WORKING GROUP ON SOUTHERN HORSE MACKEREL, ANCHOVY AND SARDINE (WGHANSA)

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Contents

i Executive summary

The ICES Working Group on Southern horse mackerel, anchovy and sardine (WGHANSA) assessed the status of anchovy in Atlantic Iberian waters (ane.27.9a; western and southern components) and horse mackerel in Atlantic Iberian waters (hom.27.9a) in the May meeting. The status of anchovy in Bay of Biscay (ane.27.8), sardine in southern Celtic Seas and the English Channel (pil.27.7), sardine in Bay of Biscay (pil.27.8abd) and sardine in Cantabrian Sea and Atlantic Iberian waters (pil.27.8c9a) will be assessed in the November meeting. The status of jack mackerel in Subdivision 10.a.2 (Azores grounds) (jaa.10.a2) won't be assessed this year, since the advice is provided biannually.

The stock of **anchovy in Bay of Biscay** (ane.27.8) has been above B_{lim} since the reopening of the fishery in 2010. SSB in 2023 has been estimated as the second highest of the historical series. Recruitment (age 1 biomass at the beginning of the year) in 2024 is estimated above the average of the time-series. Harvest rates (catch/SSB) have been stable in the last years.

The stock of **anchovy in Atlantic Iberian waters** (ane.27.9a) is composed by the western component (distributed in areas 9.a North, Central–North, and Central–South) and the southern component (distributed in area 9.a South). The advice is provided for the two components separately for the management calendar from July to June next year. Based on the MSE work developed for each component, the advice is based for the first time on constant harvest rate rules. For the western component, the combined PELACUS and PELAGO acoustic biomass estimate is used as an indicator of stock development and the advice is based on the stock indicator for 2023, multiplied by a constant harvest rate of 0.25, with no biomass safeguard. For the southern component, the relative SSB from an analytical assessment conducted with GADGET is used as the index of stock size development and the advice is based on the stock indicator for 2023, multiplied by a constant harvest rate of 0.5 with a biomass safeguard.

In the last years **sardine in the Bay of Biscay** (pil.27.8abd) shows a decreasing trend in SSB. In 2023 spawning-stock biomass is estimated below MSY $B_{trigger}$, B_{pa} and above B_{lim}. Since 2013 the fishing mortality has been oscillating above F_{MSY} and F_{pa}, and below F_{lim}.

The advice for **sardine in southern Celtic Seas and the English Channel** (pil.27.7) is based on the PELTIC survey biomass index in the total area. The index ratio indicates an increase of 62% in 2023 compared with the two previous years.

The biomass (age 1+) of **sardine in Atlantic Iberian waters** (pil.27.8c9a) in 2023 is estimated to be above MSY $B_{trigger}$, B_{pa} and B_{lim} for the fourth consecutive year. Fishing mortality in 2022 is below F_{MSY}. ICES advice is based on the ICES MSY advice rule. However, the catch options explored for 2024 include several harvest control rules that were assessed by ICES as precautionary.

The SSB of **horse mackerel in Atlantic Iberian waters** (hom.27.9a) fluctuated from 1992 (the beginning of the assessment) to 2013 and afterwards has increased continuously to historical maximum values in 2023. In 2023 SSB is estimated at 1 214 200 tonnes, well above MSY $B_{trigger}$, B_{pa}, and B_{lim}. Fishing mortality has been below F_{MSY} over the whole time-series, with a decreasing trend in the last years. Recruitment shows a decreasing trend from 2017 to 2021 but is still above the average of the time series. The lack of the survey index in 2019 and 2020 is reflected in larger confidence intervals for SSB and recruitment in the last years.

