SECOND WORKSHOP ON ATLANTIC CHUB MACKEREL (*SCOMBER COLIAS*) (WKCOLIAS2)

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i Executive summary

The Atlantic chub mackerel *Scomber colias* has become an increasingly important commercial species in the European Atlantic waters in the last 10–15 years, probably through an expansion process from NW African waters and due to market needs. However, at present there are no assessment or advice requirements. In the WK framework, available information of the species in the West Atlantic waters has been compiled in order to evaluate possible geographical differences and trends, and the feasibility to describe its population structure. Though the Atlantic chub mackerel is not routinely included among the target species in the acoustic surveys performed in the Atlantic Iberian waters and the Mediterranean Sea, a synoptic overview of the species is possible over all its West Atlantic distribution. Moreover, the data available have indicated latitudinal trends, mainly in the landings' length composition, L50 and the spawning periods. Nevertheless, even if some degree of connectivity likely exists and migrations are occurring between adjacent areas, some subunits could be considered for management purposes. From the assessment models' trials carried out, the results or reference points obtained for the European fisheries cannot be retained at present. Therefore, continuing collating information from fisheries and biological sampling of the species, obtaining reliable biomass estimations from scientific surveys and identifying management units seem the main priorities to address in future research work and in case of assessment requirements.

ii Expert group information

Expert group name	**Second Workshop on Atlantic chub mackerel (*Scomber colias*) (WKCOLIAS2)**
Expert group cycle	Annual
Year cycle started	2021
Reporting year in cycle	1/1
Chairs	Cristina Nunes, Portugal
	Alba Jurado-Ruzafa, Spain
Meeting venue and dates	25–29 January 2021, Online meeting, 28 participants

1 Introduction

1.1 Background

The Atlantic chub mackerel (*Scomber colias* Gmelin, 1978) is a middle-sized pelagic fish distributed in warm and temperate Atlantic waters (eastern and western coasts), and eastwards to the Mediterranean and southern Black Sea (Froese and Pauly, 2019; Figure 1.1). As other species, the Atlantic chub mackerel is currently reaching latitudes where it was absent or very occasional, probably due to the global warming. This expansion is reflected in its increase in catches of fisheries targeting small pelagic species in areas where it was considered as by-catch few years ago.

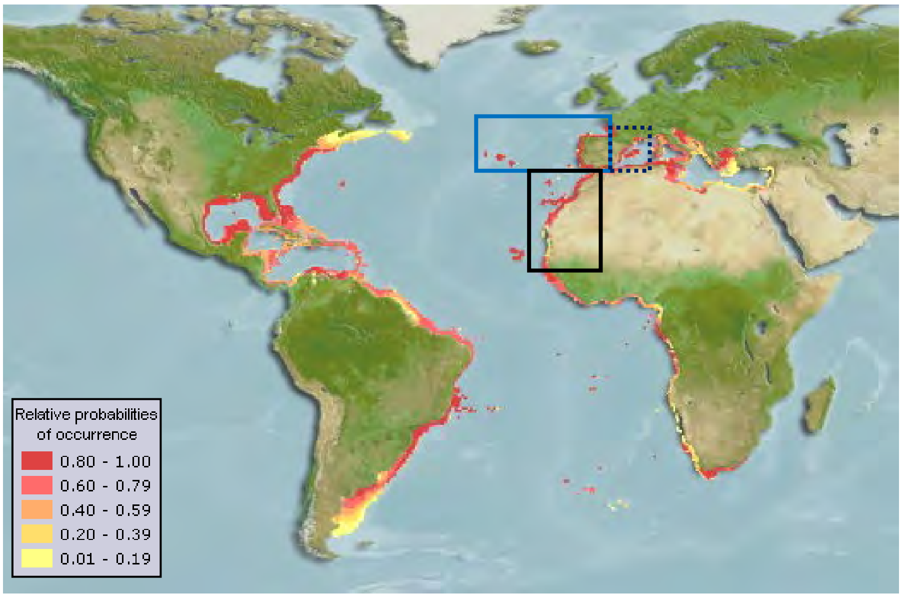


Figure 1.1. Geographical distribution of the Atlantic chub mackerel. (Source: Reviewed distribution maps for *S. colias*, with modelled year 2100 native range map based on IPCC A2 emissions scenario. www.aquamaps.org, version 10/2019). Squares indicate approximately the regions considered in the WK and the previous data call; in blue: ICES; in black: CECAF north; in dashed black: western Mediterranean Sea.

In the eastern Atlantic, the bulk of the catches take place in the northwestern waters of Africa (CECAF area of competence), surpassing 380 000 tons in the north CECAF subregion in 2017 (FAO, 2019). In Atlantic European waters, landings mainly come from the Spanish and Portuguese purse seiner fisheries (from Bay of Biscay to Gulf of Cadiz), this fleet representing in recent years ~75% and up to 98% of the catches, in Portugal and Spain, respectively. In the past, *S. colias* used to be a bycatch species with a low market price in these waters. However, during the last 15 years, the Atlantic chub mackerel landings from Atlanto-Iberian waters (i.e. ICES divisions 9a and 8c) have increased exponentially, reaching around 80 000 t per year, resulting in a new target species, partly compensating the decrease of fishing opportunities for European sardine, the traditional targeted species of the fishery in these waters (Villamor *et al.*, 2020).

However, the dynamics, stock identity and stock status of Atlantic chub mackerel in Atlantic European waters and also the connectivity with the Atlantic African and the Mediterranean populations remain unknown. Although there are some technical management recommendations for the species, catches are not limited at the national level, and there are concerns about the long-term sustainability of this resource. Atlantic chub mackerel is a key role species of the pelagic ecosystem in Atlantic waters, and an improvement on its biological and ecological knowledge, as well as the interactions with other pelagic fish species (e.g. Atlantic mackerel, sardine, anchovy or horse mackerel) is crucial in order to achieve reliable status assessment of its populations and management at the multispecies/ecosystem level.

To the WK's knowledge, advice on fishing opportunities has not been requested for chub mackerel in the ICES region, and the status of its exploited populations is unknown.

1.2 WKCOLIAS2 resolution

The **Second Workshop on Atlantic chub mackerel (WKCOLIAS2) (2021//),** chaired by Cristina Nunes (Portugal) and Alba Jurado Ruzafa (Spain), was organized by correspondence during 2020 and participants were summoned for an online meeting from 25th to 29th January 2021, to:

a) Analyse chub mackerel abundance, distribution and migrations in the Northeast Atlantic waters of Europe and Northwest Africa;
b) Explore the connectivity between Atlantic chub mackerel in Atlantic and Mediterranean waters ;
c) Analyse the population structure and propose stock units in European Atlantic waters.

Ongoing and future works performed by IPMA (Portugal) and IEO (Spain) were compiled during a previous online meeting held the 28th October 2020, with the participation of IPMA staff (Cristina Nunes (co/chair), Andreia Silva, Corina Chaves, Diana Feijó, Ana Cláudia Fernandes, João Neves and Pedro Amorim) and IEO staff (Alba Jurado Ruzafa (co-chair), Mª Rosario Navarro, Fernando Ramos, Francisco Velasco and Pablo Carrera), with the assistance of ICES staff (Ruth Fernandez and Helle Gjeding Jørgensen). The main purpose was to organize the intersession work between the participants belonging to these institutions in order to progress on the coordination of the studies/monitoring carried out on the Atlantic chub mackerel in European waters and to prepare the workshop (Annex 3: WebEx minutes).

However, it is widely known that the pandemic situation, which started after the previous workshop, has caused a great delay, if not even the cancellation, of much of the work progress in all the laboratories during almost all the intersession period.

1.3 WKCOLIAS2 data call

An official data call to obtain the available data for the Atlantic chub mackerel considered useful to address the ToRs was launched in November 2020:

https://www.ices.dk/sites/pub/Publication%20Reports/Forms/DispForm.aspx?ID=37143.

Data requested included:

- Fishery data (landings, fishing effort and discards).
- Frequencies distributions by length or age in landings and surveys.
- Maturity ogives.
- Surveys data.
- Life-history parameters available from literature.

All this information was requested to countries included in the main range distribution of the *S. colias* in the eastern Atlantic waters: ICES (France, Spain and Portugal, including Azores), CECAF (Morocco, Mauritania, Senegal and Gambia, including Madeira and the Canary Islands). A request was also sent to the GFCM to address the ToR b, by compiling information from the western Mediterranean Sea (Spain, France and Morocco). Data submitted are summarized in each section.

1.4 WKCOLIAS2 meeting

The workshop was attended by scientists from Portugal, Spain and Northwest Africa (Annex 1: List of Participants).

Several oral contributions from each considered area were presented during the first sessions (Agenda in Annex 2, and Abstracts for the presentations in Annex 4). In addition, some contributions as working documents are included in Annex 5.

Once the presentations finished, work was organized in subgroups based on the data submitted to the data call, and in order to address the ToRs, as follows:

Subgroup 1. Fishery data: To describe the fishing activity (type of fleets; catches, effort and discards) in Portugal (Iberian, Azores and Madeira), Spain (Iberian and The Canary Islands) and Northwest Africa waters. Fishing indicators were obtained to explore temporal evolution and to make them comparable in order to explore possible geographical trends.

Subgroup 2. Length frequencies in landings: To analyse possible trends in the length frequencies found in commercial landings of *S. colias* including data from Portugal (Iberian and Madeira), Spain (Iberian, The Canary Islands and Mediterranean) and Northwest Africa. Length-based indicators were also obtained and analysed.

Subgroup 3. Surveys: To compile the submitted data and analyse them in order to detect if geographical-related trends can be observed in terms of abundance, distribution and length composition, and latitudinal limits

Subgroup 4. Biology: To analyse the submitted maturity ogives, to evaluate their reliability and to obtain L50 estimates in order to explore trends related to geographical-related variations.

Subgroup 5. Life-history parameters: To compile all the available information for the species over all its distribution range.

Subgroup 6. Assessment: To assess the data quality/availability by fishing ground/geographical area, to propose ICES stock-categorization, and to identify and assay stock status assessment models suitable for the European units considered.

Most of the subgroups work was performed offline, after the closure of the meeting, independently. The contributions are included in the present report as self-concluding chapters.

2 Fishing data

2.1 Fisheries characteristics

The information on the fisheries targeting small pelagic species (including chub mackerel) in 2019 was compiled and summarized (Table 2.1). The information compiled includes fleets, the fishing gears used, number of vessels, mean values of vessel size, storage capacity and power, the fishing area, target and bycatch species, and the fishing season.

Table 2.1 indicates that the small pelagic species are mainly fished by purse-seiners in the northern areas (Portugal, Cantabrian-Northwestern, Gulf of Cadiz, Canary Islands) and both by purse-seiners and by industrial trawlers in the southern areas (Morocco, Mauritania). In addition, the number of vessels and technical characteristics of the fleet show an increase trend from the north to the south. The purse-seine fleet from all regions (with exception of the Azores and Madeira) and the trawl fleets from the southern regions (Morocco, Mauritania and Senegal) mainly target sardine, with seasonal fishing strategies targeting other small pelagic species.

Table 2.1. Summary of the fisheries targeting small pelagic species (including chub mackerel) in the East Atlantic Ocean. Updated from WKCOLIAS (2020), including 2019. Q: quarter; * number of vessels which landed chub mackerel, considering the total of the fleet in brackets; ** not updated.

Country/Region	Fleet/métier	Gears	Number of vessels	Mean vessel length (m)	Mean storage capacity	Mean power (kw)	Fishing Area	Target species	Bycatch species	Fishing Season
Portugal (Mainland)	Purse-seiners	Seine	130 (in 141)*	18.14	42.94 GT	221.5	ICES 27.9.a	Sardine, Anchovy, Chub Mackerel, Horse Mackerel	Some semi-pelagic and demersal species	All year, except sardine closure period
Portugal (Azores)	Purse-seiners	Seine	2 (in 2)*	10.95	9.26 GT	71.97	ICES 27.10.a	Blue Jack Mackerel, Chub Mackerel	Some semi-pelagic and demersal species	All year. They use at the same time longlines to fish demersal species.
Portugal (Madeira)	Purse-seiners	Seine	3 (in 3)*	19.6	245.03 GT	258.68	FAO 34.1.2	Chub Mackerel, Blue Jack Mackerel, Frigate tuna	Some semi-pelagic and demersal species	All year
Portugal (Mainland)	Polyvalent	All gears except Seine and Otter Bottom Trawl (OTB)	2160 (in 2777)*	7.91	6.20 GT	48.5	ICES 27.9.a	Chub Mackerel, Octopus, Blackbelly rosefish, Horse Mackerel, Hake	All species	All year
Canary Islands	Artisanal purse-seiners	Seine	30	11	10 GT	58.9	FAO 34.1.2	Chub mackerel, Sardine, Sardinellas		All year
Cantabrian-Northwestern	Purse-seiners	Seine	266	20.7	70.9 GT	208.7	ICES: 27.8.a, 27.8.b, 27.8.c, 27.9.a	Sardine (all year), Anchovy (2nd Q), Mackerel (1st Q), Horse Mackerel (all year), Chub Mackerel (target species in recent years)	*Scomber colias* Some semi-pelagic and demersal species	All year, mainly in the 3rd Q
Gulf of Cadiz	Purse-seiners	Seine	90	17.3	30 GT	140.3	ICES 27.9.a.s.c	Anchovy, Sardine, Chub Mackerel	Some semi-pelagic and demersal species	All year

Table 2.1. (Cont.) Summary of the fisheries targeting small pelagic species (including chub mackerel), in the East Atlantic Ocean. Updated from WKCOLIAS (2020), including 2019. Q: quarter; * number of vessels which landed chub mackerel, considering the total of the fleet in brackets; ** not updated.

Country/Region	Fleet/métier	Gears	Number of vessels	Mean vessel length (m)	Mean storage capacity (GT)	Mean power (kw)	Fishing Area	Target species	Bycatch species	Fishing Season
Morocco North	Purse-seiners	Seine	124	23	83t	350.5	FAO 34.1.11	Sardine (1st), Anchovy (2nd Q), Chub Mackerel (3rd Q), *Trachurus* spp (4th Q)	Some semi-pelagic and demersal species	All year
Morocco Central	Purse-seiners	Seine	394	23	83t	350.5	FAO 34.1.12 and 34.1.13	Sardine (1st Q), Anchovy (2nd Q), Chub mackerel (3rd Q), *Trachurus* spp (4th Q)	Some semi-pelagic and demersal species	All year
Morocco South	Purse-seiners	Seine	89	23	83t	350.5	FAO 34.1.31	Sardine (1st Q), Chub mackerel (2nd Q), Sardinellas (3th Q)	Some semi-pelagic and demersal species	All year
	Moroccan Pelagic Trawlers	Otter Pelagic Trawl (OTM)	24	55	800 t	2327.6		Sardine (1st Q), Chub mackerel (2nd Q), *Trachurus* spp (3rd Q), Sardinellas (4th Q)	Some semi-pelagic and demersal species	All year
	Russian Pelagic Trawlers	Otter Pelagic Trawl (OTM)	10		6334 t	4474.2		Sardine (2nd Q), Chub mackerel (1st Q), *Trachurus* spp (3rd Q), Sardinellas (4th Q)	Some semi-pelagic and demersal species	Mainly July to March
	European Union Pelagic Trawlers	Otter Pelagic Trawl (OTM)	6		6560 GT	5220		Sardine (1st Q), Chub ackerel (2nd Q), *Trachurus* spp (3rd Q), Sardinellas (4th Q)	Some semi-pelagic and demersal species	

Table 2.1. (Cont.) Summary of the fisheries targeting small pelagic species (including chub mackerel), in the East Atlantic Ocean. Updated including 2019. Q: quarter; * number of vessels which landed chub mackerel, considering the total of the fleet in brackets; ** not updated.

Country/Region	Fleet/métier	Gears	Number of vessels	Mean vessel length (m)	Mean storage capacity (GT)	Mean power (kw)	Fishing Area	Target species	By-catch species	Fishing Season
Mauritania**	Purse-seiners	Seine	91	36			FAO 34-1-32 and 34-3.11	Sardine, Sardinellas	Chub Mackerel	January–May: Sardine; June–October: Sardinella
	Trawlers	Trawl strategy targeted to Clupeidae	78	98	4791 GT	3586		Sardine, Sardinellas, Horse mackerel	Chub Mackerel, Anchovy,	January–May: Sardine June–October: Sardinella and Horse Mackerel
Senegal**	Small Purse-seiners	Seine		22		29.4	FAO 34-3.11 and 34-3.12	Sardinella	Sardine, Horse Mackerel, Chub Mackerel	June–October

2.2 Landings

For the analyses of the landings, all the information submitted to the WK by country/region was compiled into a single dataset. Table 2.2 comprises, for each combination of area and gear, the total landings of chub mackerel for the number of years reported, and the countries involved. The general term ‘Gear’ is used and 3 different groups of gears were defined: ‘TRAWL’ – all métiers with trawl (e.g. OTB, OTM, PTB); ‘PS’ – purse-seiners and; ‘MIS’ – all the other métiers (e.g. nets, longlines, dredges).

Table 2.2. Summary of the reported chub mackerel’s total landings – total values for each of the time-series duration. Country/Region: SP– Spain, FR– France, PT- Mainland Portugal, AZ – Azores Islands, MED – Mediterranean (Spain), MOR – Morocco, MAD – Madeira Islands, CAN – Canary Islands, SEN - Senegal. Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

Area		Fishing gear	Landings (ton)	Number of years comprised in the time-series	Countries/Regions
ICES	27.7	TRAWL	11.4	1	SP
	27.8	MIS	31596.9	12	FR, SP
	27.8	PS	216244.6	12	FR, SP
	27.8	TRAWL	17561.2	12	FR, SP, PT
	27.9	MIS	73247.1	20	SP, PT
	27.9	PS	507223	20	SP, PT
	27.9	TRAWL	26164.6	20	SP, PT
	27.10	MIS	213646.7	20	AZ
	27.10	PS	747.7	6	AZ
	27.10	TRAWL	2.9	5	AZ
GFCM	GSA 1	PS	21848.1	8	MED
	GSA 1	TRAWL	71.1	3	MED
	GSA 6	PS	5326.4	8	MED
	GSA 6	TRAWL	379.3	8	MED
FAO	34.1.11	PS	88189	5	MOR
	34.1.12	PS	75247	5	MOR
	34.1.13	PS	238289	5	MOR
	34.1.2	PS	8930.9	12	MAD, CAN
	34.1.31	PS	5002.1	1	MOR
	34.1.31	TRAWL	825675	5	MOR
	34.3	PS	242149	29	SEN

Analysis of the annual variation of chub mackerel landings was performed by fishing area (Figures 2.2.1, 2.2.2, 2.2.3 and 2.2.4). Annual total values of the chub mackerel landings submitted to the WK were used in the analysis, as well as the Mauritanian and Senegalese landings data provided during the WK.

The total landings generally show interannual fluctuations that may be linked to the natural behaviour of the species (migration processes through the geographical distribution, among fishing grounds) and the fishing strategy depending on the fish availability or the market demands. This pattern is a common trait to all areas.

In the Iberian waters (both Atlantic and Mediterranean), besides the different annual landing variations observed among areas (Figure 2.2.1), the total landings indicate an increasing trend until 2017–2019, with a noticeable decrease during the last years.

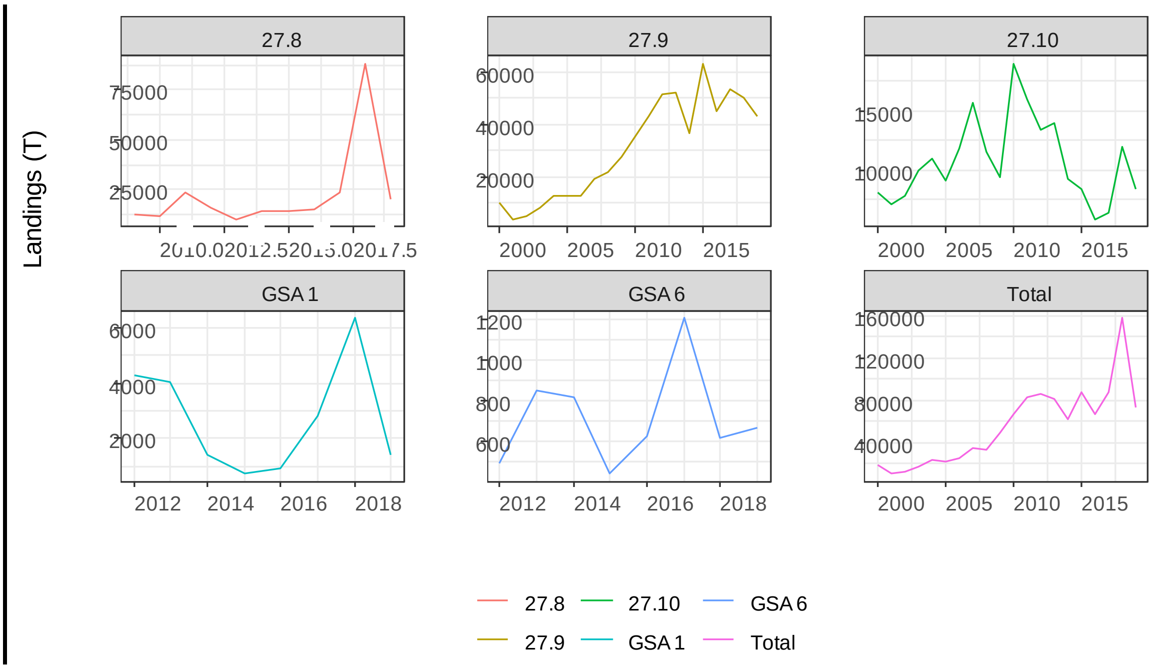


Figure 2.2.1. Annual evolution of chub mackerel landings (in tons) in ICES and GFCM areas.

In the southern areas (CECAF waters, including Canary Islands and NW African countries), there is an overall increasing trend of the chub mackerel landings since the beginning of the time-series (Figure 2.2.2), although differences in the annual evolution can also be observed among countries. This general increasing trend observed during the last years needs to be more explored. One important factor that could be contributing to this situation may be related to environmental effects.

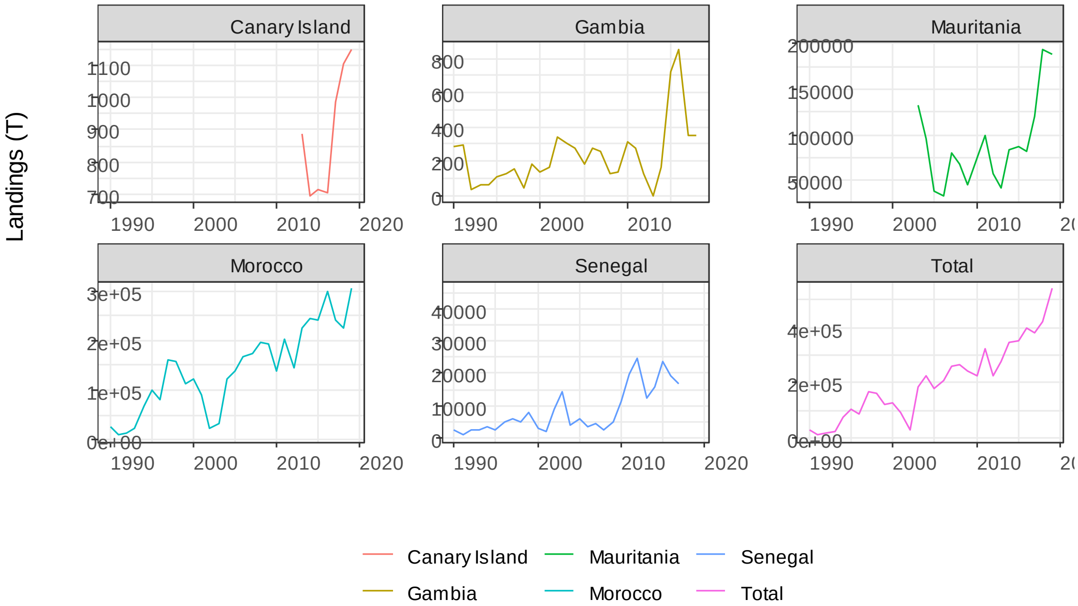


Figure 2.2.2. Annual evolution of chub mackerel landings (tons) in the NW African waters (time period: 1990–2019).

The landings reported by gear-group and countries/regions, and then considering the area, are presented in Figures 2.2.3 and 2.2.4. The heterogeneity observed in the landing values (different ranges in the y-labels of the figure) both by gear and by country/regions and area are mainly related to the species spatial distribution, possibly to the local commercial interest of the species, and other reasons which should be explored. This can also give some indications on the importance of this species by country/region and can be supported by what we have seen in Table 2.1, where, depending on the country/region, the chub mackerel can be targeted in only a part of the year, or caught and landed as a bycatch species.

The analysis of the time-series availability from the different countries/regions corroborate the findings above, the values of annual landings presented in the Figure 2.2.4 indicate that most countries/regions with longer series of data present some variability both among years and gears-group.

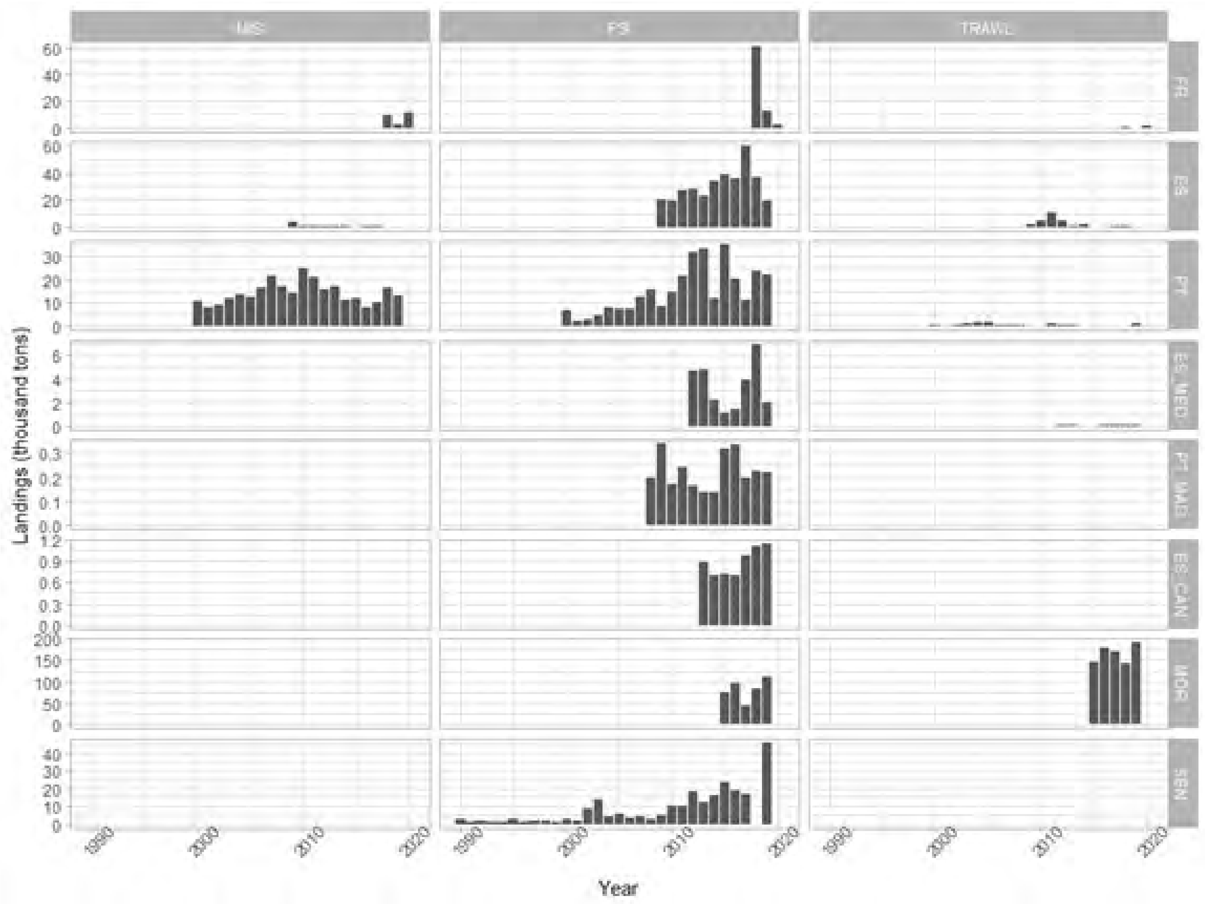


Figure 2.2.3. Chub mackerel landings (thousand tons) by Country/Region for the grouped gears MIS, PS and TRAWL (time period: 1990–2020). Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

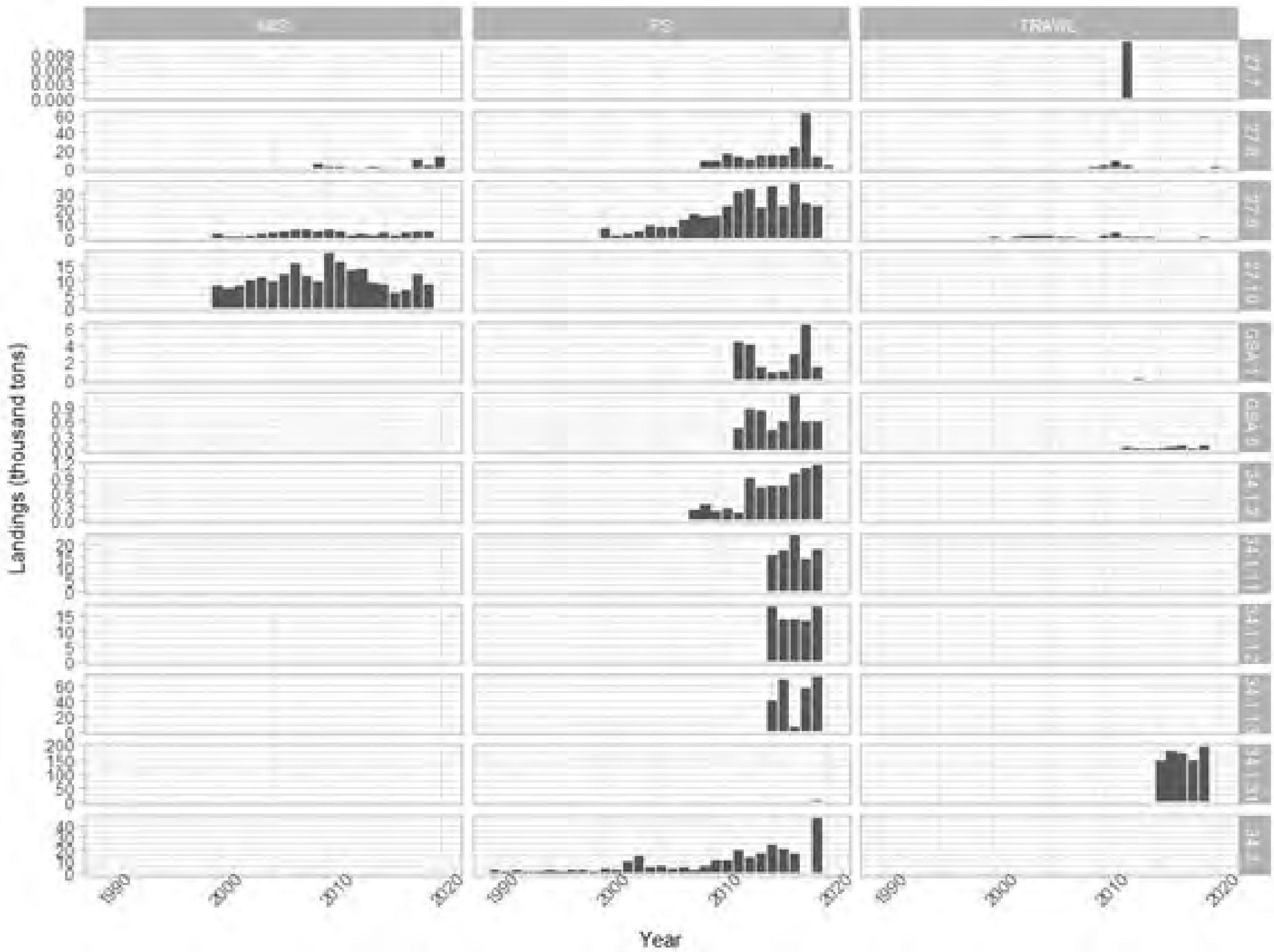


Figure 2.2.4. Chub mackerel landings (thousand tons) by FAO/ICES areas for the grouped gears MIS, PS and TRAWL (time period: 1990–2020). Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

Figure 2.2.5 also shows that higher mean annual values of landings occur in the southern areas of the chub mackerel distribution (e.g. 34.1.13 and 34.1.31), followed by the Atlantic Iberian waters (27.8 and 27.9), being 'TRAWL' the gear with the higher values (in Subarea 34.1.31). Landings in the more central European waters (27.7) and in the western Mediterranean Sea (GSA1 and 6) are comparatively low, having not been possible during the WK to obtain information characterizing the fishing activity in these areas. These results may be related to the annual variations on the fish availability (i.e. spatial distribution, recruitment, etc.), the commercial interest of the species in some countries/regions and the capacity of the fisherman to harvest the fish with largest sizes.

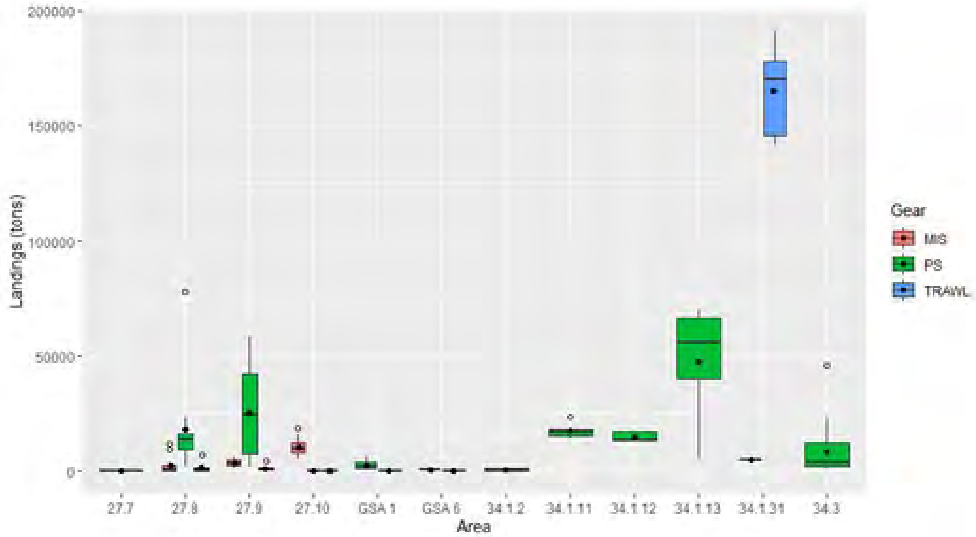


Figure 2.2.5. Boxplots representing the annual chub mackerel landings by gear and area, based on the submitted data. Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

The contribution to the chub mackerels' landings by each gear group and area is presented in Figure 2.2.6. Mean annual values of the landings gear group were used to estimate the contributing percentages of the gear by area. Likewise, the annual landings evolution by area and gear-group is presented in Figure 2.2.7. It seems clear that the purse-seine fishery (PS) strategy produces the main contribution for the chub mackerel total landings in almost all the areas considered, with the exceptions of areas ICES 27.7 and FAO 34.1.31, presenting higher percentage produced by 'TRAWL', and ICES 27.10 by 'MIS'.

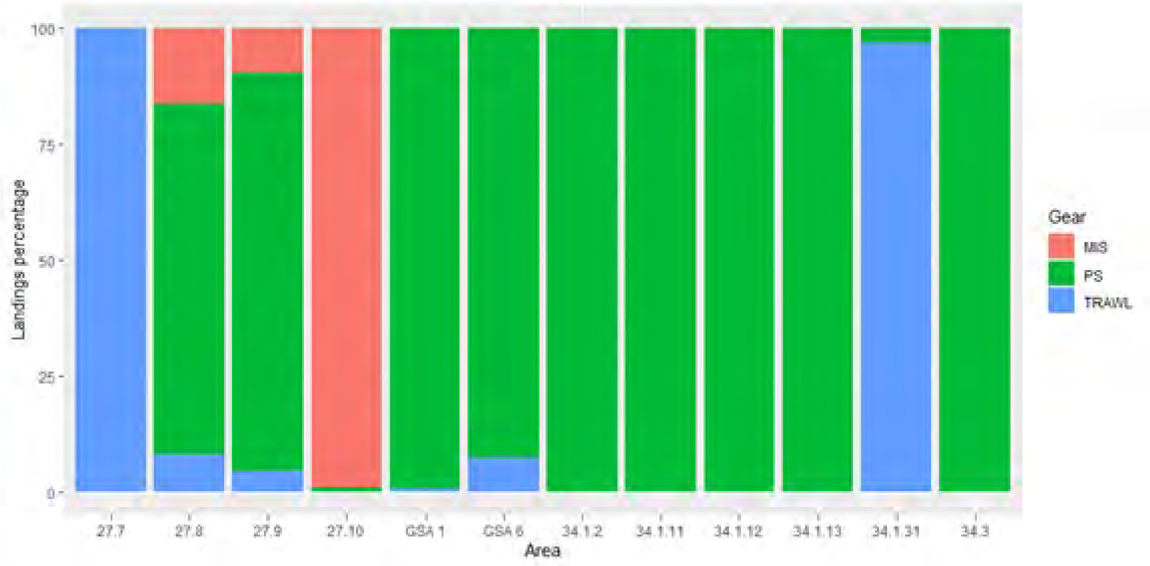


Figure 2.2.6. Landings per gear in each area, using the annual weighted mean values. Fishing gears: MIS- Other fleets, PS-Purse-seiners, TRAWL- Trawlers.

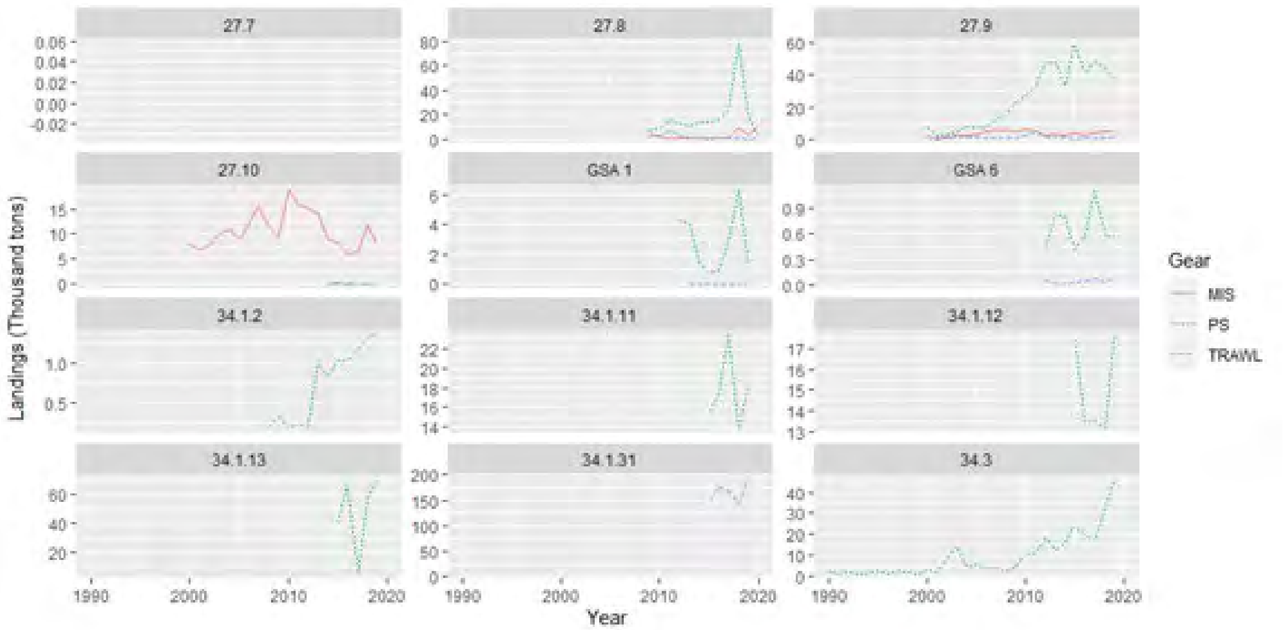


Figure 2.2.7. Interannual variation of landings by gear and by area. Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

The quarter variability of the reported landings was analysed accounting for the time-series of the data provided to the workshop (Figure 2.2.8). A mean value of the annual landings by quarter is used for the analysis and the results also present high variability of the landings by quarters between years, for the areas where the reported dataseries is longer (27.8, 27.9, 27.10 and 34.1.31).

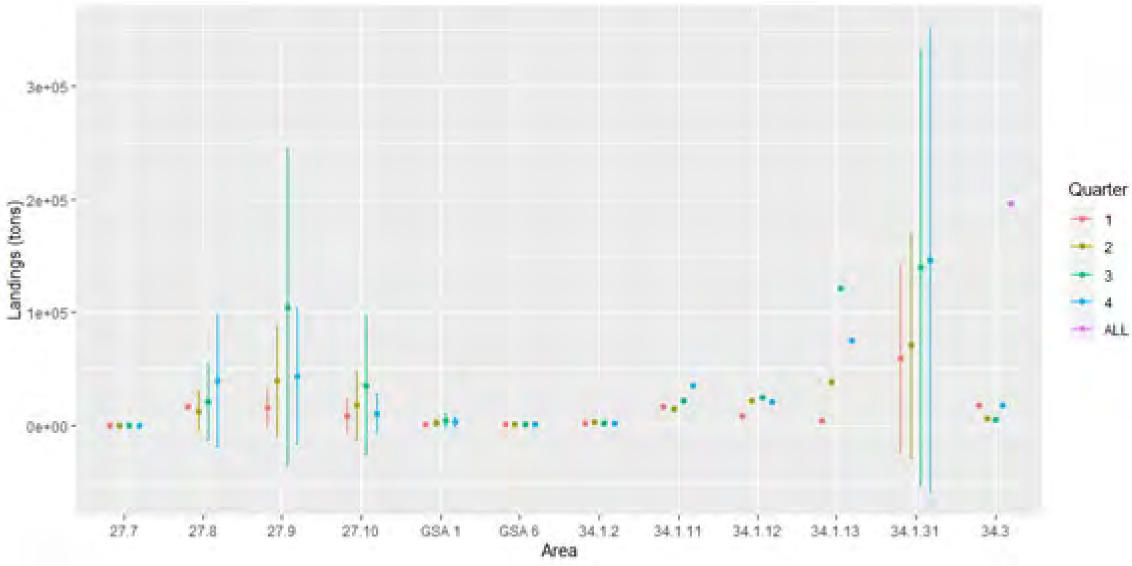


Figure 2.2.8. Quarter variability of the chub mackerel landings within area (point – mean value; vertical lines – mean ± sd).

The seasonal analysis of the chub mackerel landings was performed by area (Figure 2.2.9). The annual weighted mean values of the landings by quarter were used to estimate the landing proportions of the quarters by area. Most of the chub mackerel landings occur during the 3rd and 4th quarters in almost all the areas. The exceptions are the area 34.1.2 where quarter proportions seem evenly distributed and the area 34.3 where main landings occur in quarter 1 and 4. Conversely, in the NW African coast, *S. colias* seems to be more available in the south during the 1st quarter and in the north, in the 3rd and 4th quarters. These patterns may be related to seasonal migrations of the species along this coast (Garcia, 1982).

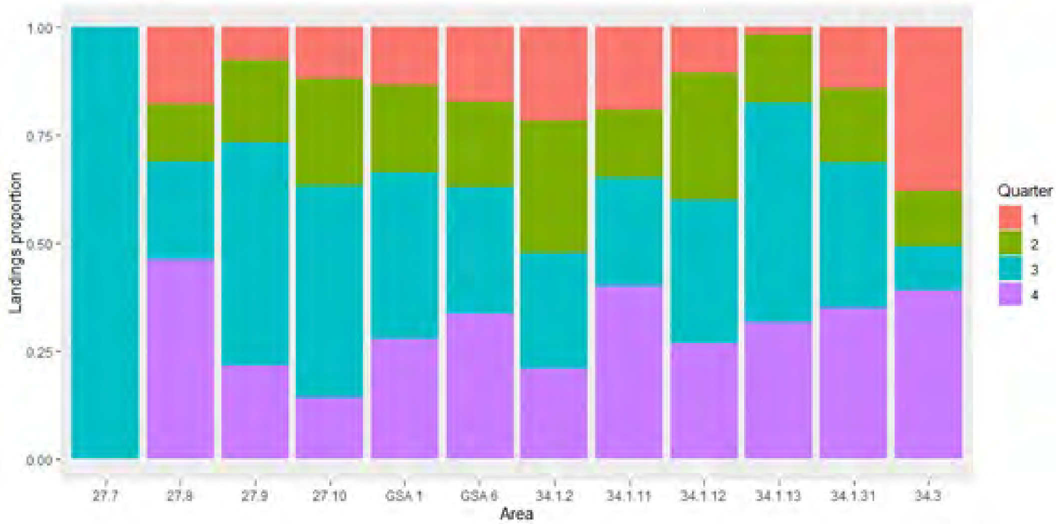


Figure 2.2.9. Proportion of chub mackerel landings, by quarter and area.

2.3 Discards

The discard data provided to the WK are summarized in Table 2.3 and comprise, for each combination of area and gear, the total discards of chub mackerel for the number of years reported, and the countries involved. The information only covers the areas 27.8 and 27.9 and few countries contributed (France- FR, Spain - SP and Portugal - PT). It is important to refer that PS discard data do not include the 'slipping' fraction of the catches, owing to there is no obligation to record it in logbooks and the information available is only collected during the fishing trips monitored on board by scientific observers. Likewise, France reported zero discards for the year/gear reported (2019 - only 2nd quarter - TRAWL). In Portugal, only discards from 'TRAWL' are estimated and the annual estimates are obtained just for years with frequencies of occurrence of chub mackerel in the sampled hauls above 30%. In the case of Spanish information, it is not clear why some of the years present no information (zero discards *vs* not estimated). For these reasons, the results presented should be considered as preliminary and interpreted with caution.

Table 2.3. Summary of discards by area and by gear – total values for each of the time-series duration. Country/Region: SP – Spain; FR – France; PT- Mainland Portugal. Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

Area	Gear	Discards (tons)	Number of years comprised in the time-series	Countries/regions
27.8	MIS	10.1	9	SP
	PS	2.8	1	SP
	TRAWL	588.4	11	FR; SP
27.9	MIS	8.7	9	SP
	PS	304.3	3	SP
	TRAWL	27301.8	16	SP; PT

The annual distributions of the reported chub mackerel's discards in the two areas by gear are presented in Figure 2.3.1. As observed in the landings annual evolution, fluctuations among years and within gears also occur when we consider annual discards. Moreover, the discards from 'TRAWL' greatly outnumber the other gears when overlapping years/gears occur (e.g. 2009–2011, 2015 and 2017 MIS and TRAWL from SP). Exceptions can be observed for the Spanish (ES) discards in 2015 and 2017, when PS presented higher values than TRAWL. These same indications come out from the between-area analysis presented in Figures 2.3.2 and 2.3.3, that summarizes the discards percentage of gears within area.

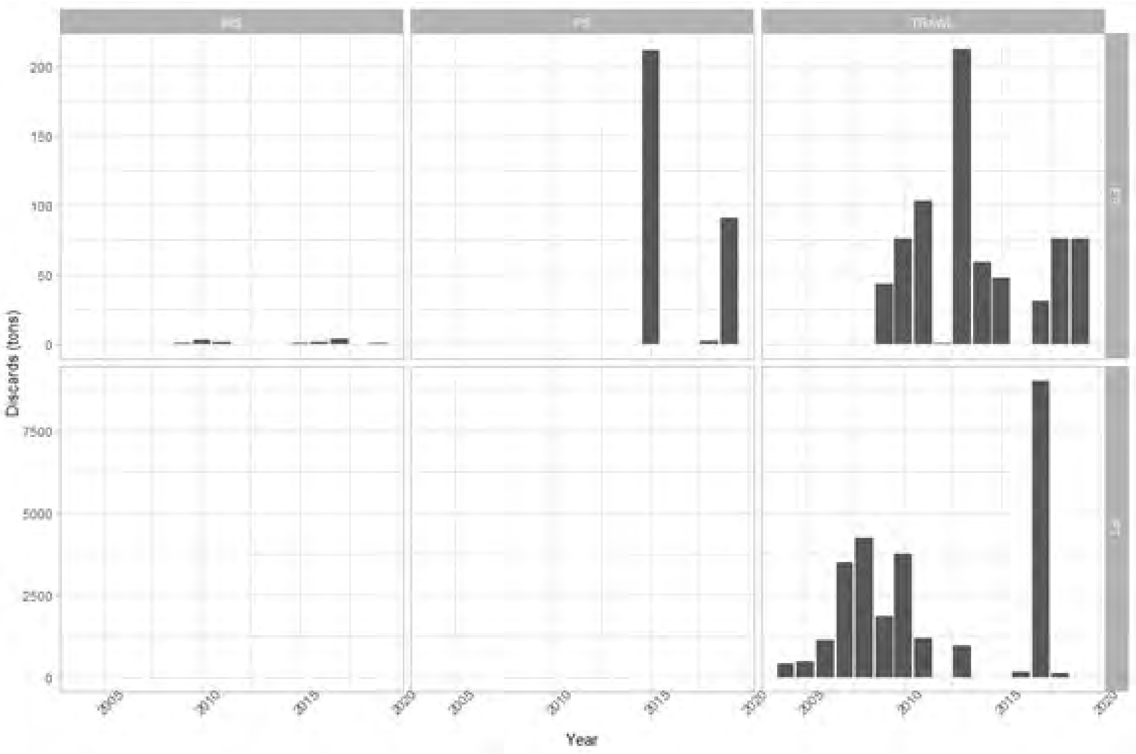


Figure 2.3.1. Chub mackerel discards (tons) by country and gear (time period: 2004–2019). Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

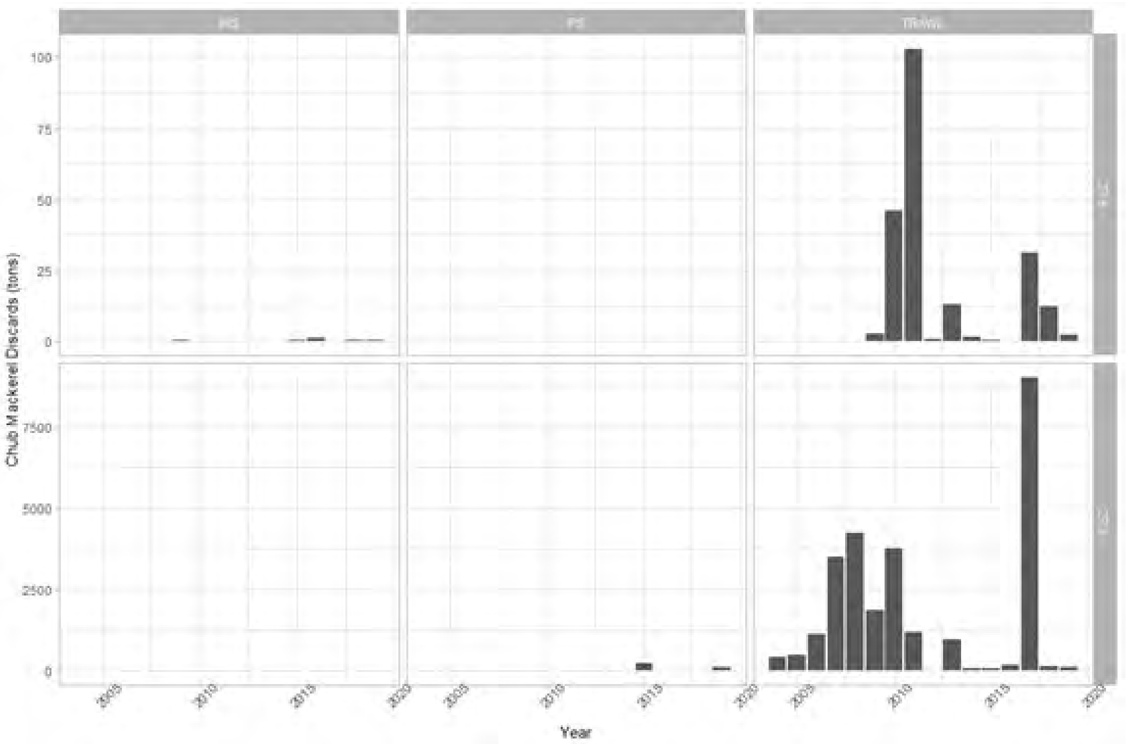


Figure 2.3.2. Chub mackerel discards (tons) in ICES areas 27.8 and 27.9 by gear (time period: 2004–2019). Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

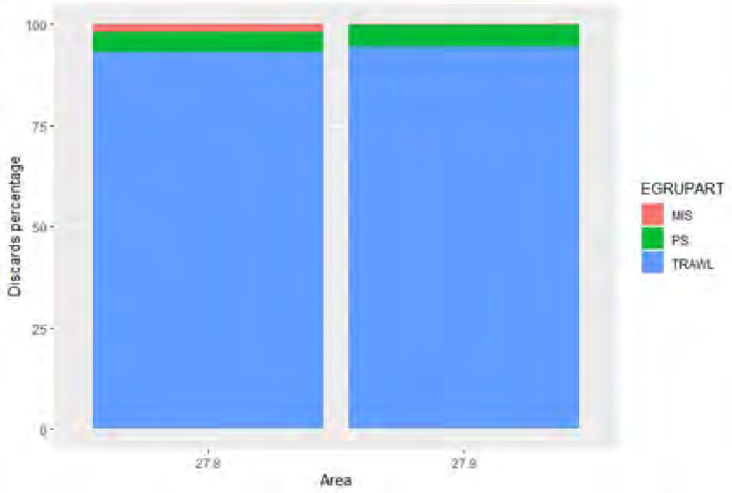


Figure 2.3.3. Discarded weight per gear in each area, using the annual weighted mean values in ICES areas 27.8 and 27.9. Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

The seasonal analysis of chub mackerel total discards was performed by estimating annual weighted values per quarter only for the Spanish data. In the case of Portugal (area 27.9), the discard raising procedure is performed on an annual basis; however, for this workshop (quarterly basis request), the annual discard estimates were quarterly distributed according to the landing weight by quarter. For this reason, the discards distribution between quarters will be the same as for the landings and no conclusions can be derived. Then, only the Spanish results are presented in Figure 2.3.4 showing the seasonal pattern for the areas 27.8 and 27.9. The figure indicates different discards percentage distribution between areas. In Cantabrian waters, more discards seem to occur during the quarters 1 and 4, while the highest values of discards in the W and SW Atlantic Iberian waters happen in the 1st and 3rd quarters.

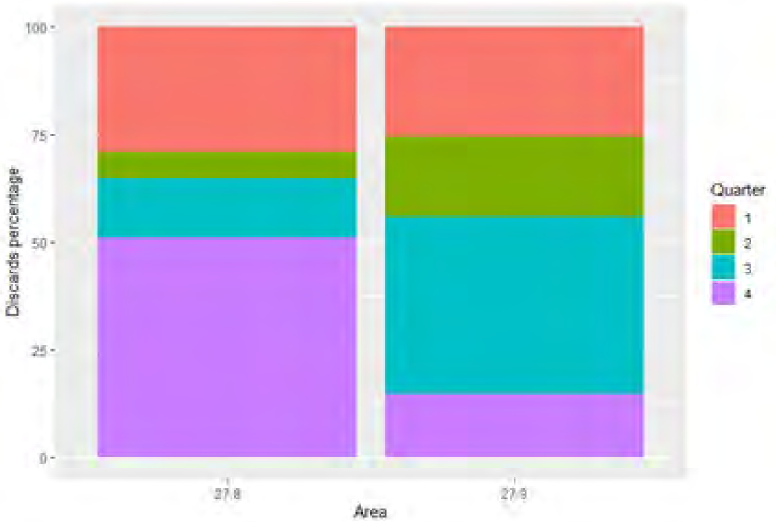


Figure 2.3.4. Discards by quarters in ICES areas 27.8 and 27.9.

2.4 Fishing effort

As in many fisheries, the fishing effort is still a difficult topic for chub mackerel's related fisheries because, in most of the areas, it is a bycatch species (targeted only during the last years), being the European sardine the main target.

The effort information provided to the workshop by country/region is summarized in Table 2.4. It includes, for each combination of area and gear, the total effort of the fleets with chub mackerel catches (landings and discards) for the reported number of years, the countries reporting in the area and also the type of effort, when known. It should be mentioned that, considering the geographical distribution of Atlantic chub mackerel (*S. colias*), the effort data provided for area 27.1 (Barents Sea) might be an error due to a presumable misclassification between the latter and its closely related species, *S. scombrus* (Atlantic mackerel). A very important note also, is that the table evidences some heterogeneity in the type of effort provided by each country/region. Therefore, analyses presented constitute a preliminary approach, with fishing effort being more a qualitative parameter, complementing the landings data provided. Therefore, although some inferences may be obtained from these preliminary results, they should be considered with precaution.

Table 2.4. Summary table of the data used in the analysis for effort – total values for each of the time-series duration (DAS - days-at-sea; FD – fishing days; PFD – positive fishing days; NT – Number of trips; Country/Region (SP – Spain; FR – France; PT- Mainland Portugal; AZ – Azores Islands; MED – Mediterranean (Spain); MOR – Morocco; MAD – Madeira Islands; CAN – Canary Islands; SEN - Senegal); (-) - no information). Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

Area	Gear group	Effort	Number of years comprised in the time-series	Countries/Regions	Effort type
27.1	MIS	2	1	FR	DAS
27.8	MIS	4716848	21	FR, SP	DAS, (-)
27.8	PS	372671	21	FR, SP	DAS, (-)
27.8	TRAWL	781886	21	FR, SP, PT	DAS, (-), PFD
27.9	MIS	796321	21	FR, SP, PT	DAS, (-), PFD
27.9	PS	343213	21	FR, SP, PT	DAS, (-), PFD
27.9	TRAWL	380690	21	FR, SP, PT	DAS, (-), PFD
27.10	MIS	3501	17	FR, AZ	DAS, PFD
27.10	PS	5050	7	AZ	PFD
27.10	TRAWL	16	5	AZ	PFD
34.1.11	PS	10997	1	MOR	FD
34.1.12	PS	12841	1	MOR	FD
34.1.13	PS	24851	1	MOR	FD
34.1.2	PS	20922	12	CAN, MAD	(-), PFD
34.1.31	PS	8050	1	MOR	FD
34.1.31	TRAWL	4885	1	MOR	NT
34.3	MIS	70692	1	SEN	FD

The mean fishing effort values by year and gear-group were used to estimate the contributing percentages of the gears in each area. The Figure 2.4.1 gives some indications on the predominance of the PS fishing effort for fleets landing chub mackerel in all areas except 27.1 (only MIS was reported), and 27.8 and 27.9 where higher mean effort was applied also in MIS fleets. Comparing the fishing effort by gear distribution with the same analysis for the landings (Figure 2.2.6), it is evident that for the areas where different gears are present (27.8 and 27.9), although the higher values of fishing effort observed are from MIS fleets, the main part of the chub mackerel landings are derived from the PS fleets.

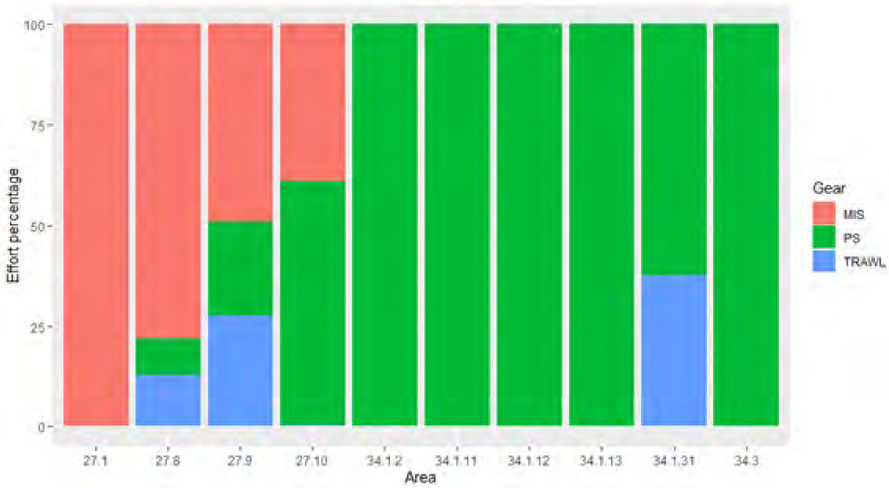


Figure 2.4.1. Fishing effort per gear in each area, using annual weighted mean values. Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

The quarter variation of the total effort (sum of all gears) by area was also explored (Figure 2.4.2). The weighted mean of the years was used to estimate effort distribution between quarters in each area. Disregarding area 27.1 where only one quarter was reported (quarter 2), the results presented in Figure 2.4.2 give some indications that the total fishing effort might be well distributed among quarters, for all the areas. Some slight differences can be seen in some areas but, because different effort types are involved, no further conclusions should be made about them. In the future, and using a standardized effort measure, a better exploration of the relations between catches/landings and effort can be performed.

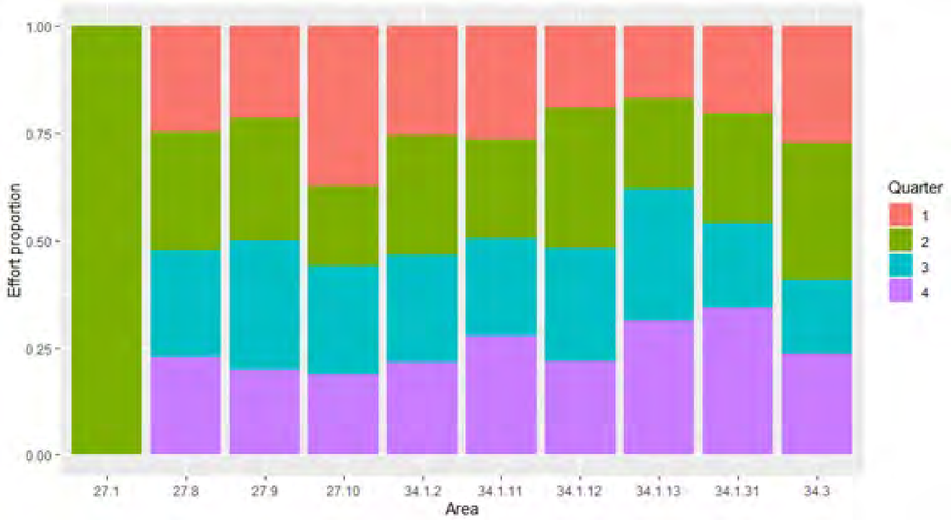


Figure 2.4.2. Fishing effort proportion per quarter in each area, using the annual weighted values.

The annual variation of the fishing effort by area and gear group for the areas presenting longer time-series is shown in Figure 2.4.3. It seems to indicate similar tendencies for areas 27.8 and 27.9, with a 'plateau' in the same period (2008–2017) and a decrease in the following years. The other areas (27.10 and 34.1.2) present more variable patterns between years.

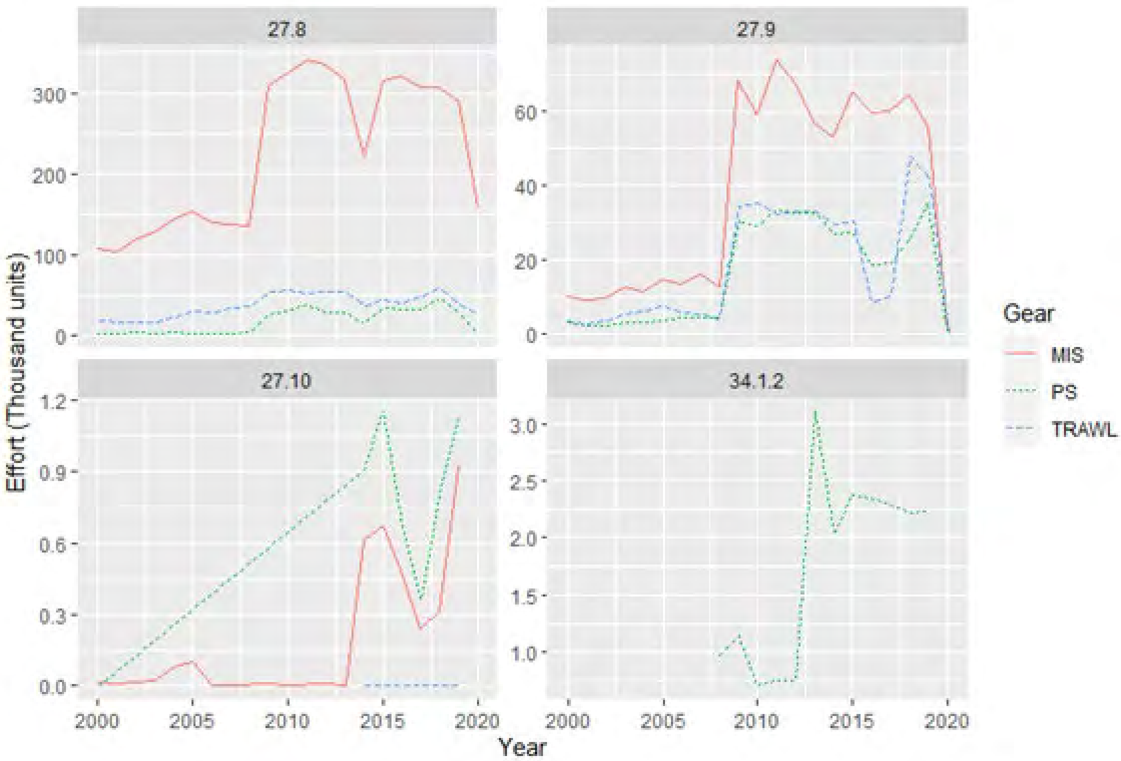


Figure 2.4.3. Interannual variation of effort by gear and by area (Areas with only one year were not included). Fishing gears: MIS- Other fleets, PS- Purse-seiners, TRAWL- Trawlers.

2.5 Catch per unit of effort (CPUE)

The analyses of the catches per-unit-of-effort were not accomplished because a standardized effort unit is required and not currently available. For this reason, it is inappropriate to estimate a reliable CPUE to measure stock abundance.

2.6 Length frequencies in landings

Length frequencies from chub mackerel landings were quarterly collected for all the areas with data submitted both to the data call and during the WK, though the number of years considered differ between areas (see Table 2.2 in this report). A preliminary analysis of these data at the annual level was carried out, the length range, median length and length–frequency distribution in the annual landings being shown in Figures 2.6.1 and 2.6.2. For these analyses, a cut of 5% of both distribution tails was considered for obtaining a more representative picture of the lengths range. However, chub mackerel up to 55 cm were reported to be landed, mainly in areas 27.8.c and 27.9.a.c.s., the largest chub mackerel in the time-series available was reported in 27.9.a.c.s area, sizing 64.7 cm.

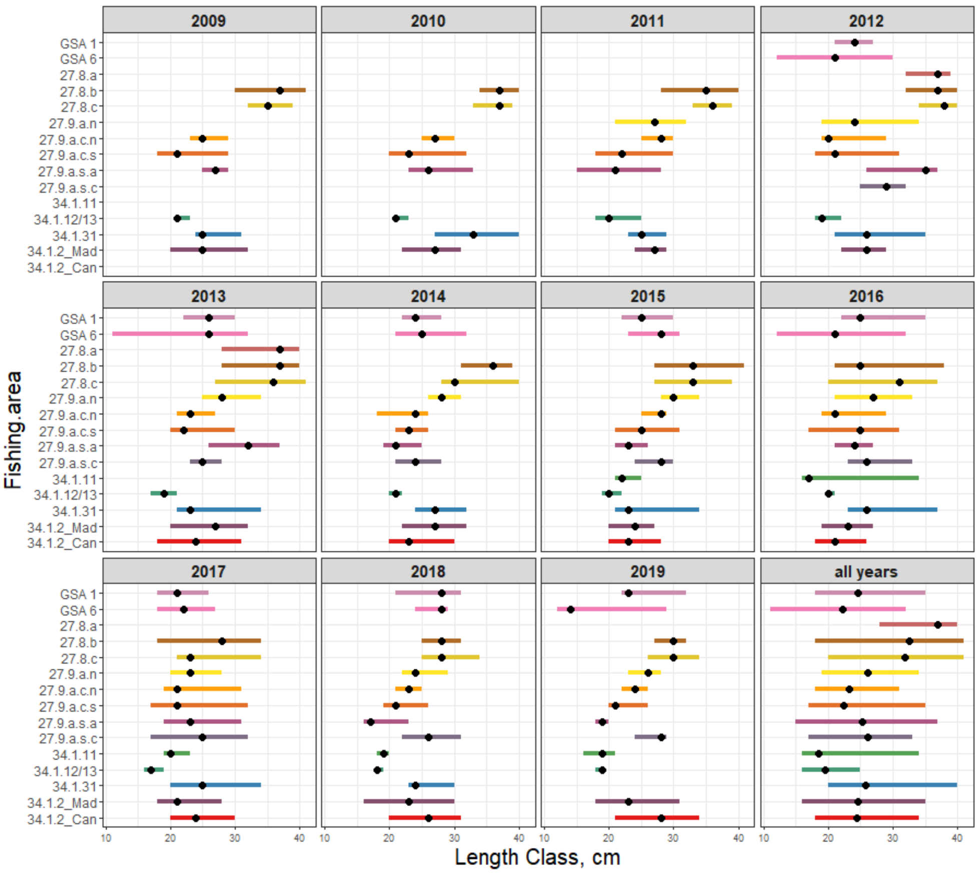


Figure 2.6.1. Length range (horizontal bars) and median length (black dot) from the length–frequency distributions of chub mackerel landings in Spanish, Portuguese, Moroccan and Mediterranean waters for each year of the period 2009–2019, and for all years pooled (data were not available for all years in each area). 5% of each distribution's tails were removed. Fishing areas correspond to subdivisions GSA1: Mediterranean Northern Alboran Sea; GSA6: Mediterranean Northern Spain; 27.8.a, 27.8.b: North and Central Bay of Biscay, respectively; 27.8.c: South Bay of Biscay - Cantabrian Sea; 27.9.a.n: Spanish Galician Waters; 27.9.a.c.n: Central North Portugal; 27.9.a.c.s: Central South Portugal; 27.9.a.s.a: South Portugal – Algarve; 27.9.a.s.c and 27.9.a.s: Cadiz Spanish Waters; 34.1.11, 34.1.12/13 and 34.1.31: North, Central and South Morocco/Mauritania, respectively; 34.1.2_Mad: Madeira Islands; 34.1.2_Can: Canary Islands.

The length range and median length in landings show differences according to years and areas, although some general trends seem to exist for the chub mackerels, particularly visible when all years are pooled. In Atlantic Iberian waters, there is a latitudinal decreasing gradient from North to South, lengths being generally higher in the Bay of Biscay and Cantabrian Sea (27.8.a, 27.8.b, 27.8.c) and increasing slightly again towards the Southern Iberia (Algarve and Gulf of Cadiz: 27.9.a.s.a and 27.9.a.s.c). For the Mediterranean area, the chub mackerel landed present sizes within the ranges observed also in the Gulf of Cadiz and West Portugal, though the lengths distributions for the Mediterranean are usually wider and include the smallest fish reported for some of the years (e.g. 11–12 cm length in 2012–2013, 2016 and 2019). The chub mackerel landed in Northern and Central Moroccan harbours have similar size ranges or slightly smaller median lengths compared to West Portugal, while in Southern Moroccan and Mauritanian waters, chub mackerel lengths increase reaching similar values to those observed in the Northern Iberia (Cantabrian Sea). As for the Madeira and Canary Islands (Subarea 34.1.2), the fish landed are frequently represented by larger sizes compared to the NW African coast at the same latitudes, with values similar to those reported for the South Morocco/Mauritania.

A complete analysis in terms of time variability was not possible; nevertheless, some observations arise from the exploration of the current set of data. In subdivisions 27.8.a, 27.8b and 27.8.c (Bay of Biscay and Cantabrian Sea), median length values from the fish reported in landings were frequently above 35 cm from 2010 to 2015 (as referred previously, the largest individuals were reported from landings in subarea 27.8.c) whereas from 2016 onwards, median values decreased significantly to 25–30 cm. Considering subareas 27.9.a.c.n and 27.9.a.c.s, median lengths in landings present relatively narrow variations along the time-series, with values generally around 20 to 28 cm, but with no clear trend. In 2017, median values were particularly similar across all areas analysed, between 20 and 25 cm length; these fish could possibly correspond to the strong 2016 year class that seems to have been present in most of the geographical distribution from Bay of Biscay to Southern Morocco, and that could be tracked in some of the acoustic and bottom-trawl surveys (see Section 3.2 of this report).

Overall, the spatial trends and the complementarity in the landings' length distributions could indicate that, at least in European waters, and assuming that landings may realistically reflect the geographical distribution of these individuals, distinct recruitment areas and ontogenetic geographical migrations might exist, though no unequivocal spatial pattern arises from these preliminary analyses.

From the length–frequency distributions obtained from landings in each fisheries area, it was not possible to track the different cohorts (Figure 2.6.2). If the above-mentioned seasonal migrations between contiguous areas may occur, the progression of the different year classes may become beclouded by the fact that for the present analyses landings were integrated over an entire year, and not disaggregated by quarters. Additionally, selectivity in the fisheries gears and minimum size landing restrictions may also limit obtaining a fully representative overview of the populations' structure.

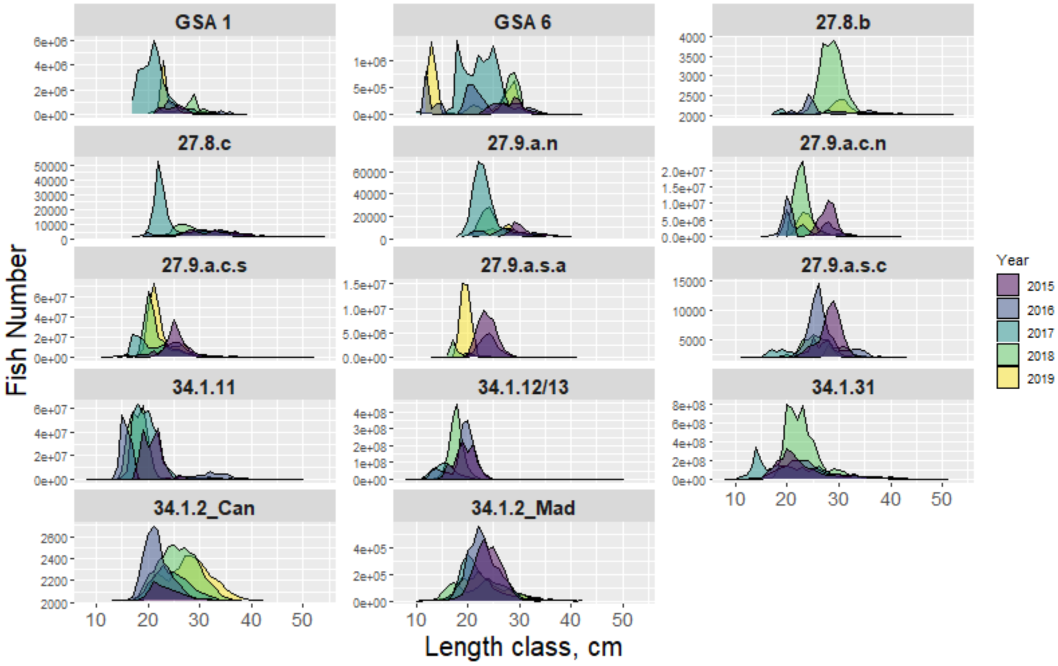


Figure 2.6.2. Length–frequency distributions in chub mackerel landings for each of the areas and for the period 2015–2019. Fishing areas correspond to subdivisions GSA1: Mediterranean Northern Alboran Sea; GSA6: Mediterranean Northern Spain; 27.8.a, 27.8.b: North and Central Bay of Biscay, respectively; 27.8.c: South Bay of Biscay - Cantabrian Sea; 27.9.a.n: Spanish Galician Waters; 27.9.a.c.n: Central North Portugal; 27.9.a.c.s: Central South Portugal; 27.9.a.s.a: South Portugal – Algarve; 27.9.a.s.c and 27.9.a.s: Cadiz Spanish Waters; 34.1.11, 34.1.12/13 and 34.1.31: North, Central and South Morocco/Mauritania, respectively; 34.1.2_Mad: Madeira Islands; 34.1.2_Can: Canary Islands.

2.7 Metadata available

The metadata submitted to the WK is presented in Tables 2.7.1 to 2.7.3. The information available shows disparities among the fishing gear/strategy, area and time period. One of the important future works is to standardize, complete and correct them properly.

Table 2.7.1. Landings of chub mackerel available by area.

Landings		Year																					Observations
Fishing Area	Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
27.10.a.c.a	PT																						
27.7.b	ES																						
27.7.c.2	ES																						
27.7.h	ES																						
27.7.j.2	ES																						
27.7.k.2	ES																						
27.8.a	ES																						
27.8.b	ES																						
	FR																						
27.8.c	ES																						
	FR																						
	PT																						
27.8.d.2	ES																						
27.8.e.2	ES																						
27.9.a	ES																						
27.9.a.c	ES																						
27.9.a.c.n	PT																						
27.9.a.c.s	PT																						
27.9.a.n	ES																						
	PT																						
27.9.a.s	ES																						
27.9.a.s.a	PT																						
27.9.a.s.c	ES																						
	PT																						

Landings		Year																					Observations
Fishing Area	Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
34.1.11	MOR																						
34.1.12	MOR																						
34.1.13	MOR																						
34.1.2	ES																						
	PT																						
34.1.31	MOR																						
34.3.12	SEN																						
GSA 1	ES																						
GSA 6	ES																						

Table 2.7.2. Fishing effort data available by area.

