*Working Document to WKCOLIAS – Workshop on Atlantic chub mackerel.*
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# The Chub Mackerel (*Scomber Colias*) in the North and Northwest Iberian Waters (ICES Divisions 8.c and 9.a North): Growth and Reproduction data

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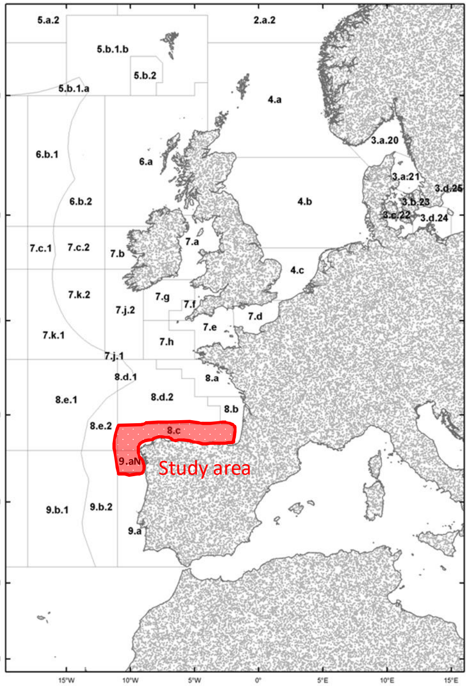
# Background and Objectives




•The recent increase of landings of Atlantic chub mackerel (*Scomber colias*) in the Atlantic Iberian waters, related to the rise in its abundance, possibly due to an increase of the water temperature, has resulted a new target species for both Portuguese and Spanish purse seiner fleets.

•This has increased the EU interest in its biological knowledge in order to launch its stock assessment in the near future.

•The biological parameters of this population are a new requirement of the EU Data Collection Framework (DCF) for Spain in recent years (since 2011).

•This work studies the **growth and reproduction** aspects of chub mackerel in North and Northwest Iberian waters, based in samples from commercial catches and scientific surveys collected between 2011 and 2018.

•Accurate age and growth information (e.g. parameters, ALKs) and validated/corroborated age estimation criteria are necessary for the analytical assessment. **This study** shows the growth pattern and parameters of chub mackerel and a **holistic approach to age validation in Northern Iberian waters** of interest for future assessment of this population (Navarro *et al*., 2019)

•The **age estimation criteria** in *S. colias* applied in this study has been **previously standardized** among the European readers in a workshop (ICES 2016), and its consistency has been checked by periodical international calibration exercises.

•This work also studies **aspects of the reproductive biology** of the chub mackerel in ICES Div. 8c and 9a-north, including the maturation process, timing of spawning and size at first maturity (L50) during a six-year period (2011-2016). Monthly evolution of gonadosomatic index and gonadal development were analysed and discussed.

# Verification and Validation studies (Growth and Reproduction)

# Growth Verification (Exchanges and Workshops)

✓**Since 2012,** there have been three exchanges and one workshop on Chub mackerel otoliths taking into accounts the Atlantic and the Mediterranean areas together. The western area of the Atlantic was also included in the last exchange

✓There is an **international annual age reading protocol** and **a consensual age reading criteria** for Atlantic and Mediterranean areas from the last Workshop on Chub mackerel age reading in 2015

✓**Agreement** between readers' estimations has **remained ~60%** during all exchanges.

✓Last exchange (2017) included an analysis for the presumed **age readers involved for the stock assessment** (Main European readers) with **68% agreement**.

*(All readers/Main European readers) ** No NWA

| Species | WK / EX | Area | Mode of preparation | Agreement (%)* | CV* |
|---|---|---|---|---|---|
| Chub mackerel | Exchange 2012 | **ALL (8.c; 9.a; GSA06)** | Whole otoliths fixed in resin (otoliths and images) | **59.5** | **22.7** |
| | Exchange 2015 preworkshop (ICES; 2016a) | **ALL** | Whole otoliths fixed in resin (images only) | **57.3** | **29.6** |
| | | ICES Div. 8.c | | 53.5 | 27.4 |
| | | ICES Div. 9.a | | 55.3 | 22.8 |
| | | Western Mediterranean Sea (GSA06) | | 62.1 | 35.2 |
| | WKARCM 2015 (ICES; 2016a) | **ALL** | Whole otoliths fixed in resin / loose submedged in water (images only) | **60.6** | **45.6** |
| | | ICES Div. 8.c | | 66.7 | 36.2 |
| | | ICES Div. 9.a | | 55.6 | 37.3 |
| | | CECAF-Mauritania | | 60.2 | 41.6 |
| | | Western Mediterranean Sea (GSA06) | | 65.3 | 29.3 |
| | | Ligurian and North Thyrrenian Sea (GSA09) | | 46.4 | 64.6 |
| | | Southern Adriatic Sea (GSA18) | | 68.2 | 65.8 |
| | Exchange 2017 (ICES; 2018) | **ALL**** | | **60.4/68.0** | **62.5/34.0** |
| | | ICES Div. 8.c | | 52.2/65.0 | 67.5/34.0 |
| | | ICES Div. 9.a | | 55.9/60.0 | 35.3/24.0 |
| | | CECAF-Canarias | | 70.3/80.0 | 68.6/24.0 |
| | | Ligurian and North Thyrrenian Sea (GSA09) | | 52.4/63.0 | 114.1/68.0 |
| | | Aegean Sea (GSA22) | | 64.7/71.0 | 34.6/28.0 |
| | | North West Atlantic | | 50.0/52.0 | 38.7/35.0 |

# Growth Validation (ICES WKVALPEL, 2019)

| | | | | | Precision | | | | Corroboration | | | | | | | Validation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Indirect Validation | | Semi-direct validation | | Indirect Validation | | | | | |
| Species | Zone | Area | Stock | Analitical Assessment | Several readings | Exchanges | Backcalculation | Verification | Modal Length/Frequency Analysis | Modal Weigth/Frequency Analysis | Nature edge | Marginal increment analysis | Daily increment widths | Daily increments between annuli | Progression of strong year-classes | Captive rearing from batch | Released marked fish | Bomb radiocarbon |
| Chub mackerel | North east Atlantic | Bay of Biscay | 27.8c | No | Y | Y | Y | Length distribution of anulli distance | Y | | Y | Y | | | | | | |
| | | Galicia | 27.9a | No | Y | Y | | | | | Y | | | | | | | |
| | | North Portugal | 27.9a | No | Y | Y | | 1st translucent | | | Y | Y | | | | | | |
| | | Gulf of Cadiz | 27.9a | No | | | Y | | | | Y | | | | | | | |
| | | Azores | 27.10a2 | No | ? | | | | | | Y | | | | | | | |
| | Central east Atlantic | Madeira | CECAF/34. | No | ? | | Y | | Y | | Y | Y | | | | | | |
| | | Canary | CECAF/34. | No | Y | Y | | | Y | | Y | | | | | | | |
| | | Mauritania | CECAF/34.1 | No | Y | Y | Y | Length distribution of anulli distance | | | - | | | | | | | |
| | Mediterranean Sea | Alboran Sea | GSA 01 | No | | | | | | | Y | | | | | | | |
| | | West Mediterranean (Murcia Coast) | GSA 06 | No | Y | Y | | | | | - | | | | | | | |
| | | West Mediterranean (Catalonian Coast) | GSA 06 | No | | | | | | | Y | | | | | | | |
| | | Tunisia waters | GSA 12 | ? | ? | - | | | | | Y | | | | | | | |
| | | Ligurian & North Thyrrenian Sea | GSA 09 | No | Y | Y | | | | | | | | | | | | |
| | | Southern Adriatic Sea | GSA 18 | No | Y | Y | | | | | | | | | | | | |
| | | Aegean Sea | GSA 22 | No | Y | Y | | | | | | | | | | | | |
| | | Hellenic Sea | GSA22 | No | ? | | | | | | Y | Y | | | | | | |
| | | Turkey waters | Unclear | No | ? | | | | | | Y | | | | | | | |

**The majority of works attempting to validate annuli of Chub mackerel apply the qualitative method** of marginal increment analysis, one of the least rigorous methods. So far, there are only three areas (**N and NW Iberian Peninsula,** Madeira and Canary Islands) where **more accurate validation methods** have been used.