The **jack mackerel in Subdivision 10.a.2 (Azores grounds)** (jaa.10.a2) is classified in category 5 and advice is provided biannually. The latest advice for this stock was provided last year.

ii Expert group information

Expert group name	Working Group on Southern Horse Mackerel Anchovy and Sardine (WGHANSA)
Expert group cycle	Annual
Year cycle started	2023
Reporting year in cycle	1/1
Chair	Leire Ibaibarriaga, Spain
Meeting venues and dates	29 May – 2 June 2023, Online meeting (14 participants)
	20–24 November 2023, Pasaia (Spain) (14 participants)

1 Introduction

1.1 Terms of reference

2022/2/FRSG13 The Working Group on Southern Horse Mackerel Anchovy and Sardine (WGHANSA), chaired by Leire Ibaibarriaga, Spain, will meet by correspondence 29 May to 2 June 2023 (WGHANSA1) and in Pasaia (Spain) 20 to 24 November 2023 (WGHANSA2) to:

a) Address generic ToRs for Regional and Species Working Groups for relevant stocks (hom.27.9a and ane.27.9a in WGHANSA1 and pil.27.7, pil.27.8abd, pil.27.8c9a and ane.27.8 in WGHANSA2);

The assessments will be carried out on the basis of the Stock Annexes. The assessments must be available for audit on the first day of the meeting.

Material and data relevant for the meeting must be available to the group on the dates specified in the 2023 ICES data call.

WGHANSA1 will report by 16 June 2023 and WGHANSA2 will report by 8 December 2023 for the attention of ACOM.

According to the generic ToRs, the working group should focus on:

a) Consider and comment on Ecosystem and Fisheries Overviews with a focus on:

   i) identifying and correcting mistakes and errors (both in the text, tables and figures), and

   ii) proposing concrete evidence-based input that is considered essential for the advice but is currently under-developed or missing (with references and Data Profiling Tool entries, as appropriate).

   The input will feed into the annual updates of the overviews. Delivery of contributions other than those outlined above is also welcomed but will be utilised during the revision process (around every 5 years).

b) Conduct an assessment on the stock(s) to be addressed in 2023 using the method (assessment, forecast or trends indicators) as described in the stock annex; - complete and document an audit of the calculations and results; and produce a **brief** report of the work carried out regarding the stock, providing summaries of the following where relevant:

   i) Input data and examination of data quality; in the event of missing or inconsistent survey or catch information refer to the ACOM document for dealing with missing data and the linked template that formulates how deviations from the stock annex are to be reported.

   ii) Where misreporting of catches is significant, provide qualitative and where possible quantitative information and describe the methods used to obtain the information;

   iii) For relevant stocks (i.e., all stocks with catches in the NEAFC Regulatory Area), estimate the percentage of the total catch that has been taken in the NEAFC Regulatory Area in 2022.

iv) For category 3 and 4 stocks requiring new advice in 2023, implement the methods recommended by WKLIFE X (e.g. SPiCT, rfb, chr, rb rules) to replace the former 2 over 3 advice rule (2 over 5 for elasmobranchs). MSY reference points or proxies for the category 3 and 4 stocks (guidelines)

v) Evaluate spawning stock biomass, total stock biomass, fishing mortality, catches (projected landings and discards) using the method described in the stock annex;

1) for category 1 and 2 stocks, in addition to the other relevant model diagnostics, the recommendations and decision tree formulated by WKFORBIAS (see Annex 2 of https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/Fisheries%20Resources%20Steering%20Group/2020/WKFORBIAS_2019.pdf) should be considered as guidance to determine whether an assessment remains sufficiently robust for providing advice.

2) If the assessment is deemed no longer suitable as basis for advice, provide advice using an appropriate Category 2- 5 approach as described in ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3 or ICES.

3) If the assessment has been moved to a Category 2-5 approach in the past year consider what is necessary to move back to a Category 1 and develop proposal for the appropriate benchmark process.

vi) Catch scenarios for the year(s) beyond the terminal year of the data for the stocks for which ICES has been requested to provide advice on fishing opportunities;

vii) Historical and analytical performance of the assessment and catch options with a succinct description of associated quality issues. For the analytical performance of category 1 and 2 age-structured assessments, report the mean Mohn's rho (assessment retrospective bias analysis) values for time series of recruitment, spawning stock biomass, and fishing mortality rate. The WG report should include a plot of this retrospective analysis. The values should be calculated in accordance with the "Guidance for completing ToR viii) of the Generic ToRs for Regional and Species Working Groups - Retrospective bias in assessment" and reported using the ICES application for this purpose.

c) Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines.