Effort (Fishing days)		Year																					Observations
Fishing Area	Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
27.1	FR																						
27.10.a.c.a	PT																						Positive fishing days
27.10.a1	FR																						
27.10.a2	FR																						
27.8.a	ES																						
	FR																						
27.8.b	ES																						
	FR																						
27.8.c	ES																						
	FR																						
	PT																						Positive fishing days
27.8.d.2	ES																						
27.8.e.2	ES																						
	FR																						
27.9.a.c	ES																						
27.9.a.c.n	PT																						Positive fishing days
27.9.a.c.s	PT																						Positive fishing days
27.9.a.n	ES																						
	PT																						Positive fishing days
27.9.a.s.a	PT																						Positive fishing days
27.9.a.s.c	ES																						
	PT																						Positive fishing days
27.9.b	FR																						
27.9.b1	FR																						

Effort (Fishing days)		Year																					Observations
Fishing Area	Coun-try	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
34.1.11	MOR																						Landing day considered as fishing day
34.1.12	MOR																						Landing day considered as fishing day
34.1.13	MOR																						Landing day considered as fishing day
34.1.2	ES																						
	PT																						Positive fishing days
34.1.31	MOR																						fishing day
34.3.12	SEN																						
	FR																						

Table 2.7.3. Data on discards.

DiscardsTons		Year																					Observations
Fishing Area	Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
27.8.a	ES																						
	FR																						
27.8.b	ES																						
	FR																						
27.8.c	ES																						
27.9.a.c.n	PT																						
27.9.a.c.s	PT																						
27.9.a.n	ES																						
27.9.a.s.a	PT																						
27.9.a.s.c	ES																						

2.8 Recommendations

By examining the aforementioned elements, the WKCOLIAS2 encourages the following activities:

- Analysis of fishing strategies (targeting season, areas, gear, etc.): to have a standardized effort and representative CPUEs for chub mackerel.
- Analysis of chub mackerel fishing areas and grounds (for example, from VMS information).
- To analyse catches and environment parameters using General Additive Model to explain the increase in catches of the species in recent years.

3 Surveys data

3.1 Geographical and seasonal distribution of the populations

Scientific surveys (both acoustic-trawl and bottom-trawl surveys) may provide valuable and direct information on geographical and seasonal distribution of chub mackerel populations throughout its distributional range in Eastern Atlantic and Mediterranean waters. Previous to the workshop, ICES member countries were formally requested through a data call to submit time-series of size- and age-based abundance and biomass indices for the period 2000–2019 (Table 3.1.1). The geographical scope of this data request comprised the ICES divisions 27.8.a (north of Bay of Biscay, BoB) to 27.9.a.s (gulf of Cadiz, GoC), and 27.10.a (Azores grounds). Additionally, Spain and France, as members of the programmes conducting coordinated/harmonized surveys in the NW Mediterranean were also invited to provide indices from those series. CECAF member countries were also invited to provide chub mackerel direct indices from their respective national or internationally coordinated surveys throughout the Atlantic waters of NW Africa.

Table 3.1.1. Scientific surveys series conducted in European waters requested by the WKCOLIAS2 data call to provide chub mackerel survey indices. ES: Spain; FR: France; PT: Portugal. MEDIAS and MEDITS surveys are conducted by Spain and France in their national NW Mediterranean continental shelf waters.

Survey type	Survey series name	Country
Acoustic-trawl	PELGAS	FR
	PELACUS	ES
	PELAGO (former SAR)	PT (PT)
	ECOCADIZ	ES
	MEDIAS	ES, FR
Recruitment (acoustic-trawl)	JUVENA	ES
	IBERAS (former JUVESAR)	ES & PT (PT)
	ECOCADIZ-RECLUTAS	ES
Bottom-trawl	EVHOE	FR
	DEMERSALES (IBTS; SP-NSGFS Q4)	ES
	DEMERSALS (PT-PGFS Q1 & Q3, IBTS PT-PGFS Q4)	PT
	ARSA (IBTS; SP-GCGFS Q1 & Q4)	ES
	MEDITS	ES, FR

The planned goals by this data call have been only partially achieved since the submitted information has not satisfied in some cases all the data requirements. Table 3.1.2 shows the results of the data call submissions for the surveys data.

Table 3.1.2. WKCOLIAS2 data call (DC) submissions of scientific surveys series data. Available data for this workshop in bold. MO: Morocco. GoC: gulf of Cadiz. NW: Northwest, SW: Southwest. AT: acoustic-trawl survey; AT-R: acoustic-trawl surveys aimed at the estimation of juveniles/recruits; BT: bottom trawl surveys. Q1–Q4: quarters. Comments: (1): available data but not provided to WKCOLIAS2 DC; (2): available data but neither indices nor LFDs provided to WLCOLIAS2 DC; (3): available data but no age-structured index provided to WKCOLIAS2 DC. N-at-age/hour by fishing haul only; (4): survey coordinated by Spain & Portugal; (5): age reading in progress; no age-structured index provided to WKCOLIAS2 DC; (6): additional data provided during WKCOLIAS2; (7): no survey's age–length key.

ZONE	ICES/FAO	COUNTRY	METHOD	QUARTER	SURVEY NAME	TIME-SERIES			COMMENTS
						N & B	LFD	AGE	
Cantabrian Sea	27.8.c	ES	AT	Q2	PELACUS	2013-2019	2013-2019 (1)	2013-2019	(1)
			BT	Q4	SP-NSGFS Q4	1982-2019 (2)	1982-2019 (2)	2011-2019 (3)	(2), (3)
W Galicia	27.9.a.n	ES	AT	Q2	PELACUS	2013-2019	2013-2019 (1)	2013-2019	(1)
			AT-R	Q4	IBERAS (4)	2018-2020	2018-2020 (1)	2018-2020	(1), (4)
			BT	Q4	SP-NSGFS Q4	1982-2019 (2)	1982-2019 (2)	2011-2019 (3)	(2), (3)
NW PT	27.9.a.c.n	PT	AT	Q2	PELAGO	2008-2009; 2013-2014; 2020	2009; 2013-2014; 2020	2009; 2013-2014; 2020 (5)	(5)
			AT-R	Q4	JUVESAR/IBERAS (4)	2018-2020	2018-2020 (1)	2018-2020	(1), (4)
			BT	Q1	PT-PGFS Q1	1992-1993 (6); 2005-2008	1992-1993 (6); 2005-2008	-	(5), (6)
				Q3	PT-PGFS Q3	1989-1991; 1993; 1995; 1997-1999 (6); 2000-2001	1989-1991; 1993; 1995; 1997-1999 (7); 2000-2001	-	(5), (6)
				Q4	PT-PGFS Q4	1989-1999 (6); 2000-2011; 2013-2018	1989-1999 (6); 2000-2011; 2013-2018	-	(5), (6)

ZONE	ICES/FAO	COUNTRY	METHOD	QUARTER	SURVEY NAME	TIME-SERIES			COMMENTS
						N & B	LFD	AGE	
SW PT	27.9.a.c.s	PT	AT	Q2	PELAGO	2008-2009; 2013-2014; 2020	2009; 2013-2014; 2020	2009; 2013-2014; 2020 (5)	(5)
			AT-R	Q4	JUVESAR/IBERAS (4)	2018-2020	2018-2020 (1)	2018-2020	(1), (4)
			BT	Q1	PT-PGFS Q1	1992-1993 (6); 2005-2008	1992-1993 (6); 2005-2008		(5), (6)
				Q3	PT-PGFS Q3	1989-1991; 1993; 1995; 1997-1999 (6); 2000-2001	1989-1991; 1993; 1995; 1997-1999 (6); 2000-2001		(5), (6)
				Q4	PT-PGFS Q4	1989-1999 (6); 2000-2011; 2013-2018	1989-1999 (6); 2000-2011; 2013-2018		(5), (6)

Table 3.1.2 (Cont.). WKCOLIAS2 data call (DC) submissions of scientific surveys series data. Available data for this workshop in bold. MO: Morocco. GoC: gulf of Cadiz. NW: Northwest, SW: Southwest. AT: acoustic-trawl survey; AT-R: acoustic-trawl surveys aimed at the estimation of juveniles/recruits; BT: bottom trawl surveys. Q1-Q4: quarters. Comments: (1): available data but not provided to WKCOLIAS2 DC; (2): available data but neither indices nor LFDs provided to WLCOLIAS2 DC; (3): available data but no age-structured index provided to WKCOLIAS2 DC. N-at-age/hour by fishing haul only; (4): survey coordinated by Spain & Portugal; (5): age reading in progress; no age-structured index provided to WKCOLIAS2 DC; (6): additional data provided during WKCOLIAS2; (7): no survey's age–length key.

ZONE	ICES/FAO	COUNTRY	METHOD	QUARTER	SURVEY NAME	TIME-SERIES			COMMENTS
						N & B	LFD	AGE	
GoC PT	27.9.a.s.a	PT	AT	Q2	PELAGO	2008-2009; 2013-2014; 2020	2009; 2013-2014; 2020	2009; 2013-2014; 2020 (5)	(5)
			BT	Q1	PT-PGFS Q1	1992-1993 (6); 2005-2008	1992-1993 (6); 2005-2008		(5), (6)
				Q3	PT-PGFS Q3	1989-1999 (6); 2000-2001	1989-1999 (6); 2000-2001		(5), (6)
				Q4	PT-PGFS Q4	1989-1999 (6); 2000-2011; 2013-2018	1989-1999 (6); 2000-2011; 2013-2018		(5), (6)
		ES	AT	Q3	ECOCADIZ	2004, 2006-2007; 2009-2010; 2013-2020	2004, 2006-2007; 2009-2010; 2013-2020	2004, 2006-2007; 2009-2010; 2013-2018 (7); 2019-2020 (5)	(5), (7)
			AT-R	Q4	ECOCADIZ-RECLUTAS	2014-2016; 2018-2020	2014-2016; 2018-2020	2014-2016; 2018 (7); 2019-2020 (5)	(5), (7)
GoC ES	27.9.a.s.c	PT	AT	Q2	PELAGO	2008-2009; 2013-2014; 2020	2009; 2013-2014; 2020	2009; 2013-2014; 2020 (5)	(5)
		ES	BT	Q1	SP-GCGFS Q1	1992-2010 (6); 2011-2016 (2); 2017-2019 (6)	1992-2010 (6); 2011-2016 (2); 2017-2019 (6)	1992-2010 (6); 2011-2016 (2) (3); 2017-2019 (6)	(2), (3), (6)

ZONE	ICES/FAO	COUNTRY	METHOD	QUARTER	SURVEY NAME	TIME-SERIES			COMMENTS
						N & B	LFD	AGE	
			AT	Q3	ECOCADIZ	2004, 2006-2007; 2009-2010; 2013-2020	2004, 2006-2007; 2009-2010; 2013-2020	2004, 2006-2007; 2009-2010; 2013-2018 (7); 2019-2020 (5)	(5), (7)
			AT-R	Q4	ECOCADIZ-RECLUTAS	2014-2016; 2018-2020	2014-2016; 2018-2020	2014-2016; 2018 (7); 2019-2020 (5)	(5), (7)
			BT	Q4	SP-GCGFS Q4	1997-2002; 2004-2010 (6); 2011-2016 (2); 2017-2019 (6)	1997-2002; 2004-2010 (6); 2011-2016 (2); 2017-2019 (6)	1997-2002; 2004-2010 (6); 2011-2016 (2) (3); 2017-2019 (6)	(2), (3), (6)
Zones North+A+B(36°N-26°N)	34.1.1	MO	AT	Q4	R/V Al Amir Moulay Abdallah	2001-2018 (6); 2019	2001-2018 (6); 2019	2001-2019 (6)	(6)
Zone C (26°N-20°48'N)	34.1.3		AT	Q4		2006-2018 (6); 2019	2006-2018 (6); 2019	2006-2019 (6)	(6)

No information was submitted for the MEDIAS and MEDITS NW Mediterranean surveys, neither from the JUVENA surveying the Cantabrian Sea and the southern BoB, nor from French surveys surveying the BoB (PELGAS, EVEHOE). Absence of data from JUVENA is justified since the target species is anchovy (juveniles) and chub mackerel is not formally assessed yet. The occurrence of chub mackerel in MEDITS hauls seems to be incidental. However, chub mackerel is regularly observed in the Bay of Biscay and NW Mediterranean during the PELGAS and MEDIAS acoustic surveys, respectively, and although data from those surveys have not been submitted they might be available from further request. For the remaining surveys/areas the length of the series was very variable and in some cases the indices were either size-based or age-based estimates only. For example, acoustic estimations submitted from PELAGO include only five years. The main reason is because this survey targets mainly sardine and anchovy and therefore fishing hauls to ground truth offshore shoals are often missing. New estimations for the surveys between 2015 and 2019 may be available soon. In the particular case of the Spanish ground-fish surveys (DEMERSALES and ARSA series), the submitted information corresponded to age-based estimates of relative indices of individual positive hauls, but not of regional stratified mean relative indices, hence these series have not been possible to be analysed in combination with their Portuguese counterparts. From the Atlantic waters of NW Africa the only information available to this workshop corresponds to the regional size-based acoustic indices of abundance and biomass obtained during the 2019 Moroccan autumn surveys.

Several attempts to set up useful methodology to acoustically survey the Canary Islands waters are being carried out by IEO since 2016 (including the last one in 2021), but unsuccessfully so far. Narrow continental shelf around the islands makes it difficult to get a trade-off, in terms of the survey design, between precision level and time optimisation. Furthermore, the sea bed over the shelf is of a hard and irregular nature, with most of the schools occurring close to the bottom, thus making difficult to catch representative samples of the species assemblages and size composition of the species using trawl nets. The complementary use of auxiliary fishing vessels providing extra samples could help in these constraints. Fisheries data suggest that the best season to perform an acoustic survey would be late autumn-early winter, when chub mackerel recruits are fully available, and also matching with the timing of the Mauritanian and Moroccan acoustic surveys.

Acoustic surveys are conducted in similar way, both in Europe and African waters. Surveys in European Atlantic waters are conducted following standardised protocols agreed within the frame of ICES specific expert groups (e.g. ICES WGACEGG). A similar standardization process is also adopted by the MEDIAS project/programme's surveys in the Mediterranean Sea. Notwithstanding the above, differences in the species-specific target strength value used by each Institute to convert acoustic back-scattering energy to biomass prevent from using the resulting acoustic indices as absolute indices of the population levels. Instead, their values should only be considered in relative terms and for the purposes of interpreting spatio-temporal trends. Considering the large number of acoustic and recruitment surveys available in the whole area of distribution of chub mackerel, WKCOLIAS recommended last year to hold a joint Workshop among the Institutions and teams (i.e. ICES and CECAF) to address the above issue and other ones related with the standardization of the surveys protocols and methods. However, no progress has been made intersessionally in this respect.

Bottom trawl surveys are also carried out throughout the chub mackerel distribution area. In European waters, those surveys conducted in ICES and GFCM-FAO GSA areas also follow internationally agreed standardised protocols developed within the frame of their own experts' groups (ICES International Bottom Trawl Surveys Working Group, IBTSWG; MEDITS project in the Western Mediterranean). However, the performance of the fishing gears, with vertical openings ranging from 1.5 to 4.5 m and towing speeds between 3–4 knots, would result in a poor representativeness of the chub mackerel population structure (either length- or age-based), accounting, as well, for uncertainties linked with the accessibility and/or catchability of the different fishing gears used by the different countries. Further analyses on chub mackerel stock dynamics representativeness from bottom-trawl surveys together with comparability among surveys should be carried out prior to estimate an index for chub mackerel based on this type of surveys.

As it will be commented below, the ground-truthing trawl hauls carried out during the acoustic surveys, despite of being carried out at faster speeds (4–4.5 knots) and with greater vertical openings (between 10 and 20 m) in some research vessels, neither show a suitable performance for the proper sampling of chub mackerel, at least for larger sizes. In fact, a major finding of the WKCOLIAS last year was precisely that in some areas, large chub mackerel individuals are usual in landings, but absent or difficult to observe in surveys' catches (both acoustic- and bottom-trawl). The gear and towing speed would be a factor, since the normal avoidance reaction (at least for young fish) is to dive close to the bottom, which in turn makes difficult to catch them on account the roughness of the bottom. The pelagic fishing gears used in the acoustic surveys analysed in this workshop are able to go up to five knots, but at higher speeds the gear performance worsens and also may result in undesirable large catches of other species which may mask the representativeness of the hauls. This limitation could explain the lack of adult fish in surveys catches (accessibility/catchability issue), but the other possibility is that those larger fish are located outside the survey area (availability issue). In this sense, as for *Trachurus picturatus*, around Azores and Madeira large individuals are more usually caught using longline, close to the surrounding sea mounts.

Regarding fish availability, Braham and Jeyid (IMROP; pers. comm.) have reported to WKCOLIAS2 unexpected high yields of large chub mackerel (mode at 40 cm) by coastal purse seiners during the fourth quarter of 2020 in the Mauritanian shelf. Conversely, some scientific observations on board fishing vessels operating offshore have shown contributions of chub mackerel in catches lower than 5%, denoting a low occurrence of *S. colias* in deeper waters. The relative importance of this coastal fraction of large fish in relation to the fishing yields in deeper waters and its comparison with the Mauritanian fishery in 2019 is still pending of a comparative analysis. Such data suggest a change in the depth distribution pattern of the species, which would become more coastal, but the causes explaining this behaviour (e.g. a reproductive migration, etc.) have not been analysed yet. However, these big fishes were not recorded in coastal waters along the Iberian Atlantic shelf waters during the same period. The bulk of the population sampled by the acoustic surveys in Southern European Atlantic waters (mainly BoB and Atlantic Iberian waters) corresponded to young fish (maximum length <30 cm), although some specimens may be bigger. Unfortunately, commercial catches are mainly taken by purse seiners, mostly close to the coast, where the size range from both commercial and surveys catches are similar. Therefore, the issue here is to know where the adult population is located, since there is an increasing trend in the abundance of small fish but without strong signal of adults (or at least showing a similar trend).

An additional constraint when jointly analysing and interpreting the resulting indices from both acoustic- and bottom-trawl surveying methods is the possible lack of synoptic spatio-temporal coverage of the species under study. The timing and spatial coverage of each survey are defined to achieve stock containment of the target species at the mesoscale of each of these surveys' components (and stocks/populations). Although currently designed as integrated surveys of the pelagic ecosystem and aimed at the provision of abundance and biomass indices of the main components of the neritic species assemblage (i.e. small and mid-sized pelagic fish species), the acoustic-trawl surveys under consideration are basically designed to assess the populations of small coastal pelagic fish species (e.g. anchovy, sardine and sardinellas) inhabiting the continental shelf waters, either in spawning or recruitment periods. The surveyed areas correspond to shelf waters usually comprised between 20 and 200 m depth (300 m in NW Africa and 500 m in the Mediterranean Moroccan waters, but only up to 100 m in the IBERAS acoustic surveys).

Surveys restricted to those shelf waters could only provide an adequate synoptic coverage for small pelagic fishes, but they could not capture the actual extension of chub mackerel and other mid-sized pelagic species because the bulk of the population of these species or a fraction of them (larger fish?) may be distributed in the upper slope waters or even in the shallowest coastal waters, not sampled by these surveys. Lags in survey components timings may also compromise the synopticity of the surveys coverage, depending on chub mackerel large scale migrations and spawning/recruitment timing.

WKCOLIAS2 requested during the present meeting some feedback from the ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST) about the issue whether the lack of larger fish is a question of availability or accessibility/catchability of the fishing gear used in the surveys. The WGFAST consensus response is that capturing large individuals of fast swimming species, such as the mackerel species (e.g. *Trachurus* and *Scomber* spp.) is difficult, especially when sampling during scientific surveys. As the WKCOLIAS participants had highlighted during the first workshop, capturing these fast swimming species is a combination of net size, vessel characteristics, tow speed and duration, and expertise of the fishing skipper. Commercial fishers often develop specialized gear (e.g. large nets, large mesh, trawl sensors), vessels (e.g., increased horse power), and methods (e.g. fast tow speeds, long duration) to make catches economically profitable, by capturing highest priced/largest specimens. Scientific surveys are often conducted on vessels that deploy many types of gear, while bridge and deck expertise is often not specialized, and net catches are meant to be representative rather than voluminous. WGFAST experts also noted that “hook and line” fishing and using cameras have been used successfully for other fast-swimming species (e.g. Fernandes *et al.*, 2016). The main conclusions drawn by WGFAST were that:

i. speeds of 4.1–4.5 knots are sufficient for a successful fishing of large mackerel. At such speeds it can be assumed that absence of large fish in the catches is due to its absence in the water;
ii. on a specific shelf area, summer surveys may yield more large chub mackerel than in winter, due to the partial migration of such fish off the shelf (at least in African waters);
iii. large chub mackerel is distributed in a wide range of depths, from the outer boundary of the littoral to the abyssal. The most accessible individuals for fishing are located above depths of 50–100 m.

Recommendations by WGFAST are:

i. either supplemental to or as a replacement for trawling, try “hook and line” sampling (it can provide representative samples and size distribution);
ii. investigate spatial and temporal distribution, and potential changes in distributions;
iii. investigate alternative ways to deploy mid-water trawls; and
iv. investigate positioning camera systems at locations where suspected large chub mackerel may occur.

Even bearing in mind all the above constraints, the synoptic mapping of chub mackerel’s geographical and seasonal distribution throughout its distributional range has not been an easy task because of the abovementioned different data availability from the surveys. After a thorough exploration of the submitted data, it has been possible to represent a map of the abundance and biomass of chub mackerel populations covering from Galician waters (ICES Subdivision 27.9.a.n) to northern Mauritanian waters (FAO Subdivision 34.1.32) only for the 2019 autumn surveys: IBERAS, ECOCADIZ-RECLUTAS and Moroccan surveys conducted by the RV Al Amir Moulay Abdallah (Figure 3.1.1). The regional population indices could differentiate between juveniles and adults, under the following assumptions: in the Iberian-Atlantic surveys, population fractions were differentiated based on age structure (i.e. age-0 juveniles *vs* age-1+ “adult” fish), whereas in the Moroccan Atlantic surveys, without age data, a size-based differentiation was carried out, assuming as adult fish those larger than 24 cm (Mamza, 2021; WKCOLIAS2 presentation). A complementary synoptic map showing the size composition of the chub mackerel in Atlantic waters has also been attempted, but in this case the information was only available for the geographical range comprised between GoC and northern Mauritanian waters (Figure 3.1.2). Although available, no size-based original estimates have been submitted from the IBERAS 2019 survey (Figure 3.1.21).

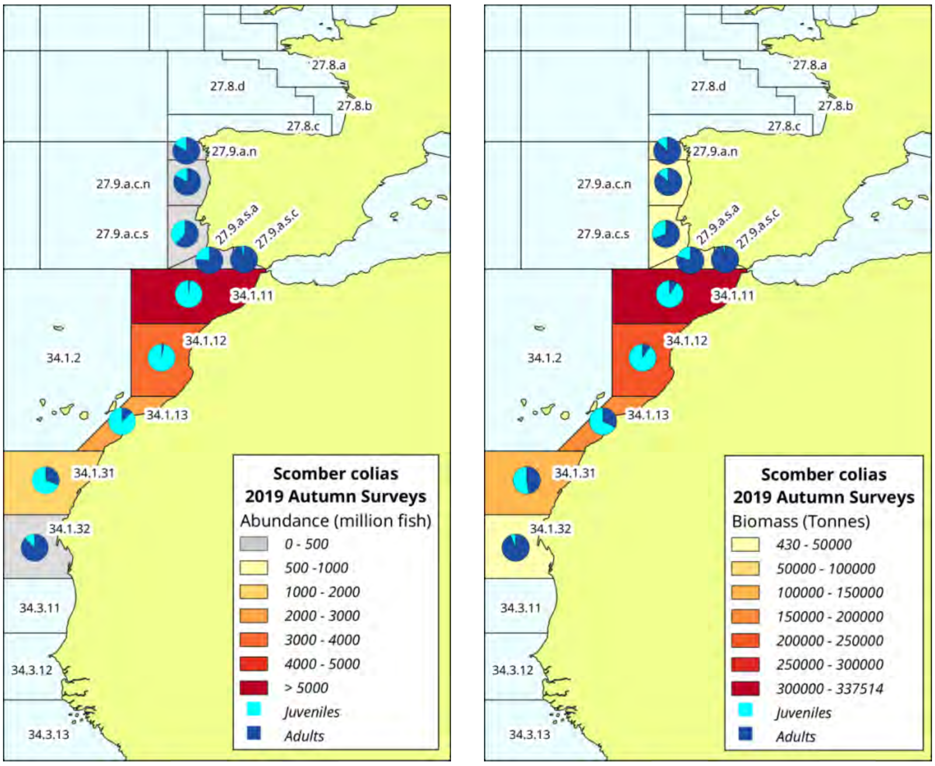


Figure 3.1.1. Chub mackerel abundance (left panel, in million fish) and biomass (right panel, in tonnes), including the available acoustic indices obtained in autumn 2019. Pie charts represent the relative importance (% in numbers) of the juvenile and adult fractions. See text for considerations about how these fractions have been defined.

Despite the limitations, this mapping referred to the autumn season provides interesting results on the most recent distribution pattern of the species in the Eastern Atlantic. Thus, in Eastern Atlantic waters, a gradual increasing of abundance/biomass along the NW African shelf waters would culminate in the main nucleus of distribution of the species in the NW Moroccan shelf waters, mainly in the Zone North (FAO Subdivision 34.1.11). The population levels of chub mackerel along the Iberian Atlantic waters are quite far from those recorded for the African populations. Within this last area, the species shows its greater densities in the Portuguese Alentejo (ICES Subdivision 27.9.a.c.s) and Algarve (27.9.a.s.a, in the GoC) shelf waters (Figure 3.1.1).

Regarding the population size-structure, NW African populations, excepting the one off northern Mauritanian shelf waters, are dominated by juvenile/sub-adult fish (fish <24 cm). The mapped information for the European waters might lead to misleading considerations on their size-structure. At first sight, they are dominated by “adult” fish, but in this case the information is referred to fish of one year and older (Figure 3.1.1). If the same 24 cm size-based criterion was applied to these populations to differentiate juveniles from adults, the contribution of juveniles/subadults, at least where the information is available (i.e. GoC), would account for 99% and

78% of the estimated abundance in Portuguese and Spanish GoC waters (Figure 3.1.2). Size composition of the estimated populations showed wider ranges in Atlantic Moroccan waters (14–39 cm) than in northern Mauritanian waters (20–31 cm) or GoC waters (17–27 cm). These data are dealt with more detail in the next subsections.

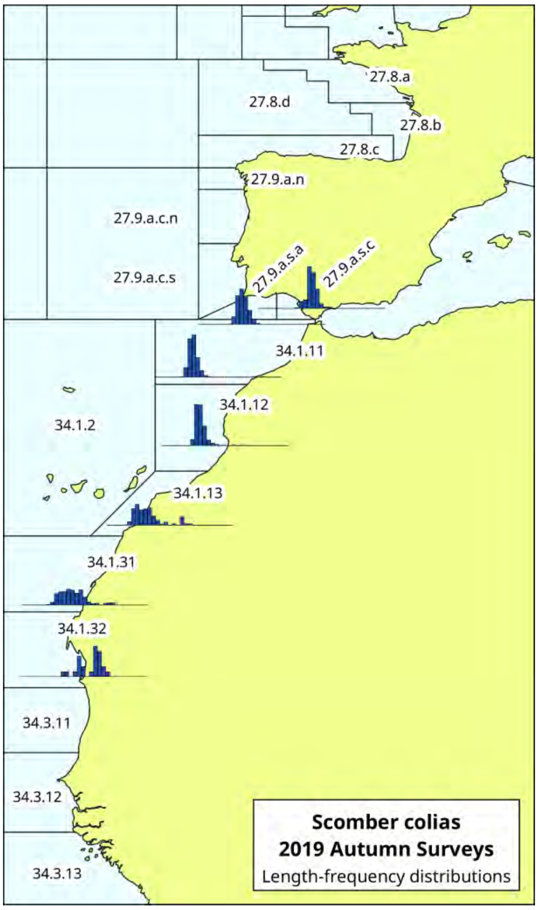


Figure 3.1.2. Chub mackerel size composition by subarea including the information obtained from the regional acoustic-trawl surveys performed in autumn 2019.

3.2 Distribution in Atlantic Iberian waters

Information on the chub mackerel distribution in Atlantic Iberian waters in spring is provided by the acoustic-trawl surveys: PELACUS and PELAGO (Tables 3.1.1 and 3.1.2). Chub mackerel should be considered so far as a secondary species within the early spring small pelagic fish (SPF) "acoustic population" sampled by the PELACUS surveys in the Cantabrian Sea and Galician waters (ICES subareas 27.8.c and 27.9.a.n), with a contribution to the total acoustic backscattering energy attributed to SPF lower than 3%, in the last years. Chub mackerel acoustic densities in those subareas experienced the highest records in 2016 and 2017, abruptly decreasing in 2018 and exhibiting a two-fold increase again in 2019 (Figure 3.2.1). No PELACUS survey was conducted in 2020 because of COVID-19 disruption.

Higher acoustic densities are usually recorded in the eastern part of the Cantabrian Sea (ICES 27.8.c. East). The species shows a scarce availability in spring time in Galician waters (Subarea 27.9.a.n), although a displacement of the centre of gravity of the species distribution towards this subarea was observed in 2017. This centre of gravity shifted again eastwards in 2019 (Figure 3.2.1).

In the Portuguese Atlantic façade and GoC waters (ICES subareas 27.9.a.c.n to 27.9.a.s.c) surveyed by the PELAGO spring surveys, the species shows the highest occurrence frequencies and acoustic densities in the Portuguese subareas 27.9.a.c.s (Alentejo, mainly around Setúbal) and 27.9.a.s.a (Algarve), with an incidental occurrence in northern Portugal (27.9.a.c.n) and relatively lower densities in the Spanish waters of the GoC (27.9.a.s.c) (Figure 3.2.2).

Regarding the time-series of spring estimates of acoustic abundance and biomass, the PELACUS time-series shown in Figure 3.2.3, derived from data submitted to the WKCOLIAS2 Data Call, should be considered with caution since it contrasts with the information reported by Ramos and Carrera (2021; WKCOLIAS2 presentation). There are some doubts whether the peak in the time-series was reached in 2016 or 2017. Neither is clear the observed trend in the recent levels of biomass in the Subarea 27.8.c. Therefore, submitted data should be thoroughly cross-checked with original data for further use. Nevertheless, both sources coincide in the very scarce presence and abundance in 27.9.a.n, except in 2017, and the constant presence in 27.8.c.

The PELAGO time-series is characterized so far by big gaps of information, although data seem to indicate that current population levels recorded in spring time are quite lower than those recorded in early and mid-2000s (Figure 3.2.4). A maximum value was recorded in 2008. However, the absence of information for 2016 and 2017 prevents from the confirmation of the observed peak in those years in the northernmost areas. In any case, population levels recorded in the PELAGO surveyed area are much higher than those recorded in Galician and Cantabrian sea waters.

Figure 3.2.5 summarises all the above comments on the overall geographical distribution of the population inhabiting Atlantic Iberian waters in spring, namely: bulk of the population mainly located in the Alentejo and secondarily in the GoC waters and comparatively an almost accidental occurrence in Galician and Cantabrian sea waters.

Information on size composition and age structure of the population in spring time along the Atlantic Iberian waters is also rather scattered. Table 3.2.1 and Figures 3.2.6 and 3.2.7 show the available information for this workshop. For the northernmost subareas the available information on size composition of the population corresponds to the one recorded for the whole Galician+Cantabrian Sea waters surveyed in 2019 and indicates larger sizes (18–38 cm; modes at 20 and 27 cm, the latter the dominant one) than in the rest of the southern areas. Regarding age structure, these northern subareas show a more age-structured population (age groups 1–11, especially in 27.8.c in 2014; mode at age-1 group), with older ages than in the rest of the Atlantic Iberian waters. Notwithstanding the above, the more common age structure in these northern subareas is that one composed by age groups 1 to 5, with the age-1 fish being the dominant one. The 2016 year class appeared as the strongest cohort in the PELACUS surveyed area in the recent years, especially in 27.8.c, but it was only able to be properly tracked in 2017.

Size composition of the population inhabiting the Iberian Atlantic façade and GoC in spring shows some regional differences, with the chub mackerel from northern Portugal (27.9.a.c.n) and Spanish waters of the GoC (27.9.a.s.c) showing larger modes (20–24 cm) than in the Alentejo+GoC-Algarve (27.9.a.c.s, 27.9.a.s.a) waters (18–19 cm). Alentejo and GoC waters show frequently bimodal size compositions. Unfortunately, the only information on age structure from these southern subareas in spring is limited to the PELAGO 2020 survey and referred only to the whole surveyed area, where the population was structured around the age-1 to age-4 groups, outstanding 1- and 2-year olds, with the latter being the dominant age group. In these areas seems to be that the strongest year classes in recent years were the 2018 and 2019 year classes, especially the 2018 one.

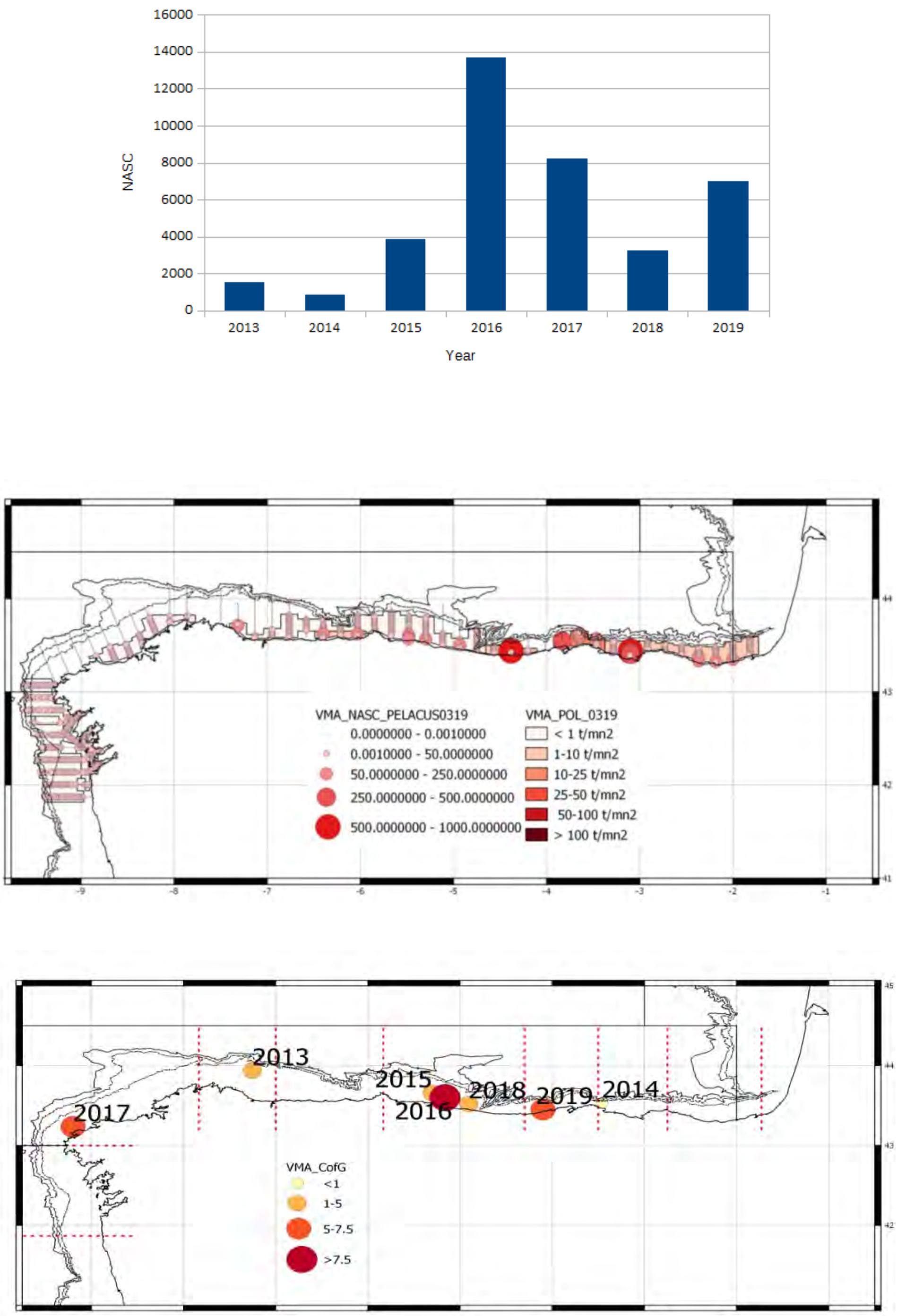


Figure 3.2.1. PELACUS Spring acoustic-trawl survey series. ICES subdivisions 27.8.b, 27.8.c and 27.9.a.n (Cantabrian Sea and Galician waters). Upper panel: time-series of estimates of acoustic density (NASC estimates; m^2nm^{-2}). Middle panel: distribution of the acoustic densities (NASC, m^2nm^{-2}) and coherent post-strata for abundance and biomass estimation (colour scale represents densities expressed in terms of biomass; $t*mn^{-2}$). Bottom panel: location of the centre of gravity of the species' distribution (source: Ramos and Carrera presentation during the WK: abstract without figures available in Annex 4).

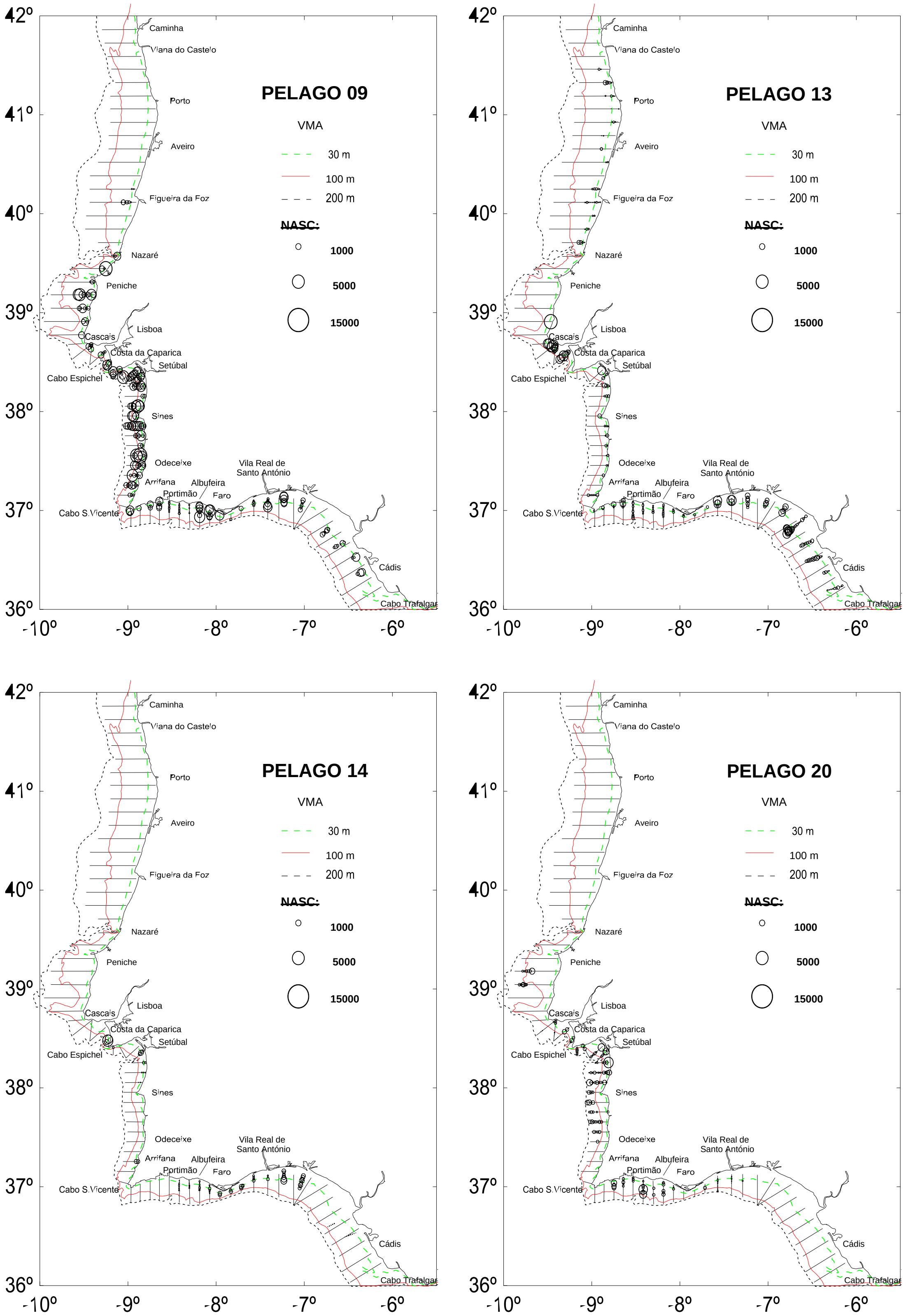


Figure 3.2.2. PELAGO Spring acoustic-trawl survey series (2009, 2013, 2014, 2020). ICES subdivisions 27.9.a.c.n, 27.9.a.c.s, 27.9.a.s.a and 27.9.a.s.c (Portuguese Atlantic façade and Gulf of Cadiz waters). Distribution of the acoustic densities (NASC, m²nm⁻²). (source: Amorim and Moreno presentation during the WK).

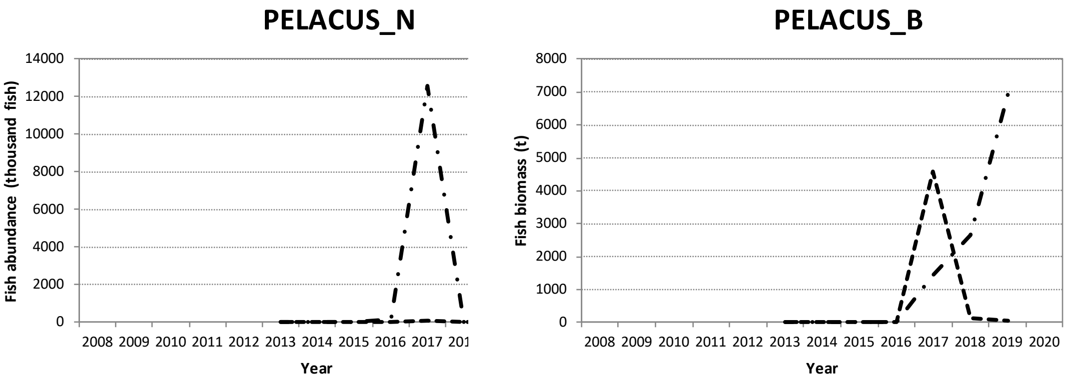


Figure 3.2.3. PELACUS Spring acoustic-trawl survey series. ICES subdivisions 27.8.b, 27.8.c and 27.9.a.n (Cantabrian Sea and Galician waters). Time-series of chub mackerel abundance (N, in thousand fish) and biomass (B, in tonnes) estimates. Period: 2013–2019.

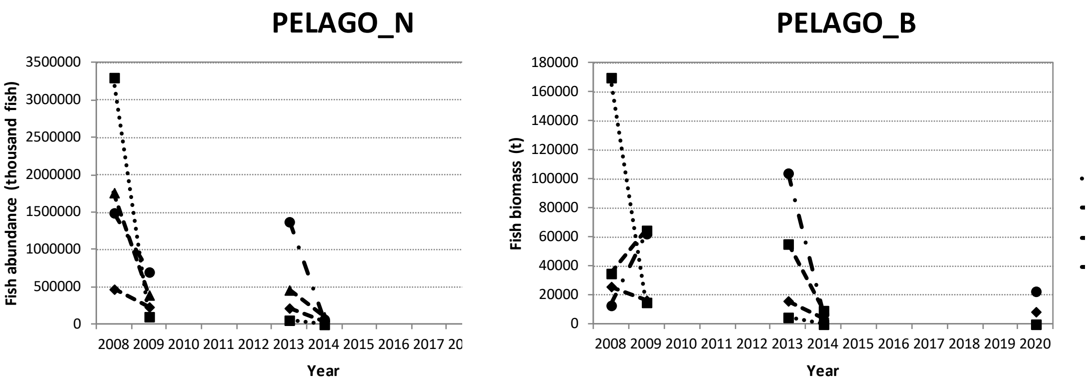


Figure 3.2.4. PELAGO Spring acoustic-trawl survey series. ICES subdivisions 27.9.a.c.n, 27.9.a.c.s, 27.9.a.s.a and 27.9.a.s.c (Portuguese Atlantic façade and Gulf of Cadiz waters). Time-series of chub mackerel abundance (N, in thousand fish) and biomass (B, in tonnes) estimates. Years 2008–2009, 2013–2014 and 2020.

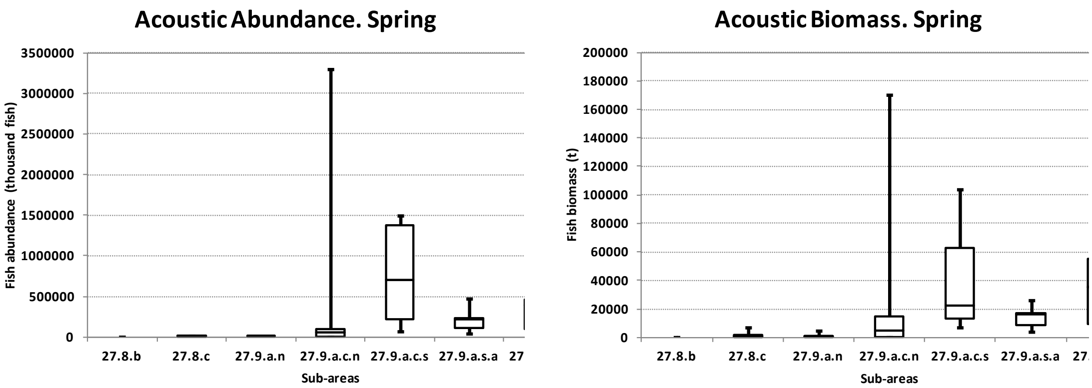


Figure 3.2.5. Spring acoustic-trawl survey series. Box-plot of regional estimates of the relative chub mackerel abundance (n/h) and biomass (kg/h). Outliers not shown. Years 2008–2009, 2013–2014 and 2020.

Table 3.2.1. Spring acoustic-trawl survey series. Main descriptors of chub mackerel size composition and age structure by subarea. Dominant mode shown in bold. (*): data referred to the 2020 survey only.

Subarea	Size class range (cm)	Size class mode (cm)	Age group range (yr)	Age group mode (yr)
27.8.b	18-38(*)	20, 27(*)	1-5	1
27.8.c			1-11	1
27.9.a.n			1-5	1
27.9.a.c.n	17-26	21	1-4(*)	2(*)
27.9.a.c.s	16-29	18		
27.9.a.s.a	16-30	19		
27.9.a.s.c	17-31	20, 24		

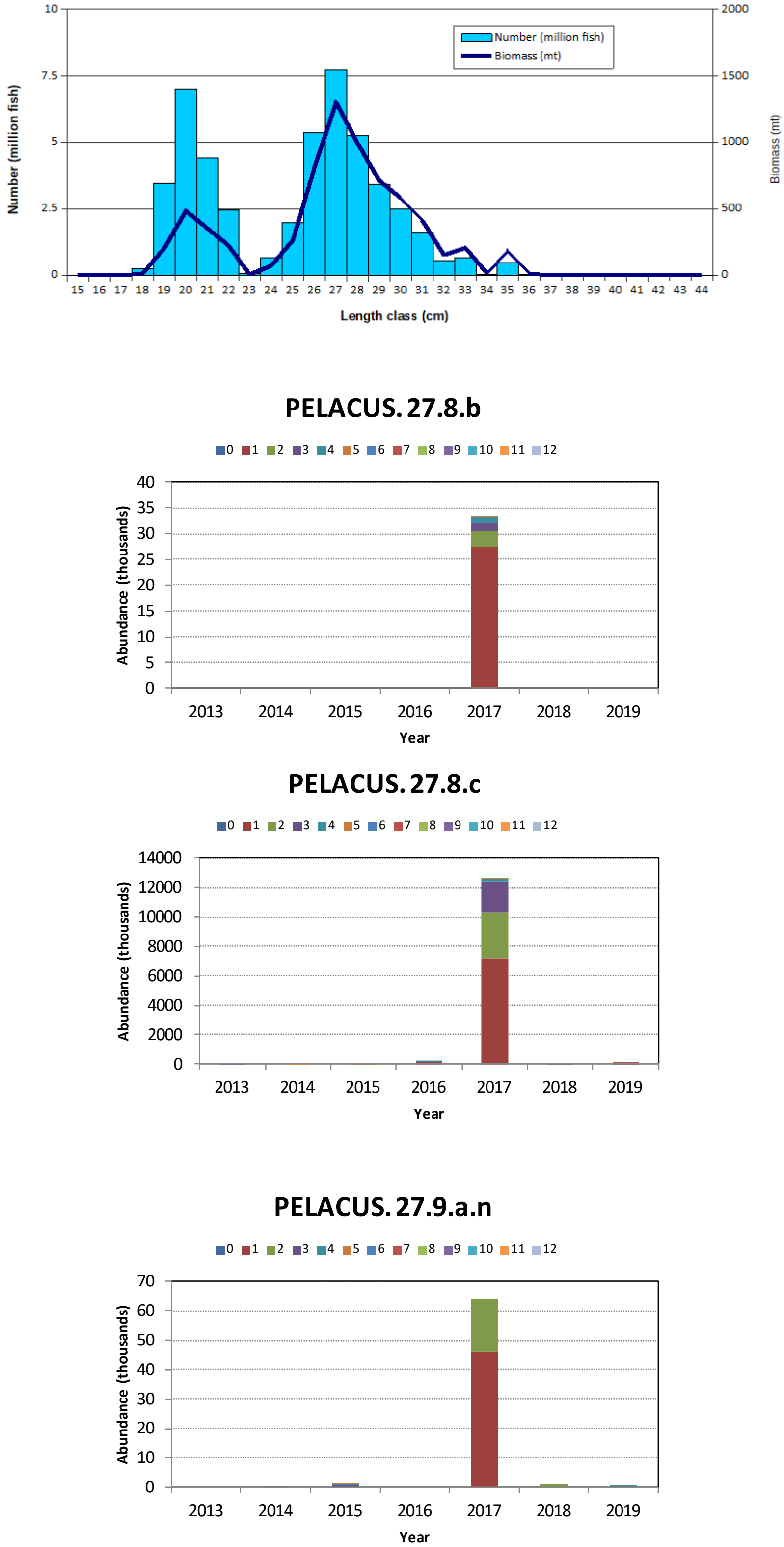


Figure 3.2.6. PELACUS Spring acoustic-trawl survey series. Upper panel: size composition of chub mackerel in the surveyed area (27.8.c and 27.9.a.n) in 2019 (no survey in 2020 because of COVID-19 disruption; source: Ramos and Carrera presentation during the WK; abstract without figures available in Annex 4). Lower panels: age structure of the estimated population by subarea in 2017.

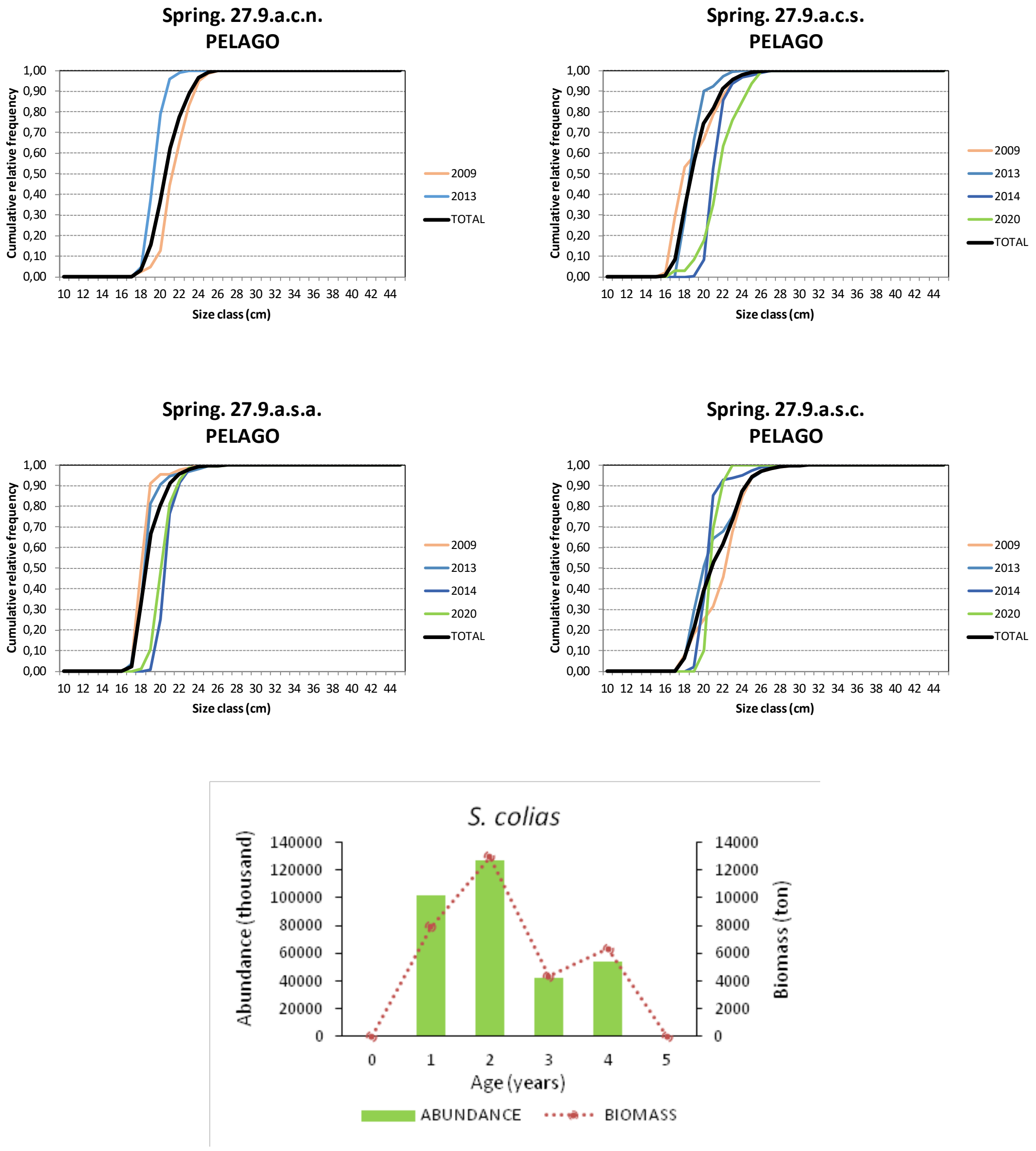


Figure 3.2.7. PELAGO Spring acoustic-trawl survey series. Upper and middle panels: cumulative size relative frequencies. Total refers to pooled data for the available time-series. Bottom panel: age structure of chub mackerel for the whole surveyed area (ICES 27.9.a.c.n, 27.9.a.c.s, 27.9.a.s.a and 27.9.a.s.c) during 2020 (source: Amorim and Moreno presentation during the WK).

Knowledge on the distribution pattern of abundance and biomass of chub mackerel in summer is limited to the information provided by two different data sources: Portuguese bottom-trawl surveys (2000 and 2001 data points only), the PT-PGFS Q3 series, surveying their national mainland waters (subareas 27.9.a.c.n to 27.9.a.s.a) and a longer time-series of ECOCADIZ acoustic-trawl surveys (2004-2020, but with several gaps) surveying the GoC waters only (27.9.a.s.a and 27.9.a.s.c; see Tables 3.2.1 and 3.2.2). No information is available from Galician and Cantabrian Sea waters. Problems when interpreting SPF data from bottom-trawl surveys have already been addressed in the introductory paragraphs in this section. In any case, chub mackerel data from these two surveys indicate higher (relative) abundance and biomass in the GoC-Algarve waters (27.9.a.s.a) than in the Portuguese shelf of the Atlantic Iberian façade (Figures 3.2.8 and 3.2.9). However, this perception might not be applicable to the recent years, but acoustic surveys confirm the importance of chub mackerel within the GoC summer "acoustic SPF assemblage", accounting for 30% of the total NASC on average (Figure 3.2.11). Higher acoustic densities in the GoC are also recorded in the Algarve waters (73% of the total NASC attributed to the species). A previous study by Canseco (2016), based on a NASC data analysis of the ECOCADIZ surveys conducted between 2007 and 2015, described the species' preferences for GoC waters of 20–90 m depth (not deeper than 120 m depth), located between Portimão (western Algarve) and Punta Umbría (western Spanish waters). The centre of gravity and the inertia of the NASC distribution in GoC exhibited inter-annual variation, but showed a preference for Portuguese waters. ECOCADIZ time-series of abundance and biomass indices do not show any clear trend. It seems that a drop in the GoC population should have occurred after the 2007–2009 high estimated values, a trend which has reversed in the most recent years indicating a sign of recovery (2018–2020; Figure 3.2.12). Acoustic indices confirm again the previously described pattern for the NASC, with the bulk of the abundance and biomass of the GoC population occurring in the Portuguese Algarve waters (Figure 3.2.13).

Size composition of the population surveyed in summer by the bottom-trawl surveys along the Portuguese waters (20–500 m depth) suggests larger fish in the subareas 27.9.a.c.n (time-series range= 26–35 cm; time-series modes= 29, 32 cm) and 27.9.a.c.s (range= 24–35 cm; mode= 27, 30, 33 cm) than in the GoC Algarve waters of the 27.9.a.s.a (range= 22–33 cm; mode= 26 cm; Table 3.2.2, Figure 3.2.10). For this last subarea, where information is available from both survey types, the acoustic surveys, although capture a relatively wider size range (range= 12–34 cm), show a size composition of the population skewed to smaller sizes (mode= 20 cm). This size composition is usually unimodal at around 18–20 cm, but showed bimodal in 2015 (19 cm, 24 cm) and 2016 (15 cm, 26 cm). Overall size range was even wider (range=10–39 cm) in the GoC Spanish waters, Subarea 27.9.a.s.c, with modes commonly found at 18 and 22 cm. The population in this subarea frequently shows mixed length–frequency distributions, with two modes (between 15–20 cm and 20–29 cm), but with a different relative importance through the series (Table 3.2.2 and Figure 3.2.14). No information about the pattern of distribution of fish size in the depth gradient is available, but a surveyed area with the deepest limit being established at 200 m in the acoustic surveys against the 500 m depth limit for bottom-trawl surveys might be the cause of such differences if it is assumed that larger fishes inhabit the GoC deepest waters in summer. A comparison between size compositions in spring and summer in GoC waters seems to indicate the occurrence of larger sizes in this last season, especially in the Subarea 27.9.a.s.c (Tables 3.2.1 and 3.2.2).

No age structure is available from the Portuguese bottom-trawl surveys. The available information is provided by the ECOCADIZ series for the GoC waters. Age structure in 2013–2018 surveys was estimated by applying IEO's 8c-9aN ALKs, whereas the age structure in summer 2019 was estimated by using the own survey's ALK. Therefore, considerations on age structure in years before 2019 should be considered with caution. Bearing in mind the above, the chub mackerel in these waters in summer time vary from age-0 up to age-8 groups, with age-0 to age-3 groups being the main ones and the juveniles (age-0) and young adults (age-1) being the dominant age groups. The age-0-age-3 range and the dominance of juveniles and sub-adults are also valid features for the 2019 age-structure. The 2016 and 2018 year classes were the strongest ones in the recent years (Figure 3.2.14).

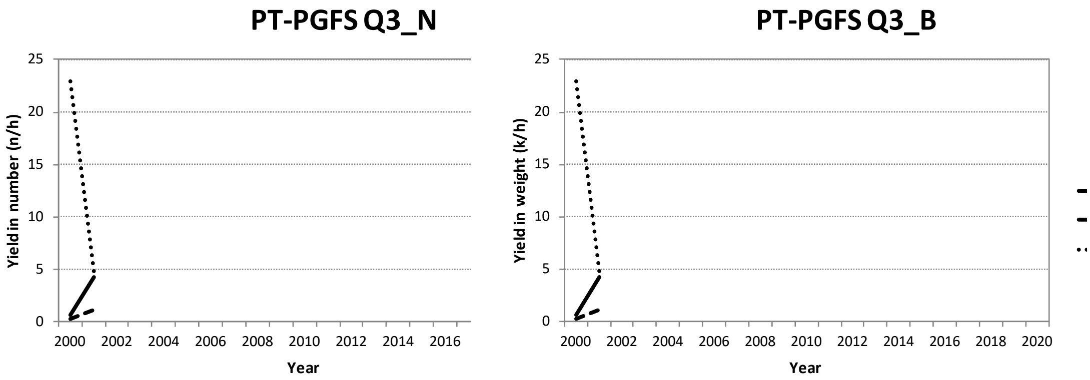


Figure 3.2.8. PT-PGFS Q3 (3rd quarter) Summer bottom-trawl survey series. ICES subdivisions 27.9.a.c.n, 27.9.a.c.s and 27.9.a.s.a (Portuguese waters). Time-series of chub mackerel relative abundance (n/haul) and biomass (kg/haul) estimates. Years 2000 and 2001.

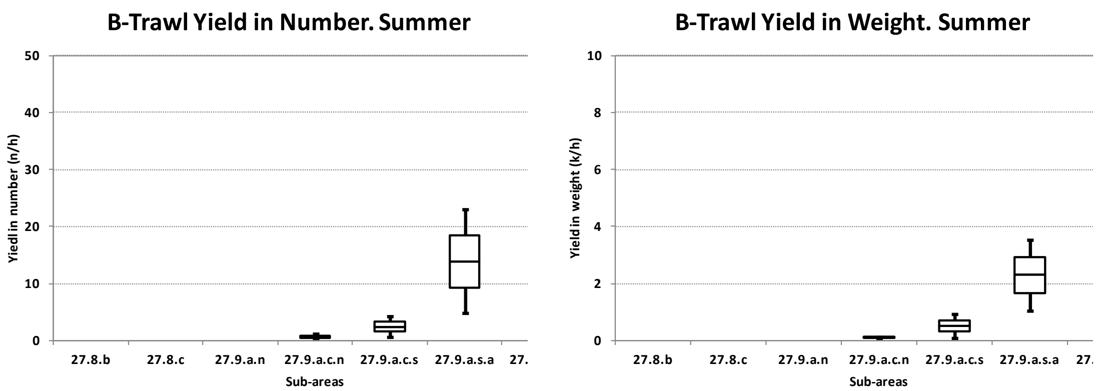


Figure 3.2.9. Summer bottom-trawl survey series. Box-plot of regional estimates of chub mackerel relative abundance (n/haul) and biomass (kg/haul). Outliers not shown. Years 2000 and 2001.

Table 3.2.2. Summer bottom- and Acoustic-trawl survey series. Main descriptors of chub mackerel size composition and age structure by subarea. The dominant mode is shown in bold. See Figures 3.2.8 and 3.2.12 for the length of the time-series. (*): data referred to the 2019 survey only.

Subarea	Survey type	Size class range (cm)	Size class mode (cm)	Age group range (yr)	Age group mode (yr)
27.9.a.c.n	Bottom-trawl	26-35	29, 32	-	-
27.9.a.c.s	Bottom-trawl	24-35	27, 30, 33	-	-
27.9.a.s.a	Bottom-trawl	22-33	26	-	-
	Acoustic-trawl	12-34	20	0-3 (*)	1 (*)
27.9.a.s.c	Acoustic-trawl	10-39	18, 21, 35	0-3 (*)	1-2 (*)

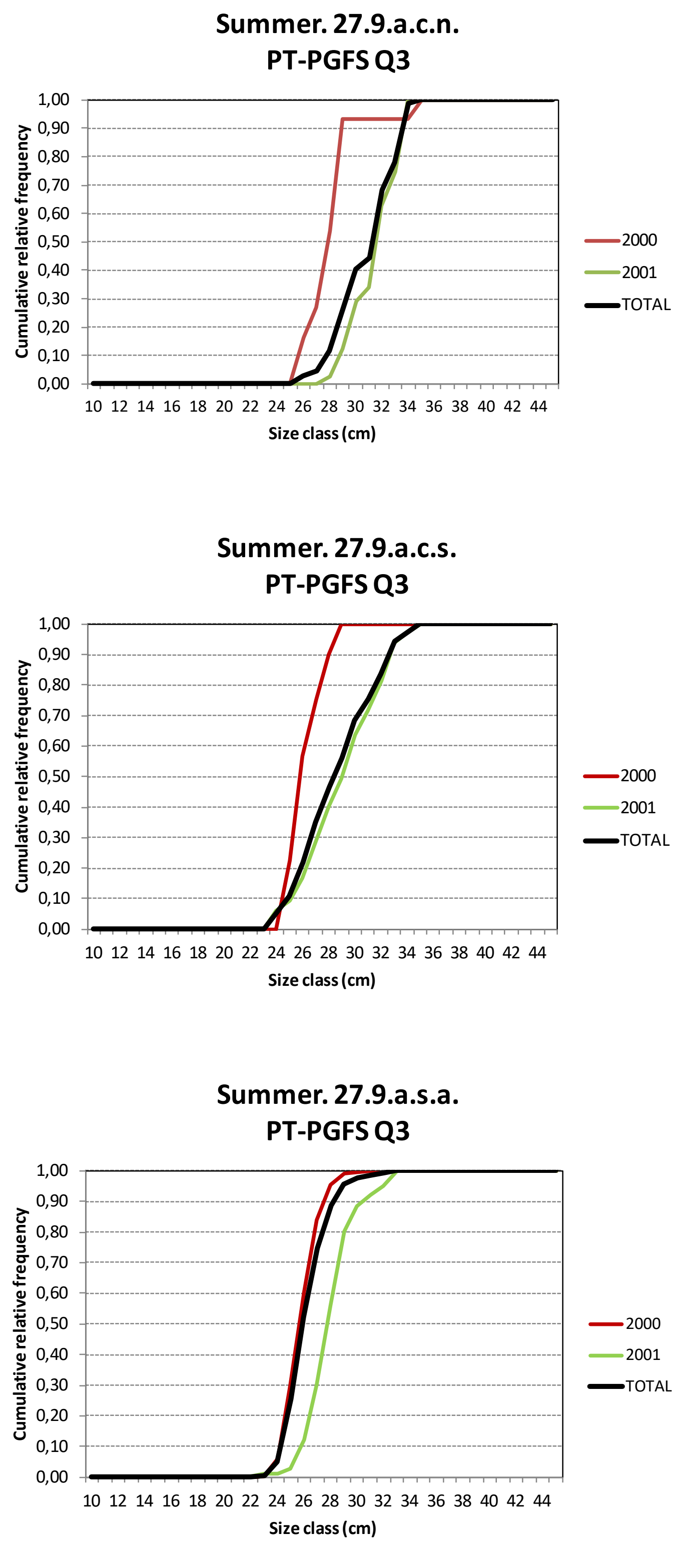


Figure 3.2.10. PT-PGFS Q3 (3rd quarter) Summer bottom-trawl survey series. Cumulative size relative frequencies for chub mackerel by ICES subdivision. Total refers to pooled data for the available time-series.

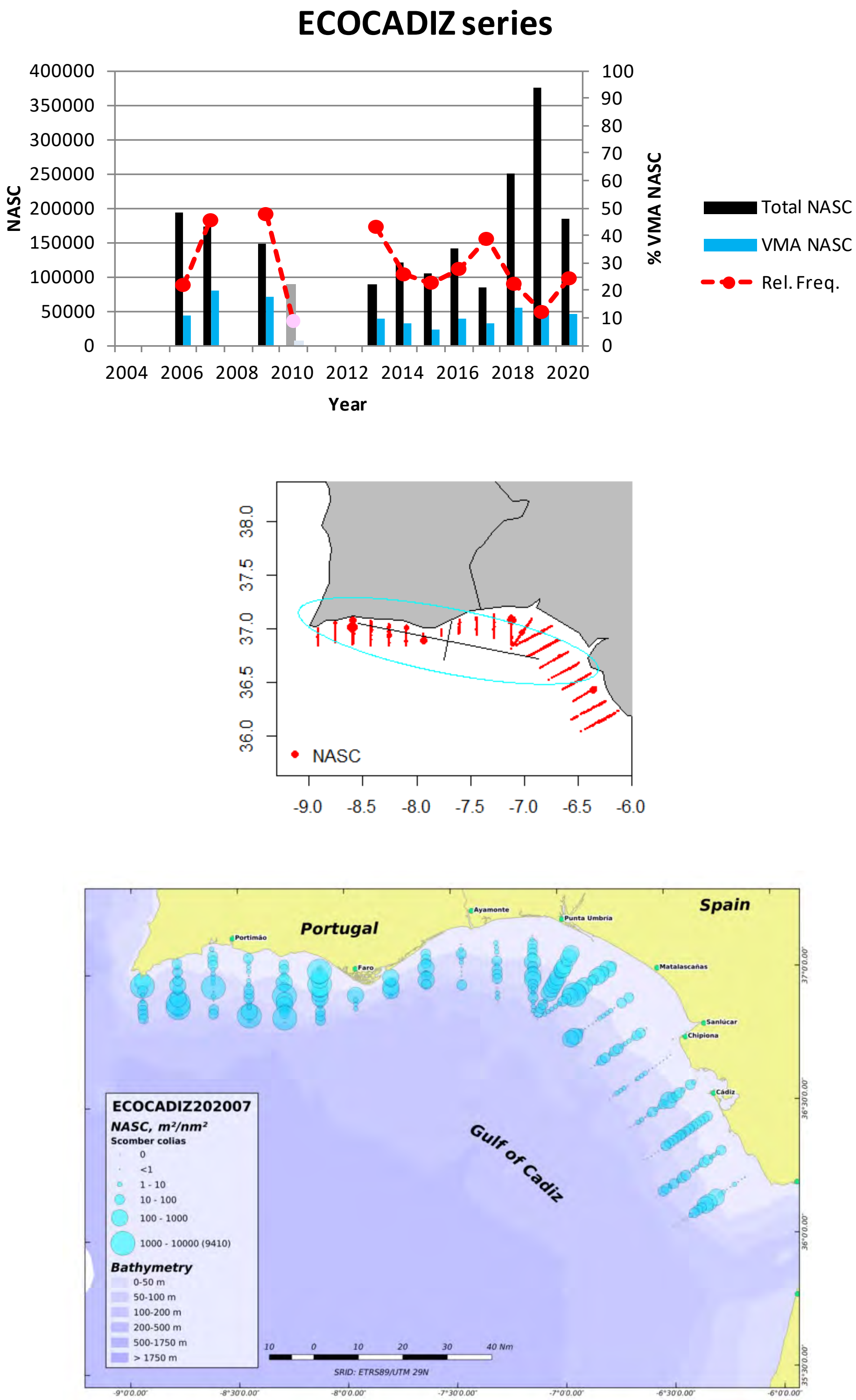


Figure 3.2.11. ECOCADIZ Summer acoustic-trawl survey series. ICES subdivisions 27.9.a.s.a and 27.9.a.s.c (Gulf of Cadiz). Upper panel: time-series of estimates of acoustic density (NASC estimates; m²nm⁻²) differentiated between total NASC and NASC allocated to chub mackerel (VMA: FAO Alpha3 code for *Scomber colias*). The 2010 survey only covered the Spanish and the Portuguese easternmost waters. Middle panel: location of the centre of gravity and the inertia of the species' distribution (pooled NASC data for years 2007–2015; sources: Canseco, 2016; Ramos and Carrera presentation during the WK; abstract without figures available in Annex 4). Bottom panel: acoustic densities (NASC, m²nm⁻²) for chub mackerel in 2020.

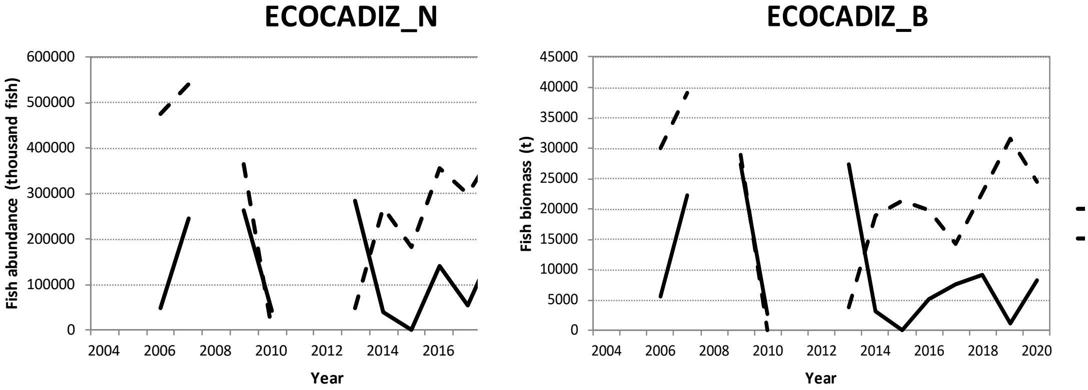


Figure 3.2.12. ECOCADIZ Summer acoustic-trawl survey series. ICES subdivisions 27.9.a.s.a and 27.9.a.s.c (Gulf of Cadiz). Time-series of chub mackerel abundance (N, in thousand fish) and biomass (B, in tonnes) estimates. Years 2004, 2006–2007, 2009–2010, 2013–2020.

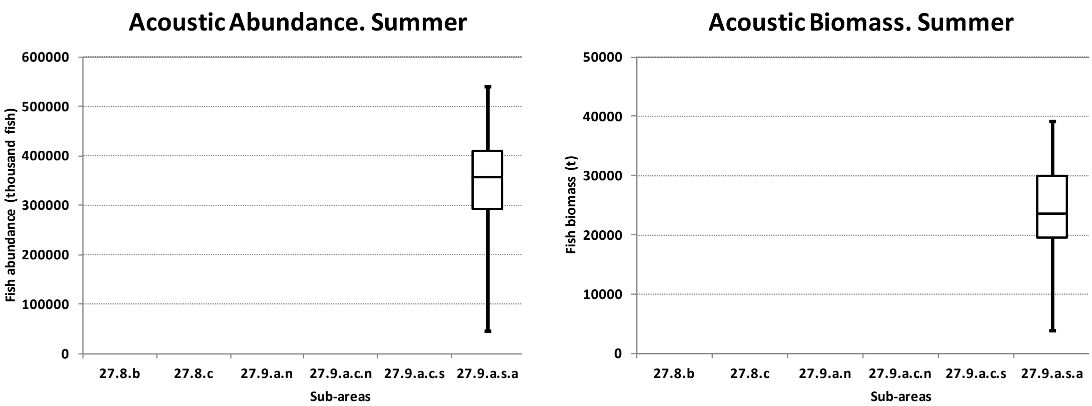


Figure 3.2.13. Summer acoustic-trawl survey series. Box-plot of regional estimates of relative abundance (n/h) and biomass (kg/h). Outliers not shown. Years 2004, 2006–2007, 2009–2010, 2013–2020.

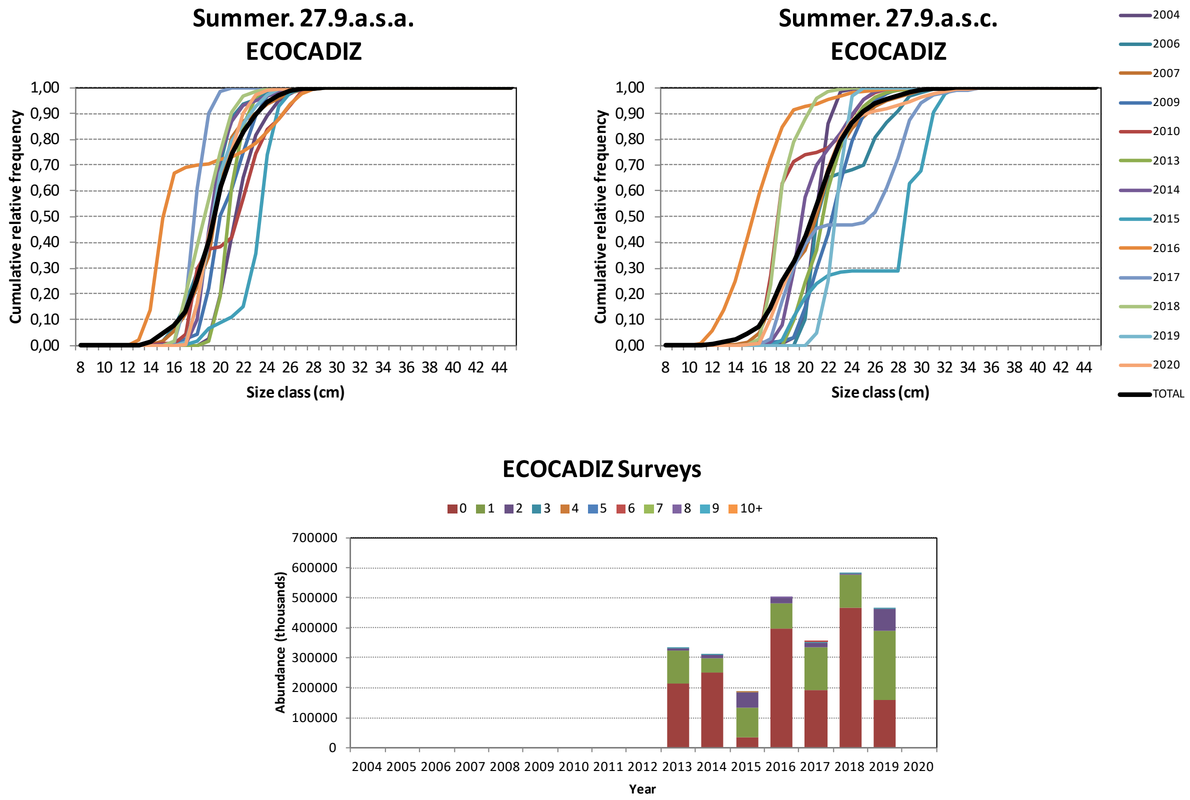


Figure 3.2.14. ECOCADIZ Summer acoustic-trawl survey series. Upper panels: cumulative size relative frequencies. Total refers to pooled data for the available time-series. Bottom panel: age structure of the estimated population in the whole surveyed area (27.9.a.s) in 2013–2019 surveys. Age structure in 2013–2018 surveys estimated by applying IEO's age–length keys from 27.8.c-27.9.a.n subareas (source: Ramos and Carrera presentation during the WK; abstract without figures available in Annex 4).