# Maturity Verification and Validation

There have been **only one exchange and one workshop** on Chub mackerel maturity stage in 2015 (ICES WKMSMAC2)

In the **macroscopic picture calibration exercise** on *Scomber colias*, the overall agreement with modal stage was **71.2%**

**Histological validation** is being performed currently.

There is an **international updated maturity scale to report to ICES (Atlantic) and Mediterrenean areas** (ICES WKMSMAC2)

| Species | WK / EX | Area | Mode of preparation | Agreement (%)* |
|---|---|---|---|---|
| Chub mackerel | Exchange 2015/WKMSMAC2 2015 | 9a (Portuguse waters) | Macroscopic/ 10 pictures | **71.2** |

| Stage | Name | Substage | Female | Male |
|---|---|---|---|---|
| 1 | Immature | | Ovaries small. Ovaries clear, torpedo shape. | Testes small. Males pale, flattened and transparent. |
| 2 | Developing | | Ovaries occupying ¼ to almost filling body cavity. Opaque oocytes visible in ovaries giving pale pink to yellow to orange coloration. Largest oocytes may have oil globules. Late developing ovaries firm and oocytes densely packed. | Testes occupying ¼ to almost filling body cavity. Testes off-white to creamy white, firm and milt not running. |
| 3 | Spawning | 3a Actively spawning | Ovaries characterized by prevailing externally visible hyaline oocytes. | Testis from filling to < ¼ of body cavity, milt running either freely or under light pressure. Testes can be shriveled (wrinkled and contracted) at anus. |
| | | 3b Spawning capable | Ovaries size variable from full to < ¼, losing firmness and increasing empty spaces between oocytes. May have hyaline oocytes when cutting. Ovaries can be bloodshot. | |
| 4 | Regressing Regenerating | | Ovaries occupying ¼ or less of body cavity. Ovaries reddish and often murky (dark and gloomy) in appearance, flaccid, sometimes with a scattering or patch of opaque oocytes or absence of visible oocytes. | Testes occupying ¼ or less of body cavity. Testes opaque with brownish tint and no trace of milt. Testes becoming translucent. |
| 5 | Omitted spawning | | No evidence of omitted spawning | No evidence of omitted spawning |
| 6 | Abnormal | | No evidence of abnormal ovaries | No evidence of abnormal testes |

# Growth studies

# Material & Methods: Age and Growth

- **Biological samples**: **9249** *S. colias* from commercial catches, **2491** individuals from spring acoustic surveys “PELACUS”, and **806** from autumn bottom trawl surveys DEMERSALES were sampled in Northern Iberian waters (ICES Div. 8c and 9aN) from 2011 to 2018.

Total fish length (TL), to the nearest mm, and total weight (TW), to the nearest gr., of all specimens were measured. Otoliths were removed and aged, following the standardized criteria (ICES 2016).

The age of a total of **8915 otoliths** was estimated by interpreting and counting annual growth rings as described in ICES (2016)

- **Age-Length Keys (ALK**) were obtained by semester each year and applied to the commercial catches by quarter.

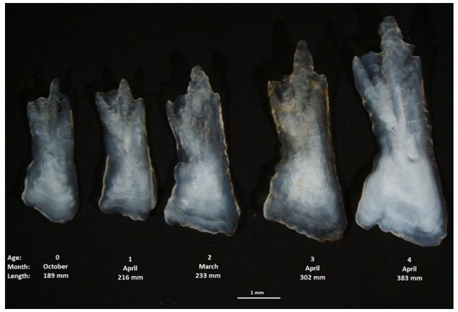
- **Length-weight relationship (2011-2018):** Length (TL, 1 cm length class)-weight (TW, g) relationships were estimated on a yearly and semester basis.

Parameters *a* and *b* and its coefficient of variation were estimated using the Gauss-Newton algorithm, with INBIO 2.0. Regression slopes were compared by analysis of variance (ANCOVA)

- The **growth parameters** of *S. colias* were estimated for both sexes combined, according to the von Bertalanffy equation

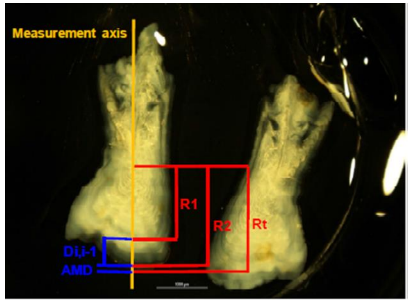
# Material & Methods: Age validation

## **Age validation methods** (Navarro *et al*., 2019)**:**




- The **nature of the edge** (opaque/hyaline) was analyzed in all otoliths (2011-2017)

- The **otolith (OR) and annuli radius (AR)** of 423 otoliths from two consecutive years (2011-2012) were measured, and their frequency distributions were analyzed. **Marginal increment** was also measured and analyzed**.**




- **Back-calculated lengths** were obtained using the Fraser-Lee equation and Body Proportional Hypothesis (BPH).

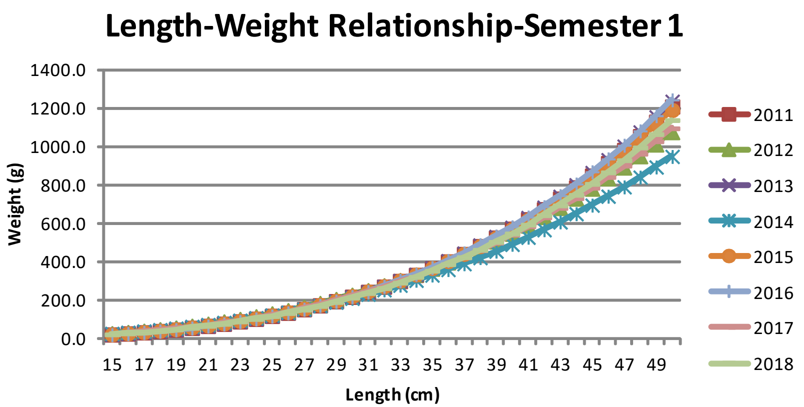
- **Length-frequencies** were analyzed using different methodologies:

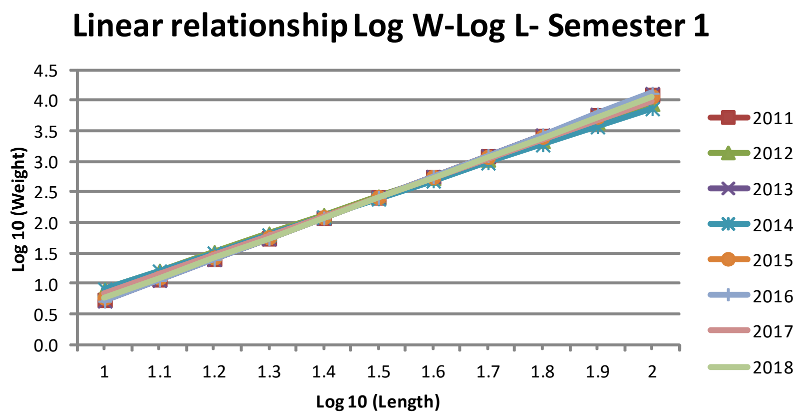
1) Modal class progression analysis (MPA), using the **Bhattacharya's method** (Bhattacharya, 1967) included in the FISAT II program (Gayanilo et al., 2005). Different scenarios were considered.

