogives at length and age were estimated based on information collected all year around, as most of immature specimens were collected during the autumn trawl surveys DEMERSALES. A second estimation was performed based only on information collected during the spawning period. Age for all

specimens was corrected considering January as date of birth, not so for length because growth rate of *S. colias* is still under study.

Maturity ogives were estimated with the *sizeMat* R package (https://cran.r-project.org/web/packages/sizeMat/vignettes/sizeMat.html). The gonad mature function was used with the frequentist method.

3. RESULTS

3.1 Spawning period

Higher percentages of actively spawning females occurred from March (23.1%) to July (32.0%) with a peak in June (64.2%) in the Subdivision 27.8.c (Fig. 2). Peak of spawning seems to be earlier (April) and less intense (21.5%) in Subdivision 9.a.N than in 8.c according to our results.

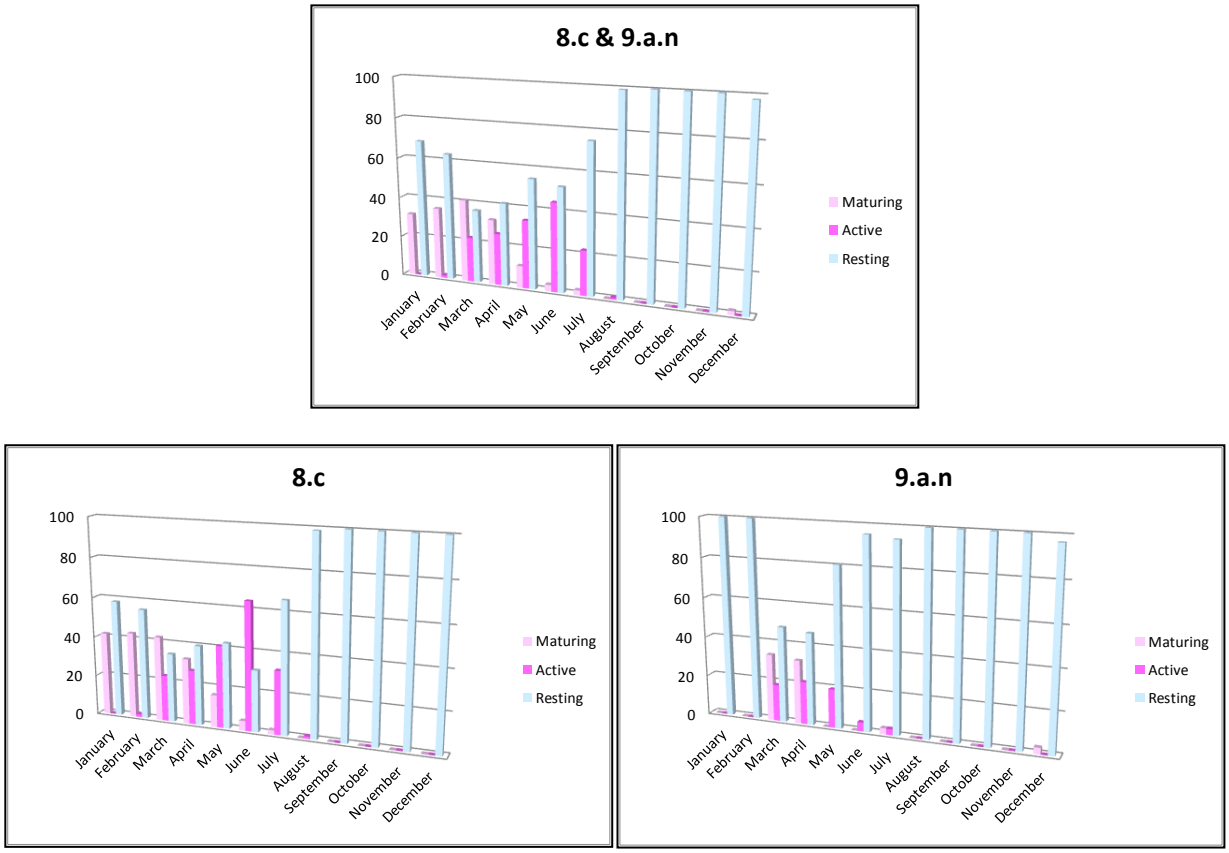

Figure 2. Percentages of maturity stages of females by month and ICES Divisions in the period 2011-2019.