d) Review progress on benchmark issues and processes of relevance to the Expert Group.
i) update the benchmark issues lists for the individual stocks in SID;
ii) review progress on benchmark issues and identify potential benchmarks to be initiated in 2024 for conclusion in 2025;
iii) determine the prioritization score for benchmarks proposed for 2024–2025;
iv) as necessary, document generic issues to be addressed by the Benchmark Oversight Group (BOG)

e) Prepare the data calls for the next year's update assessment and for planned data evaluation workshops;

f) Identify research needs of relevance to the work of the Expert Group.

g) Review and update information regarding operational issues and research priorities on the Fisheries Resources Steering Group SharePoint site.

h) If not completed previously, complete the audit spread sheet 'Monitor and alert for changes in ecosystem/fisheries productivity' for the new assessments and data used for the stocks. Also note in the benchmark report how productivity, species interactions, habitat and distributional changes, including those related to climate-change, could be considered in the advice.

i) Deliver conservation status advice in accordance with the "Technical Guidelines on the conservation status advice". The advice is only to be given when conservation aspects were identified and where clear, demonstrable management action can be recommended for any non-catch anthropogenic pressure. It can also be used to highlight clear demonstrable sensitivity to climate change. The qualification required to show clear, demonstratable management action is high. Avoid generic statements that are of no specific application to management.

j) Update SAG and SID with final assessment input and output

Information of the stocks to be considered by each Expert Group is available here.

1.1.1 The WG work in relation to the ToRs

The generic ToRs for Regional and Species Working Groups were addressed for anchovy in Division 9.a (ane.27.9a) and horse mackerel in Division 9.a (hom.27.9a) in WGHANSA1 and for anchovy in Subarea 8 (ane.27.8), sardine in divisions 8a-b and 8d (pil.27.8abd), sardine in Subarea 7 (pil.27.7) and sardine in divisions 8c and 9a (pil.27.8c9a) in WGHANSA2. The assessments were carried out on the basis of the stock annexes prior to and during the meeting and coordinated as indicated in the table below. The advice for anchovy in Division 9.a was based for the first time in the application of constant harvest rate rules evaluated by simulation before the meeting (section 1.10 and Annex 6). The status of jack mackerel in Subdivision 10.a.2 (Azores grounds) (jaa.10.a2) was not assessed this year, since the advice is provided biannually. The assessments were audited during the meeting (Annex 4). WGHANSA1 and WGHANSA2 reported by 16 June 2023 and by 8 December 2023 respectively for the attention of ACOM.

Stock	Stock code	Stock coordinator 1	Stock coordinator 2	Advice to be provided in 2023	Periodicity in years	Time period in the year for releasing the advice	Category	Advice basis	Notes
Anchovy (*Engraulis encrasicolus*) in Division 9.a (Atlantic Iberian waters)	ane.27.9a	Fernando Ramos	Susana Garrido	Yes	1	June	3 (south component); 3 (western component)	PA, in-year advice	Benchmarked in 2018. New benchmark approved for 2024. Two stock components, western and southern, assessed separately. Advice for period 1 July –30 June.
Horse mackerel (*Trachurus trachurus*) in Division 9.a (Atlantic Iberian waters)	hom.27.9a	Gersom Costas	Hugo Mendes	Yes	1	June	1	MSY	Benchmarked in 2017. New benchmark approved for 2024. There is a long-term management strategy, agreed between all parties, evaluated to be precautionary by ICES in 2018 and updated in 2021. For 2023, EU Commission requested ICES to provide advice based on the MSY approach.
Anchovy (*Engraulis encrasicolus*) in Subarea 8 (Bay of Biscay)	ane.27.8	Leire Citores	Leire Ibaibarriaga	Yes	1	December	1	Management plan	Benchmarked in 2013. New benchmark approved for 2024.
Sardine (*Sardina pilchardus*) in Subarea 7 (Southern Celtic Seas, and the English Channel)	pil.27.7	Joseph Ribeiro	Erwan Duhamel	Yes	1	December	3	PA	Benchmarked in 2021. Stock upgraded from category 5 to category 3. Advice can now be provided annually.