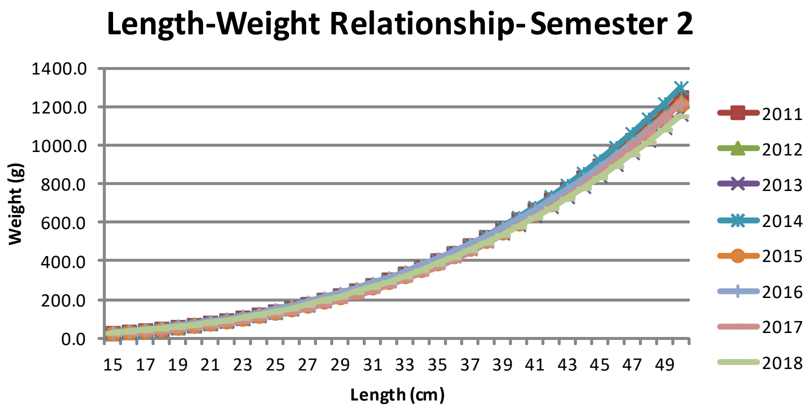
2) The software package **Length Frequency Distribution Analysis (LFDA)** (MRAG, 2001) was used by applying three methods: Shepherd's Length Composition Analysis (**SLCA**), Projection Matrix Method (**PROJMAT**) and the Electronic Length Frequency Analysis (**ELEFAN**) to the length-frequency distributions of different scenarios of the commercial catches and surveys independently, to obtain the most objective von Bertalanffy growth parameters.

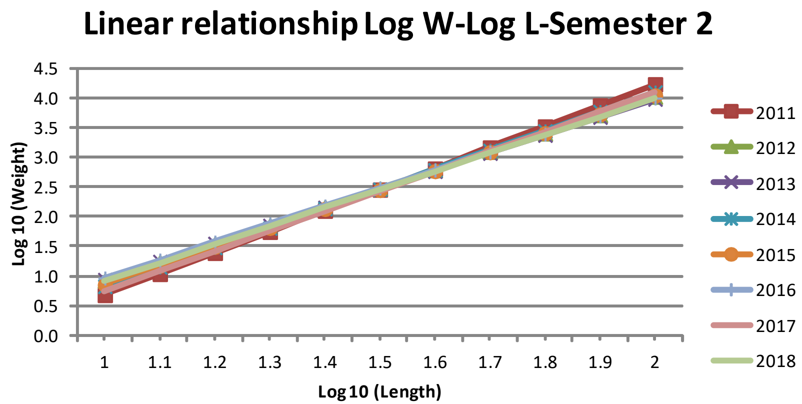
# RESULTS: Length-weight relationship (2011-2018)

- Annual LWRs lined up exponentially.
- Also a logarithmic transformation was used to express these relationships, using a linear regression.
- No significant differences (F-test; F5-59 = 0.58; P > 0.1) in the slopes (coefficient b) of annual relationships were found.



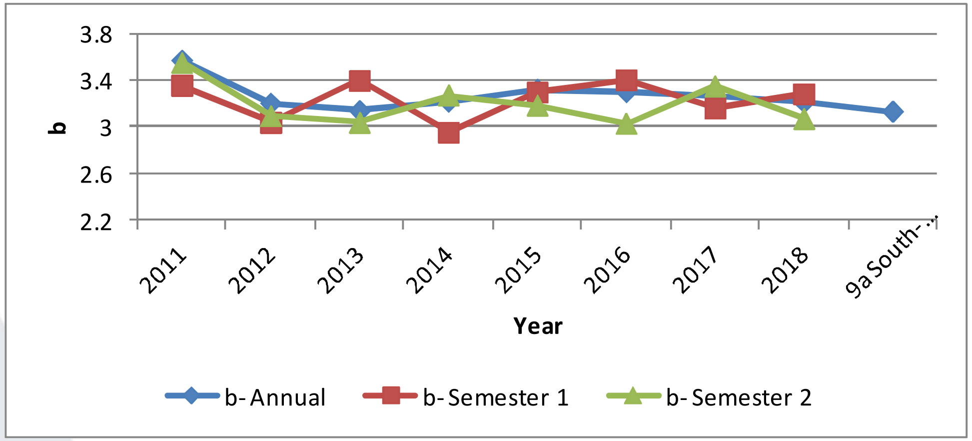



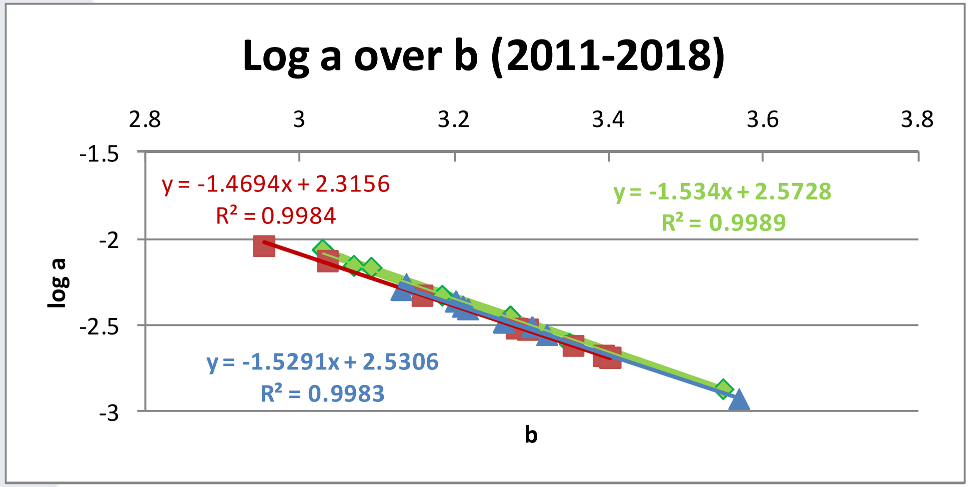



# RESULTS: Length-weight relationship (2011-2018)

Å No trend was observed in the values of b, although being more fluctuating in the first part of the year.

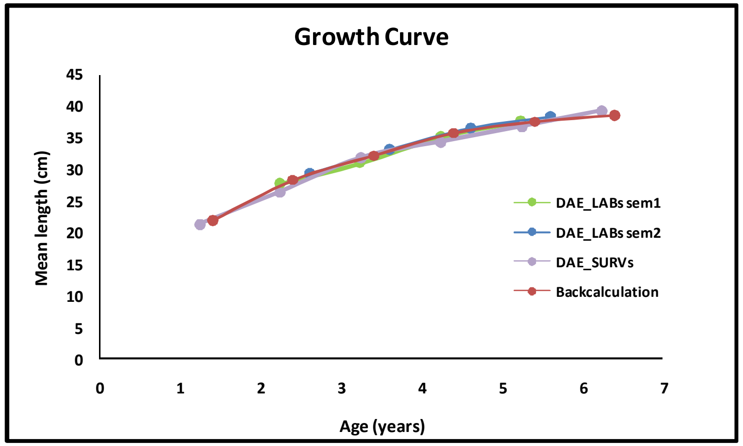



Å A regression analysis of log a over b did not find any outlier (p=0.000) and its linear regression explains 99% of the variance. Therefore all the data here estimated can be used for the analysis.

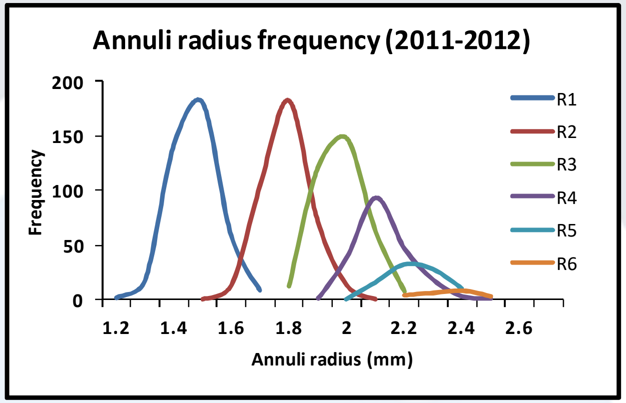


# RESULTS: Growth Validation (Navarro et al. 2019)

**Backcalculated mean lengths at age** were estimated for both scenarios (Fraser-Lee; BPH), and almost identical values were obtained between them.