Results of the GSI analyses in the total area (27.8.c and 27.9.a.N) show the same pattern than the prevalence of active females, which reveals a gradual increase of the index from 1 in March to 3.16 in June, followed by a sharp decrease in July (0.73); GSI values are almost negligible the rest of the year (Figure 3). Regarding HSI, it progressively increased from January (0.63) to June (1.51) and then decreased gradually until December (0.91) (Fig. 3).

These results indicate that the spawning period for chub mackerel in Northern Iberian waters takes place from March to July with a clear peak of activity in June.

When analysis is performed by area, similar results are found, supporting the hypothesis of early spawning in the Subdivision 27.9.a.N.

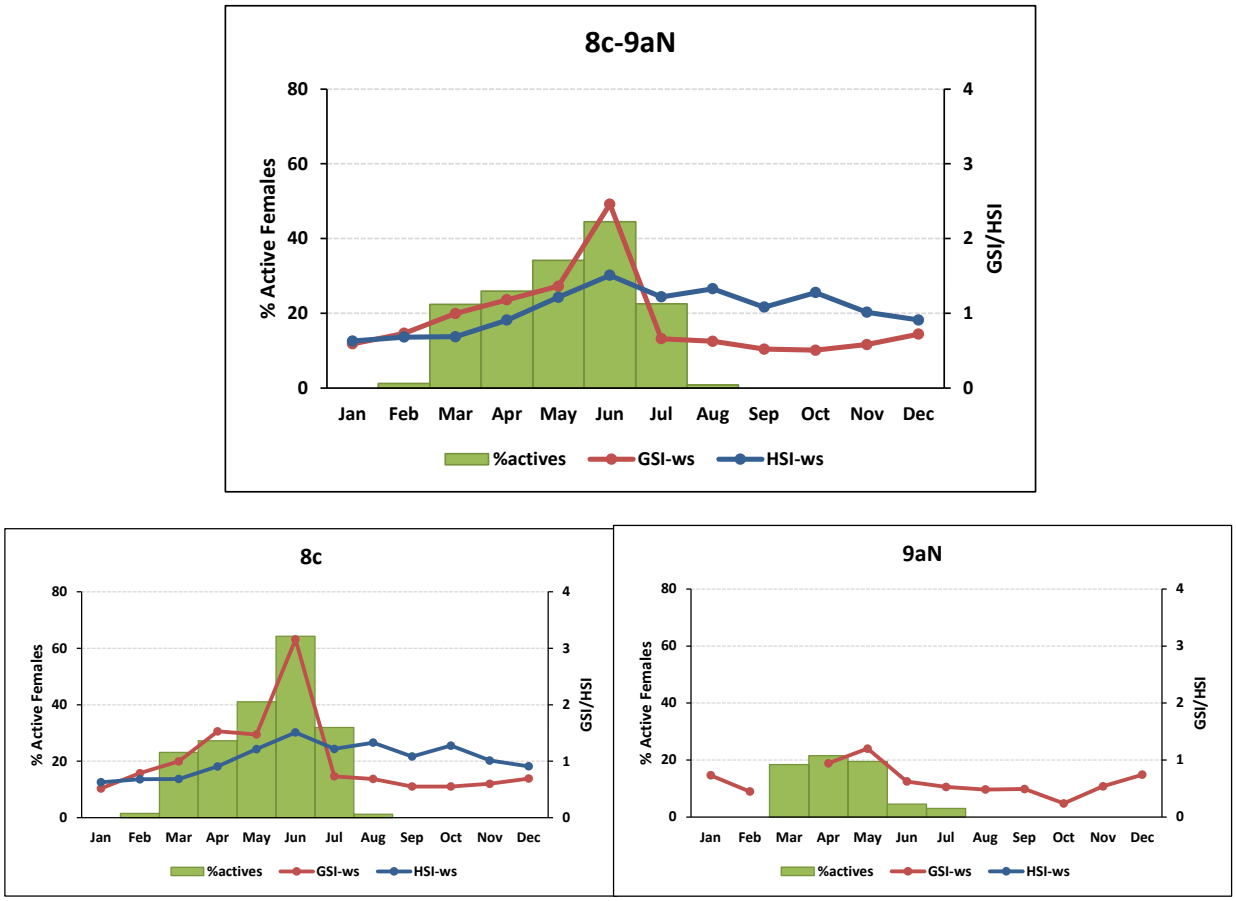

Figure 3. Percentages of active females (maturity stages 3, 4, and 5), GSI and HSI by month and ICES Divisions in the period 2011-2019.

3.2. Maturity ogives

The length at first maturity (L_{50}) for females, males and both sexes combined based on information collected all year around were 22.9 cm TL in all cases in the total area (27.8.c and 27.9.a.N) (Fig. 4), while the age at first maturity (A_{50}) was 1.6 years old in all cases (Fig. 5).