Stock	Stock code	Stock coordinator 1	Stock coordinator 2	Advice to be provided in 2023	Periodicity in years	Time period in the year for releasing the advice	Category	Advice basis	Notes
Sardine (*Sardina pilchardus*) in divisions 8.a–b and 8.d (Bay of Biscay)	pil.27.8abd	Maxime Olmos	Lionel Pawlowski	Yes	1	December	1	MSY	Inter-benchmarked in 2019.
Sardine (*Sardina pilchardus*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)	pil.27.8c9a	Isabel Riveiro	Laura Wise	Yes	1	December	1	MSY	Benchmarked in 2017 and Inter-benchmarked in 2021; reference points changed in 2019 and 2021, in the context of the evaluation of a management and recovery plan. In 2021 ICES received a request from Portugal and Spain EU members to evaluate a harvest control rule (HCR) that will be part of a management plan for 2021–2026. ICES found that the generic HCR was precautionary with maximum allowed catches between 30 000 and 50 000 tonnes. For 2023, the EU Commission requested ICES to provide advice based on the MSY approach. The precautionary generic HCR should be included in the catch scenario table.
Jack mackerel (*Trachurus pictoratus*) in Subdivision 10.a.2 (Azores grounds)	jaa.27.10a2	Dália Reis		Yes	2	December	5	PA	

1.2 Report structure

Ad hoc and generic ToRs relative to the stocks for which assessment is required are dealt stock by stock in respective chapters of the report: anchovy in Subarea 8 (Section 3), anchovy in Division 9.a (Section 4), sardine in divisions 8.a-b and 8.d (Section 6), sardine in Subarea 7 (section 7), sardine in divisions 8.c and 9.a (Section 8) and horse mackerel in division 9.a (Section 9). MSE work to update the advice rule for anchovy in division 9.a is summarised in section 1.10 and all the relevant documents are provided in Annex 6.
The list of participants, the working documents and presentations presented, the stock annexes, the audits and a summary of the joint WGACEGG-WGHANSA session conducted on 29th May are provided as annexes.

1.3 Conduct of the meeting

WGHANSA1 took place by correspondence from 29 May to 2 June 2023. WGHANSA2 took place in Pasaia (Spain) from 20 to 24 November 2023.

1.3.1 List of participants

The full list of participants to WGHANSA1 and WGHANSA2 are given in Annex 1. All the participants abided with the ICES code of conduct, and none had conflicts of interest that prevented them acting with scientific independence, integrity and impartiality.

1.3.2 Timing of the meeting

WGHANSA continues to have two meetings per year: in June, by correspondence, to address generic ToRs for the stocks of anchovy in 9.a and horse mackerel in 9.a and, in November, in a physical meeting, for the remaining stocks. The participants recognise that two meetings per year (one of them by correspondence) is not an ideal situation and admit that the duration of these meetings could be shorten as happened with WGHANSA2 that finished one day earlier than planned. However, the five days duration of WGHANSA1 allowed to cope with potential delays in the acoustic survey results that are used as input for the assessment of anchovy in 9.a and with the additional work of evaluating the performance of constant harvest rate advice rules. So, overall WGHANSA considers that the timing and duration of the meetings are adequate.

1.3.3 Interactions with other expert groups

The Working Group on Acoustic and Egg Surveys for small pelagic fish in Northeast Atlantic (WGACEGG) is the main working group interacting with WGHANSA. Both working groups continue improving their interaction by creating dedicated time slots during their own meetings. On the first day of WGHANSA1, there was a joint session between the two groups where the results of the PELAGO and PELACUS spring surveys were presented and discussed (see Annex 5). Similarly, on the first day of WGACEGG there was a joint session between the two working groups where the results of the surveys were presented and discussed. Beyond improving communication and promoting joint discussions, these joint sessions allowed to have the acceptance of WGACEGG on the survey results before their inclusion in the stock assessment.

During WGHANSA1, the ICES secretariat presented the status of the Regional Database and Estimation System (RDBES). All stock coordinators were encouraged to participate in the workshops about RDBES that will be carried out along the year.

In addition, the ACOM leadership presented the workplan of ICES on rebuilding plans and reference point framework and encouraged the group to participate in the upcoming WKREBUILD2 and WKNEWREF workshops.

During WGHANSA2, the ICES secretariat presented the most recent advances on TAF and invited the participants to the workshops planned for 2024.