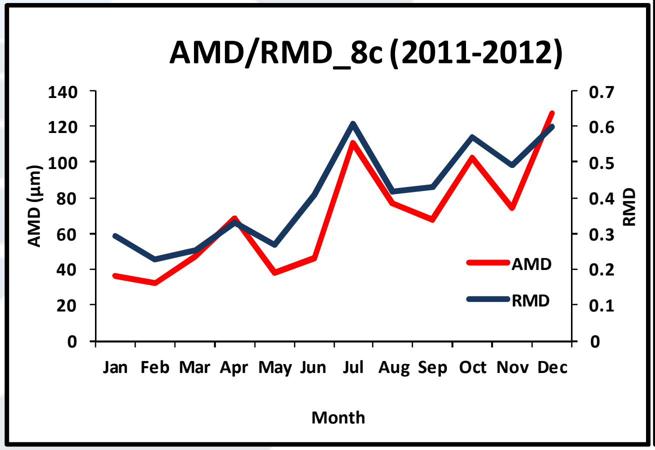


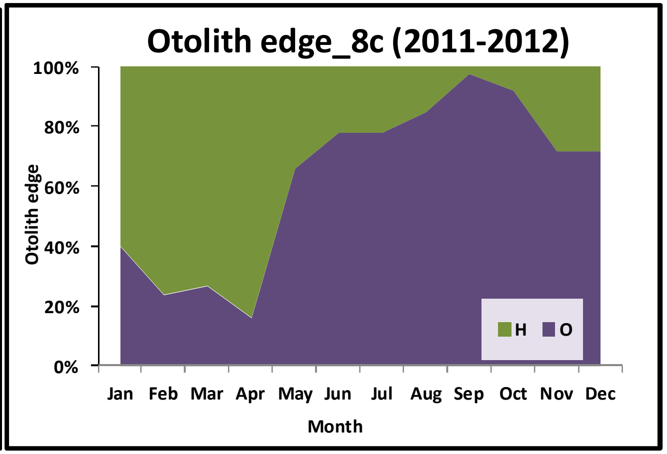

The **frequency distribution of annuli radius** showed a normal distribution (unimodal), supporting consistency in the age estimation.




The study of the **nature of the edge and marginal increment analysis** showed an annual periodicity in the formation of the opaque edge (June-December) and hyaline edge (January-June). The **winter (hyaline) annulus seems to be entirely formed in April**.

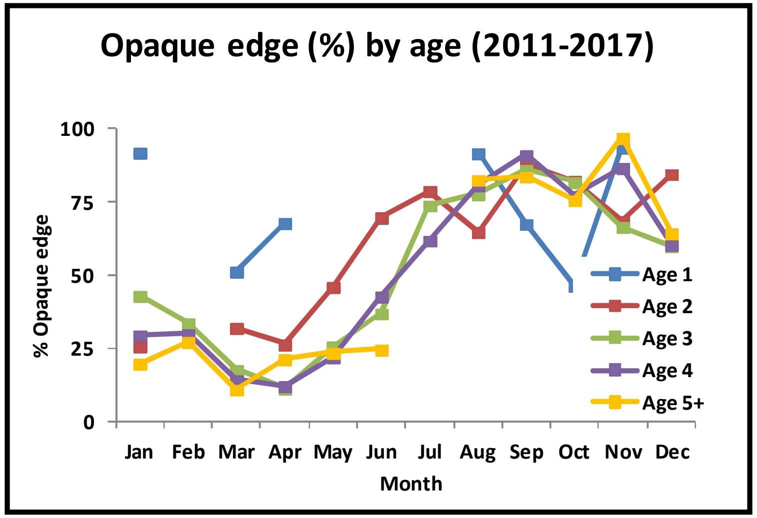
These studies give consistency to the interpretation of age with otoliths

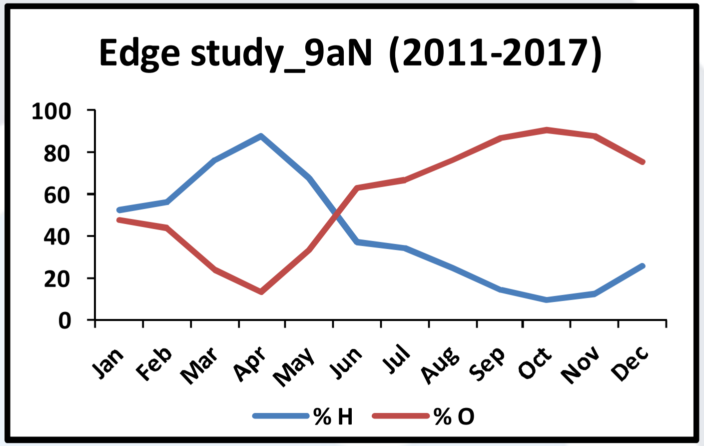


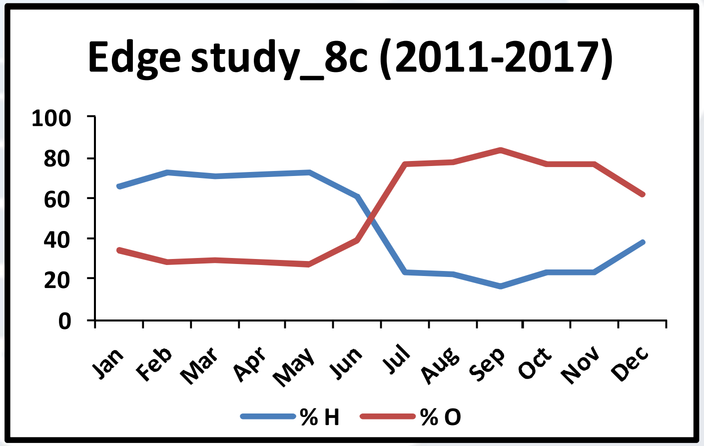
# Results: Growth Validation (Navarro et al. 2019)

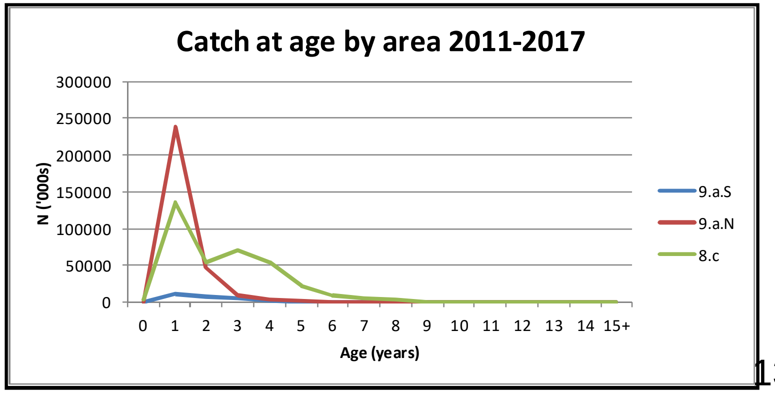
Analyzing the edge nature **by age**, younger individuals (age 1&2) otoliths showed an earlier opaque edge formation than in the older ones.




**By area**, otoliths from Div. 9aN showed earlier formation of the opaque edge than those from 8c. Which could be related with a greater abundance of younger specimens in that area or in relation to geographical distribution.



# RESULTS: Growth Validation (Navarro et al. 2019)

## Length-frequency analysis

The methodologies of the **LFDA** package estimates growth parameters that show mean lengths of ~20.5, ~29.5, ~36 and ~41 in commercial catches and slightly higher in surveys.

The modal lengths estimated by **Bhattacharya** method in commercial catches were lower: ~21.5, ~28, ~34 and ~38.5 and similar to those visually observed.