Atlantic Iberian chub mackerel abundance and biomass are assessed in autumn by two acoustic surveys (IBERAS and ECOCADIZ-RECLUTAS) which consecutively survey the subareas 27.9.a.n to 27.9.a.c.s (IBERAS) and 27.9.a.s.a and 27.9.a.s.c, the GoC waters (ECOCADIZ-RECLUTAS). IBERAS covers the most coastal waters (up to 100 m depth), whereas the GoC is surveyed by ECOCADIZ-RECLUTAS up to 200 m depth. For those waters surveyed by IBERAS the resulting chub mackerel distribution should be therefore considered as partial, but may still help to understand the dynamics of the younger fraction of the population, mainly linked to coastal waters. The eastern part of the Cantabrian Sea and BoB waters are surveyed in September by the JUVENA acoustic-trawl survey (a counterpart survey to the above ones), but it does not include so far chub mackerel as one of its target species.

Portuguese and Spanish autumn bottom-trawl surveys coordinated by the ICES IBTS program cover the entire Atlantic Iberian waters, including the Cantabrian Sea waters. Fishing gears used by each survey are different, with the Spanish one having lower vertical opening (1.5 *vs* 4.5 m) and also lower towing speed. The Spanish surveys conducted by IEO in the Cantabrian Sea (SP-NSGFS Q4, aka DEMERSALES) and GoC Spanish waters (SP-GCGFS Q4, aka ARSA) have not provided data to this workshop in the requested form by the data call and they have not been possible to be analysed in the same way than their Portuguese counterpart. Failing that, the information reported from the above Spanish surveys in the last year's report will be revisited below.

The species' distribution pattern in autumn has already been described in general terms in the introductory paragraphs accompanying the synoptic map depicted in Figure 3.1.1. IBERAS acoustic-trawl surveys show chub mackerel as a relatively common species in the Atlantic Iberian façade, especially in the Subarea 27.9.a.c.s (Alentejo area), where are recorded the species' highest acoustic densities, population abundance and biomass estimates (Figures 3.2.15, 3.2.18 and 3.2.20). The species shows a wide but patchy distribution along the IBERAS surveyed area, and data from its short time-series seem to indicate a new shift in 2020 of the centre of gravity of its distribution towards the Alentejo waters, coinciding with a sharp decrease in the population. The Portuguese bottom-trawl surveys usually record relatively low chub mackerel yields, although their regional estimates indicate, however, the Subarea 27.9.a.s.a (Algarve) as the area showing the highest yields (Figures 3.2.25 and 3.2.26). In any case, autumn data from both sources confirm the southern areas of the Atlantic Iberian waters as one of the chub mackerel preferred locations.

Noticeable changes in the aggregation patterns along the water column have also been observed during the last two IBERAS surveys. While in autumn 2019 the species showed not very dense and wide epipelagic aggregations, in autumn 2020 the species was recorded forming patchy, very thick, dense, near-bottom aggregations, which could be mixed with sardine schools (Figure 3.2.16). Additional research is needed to discern whether these patterns are exceptional or common.

Chub mackerel is still a relatively important species within the GoC autumn "acoustic SPF assemblage". Throughout the ECOCADIZ-RECLUTAS time-series the average relative contributions of the acoustic energy allocated to the species accounted on average 18% of the total NASC (Figure 3.2.17). As described for the summer counterpart survey ECOCADIZ, the highest acoustic densities (73% of the total NASC attributed to the species on average) and population estimates are recorded in the Algarve Portuguese waters (Subarea 27.9.a.s.a), reinforcing the previous observation of this area, together the Alentejo area, as one the hot spots of the species' distribution in Atlantic Iberian waters (Figures 3.2.17, 3.2.19 and 3.2.20).

The analysed time-series of autumn estimates seems to confirm two recent peaks of the population levels: one in 2017, recorded by the bottom-trawl surveys series in the Cantabrian Sea (also detected in spring) and Atlantic Iberian façade (no information is available from acoustic surveys). Recruits were the main responsible for the peak in 2017 in the Portuguese waters whereas age-1 fish were the dominant age group in the Cantabrian Sea (Figures 3.2.24 and 3.2.25). Relatively high yields were still being recorded in 2018 in the Cantabrian Sea, mainly supported by age-2 fish, but it was not the case for the Portuguese waters (Figures 3.2.24 and 3.2.25). Previous peaks in 1993 and 1995 were also recorded in Portuguese waters as estimated by the bottom-trawl survey series. The second recent autumn peak is recorded in 2019 by the acoustic surveys and it was observed in the Spanish southern Galician and Portuguese Atlantic façade waters (especially in the Alentejo area; Figure 3.2.18), as well as in the GoC (in the Algarve area; Figure 3.2.19). However, this peak was not detected in the Cantabrian Sea by the Spanish bottom-trawl survey and no information is available for Portuguese waters.

Size composition of the chub mackerel in autumn in the Cantabrian Sea has to be inferred from the Figure 3.2.24, which seems to depict an overall size range between 10–40 cm, with 24 and 26 size classes being the dominant ones, as a result of a certain increasing trend in size in the last years. Concerning the age-structure, age-0 to age-3+ groups are considered, with 1-year olds being the dominant age group followed by 2-year olds, with these older fish being more abundant in recent years. Along the Atlantic Iberian façade, no regional information on the chub mackerels' size composition is available from IBERAS surveys, with data being referred to the whole surveyed area, where a size range of 18-30 cm was recorded, with modes at 21, 22, 26 and 29 cm size classes depending on the year, although 22 cm was the most common mode. The Portuguese bottom-trawl surveys recorded wider size ranges (9–43 cm) than the acoustic ones, with smaller fish being recorded in the Algarve waters and larger ones in the Alentejo area (Table 3.2.13; Figures 3.2.21 and 3.2.27). Information available on age structure from these areas comes from the IBERAS surveys, where individuals are grouped into age-0 to age-3, with the 1-year old individuals being the most common. Fishes older than three years, even up to 7–8 years old, have been recorded in some years and areas. ECOCADIZ-RECLUTAS surveys usually record wider size ranges in the Spanish waters of the GoC than in the Algarve. Modal sizes, however, are quite similar (23 cm as the dominant size class, 15 cm as a secondary one). Age structure is quite similar to the one recorded in northern areas, with chub mackerels being structured around the age-0 to age-3 groups, and the 1-year olds being the dominant group as well (Table 3.2.13 and Figure 3.2.23).

Interestingly, the strong 2016 year class can be well tracked until 2018 in both acoustic- and bottom-trawl surveys in the Cantabrian Sea (Figure 3.2.24). The 2017 and noticeably the 2018 year classes showed a relative strength in the Atlantic Iberian façade and GoC waters, which is still detected in 2019 (2017 cohort) and 2020 (2018 cohort), respectively. In these last areas the 2016 cohort was only tracked shortly in the southernmost waters (Figures 3.2.22 and 3.2.23).

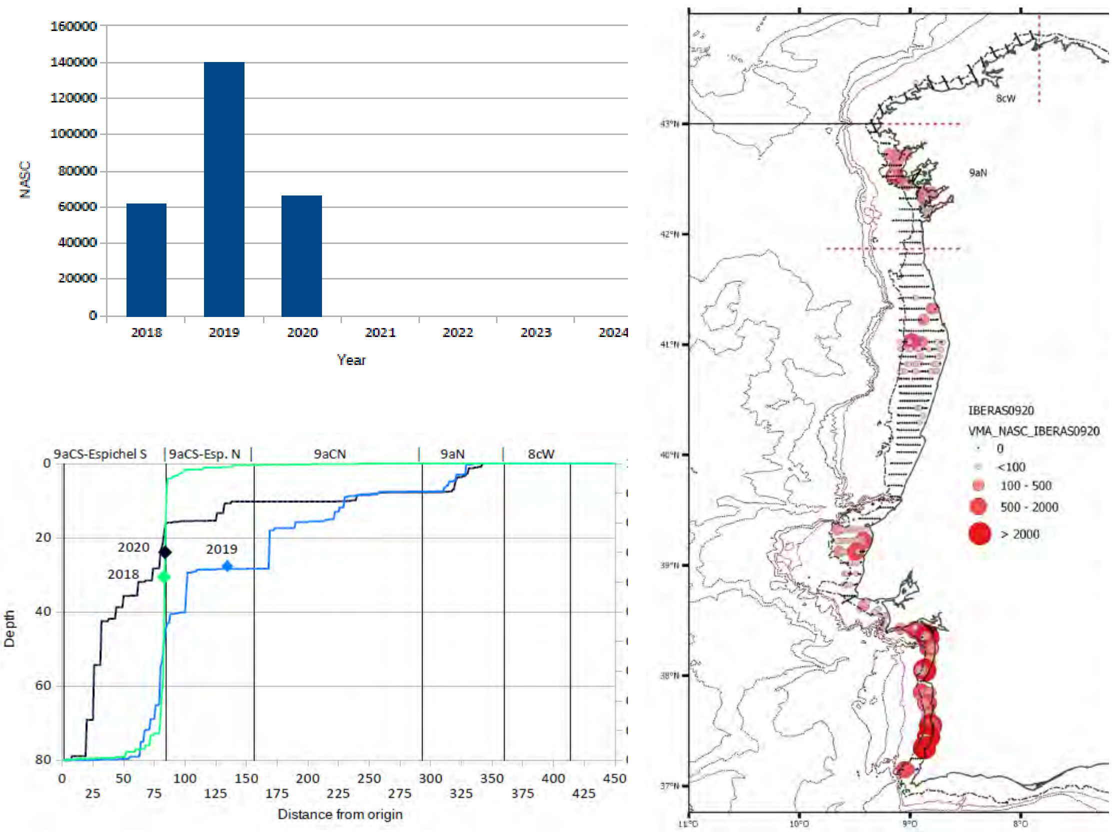


Figure 3.2.15. IBERAS Autumn acoustic-trawl survey series. ICES subdivisions 27.9.a.n to 27.9.a.c.s (southern Galician and Portuguese Iberian Atlantic façade waters). Left-upper panel: time-series of chub mackerel's estimates of acoustic density (NASC estimates; m^2nm^{-2}). Left-bottom panel: location of the centre of gravity of the species' distribution. Right panel: distribution of the acoustic densities (NASC, m^2nm^{-2}) in the 2020 survey. (source: Ramos and Carrera, 2021, presentation during the WK; abstract without figures available in Annex 4).

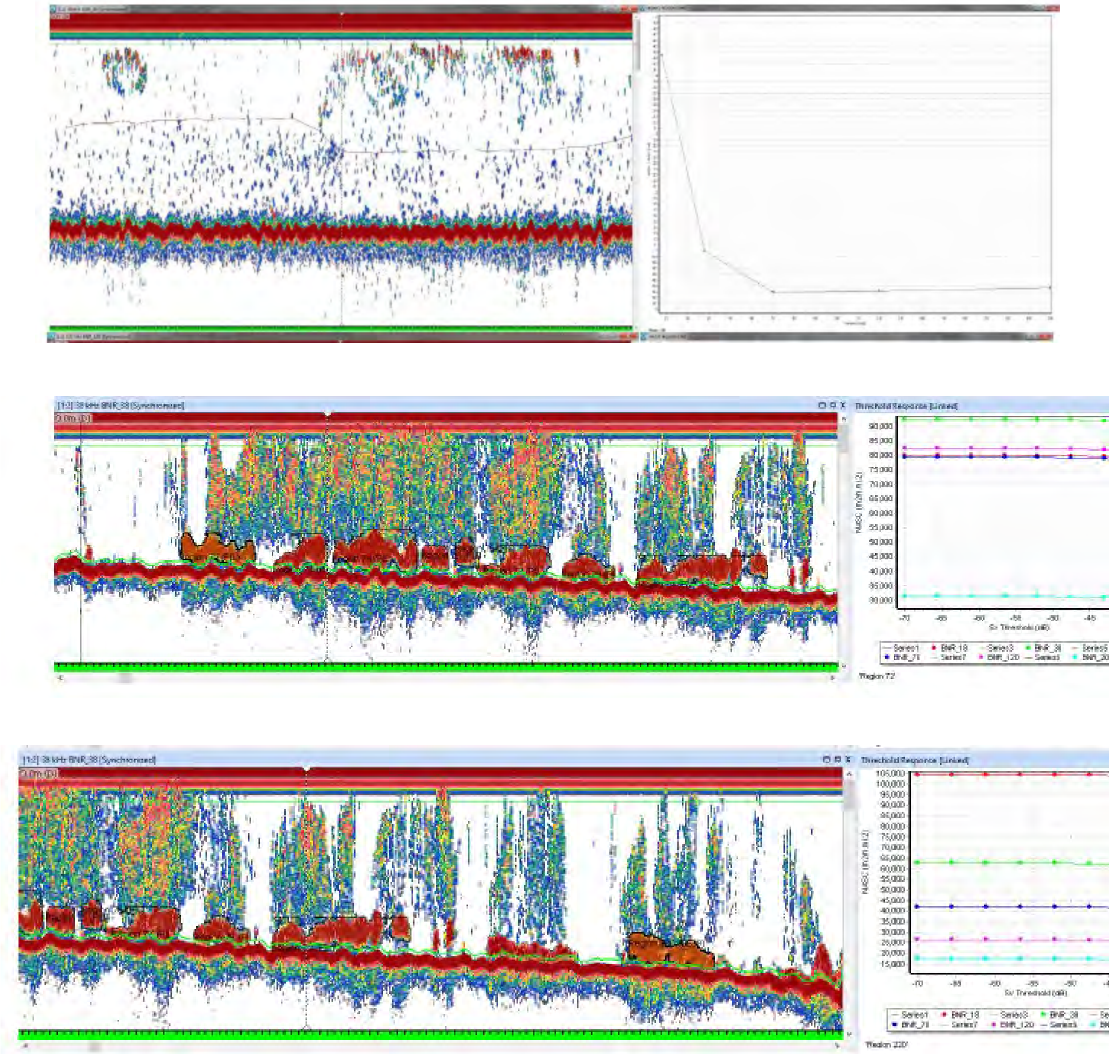


Figure 3.2.16. IBERAS Autumn acoustic-trawl survey series. ICES subdivisions 27.9.a.n to 27.9.a.c.s (southern Galician and Portuguese Iberian Atlantic façade waters). Upper panel: a 38 kHz original echogram showing not very dense chub mackerel epipelagic aggregations and their frequency response recorded during IBERAS0919. Middle and bottom panels: 38 kHz original echograms showing thick, dense and near-bottom chub mackerel aggregations (with some mixing with sardine schools) and their frequency responses recorded during IBERAS0920.

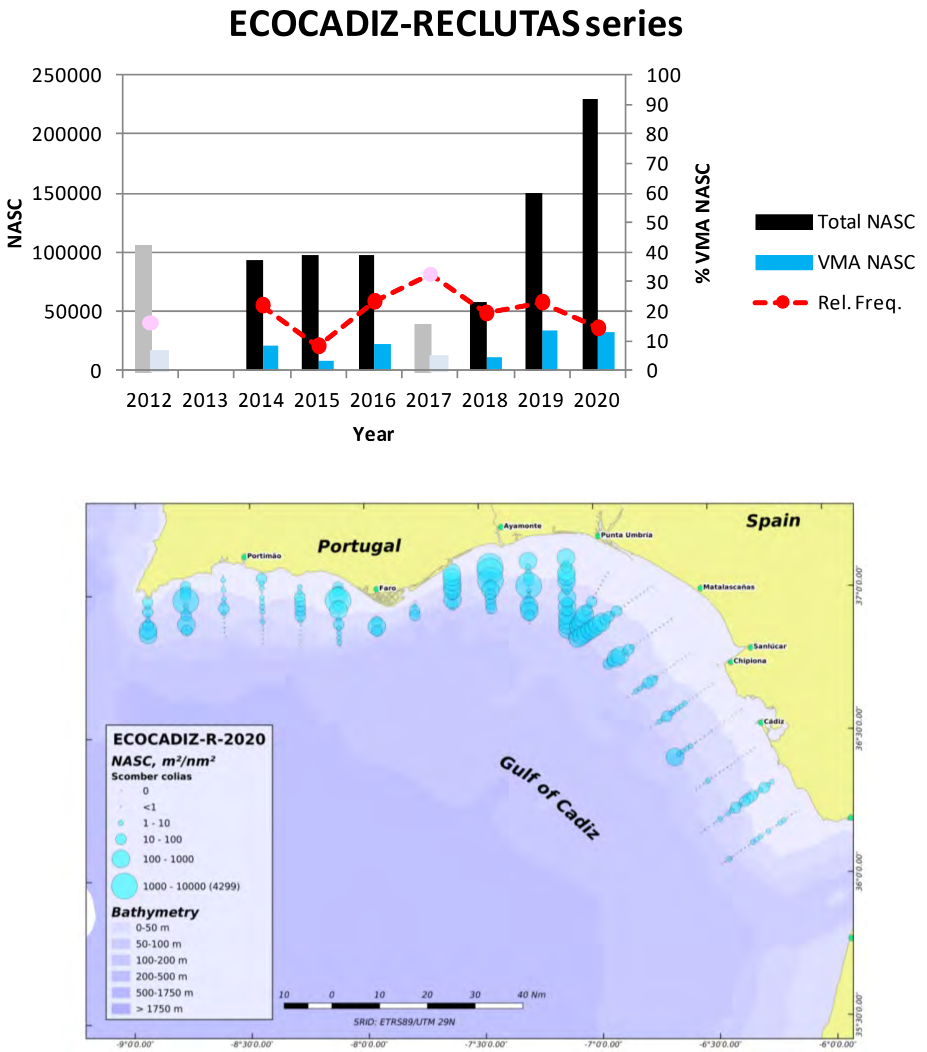


Figure 3.2.17. ECOCADIZ-RECLUTAS Autumn acoustic-trawl survey series. ICES subdivisions 27.9.a.s.a and 27.9.a.s.c (Gulf of Cadiz). Upper panel: time-series of estimates of acoustic density (NASC estimates; m²nm⁻²). The 2012 survey only covered the Spanish waters whereas the 2017 survey only covered the Spanish eastern waters because of a serious breakdown of the vessel's propulsion system. Bottom panel: distribution of the acoustic densities (NASC, m²nm⁻²) for chub mackerel in 2020 (source: Ramos and Carrera presentation during the WK; abstract without figures available in Annex 4).

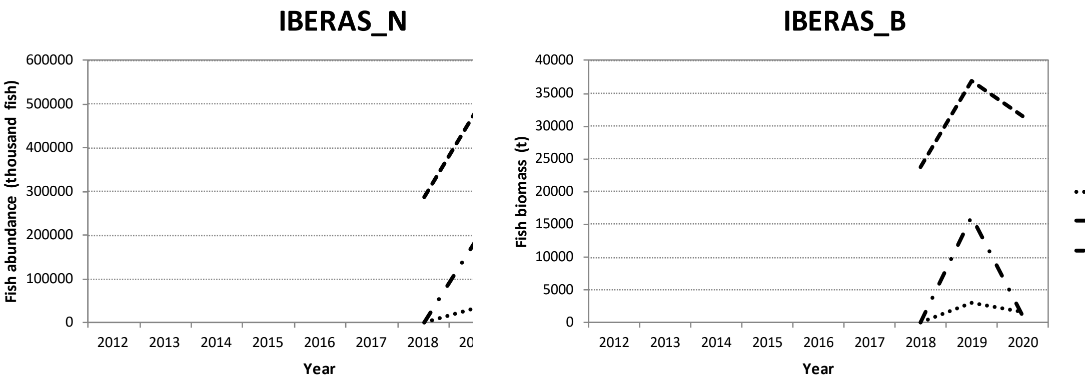


Figure 3.2.18. IBERAS Autumn acoustic-trawl survey series. ICES subdivisions 27.9.a.n to 27.9.a.c.s (Spanish southern Galician and Portuguese Atlantic façade waters). Time-series of chub mackerel abundance (N, in thousand fish) and biomass (B, in tonnes) estimates for years 2018–2020.

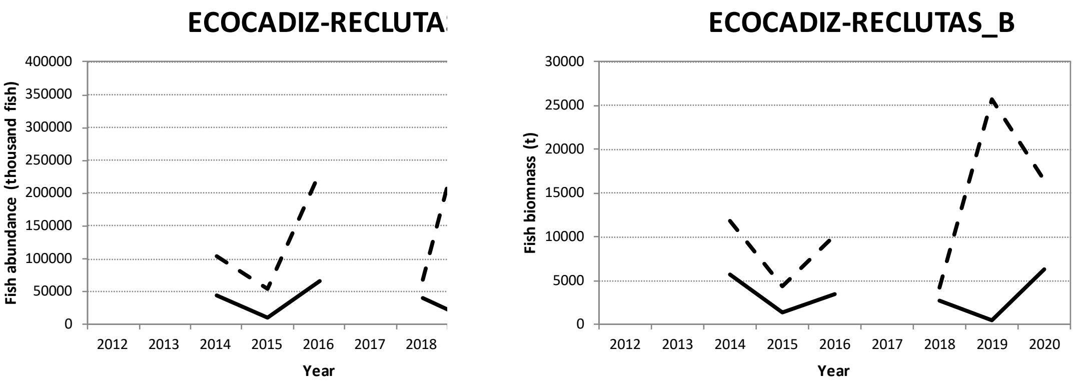


Figure 3.2.19. ECOCADIZ-RECLUTAS Autumn acoustic-trawl survey series. ICES subdivisions 27.9.a.s.a and 27.9.a.s.c (Gulf of Cadiz). Time-series of chub mackerel abundance (N, in thousand fish) and biomass (B, in tonnes) estimates. Years 2014–2016, 2018–2020.

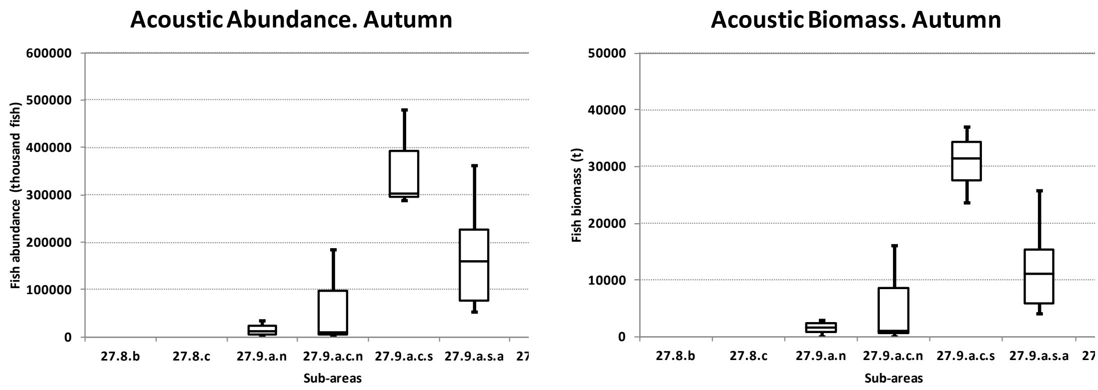


Figure 3.2.20. Autumn acoustic-trawl survey series. Box-plot of regional estimates of chub mackerel abundance (in thousand fish) and biomass (in tonnes) estimates. Outliers not shown. Years 2014–2016, 2018–2020.

Table 3.2.3. Autumn bottom- and acoustic-trawl survey series. Main descriptors of chub mackerel size composition and age structure by subarea. The dominant mode is shown in bold. See Figures 3.2.18, 3.2.19, 3.2.24 and 3.2.25 for the length of the time-series. (*): data referred to the 2018 survey only.

Subarea	Survey type	Size class range (cm)	Mode (cm)	Age group range (yr)	Mode (yr)
27.8.c – 27.9.a.n	Bottom-trawl	10-40	24, 26	0-3+	1, 2
27.9.a.n – 27.9.a.c.s	Acoustic-trawl	18-30	21, 22, 26, 29	-	-
27.9.a.n	Acoustic-trawl	-	-	0-3, (0-8)*	1
27.9.a.c.n	Bottom-trawl	15-40	19	-	-
	Acoustic-trawl	-	-	0-5, (0-7)*	1
27.9.a.c.s	Bottom-trawl	14-43	20	-	-
	Acoustic-trawl	-	-	0-3, (0-7)*	1
27.9.a.s.a	Bottom-trawl	9-39	18	-	-
	Acoustic-trawl	13-29	15, 23	0-3	1
27.9.a.s.c	Acoustic-trawl	12-36	15, 23	0-3	1

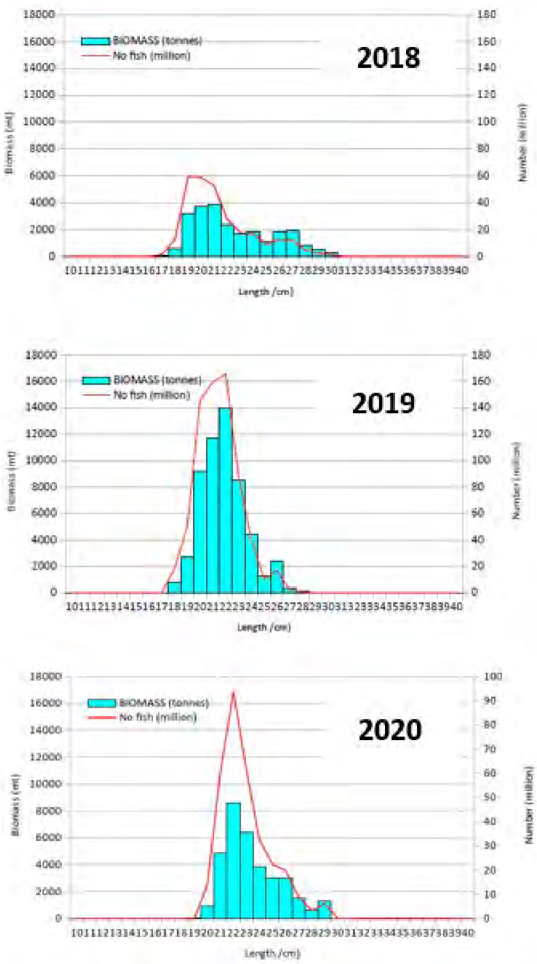


Figure 3.2.21. IBERAS Autumn acoustic-trawl survey series. Right panels: size composition of chub mackerel's population in numbers (million) and biomass (mt), (source: Ramos and Carrera presentation during the WK; abstract without figures available in Annex 4).

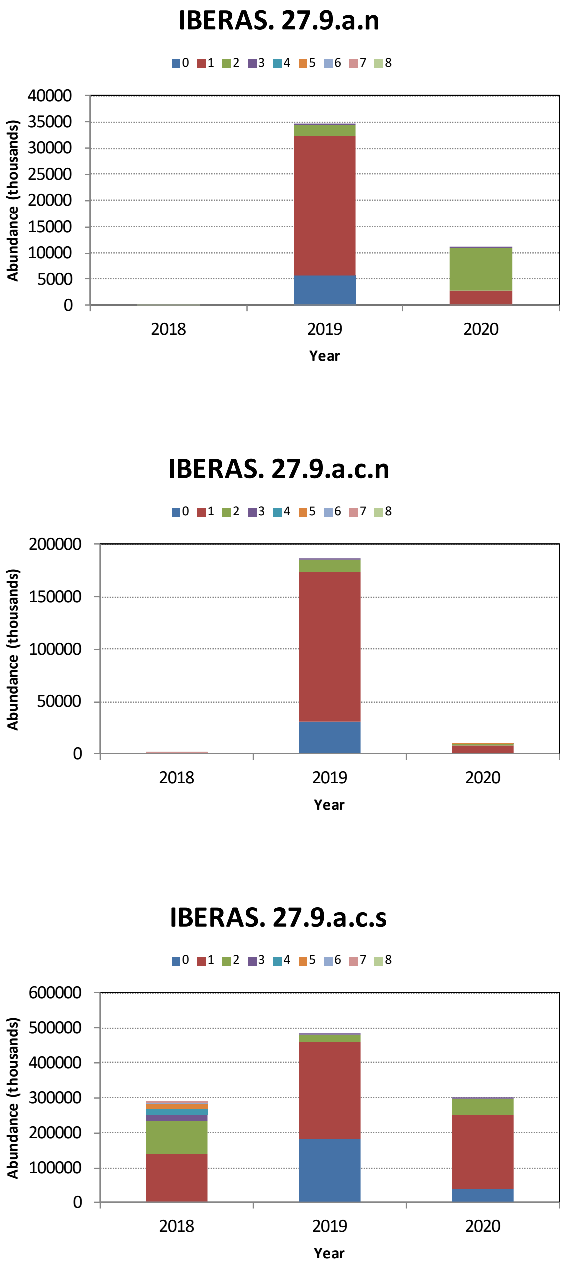
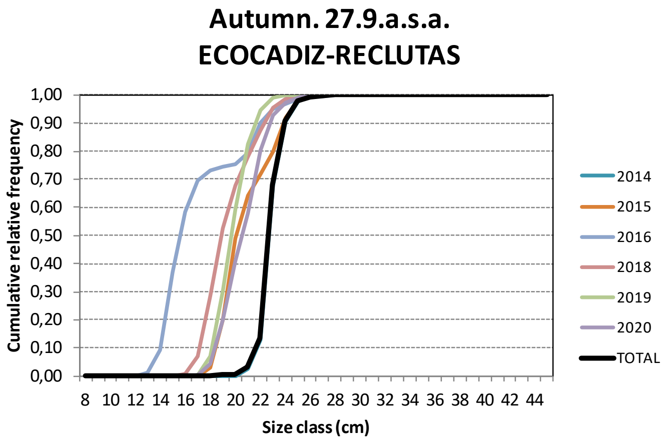
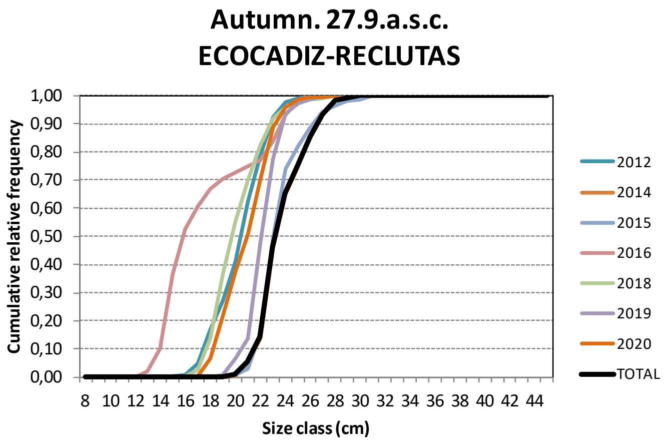


Figure 3.2.22. IBERAS Autumn acoustic-trawl survey series. Age structure of the chub mackerel estimated population (in thousands).





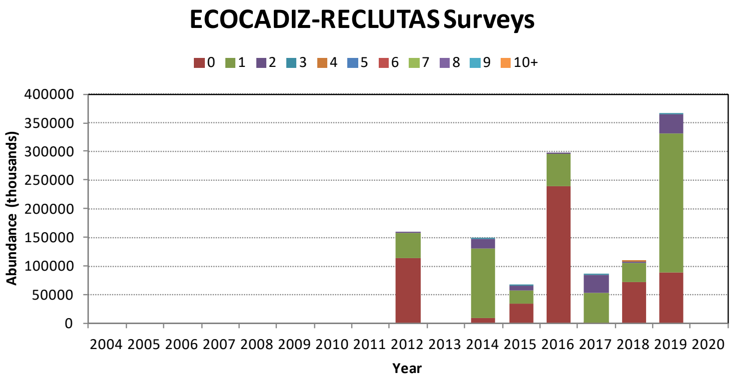


Figure 3.2.23. ECOCADIZ-RECLUTAS Autumn acoustic-trawl survey series. Upper and middle panels: cumulative size frequencies for chub mackerel. Total refers to pooled data for the available time-series (2012–2020). Bottom panel: age structure of the estimated population in the surveyed area (27.9.a.s) in 2012–2019 surveys. Age structure in 2012-2018 surveys estimated by applying IEO's age–length keys from 27.8.c–27.9.a.n subareas (source: Ramos and Carrera presentation during the WK; abstract without figures available in Annex 4).

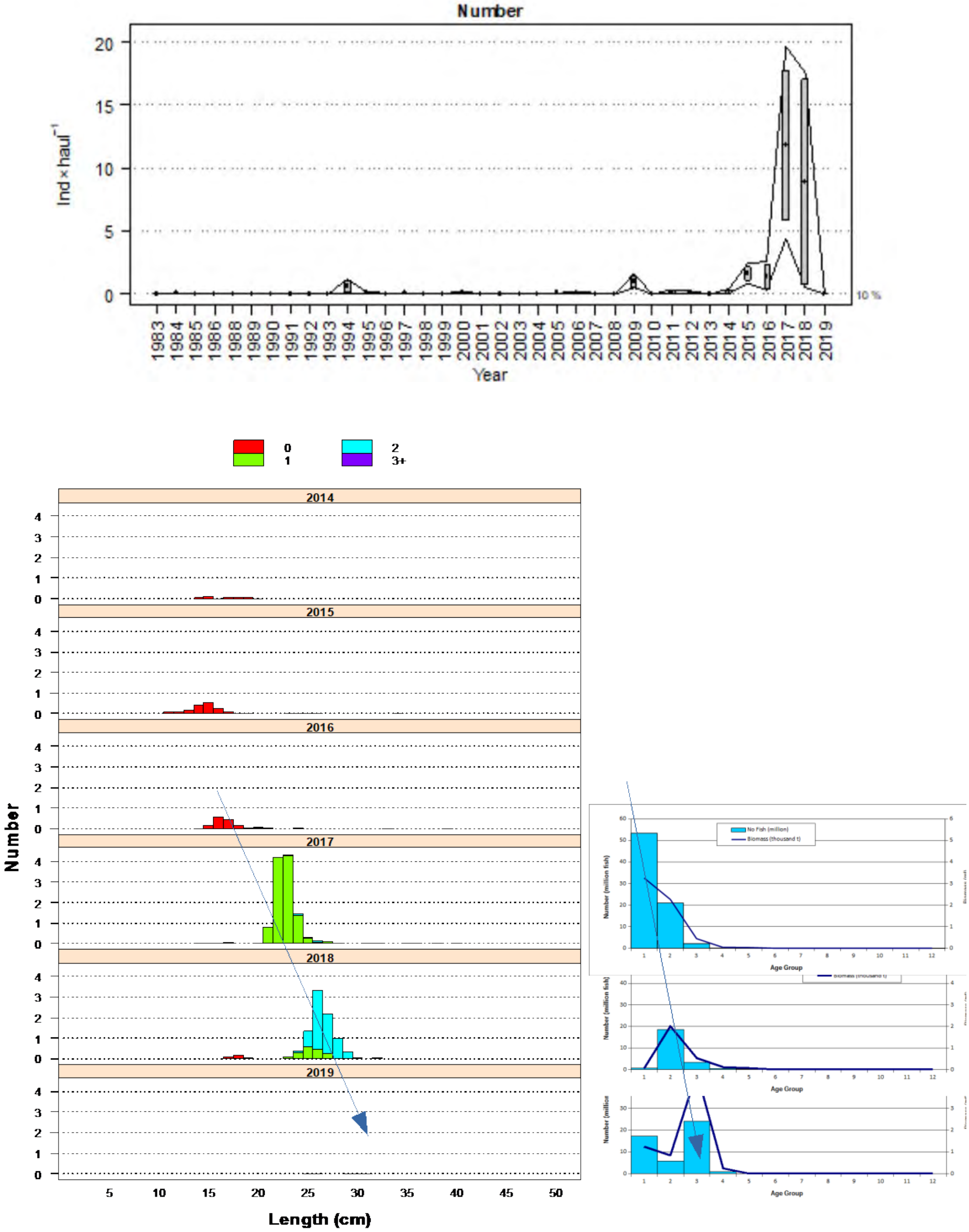


Figure 3.2.24. SP-NSGFS Q4 (DEMERSALES) bottom-trawl survey series. Autumn. ICES subdivisions 27.9.8.c to 27.9.a.n (Cantabrian Sea and Galician waters). Upper panel: time-series of estimates of relative abundance (n/haul). Time period: 1983–2019. Bottom panel: chub mackerel age structure from north DEMERSALES autumn bottom-trawl survey (left) and PELACUS spring acoustic-trawl survey (right). Arrows are tracking the 2016 cohort along the time-series (ICES, 2020).

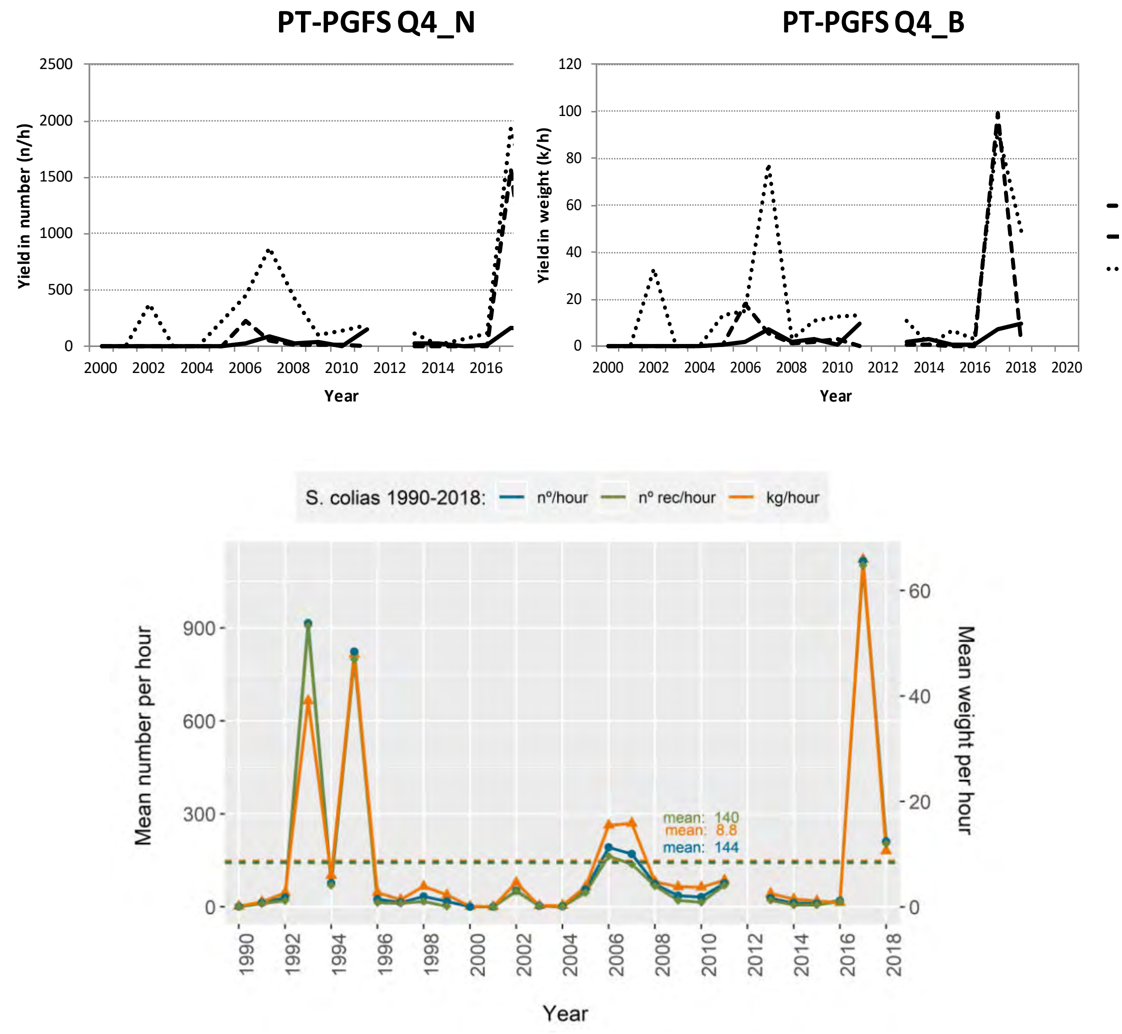


Figure 3.2.25. PT-PGFS Q4 Autumn bottom-trawl survey series. ICES sub-divisions 27.9.a.c.n to 27.9.a.s.a (Portuguese waters). Upper panels: Time-series of regional estimates of chub mackerel relative abundance (n/haul) and biomass (kg/haul). Years 2000–2011, 2013–2018. Bottom panel: time-series of overall estimates, with indication of yield in number of recruits. Years 1990–2011, 2013–2018 (ICES, 2020).

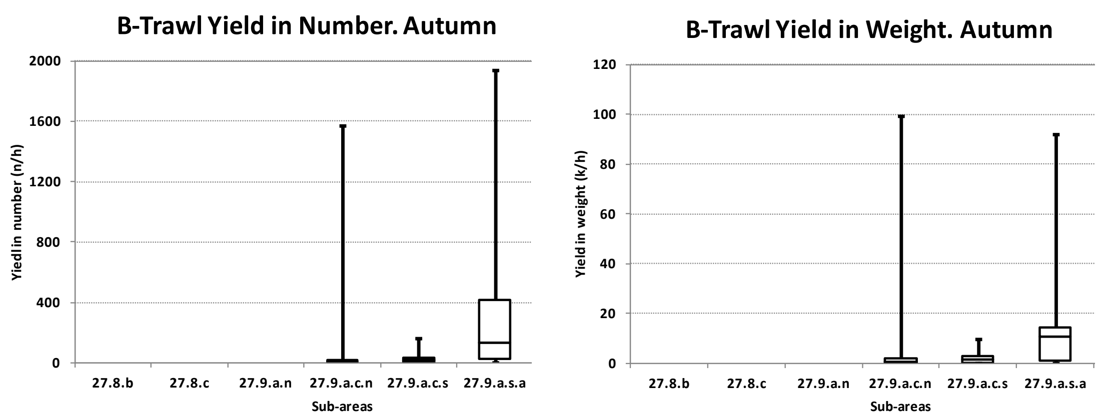
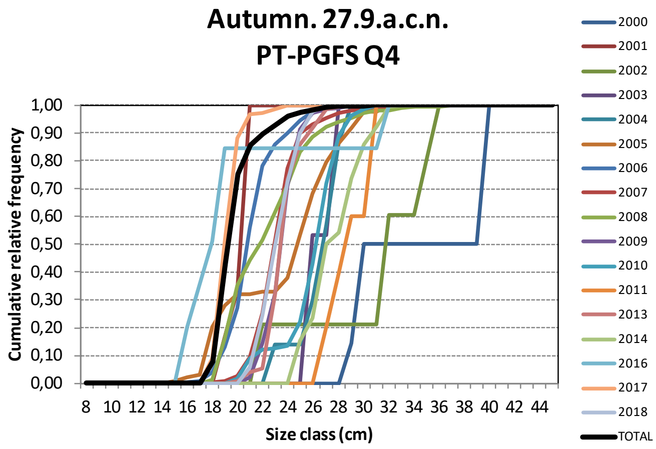
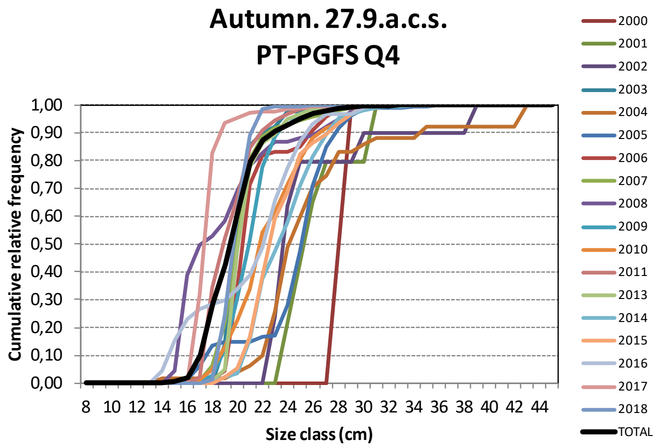


Figure 3.2.26. Autumn bottom-trawl survey series. Box-plot of regional estimates of chub mackerel relative abundance (n/haul) and biomass (kg/haul). Outliers not shown. Years 2000–2011, 2013–2018.





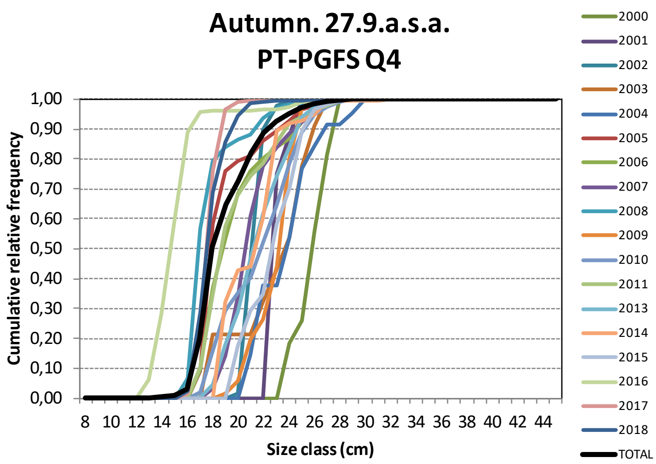


Figure 3.2.27. PT-PGFS Q4 Autumn bottom-trawl survey series. Chub mackerel cumulative size relative frequencies. Total refers to pooled data for the available time-series.

The information about the Atlantic Iberian chub mackerel levels in winter is restricted to the results from four Portuguese bottom-trawl surveys conducted in the 2005–2008 period along the Portuguese mainland waters (27.9.a.c.n to 27.9.a.s.a). As described before for warmer seasons, the species still prefers to inhabit the southernmost waters, off the Algarve (Figure 3.2.29), although during the referenced period chub mackerel seemed to exhibit a shift in its distribution in 2007 towards northernmost waters, based on the peak recorded in 2007 for the Subarea 27.9.a.c.n (Figure 3.2.28). The regional size composition for the species in winter time do not seem to differ from those described for the remaining seasons, but in summer time, when the largest sizes in the year are recorded. Size ranges varied between 15–35 cm (mode at 20 cm) in 27.9.a.c.n, 16–41 cm (mode at 18 cm) in 27.9.a.c.s, and 17-37 cm (mode at 19, the dominant one, and 23 cm; Figure 3.2.30, Table 3.2.4) in 27.9.a.s.a. No data on winter age-structure for chub mackerel are available.

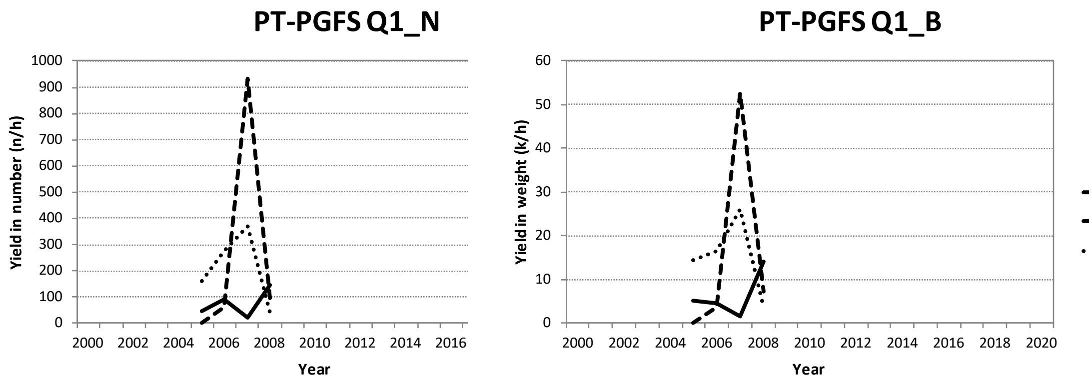


Figure 3.2.28. PT-PGFS Q1 Winter bottom-trawl survey series. ICES subdivisions 27.9.a.c.n to 27.9.a.s.a (Portuguese waters). Time-series of regional estimates of chub mackerel relative abundance (n/haul) and biomass (kg/haul). Period: 2005–2008.

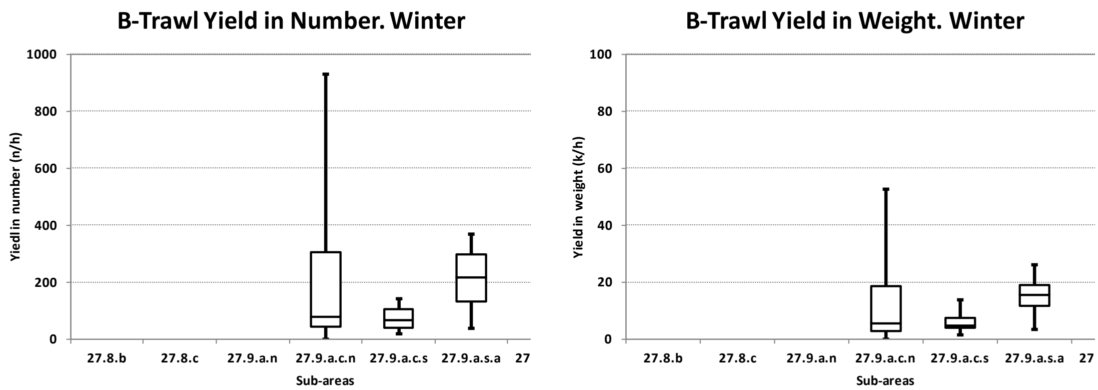


Figure 3.2.29. Winter bottom-trawl survey series. Box-plot of regional estimates of chub mackerel's relative abundance (n/haul) and biomass (kg/haul). See Figure 3.2.28 for the length of the time-series. Outliers not shown.

Table 3.2.4. Bottom-trawl winter survey series. Main descriptors of chub mackerel size composition and age structure by subarea. The dominant mode is shown in bold. See Figure 3.2.28 for the length of the time-series.

Subarea	Survey type	Size class range (cm)	Mode (cm)	Age group range (yr)	Mode (yr)
27.9.a.c.n	Bottom-trawl	15-35	20	-	-
27.9.a.c.s	Bottom-trawl	16-41	18	-	-
27.9.a.s.a	Bottom-trawl	17-37	19, 23	-	-

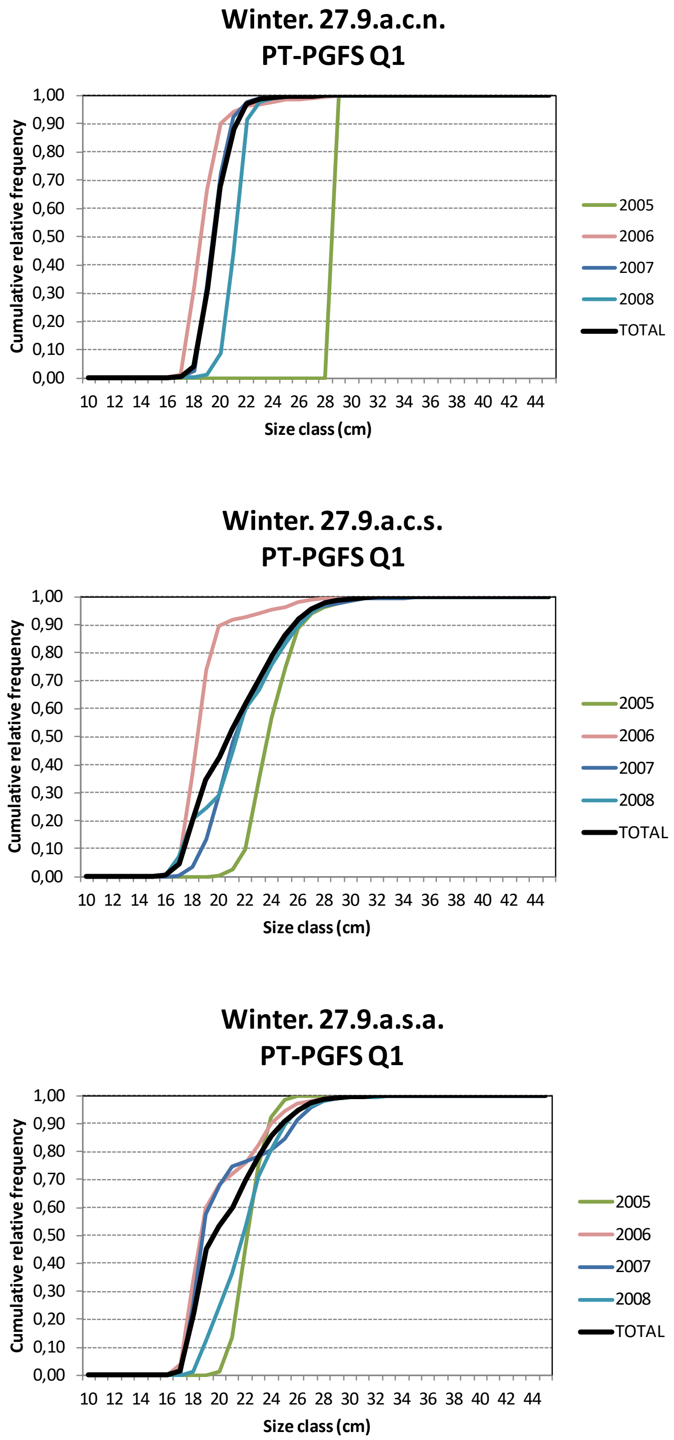


Figure 3.2.30. Bottom-trawl winter survey series. Cumulative size relative frequencies for chub mackerel. Total refers to pooled data for the available time-series.

3.3 Distribution in African waters

As part of the regular monitoring of small pelagic fish stocks in the Moroccan coasts, acoustic surveys are conducted aboard the INRH-Research vessel 'AL AMIR MOULAY ABDELLAH' along the two Moroccan façades, i.e. Atlantic and Mediterranean. The objective of these surveys is to evaluate the small pelagic fish biomass and abundance indices, their demographic structure, spatial distribution and ecological indicators.

In 2019, eight acoustic surveys were carried out in spring and autumn, covering the entire Moroccan waters, which include both the Mediterranean (Subarea: 37.1.1, or GSA4 and 6), and the Atlantic Moroccan zones (North subarea: 34.1.11; the Central subarea: 34.1.12 and 13; and the South subarea: 34.1.31 and 32). In addition, three other surveys were carried out by international research vessels; two of these surveys were undertaken by the Russian research vessel AtlantNiro, to which the researchers of the INRH also participated. One of the latter was dedicated to the acoustic assessment, and the other to the recruitment of small pelagic fish from Cap Cantin to Cap Blanc regions (subareas 34.1.13, 34.1.31 and 34.1.32). The third survey took place on board the research vessel Dr Fridtjof Nansen as part of the FAO EAF/Nansen project with the aim of assessing the small pelagic fish in the Atlantic area between Cap Blanc and Casablanca (subareas 34.1.12, 34.1.13, 34.1.31 and 34.1.32). A summary of some indicators about these surveys in 2019 are summarized in Table 3.3.1.

Table 3.3.1. NW African (Morocco) acoustic surveys indicators in 2019. Biomass and abundance of *Scomber colias* estimates obtained during these surveys are indicated.

Area	RV	Survey-type	Total number trawls	Total oceano-graphic stations	Number of work-ing days	Bio-mass (1000 tons)	Abun-dance (millions)
SPRING-2019							
Mediteranean	AMA-INRH	Acoustic	24	46	14	7	60
North (34.1.11)	AMA-INRH	Acoustic	48	39	19	452	6219
Central (34.1.12 & 13)	AMA-INRH	Acoustic	68	41	22	170	2954
South (34.1.31 & 32)	AMA-INRH	Acoustic	70	45	28	365	4446
TOTAL			210	171	83	994	13 679
AUTUMN-2019							
Mediteranean	AMA-INRH	Acoustic	26	45	12	-	-
North (34.1.11)	AMA-INRH	Acoustic	24	22	10	338	5085
Central (34.1.12 & 13)	AMA-INRH	Acoustic	68	-	26	412	5902
South (34.1.31 & 32)	AMA-INRH	Acoustic	80	38	29	153	1463
Central and South	ATLANTNIRO-Russian	Acoustic	149	75	45	-	-
TOTAL			347	180	122	903	12 450

The prospecting was carried out over the entire distribution area of the pelagic resources, following the standard methodology of acoustic surveys, consisting of radials perpendicular to the coast, spaced 10 nautical miles, and starting from about 20 meters depth onshore, up to the bathymetry of 500 meters offshore in the Atlantic area, while the transects in the Mediterranean zone were spaced 5 nautical miles, up to 300 meters depth (Figure 3.3.1).

The echosounder used was the SIMRAD-EK60 that operated with the two frequencies of 38 and 120 kHz, adopting a main pulse duration of 1 ms. The visualization and "scrutinizing" of the echograms was performed using the EchoView. One nautical mile (1 nm) was used as elementary distance sampling unit ("EDSU").

Based on the biological data collected during the surveys, the total fish length threshold considered to separate juveniles from adults of chub mackerel was 24 cm.

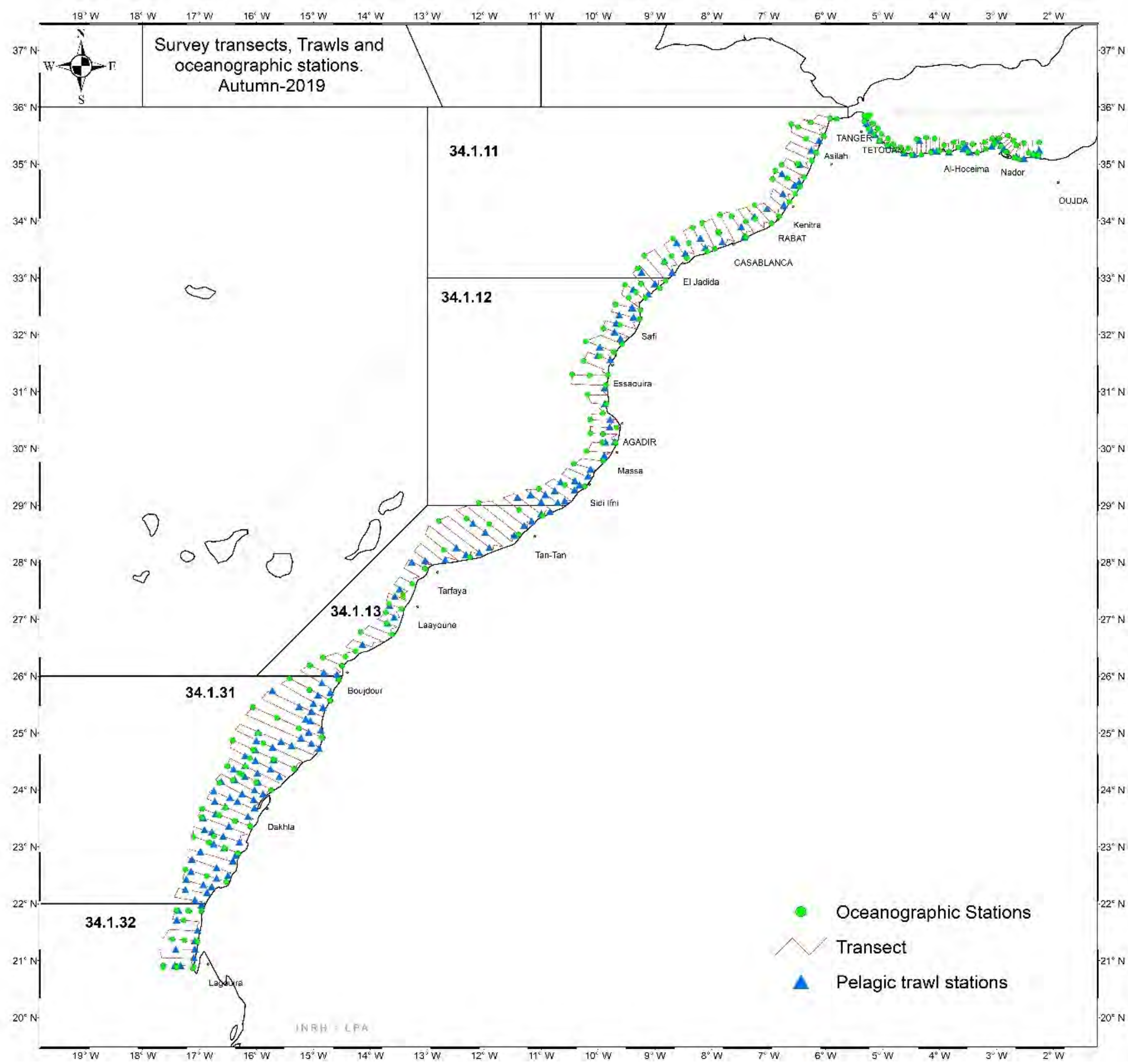


Figure 3.3.1. Prospecting acoustic transects, pelagic trawl stations and oceanographic stations during the Acoustic Autumn surveys in 2019.

3.3.1 Spatial distribution

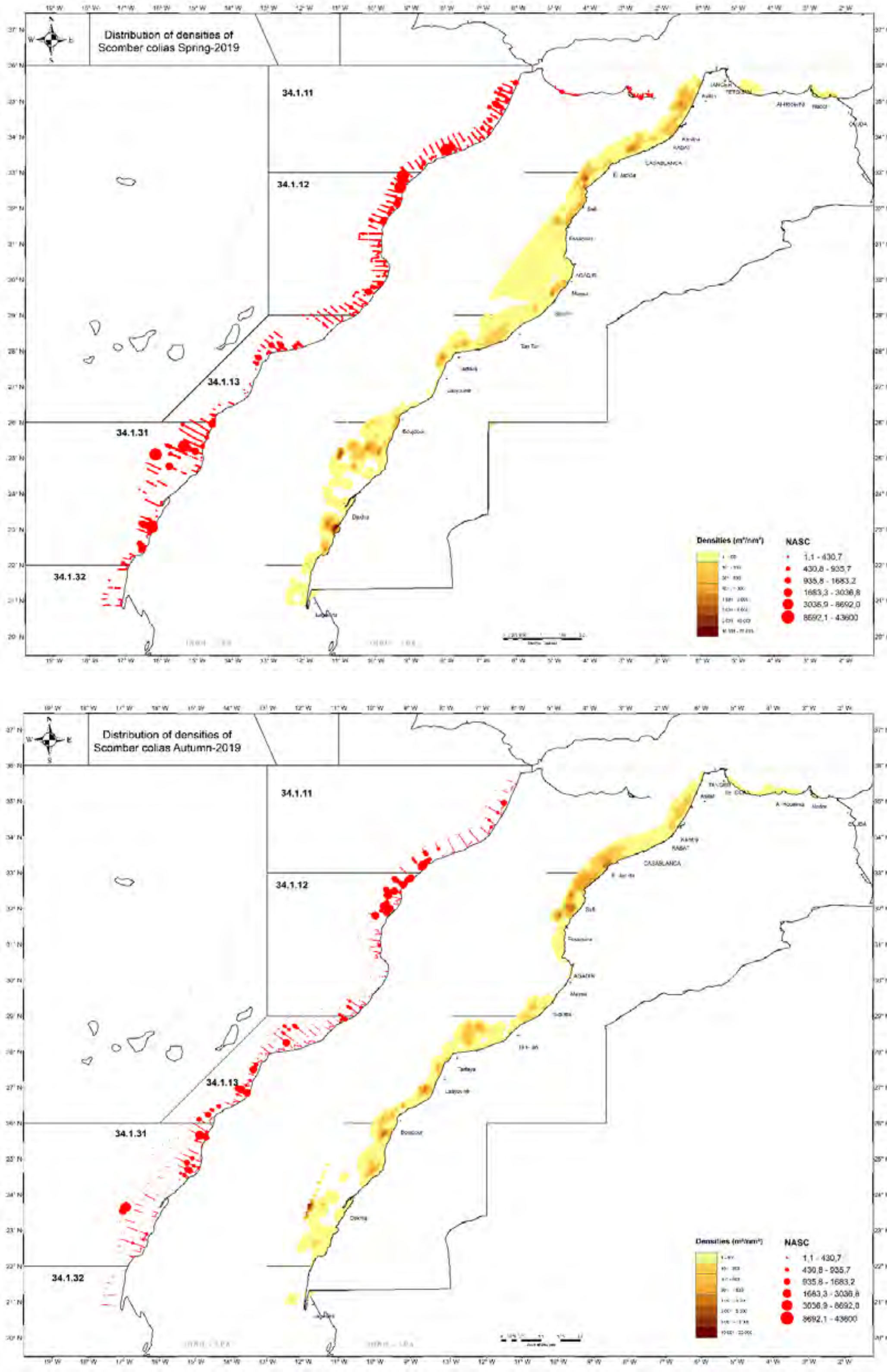
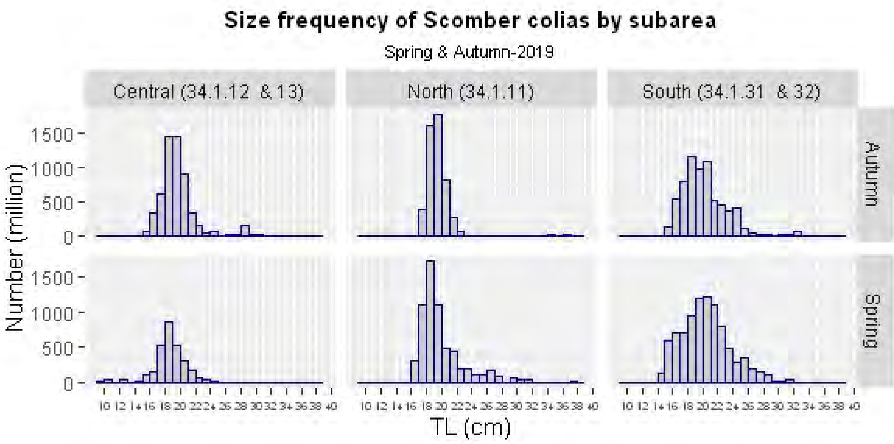


Figure 3.3.1.1. Spatial distribution of *Scomber colias* in the NW African coast (Morocco) – Spring (upper panel) and Autumn (lower panel) 2019 surveys.



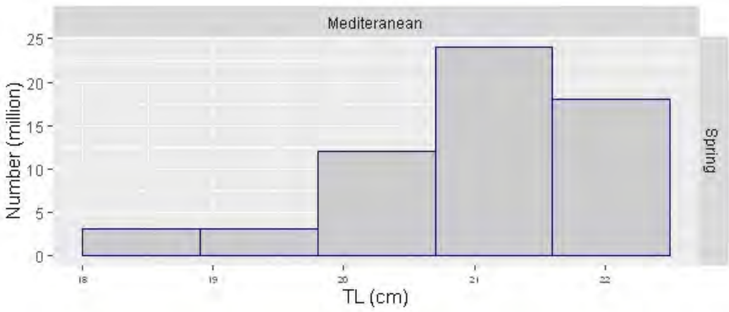


Figure 3.3.1.2. Size–frequency distribution of *Scomber colias* in the NW African coast (Morocco) (upper panel) and in the Moroccan Mediterranean area (lower panel) – Spring and Autumn 2019 surveys.

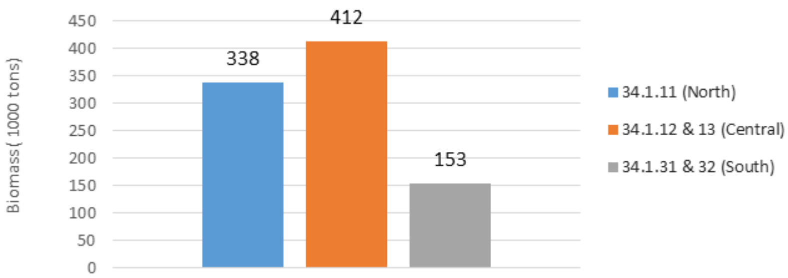


Figure 3.3.1.3. Biomass index of *Scomber colias* in the NW African coast (Morocco) – Autumn 2019 surveys.

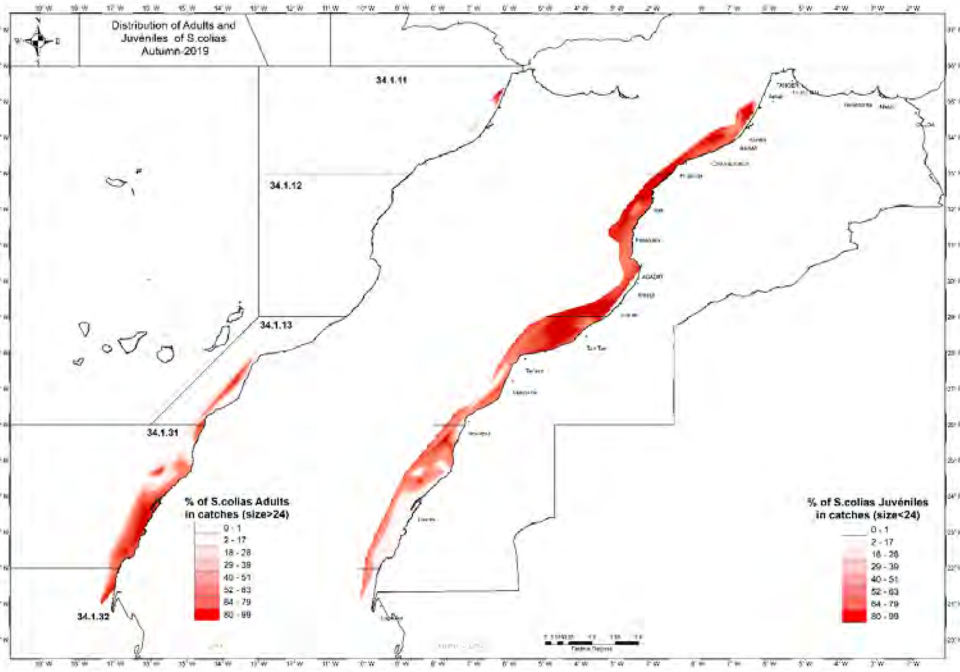


Figure 3.3.1.4. *Scomber colias* adults and juveniles' distribution in the NW African coast (Morocco) – Autumn 2019 surveys.

3.3.1.1 Moroccan Mediterranean Sea (Subarea 37.1.1)

The results of the surveys indicated that chub mackerel (*Scomber colias*) was weakly present in this area (Figure **3.3.1.1**), the species having appeared distributed in two separate strata at low densities, both in spring and in autumn. The biomass of *S. colias* in 2019 was estimated to be only 7 thousand tons in the spring period, however, in autumn, and given the very small number of individuals captured, no index could be calculated. The demographic structure of the species showed a single cohort formed only by juveniles with a peak at 21 cm in both of the seasons monitored (Figure 3.3.1.2).

3.3.1.2 Moroccan Atlantic (subareas 34.1.11, 34.1.12, 1.13, 34.1.31, and 34.1.32)

S. colias was present all over the coastline of Atlantic Morocco:

- In the northern zone (Subarea: 34.1.11): the relatively high densities of Atlantic chub mackerel were located in this area, and especially between el Jadida and Safi (Figure **3.3.1.1**). The size–frequency distribution of the fish caught in this area presented a unimodal cohort, with a peak at 19 cm (Figure **3.3.1.2**), and to which the adults accounted for only 2%. In terms of biomass, the species recorded 338 thousand tons in autumn (Figure **3.3.1.3**).
- In the central zone (subareas: 34.1.12 and 34.1.13): in this zone, the densities were moderately considerable, with concentrations between Tarfaya and Laayoune (Figure **3.3.1.1**). In the frequency distribution of sizes, two cohorts could be observed, the main one including small individuals with a peak at 18–19 cm, and the second formed by adults sizing around 28 cm (Figure **3.3.1.2**). In terms of biomass, chub mackerel recorded 412 thousand tons in this area, which was the highest value obtained, when compared to other areas (Figure **3.3.1.3**).
- In the southern zone (subareas: 34.1.31 and 34.1.32): during the autumn 2019 survey, the Atlantic chub mackerel densities in this area were slightly lower and scattered, whereas a denser aggregation was located offshore of Dakhla (Figure **3.3.1.1**). The size–frequency distribution indicated that the population was composed of fish with a wide range of

sizes, between 16 and 32 cm, peaking at 21 and 24 cm length, and from which adults represented 31% (Figure **3.3.1.2**). The biomass recorded in this area was low, around 153 thousand tons, which was the lowest value compared to other areas.

From the analysis of all the trawls data achieved during the autumn 2019 surveys, the results showed that the adults of the species were found mainly in the southern area of the Atlantic Moroccan waters (subareas 34.131 & 32), while the juveniles had an extensive distribution throughout the whole coast, becoming nevertheless more abundant towards the northern areas (Figure **3.3.1.4**).

3.4 Conclusions

Summarizing, chub mackerel seems to have a continuous distribution from Mauritania to Bay of Biscay, although the abundance in European waters is lower than that observed in Africa. Nevertheless, the strength of the 2016 year class has been above average in both African and European waters, suggesting an overall increase of the abundance throughout the distribution area. Besides in both areas, chub mackerel appears to undertake migrations. From wintering areas, mainly located in Mauritanian waters, South Portugal and the inner part of the Bay of Biscay, chub mackerel spread towards northern waters in summer time and, in the case of the Bay of Biscay, also towards the western Iberian Peninsula.

4 Maturity data

4.1 Introduction

The determination of the maturity stages' sequence during the year is essential to provide basic knowledge on the reproductive biology of a fish species, and to estimate the reproductive parameters required for stock assessment purposes. However, information on the reproductive biology of chub mackerel along all its area of distribution is still limited: the occurrence and timing of reproductive activity is still unclear in some areas, accurate estimates of the species first maturity size are lacking in some regions, and knowledge on chub mackerel's fecundity strategy, spawning grounds, spawning behaviour and frequency are deficient, preventing to correctly describe the variations of the reproductive activity and output of chub mackerel at a regional scale.

During the first WKCOLIAS in 2020, the information available in the literature was compiled and summarized in the Workshop report (ICES, 2020). Most of the existing studies on chub mackerel's reproductive biology are based on the analyses of the monthly evolution of the proportion of the gonads maturity stages and of the gonado-somatic index (GSI). These studies suggest that some variability in the timing of reproduction exists among regions and years, and also depends on the size of the fish. A gradient in the spawning seasonality appears to exist along the eastern Atlantic waters, from the Bay of Biscay to NW Africa: chub mackerel spawns mostly in winter–spring in Iberian waters, whereas the spawning period starts in autumn in NW African waters, including the Macaronesiann Islands. Regarding the maturity ogive, i.e. the proportion of mature fish observed per length and/or age, from the compilation carried out in the previous workshop, differences were also apparent, with an overall decrease of the length at first maturity (L_{50}) from North to South in European waters, and an increase from North to South off NW Africa.

The differences observed, in particularly in the length/age at first maturity, may be partly related to the distinct methodologies used in the different countries to estimate this parameter. During the WKCOLIAS2 meeting, the maturity information received during the data call was compiled, exploratory analyses were performed on the pooled set, and maturity ogives were calculated, when possible, following a common methodology.

4.2 Materials and methods

To calculate a maturity ogive, it is recommended to identify the spawning season of the species, collect representative samples of individuals during the spawning period and assign correctly their maturity stage (Domínguez-Petit *et al.*, 2017). Information on the spawning season of the species was updated during the workshop, based on the existing literature (cf. Section 5.6. of the report). The maturity staging process is the crucial step in estimating the maturity ogive, because errors in gonads maturity stage identification, when assignation is performed macroscopically, and especially between immature and resting individuals, often occur, and can lead to significant bias in the estimated parameters (ICES, 2018).The proportion of mature fish is, by definition, the fraction of fish that are likely to spawn in the current year, so fish that are not virgin but are skip spawning should be classified as immature (ICES, 2008).

Each member country/laboratory that provided data, informed about the maturity scale on which the information was based, as well as the stages from this scale that are considered sexually mature or immature. This information was not available for all data sources, and when existent, not all data were based on the same maturity scales. Nevertheless, it was assumed that separation between mature and immature fish was comparable between countries/areas.

Proportions of mature fish at length or age were calculated, based on the number of mature and immature fish by length and/or age, year, quarter and fishing area, provided by all the countries/laboratories involved in the data call. Based on the recommendation from WKMOG (ICES, 2008) to model the proportions of mature fish, a Generalized Linear Model (GLM) with a logistic function (binomial error distribution, logit link) was performed. The fitting to the model allows to estimate parameters as L_{50} or L_{95} (A_{50}, or A_{95}), i.e. the length or age at which 50% or 95% of the individuals are sexually mature.

Moreover, following the recommendations from WKMOG (ICES, 2008), the percentage of mature fish was first calculated using only the data corresponding to the spawning season, by years and areas. The length and age distributions of the fish sampled from which the available data originated, were also compared between areas, to search for sampling differences among regions.

4.3 Results

Data available for the WK are summarized in Table 4.3.1, which includes also the information on the quarters corresponding to chub mackerel's main spawning season for each area ("Spawning Quarter"), obtained using the references compiled in Section 5.6 of this report.

Only areas ICES 27.8.b, 27.8.c, 27.9.a.n, 27.9.a.s.a (Spain) and 27.9.a.s have provided age data, whereas the proportion of mature fish at length were available for all areas considered. Therefore, to make the analysis possible for all the origins, estimations were carried out using length data. The datasets by area differed in relation to the length of the maturity data time-series as well. The common period for all the origins comprises 2013 to 2019, except for Morocco from which maturity data were presented only for 2019. No data provided by other NW African countries.

Table 4.3.1. Summary of the data received from North to South subregions.

Country	ICES/ FAO-CECAF/ Mediterranean Area	Fishing Area	Years	Length range (cm)	Age range (year)	Spawning Quarter*
Spain	27.8.b	Bay of Biscay	2011-2017	13-41	0-11	2
	27.8.c	Bay of Biscay	2011-2019	11-50	0-14	2 and 3
	27.9.a.n	Galicia	2011-2019	12-41	0-6	1 and 2
Portugal	27.9.a.c.n	NW Portugal	2008-2019	15-46		1 and 2
	27.9.a.c.s	SW Portugal	2000-2019	7-64		1 and 2
	27.9.a.s.a	S Portugal	2006-2019	11-39		1
Spain	27.9.a.s.a	S Portugal	2007-2019	13-34	0-3	1 and 2
	27.9.a.s	Cádiz	2007-2019	10-36	0-5	1 and 2
	27.9.a.s.c	Cádiz	2007-2019	10-36	0-5	1 and 2
	GSA6	NW Mediterranean	2012-2019	14-39		1 and 2
Portugal	34.1.2	Madeira	2008-2019	15-49		1
Spain	34.1.2	Canary Islands	2013-2019	13-42		1 and 4
Morocco	34.1.11	N Morocco	2019	15-39		1 and 3
	34.1.12	C Morocco	2019	18-23		1
	34.1.13	S Morocco	2019	16-21		1
	34.1.31	S Morocco	2019	15-47		1 and 3

***References in section 5.6. of the report.**

The preliminary analysis showed that data corresponding to the main spawning season were not available or enough for most of the areas and most of the years (Figure 4.3.1a). Moreover, the percentage of mature individuals during the spawning season was 100% or nearly 100% in areas ICES 27.8.c, 27.9.a.c.n, 27.9.a.c.s, 27.9.a.n, 34.1.12 whereas in areas 27.9.a.s.a (from Spain), 27.9.a.s, 27.9.a.s.c, FAO 34.1.2 (Madeira Island) and 34.1.13, all or almost all specimens were assigned as immature (Table 4.3.2, all the above resulting in a worse model fitting for most of the years/sub-areas. Additionally, the fish length distribution of the maturity data available showed that the smaller specimens (i.e. the immature ones) have not been sampled or in few numbers during the spawning seasons in many of the areas considered (Figure 4.3.2). This fact is in large part related to the absence in samples originated from catches of the commercial fleet, of fish sizing less than the minimum landing size established for the species (which is related to the size at first maturity). But the same was observed in datasets that included fish samples collected during scientific surveys taking place during the spawning period as well, the smaller immature fish seemed to have been in many areas alternatively more available during the reproductively resting period (possibly recruitment period?).