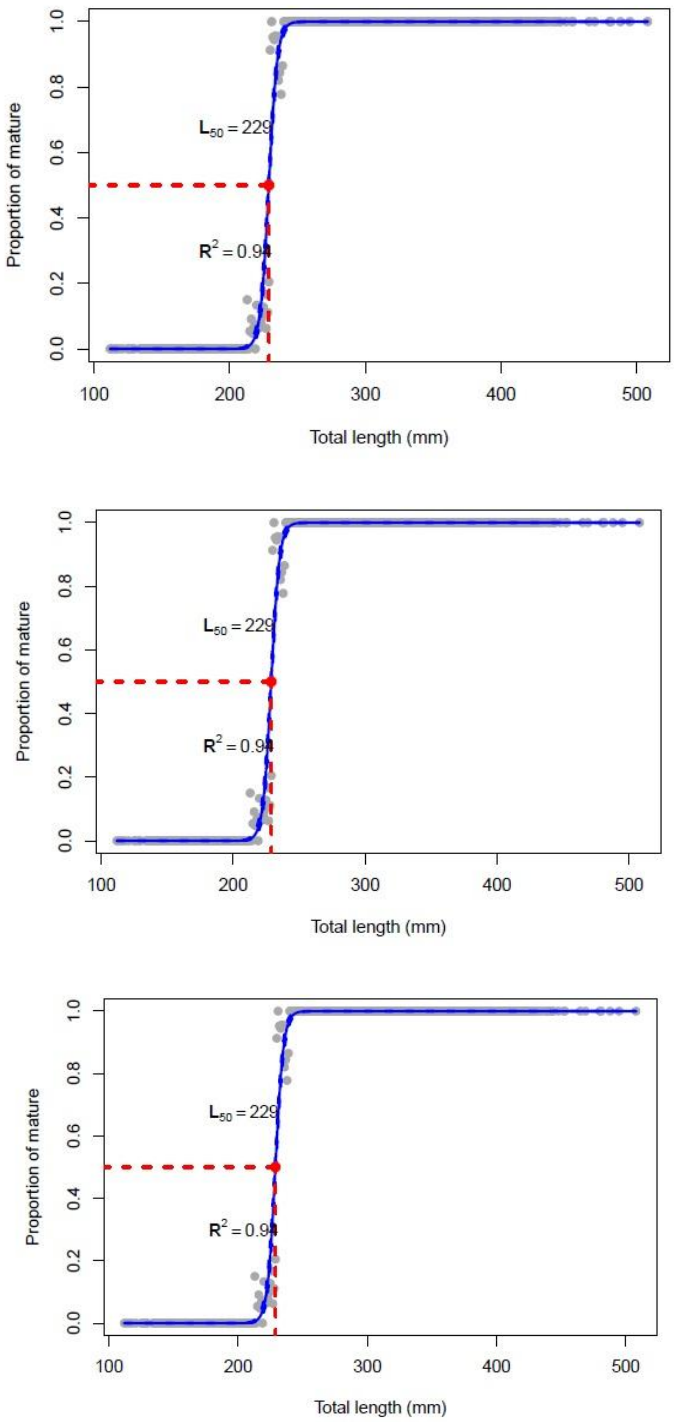

Figure 4. Proportion of mature individuals at length for females (top), males (middle) and sex combined (bottom) of *S. colias* from Northern Iberian waters (27.8.c and 27.9.a.N) for the period 2011-2019 (based on information collected all year around).