MEAN LENGTH (cm)

| Age group | Direct age estimation | Back-calculation: Faser-Lee | Back-calculation: BPH | Length-frequency analyses: Bhattacharya | Length-frequency analyses: SLCA | Length-frequency analyses: ELEFAN | Length-frequency analyses: PROJMAT |
|---|---|---|---|---|---|---|---|
| | commercial catches + surveys | | | commercial catches | | | surveys |
| 0 | 16.8 | 16.3 | 16.3 | 12.8 | 8.7 | 8.3 | 8.5 |
| 1 | 23.7 | 23.7 | 23.7 | 21.5 | 20.7 | 20.1 | 21.0 |
| 2 | 28.9 | 29.0 | 29.1 | 28.4 | 29.5 | 29.2 | 30.6 |
| 3 | 32.9 | 32.8 | 32.9 | 33.9 | 35.9 | 36.3 | 37.8 |
| 4 | 35.9 | 35.6 | 35.6 | 38.2 | 40.5 | 41.9 | 43.4 |
| 5 | 38.2 | 37.6 | 37.6 | 41.7 | 43.8 | 46.2 | 47.7 |
| 6 | 39.9 | 39.1 | 39.0 | 44.5 | 46.3 | 49.6 | 50.9 |
| 7 | 41.2 | 40.1 | 40.1 | 46.7 | 48.0 | 52.2 | 53.4 |
| 8 | 42.2 | 40.8 | 40.8 | 48.5 | 49.3 | 54.3 | 55.3 |

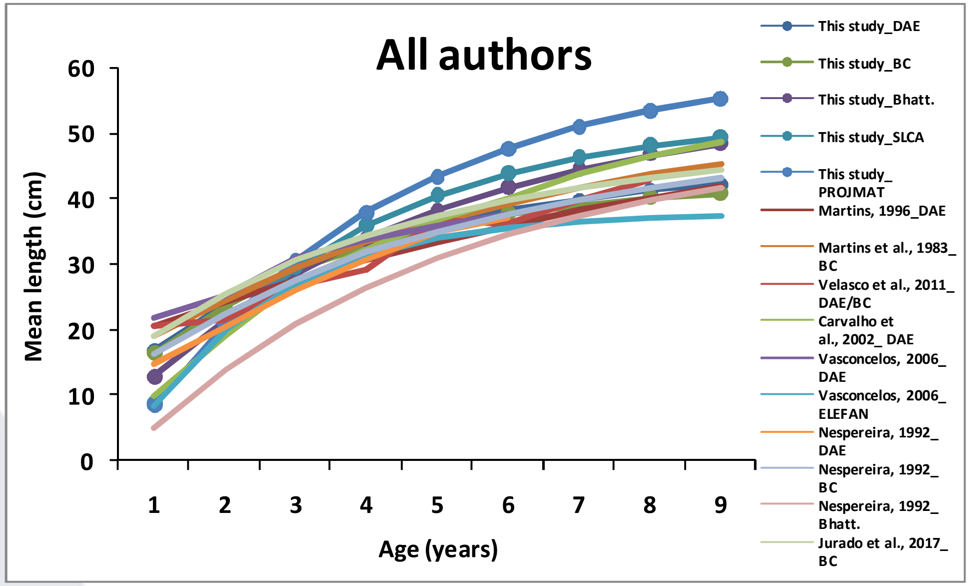
**In summary, we obtain three growth patterns**:

| Growth | Method | Growth peformance index (ϕ´) | Age groups (21-40 cm) |
|---|---|---|---|
| **Slow** | Direct estimate of age / Back-calculation | 2.76-2.78 | 7 |
| **Intermediate** | Bhattacharya | 2.84 | 5 |
| **Fast** | LFDA | 2.95-3.01 | 4 |

# RESULTS: Von Bertalanffy Growth curves (Navarro et al., 2019)

**Previous studies** of *S. colias* in the Northeast Atlantic showed growth parameters estimated mainly from direct age estimation and/or back-calculation.

Only two studies showed growth parameters estimated from **length frequency analysis,** with very different growth parameters between them, one using ELEFAN (Vasconcelos, 2006) and other with Bhattacharya (Nespereira, 1992), respectively, from Madeira and Canary Islands, showing, respectively, an **intermediate** and **slow** growth pattern (Φ‘: 2.86-2.73).




The **direct age estimation/backcalculation** studies also showed slow growth patterns (Φ‘ mainly from 2.70 to 2.82), similar to the values obtained in this study with the same method.

| Author | Present study | | | | | | | Martins, 1996 | Martins et al., 1983 | Velasco et al., 2011 | Carvalho et al., 2002 | Vasconcelos, 2006 | | Nespereira, 1992 | | | Jurado et al., 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | N & NW Iberian Peninsula | | | | | | | Portuguese coast | Portuguese coast | Gulf of Cadiz | Azores archipelago | Madeira Island | | Canary Islands | | | Mauritanian waters |
| Years | 2011-2017 | 2011-2012 | | 2011-2017 | | | | 1986-1995 | 1981-1982 | Oct. 2003-Sept. 2004 | 1996-2002 | 2002-2003 | | 1988-1990 | | | 2005-2011 |
| Methodology | Direct age estimation | Back-calculation (FL) | Back-calculation (BPH) | Length-frequency (Bhattacharya) | Length-frequency (SLCA) | Length-frequency (ELEFAN) | Length-frequency (PROJMAT) | Direct age estimation | Back-calculation | Direct age estimation / Back-calculation | Direct age estimation | Direct age estimation | Length-frequency (ELEFAN) | Direct age estimation | Back-calculation | Length-frequency (Bhattacharya) | Back-calculation |
| | commercial catches + surveys | | | commercial catches | | | surveys | | | | | | | | | | |
| Sex | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined | Combined |
| *L∞* | 45.33 | 42.78 | 42.68 | 55.32 | 52.74 | 61.46 | 61.39 | 58.52 | 53.83 | 43.00 | 57.52 | 50.08 | 38.00 | 50.69 | 49.22 | 49.22 | 48.40 |
| *K* | 0.28 | 0.33 | 0.33 | 0.23 | 0.32 | 0.25 | 0.27 | 0.10 | 0.17 | 0.27 | 0.20 | 0.25 | 0.50 | 0.21 | 0.21 | 0.22 | 0.25 |
| *to* | -1.17 | -0.96 | -0.96 | -0.66 | -0.06 | -0.08 | -0.05 | -3.68 | -2.03 | -1.10 | -1.09 | -1.34 | | -1.45 | -1.40 | | -1.51 |
| *ϕ'* | 2.76 | 2.78 | 2.78 | 2.84 | 2.95 | 2.98 | 3.01 | 2.55 | 2.70 | 2.70 | 2.82 | 2.80 | 2.86 | 2.73 | 2.71 | 2.73 | 2.76 |
| *n* | 6867 | 409 | 409 | | | | | 883 | 533 | 121 | 349 | 2115 | | 878 | 538 | | 163 |
| Length rate (cm) | 14-50 | 16-48 | 16-48 | 18-49 | 18-53 | | 14-46 | 16-54 | | 16-43 | 9-56 | 13-41 | 13-41 | 4-42 | | 4-48 | 12-49 |

# Growth Conclusions

✓The **length-weight relationship** of Chub mackerel, in Divisions 8.c and 9.a North, indicate a tendency towards **positive-allometric growth** (increase in relative body thickness or plumpness) as most of the b values are above 3.0. These relationships do not show any trend in the studied period and there are no differences between years.

✓The **age estimation criteria** in *S. colias* applied in this study **has been previously standardized** among the European age readers in a workshop (ICES 2016), and its consistency has been tested by periodical international calibration exercises, even though the agreement and precision values should improved for the stock assessment process. **When this age estimation criterion was standardized, scarce studies to corroborate/validate it were available**.

✓ On one hand, **our otolith edge study** shows **an annual periodicity** in the formation of the hyaline and opaque annuli that**, in addition of the back-calculation study and the frequency distribution of annuli radius analysis** performed in this work**, supports the consistency in the age estimation criteria**.

✓ On the other hand, our **Length-frequency study** shows two growth patterns, both faster than the one estimated from otoliths. **Length-frequency analyses** are generally useful to estimate the growth pattern at first modal ages, those with a good representation in the catch. However, due to the limited fish length range in the catches (~20-40 cm) and the limited time series available (7 years), our results of the length frequency distribution analysis are **not conclusive**. Only the **modal progression analysis** (Bhattacharya method) show similar modal lengths to those **observed visually in the length distributions**.