Nevertheless, with the exception of areas ICES 27.8.b, FAO 34.1.12 and 34.1.13 for which data were not available or in small numbers in some of the quarters (all years pooled), the analysis of fish length distribution indicated a relatively homogeneous distribution of the fish sizes between quarters in most of the areas (Figure 4.3.2). And when age data are available and/or similar length ranges have been sampled, the preliminary analyses indicated for areas ICES 27.8.b, 27.8.c, 27.9.a.n, 27.9.a.s, and FAO 34.1.31 (Spanish European Atlantic and South Moroccan waters) that no great differences in length-at-age curves between quarters were observed. Finally, the ogive curves and L50 estimates were also very similar between quarters (results not shown) for areas 27.9.a (Portuguese waters).

Following this first exploratory analysis (cf. above), the group decided to calculate the final maturity ogives using the data from the whole year (all quarters pooled), for length data only, and the combined years from 2013 to 2019 (Figure 4.3.1a).

For some areas, maturity information was available from more than one origin, though corresponding to the same ICES/FAO area (e.g. ICES 27.9.a.s.a in Iberian waters, and FAO 34.1.2 for the Canary and Madeira Islands). The first analysis undertaken considered this information jointly for these areas. However, a possible variability in the assignation of the maturity stages was detected in these subareas depending on the origin of the data. Figure 4.3.1b shows: 1) that an overlapping of the size range for mature and immature specimens exists, indicating errors in maturity staging, and 2) that maturing/resting fish may have been misclassified as immature ones and vice versa. But this maturity misidentification seems to differ between the two origins for a given area, suggesting that differences likely exist depending on the staff assigning the maturity stage and the criteria used for the maturity determination (from the different laboratories), and thus the WK decided later to make the analysis for these areas separately by country.

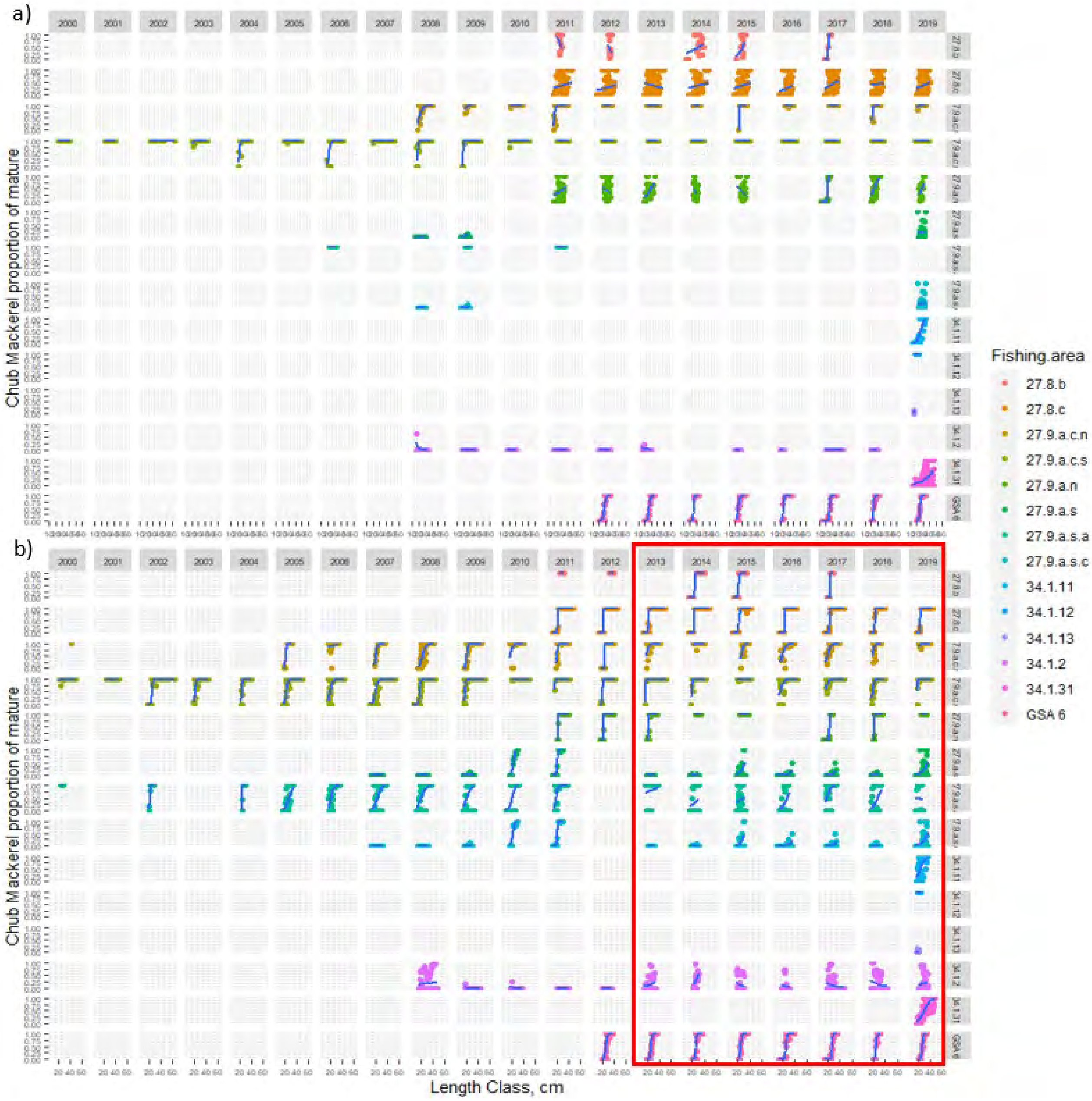


Figure 4.3.1. Proportion of mature fish per length class (cm) a) during the spawning season and b) all year around, and the corresponding fitted logistic curve (maturity ogive) (in blue). Red box indicates the data used for consequent analysis.

Table 4.3.2. Proportion of mature and immature fish using the combined data set for the years 2013–2019, considering only the spawning season or the whole year. Grey shaded cells show the areas/periods for which fish sampled were either 100% mature or 100% immature. ES: Spain; PT: Portugal; MA: Morocco; CAN: Canary Islands; MAD: Madeira; MEDIT: Mediterranean Sea.

			Proportion mature	
Fishing area		**Country**	**All year**	**Spawning season**
ICES	27.8.b	ES	0.47	0.57
	27.8.c	ES	0.90	0.92
	27.9.a.c.n	PT	0.91	0.97
	27.9.a.c.s	PT	0.92	0.98
	27.9.a.n	ES	0.91	0.89
	27.9.a.s	ES	0.05	0.08
	27.9.a.s.a	ES	0.02	1.00
	27.9.a.s.a	PT	0.84	0.09
	27.9.a.s.c	ES	0.07	0.26
FAO	34.1.11	MA	0.41	1.00
	34.1.12	MA	1.00	0.11
	34.1.13	MA	0.04	0.00
	34.1.2	ES-CAN	0.33	0.39
	34.1.2	PT-MAD	0.03	0.49
	34.1.31	MA	0.38	0.57
GFCM-GSA	6	ES-MEDIT	0.59	0.92

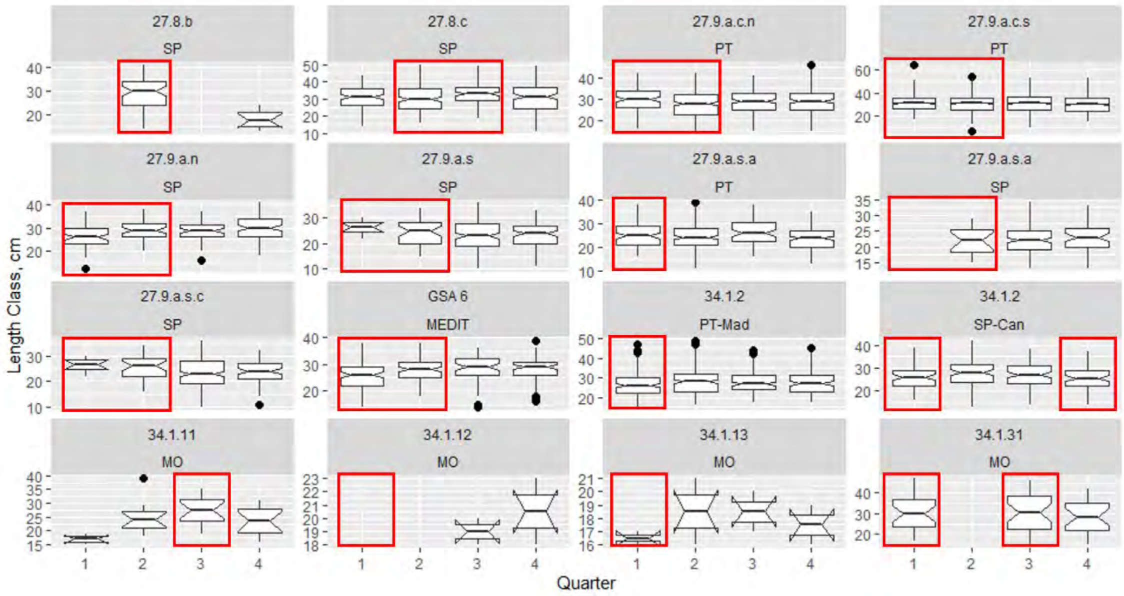


Figure 4.3.2. Length class distribution of the fish sampled, for all areas, all years pooled together. Red box corresponds to the spawning season quarter(s). SP – Spain, PT – Portugal, MEDIT – Spanish Mediterranean waters, PT-Mad – Madeira Islands, SP-Can – Canary Islands, MO – Morocco. The notched boxplots represent the median (thick black lines), 1.5× the interquartile range (whiskers) and an approximation of the 95% confidence interval of the median (notches).

Figure 4.3.3 presents the logistic curves fitting the maturity data for all areas using all quarters for the 2013 to 2019 years combined. For some of the areas, the logistic curve (maturity ogive) did not converge or the L_{50} estimates were not biologically "realistic", likely related to the aspects described above. For the Bay of Biscay area (27.8.b), a reliable L_{50} was estimated, very similar to the estimate obtained for the Cantabrian waters (area 27.8.c). However, the former was obtained based on a very low number of samples and the estimate was not considered adequate (Figure 4.3.3a). For the areas 27.9.a.s.c, 27.9.a.s.a and 27.9.a.s, (Spanish data) (Figures 4.3.3b and 4.3.3g), probably a significant number of resting specimens was classified as immature, and the logistic curve was not considered trusty, but a reliable L_{50} result was estimated for the area 27.9.a.n (Spanish data) (Figure 4.3.3g). Contrarily, a GLM model adjusted very well to the data corresponding to the Mediterranean Spanish waters (area GSA6, Figure 4.3.3e). For Madeira Islands (area 34.1.2, Figure 4.3.3c), almost all individuals were immature, and it was not possible to adjust a reliable logistic curve. For Portuguese Iberian waters (27.9.a.c.n, 27.9.a.c.s and 27.9.a.s.a, Figure 4.3.3d), a significant number of samples was available and the curves fitted well with reliable L_{50} estimates; however, the data from these areas strongly suggest the existence of the maturity stages misclassifications referred previously, and these estimates should be regarded with caution. In area 34.1.2 (Canary Islands), although routine samplings are carried out and it is regularly possible to obtain maturity ogives and L_{50} estimates, the submitted data did not allow to fitting a "realistic" maturity ogive (Figure 4.3.3f). For NW African areas, data were available only for areas 34.1.11 and 34.1.31 (Figures 4.3.3h and 4.3.3i), though the dispersion of the proportions of mature fish at length plotted also suggests a possible maturity staging misclassifications between resting and immature individuals. Finally, for areas 34.1.12 and 34.1.13 data were not enough to fit a curve (Figure 4.3.3h).

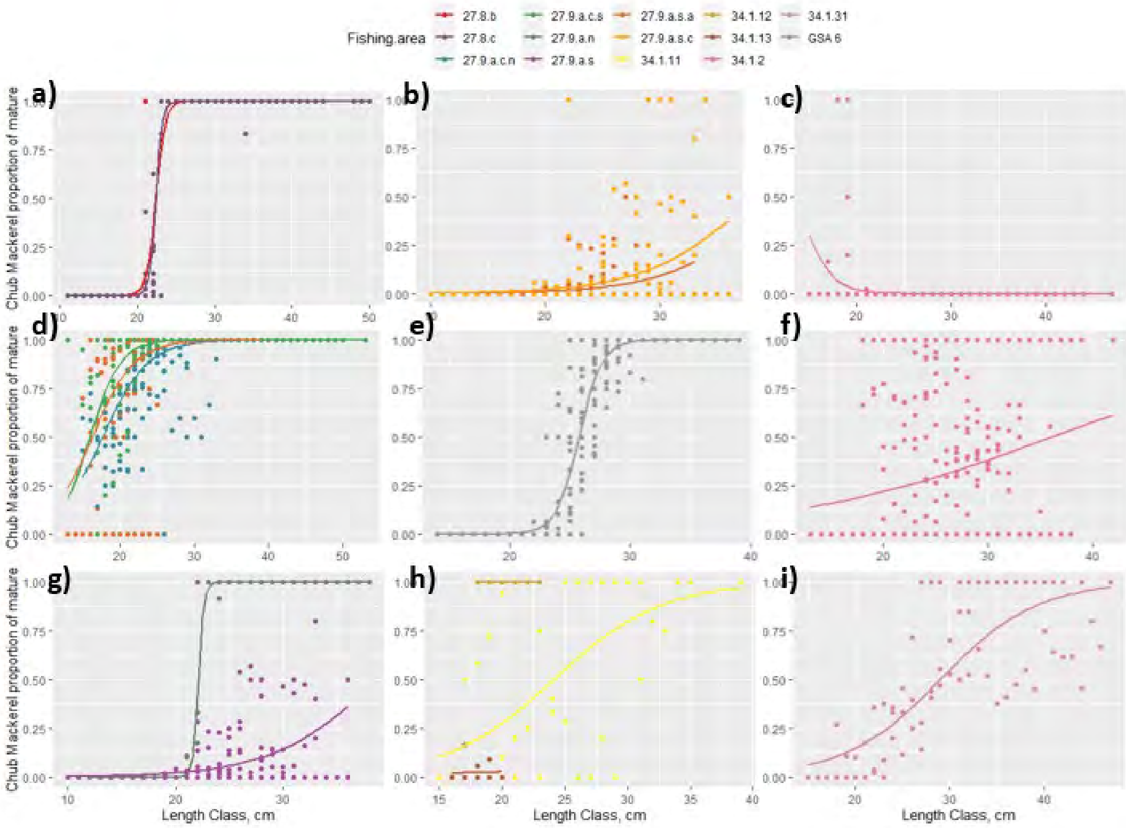


Figure 4.3.3. Logistic curve fitted at length by areas: a) 27.8.b and 27.8.c; b) 27.9.a.s.c and 27.9.a.s.a (Spain); c) 34.1.2 (Portugal-Madeira Islands); d) 27.9.a.c.n, 27.9.a.c.s and 27.9.a.s.a (Portugal); e) GSA6 (Spain-Medit); f) 34.1.2 (Spain-Canary Islands); g) 27.9.a.n and 27.9.a.s (Spain), h) 34.1.11, 34.1.12 and 34.1.13 (Morocco); and i) 34.1.31 (South Morocco).

Table 4.3.3 summarizes the L_{50} and L_{95} values estimated by fishing area. Only the analyses for areas 27.8.c, 27.9.a.n, 27.9.a.c.n, 27.9.a.c.s, 27.9.a.s.a, GSA6 and 34.1.11 resulted in reliable estimates for the WK members. The L_{50} and L_{95} values indicated a decreasing trend in European waters from area 27.8.c (L_{50} = 22.46 cm) to area 27.9.a.s.a (L_{50}= 16.29 cm), and an increasing trend in NW Africa, from area 34.1.11 (L_{50} = 23.71 cm) to area 34.1.31 (L_{50} = 30.43 cm), in accordance with the trends described during the WKCOLIAS in 2020, based on the existing literature. In Europe, the chub mackerel from Spanish Mediterranean waters (GSA6) presented the highest length at first maturity (L_{50} = 25.72 cm).

Table 4.3.3. Length at 50% (L_{50}) and at 95% (L_{95}) of mature fish, the respective Standard Errors (SE_{50} and SE_{95}) and years used in the calculations, by fishing area.

Fishing area	L_{50} (cm)	SE_{50}	L_{95} (cm)	SE_{95}	Years
27.8.c	22.46	0.03	23.31	0.06	2013-2019
27.9.a.n	22.18	0.07	22.98	0.13	2013-2019
27.9.a.c.n	17.36	0.25	27.11	0.20	2013-2019
27.9.a.c.s	16.38	0.19	22.20	0.14	2013-2019
27.9.a.s.a	16.29	0.16	22.03	0.22	2013-2019
GSA6	25.72	0.06	28.43	0.11	2013-2019
34.1.11	23.71	0.80	39.11	3.02	2019
34.1.31	30.43	0.33	45.83	1.00	2019

4.4 Conclusions

Following the compilation of maturity information from the literature undertaken during the WKCOLIAS in 2020, the possibility of estimating chub mackerel maturity ogives throughout its distribution range following a standardized methodology appeared as a logical extension, in view of contributing to ToR c of the WKCOLIAS2, by investigating the geographical variability of reproductive parameters that could help analysing the chub mackerel population structure and propose stock units in East Atlantic waters. For this purpose, the data received for the species in a common format in response to the data call launched before the WK were analysed and maturity ogives were obtained using a common method, from the Northern Iberian Cantabrian coast to the Moroccan and Mauritanian waters, including the NW Mediterranean.

The results obtained from the exploratory analysis of the data, however, revealed incompatibilities and differences among areas, and allowed to identifying several issues that are listed in Section 8.2 of this report. For this first approach for obtaining the maturity ogives, years and seasons also needed to be combined, though the results could be presented separately by area and country. Nevertheless, some of the issues aforementioned lead to the impossibility of establishing maturity ogives for all areas, and the L_{50} estimated in this study should be carefully considered.

Compared to the L_{50} estimates compiled from literature during the first WKCOLIAS (ICES, 2020) and updated in Sections 5.5 and 6.4 of the present report, although the values obtained here for *S. colias* differed more or less depending on the area considered, overall, they presented the same geographical trends: a decrease from the North to the South Atlantic Iberia, and an increase from the North to the South NW African waters. The achievable analyses here did not allow inferring spatial variability in the Mediterranean waters nor within the Macaronesiann Islands. Moreover, the calculations carried out with all years combined also hampered any conclusions in terms of temporal variability.

For all the reasons exposed, the group thus greatly encouraged the continuation of compilation of maturity information across chub mackerel's Atlantic distribution, additional work in view of the improvement and standardization of sampling strategy and data quality, and intercalibration processes between the institutions monitoring the species, for both maturity and age information (see Section 8.2 of the report).

5 Life-history parameters

5.1 Life-history data available for chub mackerel

During the meeting, the life-history traits information available for chub mackerel in whole distribution (Western and Eastern Atlantic, and the Mediterranean Sea) was updated (historical series and literature review). The biological information has been grouped in the following categories:

1. growth parameters,
2. length-at-age,
3. length–weight relationships,
4. length at first maturity (L_{50}), and
5. spawning season.

In EU waters (both for the Atlantic waters and Mediterranean Sea), biological data of *S. colias* are currently mostly collected within the EU-DCF (Data Collection Framework) from regular monitoring of the commercial fleet (including landings' samplings and scientific observations onboard), as well as from research surveys (both to study pelagic and demersal species with acoustic and bottom trawl prospection, respectively), by the Spanish and Portuguese Fisheries Institutes (IEO, IPMA) for the Iberian waters. In the NW African waters, the information which encompasses the Moroccan, Mauritanian and Senegalese waters, is obtained by the INRH (the National Fisheries Research Institute), Mauritanian Institute for Fisheries and Oceanography (IMROP), and Senegalese Oceanographic Institute and Fisheries Department (CRODT/ISRA), respectively.

In addition to the historical information obtained by the national institutes that participated in the WK, numerous biological studies have been carried out on the chub mackerel biology since the 1970s, completing the present compilation.

Geographical differences seem to occur for most of the biological parameters compiled, probably not only related to the studied area, but also to the period of the year when they were collected. In addition, interannual differences for many variables were noted, although with no consistency over time. The methodologies used to obtain these data, often are different among countries/institutes, and may also have varied along the years, which is an important issue to take into consideration within a stock assessment process.

5.2 Growth Parameters

The estimated growth parameters of chub mackerel were compiled for the whole distribution of the species, and summarized in Table 5.2. Similarly, the performance index of growth parameters for each area was calculated to make easier observations of geographical trends (Pauly, 1997), but no conclusion was possible considering this index.

The value of *k* (growth rate) ranged from 0.10 to 0.50 yr^{-1} in EU waters; 0.11 to 0.35 yr^{-1} in NW African waters; 0.16 to 0.25 yr^{-1} in SE Atlantic waters; 0.15 to 0.49 yr^{-1} in Mediterranean waters and 0.32 to 0.54 yr^{-1} in NW and SW Atlantic waters. The L_∞ (theoretical asymptotic length) value ranged between 38 and 58.52 cm in EU waters; 33.3 and 67.5 cm in NW African waters; 68 and 71.6 cm in SE Atlantic waters; 27.9 and 47.6 cm in Mediterranean waters; 31.6 and 44.2 cm in NW and SW Atlantic waters.

Like other small and medium pelagic species, the Atlantic chub mackerel presents a high growth rate during the first years of life, followed by a gradual slowdown after sexual maturity.

5.3 Length-at-age

Information on chub mackerel's length-at-age for the whole distribution of the species is summarized in Table 5.3. The time periods of the studies and surveys are noticeably different, and probably influence and cause discrepancies among results. In addition, the seasonal chub mackerel migrations should be taken into account when making inferences from the results, due to the interpretation of the growth depending on what moment during the year the samples were collected.

Moreover, a recent growth and age corroboration study carried out with samples from the Cantabrian Sea and Galicia (divisions 27.8.c and 27.9.a North), following several methodologies (including analyses based on otoliths as well as length frequencies) showed two growth patterns, one slower (direct age estimation, back calculation and PROJMAT), and the other faster (Bhattacharya and SLCA) (Navarro *et al.*, 2021c). This question needs to be clarified in the future, and age determination from otoliths requires further validation studies in all areas.

In European waters, age–length keys (ALKs) obtained both from commercial and survey age data can be applied to the length data of the same geographical area in most Iberia (ICES 27.8c, 27.9aN+C+S). The age estimation criteria in chub mackerel applied in ICES, Mediterranean, and the Canary Islands were standardized among the European age readers in a previous workshop (ICES, 2016), and its consistency has been tested by periodical international calibration exercises. In African waters, the ALK used in the assessment of the whole is the one obtained for the Russian fleet. In the Canary Islands, CECAF area, recent age, and growth estimation are not presented due to the detection of potential different morphotypes of *S. colias*, which could present different growth patterns (Jurado-Ruzafa *et al.*, 2021a).

5.4 Length–weight relationship

Chub mackerel length–weight (L–W) relationships are available for all its geographical distribution (Table 5.4), employing the formula: $TW=a\times TL^b$ (TW: total weight, TL: total length).

The coefficient *b* values of the linear regression for sexes combined ranged from 3.170 to 3.530 in EU waters, between 3.021 and 3.570 in NW African waters, and from 2.970 to 3.530 in Mediterranean waters and 2.72 (North) to 3.06 (South) in NW Atlantic waters. In general, in all areas, the coefficient *b* estimated annually is above 3, indicating a tendency towards positive allometric growth in all regions. However, variations may exist in these parameters under the influence of multiple factors, either related to biological/environmental variables or to sampling issues (sex, stage of sexual maturity, season, feeding, etc.)

5.5 Length at first maturity

Information on chub mackerel's length at first maturity (L_{50}) was compiled for the whole distribution of the species and is summarized in Table 5. Considering the total length results, L_{50} ranges from 18.71 to 30.8 cm in EU waters; from 16 to 31 cm in NW African waters; between 16.8 and 27.2 cm in Mediterranean waters; and ~27.4 in NW Atlantic. Considering sexes, a tendency to males maturing at larger sizes than females seems to occur, except for the Atlantic Iberian waters (Figures 5.5.1 and 5.5.2).

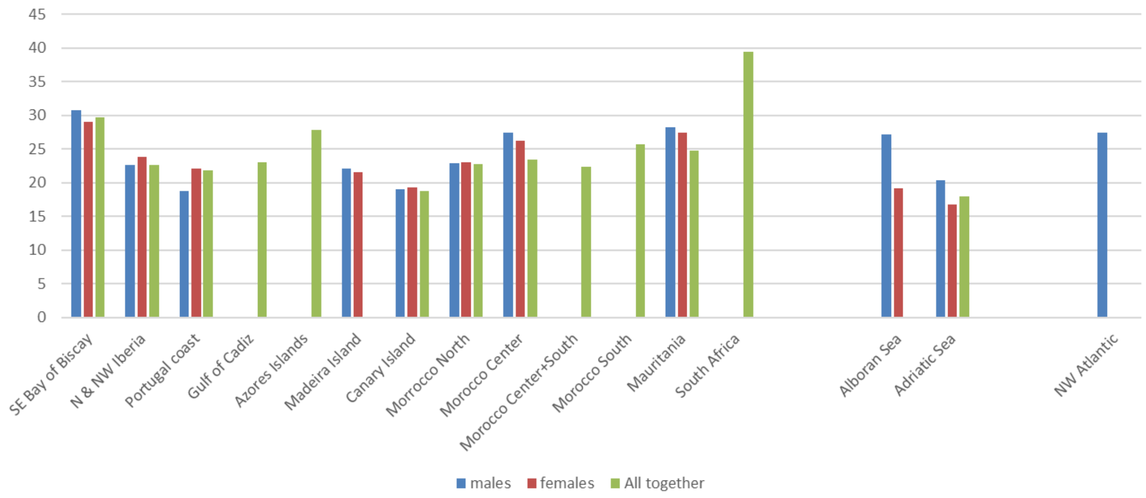


Figure 5.5.1. Average length at first maturity (L_{50}) estimated for chub mackerel, for males, females, or both sexes combined, for each area of distribution. Only studies presenting L_{50} values based on fish total length (TL) were considered in this plot (Table 5.5).

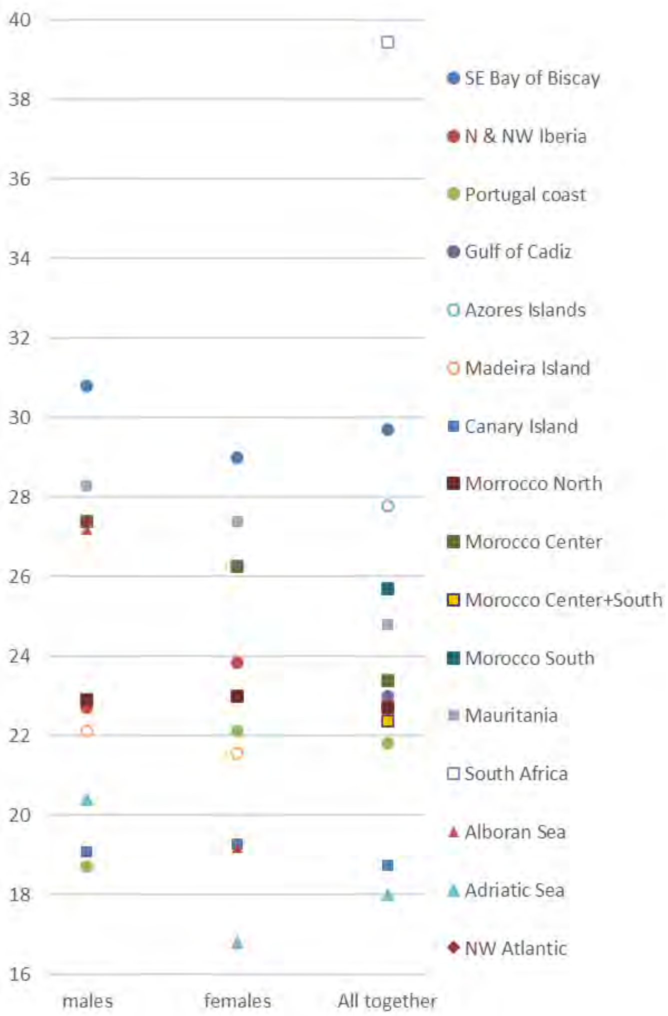


Figure 5.5.2. Average length at first maturity (L_{50}) of chub mackerel estimated for males, females, or both sexes combined, for each area of distribution.

Differences are probably related to the distinct environmental conditions existing in each area, but also to the distinct methodologies used to estimate this parameter. For example, depending on the laboratory or study, the maturity scales used may vary, and the maturation stages are not always assigned both based on the macroscopic observation of the gonads (Macroscopic) and their histological analysis (Microscopic). Most of the existing reproductive studies are indeed based on macroscopic evaluation of the gonads, which implies the risk of misidentifications between the gonads of immature and resting individuals, if their state is not validated microscopically, with possible consequences for the estimation of the maturity ogives, and hence, for the L_{50}.

Overall, a decrease of the L_{50} seems to occur from the Bay of Biscay to the Gulf of Cadiz, and an increase from North to South in NW African waters, with a transitional area which includes the northern Macaronesiann islands. In the Mediterranean waters, a decreasing trend of the L_{50} seems to occur from West to East. These geographical gradients are in agreement with the estimates which resulted from the analysis of the maturity data compiled for the WK following the data call (Section 4 of this report).

Chronologically, these sizes at first maturity showed a downward trend.

5.6 Spawning season

The spawning periods of chub mackerel are generally obtained analysing the monthly evolution of the proportion of the gonads' maturity stages and/or GSI (gonado-somatic index). The observed spawning periods by area are summarized in Table 5.6.

A latitudinal variation of the period and duration of the spawning activity seems to occur across Eastern Atlantic for chub mackerel, which spawns mostly in winter-spring in Iberian waters whereas, in NW Africa, the spawning period starts earlier, in autumn. In the studies available for Central and South Africa, the species is reported to spawn in July–September, which corresponds to summer and winter seasons, respectively. In Mediterranean waters, the spawning season occurs in spring and summer. In Western Atlantic, the spawning period starts at the beginning of the year, in the Northern hemisphere, corresponding to winter and early spring, while in the Southern hemisphere, spawning activity occurs from the mid-year to the end, corresponding to spring and early summer seasons.

Spawning seasons vary according to latitude and, as for other small and medium pelagic species, these differences may be due to the distinct temperatures triggering spawning, but also to the oceanographic conditions (upwelling) and food availability, among other factors.

Table 5.2. Summary of the growth parameters available for *S. colias* throughout its geographical distribution. L_∞: asymptotic length; k: growth rate; t_0: theoretical age when L=0; ϴ: growth performance index (ϴ = Log k +2*Log (L_∞); Pauly and Munro, 1984); n: number of individuals; FL: Fork length. (1) No VBGF fitted (very few age groups, Age 0 and Age 1 mainly); growth inferred as similar to the NW Africa populations from comparison of estimates of Fork length-at-age; (2) Not estimated; assumed as hatching size - 0.46 cm.

Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	L_∞ (cm)	*k*	t_0 *(years)*	ϴ	n	Length range (cm)	Reference
East Atlantic Ocean											
N & NW Iberia	27.8.c & 27.9.a.n	2011–2017	Acoustic surveys and commercial landings	Direct age estimation in otoliths	45.34	0.28	-1.18	2.755	6867	14–50	Navarro *et al.* (2021a)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2012	Acoustic surveys and commercial landings	Back-calculation	42.63	0.33	-0.96	2.778	409	16–48	Navarro *et al.* (2021a)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2017	Acoustic surveys	Modal Progress Analysis (Bhattacharya)	55.00	0.24	-0.77	2.861		14–46	Navarro *et al.* (2021a)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2017	Commercial landings	Modal Progress Analysis (Bhattacharya)	53.00	0.26	-0.78	2.864		18–49	Navarro *et al.* (2021a)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2017	Acoustic surveys	Length frequency distribution analysis (PROJMAT)	48.74	0.25	-0.87	2.774		14–46	Navarro *et al.* (2021a)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2017	Commercial landings	Length frequency distribution analysis (SLCA)	49.30	0.30	-0.63	2.863		18–49	Navarro *et al.* (2021a)
Portuguese coast	27.9.a.c & 27.9.a.s	1981–1982	Commercial landings	Back-calculation	53.83	0.17	-2.03	2.692	404		Martins *et al.* (1983) in Castro & Santana (2000)
Portuguese coast	27.9.a.c & 27.9.a.s	1986–1995	Purse-seine; hook and line; gillnet; trawl survey	Direct age estimation in otoliths	58.52	0.1	-3.68	2.535	883	16–54	Martins (1996) in Daley (2019)
Gulf of Cadiz	27.9.a.s.c	1977–1978	Commercial landings	Direct age estimation in otoliths			(1)				Rodríguez-Roda (1982)

Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	L_∞ (cm)	*k*	t_0 *(years)*	ϴ	n	Length range (cm)	Reference
Gulf of Cadiz	27.9.a.s.c	2003–2004	Commercial landings	Direct age estimation in otoliths + Back-calculation	43	0.27	-1.10	2.698	121	16–43	Velasco *et al.* (2011)
Gulf of Cadiz	27.9.a.s	2007–2015	Summer Acoustic & DEPM surveys	NORMSEP-based Modal Progression Analysis	51.5	0.14	(2)	2.570	n.a	13–34	Canseco (2016)
Gulf of Cadiz	27.9.a.s	2007–2015	Summer Acoustic & DEPM surveys	ELEFAN I	39	0.40	(2)	2.784	n.a	13–34	Canseco (2016)
Azores Islands	27.10.a.2	1996–2002	Purse-seine; hook and line; dipnets, liftnets	Direct Age estimation in otoliths	57.52	0.20	-1.09	2.821	349	9.6–56.6	Carvalho *et al.* (2002)
Madeira Island	34.1.2	2002–2004	Commercial landings	Direct Age estimation in otoliths	50.08	0.25	-1.34	2.797	2115	13–41	Vasconcelos (2011)
Madeira Island	34.1.2	2002–2004	Commercial landings	ELEFAN I	38	0.50		2.859		13–41	Vasconcelos (2011)
Canary Islands	34.1.2	1988–1990	Commercial landings	Direct Age estimation in otoliths	50.69	0.21	-1.45	2.732	878	4–42	Lorenzo (1992)
Canary Islands	34.1.2	1988–1990	Commercial landings	Back-calculation	49.22	0.21	-1.40	2.707	538		Lorenzo (1992)
Canary Islands	34.1.2	1988–1990	Commercial landings	Modal Progress Analysis (Bhattacharya)	49.22	0.22		2.727		4–48	Lorenzo (1992)
Canary Islands	34.1.2	1988–1990	Commercial landings	Back-calculation	49.2	0.21	-1.40	2.706			Lorenzo *et al.* (1995)
Canary Islands	34.1.2	1988–1989	Purse-seine	Direct Age estimation in otoliths	52.4	0.19	-1.61	2.717	470	13.7–42.1	Lorenzo & Pajuelo (1996)

Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	L_∞ (cm)	*k*	t_0 *(years)*	Θ	n	Length range (cm)	Reference
Morroco North	34.1.11		Not specified		44.1	0.32	-0.83	2.794			FAO (1979) in Santamaría *et al.* (2020)
Morroco North	34.1.11				37.5	0.20	-0.91	2.449			Lakhnigue *et al.* (2013) in Santamaría *et al.* (2020)
Morroco North	34.1.11			Length–frequency data analysis	44.53	0.32	-0.72	2.802			INRH/DRH (2016) in Santamaría *et al.* (2020)
Morocco Center+South	34.1.12/13;31/32				33.29	0.30	-0.76	2.522			Lakhnigue *et al.* (2013) in Santamaría *et al.* (2020)
Morocco Center+South	34.1.12/13;31/32			Length–frequency data analysis	47.14	0.16	-0.11	2.551			FAO (2015) in Santamaría *et al.* (2020)
Morocco Center+South	34.1.12/13;31/32			Length–frequency data analysis	35.78	0.27	-0.78	2.539			FAO (2015) in Santamaría *et al.* (2020)
Morocco Center+South	34.1.12/13;31/32				39.35	0.25	-0.81	2.588			INRH/DRH (2016) in Santamaría *et al.* (2020)
Morocco Center+South	34.1.12/13;31/32				35.78	0.27	-0.78	2.539			FAO (2019) in Santamaría *et al.* (2020)
Morocco South	34.1.31/32			Direct age estimation in scales (FL)	51.64	0.16	-1.22	2.625			Novoshenine & Staroselskai (1964) in Santamaría *et al.* (2020)
Morocco South	34.1.31/33			Direct age estimation in scales (FL)	44.09	0.31	-1.01	2.779			Krivospitchenko & Domanevsky (1984) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11			Direct age estimation in otoliths (FL)	63.3	0.13	-1.54	2.700			Vyskrebertsev (1970) in Santamaría *et al.* (2020)

Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	L_∞ (cm)	*k*	t_0 *(years)*	Θ	n	Length range (cm)	Reference
Mauritania	34.1.31/32 & 34.3.11			Direct age estimation in scales (FL)	55.36	0.12	-3.18	2.558			Staicu & Maxim (1974) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11			Direct age estimation in otoliths	44.82	0.34	-1.04	2.833			Holzlohner et al (1983) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11			Direct age estimation in scales (FL)	51.69	0.22	-0.89	2.763			Camarena (1986) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11			Direct age estimation in otoliths	67.51	0.11	-2.22	2.692			Lawal & Mylnikov (1988) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11			Direct age estimation in otoliths (FL)	44.19	0.31	-1.01	2.782			FAO (1989) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11			Direct age estimation in otoliths	48.74	0.20	-2.96	2.677			FAO (1989) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11				47.7	0.20	-1.69	2.658			Maxim (1990) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11				65.75	0.11	-2.45	2.675			Provotorova (1998) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11				61.18	0.14	-1.76	2.706			
Mauritania	34.1.31/32 & 34.3.11				64.13	0.11	-2.45	2.663			
Mauritania	34.1.31/32 & 34.3.11				42.4	0.20	-0.89	2.556			Lakhnigue *et al.* (2013) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11			Length–frequency data analysis	45.06	0.29	-0.75	2.770			FAO (2015) in Santamaría *et al.* (2020)

Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	L_∞ (cm)	*k*	t_0 *(years)*	Θ	n	Length range (cm)	Reference
Mauritania	34.1.31/32 & 34.3.11				45.63	0.35	-0.69	2.863			INRH/DRH (2016) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	2005–2011	European industrial trawlers; Commercial landings	Back-calculation	48.4	0.25	-1.51	2.762	163	12.4–49	Jurado-Ruzafa *et al.* (2017)
Mauritania for 1960's	34.1.31/32 & 34.3.11				49.1	0.18	-0.92	2.637			Wahbi *et al.* (2017) in Santamaría *et al.* (2020)
Mauritania for 1970's	34.1.31/32 & 34.3.11				46.7	0.21	-0.92	2.661			
Mauritania for 1980's	34.1.31/32 & 34.3.11				47.75	0.21	-0.86	2.680			
Mauritania for 1990's	34.1.31/32 & 34.3.11				49.06	0.18	-0.92	2.637			
Mauritania for 2000's	34.1.31/32 & 34.3.11				48.67	0.20	-0.88	2.676			
Mauritania	34.1.31/32 & 34.3.11				45.06	0.29	-0.75	2.770			FAO (2019) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11				55.38	0.12	-3.18	2.566			Staicu & Maxim (1974) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11				44.1	0.31	-1.01	2.780			FAO (1987) in Santamaría *et al.* (2020)
Senegal	34.3.12/13		Not specified		51.7	0.21	-0.98	2.743			Luhrs (1986) in Cikeš Keč and Zorica (2012)

Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	L_∞ (cm)	*k*	t_0 *(years)*	ϴ	n	Length range (cm)	Reference
Namibia	34.4.5				71.6	0.16	1.89	2.912			Ostapenko (1988) in Castro & Santana (2000)
South Africa	47.1.6–2.2		Commercial landings		68.01	0.25	-1.34	3.067			Baird (1977) in Castro & Santana (2000)
South Africa	47.1.6–2.2				68	0.21		2.981			van der Elst & Adkin (1991) in Castro & Santana (2000)
Mediterranean Sea											
N Alborán Sea	37. GSA 1	2003–2004	Commercial landings	Direct age estimation in otoliths + Back-calculation	40	0.37	-0.91	2.772	98	17–40	Velasco *et al.* (2011)
Catalan Sea	37.1.1	1992, 1997	Commercial landings		39.75	0.29	-1.41	2.661	158	11–39	Perrota *et al.* (2005) in Daley (2019)
Hellenic Sea	37.3.1				47.59	0.15	-2.18	2.531			Kiparissis *et al.* (2000)
Adriatic Sea	37.2.2	1998–2007			45.31	0.18	-1.65	2.568			Cikes & Zorica (2013)
Aegean Sea	37.3.1				29.87	0.20	-0.36	2.252			Bayhan (2007)
Aegean Sea	37.3.1				39	0.20	-2.13	2.483			Cengiz (2012)
Marmara Sea	37.4.1				33	0.47	n. a.	2.709			Pauly (1978) in Castro & Santana (2000)
Egyptian waters	37.3.2				27.9	0.49	n. a.	2.577			Rafail (1972)
Egyptian waters	37.3.2				39.42	n. a.	n. a.	n. a.			Rizkalla (1998)

Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	L_∞ (cm)	*k*	t_0 *(years)*	ϴ	n	Length range (cm)	Reference
West Atlantic Ocean											
NW Atlantic	31	2016–2017	Trawl		37.13	0.41	-2.44	2.752	422	17.7–39.7	Daley (2018)
Venezuela	31				31.6	0.54		2.732			Mendonza (1993) in Castro & Santana (2000)
Argentina	41	2002	Commercial landings		44.23	0.32	-1.39	2.797	392	16.3–43.5	Perrota *et al.* (2005) in Daley (2019)

Table 5.3. Total length (cm) by age based on the available growth studies on *S. colias* throughout its geographical distribution. FL: Fork length; (1) Less than three individuals.

					Age class (years)														
Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	0	1	2	3	4	5	6	7	8	9	10	11	n	Length range (cm)	Reference
East Atlantic Ocean																			
SE Bay of Biscay	27.8.b & 27.8c	1989–1997	Commercial landings	Direct age estimation in otoliths	18.4				35	38.6	40.5	41.8					81	15–44	Lucio (1997)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2017	PELACUS surveys (semester 1)	Direct age estimation in otoliths		21.3	26.4	31.8	34.4	36.8	39.3	39.9	40.5				1838	14–46	Navarro *et al.* (2021a)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2017	Commercial landings (semester 1)	Direct age estimation in otoliths		23.8	27.7	31.0	35.1	37.6	38.4	39.7	41.3				2524	18–50	Navarro *et al.* (2021a)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2017	Commercial landings (semester 2)	Direct age estimation in otoliths		26.7	29.3	33.1	36.5	38.3	40.8	39.9	41.1				2505	16–46	Navarro *et al.* (2021a) -2)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2012	PELACUS & Com. land. (semester 1)	Back-calculation		21.9	28.3	32.1	35.7	37.5	38.5	40.3	43.7				409	12–46	Navarro *et al.* (2021a)

					Age class (years)														
Fishing area	Fishing area (codes)	Period (years)	Data source	Meth-odology	0	1	2	3	4	5	6	7	8	9	10	11	n	Length range (cm)	Reference
Gulf of Cadiz	27.9.a.s.c	1977–1978	Com-mercial landings	Direct age esti-mation in oto-liths	20.6	22.4	26.4											(FL)	Rodríguez-Roda (1982)
Gulf of Cadiz	27.9.a.s.c	2003–2004	Com-mercial landings	Direct age esti-mation in oto-liths	20.7	21.6	26.7	29.2	36.9	36.4 (1)	39.9 (1)	43 (1)					121	16–43	Velasco *et al.* (2011)
Azores Island	27.10.a.2					18.91	25.63	30.89	35.01	38.23	40.75	42.73	44.28	45.49	46.44				Westhaus-Ekau & Ekau (1982) in Castro & Santana (2000)
Canary Islands	34.1.2				16.0	20.7	26.0	30.4	34.6	36.9		42.1							Lorenzo (1992)
Mo-rocco	34.1.11/12/13					15.1	23.6	29	32.5	34.8	36.3	37.3							Domanevsky (1970) in Castro & Santana (2000)
Mo-rocco	34.1.11/12/13					20	26	33	36.5	39.5	43.2	47.2							Habashi & Wojciechowsky (1973) in Castro & Santana (2000)

					Age class (years)														
Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	0	1	2	3	4	5	6	7	8	9	10	11	n	Length range (cm)	Reference
Mauritania	34.1.31/32 & 34.3.11	2005–2011	European industrial trawlers; Commercial landings	Back-calculation		22.3	28.3	32.4	35.6	38.7	41.5	42.1					163	12.4–49	Jurado-Ruzafa *et al.* (2017)
Senegal	34.3.12/13					20.4	25	29.75	34										Viskrebenzen (1963) in Castro & Santana (2000)
Gulf of Guinea	34.3.4/5					17.02	20.85	23.72	25.8										Viskrebenzen (1963) in Castro & Santana (2000)
Namibia	34.4.5					27.39	30.02	35.08	45.58	51.72	54.54	56.88	59.06	60.59	61.03	61.5			Ostapenko (1988) in Castro & Santana (2000)
South Africa	47.1.6–2.2					23.16	31.48	38.26	43.73	48.98	52.05	56.63	59.27						Baird (1977) in Castro & Santana (2000)

					Age class (years)														
Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	0	1	2	3	4	5	6	7	8	9	10	11	n	Length range (cm)	Reference
Mediterranean Sea																			
N Alborán Sea	37.1.1	2003–2004	Commercial landings	Direct age estimation in otoliths	22	23.6	28.9	29.9	30.1 (1)	29.1 (1)	40 (1)						98	17–40	Velasco *et al.* (2011)
Marmara Sea	37.4.1					14.8	18.1	20.5	22.2	22.6	26.3	32.3							Tuggaç (1957) in Castro & Santana (2000)
Black Sea	37.4.2					14.9	18.9	21.2	23.3	25.1	25.8	27.5							Atli (1960) in Castro & Santana (2000)

					Age class (years)														
Fishing area	Fishing area (codes)	Period (years)	Data source	Methodology	0	1	2	3	4	5	6	7	8	9	10	11	n	Length range (cm)	Reference
West Atlantic Ocean																			
NW Atlantic	31	2016–2017	Trawl	Mean predicted lengths	23.48	28.07	31.12	33.14	34.48	35.37	35.96	36.36							Daley (2018)
Argentina	41					16.3	18.8	30.4	33	36.7	37.8	40.1	41.1	42.4	42.8	44.3			Perrota (1992)
Argentina	41					25.25	29.73	33.35	35.86	37.94	38.91	39.5	40.75						Perrota & Forciniti (1994) in Castro & Santana (2000)
Argentina	41					28.5	30.17	33.06	34.87	36.83	38.46	39.9		42.83					Perrota & Forciniti (1994) in Castro & Santana (2000)

Table 5.4. Parameters for the length–weight relationships (coefficients *a* and *b* of the linear regression) obtained for *S. colias* throughout its geographical distribution. (1) no significant differences between Gulf of Cadiz Spanish waters and Northern Alborán Sea; (2) Estimate per survey (see Ref).

Fishing area	Fishing area (codes)	Period (years)	*b*	*a*	Length range (cm)	Reference
East Atlantic Ocean						
SE Bay of Biscay	27.8.b &27.8c	1989–1993, 1997	3.376	$1x10^{-6}$	13–47	Lucio (1997)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2016	3.267	0.003	11.2–50.8	Villamor et al (2017)
N & NW Iberia	27.8.c & 27.9.a.n	2011–2019	3.170	0.005	16–50	Navarro *et al.* (2019)
Portugal coast	27.9.a.c & 27.9.s	1981–1982	3.391	0.00183		Martins *et al.* (1983) in Castro & Santana (2000)
Portugal coast	27.9.a.c & 27.9.s	1986–1995	3.330	0.00278	19–41	Martins (1996) in Daley (2019)
Portugal coast	27.9.a.		3.230	0.004	15.8–39.50	Gonçalves *et al.* (1997) in Castro & Santana (2000)
Portugal coast	27.9.a.	1998–2000	3.41	0.0021	15.1–47.2	Santos *et al.* (2002) in Daley (2019)
Portugal coast	27.9.a.	1994–1995	3.44	0.002	19.5–46.4	Mendes et al (2004) in Daley (2019)
Gulf of Cadiz	27.9.a.s.c	2003–2004	3.5289	0.0015	16.4–43	Velasco *et al.* (2011) (1)
Gulf of Cadiz	27.9.a.s	2007–2015	(2)	(2)		Canseco (2016)
Azores Islands	27.10.a.2	1996–2002	3.26	0.004	9.10–53	Carvalho *et al.* (2002)
Madeira Island	34.1.2	2002–2003	3.38	0.00231	13–41.7	Vasconcelos *et al.* (2011)
Canary Island	34.1.2	1988–1989	3.31	0.003	14.3–42.1	Lorenzo *et al.* (1995)
Canary Island	34.1.2	2013–2015	3.34	0.003	15–38.3	Jurado-Ruzafa *et al.* (2016)
Canary Island	34.1.2	2013	3.34	0.003	17.3–38.1	Jurado-Ruzafa *et al.* (2016)
Canary Island	34.1.2	2014	3.38	0.002	17.4–38.3	Jurado-Ruzafa *et al.* (2016)
Canary Island	34.1.2	2015	3.32	0.003	15.0–35.0	Jurado-Ruzafa *et al.* (2016)

Fishing area	**Fishing area (codes)**	**Period (years)**	***b***	***a***	**Length range (cm)**	**Reference**
Canary Island	34.1.2	2016	3.475	0.0018	14.5–37.5	Jurado-Ruzafa *et al.* (2020)
Canary Island	34.1.2	2017	3.329	0.0028	16.7–36.3	Jurado-Ruzafa *et al.* (2020)
Canary Island	34.1.2	2018	3.554	0.0014	14.5–38.7	Jurado-Ruzafa *et al.* (2020)
Canary Island	34.1.2	2019	3.533	0.0013	13.2–42.50	Jurado-Ruzafa *et al.* (2021b)
Canary Island	34.1.2	2013–2019	3.317	0.0029	13.2–42.5	Jurado-Ruzafa *et al.* (2021b)
Morocco Center+South	34.1.12/13;31/32		3.145	0.005		FAO (2015) in Santamaría *et al.* (2020)
Morocco Center+South	34.1.12/13;31/32		3.34	0.0027		INRH/DRH (2016) in Santamaría *et al.* (2020)
Morocco Center+South	34.1.12/13;31/32		3.021	0.0077		FAO (2019) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11		3.362	0.0039		Camarena (1986) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11		3.444	0.00007		Provotorova (1998) in Santamaría *et al.* (2020)
Mauritania (males)	34.1.31/32 & 34.3.11		3.487	0.00005		Provotorova (1998) in Santamaría *et al.* (2020)
Mauritania (females)	34.1.31/32 & 34.3.11		3.577	0.00003		Provotorova (1998) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11		3.324	0.00343		Santamaria et al (2005) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11		3.31	0.003		Pascual-Alayón *et al.* (2009) in Santamaría *et al.* (2020)
Mauritania (males)	34.1.31/32 & 34.3.11		3.334	0.003		Pascual-Alayón *et al.* (2009) in Santamaría *et al.* (2020)
Mauritania (females)	34.1.31/32 & 34.3.11		3.308	0.003		Pascual-Alayón *et al.* (2009) in Santamaría *et al.* (2020)
Mauritania for 1960s	34.1.31/32 & 34.3.11		3.095	0.0083		Wahbi (2017) in Santamaría *et al.* (2020)
Mauritania for 1970s	34.1.31/32 & 34.3.11		3.347	0.0029		Wahbi (2017) in Santamaría *et al.* (2020)

Fishing area	Fishing area (codes)	Period (years)	*b*	*a*	Length range (cm)	Reference
Mauritania for 1980s	34.1.31/32 & 34.3.11		3.124	0.0067		Wahbi (2017) in Santamaría *et al.* (2020)
Mauritania for 1990s	34.1.31/32 & 34.3.11		3.217	0.0046		Wahbi (2017) in Santamaría *et al.* (2020)
Mauritania for 2000s	34.1.31/32 & 34.3.11		3.303	0.0034		Wahbi (2017) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11		3.05			Djimera *et al.* (2018) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11		3.05	0.007		FAO (2019) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	2005–2011	3.46	0.002	12.4–49	Jurado-Ruzafa *et al.* (2017)
Cape Verde	34.3.2		2.88	0.0196		Magnusson & Magnusson (1987) in Castro & Santana (2000)
Namibia	34.4.5		3.116	0.006		Ostapenko (1988) in Castro & Santana (2000)
South Africa	47.1.6–2.2		3.3112	0.0049		van der Elst & Adkin (1991) in Castro & Santana (2000)
Mediterranean Sea						
N Alborán Sea	37.1.1		3.5289	0.0015	17.2–40	Velasco *et al.* (2011) (1)
Tunisian waters	37.2.2	2009–2010	3.02	0.0111	16.3–31.8	Allaya *et al.* (2013)
Libyan waters	37.2.2		3.2	$2x10^{-6}$		Gasim *et al.* (1992) in Castro & Santana (2000)
Adriatic Sea	37.2.2	1998–2003	3.14	0.0066	19.6–38.8	Sinovcic *et al.* (2004) in Daley (2019)
Adriatic Sea	37.2.2	1998–2007	3.22	0.0052		Cikes & Zorica (2013)
Helenic Sea	37.3.1		3.5	$9.65x10^{-7}$	9.1–31	Kiparissis *et al.* (2000)
Aegan Sea	37.3.1		2.97	0.031	18.7–29.6	Petrakis & Stergious (1995) in Castro & Santana (2000)
Aegan Sea	37.3.1	1997–1998	3.7	0.0009	22.9–33	Moutopoulos & Stergiou (2002) in Daley (2019)
Aegan Sea	37.3.1	2009	3.1	0.0066		Cengiz (2012)
Izmir Bay	37.3.1		3.41	0.003	12.5–27.2	Bayhan (2007)
Egyptian waters	37.3.2		3.17	0.00567		Rafail (1972)

Fishing area	Fishing area (codes)	Period (years)	*b*	*a*	Length range (cm)	Reference
West Atlantic Ocean						
NW Atlantic	31	2016–2017	2.72	0.0258	22.4–38.6	Daley (2018)
Brazil	41		3.0613	0.0779		Seckendorff & Zavala-Camin (1985) in Castro & Santana (2000)
Argentina	41		2.81	0.028	17.5–44.20	Perrota (1992)

Table 5.5. Total length at first maturity (L_{50}, cm) estimated for *S. colias* throughout its geographical distribution; (FL) Fork length; (1) Individuals < 25 cm all immature; (2) Possible overestimation because of problems in the assignation of the immature stage (s).

		L_{50}				
Fishing area	Fishing area (codes)	males	fe-males	All together	Gonad evalu-ation	Reference
East Atlantic Ocean						
SE Bay of Biscay	27.8.b &27.8c	30.8	29	29.71	Macroscopic	Lucio (1997) (1)
N & NW Iberia	27.8.c & 27.9.a.n	n.a	24.99	n.a	Macroscopic	Villamor *et al.* (2017)
N & NW Iberia	27.8.c & 27.9.a.n	22.7	22.7	22.7	Macroscopic	Navarro *et al.* (2021b)
Portugal coast	27.9.a.c & 27.9.a.s	n.a	n.a	27	Macroscopic	Martins (1996) in Daley (2019)
Portugal coast	27.9.a S	n.a	n.a	19	Macroscopic	Gonçalves (2015) in ICES (2020)
Portugal coast	27.9.a C	18.71	22.12	19.47	Microscopic	IPMA (2020) in ICES (2020)
Gulf of Cadiz	27.9.a.s.c	n.a	n.a	> 30.6 cm FL	Macroscopic	Rodríguez-Roda (1982)
Gulf of Cadiz	27.9.a.s	n.a	n.a	23 (22.0-24.6) (2)	Macroscopic	Canseco (2016)
Azores Islands	27.10.a.2	n.a	n.a	27.78	Macroscopic	Carvalho *et al.* (2002)
Madeira Island	34.1.2	22.12	21.55	n.a	Macroscopic	Vasconcelos *et al.* (2012) in ICES (2020)
Canary Island	34.1.2	19.8	19.9	n.a	Macroscopic	Lorenzo & Pajuelo (1996)
Canary Island	34.1.2	18.64	18.46	18.5	Macroscopic	Jurado-Ruzafa *et al.* (2020)
Canary Island	34.1.2	18.79	19.44	19	Macroscopic	Jurado-Ruzafa *et al.* (2021b)
Morocco North	34.1.11	22.9	23	n.a	Macroscopic	Techetach *et al.* (2010) in San-tamaría *et al.* (2020)
Morocco North	34.1.11	21.6 FL	21.7 FL	21.3 FL		Wahbi *et al.* (2011) in Santama-ría *et al.* (2020)
Morocco North	34.1.11	n.a	n.a	22.72	Macroscopic	INRH/DP (2017) in Santamaría *et al.* (2020)
Morocco Center	34.1.12/13	n.a	n.a	22.56	Macroscopic	INRH/DP (2017) in Santamaría *et al.* (2020)
Morocco Center	34.1.12/13	n.a	n.a	24.24	Macroscopic	INRH/DP (2017) in ICES (2020)
Morocco Center	34.1.12/13	25.2	25	n.a	Macroscopic	Wahbi *et al.* (2017) in ICES (2020)
Morocco Center	34.1.12/13	29.6	27.5	n.a	Macroscopic	Djimera *et al.* (2018) in ICES (2020)
Morocco Center+South	34.1.12/13;31/32	n.a	n.a	22.2		Lakhnigue *et al.* (2013) in San-tamaría *et al.* (2020)

Fishing area	Fishing area (codes)	L50 males	females	All together	Gonad evaluation	Reference
Morocco Center+South	34.1.12/13;31/32	n.a	n.a	22.56		INRH/DP (2017)
Morocco South	34.1.31/33	n.a	n.a	25.7		Krivospitchenko & Domanevsky (1979) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	16-22		Razniewsky (1967) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	27-31		Alekseev (1969) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	27.5		Sedlestkaia (1978) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	31		Sedlestkaia (1978) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	20		Krivospitchenko (1979) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	22.2		Krivospitchenko & Domanevsky (1979) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	28	27	n.a		Weiss (1980) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	22 FL		Camanera (1986) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	22.1-25.7 FL		FAO (1987) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	24.4		FAO (1994) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	24.6 FL		Lawal & Mylnikov (1988) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	30	27.3	n.a		Pascual-Alayón *et al.* (2012) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	24.3		Lakhnigue et al (2013) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	n.a	n.a	24.24		INRH/DP (2017) in Santamaría *et al.* (2020)
Mauritania for 1960's	34.1.31/32 & 34.3.11	31.3	30.5	n.a		Wahbi et al (2017) in Santamaría *et al.* (2020)
Mauritania for 1970's	34.1.31/32 & 34.3.11	29.3	29.2	n.a		Wahbi et al (2017) in Santamaría *et al.* (2020)
Mauritania for 1980's	34.1.31/32 & 34.3.11	26.7	26.3	n.a		Wahbi et al (2017) in Santamaría *et al.* (2020)

		L_{50}				
Fishing area	Fishing area (codes)	males	females	All together	Gonad evaluation	Reference
Mauritania for 1990's	34.1.31/32 & 34.3.11	26.3	26.2	n.a		Wahbi et al (2017) in Santamaría *et al.* (2020)
Mauritania for 2000's	34.1.31/32 & 34.3.11	25.2	25	n.a		Wahbi et al (2017) in Santamaría *et al.* (2020)
Mauritania	34.1.31/32 & 34.3.11	29.6	27.5	n.a		Djimera et al (2018) in Santamaría *et al.* (2020)
South Africa	47.1.6-2.2	n.a	n.a	39-39.9		Baird (1977)
Mediterranean Sea						
Mediterranean Morocco	37.1.1	n.a	19.19	n.a	Microscopic	Techetach *et al.* (2019)
N Alborán Sea	37.1.1	27.2	n.a	n.a		CREANDA Project (2005) in ICES (2020)
Adriatic Sea	37.2.2	20.4	16.8	n.a	Macroscopic	Cikes & Zorica (2012)
Aegean Sea	37.3.1	n.a	n.a	18		Cengiz (2012)
Mediterranean Sea						
NW Atlantic	31	27.39	n. a.	n.a.	Microscopic	Daley (2018)

Table 5.6. Main spawning seasons (months with grey-shaded cells) of *S. colias* throughout its geographical distribution.

Fishing area	Fishing area code	Spawning period (months)	1	2	3	4	5	6	7	8	9	10	11	12	Reference
East Atlantic Ocean															
Southeastern Bay of Biscay	27.8.b &27.8c	May-June					■	■							Lucio, 1997
N & NW Iberia	27.8.c	April-July				■	■	■	■						Villamor et al. (2017))
N & NW Iberia	27.8.c	March-July			■	■	■	■	■						Navarro et al. (2021b)
N & NW Iberia	27.9.a.n	March-May			■	■	■								Villamor et al. (2017)
N & NW Iberia	27.9.a.n	March-May			■	■	■								Navarro et al. (2021b)
Portugal coast	27.9.a.c & 27.a.s	February-March and April-May		■	■	■	■								Martins (1996)
Portugal coast	27.9.a.C	January-May	■	■	■	■	■								IPMA (2020) in ICES (2020)
Portugal coast	27.9.a.S	December-March	■	■	■									■	Gonçalves (2015) in ICES (2020)
Gulf of Cadiz	27.9.a.s.c	Protracted spawning season (March-June?).			■	■	■	■							Rodríguez-Roda (1982)
Gulf of Cadiz	27.9.a.s.c	Not clearly defined (winter-early spring).	■	■										■	CREANDA Project (2005) in ICES (2020)
Azores Island	27.10.a.2	March-August			■	■	■	■	■	■					Carvalho et al. (2002) in ICES (2020)
Madeira Island	34.1.2	February-March		■	■										Vasconcelos et al. (2012) in ICES (2020)
Canary Island	34.1.2	December-January	■											■	Lorenzo & Pajuelo (1996)
Canary Island	34.1.2	January-February	■	■											Rivero (2006)
Canary Island	34.1.2	December-March	■	■	■									■	Jurado-Ruzafa et al. (2021b)
Morocco North	34.1.11	December- February and June-July	■	■				■	■					■	Techetach et al. (2010) / Wahbi et al. (2011) in ICES (2020)
Morocco Centre	34.1.12/13	December-January	■											■	INRH/DRH (2016) / INRH/DP (2017) in ICES (2020)
Morocco South	34.1.31/33	January-March	■	■	■										INRH/DP (2017) in ICES (2020)
Mauritania	34.1.31/32;3.11	December- February and August-September	■	■						■	■			■	Djimera et al. (2018) in ICES (2020)
Mauritania-Senegal	34.1.31/32 & 34.3.11/12/13	January-March	■	■	■										Wahbi et al. (2012) in ICES (2020)
Ghana	34.3.4	July-August							■	■					Kwei (1971)
South Africa	47.1.6/2.1/2.2	June - September						■	■	■	■				Baird (1977)
Mediterranean Sea															
N Alborán Sea	37.1.1	Not clearly defined (winter-early spring).													CREANDA Project (2005) in ICES (2020)
Tunisian waters	37.2.2	December-February and June-August	■	■				■	■	■				■	Allaya et al. (2013)
Libya waters	37.2.2	April-June				■	■	■							Giama (1994) in Castro & Santana (2000)
Adriatic Sea	37.2.2	May-August					■	■	■	■					Cikes & Zorica (2012)
Aegean Sea	37.3.1	June-August						■	■	■					Cengiz (2012)
Egypt water	37.3.2	May-July					■	■	■						Rizkalla (1998)
Israel	37.3.2	April-June				■	■	■							Ben-Tuvia (1957) in Castro & Santana (2000)
Marmara Sea	37.4.1	April-June				■	■	■							Tuggaç (1957) in Castro & Santana (2000)
Black Sea	37.4.2	June-August						■	■	■					Atli (1960) in Castro & Santana (2000)
West Atlantic Ocean															
NW Atlantic	31	January-April	■	■	■	■									Daley (2018)
Brazil	41	September-January	■								■	■	■	■	Matsuura & Sato (1981) in Castro & Santana (2000)
Brazil	41	July-December							■	■	■	■	■	■	Seckendorff & Zavala-Camin (1985) in Castro & Santana (2000)
Argentina	41	December-February	■	■										■	Gagliardi & Cousseau (1970) in Castro & Santana (2000)
Argentina	41	November-December											■	■	Ciechomski & Capezzani (1969) in Castro & Santana (2000)
Argentina	41	October-January	■									■	■	■	Perrota & Christiansen (1993) in Castro & Santana (2000)

6 Population structure

6.1 Spatial distribution

As seen in the Introduction, the Atlantic chub mackerel (*Scomber colias*) is widely distributed in the Atlantic Ocean. In the Western Atlantic, the species is distributed from Nova Scotia (Collette, 2002) to Argentina (Collette and Nauen, 1983). In the Eastern Atlantic, it is found from the Bay of Biscay to South Africa (Baird, 1977; Scole *et al*., 1998) and it is also found in the Mediterranean and Black Seas. *S. colias* distributes at maximum depths of around 500 m including all continental shelf and sea mountains (Martins *et al*., 2013).

6.2 Chub mackerel landings evolution

In European waters, the species landings are not regulated, being solely subjected to a minimum landing size (Mediterranean Spanish waters: 18 cm; Portuguese and Spanish Atlantic waters, Canary Islands and NW Africa: 20 cm) and general technical restrictions. The dynamics and status of chub mackerel populations are also unknown, and no formal scientific assessment and advice are undertaken at present.

The highest landing values reported corresponds to the CECAF region, mainly in Moroccan waters, although these values present noticeably annual variations (see Section 2.2). The overall trends are presented in detail in the working document by Neves and Garrido (2020) presented in the WKCOLIAS 2020, which have not changed in general terms following the analyses undertaken during the 2021 meeting. As highlighted in different sections, a general increase in landings has been reported for the species in East Atlantic waters, contrary to the landings reported for the Mediterranean waters, where a general decrease has occurred since the 1990s.

WKCOLIAS recommends exploring further the landing variations of the species to understand if they are only related to the species abundance changes or also to the fisheries dynamics/behaviour. The influence of the global warming in the expansion of the species, as well as in its abundance and biomass (which would influence landing trends) is also a pending issue that should be studied. Finally, discards information may also play an important role in this exploratory analysis because the species abundance can be reflected in the total catches (including both landings and discards), and not only in the landings.

6.3 Conclusions from scientific surveys

A great number of research surveys are conducted along the chub mackerel distribution range, becoming in an important data source for interpreting its spatio-temporal distribution patterns. A synoptic coverage of almost the whole distribution of the species in Eastern Atlantic waters, from Mauritanian to Bay of Biscay (BoB) waters, might potentially be achieved by the spring and autumn acoustic-trawl surveys regionally conducted by the different institutions and teams. BoB and Atlantic Iberian waters are also surveyed in autumn by bottom-trawl surveys coordinated by the ICES IBTS programme. Gulf of Cadiz (GoC) waters are even more intensely surveyed, with acoustic-trawl surveys in spring, summer and autumn. Notwithstanding the above, the goals pursued by the WKCOLIAS2 data call regarding research surveys have not completely been achieved. Thus, the submitted information from all these surveys has been very heterogeneous, with time-series of different length and continuity (presence of gaps), and survey indices that in some cases did not fulfil the requested format, hence the task of compiling a homogeneous and standardized set of time-series became in a very difficult one. **Accordingly, WKCOLIAS encourages that additional work of data compilation and standardization of the time-series of surveys indices and biological data be inter-sessionally carried out as backwards as possible.**

Chub mackerel shows a continuous distribution from Mauritania to Bay of Biscay, although the abundance in European waters is lower than that observed in Africa, where a gradual northwards increasing of abundance/biomass along the NW African shelf waters would culminate in the main nucleus of distribution of the species in the NW Moroccan shelf waters, mainly in the Zone North (FAO Subdivision 34.1.11).

Time-series of acoustic indices indicate a relative recent increase of the population levels in the most recent years, outstanding 2017 in the NW African waters (and Cantabrian Sea?), and 2019 in the Atlantic façade of the Iberian Peninsula and GoC. However, the true magnitude of the regional abundances estimated by the acoustic-trawl surveys is still unknown since they are needed of a proper inter-calibration and standardization (e.g. the adoption of the same value of the species-specific target strength). **WKCOLIAS highlights the potential interest to hold a joint workshop among the institutions and teams involved in the species surveying in order to address in the median term the above issues.**

Age structure and size composition surveyed by the research surveys also reveal problems when interpreting the true structure of the population. Surveys data suggest that the bulk of the populations inhabiting along the species distributional range is mainly composed by juvenile/subadult fish not older than 1–2 years. Larger (and older) fish are mainly recorded by these research surveys in northern Mauritanian waters, Spanish waters of the GoC and eastern Cantabrian Sea, but fisheries data suggest that the relative importance of this older adult fraction should be greater than that provided by the surveys, evidencing problems of availability to-, avoidance of- and catchability of larger sizes by the surveys.

Regarding avoidance and catchability issues, the WGFAST experts consulted during the workshop consider the towing speeds reached during the ground-truthing hauls (4–4.5 knots) as suitable speeds for chub mackerel fishing regardless the fish size, although they recommend exploring alternative ways of deploying the midwater trawls. Alternative sampling methods (use of cameras, hook and line sampling) have also been suggested by these experts to overcome this problem, although some of them may not be possible to be easily implemented in the current surveys' sampling designs. Furthermore, recent observations recorded during acoustic surveys in the Atlantic Iberian waters showed evident inter-annual changes in the aggregation patterns of the species which also may affect its catchability.

Regarding chub mackerel availability to the surveys, it has been reported during this workshop that stock containment may not be achieved by some of the acoustic surveys, since they may show an incomplete spatial coverage in the depth gradient, with their deepest limits being usually located in the 200 m isobaths. That is not the case for the bottom-trawl surveys, which may survey depths as deep as 700 m, but the use of sampling gears with much reduced vertical openings and slow towing speeds prevent them from being good samplers of the species.

Background and current analysed information seem to evidence that chub mackerel undertakes migration. Thus, from wintering areas, mainly located in Mauritanian waters, South Portugal and the inner part of the Bay of Biscay, chub mackerel spread towards northern waters in summer time and, in the case of the Bay of Biscay, also towards the western Iberian Peninsula.

In any case, as shown above, some issues are still pending of being properly analysed, so **WKCOLIAS strongly encourages, once the time-series are properly compiled and standardized, to carry out a detailed study of the species' size/age spatio-temporal distribution in the latitudinal and depth gradients along its distributional range**. This kind of study would require additional information on the species distribution in the depth gradient, not previously requested in this year's data call.

The exploratory SPiCT assessments presented to this workshop (see Section 7) included some preliminary analyses of the consistence of the time-series of the survey indices used as input data in the model, but only based in correlation analyses between aggregated indices. The analysis of the available data on age structure of the surveyed populations has allowed to track the strength of some cohorts in the most recent years along the whole distributional range in the Eastern Atlantic (e.g. 2016 year class along the whole area; 2018 and 2019 year classes in the Atlantic Iberian waters as well). Notwithstanding the above, if analytical (age-based) assessment approaches are going to be explored in the near future, a more detailed age-based analysis of the surveys' time-series consistence will be needed. **Therefore, WKCOLIAS highlights the importance of carrying out a proper analysis of the time-series consistency of those surveys that could potentially be included in the assessment model(s) exercise(s).**

6.4 Population differences in Atlantic chub mackerel life-history traits

Life-history traits data available for Atlantic chub mackerel in the whole distribution have been presented in Section 5, encompassing the following biological information: growth parameters, length-at-age, length–weight relationships, length at first maturity (L_{50}), and spawning season.

Available information shows that there are regional differences in the length at first maturity (Figures 5.5.1 and 5.5.2 in Section 5) and occurrence of the spawning season (Table 5.6 in Section 5), with latitudinal trends in both European and NW African waters, although further analyses should be performed to clarify these differences. Concerning growth parameters, and length-at-age data, geographical differences are also reported, but no conclusive latitudinal trends could be extracted from the information available. The length–weight relationships obtained in the different areas indicate a tendency towards positive allometric growth in all regions for chub mackerel.

The information presented in the Section 5 shows that geographical differences exist for most of the life-history traits of *S. colias*, with potential latitudinal trends that may be confirmed in future analyses, as though useful for assessment purposes, the present revision is not conclusive so far. Indeed, for all parameters considered, it should be borne in mind that the differences observed may be the result not only of factors related to different population dynamics and biological/environmental variables, but also of the fact that in general, the methodologies applied to obtain these data, do not only vary between countries/institutes but may also have changed over the years. For that, **WKCOLIAS highlights the importance of keeping the monitoring of the species to collate more and more consistent data using standardized methodologies. Clarifying these differences is of upmost importance to provide reliable input to the species assessment processes.**

6.4.1 Synopsis of published studies on Atlantic chub mackerel life-history traits

Velasco *et al*. (2011) studied the age and growth patterns of *S. colias* collected from two different areas, the Gulf of Cadiz and the Western Mediterranean. The results showed no differences in growth rate between the sampling areas, characterized by the absence of geographical differentiation in growth, demonstrating a lack of population structure for this species between both origins. The authors compared these results with other fish species such as *Pagellus acarne* (Velasco *et al*., 2011), *Engraulis encrasicolus, Trachurus trachurus* or *Mullus surmuletus* (unpubl. Data, Spanish Institute of Oceanography database 2010), suggesting that the Strait of Gibraltar does not represent a geographical break for the life history of the species.

Based on the comparisons by Daley and Leaf (2019), individuals from NW Atlantic exhibit a greater growth rate and reach smaller maximum length compared to other regions in the eastern side, including the Mediterranean Sea.

6.5 Published works addressing the Atlantic chub mackerel population structure

Some local or regional studies have been conducted on the population structure of the Atlantic chub mackerel in Atlantic and Mediterranean waters, namely using morphometrics (Roldán *et al*., 2000; Erguden *et al*., 2009; Allaya *et al*., 2016; Bouzzammit and El Ouizgani, 2019) and genetic (Scoles *et al*., 1998; Roldán *et al*., 2000; Zardoya *et al*., 2004; Infante *et al*., 2007; Catanese *et al*.,2010; Trucco and Buratti, 2017) analysis, and using parasitism (Costa *et al*., 2011; Mele *et al*., 2014) and otolith (Muniz *et al*., 2020; Correia *et al*., 2021) as population structure indicators. They are commented in the following subsections.

6.5.1 Morphometric variations in Atlantic and Mediterranean waters

Roldán *et al*. (2000) performed simultaneous genetic and morphologic analyses, from two areas of the Southwest Atlantic Ocean (Argentina) and one from the Mediterranean Sea. The morphologic analyses included six morphometric length measurements and a meristic character. The morphological results revealed a clear existence of two groups, the Mediterranean and Southern Atlantic, mostly related to head size variables and some evidence of regional stock separations among the Southern Atlantic two sites.

In the northern Mediterranean coast, morphometric and meristic analyses were used by Erguden *et al*. (2009) to discriminate stocks throughout the Black, Marmara, Aegean, and northeastern Mediterranean Seas, for Atlantic chub mackerel (as *S. japonicus*). The morphologic data results showed a clear existence of two groups, northeastern Mediterranean (Antalya Bay–Iskenderun Bay) and northern group, including the Aegean, Marmara, and Black Seas, with a high contribution from head size measurements for morphometrics. Both morphometric and meristic methods indicated that chub mackerels from the northeastern Mediterranean had a morphotype distinct from the remaining areas.

In the southern Mediterranean coast, Allaya *et al*. (2016) described the morphometric differences between the *S. colias*, from three different Tunisian locations - Ghar El Melh, Mahdia, and Zarzis. Results showed that all specimens were assigned into three morphometric groups that correspond to the three landing sites, by the discriminant analysis. For the meristic characters, results also showed a distinction between locations. The results also indicated that these landing sites had high morphological differentiation, which could be caused by differences in genetic structure or environmental parameters, according to the authors. The differentiation may suggest a relationship between the extent of phenotypic divergence and geographic distance, indicating that migration among three distant landing sites may be limited, and suggests that there may be a self-recruiting population in the Tunisian Sea.

In the Atlantic Moroccan coast, Bouzzammit and El Ouizgani (2019) demonstrated significant variation in the morphometric characters across fine Atlantic Moroccan locations and revealed the existence of four clear groups. The second group comprising El Jadida and Safi showed a major overlap, indicative of homogeneity, explained by the geographic proximity of these two locations sharing the same environmental conditions. The first - Agadir and the third - Laayoune groups are also close to each other, but still showed a significant difference in all morphometric characters, which may be due to variation in environmental conditions as these areas experience variability in upwelling intensity, according to study authors. Results revealed a significant difference in some meristic characters among samples, attributed to genetic structure or environmental factors.