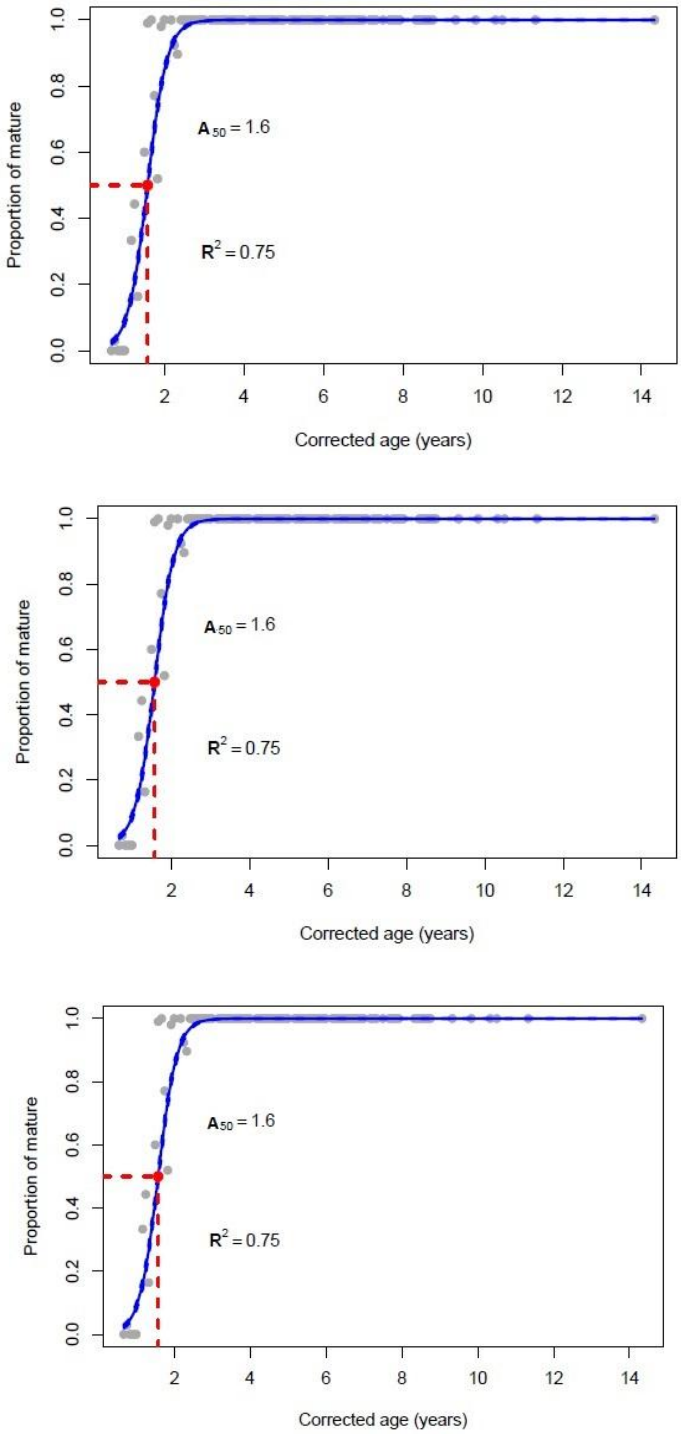

Figure 5. Proportion of mature individuals at age for females (top), males (middle) and sex combined (bottom) of *S. colias* from Northern Iberian waters (27.8.c and 27.9.a.N) for the period 2011-2019 (based on information collected all year around).