1.4 Quality of the fisheries data

The differences between the WG estimates and official data in 2022 were minimal, and as is the usual procedure, estimates of the working group were used to perform the assessment in all cases.

1.5 Overview of sampling activities

The 2022 sampling summary by stocks on national basis is the following:

Anchovy 9a

Country	Official Catch	% of catch sampled	No. samples	No. measured	No. Aged
Spain	6810	100%	224	7135	1434
Portugal	3533	100%	27	1801	510
Total	10343	100%	251	8936	1944

Horse Mackerel 9a

Country	Official Catch	% of catch sampled	No. samples	No. measured	No. Aged
Portugal	17658	100%	177	1768	335
Spain	7339	99.6%	141	7836	847
Total	24997	99.9%	318	9604	1182

Anchovy 8

Country	Official Catch	% of catch sampled	No. samples	No. measured	No. Aged
Spain	24 961	100%	261	29 206	2226
France	234	0%	0	0	1501
Total	25 196	100%	261	29 206	3727

Sardine 8abd

Country	Official Catch	% of catch sampled	No. samples	No. measured	No. Aged
France	23 298	100%	26	1293	1394
Spain	3061	100%	110	10 968	500
Total	26 359	100%	136	12 261	1894

Sardine 8c9a

Country	Official Catch	% of catch sampled	No. samples	No. measured	No. Aged
Portugal	24 665	100%	120	9 847	1742
Spain	15 764	100%	132	11 372	3773
Total	40 429	100%	252	21 219	5515

1.6 Benchmarks and interbenchmarks

The WG updated the benchmark issues lists for the individual stocks, reviewed the progress conducted and identified potential benchmarks to be initiated in 2023 (Table 1.6.1). The Benchmark Oversight Group (BOG) approved the benchmarks for anchovy in division 9.a, anchovy in Subarea 8 and horse-mackerel in division 9.a. These benchmarks are being settled on for 2024.

Table 1.6.1 History of benchmarks and proposals by WGHANSA.

Stock	Stock code	History of Benchmarks	WGHANSA 2023 Proposal 2023-2024
Anchovy (*Engraulis encrasicolus*) in Division 9.a (Atlantic Iberian waters)	ane.27.9a	Full Benchmark 2018	Benchmark approved for 2023-2024
Horse mackerel (*Trachurus trachurus*) in Division 9.a (Atlantic Iberian waters)	hom.27.9a	Full benchmark 2011 Full benchmark 2017	Benchmark approved for 2023-2024
Anchovy (*Engraulis encrasicolus*) in Subarea 8 (Bay of Biscay)	ane.27.8	Full benchmark 2013	Benchmark approved for 2023-2024.
Sardine (*Sardina pilchardus*) in Subarea 7 (Southern Celtic Seas, and the English Channel)	pil.27.7	Full benchmark 2013 Full benchmark 2017 Full benchmark 2021	-
Sardine (*Sardina pilchardus*) in divisions 8.a–b and 8.d (Bay of Biscay)	pil.27.8abd	Full benchmark 2013 Full benchmark 2017 Inter-benchmark 2019	-

Stock	Stock code	History of Benchmarks	WGHANSA 2023 Proposal 2023-2024
Sardine (*Sardina pilchardus*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)	pil.27.8c9a	Full benchmark 2013 Full benchmark 2017 Reference points updated in 2021 Inter-benchmark 2021	-
Jack mackerel (*Trachurus pictoratus*) in Subdivision 10.a.2 (Azores grounds)	jaa.27.10a2	-	-

1.7 Mohn's rho

Mohn's rho values for Category 1 and 2 stocks have been uploaded at https://community.ices.dk/ExpertGroups/Lists/Retrobias/overview.aspx and they are summarised in Table 1.7.1. Further details and corresponding plots are provided in the respective chapters of the report.

Table 1.7.1. Mohn's rho values calculated by WGHANSA for Category 1 and 2 stocks.