Commonly defended by the above-mentioned authors, for the chub mackerel case, the differences observed among regional locations and consequent groups may suggest the relationship between phenotypic divergence and geographic distance, explaining the limited migration between the areas and regions. Moreover, different environmental factors such as temperature and salinity as well as the fishing intensity and availability of food may also contribute towards size variability, based on previous studies (Tudela, 1999; Tzeng, 2004; Turan *et al*., 2006).

6.5.2 Genetic variations in Atlantic and Mediterranean waters

Several studies show that Atlantic *S. colias* and Pacific *S. japonicus* are grouped in distinct lineages within *Scomber* clade, which constitutes strong support to the recognition as separate species, rather than, as before, a subspecies - *Scomber japonicus colias*. Besides, all sequences and genetic information provided in these studies will be useful for further reviews on population structure studies of *S. colias* aimed at determining the degree of genetic structuring between them.

One of the first studies on the *Scomber* genus, from Scoles *et al*. (1998) evaluated the global phylogeography of three mackerel species (*S. scombrus, S. australasicus* and *S. japonicus*). The study focused on inter- and intraspecific genetic relationships among and within those species, by restriction site analysis of the mitochondrial DNA (mtDNA) genome and direct sequence analysis of the mitochondrial cytochrome b gene. According to this study's conclusions, the complete partitioning of *S. japonicus* haplotypes among samples from Atlantic and Indo-Pacific, which are also morphologically distinct, suggested two isolated populations, that would need to be recognized as separated species, also defended by Collette, 1997. These were some of the first studies referring to that, and encouraging more detailed future analysis, first at subspecies and then species distinction level. Also, specifically for *S. colias* (as *S. japonicus*) in the Atlantic Ocean, Scolles *et al*. (1998) found no significant differentiation in haplotype frequencies between chub mackerel from the Mediterranean coast of Israel, the Ivory Coast, and South Africa, cleared that there were no fixed restrictions site differences, corroborated by following studies - Zardoya *et al*., 2004, in the Mediterranean Sea. However, the authors did find significant differences between chub mackerel from the western Atlantic and eastern Atlantic. Specifically, for SW Atlantic, authors found that haplotype distributions were significantly different between chub mackerel samples from Panama City, Florida and Mar del Plata, Argentina, and unique haplotypes occurred within each sample at "relatively high frequencies".

In the mentioned study by Roldán *et al*. (2000), they performed simultaneous genetic and morphologic analyses, from two areas of the Southwest Atlantic Ocean and one from the Mediterranean Sea. The genetic analyses were based on 16 protein-coding loci variations. The genetic results revealed also the clear existence of two groups, the Mediterranean and Southern Atlantic, confirming the morphologic results; and some evidence of regional stock separations among the Southern Atlantic two sites. Therefore, the authors suggested a northern and southern stocks approach policy of managing chub mackerel as two separate units.

Zardoya *et al*. (2004) performed a population genetic structuring based on 5′-end of the mitochondrial control region, for *S. scombrus* and *S. colias* (as *S. japonicus*). The results for *S. colias* showed no evidence of genetic differentiation across the Mediterranean Sea and adjacent waters (South Portugal) and concluded that the stock is panmictic in this region, corroborating the previous Scoles *et al*. (1998) work.

Infante *et al*. (2007) performed a phylogenetic analysis of nuclear 5S rDNA sequences, to genetically distinguish Atlantic *S. colias* and Pacific *S. japonicus*, based on previous significant mitochondrial DNA divergence as well as great phenotypic variation among individuals from these two ocean basins. Results revealed the presence of two well-supported distinct clades corresponding to *S. colias* in the Atlantic and *S. japonicus* in the Pacific (Figure 6), fully supporting a revision of the classic taxonomic status of mackerels and recognizing them as distinct species.

For the same purpose, Catanese *et al*. (2010) have determined the complete mitochondrial DNA sequence of *S. colias, S. japonicus* and *S. australasicus*. Phylogenetic analysis results revealed a monophyletic origin of *Scomber* species regarding other scombrid fish. The study showed that *S. colias* and *S. japonicus* were significantly grouped in distinct lineages within *Scomber* cluster, which phylogenetically constitutes evidence that they may be considered as separate species.

Cheng *et al*. (2011) conducted a molecular phylogenetic analysis of the genus *Scomber*, based on both mitochondrial and nuclear DNA sequence data from a multigene perspective. The present study confirmed that *S. japonicus* and *S. colias* were genetically distinct, corroborating previous works (Infante *et al*., 2007; Catanese, Manchado and Infante, 2010), producing a well-resolved phylogeny that strongly supported the monophyly of the *Scomber* genus.

Trucco and Burrati (2017) promoted a phylogenetic study on *S. japonicus*, *S. colias*, *S. australasicus* and *S. scombrus* from different regions. The results showed the clear differentiation of *S. japonicus* from the Pacific and Argentina origin, being the Atlantic samples included in the *S. colias* group, with genetic differences corresponding to conspecific populations (0.1%). The majority of Argentine specimens shared the same haplotype with *S. colias*, and none were shared with *S. japonicus* from the Pacific. The authors suggested that the specific name of Argentine mackerel *S. japonicus* should be changed to *S. colias*, in agreement with the previously mentioned studies.

6.5.3 Parasitism as population structure indicator in Atlantic and Mediterranean waters

Some published works used parasitism as biological tags to assess host population structure, being the majority focused on marine fish and either single parasite species or more recently, whole parasite assemblages, as biological tags (Catalano *et al*., 2014).

Costa *et al*. (2011) studied the helminth parasites composition of *S. colias* from Canary Islands, Central North Atlantic, comparing their relations with Southwestern and additional Central North Atlantic regions from previous studies (Costa *et al*., 2003; Pontes *et al*., 2005; Oliva *et al*., 2008). Results showed that within the Atlantic, the comparison of present results with previous reports on the occurrence of parasites in this fish host might suggest that there is more than one population unit of *S. colias* - SW and Central North Atlantic.

Mele *et al*. (2014) described the parasite fauna in the chub mackerels' head from the western Mediterranean Sea and compared the results with previously published data from 14 localities of the eastern Mediterranean Sea and the Atlantic Ocean. The results showed that parasite occurrence reflects the biogeographical and phylogenetic history of the host, which may suggest a population structure.

6.5.4 Otolith analyses population structure indicator in Atlantic and Mediterranean waters

The study of morphological, chemical and growth patterns based on otoliths has been put forward as an efficient tool for fish stock identification (Campana and Neilson, 1985; Ferguson, Ward and Gillanders, 2011). Otolith shape, for example, is species-specific, and together with otolith isotopic signature, varies geographically within species concerning environmental factors (Cardinale *et al*., 2004; Stransky and Maclellan, 2011), being a useful tool for spatial and temporal discrimination of fish stocks (Campana and Casselman, 1993; Agüera and Brophy, 2011), having been recently established that habitat environmental conditions induce an important change in otolith shape (Vignon, 2012).

Since the last WKCOLIAS group meeting in 2020, two regional studies related to otolith analyses have been published, using the same samples collected in the NE Atlantic, including the Iberian Portuguese coast, and the oceanic islands of Azores, Madeira and Canary Islands (Muniz *et al*., 2020; Correia *et al*., 2021). Muniz *et al*. (2020) performed an otolith shape (using Fourier descriptors and shape indices) and body morphometrics analyses. On one hand, the otolith shape analysis showed a single group with a discrete separation of two main groups (oceanic islands and mainland Portugal). On the other hand, the body morphometrics analysis distinguished the Canary Islands from the rest origins. Still, a joint analysis of both methods revealed three groups: Canary Islands; Azores and Madeira; and Iberian Portugal. In addition, Correia *et al*. (2020) conducted an elemental and isotopic signatures analysis of the same otoliths, which resulted in four separated population units, corresponding to the four studied origins.

6.5.5 New information on the Atlantic chub mackerel population structure

Preliminary results of two studies based on otolith shape analysis were presented during the workshop.

In the IEO, a study conducted off the Canary Islands has analysed chub mackerels' otoliths collected monthly between August 2016 and December 2017. The otolith shape analysis has been performed using Wavelet descriptors. The preliminary results distinguished five morphotypes inhabiting the Canary waters, with differences mostly on collicum-antirostrum and dorsal margin (see Jurado-Ruzafa *et al*. (2021) in Abstracts section, Annex 4).

At IPMA, chub mackerel otoliths collected since 2017 were analysed, encompassing the following five areas: Northwest, Southwest, and South of Portugal; Gulf of Cadiz and Canary Islands. Samples were mostly collected within the EU-DCF (Data Collection Framework) by the Spanish and Portuguese Fisheries Institutes (IEO, IPMA, respectively), and from regular monitoring of the commercial fleet. An otolith shape analysis was performed for those areas, using shape indices together with Fourier or Wavelet descriptors (to compare and select the best, considering the species and shape irregularities sensitivity of each descriptor). The preliminary Fourier results showed two groups: NW and SW of Portugal; and South of Portugal, Gulf of Cadiz, and Canaries (Figure 6.2).

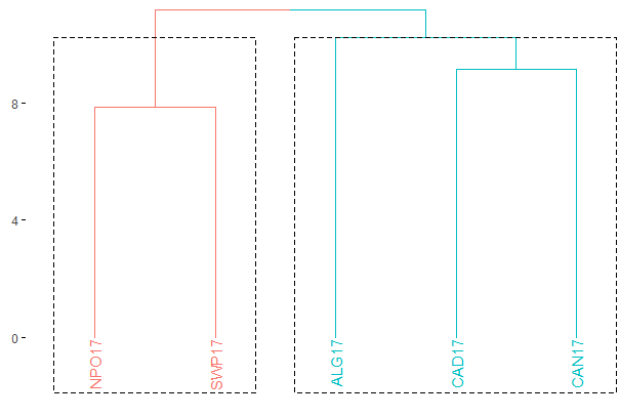


Figure 6.2. Cluster analysis describing the linkage dendrogram based on Euclidean distances among mean shape indices and Fourier descriptors.

The preliminary Wavelet results showed two different groups, with the Gulf of Cadiz area standing out from the remaining (Figure 6.3).

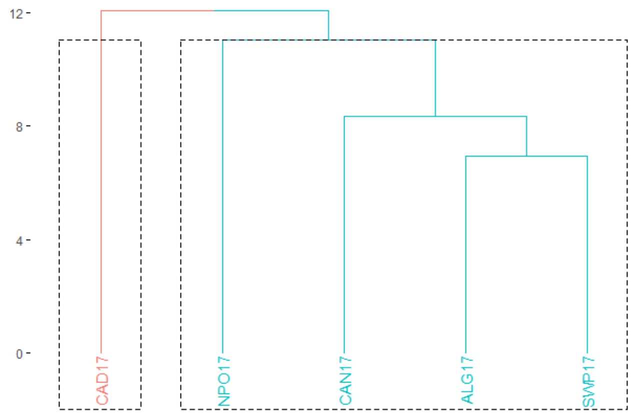


Figure 6.3. Cluster analysis describing the linkage dendrogram based on Euclidean distances among mean shape indices and Wavelet descriptors.

However, and as defended by the authors, the results were overly local (area-specific) and inconclusive so far, both in terms of population structure, as well as regarding the best otolith shape descriptors for this species. Besides, the authors defended that to establish a correct population structure, studies at a global level are necessary, being the universal belief of all participants of this WK. Nevertheless, during the mentioned study, some obstacles to compose/complete data related to time and proper resources were found, mostly related to recent global events - the COVID19 pandemic.

6.6 Connectivity hypothesis

Overall, and despite the efforts endeavoured during the WKCOLIAS2 to address the ToR related to the connectivity between *S. colias* populations in the East Atlantic and Mediterranean Sea, the available information does not allow at present to propose clear hypotheses. So far, to our knowledge, any study about tag-recapture has been performed for *S. colias*.

Though surveys data could potentially provide a synoptic overview for the species distribution range in East Atlantic, including geographical differences in the chub mackerel distribution, abundance and length/age composition, which in fact have allowed to track the strength of a few cohorts in the most recent years, no clear information about connectivity is currently available, although suspects about latitudinal interchanges in the East Atlantic waters and also with the Mediterranean, is strongly suspected.

Early life stages (eggs, larvae and small juveniles' distribution) data for *S. colias* could potentially be derived from existing ictyoplankton surveys and/or plankton sampling during other monitoring sea campaigns, which additionally to clarify the connectivity between populations at these life stages, could also be helpful for identifying the reproduction and nursery areas.

6.7 Conclusions

Morphometric studies have proved to provide an insight into discrimination of marine stocks. However, it is now commonly accepted that morphological variation has both environmental and genetic components. Thus, morphometric differences may reflect genetic differences between the stocks and/or environmental differences between localities. Therefore, stock identification based on morphological characters must be confirmed by genetic evidence to verify that the phenotypic differences reflect some degree of reproductive isolation rather than simply environmental differences. Together with local environmental factors, the otolith shape, among other morphometric traits like the body shape, can also reflect genetic variation (Tudela, 1999; Cardinale *et al*., 2004; Vignon and Morat, 2010). On the other hand, stock discrimination by morphologic markers (both body and otolith shape) might be appropriate for fisheries management even if this phenotypic divergence is not reflected by genetic differentiation. For that, moving forward with wide geographic shape analysis-based population structure studies seems to be also important whereas the best results are obtained for species that have an otolith contour with very specific morphology, as the *S. colias* case (Parisi-Baradad *et al*., 2010). The use of otoliths as natural tags to describe population structure for this species is still local. Nevertheless, studies for age and growth that use otoliths may provide some information about population structure. Adding to this, the advent of molecular genetic techniques allowed new ways how to use parasite genetic data. Besides that, parasitological data analysis can be used together with other techniques (e.g. artificial tags, phenotypic characters, biometrics, life history, genetics, otolith microchemistry), in a multiapproach population structure assessment. The spatial and temporal progress of cohorts based on abundance-at-age from surveys data can also be modelled to infer about possible movements between adjacent areas. Further studies from missing information areas and adding an otolith isotopic signature approach for this species to assess their natal origin and complement all existing population structure and promote connectivity analysis are strongly recommended.

7 Stock assessment

As commented through the sections, several studies on chub mackerel stock identification have been published so far, and others are in progress. The species is likely to be migratory but the extent of migrations is uncertain. WKCOLIAS 2020 concluded (ICES, 2020): "*If an assessment of chub mackerel is required in the ICES area, the WK considers that the most plausible stock scenarios are:*

a) *a single stock in the Bay of Biscay and Iberia waters ecoregion, or*
b) *two stocks in the above ecoregion separated in the mid-Cantabrian Sea.*"

The participants of WKCOLIAS 2021 were asked to update their expert view on stock structure and provide hypothesis alternative to the base case hypothesis presented in Table 7.1. While most participants were not confident enough to propose alternatives, there was a proposal that the Cantabrian Sea might be part of an Iberian stock unit. With respect to the European Macaronesiann Islands, literature suggests almost all the options: a) Açores+Madeira / Canary; b) Açores / Madeira+Canary; c) all together; d) all separated.

7.1 Suitable assessment models and biological reference points by area/population units

Based on the WK expert view and on the available data, the current 'population units' have been classified following the ICES checklist (https://doi.org/ 10.17895/ices.pub.4503) in the Table 7.1. According to this classification system, chub mackerel only could be considered as data-rich in the Iberian Peninsula (ICES 27.9a) and Moroccan waters (Central area); while in the Bay of Biscay, Mediterranean, Canary Islands and Madeira, the data available to the WK indicate an intermediate level.

There are candidate methods appropriate for the different stock categories that might be applied in each area to evaluate stock status and provide biological reference points if requested.

Following the ICES classification obtained in Table 7.1, different assays were performed and are presented in the following subsections. A surplus production model in continuous time (SPiCT) was thus experimentally implemented for both Iberian (Section 7.2.1) and Central and Southern Moroccan waters (Section 7.2.2). Moreover, the common minimum denominator to all areas seeming to be length–frequency data, thus Length-Based indicators (LBI) and Length-based Spawning Potential Ratio (LBSPR) methods could be implemented. They require length–frequency distributions but also information on L_{50}, L_{95}, M and growth parameters (L_{inf} and k) that is available in Section 5 of this report. The LBSPR methodology was applied to the different geographical areas considered in the WK (Section 7.3) and LBI has been left to be implemented in the future.

The work carried out during the WKCOLIAS2 based on the SPiCT and LBSPR were scientific and exploratory exercises, which need further investigation and discussion. The results obtained should by no means be considered as a formal evaluation of the condition of the chub mackerel in the different areas, or have any implications in terms of management advice.

Table 7.1. Summary of the fisheries, surveys and biological data compiled by the WG on chub mackerel from the Bay of Biscay to the NW African waters and Macaronesiann **Islands and indication of potential assessment methods that may be explored in each of the hypothetical stock units ("hypothetical stock units" considered here as "hypothetical population units" for the purpose of assessment model exploratory exercises).**

Zone	ICES/FAO area	Country	Fishery	Landings	Catches	Catch-at-length	Catch-at-age	Effort	Surveys abundance index	Surveys abundance-at-length	Surveys abundance-at-age	CPUE/LPUE	Biological parameters	Stock Unit_H0	Candidate category (ICES)	Potential assessment methods	Biological Reference Points (BRP) methods/Advice method	Comments	References
North Bay of Biscay	27.8a	Spain	Purse seine+Bottom Trawl	2009-2019	2009-2019	NA	NA	2009-2019	Some: 2013-2019 for 27.8c; possibly exists for 8ab	Y	Y	Y (?)	Maturity; Growth; Weight-Length	Bay of Biscay and Cantabrian Sea	3 Or 4 Or 5	Trend-based on CPUE (?); Length-based indicators; Length/Age based SPR; Catch-curve analysis; Mean-length Z; Depletion-Corrected Average Catch (DCAC)	Trend-based rules; Length-based indicators BRPs; Length/Age-based Yield-per-Recruit BRP; no BRP	Approaches depend on the possibility to assume that the data from the Spanish fishery in area 8 are representative of the whole fishery and on the reliability of the effort data (chub mackerel is not a target and purse seine effort should include the time spent searching for schools). Some of the DLS methods assume constant or modest, random variability in recruitment. Age-based methods may be possible if there is some age/growth data can be applied (borrow from other area, apply inverse ALK method)	http://ices.dk/sites/pub/Publication%20Reports/Guidelines%20and%20Policies/16.04.03.02_Category_3-4_Reference_Points.pdf
South Bay of Biscay	27.8b	Spain	Purse seine+Bottom Trawl	2009-2019	2009-2019	2011-2019	2011-2019	2009-2019		Y	Y								
Cantabrian Sea	27.8c	Spain	Purse seine+Bottom Trawl+Multi-gear	1982-2019	2009-2019	2011-2019	2011-2019	2009-2018		Y	Y								
West Galicia	27.9an	Spain	Purse seine+Bottom	1993-2019	2009-2019	2011-2019	2011-2019	2009-2018	Various: Acoustic in 9an since 2013, 9as since 2004 with gaps, 9acn+9acs since 2018; IBTS in 8c and 9a	Y	Y	Y(?)	Maturity; Growth; Weight-Length	Atlantic Iberian waters	1 (2011-)	Stock Synthesis; SAM; a4a,etc	MSY BRPs / MSY approach	Time series not very long. LFD and ALK from 9an+8c applied to 9asc until 2016 (to be confirmed).	https://www.ices.dk/sites/pub/Publication%20Reports/Guidelines%20and%20Policies/12.04.03.01_Reference_points_for_category_1_and_2.pdf
West Portugal	27.9acn+9ac	Portugal	Purse seine+Bottom	1980-2019		2000-2019	2000-2019	NA ?											
South Iberia-Algarve	27.9as_Port	Portugal	Purse seine+Bottom	1980-2019	2004-2019	2000-2019	2000-2019	NA ?											
South Iberia- Gulf of Cadiz	27.9as_Spain	Spain	Purse seine+Bottom Trawl+Multi-gear	1992-2018	2009-2019	2011-2019	2011-2019	2009-2018											
NW Africa Zone North (35ºN-32ºN)	34.1.1	Morocco	Purse seine	1990-2018	1990-2018	2015-2018	NA	NA	NA	NA	NA	NA	Maturity	North Morroco				Low chub mackerel abundance in the shelf area between the eastern Gulf of Cadiz and Tangier from observations in Moroccan acoustic surveys and also lack of a fishery in the area.	
NW Africa Zone A+B (32ºN-26ºN)	34.1.1	Morocco	Purse seine	1990-2018	1990-2018	2002-2018	1990-2018	1990-2018	several series, since 1994	Y	Y		Maturity	Central Morrocco			Bcur/B0.1 and Fcur/F0.1; where Bcur and Fcur are derived from the XSA assessment and B0.1 and F0.1 are calculated in Yield-per-recruit analysis.	Catch-at-length compositions from all NW African areas aggregated to build a combined age composition. Various methods used to explore the dynamics of the stock: dynamic version of the Schaefer model and age-based methods, extended survivor analysis (XSA) and integrated catch analysis (ICA). Work in progress to explore length-based methods to data from the whole NW African coast within project FARFISH.	http://www.fao.org/3/cb0490en/CB0490EN.pdf
NW Africa Zone C (south of 26ºN)	34.1.3	Marocco-Mauritania-Senegal-Gambia	Purse seine+Pelagic trawlers EU&others	Depends on the fleet (since 1993, etc)	2002-2018	2002-2018 (combined fleets)	1992-2018 (from Russian fleets)	1990-2018	Acoustic surveys since 2006	Y	Y	CPUE (A+B+C) standardized to units of RTMS (1992-2018), and CPUE (A+B zone) by t/positive trips of Moroccan purse seiners (1992-2018)	Maturity	South Morocco/ Mauritania/Senegal/Gambia					
Madeira Island	34.1.2	Portugal	Purse seine	2008-2019	2008-2019	2008-2019	NA	2008-2019	NA	NA	NA	Y (?)	Maturity; possibly Growth; Weight-Length(?)	Madeira	3 Or 4 Or 5	Trend-based on CPUE (?); Length-based indicators; Length/Age based SPR; Mean-length Z; Catch-curve analysis; Depletion-Corrected Average Catch (DCAC)	Trend-based rules; Length-based indicators BRPs; Length/Age-based Yield-per-Recruit BRP; no BRP	Age-based methods may be possible if there is some age/growth data can be applied (borrow from other area, apply inverse ALK method)	
Canary Islands	34.1.2	Spain	Purse seine	2013-2019	2013-2019	2013-2019	NA	2013-2019	NA	NA	NA	Y (?)	Maturity;	Canary	3 Or 4 Or 5				
Mediterranean Sea-Alboran Sea	GSA1	Spain	Purse seine	2012-2019	2012-2019	2012-2019	NA		NA	NA	NA	N		North Alboran Sea					
Mediterranean Sea-Catalan Sea	GSA6	Spain	Purse seine	2012-2019	2012-2019	2012-2019	2012-2016		NA	NA	NA	N		Catalan Sea					

7.2 Exploratory assessments with SPiCT

7.2.1 Iberian Peninsula

In the following SPiCT trials, it was assumed that the hypothesis of two stocks in the ecoregion separated in the mid-Cantabrian Sea was more likely. However, since the data available were not split into east and west Cantabrian Sea for some of the years, the northern stock limit was set either at Cape Finisterre (Dataset 1) or at the Portuguese-Spanish (between Galicia and north to Portugal) (Dataset 2). The latter dataset takes advantage of a longer time-series (36 years) while the former is ten years shorter.

Survey data with reasonably long and continuous time-series of abundance estimates were considered: the Portuguese Autumn bottom trawl survey (IBTS.autumn), the Portuguese Summer bottom-trawl survey (IBTS.summer), both cover the Portuguese waters, and the Spanish summer acoustic survey (ECOCADIZ.summer) which covers the southern Iberian waters (Algarve and the Gulf of Cadiz) where a large part of the stock distributes. The consistency between survey trends indicated a significant positive correlation between the two IBTS surveys (Spearman Rho= 0.56, $p<0.05$) but not between each IBTS survey and the ECOCADIZ.summer (Spearman Rho=0.32, $p>0.05$).

SPiCT assumes that catch data should be representative and to include both landings and discards. For chub mackerel, discard estimates were lacking for the early years and for several areas thus landings were used instead of catches in the analyses. The available discard estimates for the Portuguese bottom-trawl fleet 2004–2013 represented on average 9% of the total Portuguese landings and 300% of the landings of the bottom-trawl fleet. SPiCT also assumes that the stock size indices should be representative of the part of the stock vulnerable to the commercial fleets (exploitable stock biomass, ESB). The analyses of length compositions of landings, discards and the IBTS.autumn survey indicated that this assumption is not violated. The mean length composition of the IBTS.autumn is slightly shifted to the left (1–2 cm) compared to landings mean length composition. Discards 2004–2013 have a mean modal length of 20 cm (Fernandes *et al.*, 2017) compared to a modal length of 22 cm in the landings.

Based on the submitted data, the datasets considered for the SPiCT model assays are presented in Table 7.2.1.1.

Table 7.2.1.1. Datasets considered for the SPiCT analyses (see also Figures 7.2.1.1 and 7.2.1.2).

Data	Iberian stock	Portuguese stock
Landings	1993–2019	1985–2000
IBTS.autumn	1993–2018	1985–2018
IBTS.summer	1993–2002	1985–2002
ECOCADIZ.summer	2004–2019	2004–2020

The default priors on the ratio of process to observation error of the biomass and fishing mortality were kept in all trials:

logalpha ~ dnorm[log(1), 2^2]
logbeta ~ dnorm[log(1), 2^2]

For each dataset, the following scenarios were considered for the shape of the production curve (*n* parameter):

1. No prior.
2. Default prior (logn~dnorm[log(2), 2^2]; wide prior, Schaefer-type).
3. Schaefer model (logn~dnorm[log(2), 1e-3^2]; narrow prior).
4. Fox model (logn~dnorm[log(1), 1e-3^2], narrow prior).
5. Thorson prior for pelagics from meta-analysis (logn~dnorm[log(0.599), 0.342^2]).
6. Best model of 1:5 + robust fitting to surveys.
7. Best model of 1:5 + weighting of IBTS survey observations by the relative uncertainty (CV normalized to zero mean).

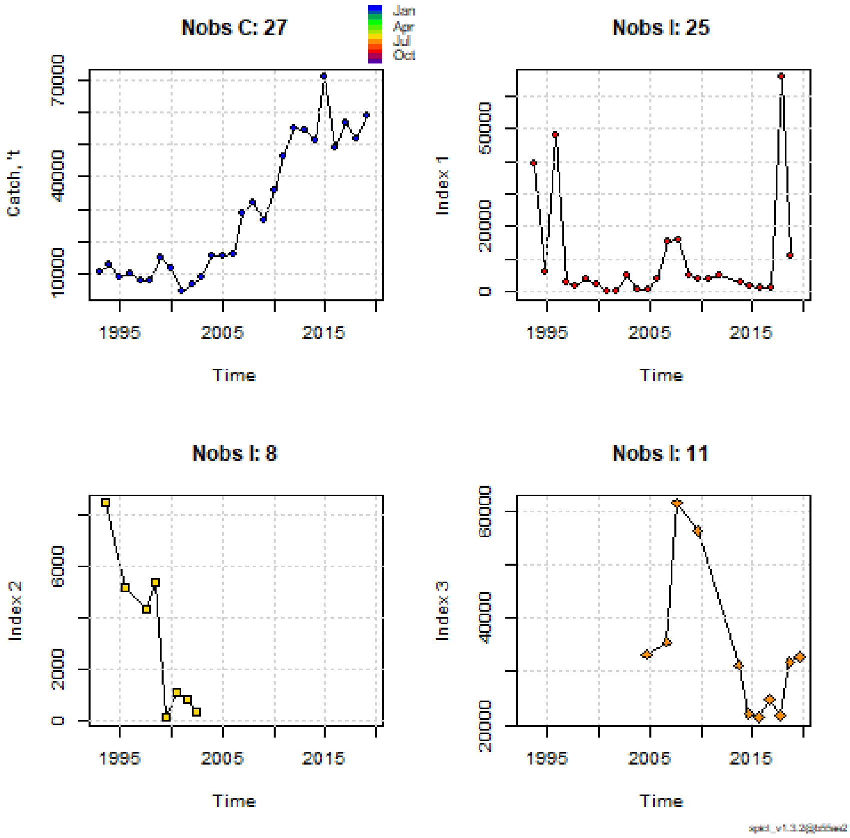


Figure 7.2.1.1. Chub mackerel: SPiCT input assessment data for the Iberian stock.

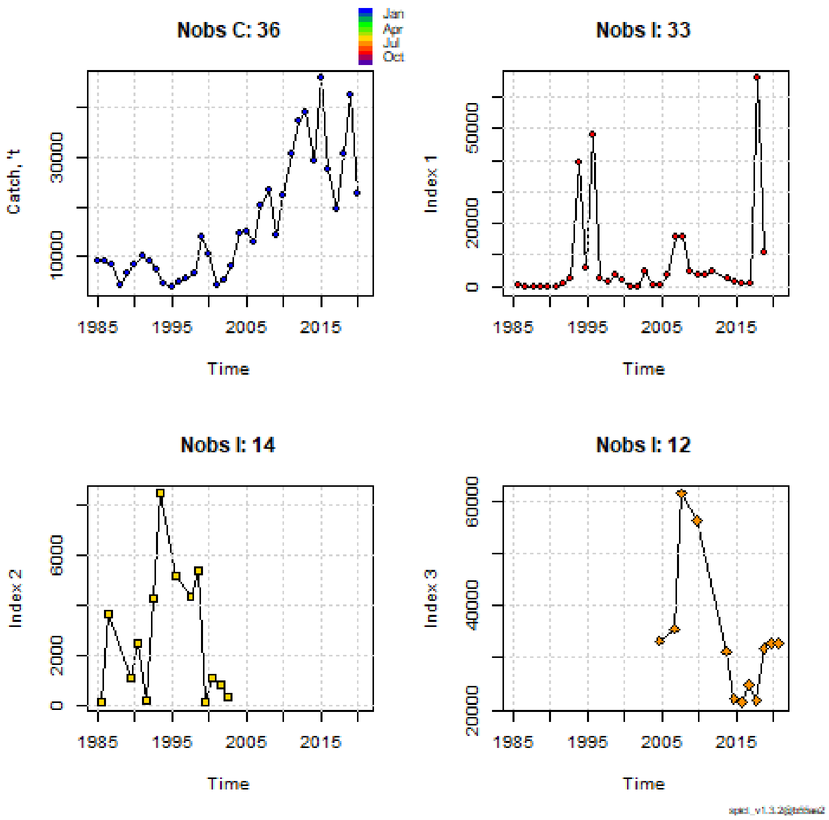


Figure 7.2.1.2. Chub mackerel: input assessment data for the Portuguese stock.

Models estimating *n* without prior and models with robust survey fitting did not converge for any of the datasets. In addition, the model with default *n* prior and the Fox model did not converge for the Iberian and Portuguese stocks, respectively.

For the Iberian stock, none of the models that converged passed the ICES checklist (https://github.com/DTUAqua/spict, ICES, 2021) plus the requirement that Mohn's Rho for B/B_{MSY} and F/F_{MSY} is in the interval [-0.22, 0.3] (the criteria applied to catch-at-age assessments) (Table 7.2.1.2). In most models, F/F_{MSY} had large uncertainty (CV>0.8) and high sensitivity to initial values. In all models F/F_{MSY} showed large (>0.40) retrospective bias (overestimation) (Figure 7.2.1.3). Overall, the two Schaefer models had the best performance with the survey weighting model showing better stability.

For the Portuguese stock, all models passed the ICES checklist (Table 7.2.1.2). Retrospective patterns were reasonable for both B/B_{MSY} and F/F_{MSY} with Mohn's Rho values within the interval [-0.22, 0.3] (Figure 7.2.1.5). The Schaefer models, with or without survey weighting, showed a similar performance and overall corresponded to the best models.

Table 7.2.1.2. Chub mackerel: Diagnostics and summary results of the SPiCT trial assessment models. "Stock units" considered here as "hypothetical population units" for the purpose of the assessment model exploratory exercises. Model: refer to the different scenarios described previously.

Stock unit	Model	Conv	AIC	Fin.Var	BMSY/K	Bmsy Fmsy	MSY	Result	Estimate	CV	CI magnitude	Mohns Rho	Distance percentile	Initial distance	Results distance
Portuguese stock	Default prior	Y	288.69	TRUE	0.38	111917	29877	B/Bmsy	1.72	0.57	1	-0.06	50%	4.54	0
Portuguese stock						0.27		F/Fmsy	0.4	0.77	1	0.28	90%	4.95	3.85
Portuguese stock	Schaefer	Y	273.98	TRUE	0.5	108041	32465	B/Bmsy	1.45	0.24	1	-0.07	50%	4.54	0
Portuguese stock						0.30		F/Fmsy	0.44	0.62	1	0.11	90%	4.95	4.51
Portuguese stock	Thornson	Y	302.6	TRUE	0.37	46651	28428	B/Bmsy	0.9	1.22	1	0.85	50%	4.54	0
Portuguese stock						0.61		F/Fmsy	0.93	1.2	1	-0.27	90%	4.95	250132.3
Portuguese stock	Schaefer survwei	Y	272.43	TRUE	0.5	101258	31816	B/Bmsy	1.39	0.24	1	-0.05	50%	4.54	0.48
Portuguese stock						0.32		F/Fmsy	0.48	0.6	1	0.08	90%	4.95	7.16
Iberian stock	Schaefer.ib	Y	205.33	TRUE	0.5	65689	50707	B/Bmsy	1.05	0.25	1	-0.03	50%	4.54	0
Iberian stock						0.77		F/Fmsy	1.1	0.36	1	0.4	90%	4.95	440696.2
Iberian stock	Fox.ib	Y	187.59	TRUE	0.37	159999	69033	B/Bmsy	1.96	0.3	0	-0.08	50%	4.54	0
Iberian stock						0.43		F/Fmsy	0.43	0.88	2	0.45	90%	4.95	445734.9
Iberian stock	Thornson.ib	Y	198.73	TRUE	0.27	93968	76975	B/Bmsy	2.51	0.34	0	-0.21	50%	4.54	0.73
Iberian stock						0.82		F/Fmsy	0.3	0.84	2		90%	4.95	334393
Iberian stock	Schaefer.survwei.ib	Y	187.17	TRUE	0.5	351551	49649	B/Bmsy	1.5	0.37	1	-0.08	50%	4.54	0.96
Iberian stock						0.14		F/Fmsy	0.77	1.21	1	0.49	90%	4.95	11.75

The four best models pass all residual checks except: a) significant residuals auto-correlation at lag-1 in the IBTS-autumn survey for the Portuguese stock (Figure 7.2.1.4) and b) non-normal residuals for the IBTS-autumn survey for the Iberian stock. The use of CVs as weighting factors for the IBTS surveys did not change the model fit or the results significantly in the case of the Portuguese data but it had a large impact for Iberian models in the early part of the time-series.

The two best models for the Portuguese stock show comparable trends in the relative indices of stock abundance and fishing pressure (Figure 7.2.1.6). B/B_{MSY} shows an increasing trend from 1985 to 2009 and thereafter a decrease but was above 1 most of the period. F/F_{MSY} dropped in the early period and fluctuated at a low level until the late 2010s. F/F_{MSY} peaked in 2015 when the catches reached the historical maximum (45 000 t).

The two best models for the Iberian stock show different trends, mainly in the earlier period. Trends from the Iberian model with survey weighting are similar to those from the Portuguese models since the mid-2000s and suggest a similar stock status (Figure 7.2.1.6).

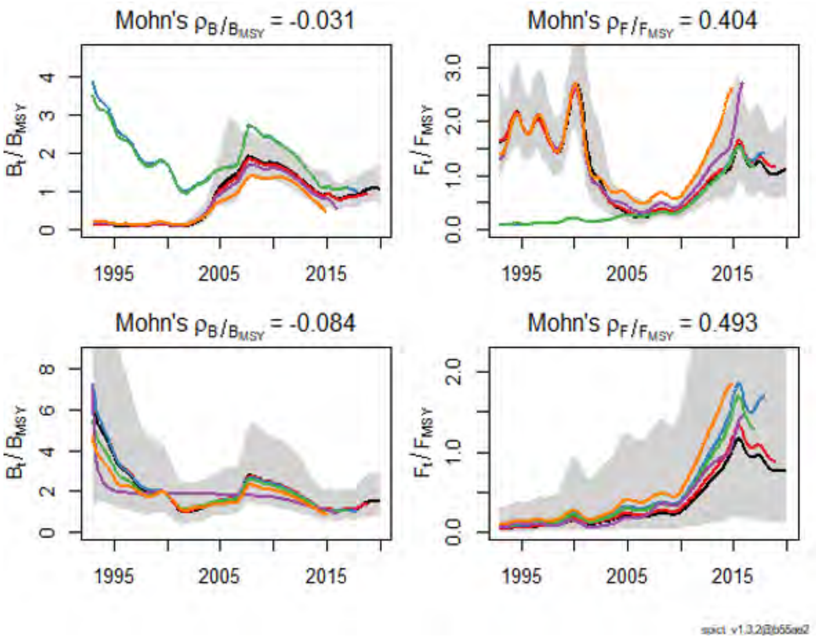


Figure 7.2.1.3. Retrospective plots of the Schaefer (top panel) and Schaefer with survey weighing (bottom panel) SPiCT models fitted to the Iberian stock of chub mackerel.

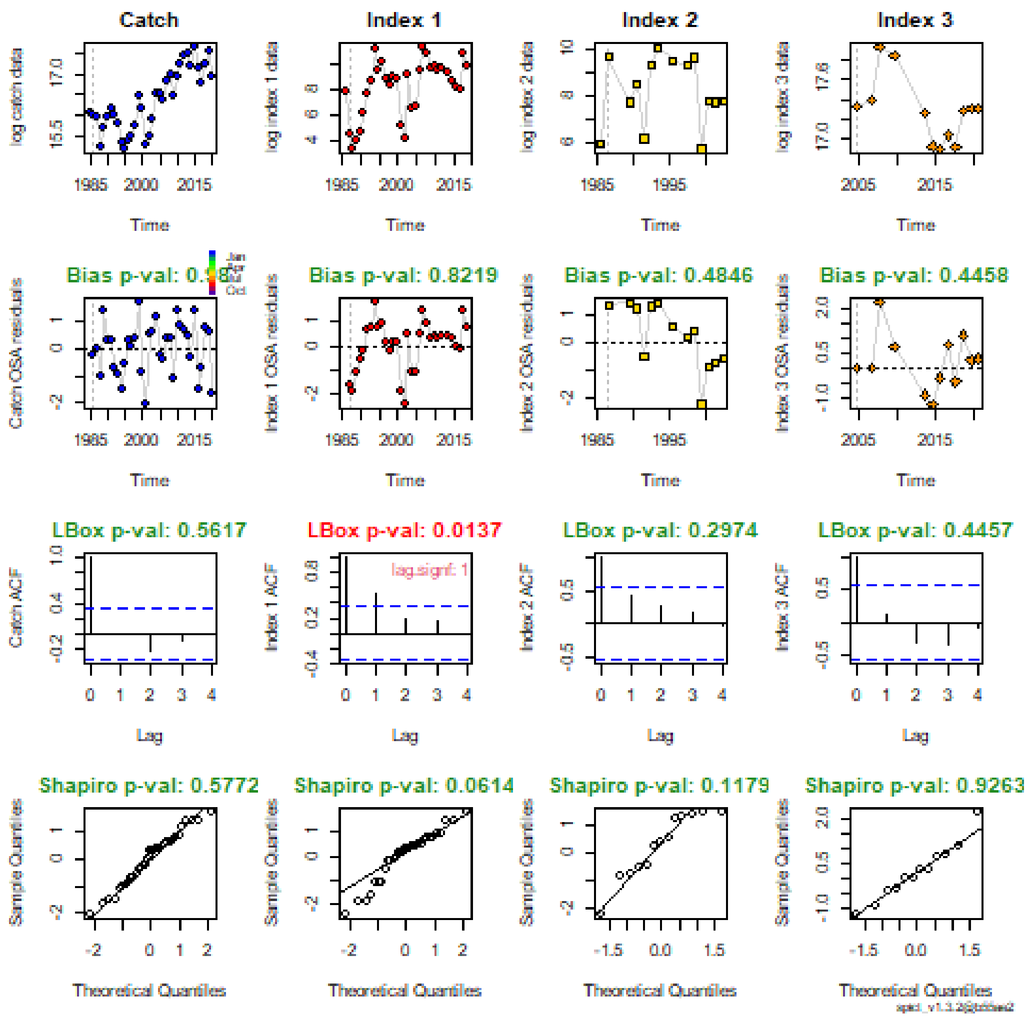


Figure 7.2.2.4. Residual plots of the SPiCT Schaefer model fitted to the Portuguese stock data.

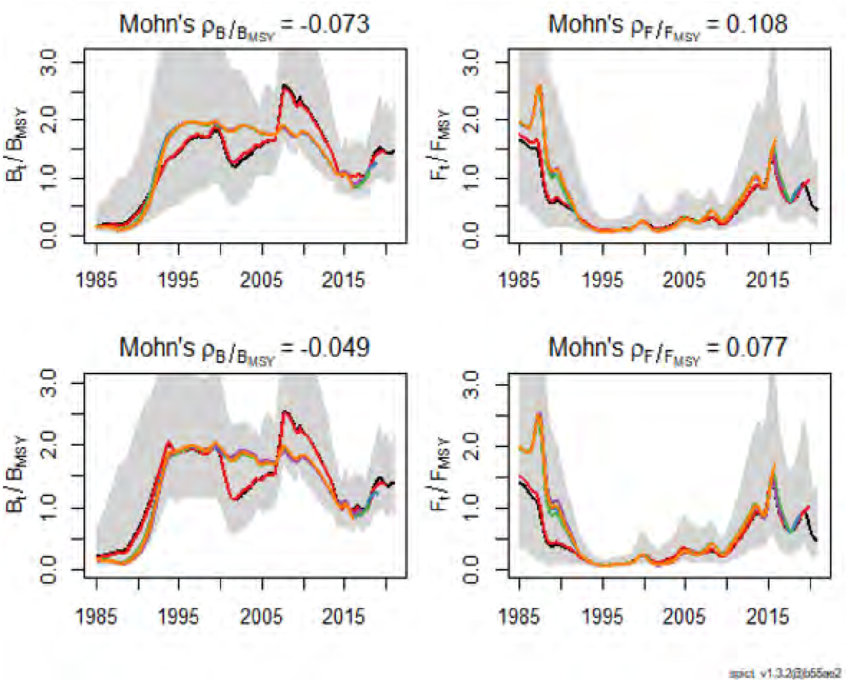


Figure 7.2.1.5. Retrospective plots of the SPiCT Schaefer (top panel) and Schaefer with survey weighing (bottom panel) models fitted to the Portuguese stock of chub mackerel.

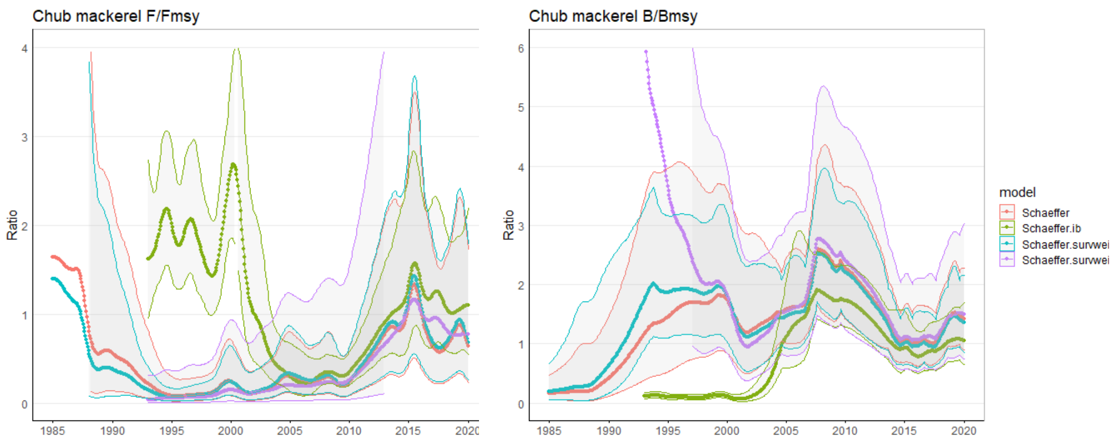


Figure 7.2.1.6. Summary plots of the relative fishing mortality (F) (left panel) and biomass (B) (right panel) estimates for the four best SPiCT models fitted to chub mackerel in the Iberian (.ib) and Portuguese waters.

7.2.2 Moroccan waters

A SPiCT model was also implemented for the chub mackerel stock in the centre and south of Moroccan Atlantic coast by using catch time-series and three different abundance indices (Russian trawl CPUEs, biomass data from 'Fridtjof Nansen' and 'Atlantida' acoustic surveys).

The model was implemented by testing four different sets of assumptions:

Scenario 1: default priors,

Scenario 2: reducing the estimated catch variability by shortening data time-series,

Scenario 3: imposing a Schaefer model on the production curve, and

Scenario 4: imposing a Schaefer model and changing the default prior for the ratio between biomass at the beginning of the time-series relative to the carrying capacity.

Details on the scenarios definition and results are presented in Derhy *et al.*, WD (2021) (working document 4 in Annex 5).

7.2.3 Summary of the SPiCT model results

The results obtained from the SPiCT trials for the Iberian Peninsula suggested that a Schaefer model fitted well to the biomass and catch dynamics of chub mackerel in the Portuguese waters. While the majority of chub mackerel biomass in ICES Division 9a appears to be distributed in the Portuguese waters there is uncertainty about the stock limits. Other issues, such as autocorrelation of residuals in the IBTS autumn survey, the magnitude of discards/slipping, need to be further addressed to improve the model.

For the Moroccan waters, according to Derhy *et al.*, WD (2021) best results in terms of goodness of fit and uncertainty were obtained by assuming a Schaefer-type production curve (scenario 3). Biomass time-series and reference points estimates in this scenario were consistent with those estimated by the Biodyn model (INRH/DP, 2017), one of the models used currently for the assessment of this species in the area.

7.3 Length-Based Spawning Potential Ratio method (LBSPR) assay

7.3.1 Input data

A summary of the input data used for the different LBSPR model implementations is presented in the Table 7.3.1.1. Estimates of the von Bertalanffy's growth parameters (L_{inf} -asymptotic length- and k -growth rate), the length at 50% (L_{50}) and 95% of maturity (L_{95}) are available in Section 5 of the report. When different values were available for the same parameter and the same area, different scenarios were defined to test the sensitivity in the results. Natural mortality values (M) were extracted from FishBase.

Table 7.3.1.1. LBSPR model input data for each fishing area.

Fishing area	Catches' length composition-time period available	Life-history parameters				
		L_{inf} (cm)	k	M ($years^{-1}$)	L_{50} (cm)	L_{95} (cm)
Cantabrian Sea (27.8.c)	2013–2019	S1=45.34 S2=55.00 S3=48.74 S4=49.30	S1= 0.28 S2=0.24 S3=0.25 S4=0.30	0.35	22.46	23.31
Portuguese waters (27.9.a.c.n + 27.9.a.c.s + 27.9.a.s.a)		53.83	0.17	0.35	16.67	23.78
Mediterranean Sea – Catalan Sea (GSA6)		38.1	0.21	0.35	25.72	28.43
Madeira island		50.08	0.25	0.35	27.78	30.9
Canary Islands		49.5	0.23	0.47	19	22
North of Moroccan Atlantic coast	2015–2018	44.53	0.32	0.5	22.72	35.78
Centre (A+B) and south (C) of Moroccan Atlantic coast	2002–2018	S1=39.35 S2=47.14	S1=0.25 S2=0.16	0.5	23.71	35.78

7.3.2 LBPSR model results

7.3.2.1 Cantabrian Sea (27.8.c)

The model fit to the length distributions of **landings** data and the specified maturity and estimated selectivity-at-length for scenarios 1, 2, 3, and 4 are presented in Figures 7.3.2.1.1 and 7.3.2.1.2, respectively. These estimates are equal for both scenarios because the length data input was the same for these scenarios.

Figures 7.3.2.1.3, 7.3.2.1.4, 7.3.2.1.5 and 7.3.2.1.6 show the different estimated values for SPR, selectivity and F/M, for scenarios 1, 2, 3 and 4, respectively.

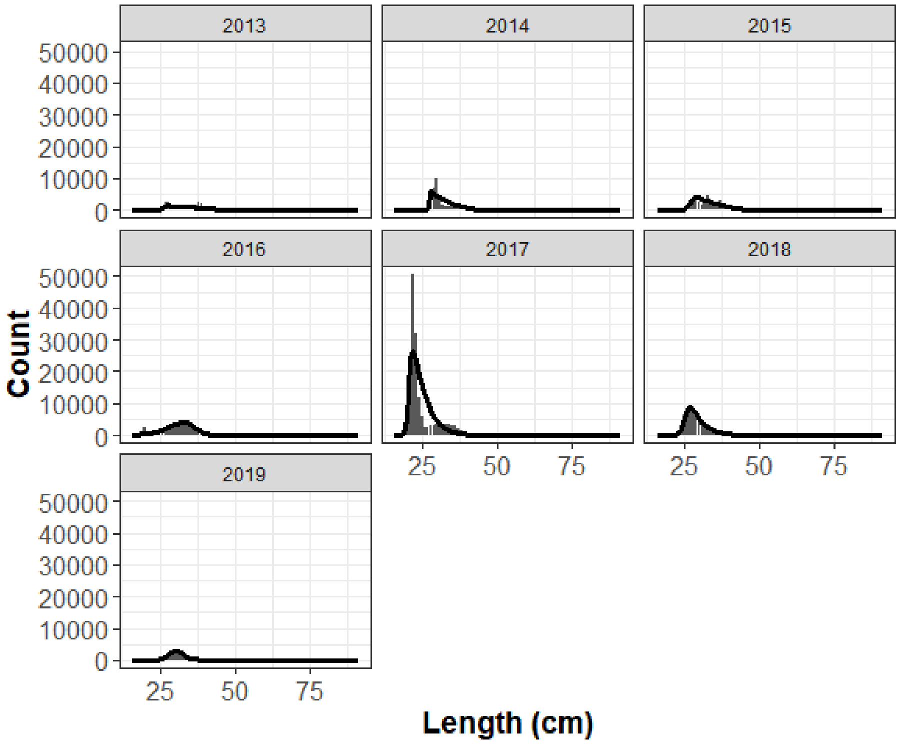


Figure 7.3.2.1.1. Length composition distributions for Cantabrian Sea chub mackerel landings (bars) and LBSPR model fit (solid black line) for scenarios 1, 2, 3 and 4.

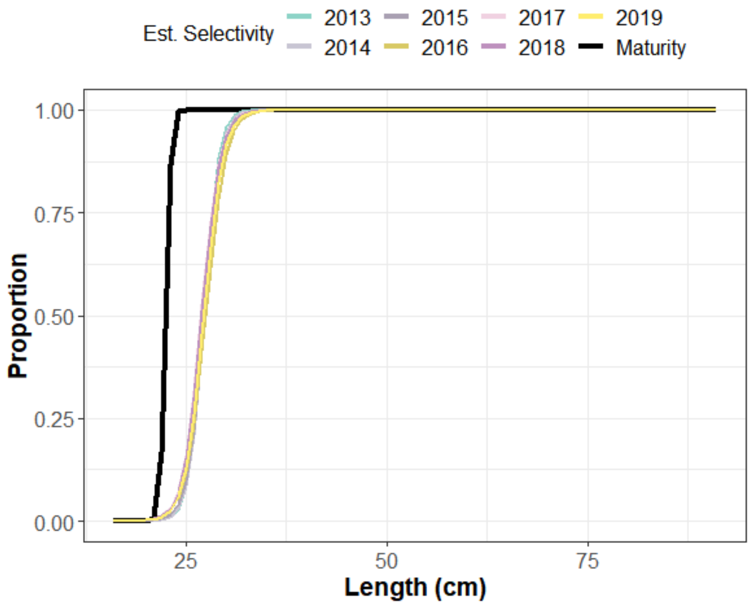


Figure 7.3.2.1.2. Cantabrian Sea (27.8.c) chub mackerel: Specified maturity and estimated selectivity-at-length for scenarios 1, 2, 3 and 4.

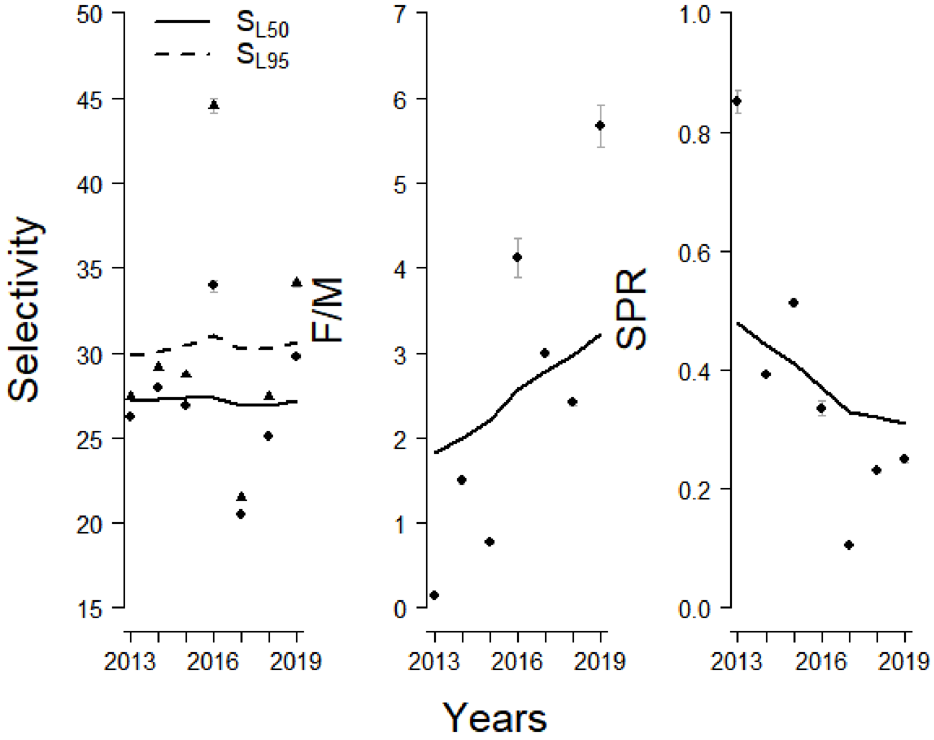


Figure 7.3.2.1.3. Cantabrian Sea (27.8.c) chub mackerel: Estimated values for SPR, SL50, SL95 and F/M for scenario 1; the black line corresponds to the smoother line to the estimated points.

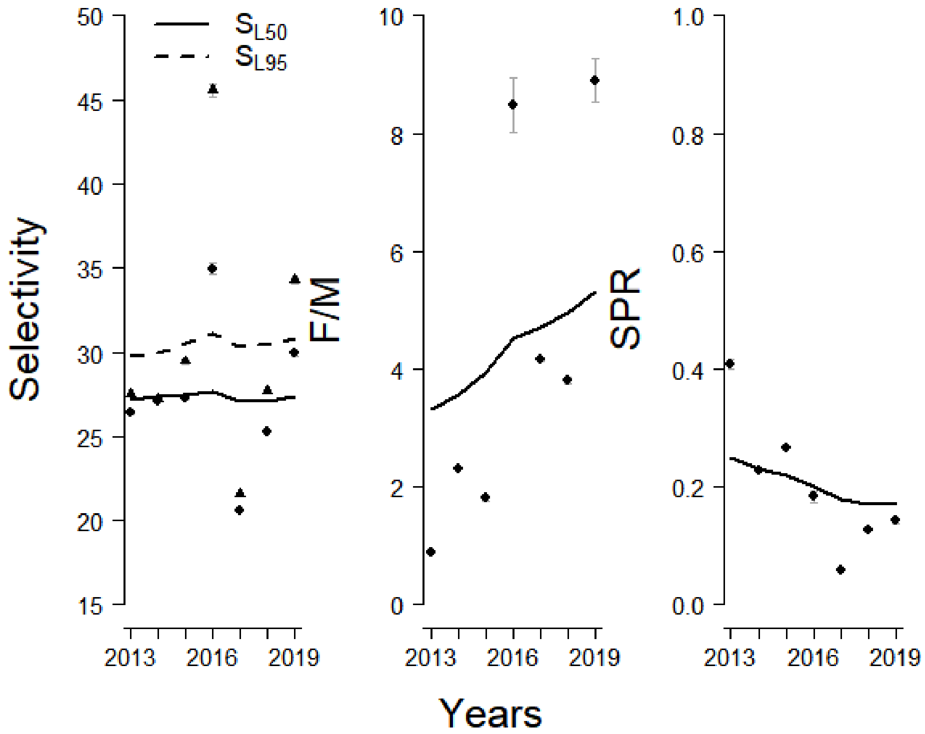


Figure 7.3.2.1.4. Cantabrian Sea (27.8.c) chub mackerel: Estimated values for SPR, SL50, SL95 and F/M for scenario 2; the black line corresponds to the smoother line to the estimated points.

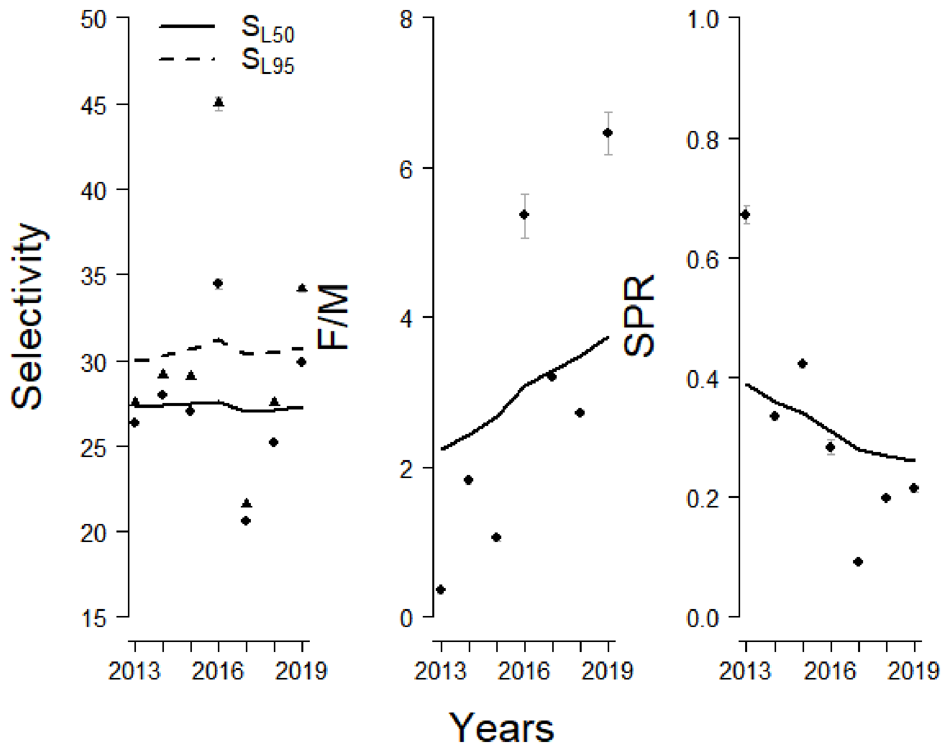


Figure 7.3.2.1.5. Cantabrian Sea (27.8.c) chub mackerel: Estimated values for SPR, SL50, SL95 and F/M for scenario 3; the black line corresponds to the smoother line to the estimated points.

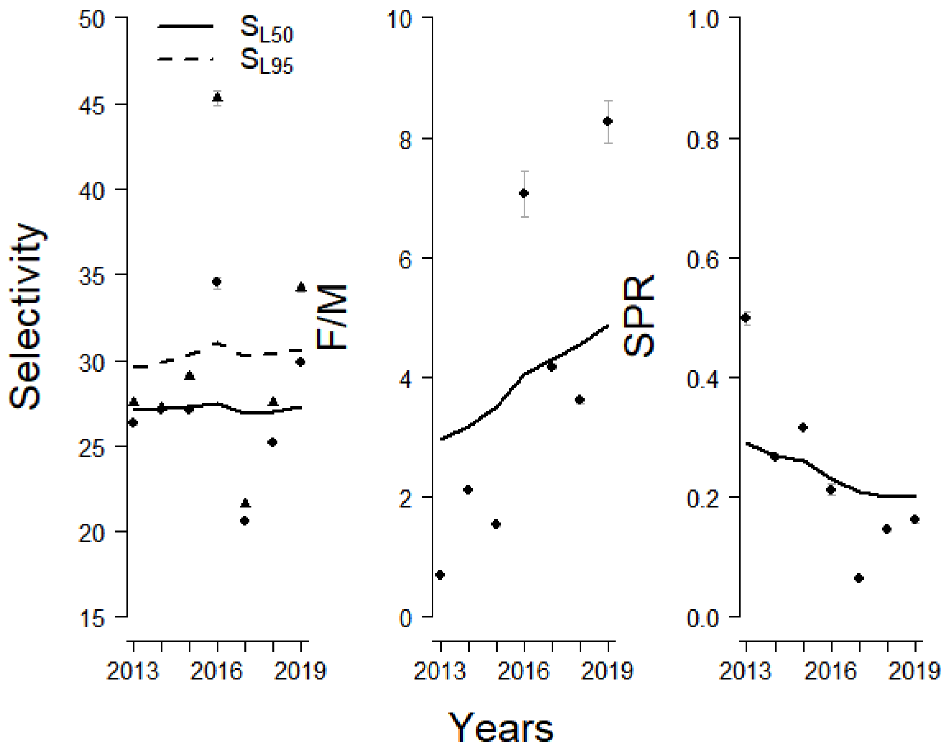


Figure 7.3.2.1.6. Cantabrian Sea (27.8.c) chub mackerel: Estimated values for SPR, SL50, SL95 and F/M for scenario 4; the black line corresponds to the smoother line to the estimated points.

The model fit to the length distributions of **discards** data and the specified maturity and estimated selectivity-at-length for scenario 1 are presented in Figures 7.3.2.1.7 and 7.3.2.1.8, respectively.

Figure 7.3.2.1.9 shows the different estimated values for SPR, selectivity and F/M, for scenario 1 but only using **discards** data.

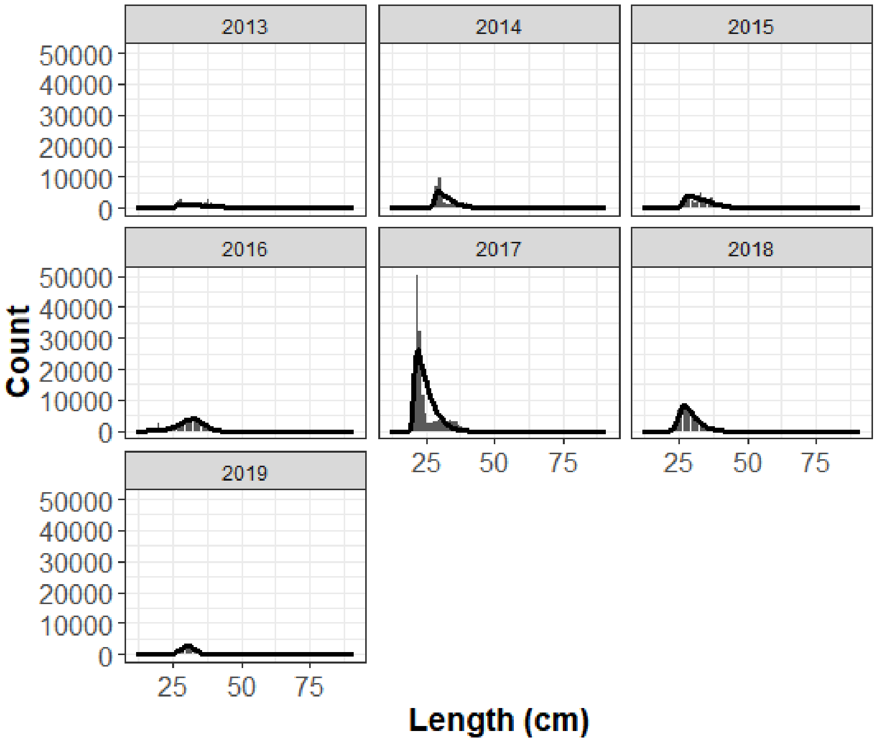


Figure 7.3.2.1.7. Length composition distributions for Cantabrian Sea chub mackerel's discards (bars) and LBSPR model fit (solid black line) for scenario 1.

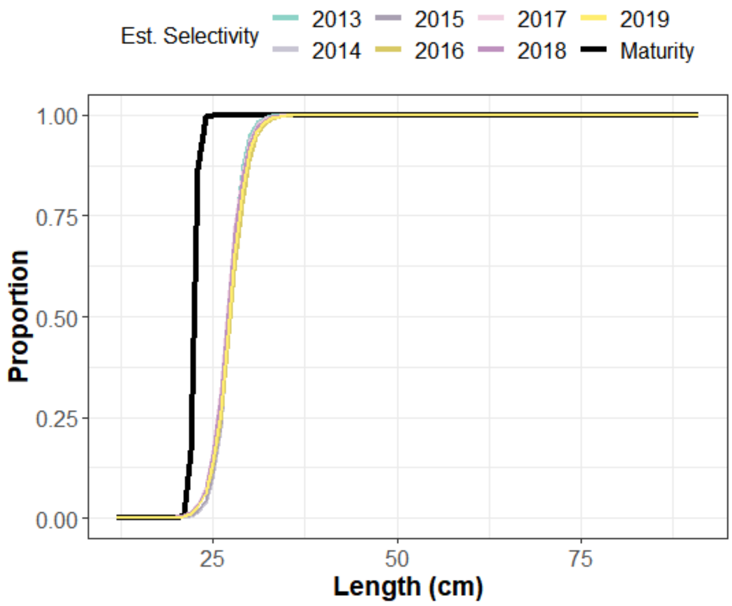


Figure 7.3.2.1.8. Cantabrian Sea (27.8.c) chub mackerel discards: Specified maturity and estimated selectivity-at-length for discards and scenario 1.

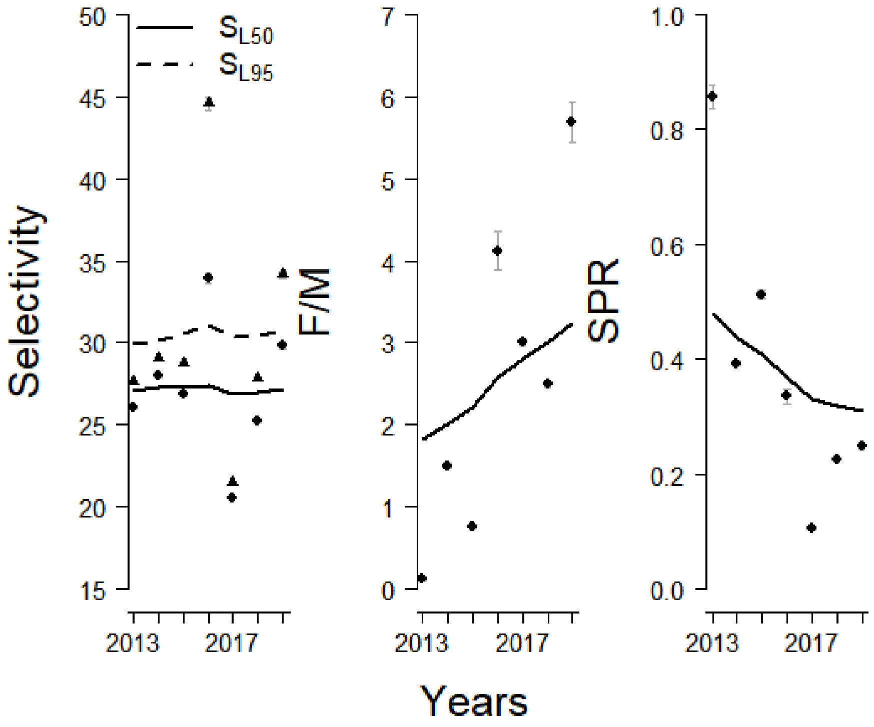


Figure 7.3.2.1.9. Cantabrian Sea (27.8.c) chub mackerel discards: Estimated values for SPR, SL50, SL95 and F/M for discards and scenario 1; the black line corresponds to the smoother line to the estimated points.

7.3.2.2 Portuguese waters (27.9.a.c.n + 27. 9. a. c. s + 27. 9. a. s. a)

Figures 7.3.2.2.1, 7.3.2.2.2 and 7.3.2.2.3 show the model fit to the length distributions **landings** data, the specified maturity and estimated selectivity-at-length and, estimated values for SPR, selectivity and F/M, respectively.

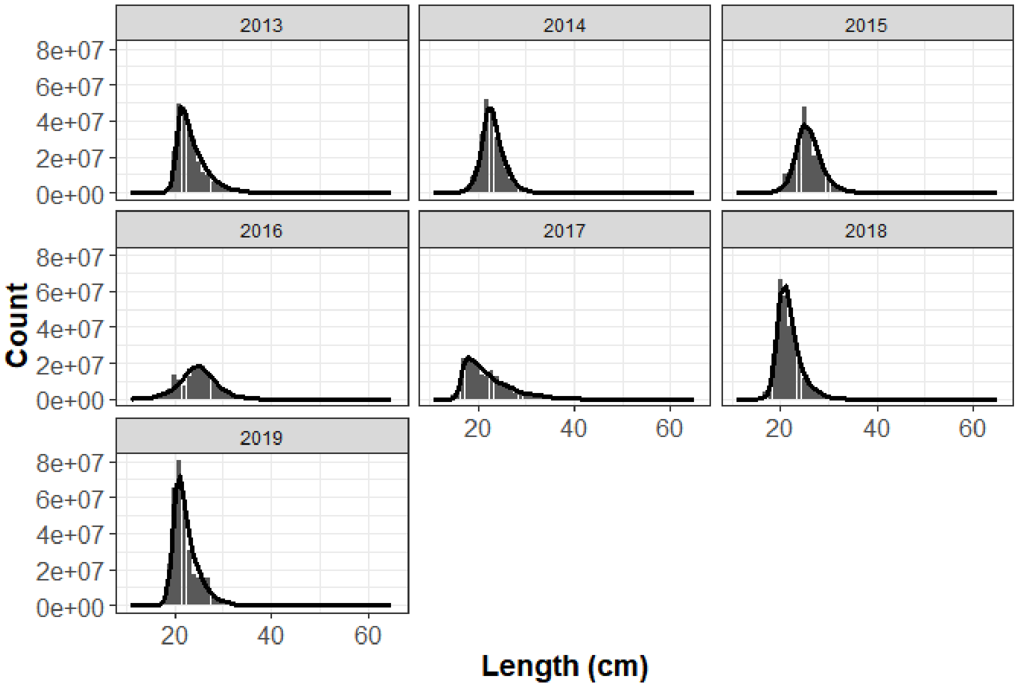


Figure 7.3.2.2.1. Length composition distributions for Portuguese chub mackerel landings (bars) and LBSPR model fit (solid black line).

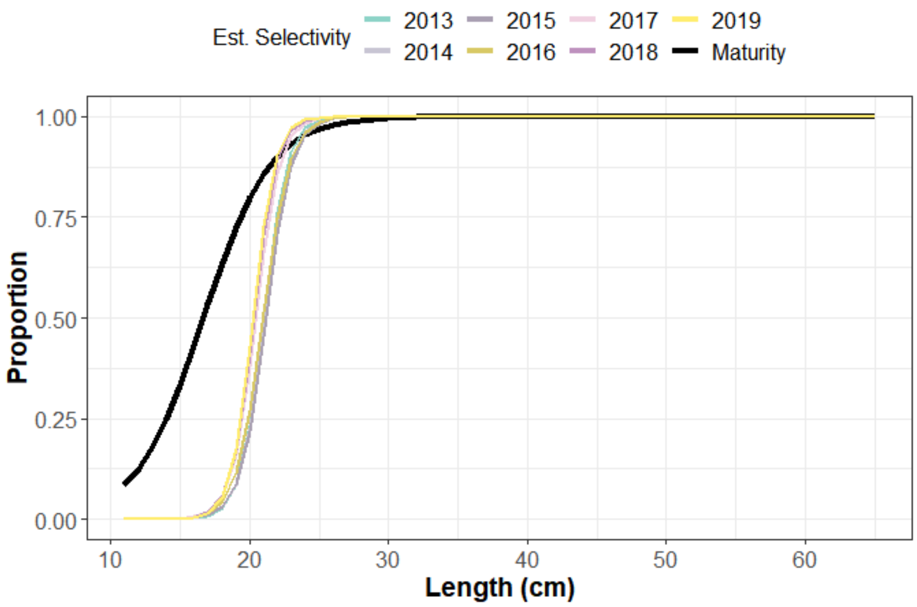


Figure 7.3.2.2.2. Chub mackerel in Portuguese waters: Specified maturity and estimated selectivity-at-length.

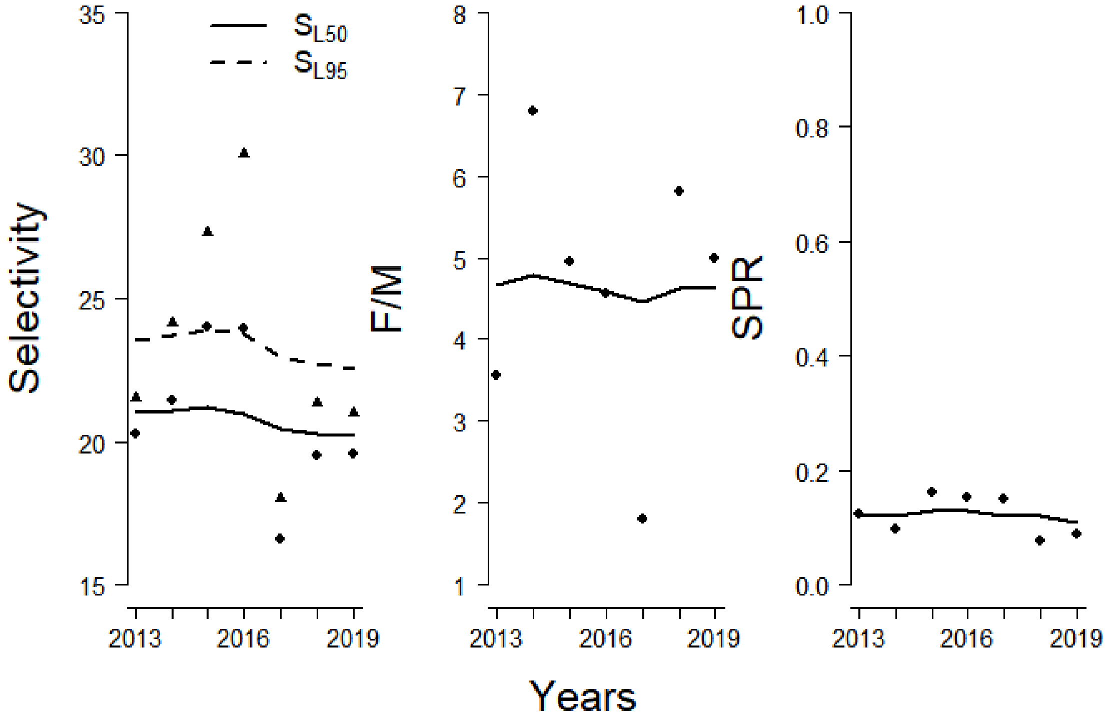


Figure 7.3.2.2.3. Chub mackerel in Portuguese waters: Estimated values for SPR, SL50, SL95 and F/M for scenario 41; the black line corresponds to the smoother line to the estimated points.

7.3.2.3 Mediterranean Sea – Catalan Sea (GSA6)

Figures 7.3.2.3.1, 7.3.2.3.2 and 7.3.2.3.3 show the model fit to the length distributions **landings** data, the specified maturity and estimated selectivity-at-length and, estimated values for SPR, selectivity and F/M, respectively.

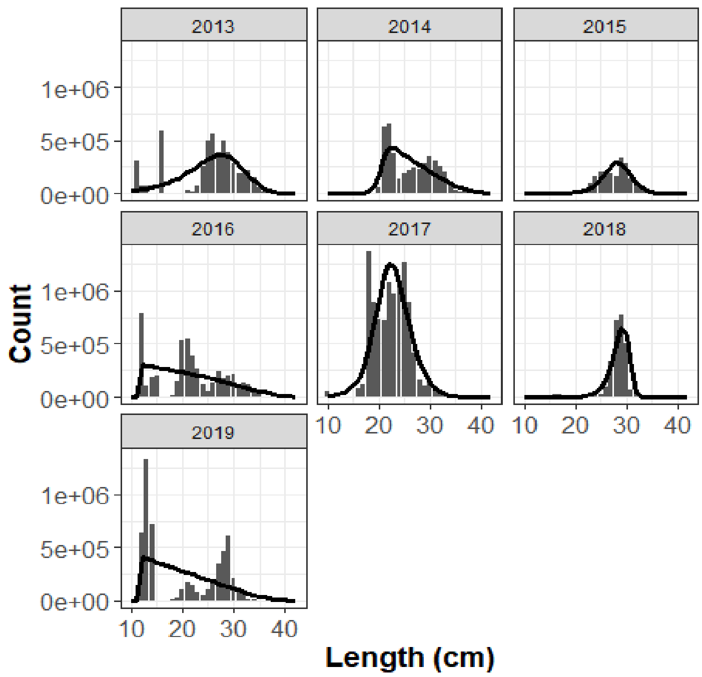


Figure 7.3.2.3.1. Chub mackerel in Mediterranean Sea – Catalan Sea: Length composition distributions for chub mackerel landings (bars) and LBSPR model fit (solid black line).

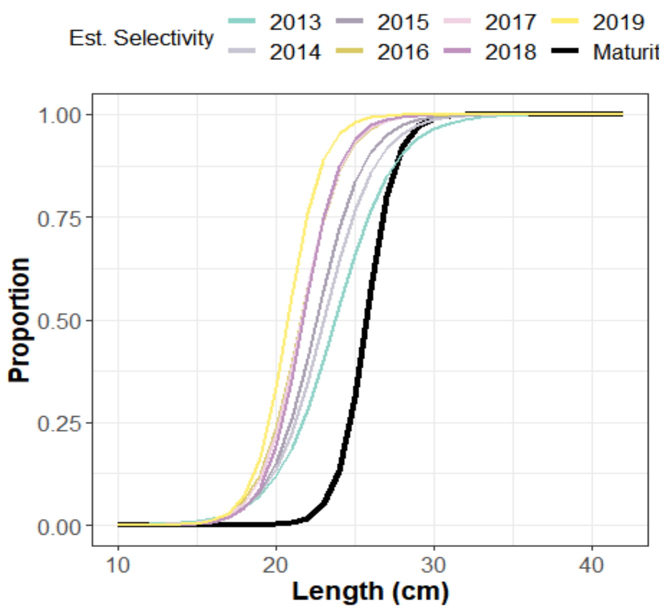


Figure 7.3.2.3.2. Chub mackerel in Mediterranean Sea and Catalan Sea: Specified maturity and estimated selectivity-at-length.