The length at first maturity (L_{50}) for females and males based on information collected only during the spawning period was 22.7 cm TL for females, males and both sexes combined in the total area (27.8.c and 27.9.a.N) (Fig. 6), while the age at first maturity (A_{50}) was 1.5 years old in all cases (Fig. 7).

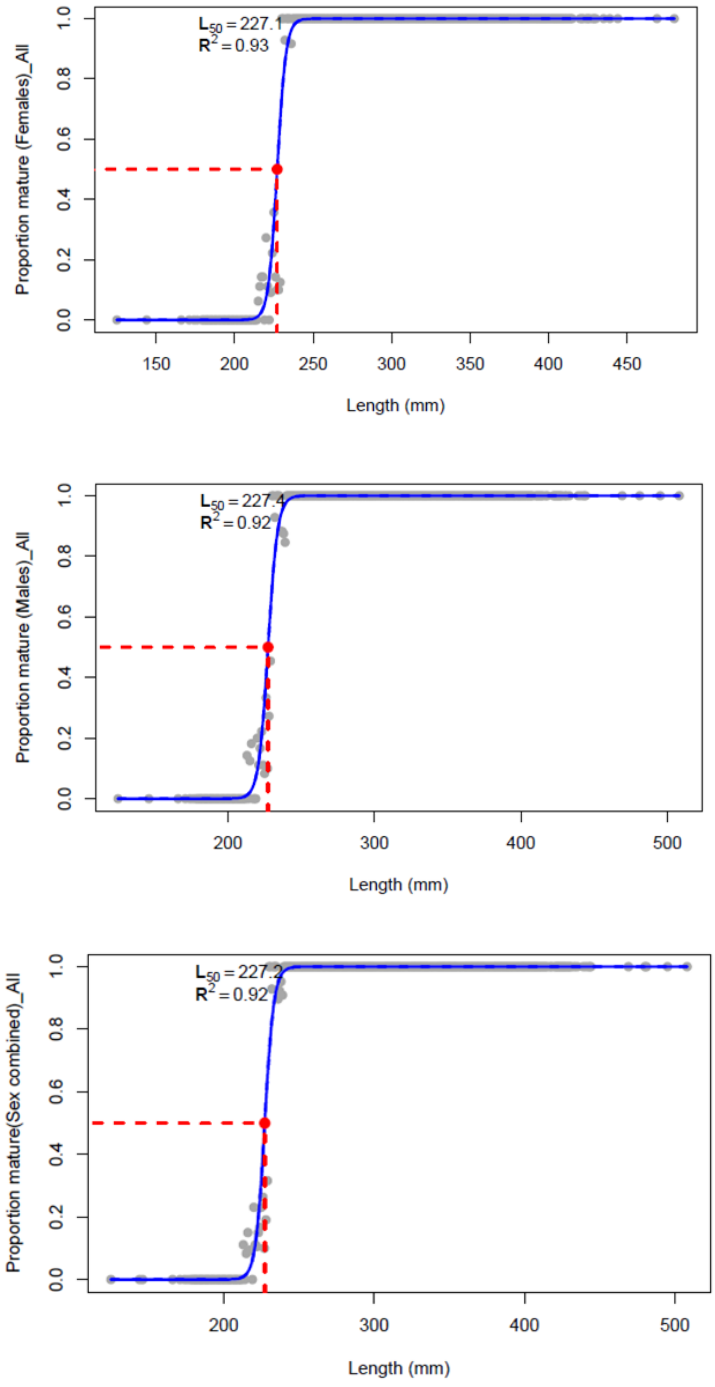

Figure 6. Proportion of mature individuals at length for females, males and sex combined of *S. colias* from Northern Iberian waters for the period 2011-2019 (based on information collected only during the spawning period).