✓Moreover, **the use of lengths in migratory species for growth studies is questionable**, as described in mackerel (Skagen, 1989; Villamor et al., 2004). According to the age sequence in the mackerel migration routes, the interpretation of **the growth will depend on the time at which the samples are collected**.

To solve the age and growth information gaps of this species for stock assessment, attempts with the parameters obtained with age estimates from otoliths and Bhattacharya method as inputs in the analytic assessment model is recommended.

# Remarks and further growth works

✓ In recent years, the interest in implementing the *S. colias* **stock assessment** in Atlantic Iberian waters has grown within ICES. **Accurate age and growth information** (e.g. parameters, ALKs) and **validated/corroborated age estimation criteria are necessary for the analytical assessment.**

✓ **The season of formation of opaque and translucent zones may change during development** and **in relation to geographical distribution**, as in the Atlantic cod (Høie et al., 2009) and *Sebastes* in the Pacific coast (Pearson, 1996).

✓In our study, **it seems that geographical differences** are found between areas 8c and 9a N. **It is advisable to make this type of study for all distribution areas** of chub mackerel to test whether or not there are seasonal differences in the formation of opaque-hyaline zones in otoliths and to study that factors influencing variation in otolith opacity.

✓ Preliminary analysis of length distribution of the surveys in 2018 and 2019 shows a good tracking of the abundant 2016 cohort that could corroborate these two first modal lengths (~23 and 28 cm) observed by both, direct age estimation/back-calculation and Bhattacharya analyses. Further length frequency analyses and the tracking of the 2016 cohort through 2020 and later years and will help to clarify the growth pattern of this species.

✓ To extend the use of alternative methods to direct age estimation, such as **length-frequency analysis, in other distribution areas** (specially with a wider length range in catches) **is recommended** and can help to confirm this faster growth rate obtained in this study.

✓**Other direct validation studies**, such as tag-recapture and daily increment analysis, can also confirm **whether checks are being identified as true annuli** in the age estimation process.

✓ In addition, **other studies about the biology** of this species (migration, feeding activity, etc.) would led to a better understanding of the otolith growth pattern.

# Reproduction study

# Material & Methods. Reproduction

Å**Biological samples**: A total of **9920** specimens (**7795** from the commercial fleet, **1788** from spring research survey PELACUS and **337** from autumn research survey DEMERSALES) were analyzed, 2011-2016

ÅFor each of them, the following variables were recorded: total body length (TL, cm), total weight (TW, g); sex and maturity stage, determined by macroscopic examination of the gonads **following Walsh *et al.* (1990) scale as recommended in ICES, (2015).**

ÅA total of **3370 gonads** were dissected and weighted (Wo) and the gutted weight (Wg) of 3544 specimens was also measured. All weights were measured at 0.001 g accuracy.

Å**Annual reproductive cycle by ICES Division** and for the whole area was analyzed through **macroscopic indexes for the period 2011-2016.**

Å**Spawning period.** was determined from the **analysis of the monthly evolution** of both the percentage of mature females (active stages) and the **mean gonadosomatic index** (GSI). Only potentially mature individuals were used, i.e. individuals with length > L25

Å**Individual GSI of active females** >25cm were calculated using the gutted weight values: GSI = (Wo / Wg) x 100; Wo = Gonad weight (g); Wg = Gutted weight (g);

Å**Maturity ogives** by length and age were constructed using only data collected during the main spawning period, when a high percentage of mature (active stage) fish was observed (March to July).

ÅFor the estimation of maturity ogives the **logistic model** has been used: p= 1/1+exp (-(B0+B1x)) where p is the predicted proportion of mature by age class, x is the age class, B0 and B1 are the parameter of the model to be estimated.

Å**Generalized linear model (GLM**) with a binomial error distribution and a log-likelihood fit were applied with INBIO 2.0.

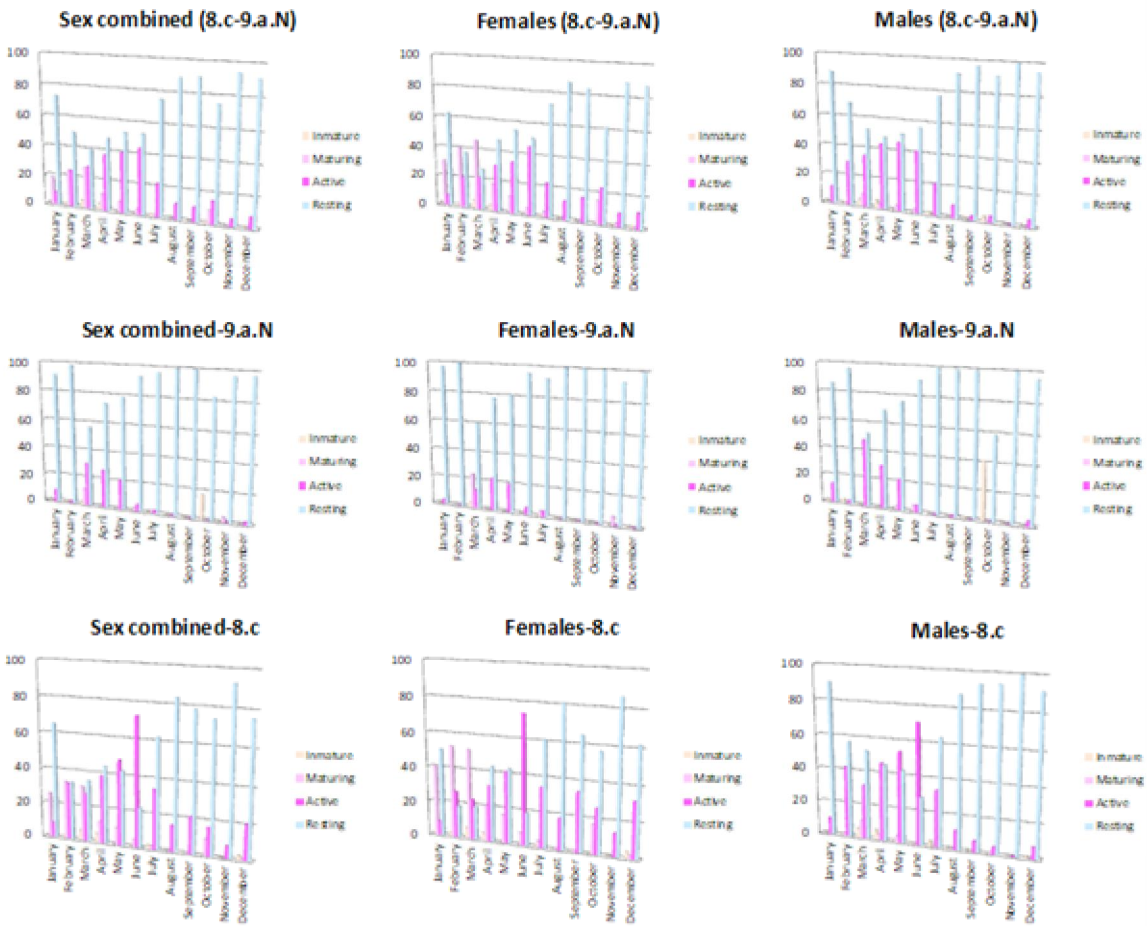
# RESULTS: Reproduction

## Spawning period (2011-2016): % of mature by month

✓ Higher percentages of mature (active stages) males and females occurred from March to July, being more evident from April to June for the two areas together.

✓In Subdivision **9.a North** percentages of active stages are higher from **March to May**.