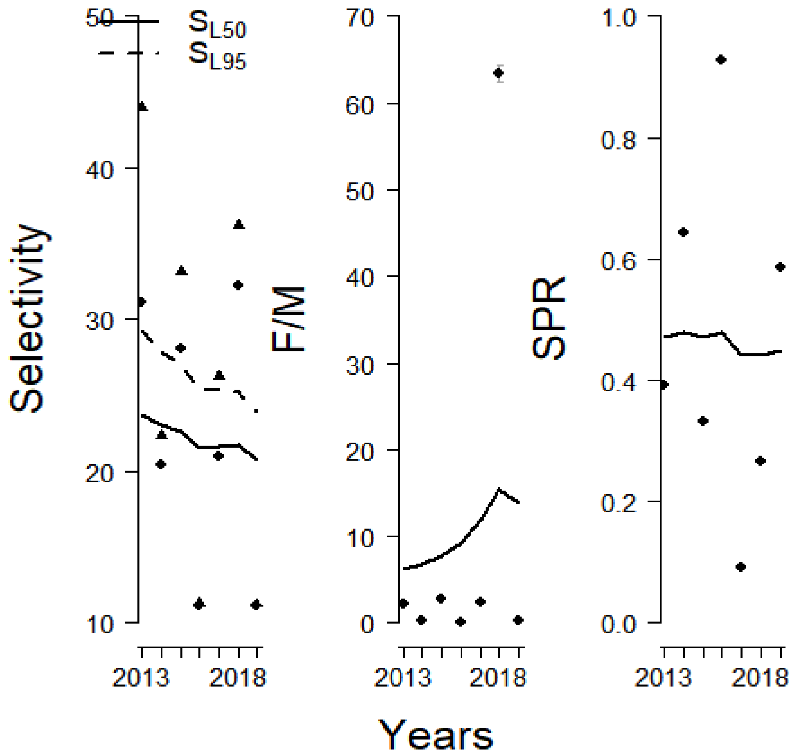


Figure 7.3.2.3.3. Chub mackerel in Mediterranean Sea and Catalan Sea: Estimated values for SPR, SL50, SL95 and F/M for scenario 41; the black line corresponds to the smoother line to the estimated points.

7.3.2.4 Madeira

Figures 7.3.2.4.1, 7.3.2.4.2 and 7.3.2.4.3 show the model fit to the length distributions **landings** data, the specified maturity and estimated selectivity-at-length and, estimated values for SPR, selectivity and F/M, respectively.

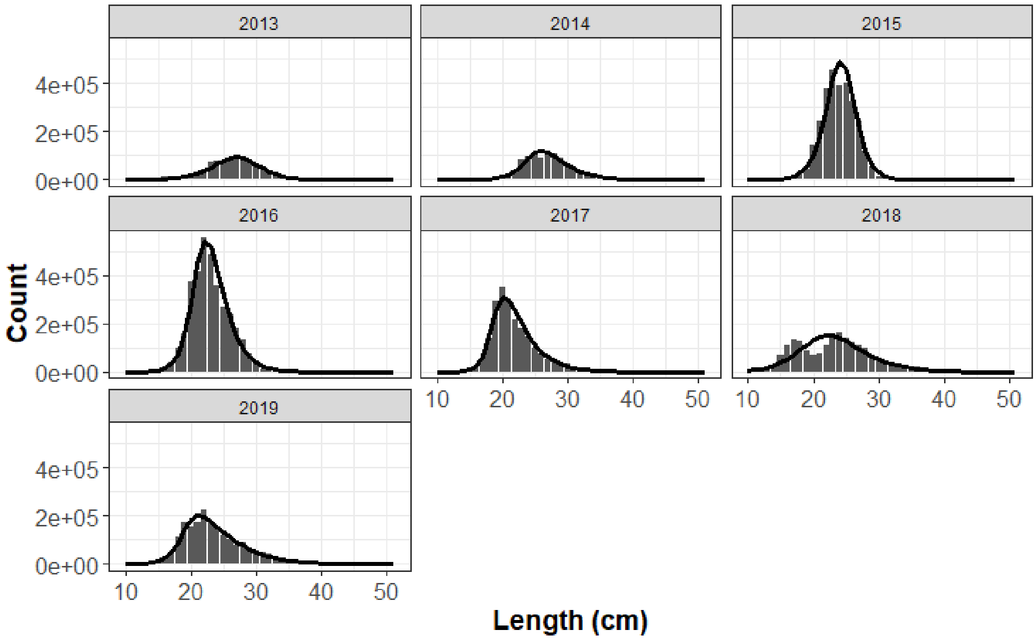


Figure 7.3.2.4.1. Chub mackerel in Madeira: Length composition distributions (bars) and LBSPR model fit (solid black line).

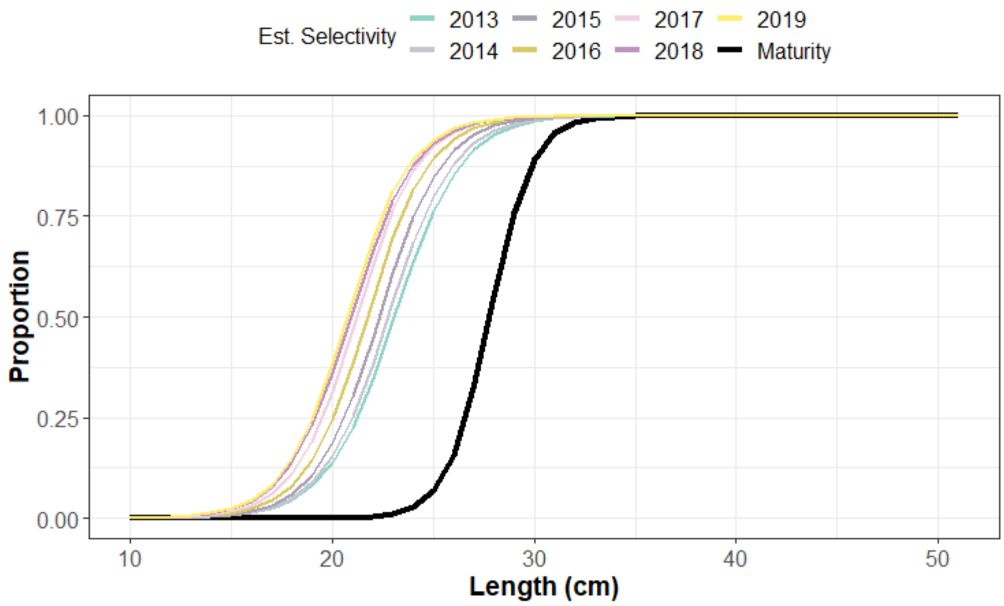


Figure 7.3.2.4.2. Chub mackerel in Madeira: Specified maturity and estimated selectivity-at-length.

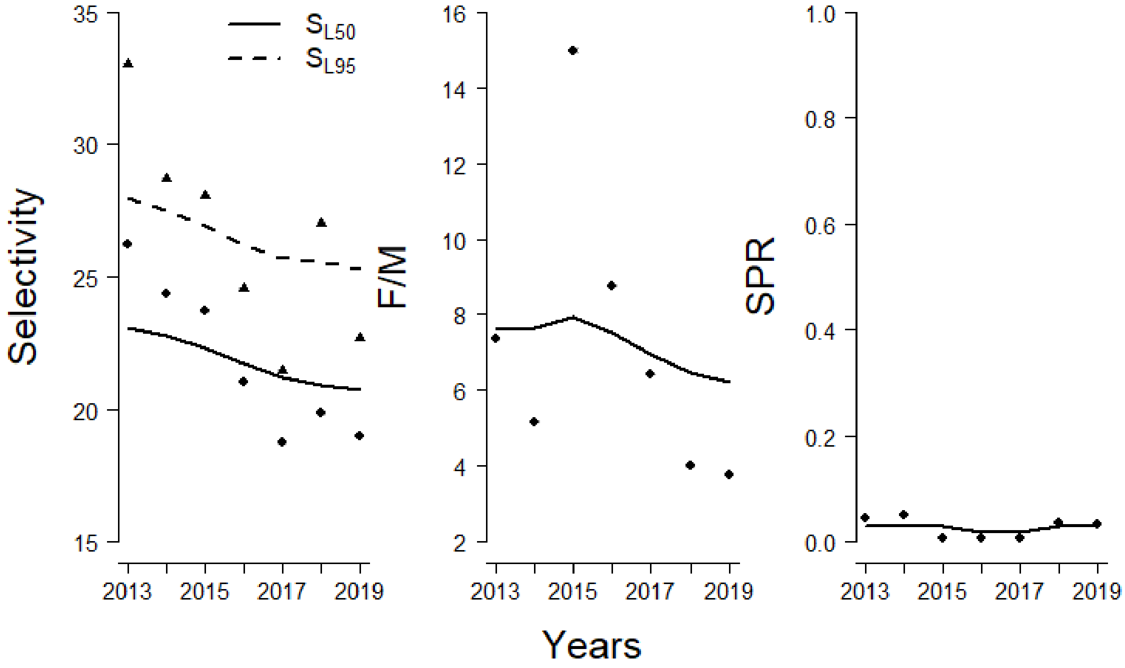


Figure 7.3.2.4.3. Chub mackerel in Madeira: Estimated values for SPR, SL50, SL95 and F/M for scenario 41; the black line corresponds to the smoother line to the estimated points.

7.3.2.5 Canary Islands

Figures 7.3.2.5.1, 7.3.2.5.2 and 7.3.2.5.3 show the model fit to the length distributions **landings** data, the specified maturity and estimated selectivity-at-length and, estimated values for SPR, selectivity and F/M, respectively.

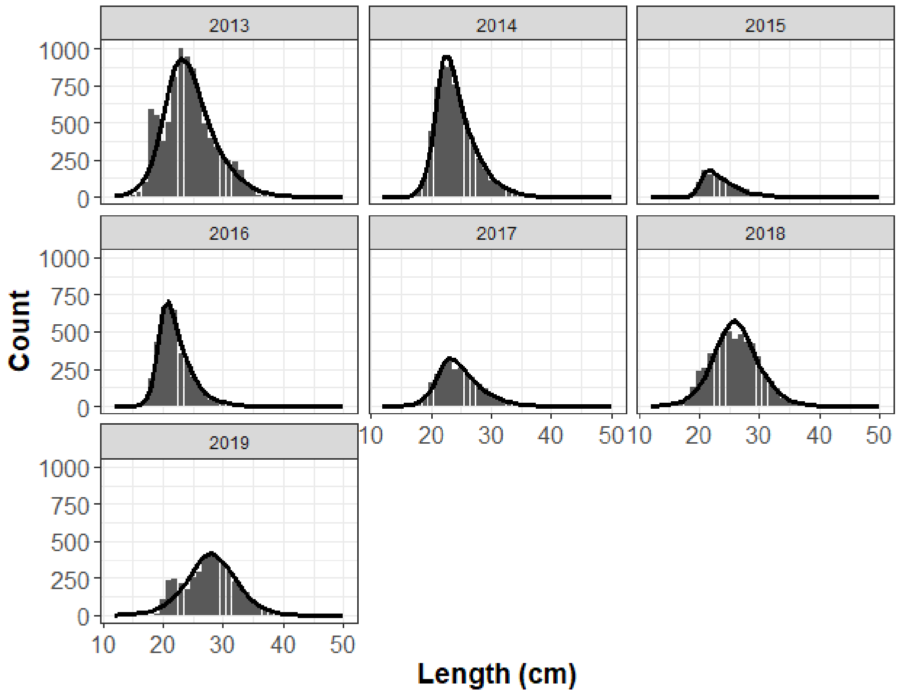


Figure 7.3.2.5.1. Chub mackerel in Canary Islands: Length composition distributions (bars) and LBSPR model fit (solid black line).

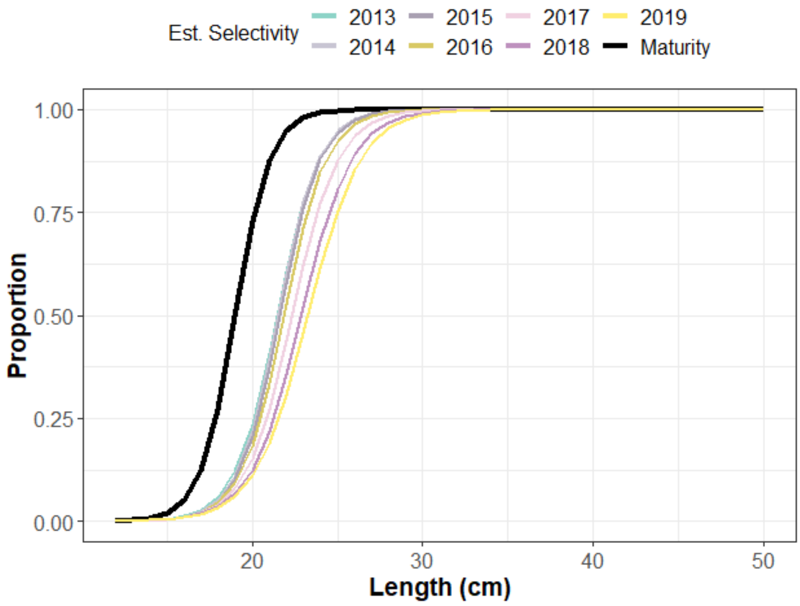


Figure 7.3.2.5.2. Chub mackerel in Canary Islands: Specified maturity and estimated selectivity-at-length.

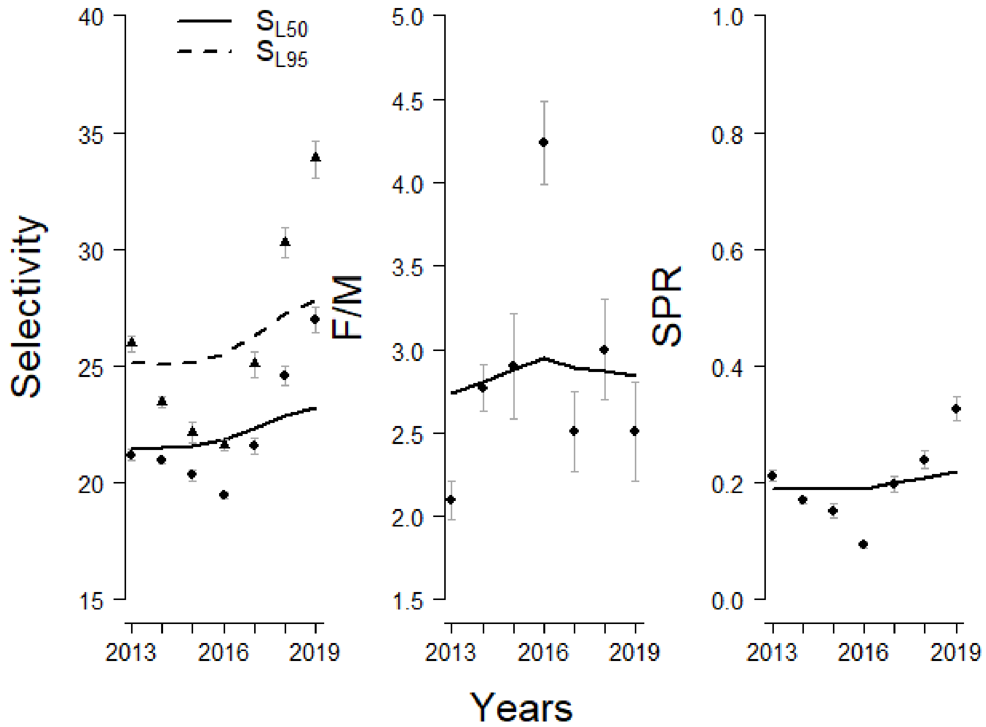


Figure 7.3.2.5.3. Chub mackerel in Canary Islands: Estimated values for SPR, SL50, SL95 and F/M for scenario 41; the black line corresponds to the smoother line to the estimated points.

7.3.2.6 Moroccan central and southern stock (A+B+C zones)

The model fit to the length distributions **landings** data and the specified maturity and estimated selectivity-at-length for scenarios 1 and 2 are presented in Figures 7.3.2.6.1 and 7.3.2.6.2, respectively. These estimates are equal **for both scenarios because the length data input were the same.**

Figures 7.3.2.6.3 and 7.3.2.6.4 show the different estimated values for SPR, selectivity and F/M, for scenarios 1 and 2, respectively.

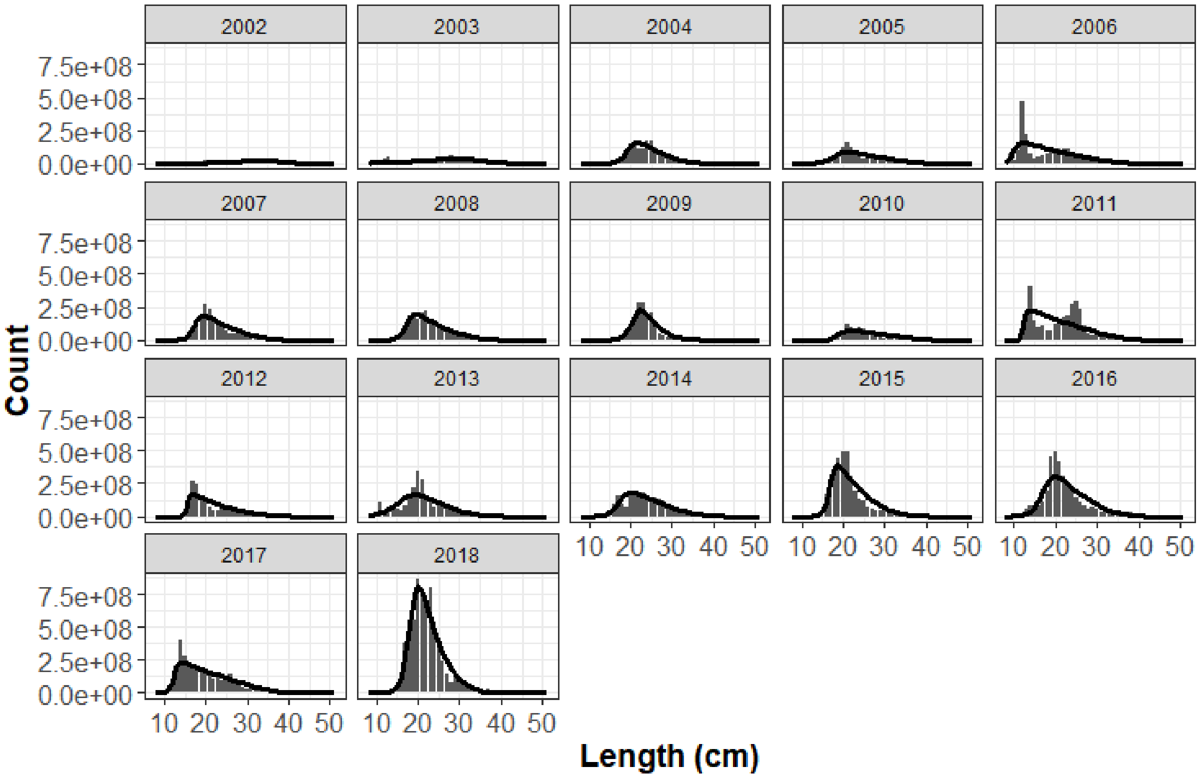


Figure 7.3.2.6.1. Length composition distributions for Moroccan central and southern chub mackerel stock (bars) and LBSPR model fit (solid black line) for scenarios 1 and 2.

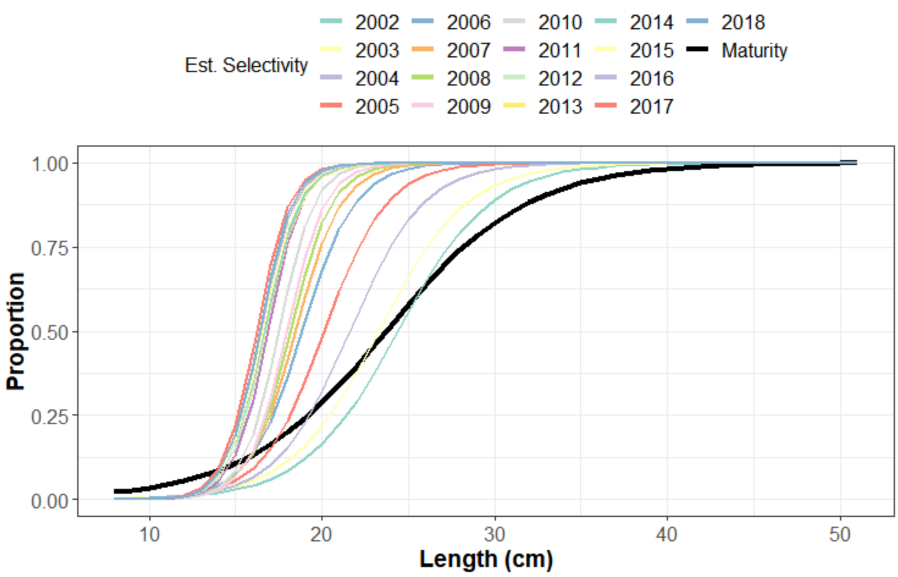


Figure 7.3.2.6.2. Moroccan central and southern chub mackerel stock: Specified maturity and estimated selectivity-at-length for scenarios 1 and 2.

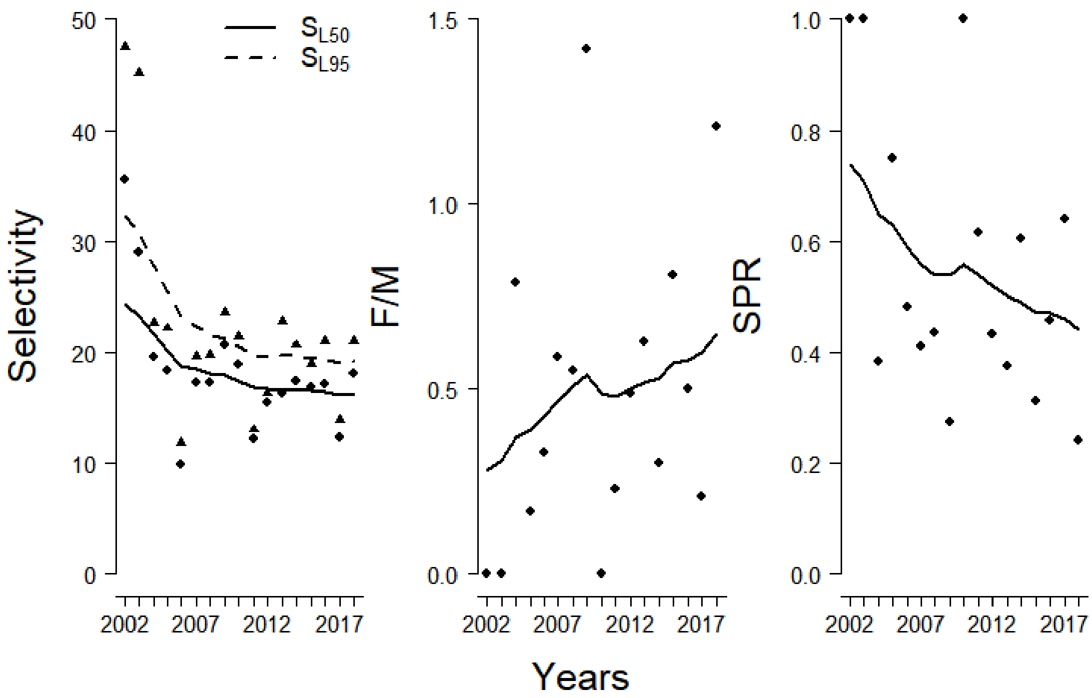


Figure 7.3.2.6.3. Moroccan central and southern chub mackerel stock: Estimated values for SPR, SL50, SL95 and F/M for scenario 1; the black line corresponds to the smoother line to the estimated points.

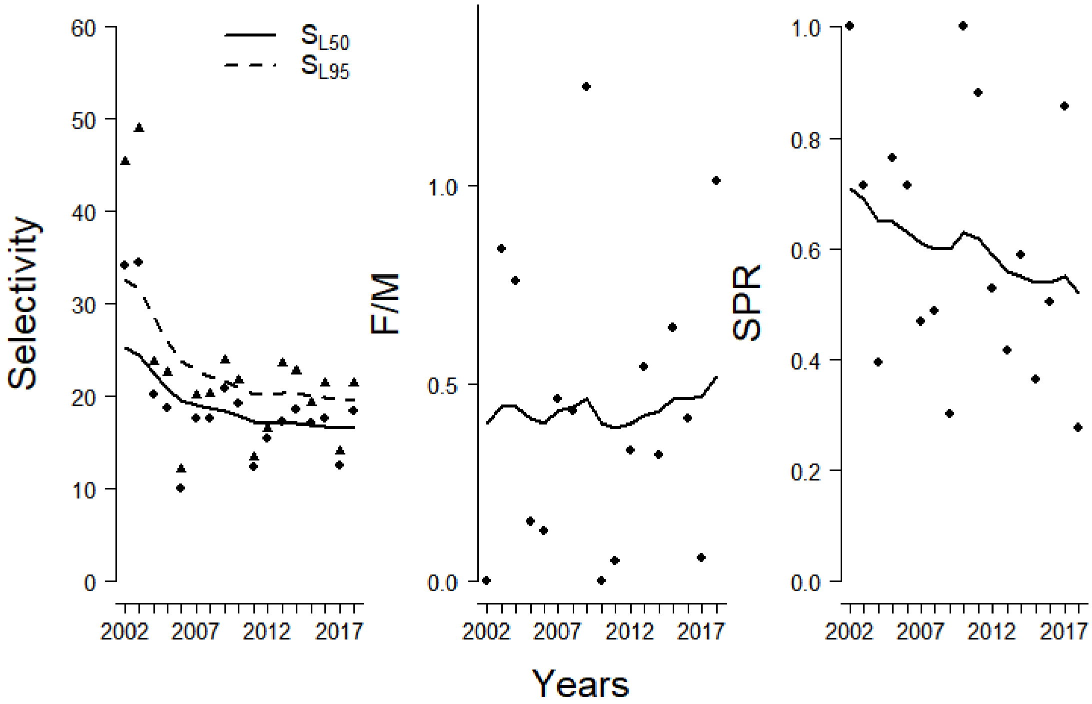


Figure 7.3.2.6.4. Moroccan central and southern chub mackerel stock: Estimated values for SPR, SL50, SL95 and F/M for scenario 2; the black line corresponds to the smoother line to the estimated points.

7.3.2.7 Moroccan northern stock (N zone)

Figures 7.3.2.7.1, 7.3.2.7.2 and 7.3.2.7.3 show the model fit to the length distributions **landings** data, the specified maturity and estimated selectivity-at-length and, estimated values for SPR, selectivity and F/M, respectively.

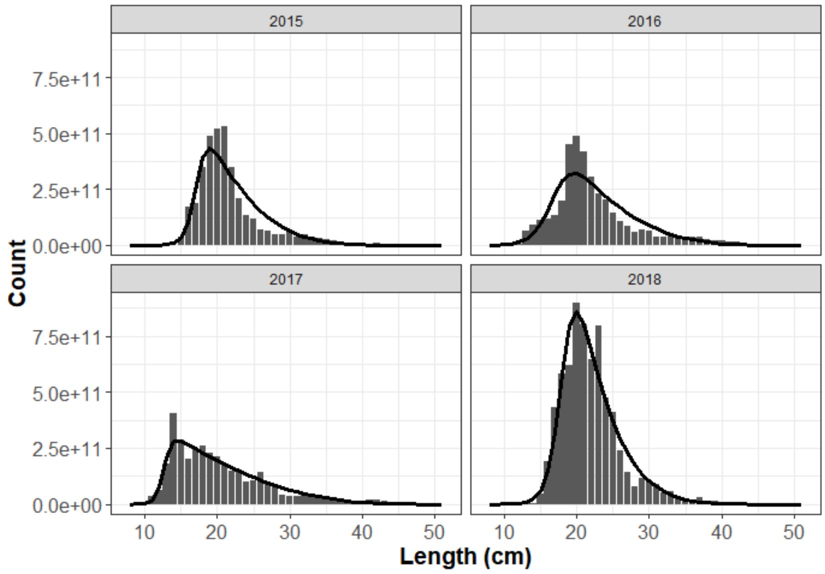


Figure 7.3.2.7.1. Length composition distributions for Moroccan northern chub mackerel (bars) and LBSPR model fit (solid black line).

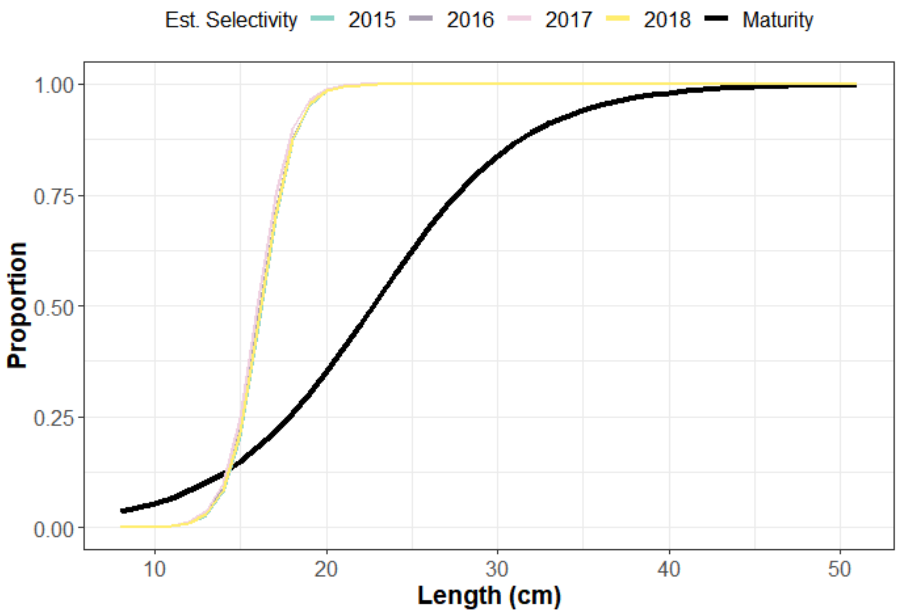


Figure 7.3.2.7.2. Moroccan northern chub mackerel: Specified maturity and estimated selectivity-at-length.

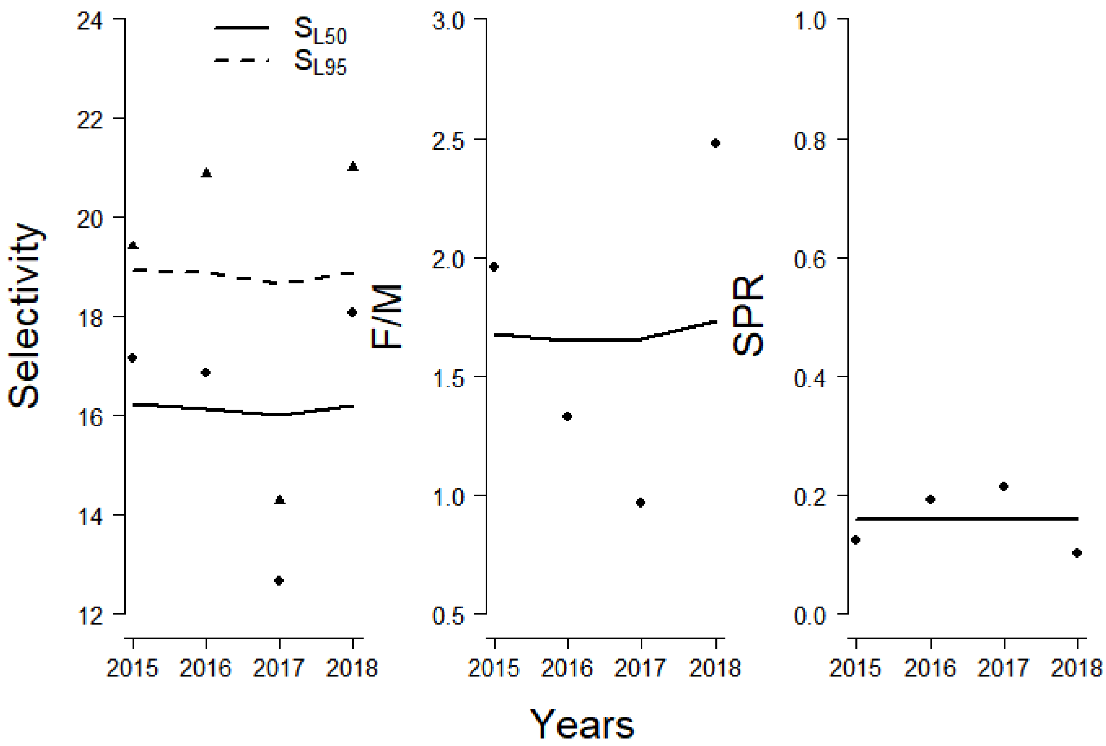


Figure 7.3.2.7.3. Moroccan northern chub mackerel: Estimated values for SPR, SL50, SL95 and F/M; the black line corresponds to the smoother line to the estimated points.

7.3.3 Summary of the LBPSR model results

As a summary of the LBSPR trials performed:

- The length–frequency distributions of the catches for all the areas are mainly unimodal. The peak of catches by length was smaller than length at first maturity (L_{50}) for Spanish Mediterranean, Madeiran and Moroccan data, suggesting that the fishing fleets are catching mostly on the juvenile fraction of the population; whereas in the Spanish Cantabrian, the Portuguese and the Canary Islands areas, the landed individuals are of larger size than L_{50}, therefore mainly adult fish.
- For most of the areas, the selectivity pattern has remained more or less constant over the time-series considered, with the exception of Mediterranean, Madeira and Moroccan (centre and south) catches, for which the length at 50% selectivity (SL50) and the length at 95% selectivity (SL95) have decreased over time, indicating that in these regions, the proportion of smaller fish is increasing in the catches.
- In most of the scenarios for the landings from the Cantabrian Sea, the spawning potential ratio (SPR) values were between the LRP (LRP=0.2) and the target (TRP=0.4) reference points, while for the discards, the SPR values were around 0.4.
- In Portuguese waters and Madeira, the SPR values were very low and below LRP. For the Canary Islands, SPR values fluctuate around 0.2. For the Mediterranean-Catalan Sea, the SPR values were above TRP.
- The SPR values for the Moroccan central and southern areas (A+B+C) were higher than the target reference point (TRP), SPR_{TRP}=0.4, considered as a proxy of MSY. For the northern area, the SPR values were around the limit reference point (LRP) of 0.2, fluctuating between 0.15 and 0.21.
- The fitted F/M plots did not show a remarkable trend for most of the areas except for the central and southern Moroccan stock (mainly in scenario 1) and in the Cantabrian Sea for

the landings and discards (all scenarios), where there is an increase of relative fishing mortality at the end of the time-series, which is consistent with a decrease on SPR values in the same period. These opposite trends may reflect a negative impact of increasing fishing mortality on the population reproductive biomass.

7.4 Conclusions

Both SPiCT and LBSPR assessment trials represent exploratory work and should not be used to take conclusions about the status of chub mackerel in the different areas. Chub mackerel stock structure is uncertain mainly in the European waters, and neither the consistency of the data, nor the methods (assumptions and limitations of the different models) or reference points (and their uncertainties) have been sufficiently discussed in scientific *fora*.

8 Conclusions and recommendations

8.1 Ongoing and future works

8.1.1 Fisheries

In the purse-seine fishery operating off Portugal (Division 27.9a.), skippers can choose to slip part or total catch, if there is no market value or the fish length is lower than the legal landing size, for example. Fishermen assume this fish have 100% survival rate.

Under the project SARDINHA2020 conducted by IPMA in Portugal, studies on survivability rate after slipping of sardine and chub mackerel caught by the purse-seine fleet are planned. These studies will be based on experiences carried out in small net pens moored in the open ocean where fish slipped by a purse-seiner will be monitored for 7–10 days and the survivability rate evaluated twice a day. The first experience on survivability rate of chub mackerel was conducted in July 2020. Due COVID-19 disruption, the experiments with chub mackerel and sardine were delayed to April and July 2021. Results are expected to be available at the end of 2021 and presented in the final report of the Project SARDINHA2020.

The knowledge and update information for survival rate of chub mackerel and sardine, and the evaluation of the practice of slipping on the daily operation, are expected to promote and contribute to a reduction in the fishing mortality on those stocks.

8.1.2 Population structure

For the chub mackerel in Atlantic European waters, from the Bay of Biscay to the Canary Islands, joint analyses have been initiated both addressing reproductive and growth issues (V SIBECORP). In addition, IPMA is coordinating a holistic study, also including Moroccan samples.

In West African waters, a holistic approach is being performed in the EAF-Nansen Programme.

8.1.3 Stock assessment

In Portugal, in the framework of project SARDINHA2020, a multispecies bioeconomic management model is being developed by the University of Economy (NOVA-SBE) in collaboration with IPMA. A SPICT model, developed for chub mackerel in the Portuguese waters, will be used to feed the management model.

8.2 Conclusions and recommendations by subgroup

8.2.1 Fisheries

During the meeting, and based on the data compiled for landings (including length/age composition), effort and discards, an update of the description of the fleet and the fishery activity and an analysis of the spatial (between areas) and temporal (between years and quarters) variability of these variables were carried out.

The group's major conclusions were:

- Still a general increasing trend of the landings in the last two decades in all Atlantic, though some decrease in the last 2–3 years for some areas; the factors behind this general increase should be further analysed, could possibly be related to environmental effects;
- Large interannual fluctuations in the landings, linked to the species migratory patterns, fishing strategies and/or market demands;
- Landings generally increase from the North to the South, and are more important in the 3rd and 4th quarters in all areas;
- Purse-seiners (PS) contribute to most of landings in the northern areas, whereas trawlers (TRAWL) remain the main fleet that catch chub mackerel in the southern areas, mixed-gear fleets (MIS) operating more in European waters;
- Few discards data are available, they do not include "slipping for the purse-seiners"; when data available for different gears, discards in TRAWL fleet usually surpass those from other gears; discards show important annual fluctuations;
- Effort data could only be considered as a qualitative parameter complementary to the landings information, as in many areas chub mackerel is not the target species of the fishery (mainly sardine) but rather a bycatch, and the effort type reported differs between areas/ countries;
- Total fishing effort possibly evenly distributed among quarters for all the areas; for areas 27.8 and 27.9, fishing effort higher in period 2008–2017 and then decreased; higher values of fishing effort observed in MIS fleets, though the bulk of chub mackerel landings de-rived from the PS fleets;
- For the moment, no CPUE from catch and effort data available to infer on abundance.

Data main gaps/limitations:

- Data submitted to the WK showed disparities between fishing gears, areas and time period, in particular for effort data which are not fully comparable, information should be standardized and completed.

By examining the aforementioned elements, the WKCOLIAS2 encourages the following activities:

- Analysis of fishing strategies (targeting season, areas, gear, etc.): to have a standardized effort and representative CPUEs for chub mackerel;
- Analysis of chub mackerel fishing areas and grounds (for example, from VMS information);
- To analyse catches and environment parameters using General Additive Model to explain the increase in catches of the species in recent years.

8.2.2 Surveys

Several surveys are carried out in both European and NW African waters, covering these areas at different seasons in the year, this information having been thoroughly compiled, updated and explored during the workshop.

A synoptic view of chub mackerel distribution and abundance over time would *a priori* be possible from Bay of Biscay to Mauritania and for the Western Mediterranean waters. Nevertheless, several issues were identified, related both to the data submitted and to the surveys' characteristics, which have precluded the targeted goals with these surveys' information to be fully attained. Because of that, a synoptic mapping of chub mackerel's geographical distribution was possible, but only covering the area from the Galician to the northern Mauritanian waters, and for the 2019 autumn surveys uniquely.

The group's major conclusions, in line with the findings already reported in 2020, were:

- Chub mackerel appears to have a continuous distribution from Mauritania to Bay of Biscay, although the abundance in European waters is lower than that observed in Africa, the main nucleus of distribution of the species being in the NW Moroccan shelf waters;
- In European Atlantic waters, the South Atlantic Iberian waters are ones of the chub mackerel preferred locations, the bulk of the population being mainly located in the SW of Portugal, and secondarily in the Portuguese Gulf of Cadiz waters, whereas it is comparatively almost accidental in Galicia and western Cantabrian Sea; in the latter, chub mackerel seem to be present in years of higher abundance;
- Chub mackerel seems to be a secondary species in the "SPF population" (in terms of contribution to the total acoustic energy attributed to SPF) off Galicia and the Cantabrian Sea, whereas in the SW and the S Atlantic Iberian waters (SW Portugal, Algarve, Spanish Gulf of Cadiz), it is an important species of the "acoustic SPF assemblage";
- Both Atlantic European and NW African populations, excepting the one-off northern Mauritanian shelf waters, are dominated mainly by juvenile and subadult individuals, the issue being where the adult population might be located (cf. below the lack of larger fish in both commercial landings and scientific surveys' hauls);
- Nevertheless, as already observed in the landings size composition, spatial and temporal differences exist in the length–frequency distributions obtained from the surveys: for instance, in Atlantic Iberia, smaller fish are recorded in the South Portugal, and comparatively larger ones in the SW Portugal and Spanish Gulf of Cadiz;
- The analysed time-series seem to confirm two recent peaks of the population abundance in almost all the Iberian waters: one in 2017 and the other in 2019, noticeable in both bottom-trawl and acoustic surveys;
- The strength of the 2016 year class has been above the average in both African and European waters, suggesting an overall increase of the abundance throughout the distribution area, and this cohort could be well tracked in both acoustic- and bottom-trawl surveys in some areas of the European waters;
- Chub mackerel population dynamics, in terms of their wintering/spawning/recruitment areas and migration patterns, is at present not fully understood; the information available suggests that in both African and European waters, the species would migrate from the wintering areas (mainly located in Mauritanian waters, South Portugal and the inner part of the Bay of Biscay) towards the northern waters in summer time and, in the case of the Bay of Biscay, also towards the western Iberian Peninsula.

The main surveys' data and joint analysis constraints identified by the group were:

- No information was submitted from the Mediterranean (MEDIAS and MEDITS NW Mediterranean surveys) nor from the southern and northern Bay of Biscay (JUVENA survey in the Cantabrian Sea and the southern BoB; PELGAS and EVEHOE French surveys in the BoB), preventing from delimiting the northernmost distribution boundary of the species and from contributing to understand the connectivity between the Atlantic and the Mediterranean populations;
- The data submitted were heterogeneous and with gaps in time, space and biological information: the length of the time-series differed significantly between areas/surveys, in some cases the indices were either size-based or age-based estimates only, the same type of information was not always provided, restraining the combination of data from all areas available;
- Though both acoustic and bottom-trawling surveys are coordinated internationally following standardized protocols in European Atlantic and Mediterranean waters, some differences exist between institutes and vessels in relation to the gears used, and the TS values applied to convert acoustic energy in biomass, the group feeling that the survey

indices should for the time being, be considered only in relative terms and for the purposes of identifying trends;

- A possible lack of large scale spatio-temporal coverage of the species, related to 1) the fact that the surveys considered usually target the SPF species and may not cover the whole bathymetric range of chub mackerel and of the other mid-sized pelagic species which can be distributed outside the monitored area (in the upper slope and/or the shallowest coastal waters), especially the largest individuals; and 2) the different timings of the surveys covering contiguous geographic areas that may compromise the synopticity of the surveys in regard to the chub mackerel migrations and spawning/recruitment periods;
- Chub mackerel catchability issues, especially in relation to the largest fish which are lacking in both surveys and landings for most of the areas considered; possibly related to the gear, the trawling speed, the distribution of part of the population (especially the largest individuals) outside the surveys' monitored area and/or migration patterns, which can constrain the distribution of the species in the fishing hauls from being fully representative of the populations;
- Related to the above catchability issue, WKCOLIAS2 requested some feedback from the ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST). The main conclusions and recommendations were: i) either supplemental to or as a replacement for trawling, try "hook and line" sampling; ii) investigate spatial and temporal distribution, and potential changes in distributions; iii) investigate alternative ways to deploy mid-water trawls, and iv) investigate positioning camera systems at locations where suspected large chub mackerel may occur.

In view of the above, the WKCOLIAS2 encourages the following:

- Concerning bottom trawl surveys, further analyses on chub mackerel stock dynamics representativeness from these surveys together with comparability among surveys should be carried out prior to estimate an index for the species based on this type of surveys;
- Additional work compiling the available information from regional surveys in a standardized format should be encouraged, as well as undertaking further analysis on the consistency between the different surveys time-series;
- WKCOLIAS recommended last year to hold a joint workshop among institutions/teams (i.e. ICES and CECAF) to address the different issues as regards to standardization of surveys protocols and methods; such exchange could not be possible, but until this workshop cannot take place, the group feels as highly beneficial sharing the methodologies applied and continue to jointly address the above issues;
- Additional research on the aggregation patterns observed during the acoustic trawling surveys are encouraged, to better understand seasonal/interannual changes in the fish behaviour, in the distribution within the water column, and in the aggregation pattern inside the pelagic community, which will impact the acoustic assessment of the species populations.

8.2.3 Maturity

The maturity data received for the species in a common format in response to the data call launched before the WK were analysed and maturity ogives were obtained using a common methodology, from the Northern Iberian Cantabrian coast (area 27.8.c) to the Moroccan-Mauri-tanian waters (area 34.1.31), including the NW Mediterranean (area GSA6).

The results obtained from the exploratory analysis of the data allowed to identifying several issues mostly related to the following:

- The data call format: it was possibly not the best suitable exchange format for maturity data, as it did not accept other variables as month, sex, etc.;
- The sampling time: the time-series differed between countries, and in many areas, the data collected during the spawning season were not suitable/representative in terms of the fish length range, though ogive estimates are recommended during the spawning period to minimize the risk of maturity misclassification between immature and resting fish;
- The number of samples, and in particular the suitability of the fish length range, as in some areas fish sampled were all either mature or immature; these limitations were in part related to the samples obtained from commercial landings;
- The plausible differences in maturity stages assignation among laboratories, probably due to the use of different maturity scales and the different observers involved in sampling, and namely, the misclassification between immature and resting individuals; which has been the main problem identified for all areas, and prevented obtaining maturity ogives pooling data from different countries.

These major sampling and data constraints made impossible the estimation of reliable maturity ogives for all areas, which besides should be considered with caution. Nevertheless, the results obtained were in line with previous/parallel analyses (ICES, 2020; Sections 5.5 and 6.4 of this report), the major conclusions being:

- A decrease of the length at first maturity from the North to the South Atlantic Iberia, and an increase from the North to the South NW African waters;
- Inference on the spatial variability in the Mediterranean waters and the Macaronesian Islands not achievable with the data available to the WK;
- Conclusions in terms of temporal variability not possible with this dataset.

From the results obtained during the WK, the group recommended that:

- Upcoming data calls for maturity data consider including other parameters than uniquely the proportion of mature or immature fish at length/age;
- A maturity stage calibration exercise (exchange/workshop) between all countries and laboratories to be considered, with the following objectives (as indicated by ICES, WGBIOP 2019): i) to agree on a common maturity scale for the species/stock (see WKASMSF 2018 report) based on a comparison of existing scales and standardization of maturity determination criteria; ii) to establish correspondence between old and new scales so that time-series of previous data can be converted; iii) to reduce sources of error in maturity determination by validating macroscopic staging, and iv) to propose an optimal sampling strategy to estimate accurate maturity ogives;
- The different institutes thoroughly review particularly the potential misclassifications between immature and resting individuals in the samples. For that purpose, it is recommended to obtain 'microscopic maturity ogives' (i.e. based on the histological analysis of the gonads), focusing on the main spawning season, including either market or survey samples (or both), and guaranteeing that an adequate fish length range is sampled. Compared to the L50s obtained from a preliminary histological maturity work carried out with chub mackerels from areas 27.9.a.c.n and 27.9.a.c.s (by IPMA), the L50 values obtained here using the 'macroscopic maturity data' may be slightly underestimated;
- Parallel to maturity analyses, ageing work and inter-calibration on age reading be promoted between laboratories and countries in order to have accurate age information to be used in the estimation of maturity-at-age.
- The interannual variability of length-/age-at first maturity should be also investigated, this analysis having not been possible by the WK members as the maturity ogives were

obtained pooling all the data submitted; in case of significant differences among years, mean values of length-at- first maturity could be provided for each area.

- Chub mackerel spawning behaviour be investigated in terms of: i) timing of the reproductive activity, ii) geographic and bathymetric distribution of the reproductively active individuals (preliminary analyses have shown that in Galicia, NW Portugal and Gulf of Cadiz Spanish waters, the proportion of active fish during the spawning season is lower than in the Cantabrian, SW and South Portuguese waters (Villamor *et al*., 2017, Nunes *et al*., 2019)), iii) aggregation behaviour during spawning events, iv) migration patterns among spawning, feeding and recruitment areas.

8.2.4 Life history

Life-history trait data available for Atlantic chub mackerel, from both literature and biological sampling in the different institutions, relative to the species distribution range, has been updated during the meeting in what concerns growth parameters, length-at-age, length–weight relationships, length-at- first maturity (L_{50}), and spawning season.

Major conclusions:

- Growth parameters: they vary significantly with the geographical area and with the source of the information, but no conclusions could be possibly drawn;
- Length-at-age: the information compiled was not fully comparable due to sampling issues, the biology of the species, and questions related to age validation;
- Length–weight relationships: estimates obtained in the different areas indicate a tendency towards positive allometric growth in all regions;
- Length-at- first maturity and spawning season: regional differences were observed with latitudinal trends in both European and NW African waters.

Though undoubtedly useful in terms of the species biology, the present revision was not conclusive in view of contributing to elucidate on chub mackerel populations' structure and dynamics. Distinct and/or changing sampling/estimation methodologies among institutions/countries, and over time, makes the information compiled difficult to be fully comparable. The group greatly encourages that the biology of the species continues being monitored following standardized approaches, for better clarifying the geographical differences that seem to exist in chub mackerel life history.

8.2.5 Population structure

The population structure of the chub mackerel in the East Atlantic and the migration processes through the distribution range, and connectivity including the Mediterranean Sea, remain unknown. However, latitudinal trends for some of the aspects addressed during the WK seem to occur, with the Strait of Gibraltar as inflection point. Although much effort should be done to improve the knowledge of the population structure of the species to provide reliable stocks status assessments, considering the European and the African chub mackerel separately in Atlantic waters could be taken as a departing point.

8.2.6 Stock assessment

A large volume of data was compiled during this WK and the group considered that the length of the time-series available could be appropriate to perform exploratory exercises in view of evaluating the suitability of the candidate assessment methods. Therefore, and following the WK expert examination of the methods appropriate for the geographical areas considered, two approaches were tested: a Surplus Production Model in Continuous Time (SPiCT) and a Length-Based Spawning Potential Ratio method (LBSPR).

Both methods were explored for European and NW African waters, while the latter was also applied to the Western Mediterranean and to the Macaronesian Islands of Canary and Madeira, for comparative purposes. The WK members considered that in fact a combined approach to stock assessment in European areas including different assessment methods (such as, surplus production models, length-based models, and more complex length–age based statistical models) should be preferentially addressed, as done in NW Africa, if requested in the future. In addition, the exercises carried out during the WK require additional exploratory analyses and discussion. The results obtained do not represent a formal evaluation of the condition of the chub mackerel populations nor the short-term predictions be considered in terms of management advice. Moreover, considering the uncertainties still remaining in regard to the chub mackerel stock units, namely in European waters, the group recommends that "management units" or "hypothetical population units" be referred to, instead of "stock units", and that all surveys indices considered reliable be used as complementary and qualitative information even if they do not enter the assessment models.

8.3 General conclusions and recommendations

The data call submitted prior to the meeting, targeting geographical areas under the auspices of ICES, GFCM and CECAF contributed to addressing the ToRs agreed for this year, and provided datasets compiled in a common format that could be jointly explored during the workshop to help better understanding the population dynamics and biology of *S. colias* in Eastern Atlantic waters.

The exploratory analyses undertaken by each subgroup on the data obtained allowed drawing relevant general conclusions in view of the proposed goals, but also identifying the gaps and limitations on the information available, not only in terms of the type/amount of the latter, but also in terms of the quality of the data, the objectives targeted during the WK in view of the ToRs having not been fully attained.

Additional data are still necessary, especially from the Mediterranean and the limits of the species distribution range, to understand the population dynamics and connectivity.

The goal is to continue directing the best efforts to compile and standardize the available data and keep on monitoring/studying the species to improve the quality of the time-series and enhance the knowledge on the biology/ecology.

The group wishes to carry on meeting at least every two years (next meeting: possibly 2023) and working jointly, having in mind the goals for this pelagic species that distributes across European and African waters.

The group also agreed on following recommendations to be addressed, but also on a "roadmap" of future actions and research work to be carried out at medium–long term.

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Annex 1: List of participants

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Annex 2: Agenda

DAY 1 – 25 JANUARY

09:30–10:30 Welcome and participants' introduction.

Nunes, C. and A. Jurado-Ruzafa. 2nd ICES Workshop on Atlantic chub mackerel (WKCOLIAS2): intersession work.

10:30–11:30 Presentations

- Carrera, P. ICES WKCOLIAS2 background and ToRs.
- Bensbai, J., A. Najd and A. Faraj. *Scomber colias*. State of Moroccan fishery in 2019.
- Mamza, K. Distribution of densities and size structure of Atlantic mackerel *Scomber colias* in the Moroccan waters: Atlantic and Mediterranean Sea – Autumn 2019, acoustic data.

11:30–12:00 Coffee break

12:00–15:00 Presentations (cont.)

- Jurado-Ruzafa, A., B. Sotillo, E. Hernández, J.L. Otero-Ferrer and V.M. Tuset. Canary 2019-updating highlights.
- Nunes, C. (on behalf of IPMA's team). Data and assessment of Atlantic chub mackerel (*Scomber colias*) in Portuguese waters (ICES areas 9aN and S): Update since WKCOLIAS 2020.
- Silva, A.V., D. Feijó, A. Rocha, C. Nunes. Landings of *Scomber colias* in Portuguese waters (ICES areas 27.9.a.c.n, c.s and c.a): Update.
- Neves, J. and S. Garrido. Population structure of the Atlantic chub mackerel (*Scomber colias*): an updated review and future work.
- Feijó, D. and A. Rocha. Update of information about purse-seine fleet catching chub mackerel in Portugal.
- Amorim, P. and Ana Moreno. PELAGO 20 Acoustic survey – VMA – ICES 27.9.a (Caminha – Cape Trafalgar).
- Fernandes, A.C. Representativeness of the on-board sampling trips and discards estimation for chub mackerel.
- Ramos, F. and P. Carrera. Iberian-Atlantic chub mackerel. IEO's acoustic-trawl surveys data update.

DAY 2 – 26 JANUARY

10:00–11:30 Presentations (cont.)

- Navarro, M.R., J. Landa, R. Domínguez-Petit, C. Hernández and B. Villamor. Growth and preliminary results of the reproductive biology of Atlantic chub mackerel (*Scomber colias*) in the North and Northwest Iberian Waters (ICES divisions 8.c and 9.a North).
- Derhy, G., M.M. Rincón, K. Elkalay and K. Khalil. Stock assessment for chub mackerel in the Moroccan Atlantic coast using SPiCT model.
- Silva, A., F. Ramos, C. Nunes, P. Carrera, A. Silva, C. Chaves, *et al*. Exploratory assessment of chub mackerel in Iberian waters with SPiCT.

11:30–12:00 Coffee break

12:00–13:00 Plenary discussion on how to address WKCOLIAS2 ToRs: Covid breakout, main WK goals definition, methods or approaches to achieve them and working subgroups proposal. Designation of subgroup participants based on the data received from the data call.

Subgroups (coordinators):

1. Assessment (Xana and Ghoufrane)
2. Fishery data (Jilali)
3. LFDs analyses (Pablo)
4. Survey data (Ana Moreno/Pablo)
5. Maturity ogives data (Charo)
6. Life-history parameters (Joao)

13:00–() Work in subgroups

DAY 3 – 27 JANUARY

10:00–11:30 Plenary session: Presentation of subgroups progress and discussion.

11:30–() Work in subgroups

DAY 4 – 28 JANUARY

10:00–10:30 Plenary session. Last updating presentation:

- Ahmed, M. and C. Baye Braham. Evolution of the Mauritanian pelagic fishery in 2020 with emphasis on chub mackerel.

10:30–11:30 Plenary session: Presentation of subgroups results and Report writing coordination.

11:30–() Work in Subgroups: Progress in the subgroup work and Report writing.

DAY 5 – 29 JANUARY

09:30–11:00 Plenary session: Discuss the results considering ToRs: conclusions and recommendations by subgroup topic.

11:30–12:00 Coffee break

12:00–14:00 Plenary session: Discuss the results considering ToRs: conclusions and recommendations by subgroup topic.

14:00–15:00 Lunch break

15:00–16:00 Plenary session: Discuss ongoing and future works: Resolutions.

16:00 Closure of the meeting.

Annex 3: Pre-workshop WebEx minutes 28 October 2020

Introduction

The **Second Workshop on Atlantic chub mackerel** (WKCOLIAS2), chaired by Cristina Nunes (IPMA, Portugal) and Alba Jurado-Ruzafa (IEO, Spain), will work by correspondence during 2020 and meet by WebEx in 25–29 January 2021, to:

a) Analyse chub mackerel abundance, distribution and migrations in the Northeast Atlantic waters of Europe and Northwest Africa;
b) Explore the connectivity between Atlantic chub mackerel in Atlantic and Mediterranean waters;
c) Analyse the population structure and propose stock units in European Atlantic waters.

The aim of this WebEx, as a first step, was to update the work and available information of *Scomber colias* in the IPMA (Instituto Português do Mar e da Atmosfera) and the IEO (Instituto Español de Oceanografía) carried out from the first workshop, and to identify and coordinate tasks/works to be developed together between both institutions in the Iberian basis.

Participants

- IPMA: Cristina Nunes, Andreia Silva, Corina Chaves, Diana Feijó, Ana Cláudia Fernandes, João Neves and Pedro Amorim.
- IEO: Alba Jurado-Ruzafa, Mª Rosario Navarro, Fernando Ramos, Francisco Velasco and Pablo Carrera.
- ICES: Ruth Fernandez and Helle Gjeding Jørgensen.

Results

The WebEx was organized in three sessions:

A) Oral presentation of each Institution. Presentations available on the WKCOLIAS Sharepoint:
[http://community.ices.dk/ExpertGroups/wkcolias/SitePages/HomePage.aspx?RootFolder=%2FExpertGroups%2Fwkcolias%2FMeeting%20documents%202021%2F09%2E%20Preparatory%20Work%2DOctober2020&FolderCTID=0x012000FA8477FE7DA93A4389121936A1CAA995&View=%7B39C3F33E%2D28F8%2D4C73%2D8ECD%2DF553CEC1878A%7D]

A summary of the available information to be updated by area was presented by IPMA and IEO, based on the previous documents presented in WKCOLIAS (January 2020).

B) Discussion of the tasks that could be carried out jointly for the Iberian area, and "distribution of the work" among participants.

Task	Iberia Data	Before January 2021	After January 2021	PT	ES
Landings-at-length, and fish median weights-at-length in catches	Yes	x		From 2003–2019, single W–L relationship, per métier and area, by semester (Andreia, Cristina, Alberto)	Update until 2019, by métiers (Pablo)
Analysis of cohort progression from both acoustic and demersal surveys data (follow in particular 2016 strong cohort), to validate ages	n.a	x (preliminary)	x (complete)	Andreia coordinates with Pedro and Corina	Coordination between Pablo, Fran, and Fernin, then contact Andreia
Growth studies following different approaches	n.a		x	Work in progress, Andreia contacts Charo	Charo PhD, publication
Establish a reference fleet and use logbooks and IOE data to determine main fishing grounds	Yes (SP), Not yet (PT)		x	Diana	Existent maps 2011–2016 with ICES grid/month, update until 2019 (other colleagues do that)
Analyse length distribution in relation to depth (for surveys, update analysis from WKCOLIAS; for the commercial fleet, after task above)	n.a	x (preliminary)	x (complete)	Andreia, Cristina, Diana	Coordination between Pablo, Fran, and Fernin, then contact Andreia
Analyse temporal and spatial evolution of chub mackerel market price	Yes		x	PhD Diana (+ Univ. Minho?)	Galicia: data available from website https://www.pescadegalicia.gal/; for remaining Spain: Secretaria Geral Pescas?
Improve abundance index from demersal (IBTS) surveys data	Yes		x	CPUE available per length class; improve index, stratified by area and depth	Corina contacts Fran
Evaluate the possibility of deriving a recruitment index from IBTS surveys	Yes		x	Cristina contacts Charo for L50 (assumption that recruits ~1st maturation) or consider age 1 individuals	
Population structure by length/age in landings per area and years. Test growth differences or migration between areas?	Yes		x	Andreia	Coordination between Pablo, Fran, and Fernin, then contact Andreia

Task	Iberia Data	Before January 2021	After January 2021	PT	ES
Reproduction cycle; review data, prepare study of new cycle, review maturity scale	n.a	x	x	Cristina contacts Charo and Carmen in 2021	PhD Charo
Landing evolution vs environmental data; GAMs analysis	n.a.		x	Andreia (+ Univ. Minho?)	Evaluate if possible at Iberian level, depending on the temporal/spatial scales, which environmental data available
Population structure using otolith and body morphometry	Ongoing	x (otolith - PT, first attempts)	x (otolith and body-expecting more data from other areas)	João, Susana: first, a global approach, then at regional level; contact Açores for sampling in 2021; length data from Canarias needed; already preliminary tests with PIL and VMA, needs to correlated areas	Ongoing study on otoliths from the Canary Islands (IEO-CSIC), Joana Vasconcelos (Madeira) contacted; all Iberian otoliths with Charo; Charo and Carmen will evaluate if study possible at medium term
Acoustic surveys (Pedro e Pablo)	Not yet		x	Pedro	Pablo: index not available at present and likely difficult to obtain in short term for West and North; possibility of a qualitative info on recruitment; evaluate index from IBERAS when longer series; South: more direct relationship between landings and acoustic index.
Discards	Yes (PT, only South SP)	x (PT)	x (SP)	Ana Claudia updates until 2019, by length class	South (Cadiz): available data 2008–2019, mostly from purse-seine and bottom trawl (Fernin); North: Pablo checks available info, but likely few (sampling onboard more limited) Canarias: available data, discards very few, most slipping (Alba)
Stock assessment	Not yet		x	Alexandra preliminary tests with SPICT	

C) Forthcoming work focused on the Workshop

- Proposal of age exchange/workshop to WGBIOP (Exchange to be carried out during 2022 and, based on the results, the WK would be proposed to be held in 2023). **Charo Navarro and Andreia Silva**
- Proposal of maturity exchanges/workshops to WGBIOP. **Carmen Hernández and Cristina Nunes**
- Informal data calls have been sent to the Mediterranean chairs (GFCM), to the ICES IBTSWG and the WGACEGG chairs as well as to the colleague co-responsible for the French survey (Ifremer) in the Bay of Biscay. Official ICES data calls will be sent in month of November in order to be able to revise the available information to address the WKCOLIAS2 ToRs. **Cristina Nunes, Alba Jurado, Fernando Ramos and Ruth Fernández.**
- WGACEGG (16–20 November 2020): presentation of WKCOLIAS and contact with other European ICES partners (AZTI, IFREMER). **Cristina Nunes**
- Invitation to participate to the NW African and the Mediterranean colleagues. **Alba Jurado**

Other highlighted topics

- The workshop in January 2021 will be performed by WebEx, in morning sessions.
- "Covid-19 disruption": all the participants were concerned about the data lack (from both surveys and biological sampling) in 2020 provoked by the pandemic situation. It will be discussed during the WK.

Remark: All gathering literature will be uploaded to the SharePoint of the meeting: http://community.ices.dk/ExpertGroups/wkcolias/SitePages/HomePage.aspx

Annex 4: Presentation abstracts

I. Bensbai, J., A. Najd and A. Faraj. *Scomber colias*. State of Moroccan fishery in 2019.

II. Mamza, K. Distribution of densities and size structure of Atlantic mackerel *Scomber colias* in the Moroccan waters: Atlantic and Mediterranean Sea - Autumn 2019, acoustic data.

III. Jurado-Ruzafa, A., B. Sotillo, E. Hernández, J.L. Otero-Ferrer and V.M. Tuset. Canary 2019-updating highlights.

IV. Silva, A.V., D. Feijó, A. Rocha, C. Nunes. Landings of *Scomber colias* in Portuguese waters (ICES areas 27.9.a.c.n, c.s and c.a): Update.

V. Neves, J. and S. Garrido. Population structure of the Atlantic chub mackerel (*Scomber colias*): an updated review and future work.

VI. Feijó, D. and A. Rocha. Update of information about purse-seine fleet catching chub mackerel in Portugal.

VII. Amorim, P. and A. Moreno. PELAGO 20 Acoustic survey – VMA – ICES 27.9.a (Caminha – Cape Trafalgar).

VIII. Fernandes, A.C. Representativeness of the onboard sampling trips and discards estimation for chub mackerel (adapted from Fernandes *et al*., 2021).

IX. Ramos, F. and P. Carrera. Iberian-Atlantic chub mackerel. IEO's acoustic-trawl surveys data update.

X. Navarro, M.R., J. Landa, R. Domínguez-Petit, C. Hernández and B. Villamor. Growth and preliminary results of the reproductive biology of Atlantic chub mackerel (*Scomber colias*) in the North and Northwest Iberian Waters (ICES divisions 8.c and 9.a North).

XI. Derhy, G., M.M. Rincón, K. Elkalay and K. Khalil. Stock assessment for chub mackerel in the Moroccan Atlantic coast using SPiCT model.

XII. Silva, A., F. Ramos, C. Nunes, P. Carrera, A.V. Silva, C. Chaves and B. Villamor. Exploratory assessment of chub mackerel in Iberian waters with SPiCT.

XIII. Braham, C. B. and M. A. Jeyid. Exploitation of chub mackerel in the Mauritanian area.

I. Bensbai, J., A. Najd and A. Faraj. *Scomber colias*. State of Moroccan fishery in 2019

In Moroccan waters, an increasing trend of total small pelagics catches has been observed since 2011 (1.4 million in 2019, what means an increase of 9% respect 2018), mainly caught using purse-seines or trawl nets. The sardine is the most landed and targeted species by Moroccan fisheries. Concerning chub mackerel, it only represents the 7% of the total small pelagic landings considering data reported since 1990. Although small fluctuations occur, landings have increased since 2004. In fact, it is a bycatch species for purse-seiners except during some periods when the fish sizes are suitable for manufacturing. In the case of pelagic trawlers, some fishing strategies are focused on this species.

In 2019, the small pelagic operational fleet was compound by 607 purse-seiners on north Cap Boujdor (26°00 N) and 8 European purse-seiners. In the southern part, 89 purse-seiners, 24 Moroccan pelagic trawlers (RSW) and ten Russian pelagic trawlers have developed fishing activity.

The fishing activity with positive catches for chub mackerel shows variability along the year, with an intense activity in the two last quarters of year. Some periodicity is detected in landings, probably related to the seasonal availability the fish in these fishing grounds. Considering areas, there is no clear stratification the fishing activity for chub mackerels. Concerning landings, chub mackerel is mainly caught from September to December.

According to the length–frequency distribution, collected by the INRH sampling programme and on board the Russian fleet, the recruits seem to be observed first during the first quarter at the north and central areas and during the second quarter at the south, where bigger sizes are sampled. However, there is no clear scheme for size stratification by time.

Generally, the smallest chub mackerels are harvested in the north of Cap Boujdor and the biggest ones in the south (targeted by the pelagic trawlers). The reasons which could explain these trends are: 1- Fishing ground deeper and less accessible to the purse-seiners, 2- Vessel engine performance and fish detection devices (more catchable for trawlers), 3- presence of bigger sizes in the fishing ground.

The assessment performed in 2019 in the CECAF framework using data until 2018 through different analytical and production models showed that the stock is fully exploited along the Northwest African coast.

Finally, the fisheries indicators do not provide more information about fish movement nor species migration between fishing grounds. Further information from surveys and from the holistic approach are necessary to describe the population structure of the Atlantic chub mackerel for future stocks identification.

II. Mamza, K. Distribution of densities and size structure of Atlantic mackerel *Scomber colias* in the Moroccan waters: Atlantic and Mediterranean Sea – Autumn 2019, acoustic data

For the of assessment and management purposes in the Moroccan Economic Exclusive Zone (EEZ), the National Institute of Fisheries Research performs annual scientific sea surveys to monitor the biomass and abundance indexes of small pelagic stocks. In this context, and as part of its activities for the year 2019, the Pelagic Resources Prospecting Laboratory conducted an acoustic survey onboard the RV *Al Amir Moulay ABDALLAH*. This survey started in the Mediterranean Sea between Saidia and Ceuta in October 2019, and continued in the Atlantic waters between Tangier and Cape Blanc on the Mauritanian borders in November–December 2019. In addition to the main objective of the survey, which is the calculation of biomass and abundance indexes, it also aims to produce distribution maps of the main small pelagic targeted in the region (i.e. sardines, anchovies, chub mackerel, horse mackerel and sardinellas), their size–frequency distributions and the characterization of their biological specificities.

In Moroccan Mediterranean Sea (FAO area 37.1.1): The results of this survey indicate that mackerel *Scomber colias* is weakly present in this area, where is distributed in two strata in low densities. The biomass in 2019 was estimated at only 7000 tons. But indeed, the biomass levels recorded in this area between 2005 and 2019 did not exceed 12 000 tons, with a peak in autumn 2005. The demographic structure of the species is displayed in a single cohort formed only by juveniles with a mode at 21 cm of total length (TL).

In Moroccan Atlantic coast (FAO area 34: 1.11, 1.12, 1.13, 1.31, and 1.32) *Scomber colias* is present on all Moroccan coastlines.

- In the northern zone *(FAO area 34.1.11):* the relatively high densities of Atlantic chub mackerel are located in this area especially between el Jadida and Safi. The size distribution reflects a unimodal cohort with a peak at 19 cm TL, with adults accounting only 2%. In terms of biomass, the species recorded 338 000 tons with an increase of around 40% compared with the same period in 2018. The peak of biomass in this area between 2005 and 2019 was recorded in 2017, with 604 000 tons.
- In the central zone (*FAO areas 34.1.12 and 34.1.13)*, the densities are moderately considerable with higher concentrations between Tarfaya and Laayoune. Regarding the size distribution, two cohorts can be observed, the main including small individuals with a mode at 18–19 cm TL, and the second represented by adults around 28 cm TL. Concerning biomasses, the great values in the historical series of the species are recorded in this zone with a peak in autumn 2015 with 887 000 tons. A decreasing trend seemed to occur from autumn 2017 to autumn 2019, when the biomass was estimated at 412 000 tons.
- In the southern zone *(FAO areas 34.1.31 and 34.1.32)*, in autumn 2019, the Atlantic mackerel densities in this area were slightly low and scattered, a denser aggregation is generally located off Dakhla. In terms of size distributions, the population includes a wide range of sizes between 16 and 32 cm TL, with a mode at 21 and 24 cm TL, with adults over 24 cm representing 31%. After the biomass record of 858 000 tons in 2017, the trend is decreasing with an estimation of only 153 000 tons of chub mackerel in autumn 2019.

The analysis of the distribution of adults and juveniles indicates that adult individuals whose size is greater than 24 cm are located along the southern waters (especially area 34.1.32), and the opposite for juveniles, which are more abundant in the northern waters (34.1.11).

III. Jurado-Ruzafa, A.[1], B. Sotillo[1], E. Hernández[1], J.L. Otero-Ferrer[2] and V.M. Tuset[3]. Canary 2019-updating highlights

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Small pelagic fishery in the Canary Islands is carried out by an interannual quite variable artisanal fleet of purse-seiners. Total landings produced by the Canary purse-seiners have experienced a decrease from 2017–2019. However, it is not the case for the Atlantic chub mackerel, which not only is the main of the four species targeted by this fleet (>50%), but whose landings have increased since 2014, with European sardine and sardinellas almost absent in 2019.

Concerning the length frequencies present in landings, the most relevant observation is that a noticeable increase in the modal lengths has been registered since the beginning of the monitoring programme in 2013, from around 22 cm to individuals ≥27 cm in 2019.

Regarding ongoing studies, a new work has been launched based on the otolith shape analysis of a sizable sample comprising 792 otoliths corresponding to a time period from August 2016 to December 2017. A DIvisive ANAlysis (DIANA) Clustering method using the 4th wavelet obtained from otolith contours resulted in the detection of five different morphotypes or otolith phenotypes. Differences were found mainly in the collicum-antirostrum and the dorsal margin areas of the otolith contours. Two of the morphotypes represents 85% of the samples analysed, whose individuals were slightly larger than the other morphotypes, considering mean lengths (≥25 cm vs ≤24.5 cm).

These very preliminary results open many future questions to be explored:

1. Do these results suggest intraspecific variation in the growth rate among phenotypes?
2. Do phenotypes proportions change in relation to seasonal variations?
3. May exist different ecological strategies related to each phenotypes? and
4. Are these otolith phenotypes present in other geographical areas?

IV. Silva, A.V.[1], D. Feijó[1], A. Rocha[1], C. Nunes[1]. Landings of *Scomber colias* in Portuguese waters (ICES areas 27.9.a.c.n, c.s and c.a): Update

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To improve data presented to the Workshop on Atlantic Chub Mackerel 2020 (WKCOLIAS 2020) this study updates the fishing activity and biology on the Portugal continental coast (ICES 27.9.aCN area). The biological data of chub mackerel were collected since 1981 at the harbours, landings were collected since 1986 and discards were collected on board commercial vessels since 2004. Biological sampling was carried out monthly at three different harbours (Matosinhos, Sesimbra and Olhão) from Northwest (NW), Southwest (SW) and South (S) areas of Portugal. During the last WKCOLIAS 2020, the analysis of these data indicate that purse-seine fleet represents about ¾ of the total chub mackerel landings, being the SW and S areas with the larger proportion. Also, the analysis indicates that chub mackerel frequently scarcely available to the fisheries during the first and second trimester of the year in NW area.

For the present WKCOLIAS 2021, new analyses were performed: 1) add the 2019 to the data, 2) recalculate total length–total weight relationship by year, semester and areas, 3) analyse the length composition of landings by trimesters, areas and fleet, 4) analyse the cumulative length distribution and 5) present the landing data by age.

Until 2000s, chub mackerel total landings in Portugal were below 20 thousand tones. Since 2003, landings increase faster, reaching a maximum historical in 2015 with 45 951 thousand tones. The SW region showed a larger increase from 2576 thousand tons in 2003 to 20 241 thousand tons in 2015. In 2019, chub mackerel's landings reached its maximum historical with 29 094 thousand tons.

The regression coefficients of the length–weight relationship by year, semester and areas indicate interannual and geographical significant differences. The coefficients differ between areas and semesters, ranged, between 0.0025–0.0125, 0.001–0.0025 and 0.001–0.020 for NW, SW and S areas, respectively for coefficient a. Coefficient b ranged between 3.0–3.45, 2.85–3.6 and 2.7–3.85 for NW, SW and S areas, respectively. Northwest area of Portugal doesn't have data from 2000 to 2007 and in the S, only data available from 2005 to 2011. To overcome this issue, "historical" relationships per region/semester were estimate.

The analysis of length composition of landings by trimester and fleets (Bottom trawl fleet; Polyvalent fleet and Purse-seine fleet) indicate that purse-seine fleet add most of the chub mackerel landings. Also, small fish are present in all fleets, throughout most of the year, but proportionally larger landings of smaller fish occur in the fourth trimester of the year in purse-seine. Bigger fish are mostly present in Polyvalent, throughout most of the year.

Regarding the analysis on cumulative length distribution, a decreasing trend in length in the NW area was observed. In SW and S areas, no clear trend is visible.

Concerning the exploration analysis of age composition of landings by region and fleet, the Aged-0 fish (age convention) is caught mostly in second semester and is negligible in Bottom Trawl and Polyvalent fleets, representing about 7% in purse-seine landings. Fish with age 1 are presented mostly in the second semester in all fleets. The majority of chub mackerel landed aged up to three years-old, about 80% in the Purse-seine and Bottom Trawl fleets. Polyvalent fleet presents a larger age distribution (about 60% fish aged less than three years old).

V. Neves, J.[1,2] and S. Garrido[2]. Population structure of the Atlantic chub mackerel (*Scomber colias*): an updated review and future work

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The presentation aims to provide to the Expert Group of the ICES WKCOLIAS an updated review of the state of the art of studies devoted to the population structure of Atlantic chub mackerel in the Atlantic and expected future advances.

Chub mackerel (*Scomber colias*) is widely distributed in the Atlantic, In the western Atlantic, chub mackerel is distributed from Nova Scotia until Argentina on the western side, and from the Bay of Biscay to South Africa on the eastern side. It is also distributed in the Mediterranean and Black Seas.
In the Eastern Atlantic, a global increasing trend in recent years (until 2016) was evident, as well as in the Western Atlantic with a peak in 2013/2014. In the Mediterranean Sea, a decreasing trend was observed since great peaks (1986/1987 and 1994), although recently a smaller peak in 2004 and a slight increase since 2014 were detected.

In Atlantic European and Mediterranean waters, no management of chub mackerel stocks is made, but in the Iberia case, regular biological sampling of fisheries, acoustic and demersal surveys is made. Thereby, to manage a fishery effectively, it is important to understand the stock structure of a species to design appropriate management regulations in fisheries.