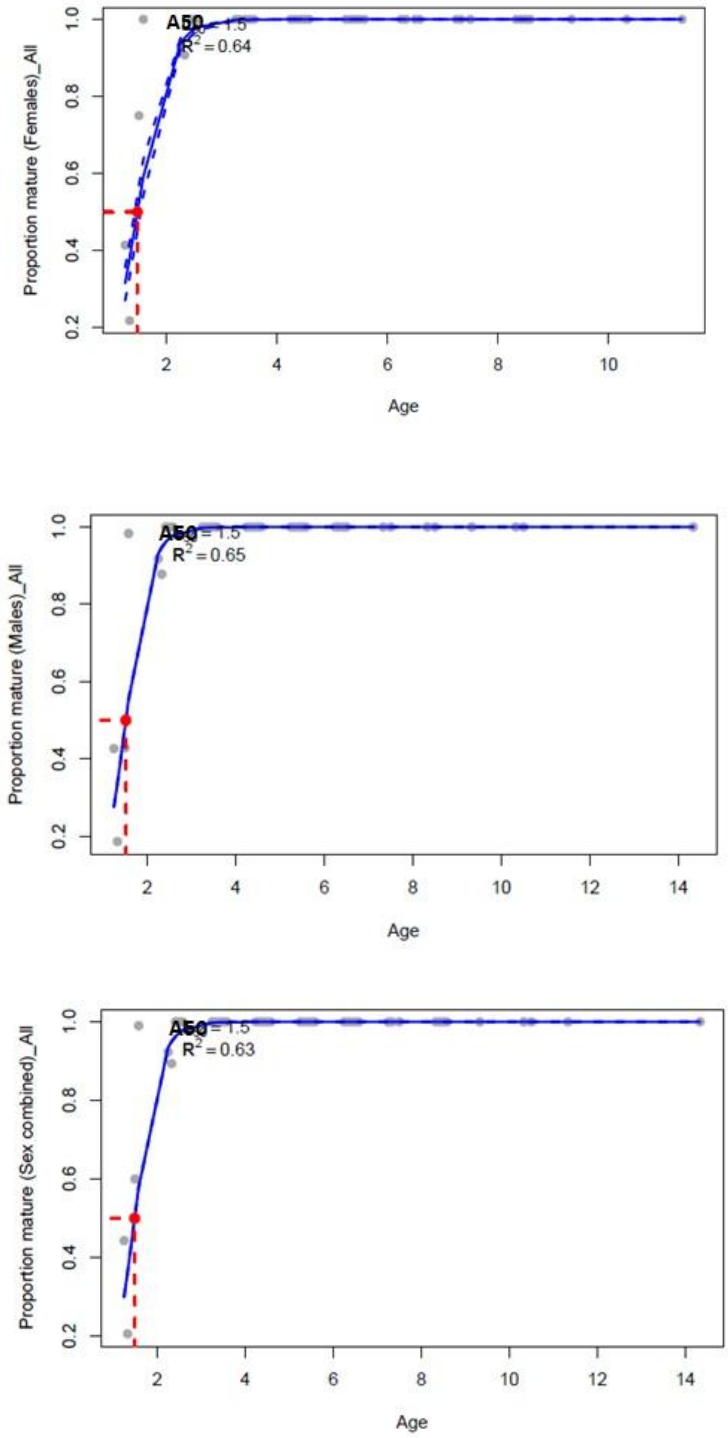

Figure 7. Proportion of mature individuals at age for females, males and sex combined of *S. colias* from Northern Iberian waters for the period 2011-2019 (based on information collected only during the spawning period).

4. DISCUSSION

According to our results, the spawning period of *S. colias* in the ICES Division 8.c takes place from March to July with a clear peak of activity in June. Peak of spawning seems to be earlier (April) and less intense in Subdivision 9.a.N than in 8.c. Differences in spawning phenology between both areas could be related to differences in length and/or age structure, because the oldest fish were found in the 27. 8.c (Navarro et *al.*, 2019). These differences could be also derived from environmental conditions, such as

temperature (Castro & Santana, 2000) or migratory behaviour of spawners, as happens in the congener Atlantic mackerel (ICES, 2016a). In any case, our data only represents partially the Subdivision 27.9.a (northern zone), preventing us from drawing conclusions about possible geographical differences in the spawning activity of this species between both Divisions, 27.8.c and 27.9.a.