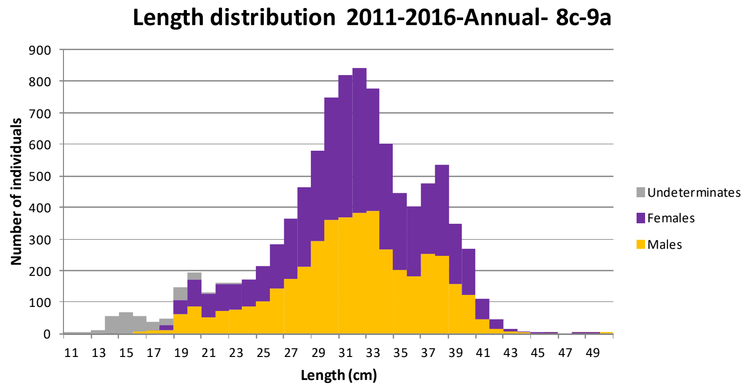
✓ In Division **8.c**, although there seems to be active stages all year round, the highest percentages of active stages are between **February and July with a very clear peak in June.**

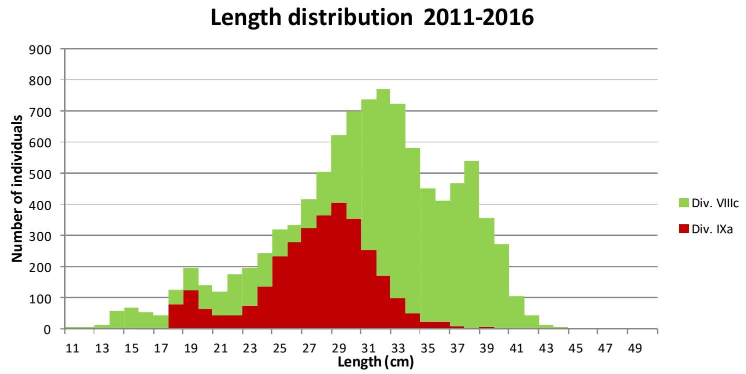


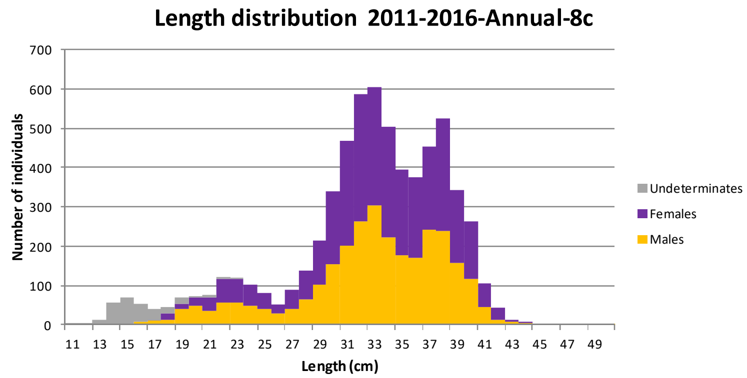
# RESULTS: Reproduction

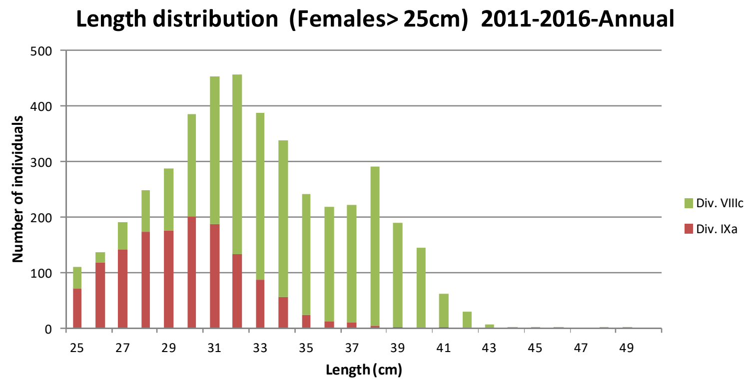
## Spawning period (2011-2016): % Active females-GSI

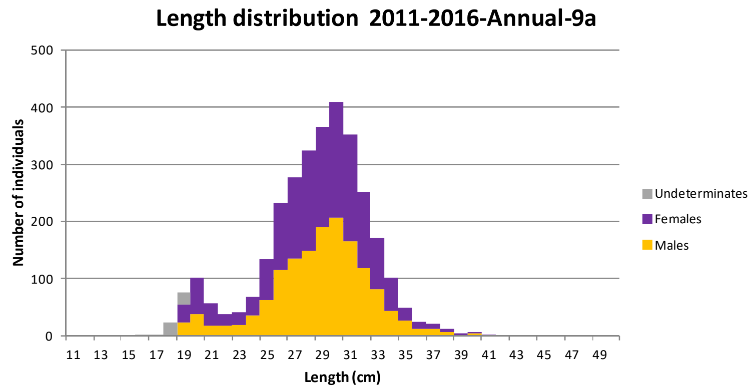
✓Individuals in Division 9.a north are smaller in size than in Division 8.c.