In terms of population structure and the studies dedicated to it, some regional life-trait differences were detected, such as length-at-age, time of the first maturity, and spawning season; even as differences among Western and Eastern Atlantic population units, but no differences between Mediterranean and Atlantic waters. The state of art devoted itself to different aspects, such as body and otolith morphometry, otolith elemental and isotopic signatures, genetic variations, and parasitism as structure indicators. Besides that, most of the existent studies give a local perspective and a low range of information in terms of the global structure.

Related to that, in IPMA a first approach was made in terms of otolith morphometry using historical collections (2017 year), showing preliminarily two groups from Northwest of Portugal to the Canary Islands, depending on the shape descriptors used. Since these preliminary results were overly local, the objective is to include the maximum of areas available to perform a global population structure.

Besides that, new data on population structure can potentially be done in the short term, such as cohort analysis, and growth, maturity, and distribution population dynamics studies using WKCOLIAS data. Using otoliths, besides shape analysis, stable isotopes as natal origin and connectivity study is also important. Genetically speaking, new studies on population structure within the Atlantic are needed, using for instance Genetic Next Generation Sequencing techniques, being a powerful tool to study genetic variability within between populations.

VI. Feijó, D.[1] and A. Rocha[1]. Update of information about purse-seine fleet catching chub mackerel in Portugal

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In Portugal, the purse-seine fleet targets small pelagic species, with sardine (*Sardina pilchardus*) and chub-mackerel (*Scomber colias*) being the main species landed in 2019. In the report of WKCOLIAS 2020, we presented some fleet characteristics catching chub mackerel in Portugal in 2018 (Feijo and Rocha, 2020). At this time and using the same methodology, we update the information by year and area and information about main species landed, for the period 2003–2019.

We present results comparing the official data (reported by Direcção-Geral dos Recursos Naturais, Segurança e Serviços Marítimos - DGRM), total and chub-mackerel landings by the purse-seine fleet for the period 2003–2019. We observed differences between official data and the fleet that we determined, using information of fishing licences, active vessels that landed each year in the purse-seine action, in Portuguese harbours. In 2009, DGRM aggregated vessels by licences and landings concerning the main gear (purse-seine). In 2011, the purse-seine fleet (4K4) includes vessels from 4K1 and 4K2 or artisanal fleets that operated mainly the purse-seine net (e.g. they are licensed for other fishing gears such gillnets), applying the Regulation (CE) nº 2091/98.

For the Portuguese purse-seine fleet identified by this work, the number of vessels that didn't land chub-mackerel once per year has decreased (mean ± SD: 5.56% ± 2.73). These data are important, considering that purse-seiners target mainly sardine, and after the sardine landing restrictions (since 2011), this fleet starts to target other small pelagic to compensate the lack of income during the periods that it couldn't fish sardine. We observed an increasing trend in the capture of chub-mackerel since 2012 in 27.9.a.c.n and 27.9.a.c.s areas. In 27.9.a.c.n area and since 2016, anchovy has become almost half of total landings, compared with the sum of sardine and chub-mackerel landings. Looking for the landings from the fleet that never landed chub-mackerel one per area and per year, we noticed in 27.9.a.c.n area the same tendency for anchovy. For all three areas, sardine is the main species landed and since 2013, other demersal species are the main target in 27.9.a.c.s and 27.9.a.s.a areas.

In terms of technical specifications for the purse-seine fleet (2003–2019), in the North of Portugal we observed almost half of the total fleet. In this area, vessels are bigger and younger and in the South of Portugal, are smaller, less powerful and older. All areas show large differences in tonnage and power.

In conclusion, despite the sardine landings restrictions, that could be expected to lead to a reduction in the size or engine power of the purse-seine fleet, this fleet has become younger and more powerful and has grown in number in recent years. With sardine landings restrictions, this fleet changed target species for chub-mackerel or other more abundant/profitable species, such as anchovy in the last years mainly in the north of Portugal. The differences between the official data and these results have to be more explored. The same analysis is expected to be done in the Trawler and Polyvalent fleet, in the near future.

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VII. Amorim, P. and Ana Moreno. PELAGO 20 Acoustic survey – VMA – ICES 27.9.a (Caminha – Cape Trafalgar).

Biomass, abundance and spatial distribution of chub mackerel in 2020 was evaluated in the Portuguese spring acoustic survey that covers the continental shelf of Portugal and the Bay of Cadiz, in Spain. Although the main objective of this survey time-series is to estimate the abundance and spatial distribution of sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*), other small pelagic species are also assessed in some years. PELAGO20 survey was carried out onboard the IEO R/V Miguel Oliver between the 4th and the 25th of March 2020, for a total of 21 working days. About 1118 nautical miles (71 transects) were tracked, 25 pelagic fishing hauls and 25 purse-seine fishing operations were undertaken. Chub mackerel was mainly concentrated on the southwest coast and in the Algarve areas. It was not observed in the northwest, and in the Cadiz area the species only occurred in the closest transect to the Algarve. In the southwest area, chub mackerel occurred south of Peniche (the northern limit) concentrated on the 100 m isobath. The species appeared further south between Cascais and Sines with a more homogeneous and more coastal distribution. Between Sines and Odeceixe, chub mackerel occurred essentially between the 100 and 200 m of depth. In the Algarve the greatest abundance was registered in the western area in coastal waters up to 100 m. The total estimated biomass of chub mackerel was 31 500 tons, corresponding to a total of 325 million individuals. Considering the total area sampled, length distribution comprised individuals between 17 and 29 cm, with a mode at 22 cm and ages distribution between one and four years, most of them with one and two years (mode = two years).

VIII. Fernandes, A.C.[1] Representativeness of the on-board sampling trips and discards estimation for chub mackerel (adapted from Fernandes *et al.*, 2021)

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The on-board observer programmes are key to collect data for fishery dynamics analysis, and species bycatch and discards estimation. They provide the best mechanism to obtain reliable and accurate bycatch estimates for many fisheries and typically are designed to achieve a fixed level of precision with minimum observer effort, or to achieve maximum precision for a fixed observer effort, while attempting to minimize bias (NMFS, 2004; Vølstad and Fogarty, 2006).

For observer-collected data to be useful for fish stock assessment and management, they should be unbiased and representative of fishing operations because underestimates of total removals jeopardize the future of the resource, while overestimates may inhibit future economic opportunities (Faunce and Barbeaux, 2011). The work presented focused on the Portuguese on-board sampling programme for the bottom otter trawl fishery, targeting demersal species (OTB_DEF) in 2012–2015 period. It is a stratified random sampling design with region and quarter as strata, the vessel selection is based on an opportunistic sampling of cooperative vessels, and the fishing trips within vessel are randomly selected.

The results presented show that the sampled trips are representative of the total fleet in terms of fishing patterns (e.g. spatial distribution of the fishing effort and the landed weights per trip and area) and vessel characteristics (e.g. vessel length). Also concerning bias, the results obtained from the trip clustering and comparison of trips with and without observer from the sampling frame indicate that there is no observer effect, when comparing landings composition and fishing behaviour between the two groups of data. The clustering also aimed to analyse possible improvements on the precision of discard estimates obtained.

The chub mackerel (*Scomber colias*) is included in the list of the selected species used in this analysis, which considered the main landed species by OTB_DEF and with national interest. Chub mackerel is a species with an irregular discard pattern both related to its frequency of occurrence in the discarded fraction of sampled hauls and to the variable discard volumes between hauls/trips.

The annually-based discard estimation algorithm presently used, is sensitive to large number of zeros in the dataset and so, discard estimates obtained may be inaccurate when the frequency of occurrence of the species is below 30% - a negative correlation was observed between the frequency of occurrence and the coefficients of variation. The cluster-based discard estimation procedure is derived from the annual-based procedure but includes clusters as a new stratum. The comparison of the discard estimates obtained from the two procedures for the analysed species (including the chub mackerel), and considering or not the 30% threshold in the estimation, showed that the cluster stratified estimates, obtained from the cluster-based approach, presented higher precision in the whole period for all species, when compared to the fleet-based approach.

The main conclusions are that the vessels in the sampling frame are representative of the target fleet with no sources of bias detected, constituting an 'Indicator fleet'. The results obtained increase the reliability of the discard estimates obtained from the Portuguese observer data. Also, the clustering of the fishery data resulted in an important step for the characterization of the fishing behaviour and, consequently, of discards composition. Regarding the implementation of a threshold on species occurrence for the estimation with fleet- and cluster-based approaches, though resulting in increased precision for some years (and species), it may potentially introduce bias in the estimates. The application of that threshold should then be dictated by end-users needs and based on the trade-off between reducing variance but potentially introducing bias or the other way around. Another important conclusion is that the cluster stratified approach greatly improved estimates precision. The bias of the estimates was not considered in the study and should be further investigated.

The presented study showed improvements on the chub mackerel discard estimates obtained using the stratified cluster-based approach. However, because this species may present significant proportion of zeros in some of the sampled years, the exploration of a model-based discard estimator for chub mackerel is being performed to evaluate the differences in the performance between a ratio estimator (design-based approach) and a standardized discard per-unit-of-effort (DPUE) (model-based approach), in the discard raising procedure.

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IX. Ramos, F.[1] and P. Carrera[2]. Iberian-Atlantic chub mackerel. IEO's acoustic-trawl surveys data update

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At present IEO performs four acoustic-trawl surveys in the Iberian-Atlantic shelf waters (ICES areas 8.c, 9.a): PELACUS (spring, ICES 8.c and 9.a N, since 1991), ECOCADIZ (summer, ICES 9.a S, since 2004), IBERAS (autumn, ICES 9.a N-9.a C-S, since 2018), and ECOCADIZ-RECLUTAS (autumn, ICES 9.a S, since 2012). PELACUS survey was not conducted in 2020 because COVID-19 disruption, and this same cause has prevented from the realization of several research activities in the remaining surveys in this same year, although this constraint not affected to the provision of acoustic indices. The most recent information available from PELACUS is from the 2019 survey. In spring 2019, chub mackerel was relatively common in the surveyed area, although was more frequent and abundant in ICES Subarea 8.c East, entailing a new shift in the centre of gravity of its distribution towards this sub-area. The population recorded a peak in 2016, but showed a decreasing trend since then. The population is structured by the Age 1 to Age 7 age groups, with Age 1 to Age 3 fish being the main age groups, and Age 1 dominating in many years. 2012, 2015 and 2016 were strong year classes. IBERAS survey series is still a very short one. IBERAS recorded a frequent species occurrence in the surveyed area in autumn 2020, with the species showing a wide but patchy distribution and higher densities being recorded in 9.a C-S, resulting in a shift in the centre of gravity of its distribution towards this subarea. The aggregation patterns (near bottom, patchy, dense and thick schools in autumn 2020) were also different to those ones recorded in previous years. Chub mackerel is a very important species within the Gulf of Cadiz "acoustic species assemblage". The species shows both in ECOCADIZ (summer) and ECOCADIZ-RECLUTAS (autumn) surveys seasons a preference for the inner and mid-shelf GoC waters, but specially the Portuguese ones. The population was composed by fish belonging to Age 0 to Age 8 groups, although the more frequent ages are Age 0 to Age 3, with the Age 0 and Age 1 groups being the dominant ones (juveniles and young adults). 2016 and 2018 year classes have been the stronger ones in the last years. Population levels have not shown any clear trend through their respective historical series, although a probable peak could have occurred in 2007–2009, and increased levels in relation to the historical average are observed in very recent years (2018–2019).

X. Navarro, M.R.[1*], J. Landa[1], R. Domínguez-Petit[2], C. Hernández[1] and B. Villamor[1]. Growth and preliminary results of the reproductive biology of Atlantic chub mackerel (*Scomber colias*) in the North and Northwest Iberian Waters (ICES Divisions 8.c and 9.a North)

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Updated information on growth and reproductive biology of Atlantic chub mackerel in several areas of its distribution is required for the first stock assessment. This study has been performed in Northern Iberian Atlantic waters (ICES divisions 27.8.c and 27.9.a.N) with samples from commercial landings and scientific surveys.

Its growth pattern in Northern Iberian waters (2011–2017) was analysed with different approaches: those based on otolith analyses (direct age estimation-DAE, back-calculation-BC and otolith marginal analyses) and those based on length–frequency analyses (Bhattacharya, SLCA and PROJMAT methods).

Two main different growth patterns were obtained, a "slow" one based on DAE, BC and LFDA from surveys; and a "fast" one based on Bhattacharya and LFDA from commercial landings. The divergence between both patterns begins to be evident at age 3 and older.

Otolith marginal analyses that shows an annual periodicity in the formation of the hyaline and opaque edge, the unimodal distribution of the annuli radius and the similarity of the back-calculated mean lengths to those obtained by DAE, support the age estimation criteria used in our analysis.

The VBGF growth parameters (L_∞=45.34, k =0.28, t_0=-1.18) obtained by otolith age estimation are available for the upcoming stock assessment process.

A study of the reproductive biology of the Atlantic chub mackerel (*Scomber scolias*) has been performed, based on samples of 14 538 specimens (11–50 cm total length) 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 this could be because sampling was limited to a partial zone of the total 27.9.a area (we do not cover Portuguese coast).

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

XI. Derhy, G.[1], M.M. Rincón[2], K. Elkalay[1] & K. Khalil[1]. Stock assessment for chub mackerel in the Moroccan Atlantic coast using SPiCT model

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A surplus production model in continuous time (SPiCT) was implemented for the Moroccan Atlantic coast by using catch time-series and three different abundance indices (biomass data from Moroccan, Nansen and Atlantida acoustic surveys).

The model was implemented by testing four different sets of assumptions:

- Scenario 1: default priors;
- Scenario 2: reducing the estimated catch variability by shortening data time-series;
- Scenario 3: imposing a Schaefer model on the production curve; and
- Scenario 4: imposing a Schaefer model and changing the default prior for the ratio between biomass at the beginning of the time-series relative to the carrying capacity.

Best results in terms of goodness of fit and uncertainty were obtained by assuming a Schaefer type production curve (scenario 3). Biomass time-series estimates in this scenario were consistent with those estimated by the model used currently for the assessment of this species in the area. Details on the scenarios definition and results are presented in Derhy *et al*. 2021 (Working document 4 in Annex 5).

XII. Silva, A.[1], F. Ramos[2], C. Nunes[1], P. Carrera [3], A.V. Silva [1], C. Chaves[1], B. Villamor[4]. Exploratory assessment of chub mackerel in Iberian waters with SPiCT

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Surplus production models in continuous time (SPiCT) were explored to assess chub mackerel assuming a single stock in the Iberian waters (ICES 9a). Five different assumptions on the shape of the production curve were tested (including Schaefer and Fox like models) using two datasets: one with landings from the whole 9a area from 1993 to 2019 and another with landings from the Portuguese waters, where the bulk of chub mackerel is distributed, covering a longer period, from 1985 to 2020. In both cases the Portuguese Autumn and summer IBTS surveys and the Spanish acoustic ECOCADIZ summer survey were used as independent indices of abundance. The best model fitted to each dataset was then expanded to allow robust fitting to survey data and weighting of the IBTS survey observations by the relative CV. Model performance was evaluated following the ICES checklist and retrospective analyses. For the Iberian waters, none of the models passed the checklist plus the Mohn's Rho criteria; overall, the Schaefer with IBTS survey weighting had the best overall performance but showed high F/F_{MSY} overestimation.

For the Portuguese waters, the Schaefer model showed the best fit. In this case, the use of CVs as weighting factors for the IBTS surveys did not change the model fit or the results significantly. The model indicates that in the beginning of 2021 the biomass is estimated to be above B_{MSY} and the fishing mortality below F_{MSY}; MSY = 32 thousand t. A comparable stock status is indicated for the whole Iberian waters, with MSY = 50 thousand t. The approach with SPiCT appears to be promising while several options may still be improved. It might be worth exploring a longer time-series of landings (since the 1960s) available for Portuguese waters and for both datasets it will be important to test assumptions on the ratio B0/K. It might also be possible to "borrow" some parameters which are well estimated with the longer Portuguese dataseries to improve the model for the whole Iberian waters. Since chub mackerel is a pelagic species some of the population parameters are not expected to change from the Portuguese waters to other areas of the Iberian Peninsula.

Stock identity, autocorrelation of residuals in the IBTS autumn survey and discards/slipping are some of the issues that needed to be further explored for this stock.

XIII. Baye Braham C.[1] and M. Ahmed Jeyid [1]. Exploitation of chub mackerel in the Mauritanian area

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On the NW African coasts, it is known that populations of small pelagic fish undertake migrations between southern Morocco and Senegal, being considered transboundary resources in terms of fishery management. These populations, whose limits and abundances are highly variable in relation to seasons and between years, are very influenced by the one of the major upwelling processes which occurs in this region.

Regarding the fisheries targeting those resources, "domestication" has happened since 2009, when the activity was mostly performed by great foreign pelagic trawlers that exported the catches abroad. Then, a coastal artisanal fleet emerged as the fishmeal plants developed. From 2016 this fleet growth has been supported by regulations and a new national strategy.

Considering the fishing activity since 1990, average landings of small pelagic fish in the Mauritanian Economic Exclusive Zone (MEEZ) attain the 80% of the total. The main small pelagic groups in MEEZ waters are clupeids (sardine and sardinellas) and carangids (*Trachurus* spp), with noticeable seasonal variations in their abundance and distribution when comparing cold/warm seasons. However, landings of *S. colias* have a clear increasing trend and are getting importance during the last years, matching with the augment of the coastal artisanal fishing activity.

Different socio-economic and scientific issues concerning small pelagic species should be considered for the proposal of management measures, such as mesh size, zoning, catch size, fleet segmentation, licensing separation and fisheries certification. Regarding the mesh, not only the size, but its height in relation to the depth in the fishing ground, among other questions.

However, some key issues remain not addressed to have a global vision of these transboundary species inhabiting the NW African waters. Some recommendations to improve the current knowledge are:

- Increase the sampling effort in relation to the evolution of new fleets.
- Improve small pelagic fish assessments.
- Consider the scenario of changes in the status of these stocks under the combined effects of overexploitation and Climate Change.
- Strengthen the cooperation among countries in the subregion, and outside the area, to improve the knowledge of these shared resources.
- Implement different techniques to identify stocks, substocks and to detect/monitor/describe their transboundary migrations.
- Resume recruitment surveys for small pelagic species.

Annex 5: Working documents

WD1: Jurado-Ruzafa, A., B. Sotillo, E. Hernández, Z. Santana, G. González-Lorenzo and C. Perales-Raya. The Atlantic Chub Mackerel (*Scomber colias*) in the Canary Islands (Spain): Fishery and Biological data Update.

WD2: Navarro, M.R.; Landa, J.; Villamor, B.; Domínguez-Petit, R. Growth, age estimation and corroboration of northeast Atlantic chub mackerel (*Scomber colias*) in northern Iberian waters: a first attempt**.**

WD3: Navarro, M.R., Domínguez-Petit, R., Landa, J., Hernández, C., Villamor, B. 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).

WD4: Derhy, G., K. Elkalay, K. Khalil, M.M. Rincón. Stock assessment for chub mackerel in the Moroccan Atlantic coast using SPiCT model.

Please see the four working documents in full in the pages below.

Working Document to ICES WKCOLIAS2 2021

The Atlantic Chub Mackerel (*Scomber colias*) in the Canary Islands (Spain):

Fishery and Biological data Update

By

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Gustavo González-Lorenzo
Catalina Perales-Raya

INDEX

1. Introduction

All the background information for the Atlantic chub mackerel *Scomber colias* (Gmelin, 1789) targeted by the artisanal purse-seine fishery in the Canary Islands was presented during the first ICES WKCOLIAS (Jurado-Ruzafa et al., 2020). In order to provide the most updated basis, the time series and the parameters estimations for the species in this area are here presented including data corresponding to 2019.

The 'Canary stock' status assessment is included in the framework of the Fishery Committee for the Eastern Central Atlantic (CECAF). However, until now, available data have not allowed carrying out reliable assessment due to the short time series available, considered consistent just since 2013. In this context, the aim of this document is to update for 2019 the existing data of fisheries and biology of the species collected data in the Data Collection Framework in the Canary Islands.

2. Material and Methods

All this information was already detailed in Jurado-Ruzafa et al. (2020), for fishery statistics and biological analyses.

3. Results

3.1 Fishery description

Fleets operating in the Canary Islands waters are composed by artisanal vessels, mainly targeting tuna, small pelagic fish and demersal species. Small pelagic are targeted by a relatively stable purse-seiners fleet, one of the monitored *métiers* in the region as part as the EU-Data Collection Framework. This is a mixed fishery, where vessels catch mainly four small pelagic species (*S. colias*, *Trachurus* spp Rafinesque, 1810, *Sardina pilchardus* (Walbaum, 1792) and *Sardinella* spp Valenciennes, 1847). Although the overall landings decreased in 2018 and 2019, the Atlantic chub mackerel was the most caught species during the whole period (40%), achieving the 60% in landings of the purse-seine fleet during the last year (Fig. 1).

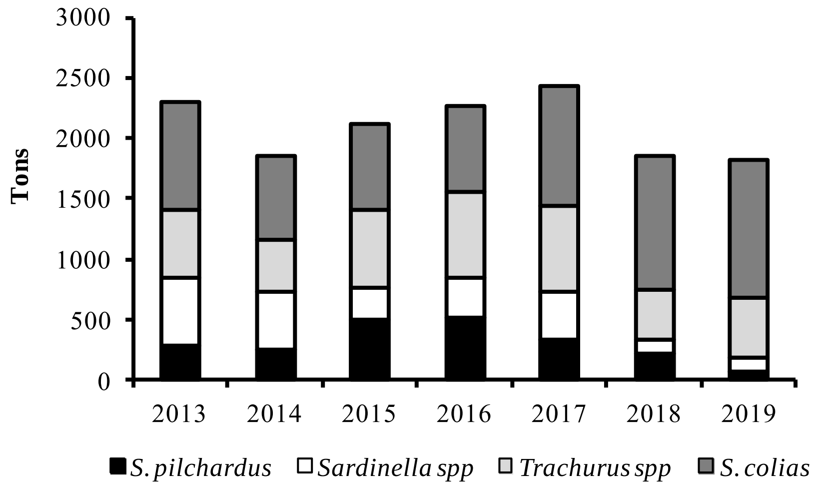

Figure 1. Annual landings of the main small pelagic fish by the artisanal purse-seiners in the Canary Islands

No regulation on maximum allowance catches is implemented for Atlantic chub mackerel, but legal minimum size is established at 20 cm of total length. In addition, it worth to notice that landing obligation regulation (Commission Delegated Regulation (EU) 1394/2014) includes a *survivability exemption* for artisanal purse-seine fisheries of the species in the region, which may release catches while the net is not fully taken on board.

The activity of the artisanal purse seine fleet in the Canary Islands is considered as one of the monitored *métiers* within the EU Data Collection Multiannual Programme (DC-MAP): purse seine targeting small pelagic fish (acronym: PS_SPF_10_0_0).

3.2 Fleet composition

The Canary (artisanal) fleet is polyvalent and very adaptable to annual variations, and the purse-seine artisanal *métier* is yearly revised. One of the criteria used to characterize this *métier* is to include vessels whose small pelagic landings reach 60%. In 2019, it consisted of 30 vessels with a gross tonnage of 10 t, 78.7 hp of power and 11 m of length on average. The duration of each fishing trip is one day.

3.3. Fishing effort

Total catches and fishing effort recorded for the *métier* from 2013 to 2019 are presented in Table 1. An increase of the CPUE (in kg/fishing days with positive catch for *S. colias*) seems to be happening since 2016 (Fig. 2).

Table 1. Landings (in tons) of Atlantic chub mackerel and fishing effort (fishing days with positive catch for *S. colias*) of the artisanal purse seine fleet in the Canary Islands (2013-2019)

	2013	2014	2015	2016	2017	2018	2019	Average
Landings (t)	889	696	712	706	987	1105	1149	892
Fishing effort (days)*	2492	1460	1739	1627	1808	1669	1701	1785

* only fishing trips in which one of the species is landed, are considered as "positive" fishing effort for this species

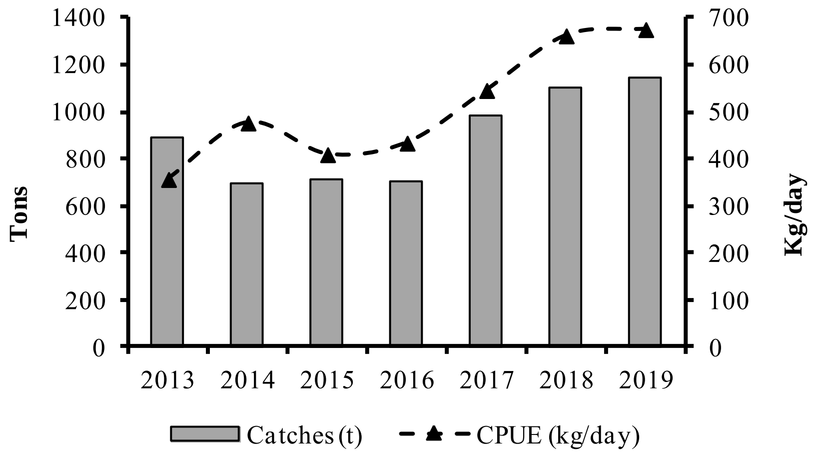

Figure 2. Total landings of *S. colias* and Catch per Unit Effort (CPUE; effort corresponding to days with positive catch in the species) in the Canary Islands from 2013 to 2019

3.5 Biological Data

3.5.1 Length-Weight relationships

Length samplings include stock-specific samplings at landing sites and from fish markets, as well as samplings on board. Comparing LWRs between sexes (from biological samplings), no significant differences were found (p≥0.2) and LWRs obtained for pooled sexes seems to be adequate for further analyses.

The number of measured specimens, ranges and mean total length (cm), parameters *a* and *b* of the LWRs and coefficients of determination (R^2) are presented in Table 2. The minimum R^2 achieved for the LWRs was obtained in the quarterly analyses (Q1 2015 (0.84)), but it is ≥0.95, when considering whole years.

The *b* values estimated by year ranged from 3.315 (in 2015) to 3.554 (in 2018). Whether data is considered by quarter, *b* values ranged from 2.696 (Q 4 in 2014) to 3.719 (Q 1 in 2019) (Table 2). Most of the values of *b* were above 3. No seasonal trend was observed in the values of *b*.

Table 2. Length-weight relationships for the Atlantic chub mackerel analyzed from commercial landings in the Canary Islands, 2013-2019. TL: Total length (cm).

Year	Quarter	N	TL (mean±sd)	TL (min-max)	*a*	*b*	R^2
2013	1	607	19.8±2.55	17.3-28.7	0.0039	3.216	0.98
	2	155	29.6±1.76	25.6-33.9	0.0035	3.265	0.89
	3	160	28.2±4.17	21.7-38.1	0.0080	3.040	0.99
	4	256	27.5±2.74	19.9-34.6	0.0011	3.601	0.96
	Total	1178	23.9±5.10	17.3-38.1	0.0028	3.337	0.99
2014	1	235	25.6±3.19	21.2-38.3	0.0030	3.302	0.97
	2	332	24.6±2.79	19.1-36.1	0.0032	3.307	0.95
	3	238	25.3±3.74	17.4-33.7	0.0018	3.489	0.98
	4	287	21.5±1.08	19.2-25.4	0.0196	2.696	0.87
	Total	1092	24.2±3.26	17.4-38.3	0.0025	3.375	0.97
2015	1	269	21.7±1.55	18.5-27.2	0.0061	3.091	0.84
	2	194	27.1±3.05	20.3-35.0	0.0017	3.488	0.97
	3	243	25.4±2.19	17.9-32.6	0.0045	3.195	0.95
	4	347	23.1±2.15	15.0-29.2	0.0033	3.269	0.95
	Total	1053	24.0±2.97	15.0-35.0	0.0030	3.315	0.96
2016	1	278	23.8±3.28	19.0-34.8	0.0026	3.362	0.97
	2	246	25.3±1.62	21.2-30.2	0.0044	3.216	0.86
	3	214	24.9±4.86	15.1-37.5	0.0011	3.629	0.98
	4	217	24.1±2.24	14.5-30.5	0.0158	2.758	0.94
	Total	955	24.5±3.25	14.5-37.5	0.0018	3.475	0.95
2017	1	473	23.1±2.31	18.0-33.2	0.0108	2.884	0.94
	2	331	26.3±2.88	16.7-36.3	0.0049	3.160	0.95
	3	271	26.5±2.95	21.0-34.6	0.0028	3.346	0.96
	4	312	23.8±2.05	20.2-33.7	0.0036	3.242	0.94
	Total	1387	24.7±2.96	16.7-36.3	0.0028	3.329	0.95
2018	1	306	24.7±2.02	17.5-31.2	0.0054	3.113	0.93
	2	262	27.2±4.02	16.1-38.7	0.0025	3.392	0.98
	3	231	26.9±3.78	14.5-34.2	0.0012	3.610	0.98
	4	324	26.2±3.52	15.3-35.3	0.0013	3.557	0.97
	Total	1123	26.2±3.51	14.5-38.7	0.0014	3.554	0.96
2019	1	261	27.0±3.70	15.8-39.9	0.0007	3.719	0.95
	2	227	30.2±3.56	13.2-42.5	0.0019	3.411	0.96
	3	257	30.3±4.78	14.0-38.8	0.0010	3.589	0.94
	4	99	29.1±4.60	14.5-37.0	0.0027	3.312	0.94
	Total	844	29.1±4.37	13.2-42.5	0.0013	3.533	0.96
Overall total		7632	25.1±4.02	13.2-42.5	0.0029	3.317	0.97

3.5.2 Catch length frequencies

Based on the length sampling of landings from the artisanal purse-seine fleet, annual length frequency distributions (LFD) for the period 2013-2019 were obtained. Two clearly differentiated modes were registered only in 2013 and 2019 (Figs. 3 and 4).

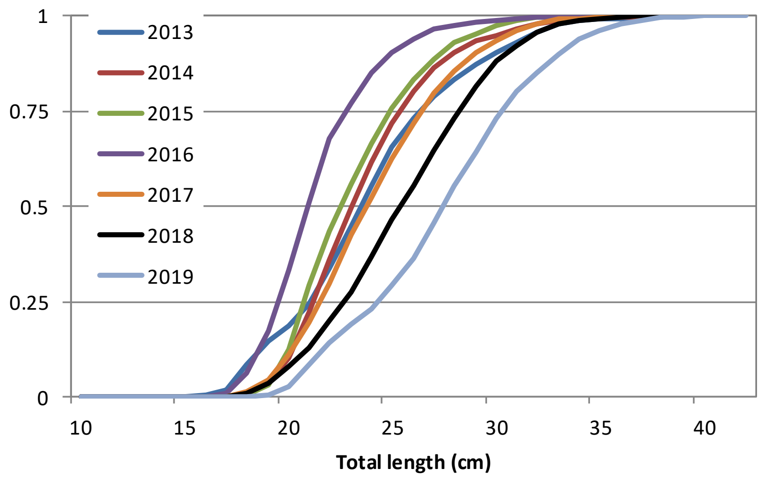

Figure 3. Length cumulative frequencies for the *S. colias* analyzed in the Canary Islands between 2013 and 2019.

Due to the differences observed among interannual quarters, LFD were not averaged or accumulated in this basis. However, separated quarterly (and total) LFD accumulated are presented jointly to the annual LFD in Figure 4. On one hand, quarterly cumulated length frequencies indicated smaller sizes during autumn or winter, depending on the year. On the other hand, when comparing years, the greatest difference occurred between sampled fish in 2016 and 2019.

Since the start of the monitoring, a general trend to larger chub mackerels in landings seems to be noticed. In fact, main modes have moved from 20-22 cm to 27-28 cm in 2019. It should be highlighted that the widest length range has been found during the last year of the period, including the smallest and the largest sampled individuals so far.

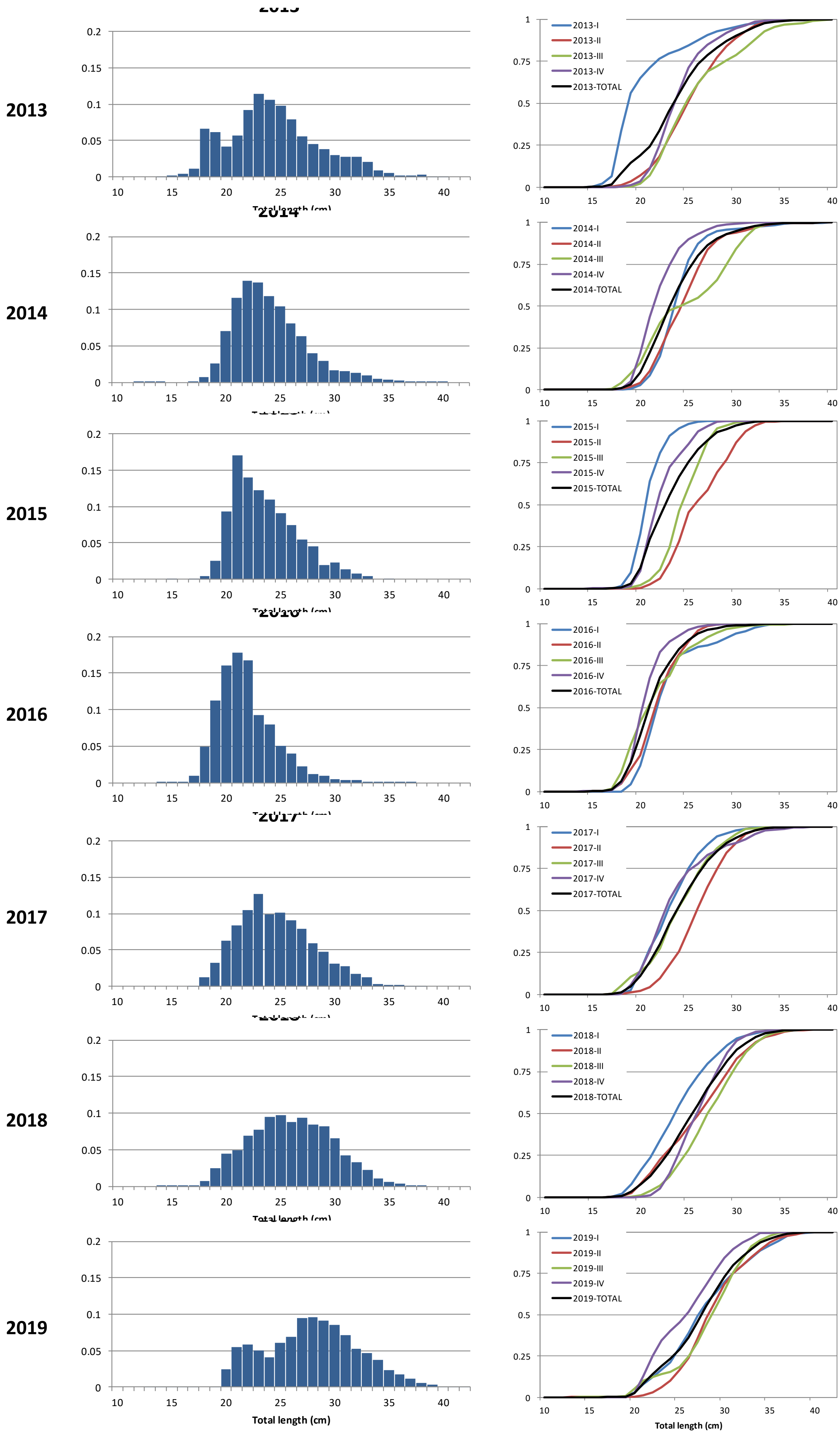

Figure 4. Catch length frequency distributions by year (left), quarterly accumulated (right). The last one on the bottom is presented for interannual comparison.

3.5.3 Sex ratio

The overall sex ratio resulted balanced for the whole period (1:1, p=0.20), and also considering each year separately (p>0.2, except in 2013 with p=0.035). When considering sex proportion by length class (Fig. 5), sex ratio resulted balanced from 20 cm to 30 cm both included (p>0.2).

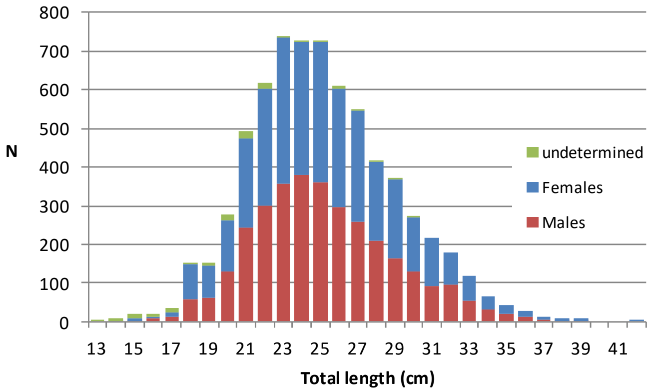

Figure 5. Length distribution of *S. colias*, from the biological samplings (2013-2019)

3.5.4 Spawning season and Length at First Maturity

Higher proportions of active stages (>50%) occurred from December to March for both sexes (Fig. 6), and GSI analysis also revealed an increase of the spawning activity from December to March (Fig. 7). In both cases, activity peaks in January-February. Accordingly, the spawning period for *S. colias* in the Canary waters seems to be between December and March.

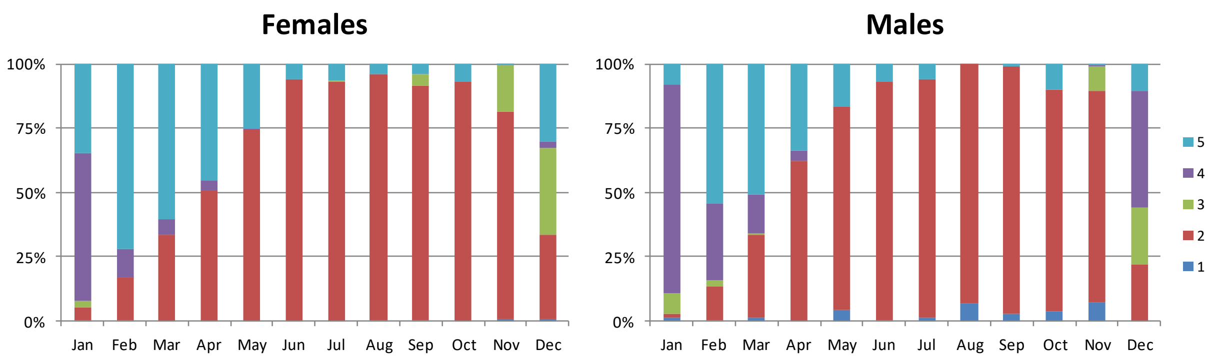

Figure 6. Monthly proportions of maturity stages by sex (2013-2019)

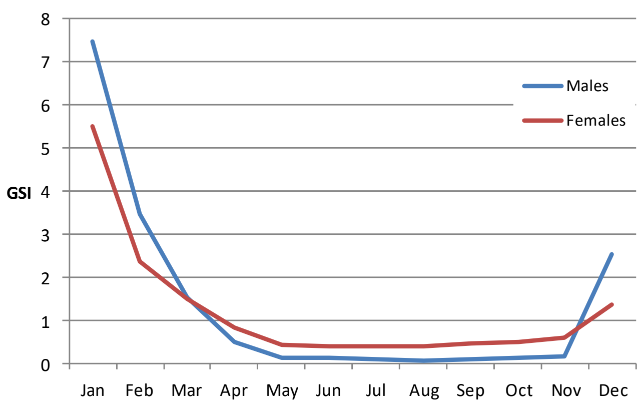

Figure 7. Monthly averaged GSI by sex (2013-2019)

When comparing the overall GSI for *S. colias* with the monthly evolution of the condition factor (*Kn*) (Fig. 8), it is possible to distinguish the somatic growth period (March-August) from the pre-spawning period (September-December).

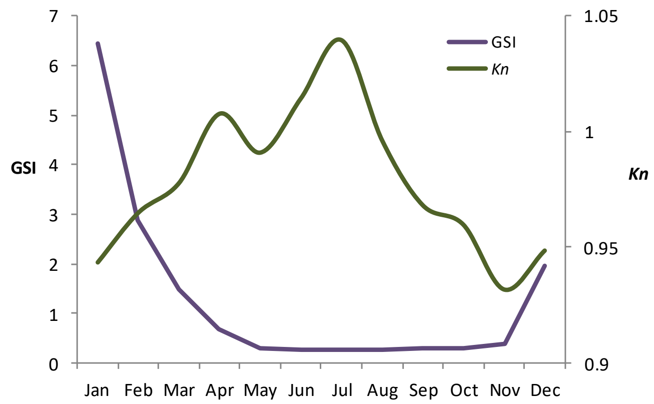

Figure 8. Monthly averaged GSI and *Kn* of *S. colias* (sexes pooled, time period: 2013-2019)

Table 3 presents the proportion of mature individuals by length class for undetermined, females and males during the spawning period. The fitted ogives to the Gompertz model (Fig. 9) gave very good results based on the coefficient of determination, both for males and females. These values and the estimated parameters for the function are presented in Table 4. Based on those results, length at first maturity resulted around 19 cm considering both sexes.

Table 3. Individuals analyzed (N) and proportion of sexually matures (p_i) by length class (L_i) for undetermined, females and males of Atlantic chub mackerel during spawning season (December to March)

	Undetermined	**Females**		**Males**	
L_i (cm)	**N**	**N**	**p_i**	**N**	**p_i**
14	1	1	0		
15	1	3	0.11		
16	2	3	0.28	2	
17	5	8	0.34	8	0.23
18	3	72	0.53	45	0.40
19	2	62	0.57	40	0.51
20		81	0.64	59	0.69
21	2	103	0.70	125	0.78
22	1	157	0.75	137	0.77
23		177	0.78	153	0.81
24		126	0.82	155	0.86
25		115	0.86	110	0.91
26		76	0.88	93	0.93
27		79	0.90	53	0.93
28		38	0.92	35	0.95
29		18	0.91	25	0.98
30		10	0.95	13	0.95
31		5	0.97	7	0.95
32		13	1.00	6	0.95
33		10	1.00	6	1.00
34		8	1.00	8	1
35		5	1.00	6	1
36		3	1	1	1
37			1		1
38			1	1	1
39		**1**	**1**	**1**	**1**
Total	17	1174	-	1089	-

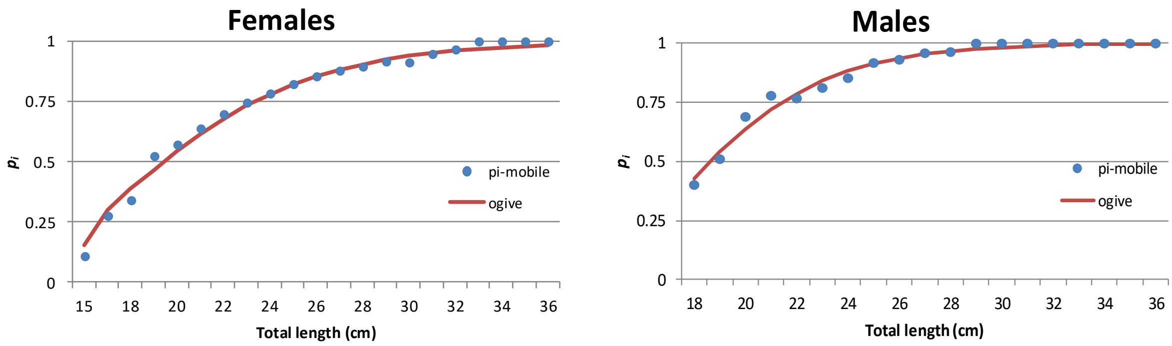

Figure 9. Maturity ogives for females and males of *S. colias* in the Canary Islands (spawning period December-March, for the period 2013-2019), fitting the mature fraction to the Gompertz function. p_i: proportion of mature individuals by length

Table 4. Estimated parameters *c* and *d*, and coefficient of determination (R^2) for the Gompertz model, Length at First Maturity (LFM), and the number of specimens analyzed during the spawning period (December to March, 2013-2018)

	c	*d*	R^2	LFM (cm)	N
Females	53.3	-0.223	0.99	19.44	1174
Males	241.02	-0.311	0.97	18.79	1089

4. Discussion and conclusions

Any noticeable change was observed for the *S. colias* analyzed during 2019, respect the results in Jurado-Ruzafa et al. (2020).

4.1 Fisheries

Since 2013, among the purse-seine landings in the Canary Islands, the Atlantic chub mackerel is the only targeted species which has increased.

Regarding the length frequencies, juveniles (absent in landings) seem protected by the minimum legal size, established at 20 cm in the Canary Islands. In addition, the smallest and the largest individuals analyzed so far were found in 2019, and a clear trend to larger Atlantic chub mackerels has been observed based on landing samplings.

4.2 Biological aspects

The slight increase in the LFM (from 18.5 to 19 cm) is closer to the previous results for the species in the area by Lorenzo (1992), around 20 cm. It could be explained for the commented trend to largest sizes in landings, what obviously influences on the data analysis and results.

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GROWTH, AGE ESTIMATION AND CORROBORATION OF NORTHEAST ATLANTIC CHUB MACKEREL (*SCOMBER COLIAS*) IN NORTHERN IBERIAN WATERS: A FIRST ATTEMPT

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ABSTRACT

Updated information on growth of Atlantic chub mackerel in several areas of its distribution is required for the first stock assessment.

Its growth pattern in Northern Iberian waters (2011-2017) is here analysed with different approaches: those based on otolith analyses (direct age estimation-DAE, back-calculation-BC and otolith marginal analyses) and those based on length frequency analyses (Bhattacharya, SLCA and PROJMAT methods).

Two main different growth patterns are obtained, a “slow” one based on DAE, BC and LFDA from surveys; and a “fast” one based on Bhattacharya and LFDA from commercial landings. The divergence between both patterns begins to be evident at age 3 and older.

Otolith marginal analyses that show an annual periodicity in the formation of the hyaline and opaque edge, the unimodal distribution of the annuli radius and the similarity of the back-calculated mean lengths to those obtained by DAE, support the age estimation criteria used in our analysis.

The VBGF growth parameters (L_{∞}=45.34, k =0.28, t_0=-1.18) obtained by otolith age estimation are available for the upcoming stock assessment process.

KEY WORDS

Scombridae, Atlantic Ocean, length frequency analysis, Bhattacharya, direct age estimation, back-calculation, growth curve, otolith edge analysis

1. INTRODUCTION

Atlantic chub mackerel, *Scomber colias,* in Eastern Atlantic is mostly captured in African waters (FAO, 2020), although landings and importance of this species in the Iberian Atlantic Peninsula have increased notably since 2007 (Villamor et *al.*, 2017).

ICES recommends the stock assessment of this species in European waters (ICES, 2020a) and validated or corroborated age estimation criteria are necessary to provide unbiased growth information for the analytical assessment.

The growth of *S. colias* in the NE Atlantic has been studied based on otoliths (estimated mainly from direct age estimation and/or back-calculation) (Martins *et al.*, 1983; Lorenzo, 1992; Martins, 1996; Carvalho *et al.*, 2002; Vasconcelos, 2006; Velasco *et al.*, 2011; Jurado-Ruzafa *et al.*, 2017) and length frequency analyses (Lorenzo, 1992; Vasconcelos, 2006).

The age estimation criteria in otoliths of Atlantic chub mackerel were internationally standardized in 2015 (ICES, 2016) although just a few age validation/corroboration studies to support it were available (Villamor et *al.*, 2019; ICES, 2020b).

Considering the scarcity of recent studies, updated growth parameters are required, as well as the use of methodologies to corroborate or validate the growth pattern obtained, as the recent workshop on Atlantic chub mackerel recommended (ICES, 2020a).

The present work studies the growth pattern and parameters of this species in Northern Iberian Atlantic waters using different approaches: i) methods related with the direct age estimation in otoliths (DAE), including back-calculation (BC) and otolith marginal analyses (nature of the edge and marginal distance analyses); and ii) length frequency distribution analyses (MPA and LFDA); as well as to assess whether these methods corroborate the current age estimation criteria of this species.

2. MATERIAL & METHODS

2.1. Sampling

A total of 10403 *S. colias* from the Northern Iberian Atlantic waters (ICES Div. 8.c, 9.a N) were analysed (Fig.1). The total length (TL) and the otoliths of each specimen were collected from landings (8272 specimens) in Spanish fish markets (Santander, A Coruña and Vigo) from 2011-17, and in scientific acoustic surveys "PELACUS" (Massé *et al*., 2018) (2131 specimens) organized by the IEO on board of the R/V "Miguel Oliver" during March-April in 2011 and 2013-17.

Length distributions of *S. colias* from commercial landings by quarter were additionally measured in the fish markets from northern Atlantic Spanish harbours from 2011-17, as well as the length distributions from the aforementioned surveys "PELACUS".

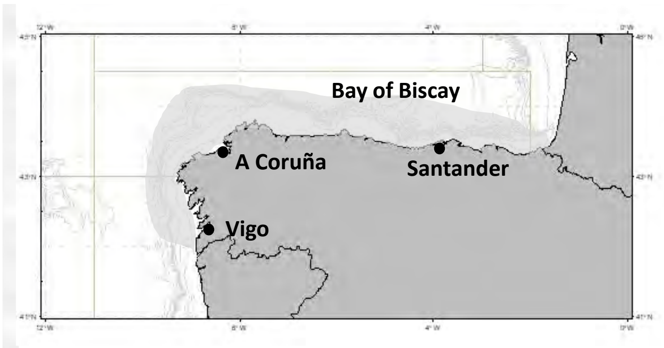


Figure. 1. Area of study (gray shading) corresponding to the area covered by the pelagic surveys PELACUS and where the commercial fleet operates, highlighting the fishing harbours of origin of the biological samples.

2.2. Age estimation

Whole otoliths mounted on black slides covered with transparent resin were observed under reflected light with a binocular microscope (Villamor *et al*., 2015) (Fig. 2). Otoliths were aged twice by the same reader and those with disagreement in age estimations were examined again. 6867 otoliths were aged (5029 from commercial landings and 1838 from surveys) following standardized criteria (ICES, 2016).

Biannual Age-Length Keys (ALK) from the commercial landings were built per year and applied to the respective biannual length distribution (LD). Each ALK from the PELACUS survey was applied to the respective LD surveys catches. Thus, mean lengths (ML) at age based on the Direct Age Estimation (DAE) were averaged for the time series and compared to those obtained from back-calculation and length frequency analyses.

2.3. Age corroboration studies

The methodologies of back-calculation (BC) and frequency distribution of annuli distances in the otoliths were used to analyse the consistency of the age estimation on otoliths. The corroboration of the age was analysed based on the otolith marginal analysis and the length frequency analyses (LFA) (ICES 2020b).

2.3.1. Back-calculation and frequency distribution of annuli distance analyses

The total otolith radius (OR) and the annuli radius (AR) were measured in 423 otoliths from 2011-12, covering the whole length range of catches (Fig. 2).

To verify the regularity in annuli formation and to demonstrate the consistency in age interpretation, the considered annual growth increments were analysed.

The TL-OR relationship was estimated fitting a power equation. The BPH (Body Proportional Hypothesis) method and the Fraser-Lee method were applied (Ricker, 1992) for obtaining back-calculated lengths:

1) Fraser-Lee equation: $\ln L_i = \frac{\ln R_i}{\ln R_t}(\ln L_t - \ln a) + \ln a$
2) Body Proportional Hypothesis (BPH): $\ln L_i = \frac{\ln L_t(\ln a + b \ln R_i)}{\ln a + b \ln R_t}$

where, L_i is the TL when the OR was R_i (cm); L_t the TL when the specimen was caught (cm); R_i the OR of the annulus i (mm); R_t the OR when the specimen was caught (mm); a and b are the parameters of the power regression.

2.3.2. Otolith marginal analyses

The following analyses were performed to determine the seasonality in the annuli formation:

- Nature of the edge: the percentage of hyaline (H) and opaque (O) edge was estimated by month in 8852 otoliths from 2011-17.

- Marginal distance analysis: the absolute marginal distance (AMD - from the end of the last hyaline annulus to the edge); the distance between the last two hyaline annuli ($D_{i,i-1}$) and the relative marginal distance (RMD = ratio of the AMD and $D_{i,i-1}$) (Panfili *et al.*, 2002) (Fig. 2) were obtained in 423 otoliths from 2011-12.

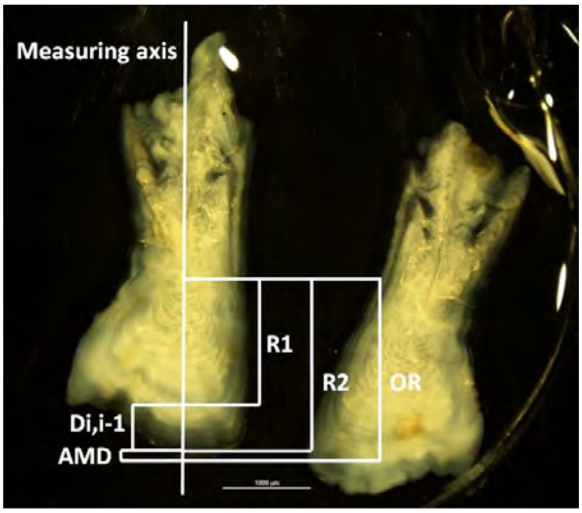


Figure. 2. Measurement axis and otolith measures of *S. colias* from Northern Iberian waters: AMD (Absolute Marginal Distance), $D_{i,i-1}$ (distance between the last two hyaline annuli), OR (otolith radius) and R_i (annuli radius).

2.3.3. Length-frequency analyses

Both LD from surveys and commercial landings were analyzed separately. The commercial landings of *S. colias* represent a wider length range, especially of larger specimens, providing a complementary information to surveys information. Although the pelagic survey series PELACUS data offer less biased information about juvenile *S. colias* length distributions than the commercial data, these surveys are focused on other small pelagic species (mackerel, horse mackerel, sardine or anchovy), not being *S. colias* a target species (Massé *et al*., 2018).

The methods used were: i) the Modal class Progression Analysis (MPA), by the Bhattacharya's method (Bhattacharya, 1967) included in the FISAT II program (Gayanilo *et al.*, 2005), and three methods of length frequency analysis included in the software package Length Frequency Distribution Analysis (LFDA) (MRAG, 2001): ii) Shepherd's Length Composition Analysis (SLCA), iii) Projection Matrix Method (PROJMAT) and iv) Electronic Length Frequency Analysis (ELEFAN). The MPA analyses were performed, on the one hand, for the six years data of surveys, and on the other hand, for the first semester of the seven years of commercial landings, in each case pooled as a single distribution (1 LD). The LFDA methods were applied to the six years of length distributions of surveys and to the seven years of length distributions of the first semester of commercial landings, corresponding, with a scenario with six and seven LD, respectively.

2.4. Annual growth pattern and growth parameters

The growth parameters of the von Bertalanffy growth function (VBGF) were estimated for both sexes combined of *S. colias*, according to the equation:

$$L_t = L_\infty(1 - e^{-k(t-t_0)})$$

where L_t is the TL at age t; L_∞ is the mean asymptotic fish length; k is the instantaneous growth coefficient; t is the age; and t_0 is the age at which the TL is 0.

The VBGF were estimated from DAE, BC lengths at age and mean lengths at age obtained by MPA. In the case of the LFDA analyses, the parameters were provided directly by the program.

Growth curves for both sexes combined and each method were compared using the Likelihood Ratio Test (Kimura, 1980). This test was conducted using equivalent age ranges as recommended by Haddon (2001), and the growth parameters were recalculated for it, using SPSS (IBM Corp. Released 2017), from their ML at age.

The growth performance index (ϕ') (Pauly and Munro, 1984), that takes into account the correlation between L_∞ and *K*, was used to compare growth parameters among *S. colias* studies:

$$\phi' = \log_{10}K + 2\log_{10}L_\infty$$

where L_∞ and k are the parameters of the VBGF.

3. RESULTS

3.1. Direct age estimation

Age was estimated in 6867 otoliths (5029 from commercial landings and 1838 from surveys), ranging 14-50 cm in length and 1-14 years in age. The ML at age from surveys (March-April) and those from the first semester of commercial landings showed similar values (Table 1).

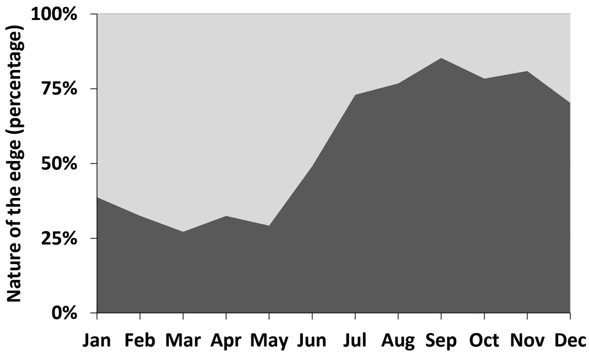
Table 1. ML at age (cm), obtained from direct age estimation (DAE), back-calculation (BC), Bhattacharya method and LFDA packet (PROJMAT and SLCA methods) of surveys (surv) and commercial landings (land) of *S. colias* in Northern Iberian waters. Sem1: first semester; Sem2: second semester.

	DAE			BC	Bhattacharya		PROJMAT	SLCA
Age group (years)	surv	land		surv + land	surv	land	surv	land
	Sem1	Sem1	Sem2	Sem1	Sem1	Sem1	Sem1	Sem1
1	21.3	23.8	26.7	21.9	21.8	21.5	21.8	23.3
2	26.4	27.7	29.3	28.3	27.4	28.4	27.8	30.0
3	31.8	31.0	33.1	32.1	33.6	34.9	32.4	35.0
4	34.4	35.1	36.5	35.7	39.0	38.2	36.0	38.7
5	36.8	37.6	38.3	37.5	42.5	41.5	38.8	41.5
6	39.3	38.4	40.8	38.5		44.5	41.0	43.5
7	39.9	39.7	39.9	40.3		46.5	42.7	45.0
8	40.5	41.3	41.1	43.7			44.1	46.1

3.2. Age corroboration studies

3.2.1. Otolith marginal analyses

The otoliths showed opaque edge mainly from June to December, in agreement with the higher AMD and RMD values in that period (Fig. 3).



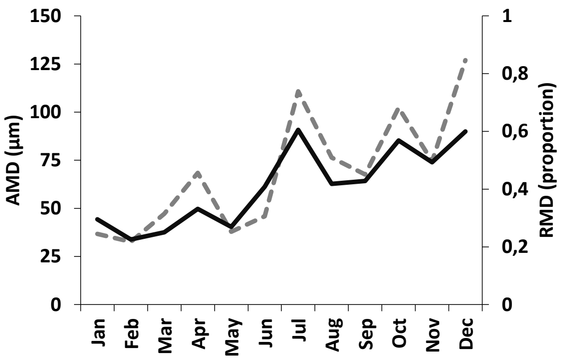


Figure 3. Otolith marginal analyses of *S. colias:* monthly proportion of opaque (dark) and hyaline (light) edge (left); monthly mean values of RMD (continuous line) and AMD (discontinuous line) in otoliths from Northern Iberian waters (right).

3.2.2. Back-calculation and frequency of annuli distance analyses

The relationship between total fish length (TL) and otolith radius (OR) fitted to the power model:

$TL = 13.29 \cdot OR^{1.283}$ (r^2=0.87, p<0.005).

A total of 1341 back-calculated lengths were estimated by both BC methods (Fraser-Lee, BPH), with very similar values between them and closed to the values of the ML at age based on DAE in the most abundant age groups (up to age 5) (Table 1). Unimodal distributions were found in the measures of the considered annual growth increments.

3.2.3. Length-frequency analyses

MPA of surveys was performed by sum of percentages of the length distribution for the time series to reduce the abundance influence of some extremely abundant years (Fig.4a). MPA of length distribution of commercial landings (first semester) was performed by absolute values for the time series pooled data (Fig.4b). ML of both sources showed closed values between them (Table 1).

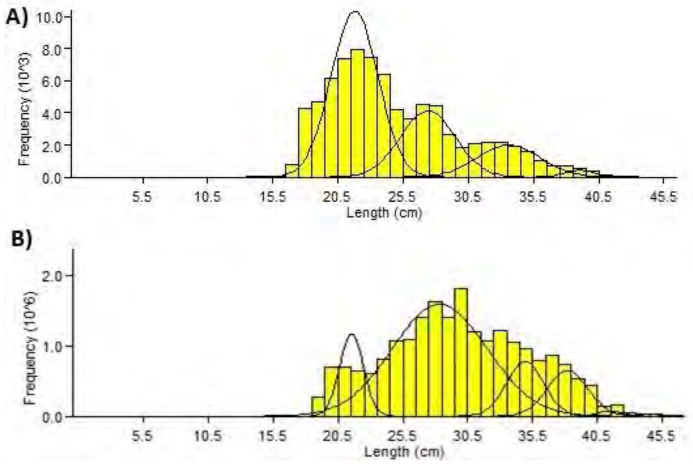


Figure 4. Plots obtained by Bhattacharya method (FISAT II) from A) relative values of length distributions from the six years pooled together (2011, 2013-2017) of the scientific surveys PELACUS; and B) absolute values of length distributions of the first semester from the seven years pooled together (2011-2017) of commercial landings. Rectangles: length classes frequencies; black lines: log-plots of the slopes between successive size-components

Regarding the Length Frequency Distribution Analysis (LFDA), the optimal growth parameters obtained by the program, based on the maximization of a goodness-of-fit function through iterations, were obtained by the PROJMAT method (Score: -0.983) for the survey data and by the SLCA method (Score: 6472) for the commercial landings data. The estimated ML are shown in Table 1.

3.3. Annual growth pattern and growth parameters

Two different growth patterns were obtained, with similar ML at ages 1 and 2, but divergent growth from age 3 (Table 1):

- A **slower growth pattern**, based on age estimation in otoliths (DAE and BC), showed similar ϕ' values (2.76-2.79) (Table 2), and no significant differences ($p>0.05$) between both growth curves according to the likelihood ratio test. The PROJMAT length-frequency analysis based on surveys data showed a ϕ' value of 2.77, a growth pattern close to that of DAE-BC, but with significant differences ($p<0.001$). Likelihood test showed no differences between the growth curves of both BC methods, and only BPH method was considered for the rest of the study in back-calculation.

- A **faster growth pattern**, from the length-frequency approaches performed by the Bhattacharya method (MPA), both for surveys and commercial landings, and by SLCA in commercial landings, all of them showing a ϕ' value of 2.86 and similar mean lengths at age (Table 1, Table 2). No significant differences ($p>0.05$) between Bhattacharya from landings and SLCA were found, but significant ones ($p<0.01$) in the other comparisons performed (Bhattacharya surveys-Bhattacharya landings; Bhattacharya surveys - SLCA).

Table 2. Growth parameters obtained by different methods in the present and previous studies of *S. colias* in the NE Atlantic. DAE: Direct age estimation; BC: Back-calculation; surv: surveys; land: commercial landings.

Author	**Present study**						Martins et al., 1983	Martins, 1996	Velasco et al., 2011	Carvalho et al., 2002	Vasconcelos, 2006		Lorenzo, 1992			Jurado-Ruzafa et al., 2017
Area	**N & NW Iberian Peninsula**						Portuguese coast	Portuguese coast	Gulf of Cadiz	The Azores	Madeira		The Canary Islands			Mauritanian waters
Years	**2011-2012**	**2011-2017**					1981-1982	1986-1995	Oct. 2003-Sept. 2004	1996-2002	2002-2003		1988-1990			2005-2011
Methodology	**BC**	**DAE**	**Bhattacharya**		**PROJMAT**	**SLCA**	BC	DAE	DAE-BC	DAE	DAE	ELEFAN	DAE	BC	Bhattacharya	BC
	surv + land	**surv + land**	**surv**	**land**	**surv**	**land**										
L_∞	**42.63**	**45.34**	**55.00**	**53.26**	**48.74**	**49.30**	53.83	58.52	43.00	57.52	50.08	38.00	50.69	49.22	49.22	48.40
K	**0.33**	**0.28**	**0.24**	**0.26**	**0.25**	**0.30**	0.17	0.10	0.27	0.20	0.25	0.50	0.21	0.21	0.22	0.25
t_0	**-0.96**	**-1.18**	**-0.77**	**-0.78**	**-0.87**	**-0.63**	-2.03	-3.68	-1.10	-1.09	-1.34		-1.45	-1.40		-1.51
ϕ'	**2.78**	**2.76**	**2.86**	**2.86**	**2.77**	**2.86**	2.7	2.55	2.7	2.82	2.8	2.86	2.73	2.71	2.73	2.76
n	**409**	**6867**					533	883	121	349	2115		878	538		163
ength range (cr	**16-48**	**14-50**	**14-46**	**18-49**	**14-46**	**18-49**		16-54	16-43	9-56	13-41	13-41	4-42		4-48	12-49

4. DISCUSSION

The scarcity of updated and corroborated/validated information about the growth pattern and parameters in *S. colias* in the NE Atlantic makes the results here obtained very relevant because improve biological knowledge about this species as well as provide inputs for its future analytical assessment. *S. colias* stock assessment requires knowledge on the status of their populations in European Atlantic waters for sustainable fisheries and ecosystem management. The present study offers this updated and validated information on growth of *S. Colias*.

4.1. Direct age estimation, otolith marginal analyses, back-calculation and frequency of annuli radius analyses

The increasing of the ML at age between both semesters from DAE supports the age estimation criteria applied on otoliths age reading used here. This age estimation criterion is also supported by the consistency of the annual periodicity of formation of opaque and hyaline increments found, as a result of the otolith edge analysis. The predominance of opaque edge observed is in agreement with an overall geographical gradient from South to North observed in Iberian waters, starting its deposition in the Gulf of Cadiz from March/April to September/October (Rodriguez-Roda, 1982; Velasco et *al.*, 2011), then Portugal from May to August (Martins et *al.*, 1983) until the North western and North Iberian Peninsula from June to December (present study).

In relation to the back-calculation, the fish length-otolith radius relationship in *S. colias* showed a better fit to a power model in the present and previous studies (Lorenzo, 1992; Velasco *et al.*, 2011; Jurado-Ruzafa *et al.*, 2017). The unimodal distribution showed by the analysis of annuli radius frequency in addition to the back-calculation results also supports the consistency of the age estimation criteria used.

4.2. Length-frequency analyses

A general consistency was observed in the mean values estimated in both MPA analyses (surveys and commercial landings). Differences were found between our results based on the different length-frequency analyses and those obtained in previous studies using the same methods (Lorenzo, 1992; Vasconcelos, 2006), although differences in the time-series amplitude, sample size and length range analyzed among the studies can influence.

4.3. Annual growth pattern and growth parameters

The otolith edge, the back-calculation and the frequency distribution of annuli radius analyses performed in the present study, support the consistency of the age estimation in otoliths of *S. colias* based on ageing standardized criteria (“**slow” growth hypothesis**). Compared with previous studies, the “slow” growth pattern (DAE/BC) here obtained (ϕ‘: 2.76-2.78) is within the total range of ϕ` obtained for the species ($\phi$`: 2.55-2.82, mainly 2.70-2.80) (Table 2). Geographical and temporal differences, differences in the time series, sample size or length range analysed could explain the diversity of growth parameters among all studies.

However, our length frequency analyses results from MPA and SLCA (“**fast” growth hypothesis**) do not support the pattern observed in age estimation (from age group 2). Some difficulties have been already reported in the estimation of growth based on length frequencies in migratory pelagic species, as in the congener *S. scombrus*, where growth differences were found in relation to its annual migration (Dawson, 1986), what could also be relevant in *S. colias* when length frequency analyses are used. Furthermore, if the faster growth rate hypothesis here obtained by length frequency analyses is true, the age interpretation in otoliths would have to be biased due, for example, to the presence of checks that could be misinterpreted as true annuli. However, this seems to be quite unlikely due to the aforementioned evident and regular decreasing growth pattern of increment widths observed in *S. colias* otoliths.,

Taking into account all the aforementioned, and considering the Precautionary Principle of stock assessment, we recommend the use of the “slow” growth parameters in the upcoming stock assessment process, (DAE parameters: L_∞=45.34, k=0.28, t_0=-1.18). However, it would also be interesting to carry out some assay in the assessment model using the “fast” growth hypothesis (ej. SLCA parameters: L_∞=49.30, k =0.30, t_0=-0.63) to test the impact of differential growth in the assessment results, especially the impact of differences between both models in the cohort tracking.

Delivering more corroboration/validation studies on *S colias* growth in other areas, as well as providing updated growth information, will contribute to a more complete understanding of the growth of this species throughout its distribution area what is an essential input for analytical assessment models.

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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).

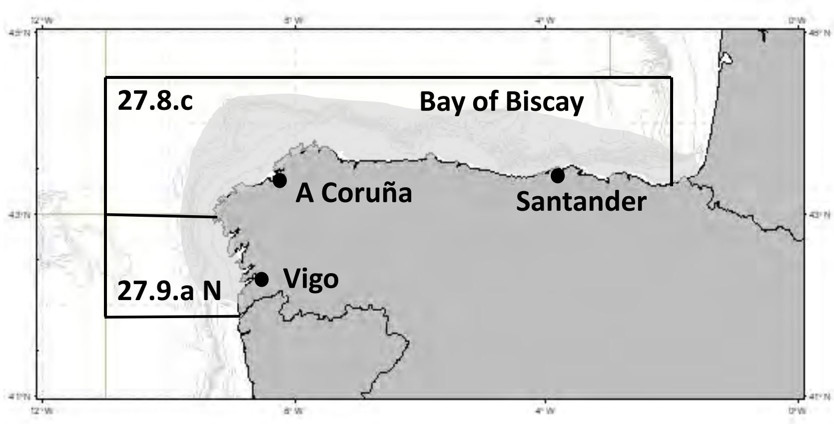

Figure 1. Area of study (gray shading) corresponding to the area covered (ICES Div. 27.8.c and 27.9.a.N) by the scientific surveys PELACUS and DEMERSALES, and where the commercial fleet operates, highlighting the fishing harbours sampled.

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.

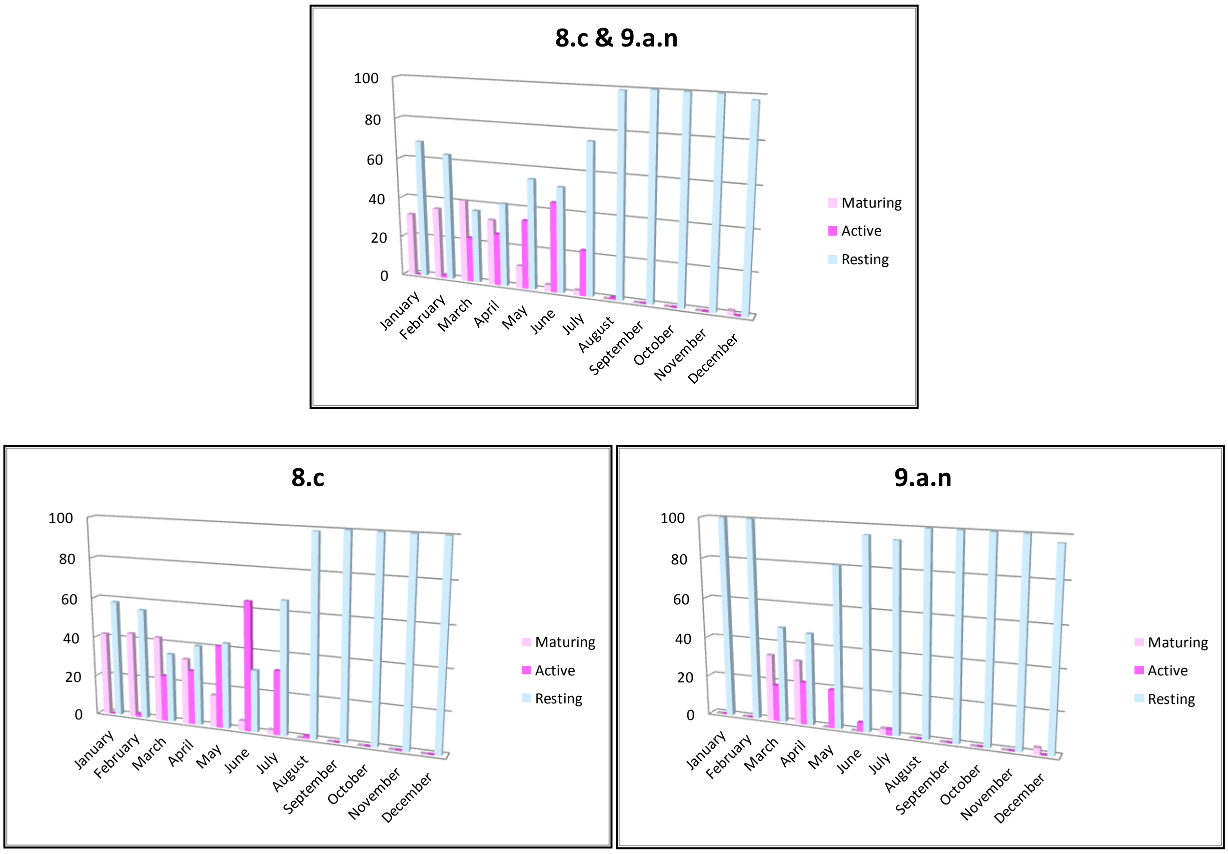

Figure 2. Percentages of maturity stages of females by month and ICES Divisions in the period 2011-2019.

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.

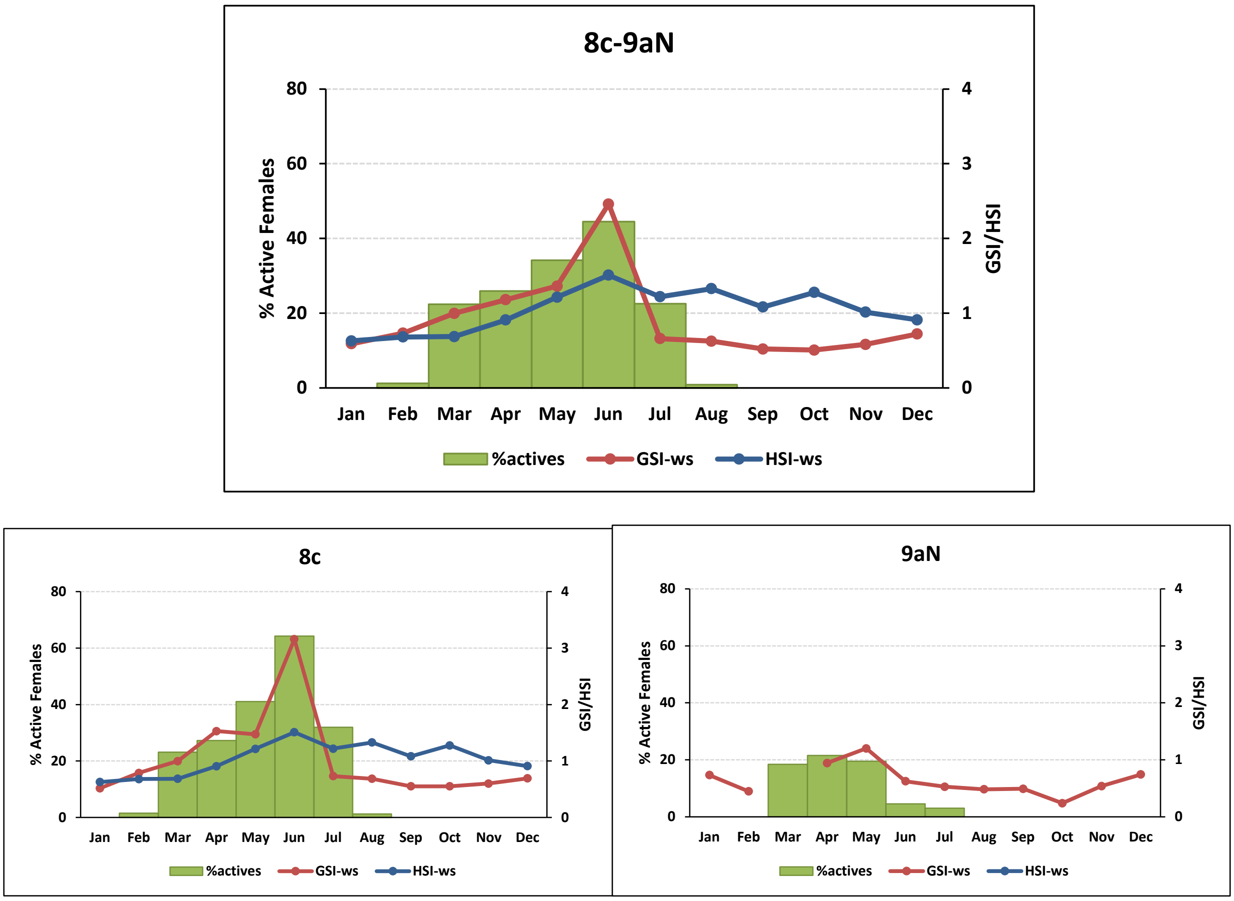

Figure 3. Percentages of active females (maturity stages 3, 4, and 5), GSI and HSI by month and ICES Divisions in the period 2011-2019.

3.2. Maturity ogives

The length at first maturity (L_{50}) for females, males and both sexes combined based on information collected <u>all year</u> 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).