Previous studies show a temporal gradient of the spawning period of *S. colias* in the NE Atlantic that seems to occur from south to north, starting in the Canary Islands from November to March (peak in December/January) (Lorenzo & Pajuelo, 1996), followed in the Northwest Morocco waters from December to March (peak in January) and June/July (Techetach et *al.*, 2010), then in Madeira Archipelago from January to April (peak in February/March) (Vasconcelos et *al.*, 2012), in Portugal from February/March to May/June (Martins, 1996), in Azores Islands from March to July/August (Carvalho et *al.*, 2002) and in the Bay of Biscay during spring and summer (Lucio, 1997), or more specifically, from March to July (peak in June) (Villamor et *al.*, 2017 and present study). This temporal and geographical gradient of the spawning period of *S. colias* from south to north is likely related to the sea temperature, as the spawning activity of this species occurs above 10ºC and most often between 15º and 20ºC (Castro & Santana, 2000), as happens in other migratory species such as Atlantic mackerel (ICES, 2016a).

Regarding maturity, our L_{50} values (22.9/22.7 cm) are lower than previous estimations in Atlantic Iberian waters. In Portugal waters Martins (1996) estimated L_{50} in 27 cm (for combined sexes), while Lucio (1997) calculated it in 29.0 cm (for females) and 30.80 cm (for males) in the Bay of Biscay, where Villamor *et al*. (2017) reported lower values for females some years later (24.99 cm). However, the high values estimated by Lucio (1997) could be due to sampling length bias because 95% of specimens were larger than 30 cm. Our values are similar to those estimated in Madeira (21.55 cm for females; 22.12 cm for males) (Vasconcelos et *al.*, 2012) and the Northwest Morocco waters (23.01 cm for females; 22.88 cm for males) (Techetach et *al.*, 2010). The L_{50} value estimated in Azores (27.78 cm for combined sexes) (Carvalho et *al.*, 2002) was similar to that from Portugal (27 cm for sex combined) (Martins, 1990). The lowest L_{50} values were estimated in the Canary Islands (19.90 cm for females; 19.85 cm for males) (Lorenzo & Pajuelo, 1996). These differences between areas can be driven by geographical differences in maturity, but the different size and sample coverage, maturity staging, or scales methodology used (data collected from spawning season or all year) among studies could have also influenced.

Regarding age at maturity, important geographical differences have been previously reported in the East Atlantic, varying from 1 to 4 years depending on the area. The highest A_{50} (4 years old) was estimated in the Bay of Biscay (Lucio, 1997), likely influenced by the sampling length bias mentioned before, followed by estimations from Portugal (3 years old) (Martins, 1996) and the one estimated in the Azores (2.23 years old for combined sex) (Carvalho et *al.*, 2002). Our values (1,6/1.5 years old, for females, males and combined sex) are closer to those obtained by Villamor et *al.* (2017) (1.9 years old for females) also in the Bay of Biscay. The lowest values of A_{50} were reported in the study delivered in Madeira (0.82 years old for females; 1.05 years old for males) (Vasconcelos et *al*., 2012). These geographical differences in A_{50} values could be related to the different L_{50} estimated in each area as well as differences in the age estimation criteria used in each study as the standardized ages estimation criteria (ICES, 2016b) were established after most of these studies were performed.

The present study is the first deep investigation of the reproductive biology of *S. colias* in northern Iberian waters (ICES Div. 8.c and 9.a N). However, it will be completed with more statistical analyses and the estimation of histological maturity ogives during the following months. Anyway, our preliminary results can contribute to increase the knowledge of the reproductive biology of this species in this area and could be used as input for analytical stock assessment and useful for fish management.

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