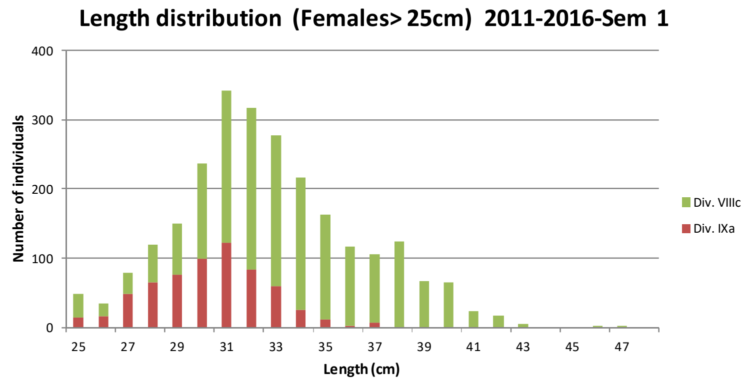


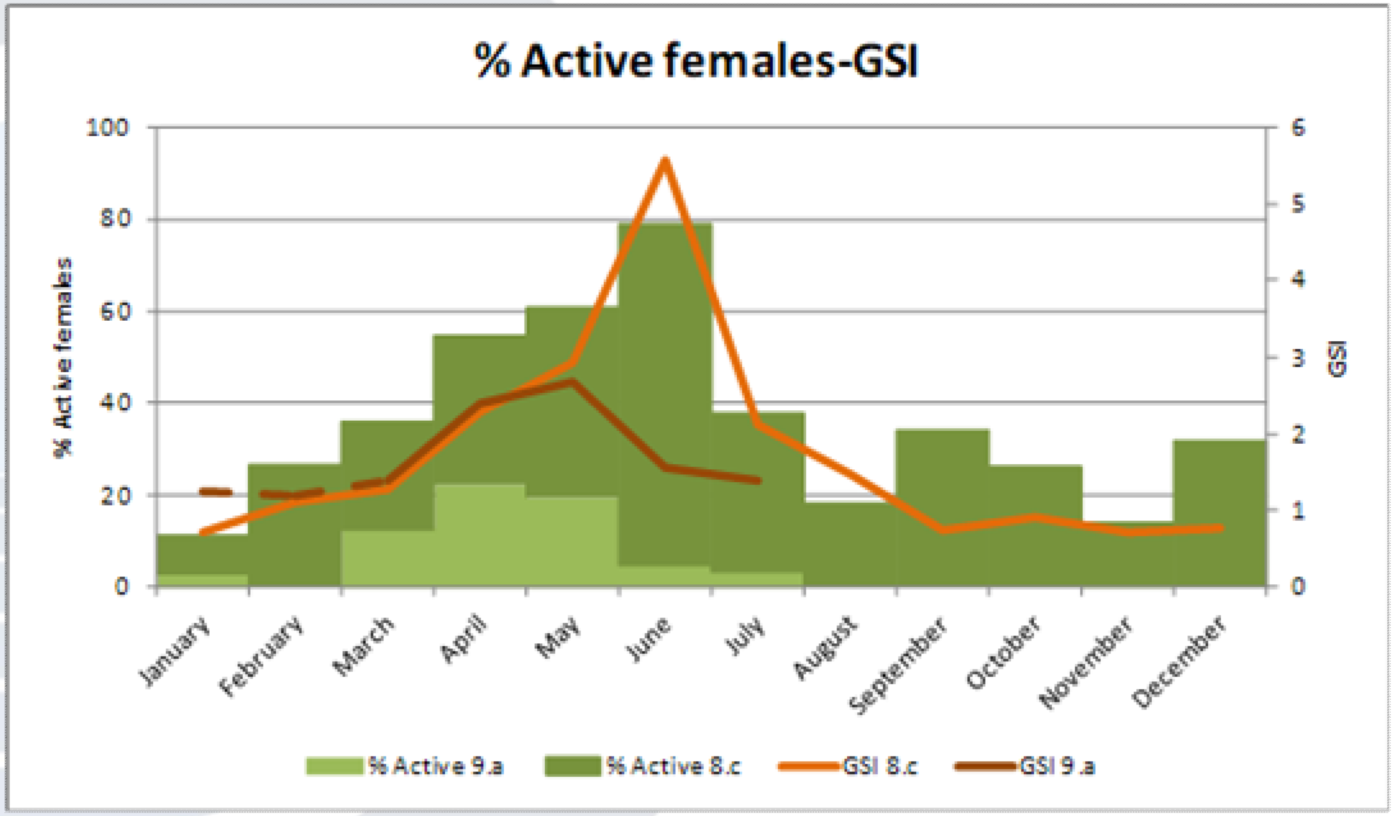



# RESULTS: Reproduction

## Spawning period (2011-2016): % Active females-GSI

✓ In the studied area, it seems that **Division 8.c is the main spawning area**, with a larger number of the spawners and older, and also with a more extensive spawning season than in 9.a North.

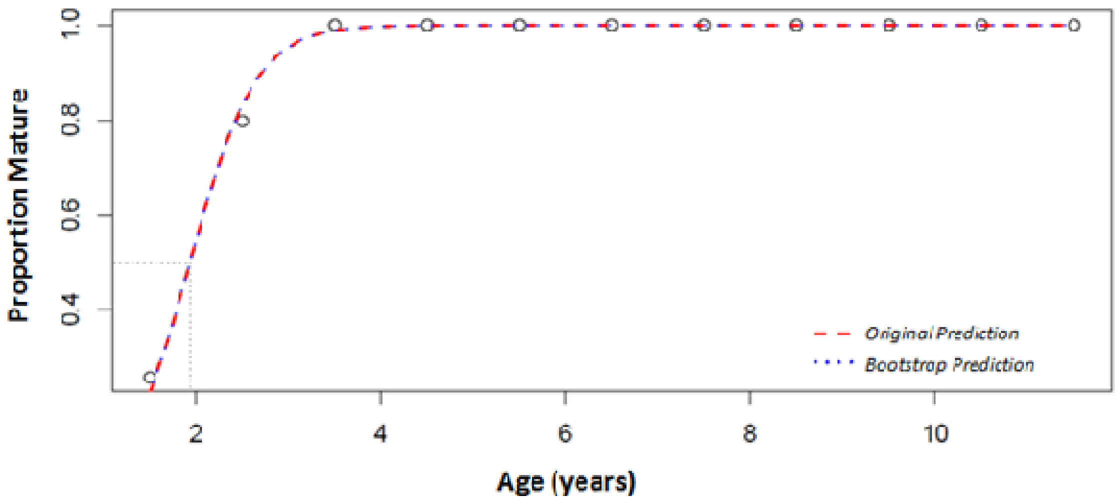


sampled.

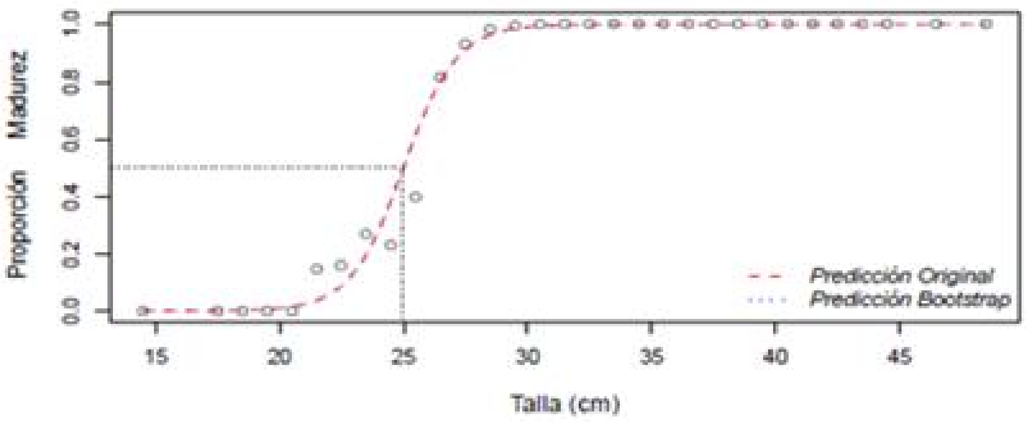
# RESULTS: Reproduction

## Maturity ogives(2011-2016)

✓The logistic model fits to the maturity data.




| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 | Age 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Original Data** | 0.258 | 0.797 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| **GLM model** | 0.064 | 0.546 | 0.955 | 0.997 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |



sampled.

# RESULTS: Reproduction

## Maturity ogives(2011-2016)

✓The estimation of mean age at first maturity was 1.9 years old and 24.9 cm of size:

| | B0 | CV | B1 | CV | A50 | CV | n |
|---|---|---|---|---|---|---|---|
| **Females** | -5.534 | 0.061 | 2.8592 | 0.048 | 1.9335 | 0.02 | 1783 |

| | B0 | CV | B1 | CV | L50 | CV | n |
|---|---|---|---|---|---|---|---|
| **Females** | -23.5174 | 0.063 | 0.9407 | 0.059 | 24.9939 | 0.006 | 2468 |

# Reproduction Conclusions

✓ In the **Division 8.c and 9.a North**, the **reproductive season** of chub mackerel extends between **February and July with a peak in June**, although there are actively spawning individuals throughout the year.

✓**Most of individuals from the 8.c area observed during autumn and winter correspond to a post-spawning maturity stage.** It is possible they actually correspond to a resting maturity stage that has been misidentified, which would require histological studies.

✓ A **gradient of spawning periods is observed along east Atlantic waters when considering previous studies** (Navarro et al, 2014), being from November to February in lower latitudes (Canary Islands) and from March to July in northern Iberian waters. Could there be reproductive migration like mackerel?

✓ The **L50 values of around 25 cm** (and A50= 1.9 years) obtained in 8.c and 9.a North are in the range of those estimated in previous studies in Atlantic (L50=20-30 cm). This L50 value is smaller than the L50 of other studies from Iberian waters from the 90's (Martins, 1996; Lucio, 1997, L50=27-30) but similar to most recent works (Navarro et al., 2014; Canseco, 2016, L50=25.54-22). This may be due to differences in environmental conditions among the areas and the different period when each study took place. It may also be because maturation varies temporarily and is also strongly influenced by the effect of strong cohorts or by changes in growth

✓In general, **higher L50 values are obtained in Iberian waters** (Martins, 1996; Lucio, 1997; Canseco, 2016) than in Atlantic Islands (L50=20-22cm) (Nespereira, 1993; Vasconcelos, 2006; Vasconcelos et al., 2011). Spawning onset in the Bay of Biscay takes place later than in southern areas, likely due to this area is the northern boundary of this species distribution and has colder waters.

# Remarks and further works

✓**Histological studies to validate macroscopic maturity staging are required**.

✓**Study of the reproductive maturity and cycle** (data from **2011-2019**, commercial catches and surveys, ICES Div. 8c and 9aN): **Results by 2020**.

✓**Study of the reproductive strategy and potential of chub mackerel** of the N and NW Iberian Peninsula (determination of fecundity type, oocyte development dynamics, energetic strategy, estimation of egg production and analysis of temporal variability of reproductive potential). **Data from 2020: Results by 2021**

**Other biological studies**:

**Study of trophic ecology**: analysis of **stomach contents and isotopic signature**. Data from 2018-2019, commercial catches and surveys, ICES Div. 8c and 9a North: **Results by 2021**

***Thank you !***