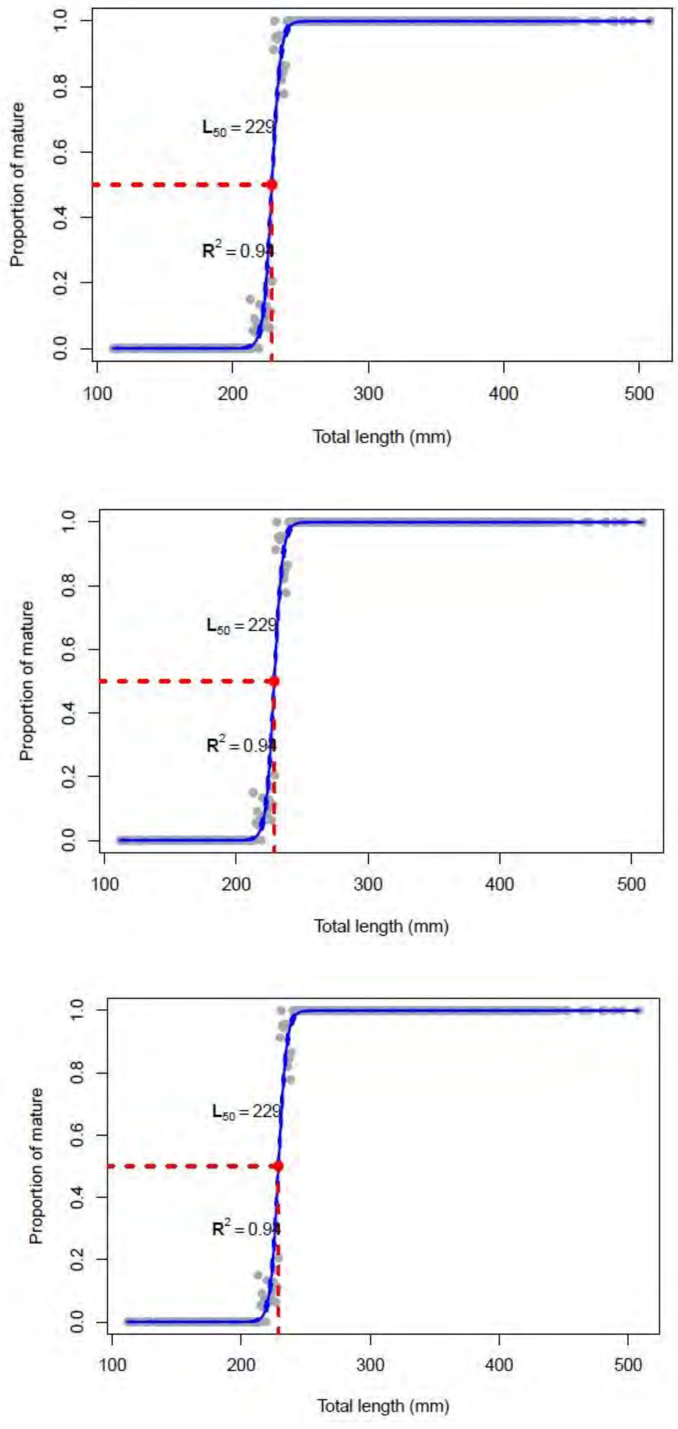

Figure 4. Proportion of mature individuals at length for females (top), males (middle) and sex combined (bottom) of *S. colias* from Northern Iberian waters (27.8.c and 27.9.a.N) for the period 2011-2019 (based on information collected all year around).

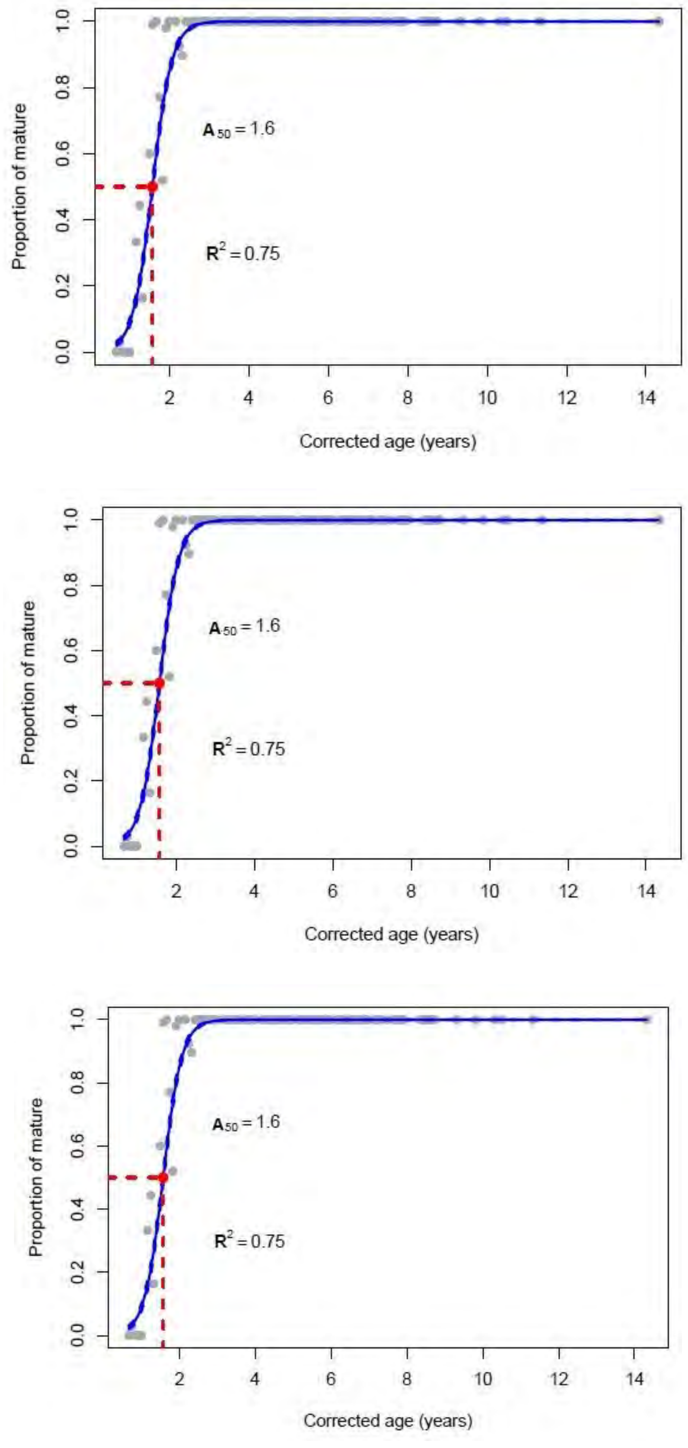

Figure 5. Proportion of mature individuals at age for females (top), males (middle) and sex combined (bottom) of *S. colias* from Northern Iberian waters (27.8.c and 27.9.a.N) for the period 2011-2019 (based on information collected all year around).

The length at first maturity (L_{50}) for females and males based on information collected only <u>during the spawning period</u> 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).

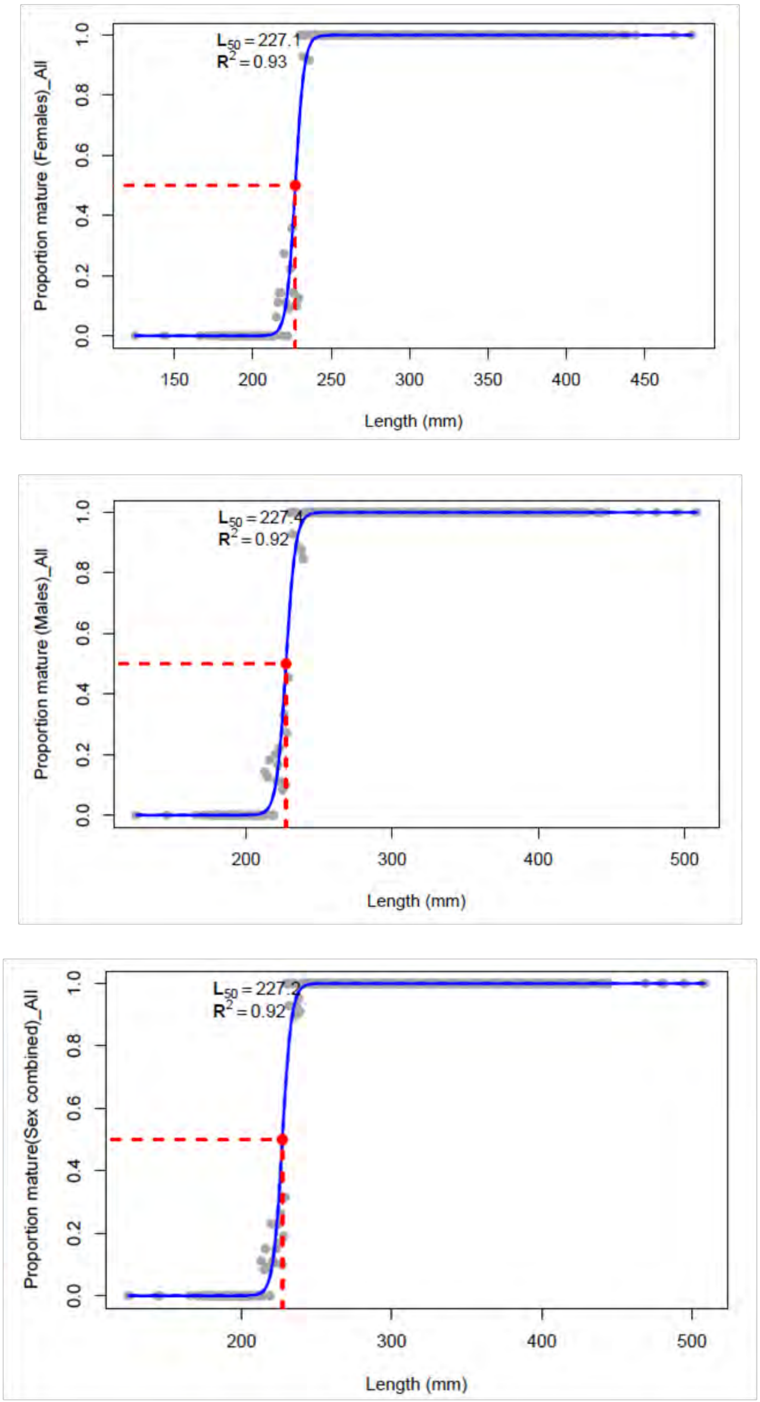

Figure 6. Proportion of mature individuals at length for females, males and sex combined of *S. colias* from Northern Iberian waters for the period 2011-2019 (based on information collected only during the spawning period).

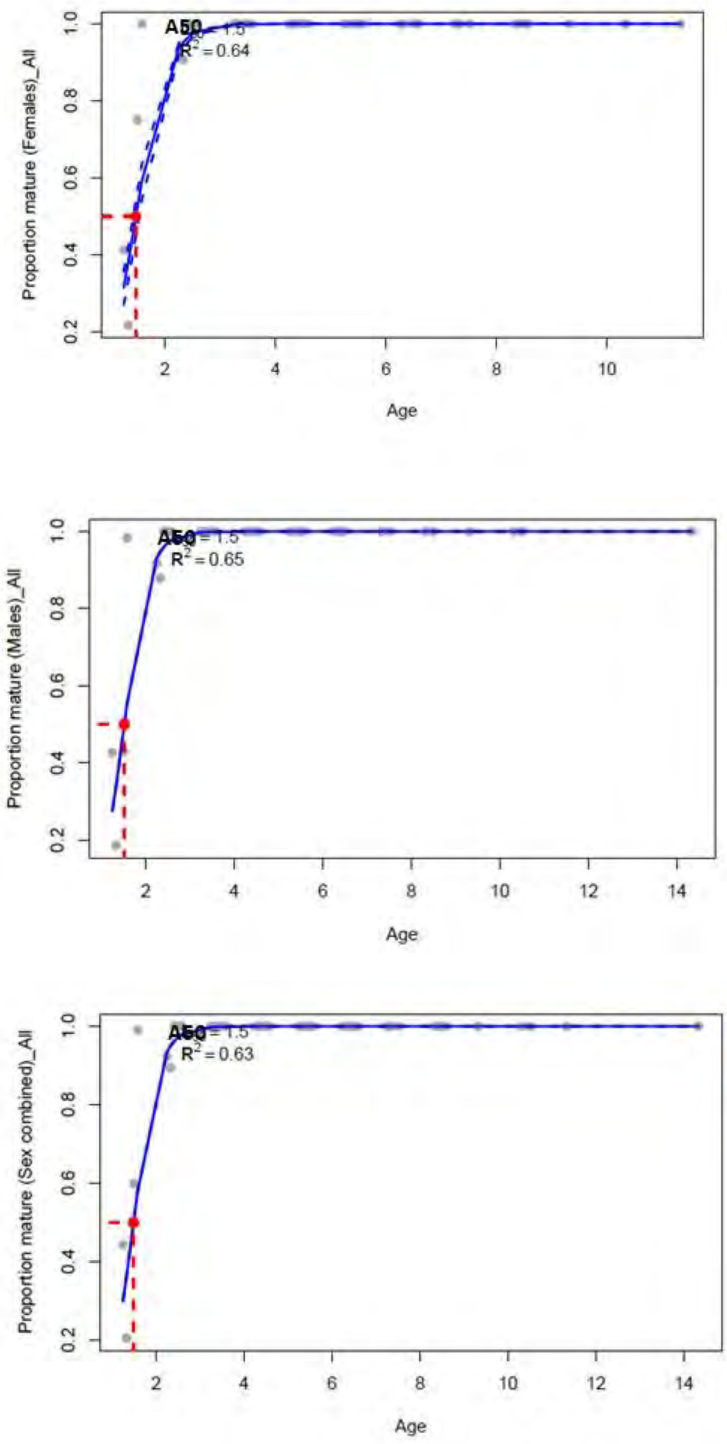

Figure 7. Proportion of mature individuals at age for females, males and sex combined of *S. colias* from Northern Iberian waters for the period 2011-2019 (based on information collected only during the spawning period).

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.

ACKNOWLEGMENTS

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Stock assessment for chub mackerel in the Moroccan Atlantic coast using SPiCT model

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Abstract

An assay application of a SPiCT (Surplus Production model in Continuous Time) model has been implemented for the chub mackerel stock in the center and south of Moroccan Atlantic coast. Yearly catch data and three biomass indices from acoustic surveys were used to test four scenarios corresponding to different sets of assumptions. The results presented for each scenario include estimates for biomass and fishing mortality time series, as well as reference points. Finally, the consistency of the best scenario in terms of goodness of fit and uncertainty is assessed using the trends obtained by a Biodyn model that is already being applied on this stock.

1. Introduction

The Atlantic chub mackerel (Scomber colias) is a coastal pelagic species and considered as one of the most important fishery resources of the Moroccan coast. It represents about 16% of Morocco's total small pelagic species in 2018 with 420000 tonnes, which is a decrease of 21% in comparison to 2016 (305759 tonnes) (FAO, 2020). This species is frequent on the continental slope, from the surface to a depth of 300 m. The average catches of this species during the last five years (2014-2018) is 379000 tonnes in comparison with 1924000 tonnes for the period 1990-2018 (FAO, 2019). Chub mackerel is detected along the continental shelf from Tangier to Laayoune. In the north, The different acoustic surveys have found that it's more abundant in the coasts of Moulay-Bouselham, Oualidia and Sidi Abed (mainly between 301 m^2/nm^2 and 1000 m^2/nm^2) (INRH, 2017).In the center (A+B zones), the highest abundance of chub mackerel is located between Safi and Essaouira, and also in the north of Laayoune, which can be fluctuated in a range of 300m^2/nm^2 to 3000 m^2/nm^2 (INRH, 2017). However, for the small-scale fisheries, the catches of this species characterize more the landings from the port of Tarfaya, which alone represents 51% of the central Atlantic production, while the fishing effort in this area does not exceed 12% in 2014 (INRH, 2015). The south Moroccan Atlantic zone is characterized by the highest densities (510 m^2/nm^2-10000 m^2/nm^2) between Cap Barbas and Cap blanc (INRH, 2017).

2. Materials and methods

2.1. Study area

This study is focused on the central (between Cape Cantin and Cape Boujdor (32° 32′ 24°N - 26° 07′ 59°N) and the south of the Moroccan Atlantic shelf (26°N-north Cap Blanc) (Figure 1). These two areas enclose the central and the south stocks of small pelagic fish, mainly composed of sardines, anchovies, chub mackerel, horse mackerel and occasionally sardinellas. These zones produce about 45% of the total catch of small pelagic fish in the Moroccan Atlantic area (INRH DRH, 2017). The abundance of these resources seems to be strongly correlated with the intensity, seasonal and interannual variability of the coastal upwelling phenomena which occur in the Grand Canary Ecosystem(Benazzouz, 2014 INRH, 2015).

Figure 1: chub mackerel Moroccan distribution

2.2. Model description

The Surplus Production model in Continuous Time (SPiCT) is a state-space model that provides stock status estimation and reproduces population dynamics by aggregating biomass across size and age groups by following Pella and Tomlinson equations (Pella and Tomlinson,1969). The basic model equations are classified into process and observation equations.

Process equations describe population dynamics:

- **Biomass equation**

$$dB_t = rB_t(1 - [\frac{B_t}{k}]^{(n-1)})dt - F_tB_tdt + \sigma_B B_t dW_t \tag{1}$$

- **Fishing equation**

$$d\log(F_t) = f(t, \sigma_F) \tag{2}$$

while observation equations link observed data with dynamics:

- **Index equation**

$$\log(I_t) = \log(qB_t) + e_t, e_t \sim N(0, [\alpha\sigma_B]^2) \tag{3}$$

- **Catch equation**

$$log(C_t) = \log(\int_t^{t+\triangle} F_s B_s ds) + \epsilon_t, \epsilon_t \sim N(0, [\beta\sigma_F]^2) \quad (4)$$

2.3. Input data

The SPiCT model was fitted using a time series of FAO landings from 1990 to 2018 and three different time series of abundance indices: The RV Dr. Fridjof Nansen survey (1999-2015), The RV Atlantida survey (1994-2015) and The Moroccan survey R/V Al Amir Moulay Abdellah in the period 2000-2017. These time series are presented in Figure 2.

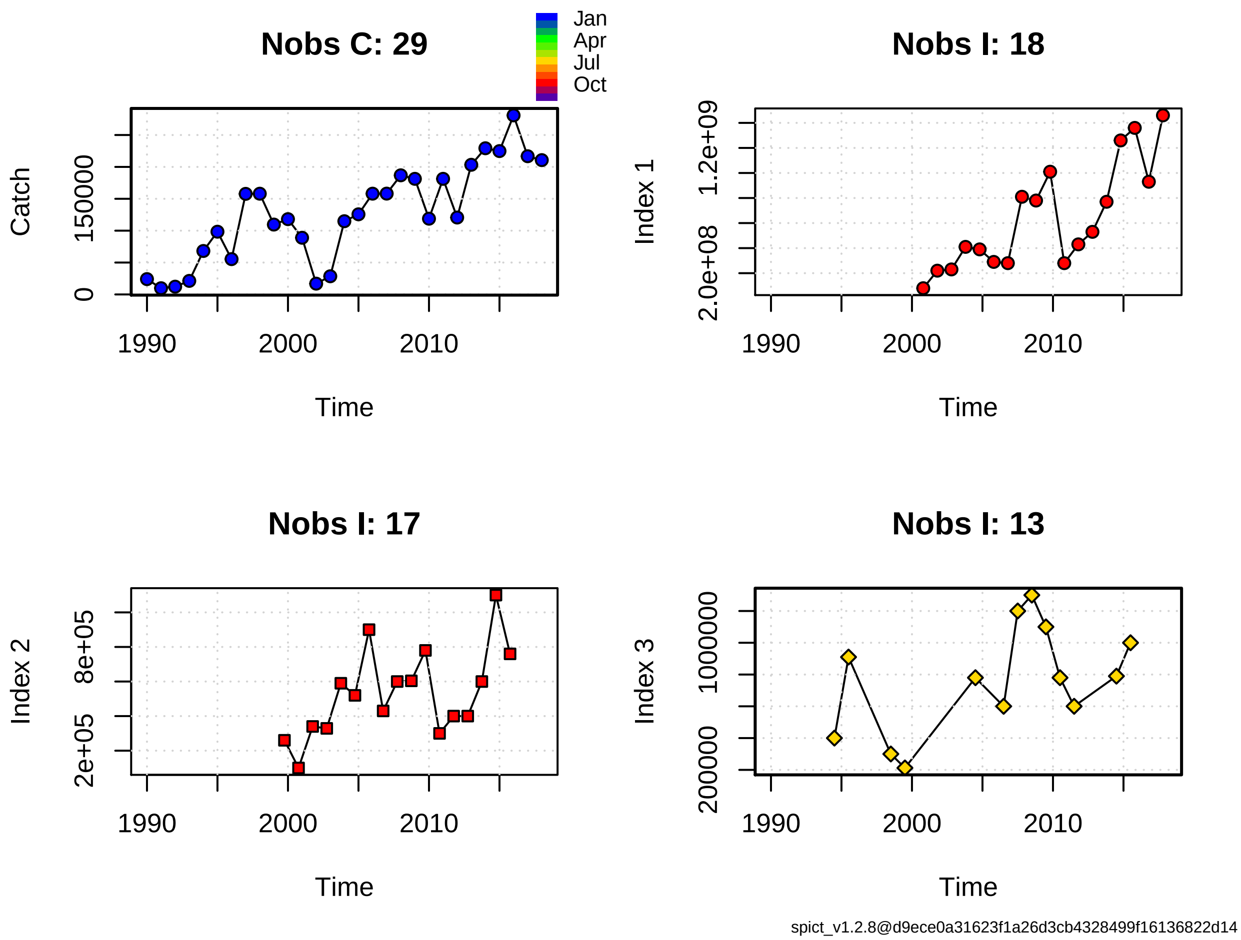

Figure 2: Data input summary. Top left: chub mackerel catches in tonnes. Top right: Amir Moulay Abdellah acoustic estimates (autumn). Bottom left: Nansen acoustic estimates (autumn). Bottom right: Atlantida acoustic estimates (summer).

2.4. Model scenarios

Four scenarios were tested corresponding to different sets of assumptions. The first scenario included the data without any change, using the default configuration. For the second scenario, the catch time series period was reduced: instead of going from 1990 to 2018, it is going from 1994 to 2018. In the third scenario, the value of the parameter n (determining the shape of the production curve) was fixed at 2, instead of 1.22, imposing a Schaefer model on population dynamics. The last scenario was equal to the third but changing the default prior for the logarithm of the ratio between biomass at the beginning of the time series and the carrying capacity (K). It was defined as a lognormal distribution with mean (μ) equal to ln(0.5) and standard deviation (σ) equal to 0.2.

2.5. Model implementation

The different scenarios were implemented using the SPiCT R package (version 1.2.8) (Martin W. Pedersen and Casper W. Berg, 2017).

3. Results and conclusions

The main results for each scenario are detailed below. These results include estimates for biomass and fishing mortality time series, as well as reference points and Kobe plots. A diagnostic, residuals and retrospective analysis is also presented, allowing to detect if there is any violation of model assumptions and showing the consistency of the model/data and the robustness of the results. Estimated parameters for all scenarios are shown in Table 1.

Table 1: estimated parameters for each scenario

Scenario number	Estimated parameters								
	α	β	n	r	K	sdb	B/B_{MSY}	F/F_{MSY}	MSY
1	1.01	3.56	1.22	12.4	51914.3	0.29	0.70	1.32	214678.4
2	1.31	2.79	0.79	1.87	252947.1	0.24	0.62	1.47	200344.2
3	1.02	0.47	Fixed (2)	0.77	1119760	0.35	1.94	0.65	172723.8
4	0.96	0.33	Fixed (2)	0.47	2250328	0.37	2.89	0.41	175053

3.1. Scenario 1- Default priors

Model outputs, diagnostics and retrospective analysis for the first scenario are presented in figures 3, 4 and 5, respectively.

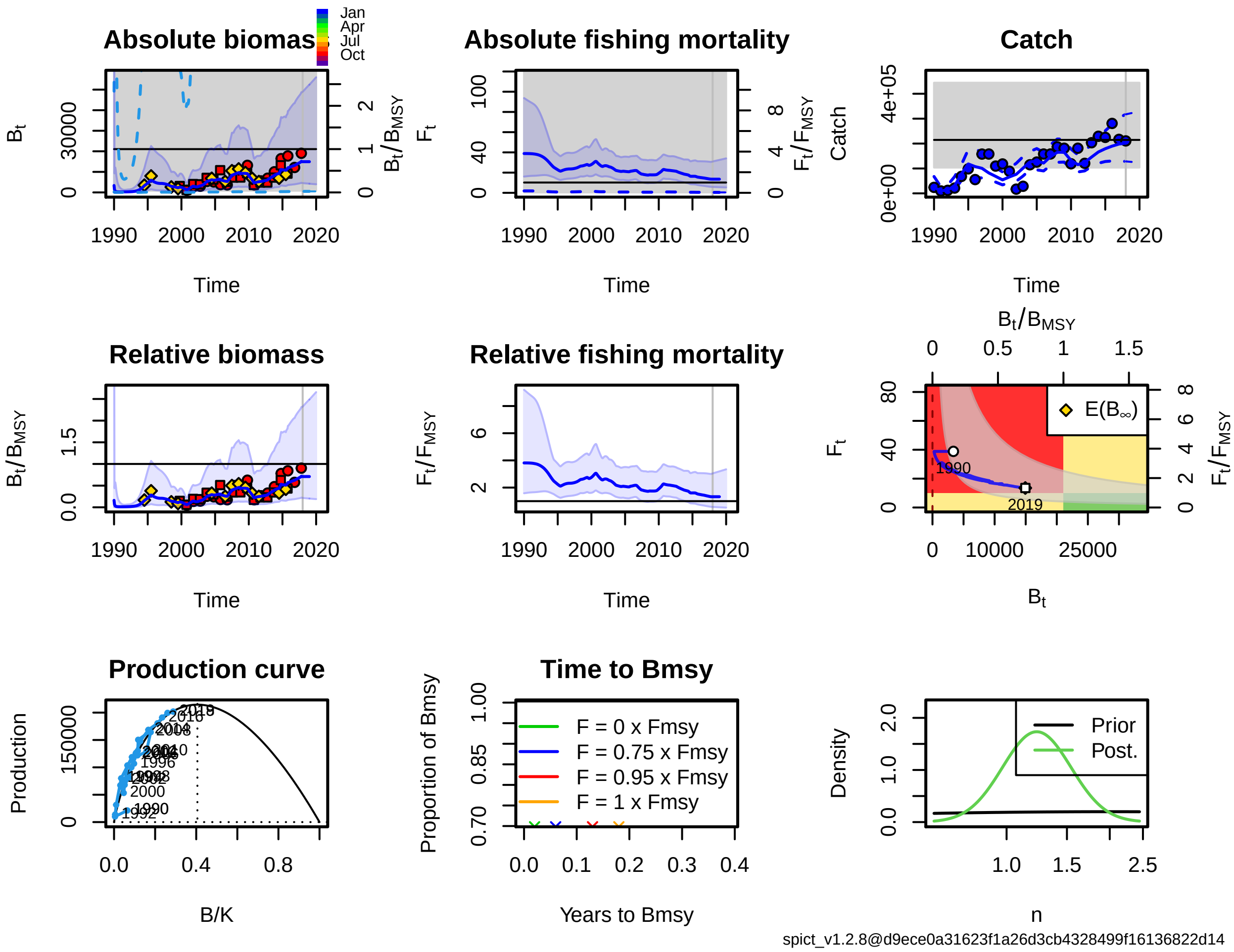

Figure 3: Summary results for scenario 1

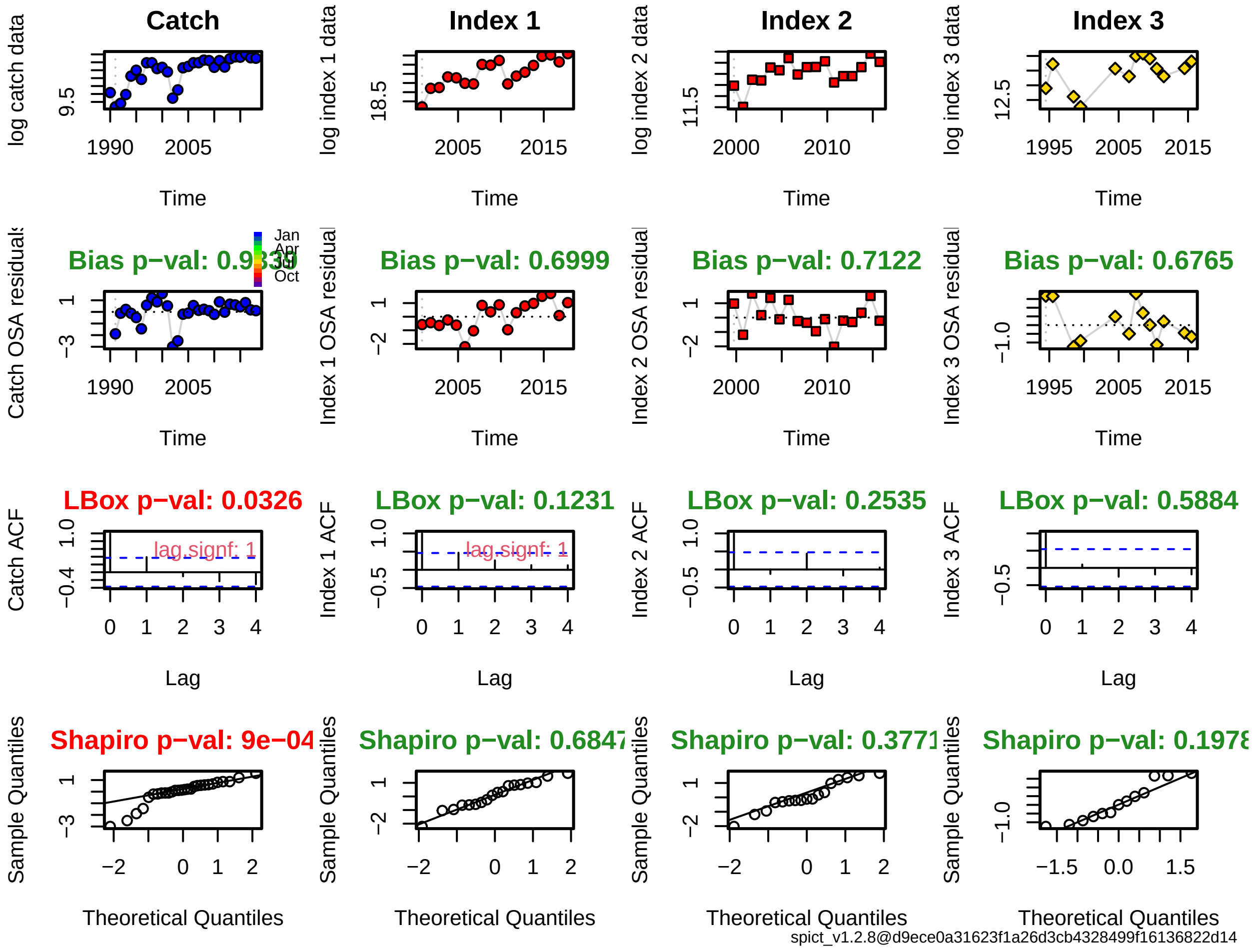

Figure 4: Summary diagnostics for scenario 1

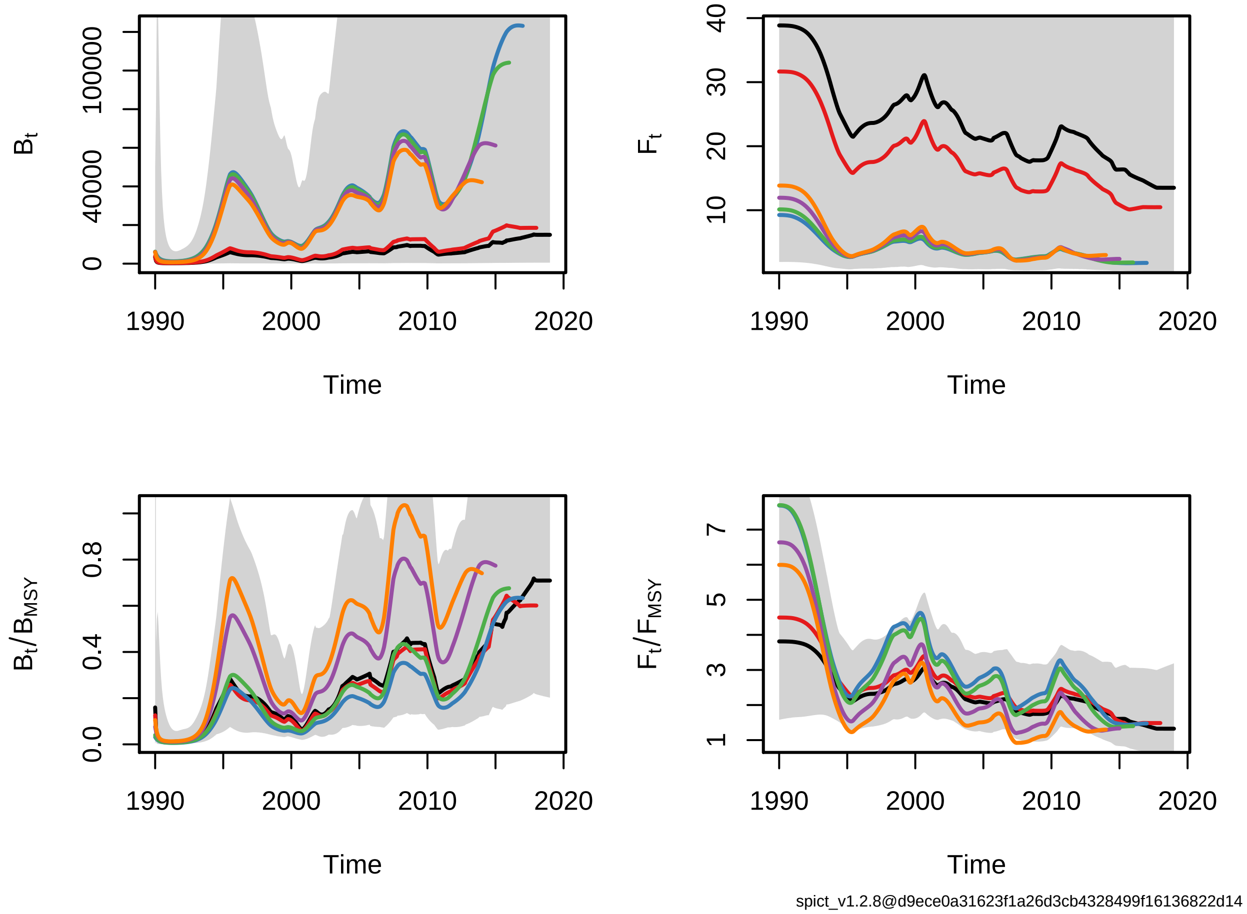

Figure 5: Retrospective analysis for scenario 1

3.2. Scenario 2- Reducing catch data time series period.

In this scenario, the historical catch data period was reduced to match the abundance time series length. Model outputs, diagnostics and retrospective analysis for the second scenario are presented in Figures 6, 7 and 8, respectively.

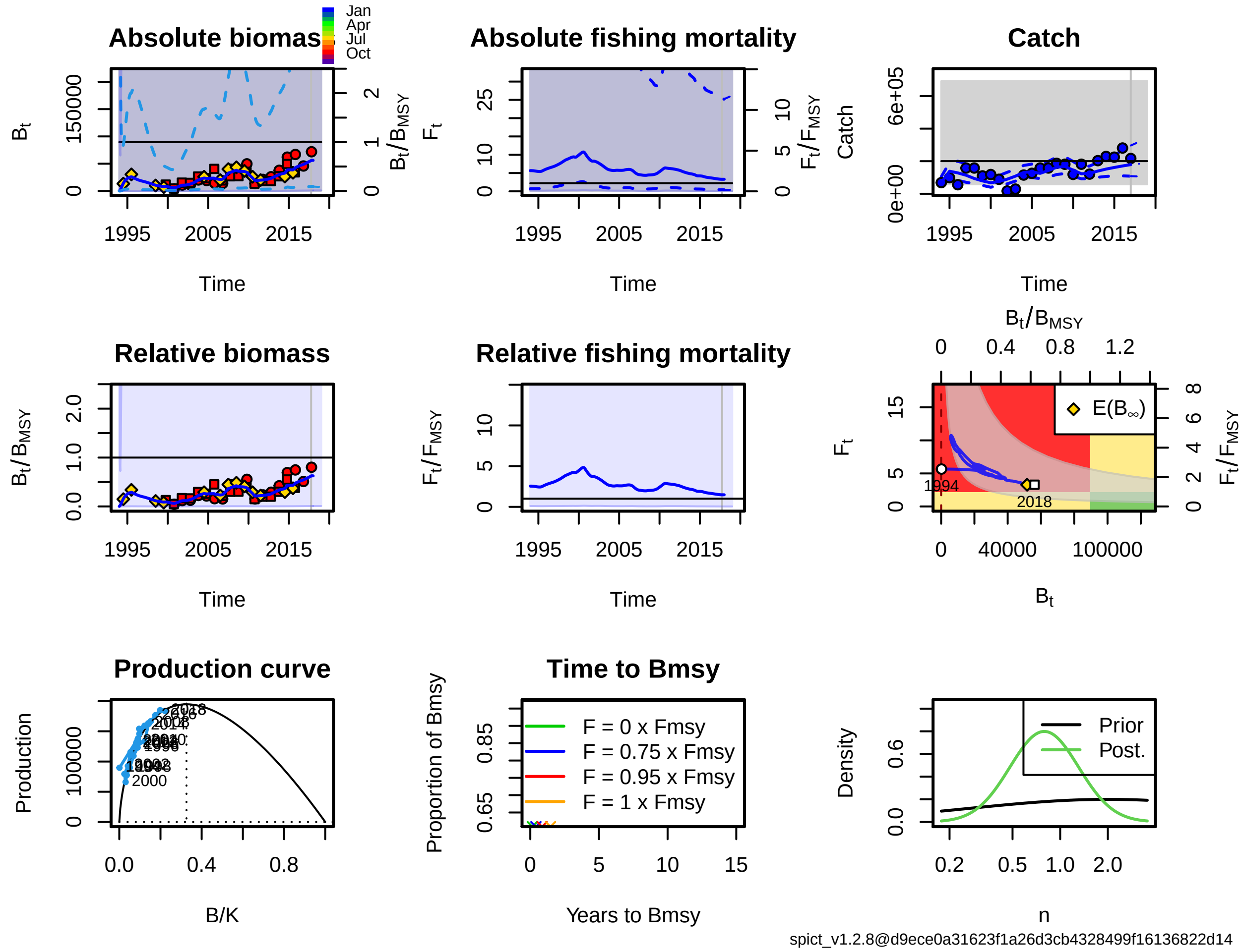

Figure 6: Summary results for scenario 2

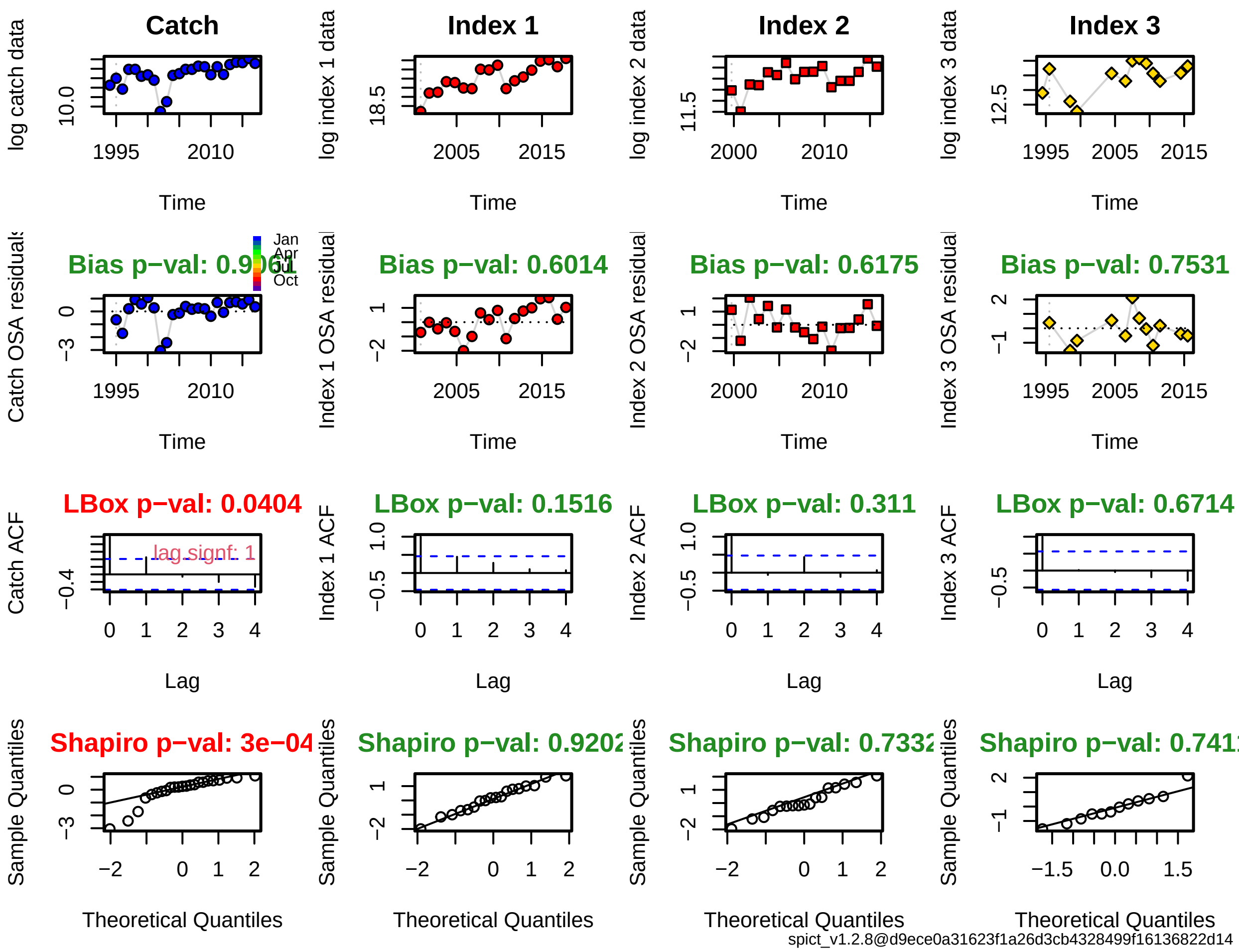

Figure 7: Summary diagnostics for scenario 2

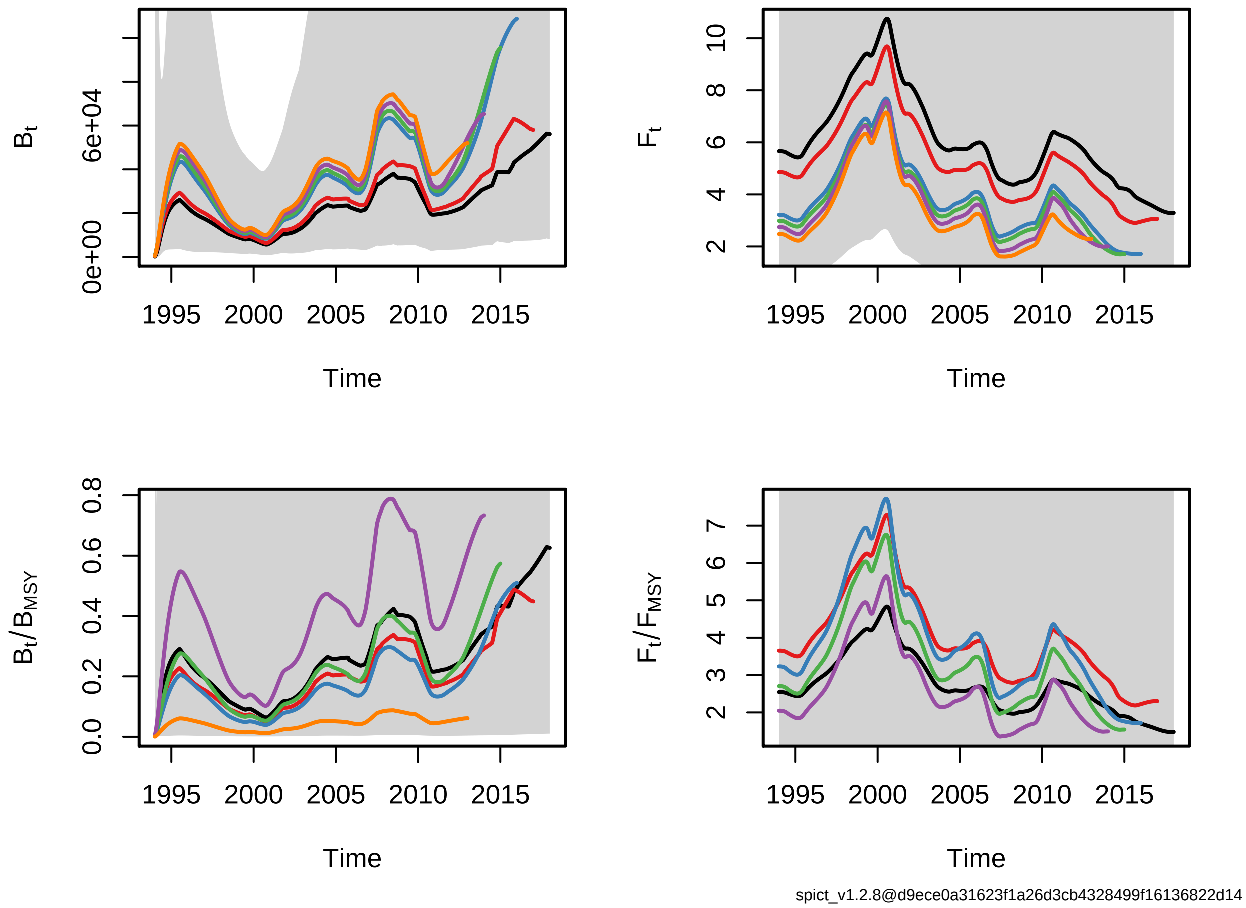

Figure 8: Retrospective analysis for scenario 2

3.3. Scenario 3- Imposing a Schaefer model on the production curve

For this scenario the value for parameter n was fixed and equal to two, imposing a Schaefer model for population dynamics. Model outputs, diagnostics and retrospective analysis for this scenario are presented in Figures 9, 10 and 11, respectively.

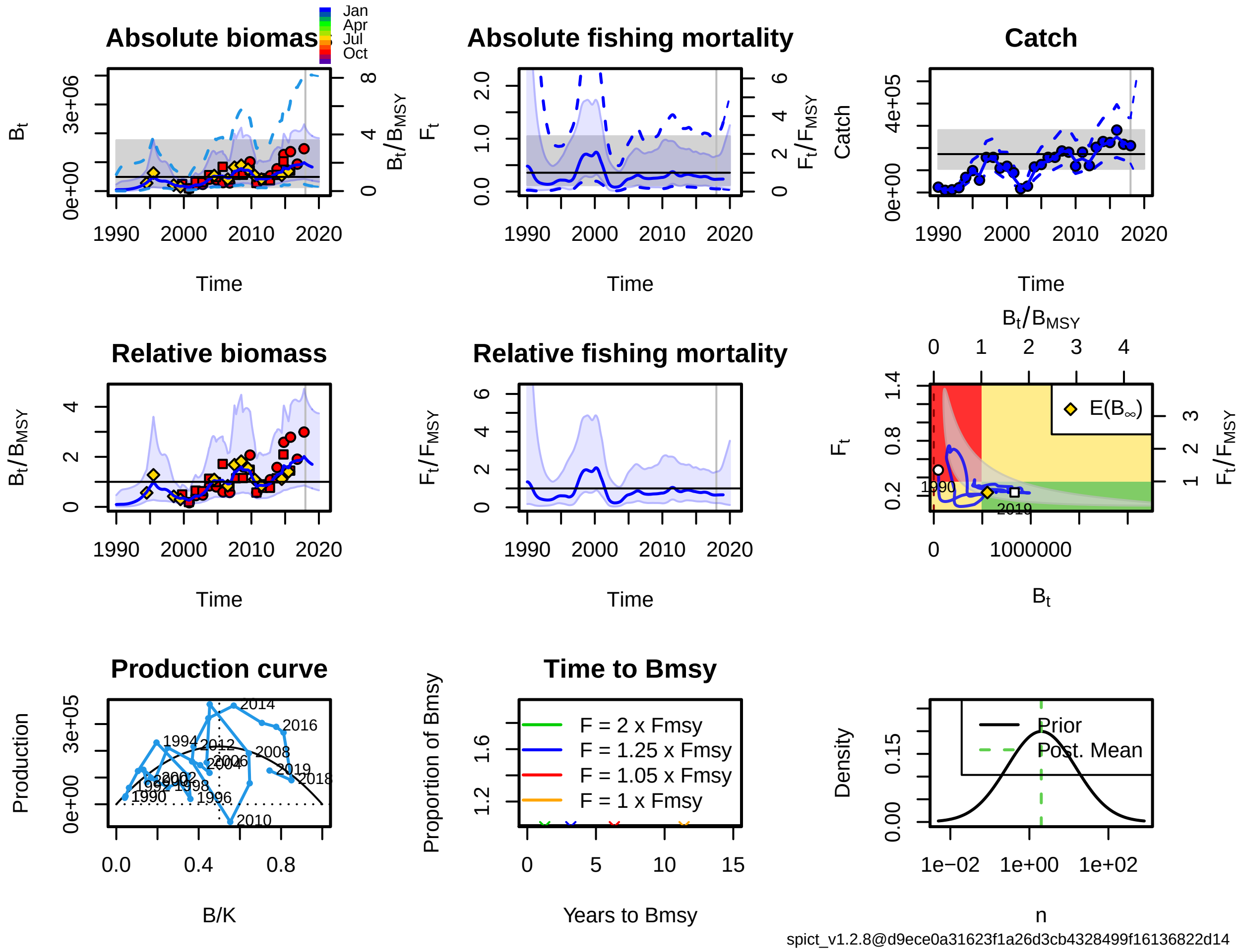

Figure 9: Summary results for scenario 3

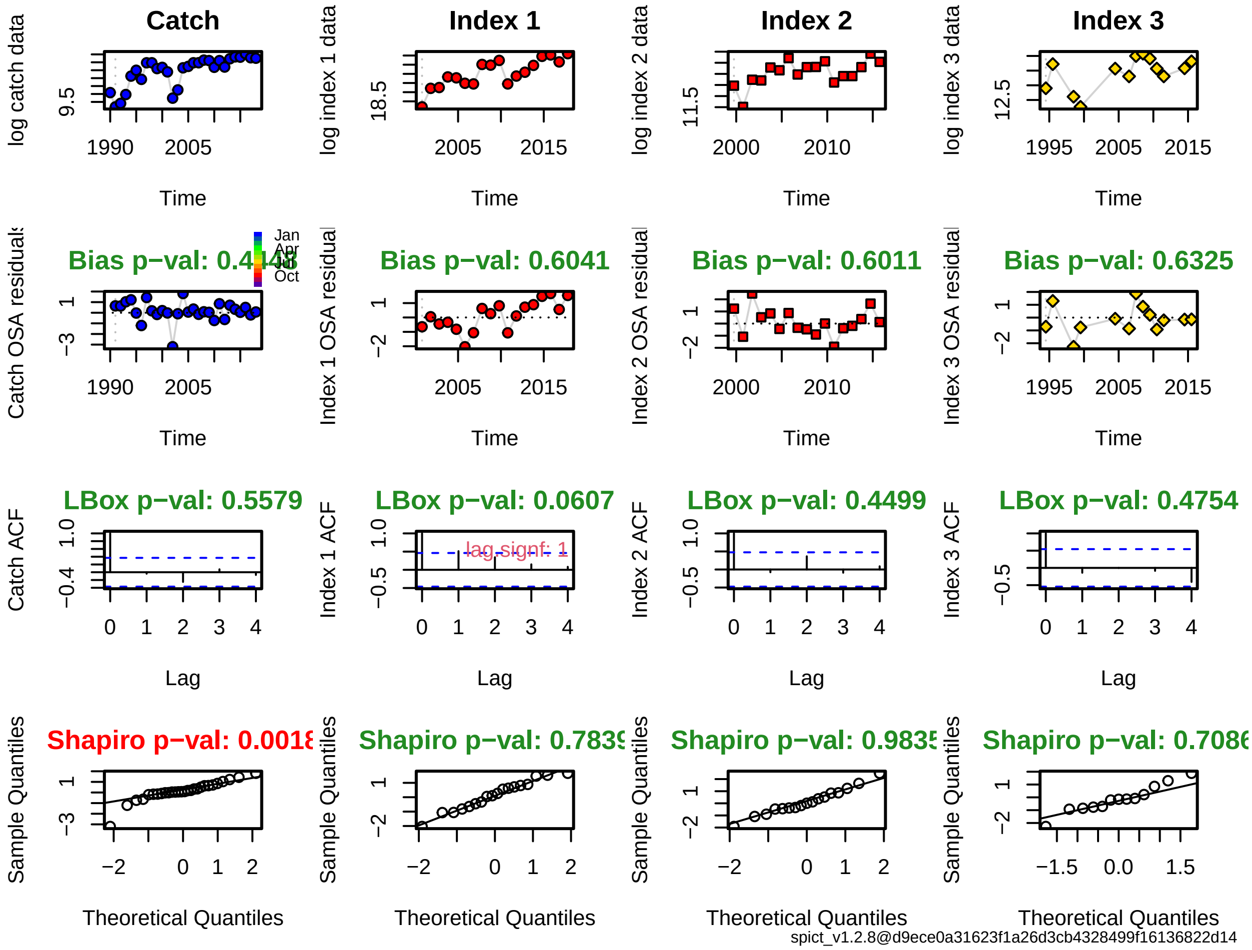

Figure 10: Summary diagnostics for scenario 3

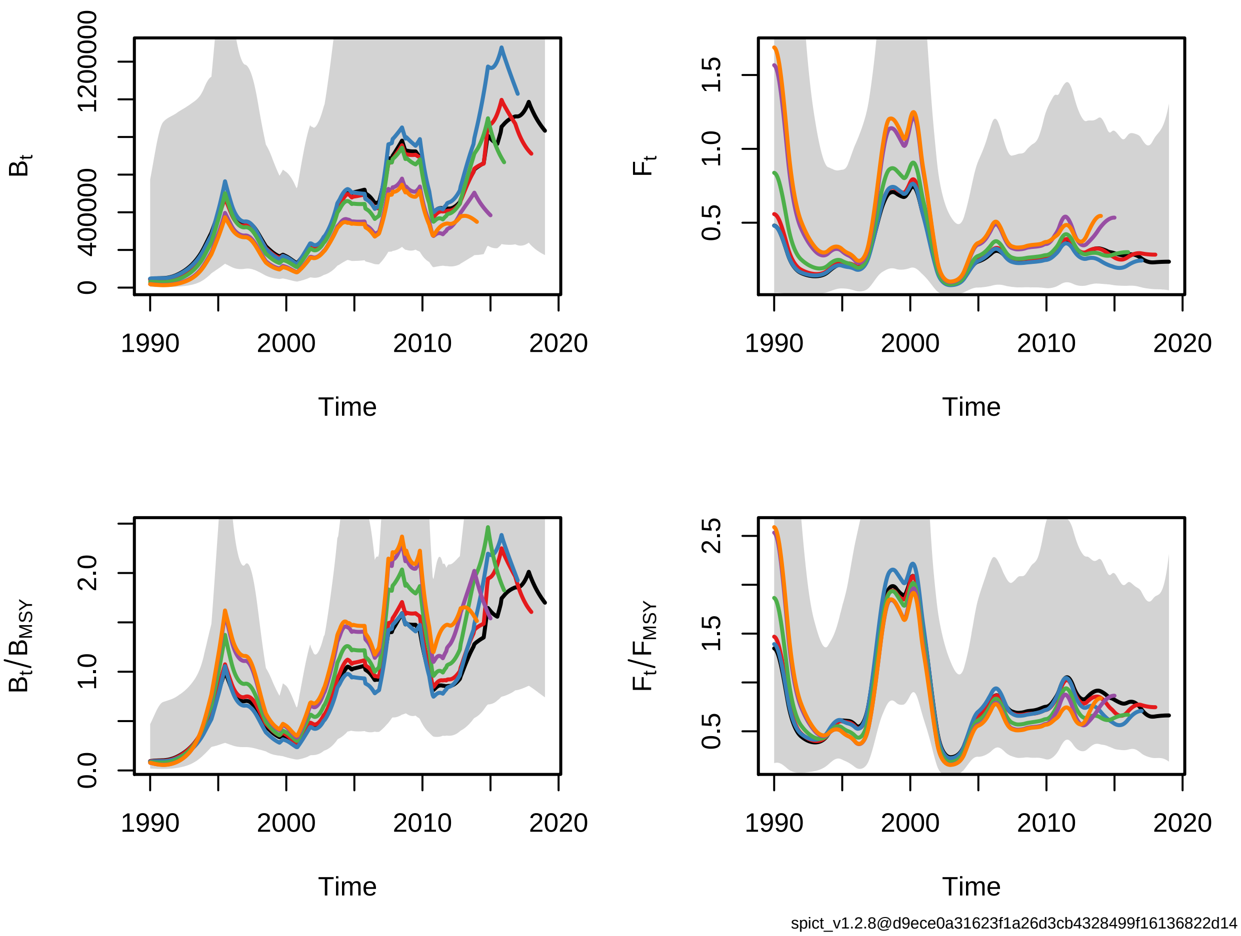

Figure 11: Retrospective analysis for scenario 3

3.4. Scenario 4- Imposing a Schaefer model on the production curve and changing prior for logBKfrac

For this scenario, the model was also fitted by fixing the parameter n=2, but changing the prior for the logarithm of the ratio between the initial biomass and K. This prior was defined as a lognormal distribution with $\mu = \ln(0.5)$ and $\sigma = 0.2$. Model outputs, diagnostics and retrospective analysis for the second scenario are presented in Figures 12, 13 and 14, respectively.

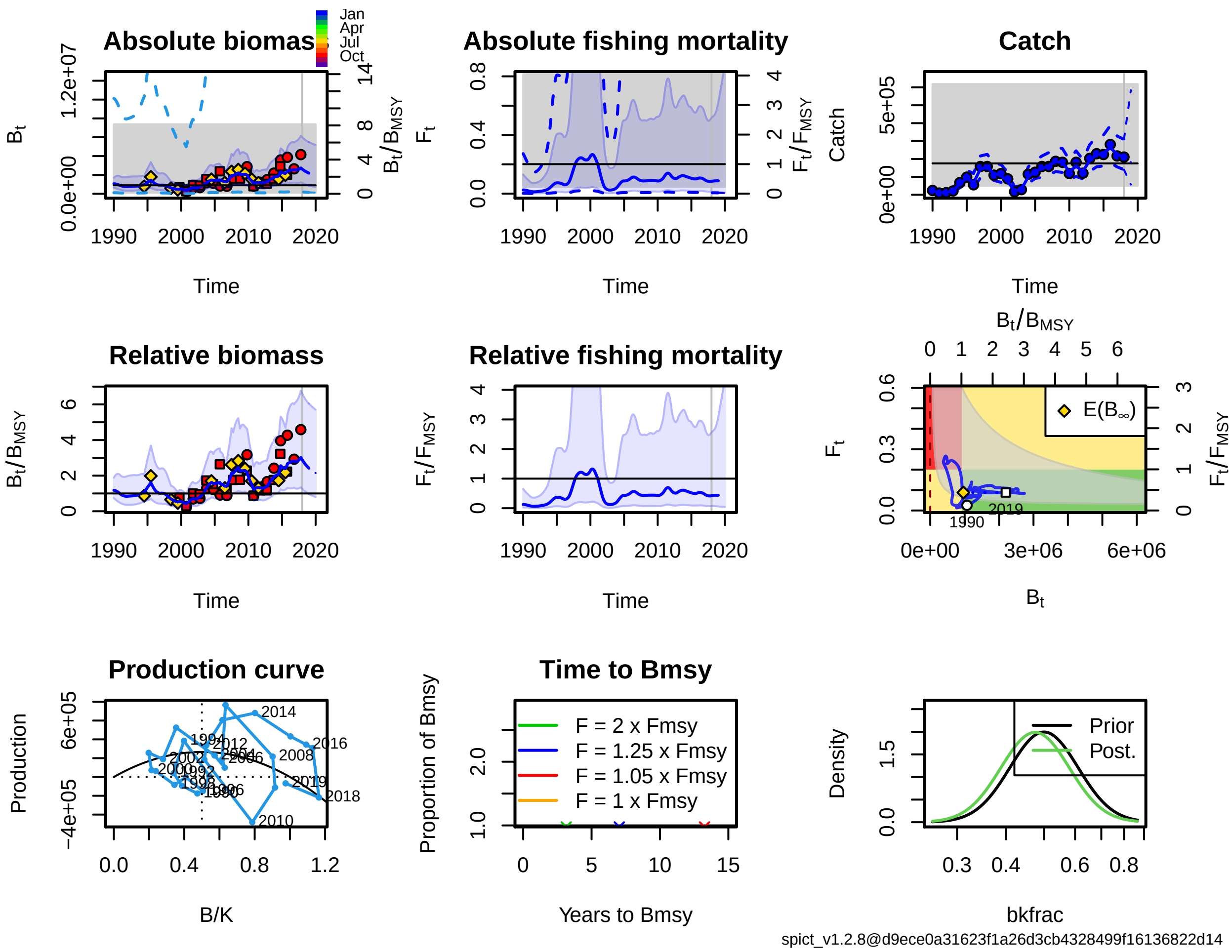

Figure 12: Summary results for scenario 4

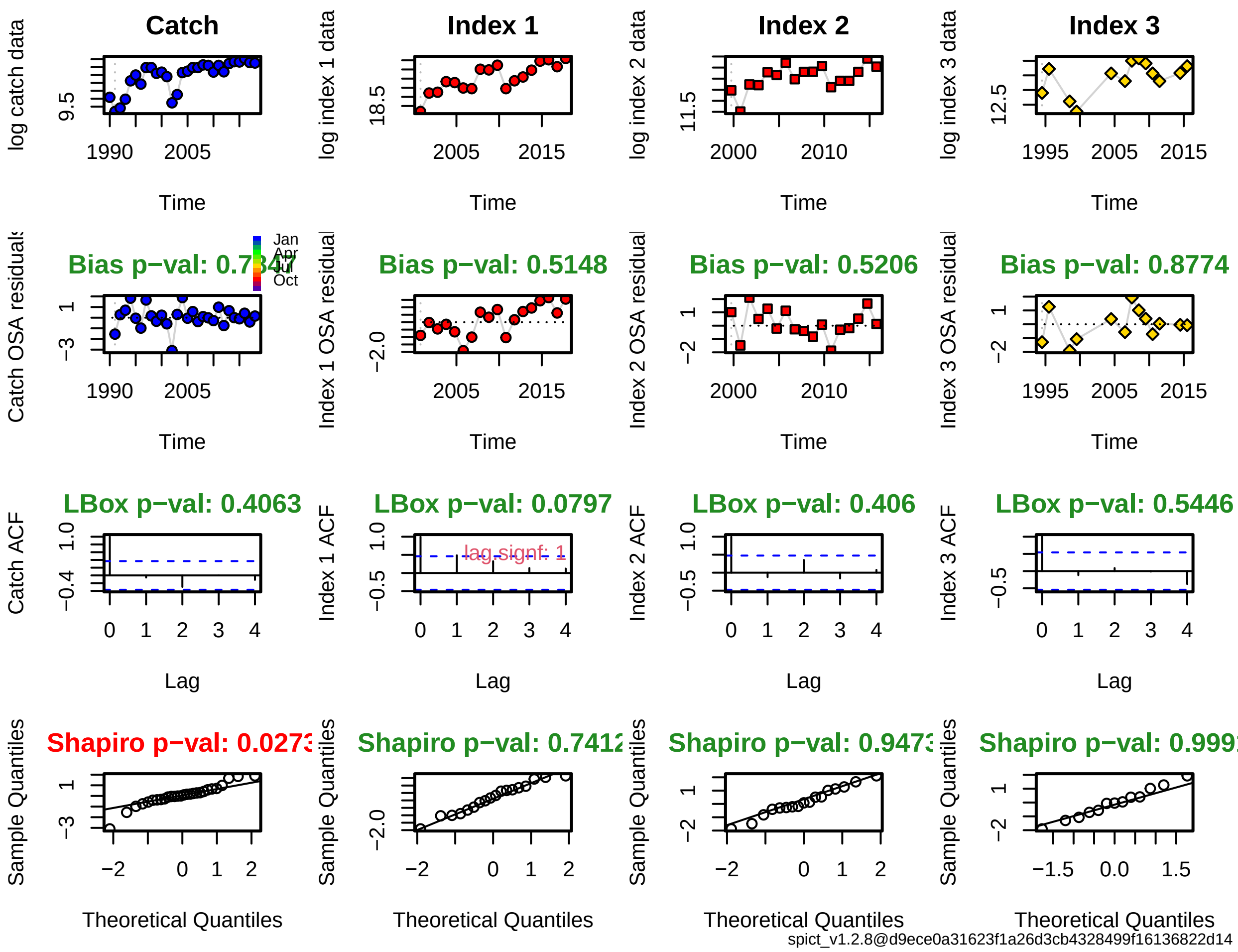

Figure 13: Summary diagnostics for scenario 4

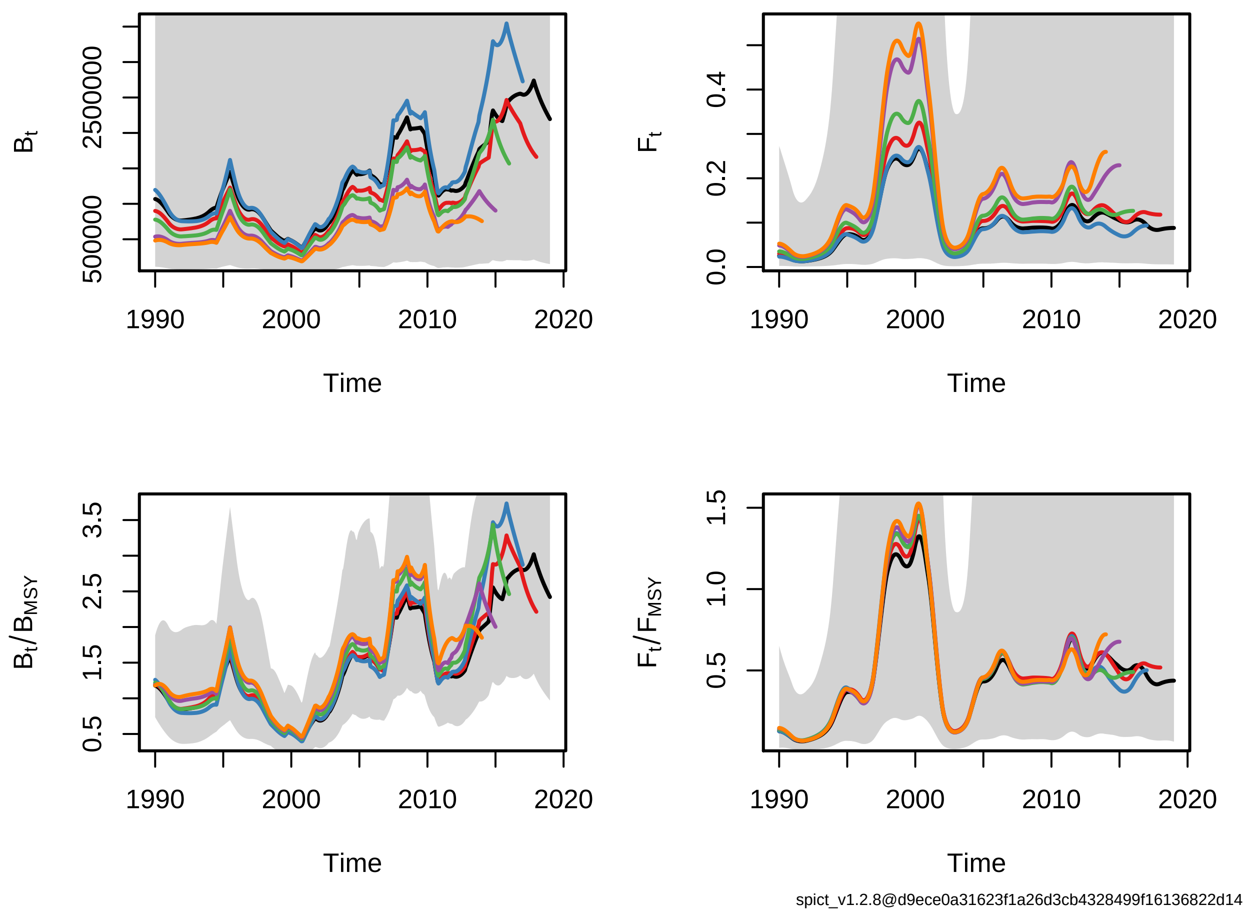

Figure 14: Retrospective analysis for scenario 4

3.5. The best scenario results: scenario 3

Scenario 3 provides the best results in terms of uncertainty. In addition, the production curve assumed for this scenario (Schaefer model) is the same used in the scientific assessment of this stock, which is performed with a Biodyn model (INRH, 2017). Estimated MSY is also consistent with the one estimated by the Biodyn model (SPiCT MSY = 172723.8 and Biodyn MSY central stock + Biodyn MSY Southern stock = 391875). The comparison between estimated biomass and reference points is also coherent with Biodyn results, showing a good status of the stock in the last years (See the Kobe plot green area in Figure 9).

A more complete description of the results for this scenario is presented below, including a summary of the main parameters estimated with their corresponding confidence intervals, and an isolated figure which illustrates better the relative biomass time-series estimates (Figure 15) with its corresponding interpretation against B_{MSY} reference point.

```
## Convergence: 0  MSG: relative convergence (4)
## Objective function at optimum: 69.3603699
## Euler time step (years):  1/16 or 0.0625
## Nobs C: 29,  Nobs I1: 18,  Nobs I2: 17,  Nobs I3: 13
##
## Priors
##      logn  ~  dnorm[log(2), 2^2]
##  logalpha  ~  dnorm[log(1), 2^2]
##   logbeta  ~  dnorm[log(1), 2^2]
##
## Fixed parameters
##    fixed.value
##  n           2
##
## Model parameter estimates w 95% CI
##             estimate        cilow        ciupp    log.est
##  alpha1 1.025100e+00 4.133546e-01 2.542202e+00  0.0247906
##  alpha2 8.641296e-01 3.394489e-01 2.199801e+00 -0.1460325
##  alpha3 5.528545e-01 1.065759e-01 2.867891e+00 -0.5926604
##  beta   4.765024e-01 9.853240e-02 2.304364e+00 -0.7412826
##  r      7.718090e-01 2.750157e-01 2.166019e+00 -0.2590182
##  rc     7.718090e-01 2.750157e-01 2.166019e+00 -0.2590182
##  rold   7.718090e-01 2.750157e-01 2.166019e+00 -0.2590182
##  m      2.160601e+05 1.253856e+05 3.723073e+05 12.2833120
##  K      1.119760e+06 3.121478e+05 4.016883e+06 13.9286245
##  q1     9.955304e+02 2.810314e+02 3.526583e+03  6.9032756
##  q2     1.070206e+00 3.052671e-01 3.751929e+00  0.0678509
##  q3     1.453472e+00 4.220815e-01 5.005147e+00  0.3739550
##  sdb    3.534625e-01 1.803257e-01 6.928338e-01 -1.0399780
##  sdf    5.651454e-01 2.976978e-01 1.072864e+00 -0.5706723
##  sdi1   3.623345e-01 2.231411e-01 5.883556e-01 -1.0151874
##  sdi2   3.054374e-01 1.826976e-01 5.106360e-01 -1.1860105
##  sdi3   1.954133e-01 5.968080e-02 6.398429e-01 -1.6326384
##  sdc    2.692931e-01 9.374580e-02 7.735687e-01 -1.3119549
##
## Deterministic reference points (Drp)
##            estimate        cilow        ciupp    log.est
##  Bmsyd 5.598798e+05 1.560739e+05 2.008442e+06 13.2354773
##  Fmsyd 3.859045e-01 1.375078e-01 1.083009e+00 -0.9521653
##  MSYd  2.160601e+05 1.253856e+05 3.723073e+05 12.2833120
```

```
## Stochastic reference points (Srp)
##           estimate        cilow        ciupp   log.est rel.diff.Drp
##  Bmsys 4.903064e+05 1.365912e+05 1.759999e+06 13.102786  -0.14189775
##  Fmsys 3.564559e-01 1.214957e-01 1.045805e+00 -1.031545  -0.08261499
##  MSYs  1.727238e+05 1.063925e+05 2.804100e+05 12.059449  -0.25089961
##
## States w 95% CI (inp$msytype: s)
##                   estimate        cilow        ciupp    log.est
##  B_2018.00      9.523846e+05 2.233366e+05 4.061297e+06 13.7667242
##  F_2018.00      2.325419e-01 4.994950e-02 1.082607e+00 -1.4586850
##  B_2018.00/Bmsy 1.942427e+00 8.407940e-01 4.487454e+00  0.6639384
##  F_2018.00/Fmsy 6.523720e-01 2.261731e-01 1.881697e+00 -0.4271404
##
## Predictions w 95% CI (inp$msytype: s)
##                 prediction        cilow        ciupp    log.est
##  B_2019.00      8.331978e+05 1.727963e+05 4.017555e+06 13.6330263
##  F_2019.00      2.360872e-01 4.265810e-02 1.306601e+00 -1.4435541
##  B_2019.00/Bmsy 1.699341e+00 7.409258e-01 3.897502e+00  0.5302406
##  F_2019.00/Fmsy 6.623180e-01 1.895240e-01 2.314562e+00 -0.4120095
##  Catch_2019.00  1.889670e+05 6.661260e+04 5.360629e+05 12.1493279
##  E(B_inf)       5.527063e+05           NA           NA 13.2225820
```

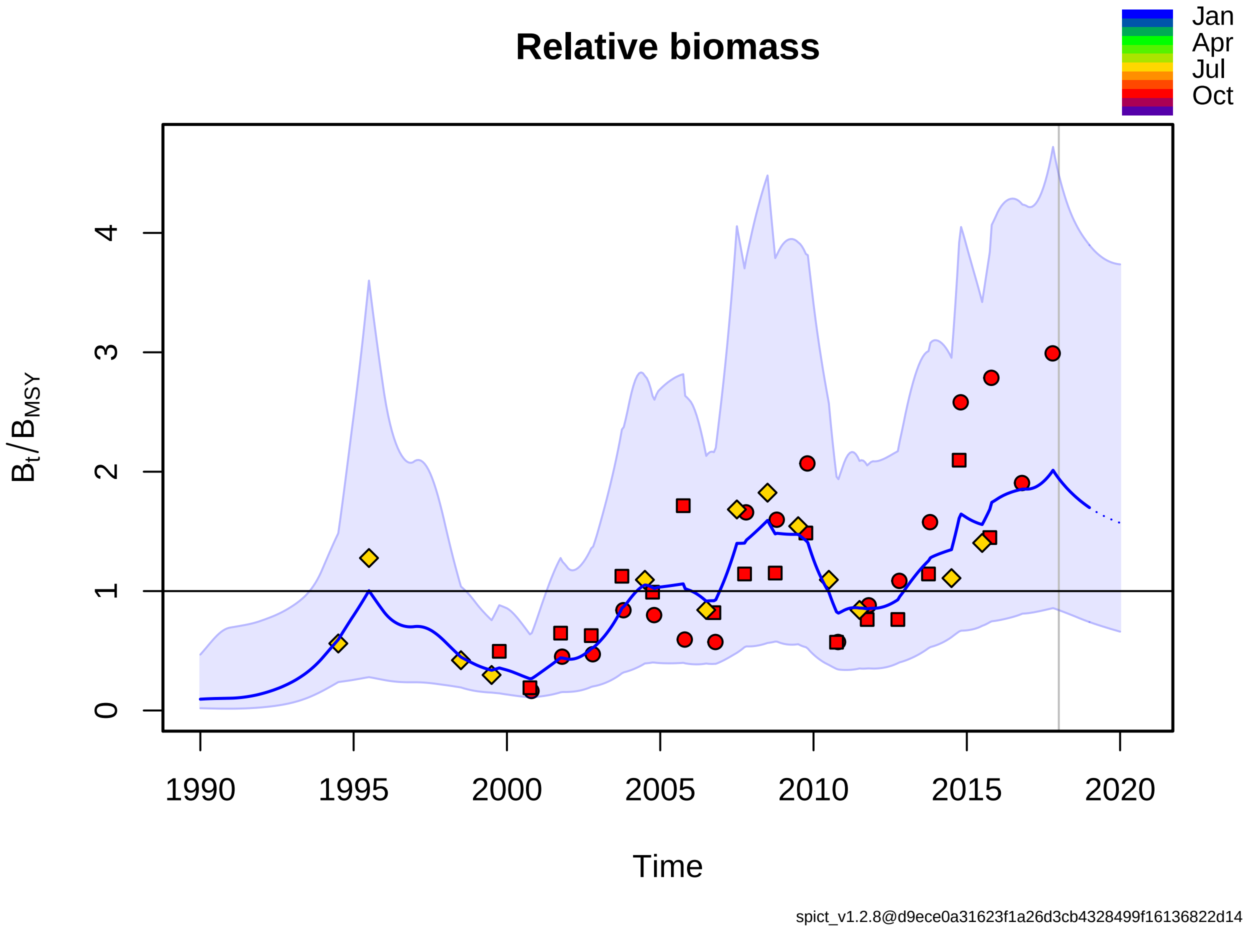

Figure 15: The relative biomass plot for scenario 3

It can be observed that chub mackerel mean relative biomass has fluctuated from 1990 to 2003 below B_{MSY}. After this period, the biomass increased until B_{MSY} was reached in 2005. From this year onwards, it was mostly above B_{MSY}, showing its maximum value in 2018.

4. References

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Annex 6: Recommendations

Recommendations	Addressed to
The WKCOLIAS2 recommends that ACOM draw the attention of competent authorities to the increase of landings and the uncertainty about the population structure and the stocks status of the Atlantic chub mackerel in European waters, which may require policy and management attention.	ACOM
The WKCOLIAS2 proposes to WGBIOP that *S. colias* maturity and otoliths/age exchanges using SmartDots to be held in 2022 and, if possible a physical workshop in 2023, involving both European and African participants.	WGBIOP
WKCOLIAS2 recommends that size-based and age-structured abundance and biomass estimates of *S. colias* are computed from all those acoustic- and bottom-trawl surveys conducted along its distributional range, whenever possible, and provided to this WK. This recommendation is applicable to those surveys conducted in ICES, FAO CGFM and CECAF areas.	WGACEGG, IBTSWG, FAO CGFM Scientific Advisory Committee on Fisheries (SAC), DCRD MEDITS & MEDIAS Programmes, WGSASP, FAO CECAF: Scientific Subcommittee, WG on the Assessment of Small Pelagic Fish off Northwest Africa
The next WKCOLIAS3 to be held in 2023 (dates and venue to be defined) involving the countries and institutions from both ICES and CECAF areas, and if possible, extending to the Mediterranean area (CGFM), and also to the northern European waters where chub mackerel is found (AZTI, IFREMER). The WK constitutes the unique realistically viable opportunity for these experts to jointly share data, analyses and expertise to continue addressing the issues relevant to the Atlantic chub mackerel (*S. colias*).	ACOM-SCICOM, FRSG