Stock	Stock code	Terminal year of catch data	Number of retrospective assessments used	F_{bar} rho value	SSB rho: was the intermediate year used as the terminal year?	SSB rho value	R rho: was the intermediate year used as the terminal year?	R rho value
Horse mackerel (*Trachurus trachurus*) in Division 9.a (Atlantic Iberian waters)	hom.27.9a	2022	5	-0.0757	No	0.0821	No	0.1907
Anchovy (*Engraulis encrasicolus*) in Subarea 8 (Bay of Biscay)	ane.27.8	2023	5	-0.301*	Yes	0.437	Yes	-0.168
Sardine (*Sardina pilchardus*) in divisions 8.a–b and 8.d (Bay of Biscay)	pil.27.8abd	2022	5	-0.14	Yes	0.24	Yes	0.29

Stock	Stock code	Terminal year of catch data	Number of retrospective assessments used	F_{bar} rho value	SSB rho: was the intermediate year used as the terminal year?	SSB rho value	R rho: was the intermediate year used as the terminal year?	R rho value
Sardine (*Sardina pilchardus*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)	pil.27.8c9a	2022	5	0.457	Yes	-0.363	Yes	-0.138

*Corresponds to the harvest rate Mohn's rho.

1.8 Transparent assessment framework (TAF)

The Transparent Assessment Framework (TAF) is an online open resource of ICES stock assessments for each assessment year. All data input and output are fully traceable and versioned using a sequence of R scripts. This allows anyone to easily find, reference, download, and run the assessment.

WGHANSA continues making progress towards implementing the assessments into TAF. Anchovy in division 9.a has different repositories for each of the stock components (western and southern). The western component is fully implemented in TAF. The assessment of the southern component could not be implemented in TAF as it is conducted with GADGET and it is run in external high-computing facilities. However, once the model outcomes are available, the process to automatically generate the working document on the assessment of the western component of anchovy in 9.a is uploaded into TAF. The stocks of anchovy in Subarea 8, sardine in Subarea 7, sardine in divisions 8.c and 9.a and sardine in divisions 8.a-b and 8.d are fully implemented in TAF. Furthermore, some of the report sections for anchovy in Subarea 8 are semi-automatically generated using markdown and some progress has been made to automatically produce a draft of the advice sheet for sardine in Subarea 7. The WG will continue working inter-seasonally to finalise the implementation in TAF of the assessment of horse mackerel in division 9.a.

1.9 Ecosystem and Fisheries overviews

No additional progress has been made on these ToRs.

1.10 MSE to propose alternative HCRs for anchovy in division 9.a

During the WGHANSA 2022 meeting it was agreed to conduct a dedicated workshop in the first quarter of 2023 to evaluate by Management Strategy Evaluation the performance of constant harvest rate rules that could be used as an alternative to the current advice rule. Following the new ICES strategy for specific minor modifications during inter-benchmarks periods, the MSE for the two components of the 27.9.a anchovy was presented at an online meeting with

WGHANSA members and ICES designated external reviewers' on the 5th of May 2023. The results, conclusions and extra work developed is described in section 4.15 of this report, indicating the working documents that contain detailed information on the work done, reviewers comments and conclusions. All the relevant documents are included in Annex 6. Based on that work ICES advice for anchovy 9.a for the period July 2023-June 2024 was based on constant harvest rates advice rules for each component that were assessed as precautionary.

1.11 Research needs

Beyond the specific issues identified for each stock, the WG identified the following topics of general interest for future research:

- For the stocks assessed using Stock Synthesis, explore the possibility of conducting the short-term forecast with Stock Synthesis.
- Evaluate the possibility of conducting stochastic short-term forecasts. This would allow to estimate the probability of SSB or F being below/above PA and MSY reference points.
- For stocks for which a MSE framework is available, further investigate potential discrepancies between ICES MSY advice rule and alternative precautionary harvest control rules. Approaches to better communicate these alternative options to managers and stakeholders are needed.
- Further investigate the assessment bias found in the MSE frameworks developed for sardine in divisions 8.c and 9.a and sardine in divisions 8.a-b and 8.d and assess their impact when evaluating harvest control rules and when calculating reference points based on the MSE framework.
- Develop research models aimed at better representing the population dynamics of small pelagic fish, taking into account all stages of the life cycle and explicitly representing demographic rates such as growth, recruitment and mortality (fishing and natural mortality).
- Maturity and reproductive parameters of sardine need to be further studied.
- The exact boundaries of some of the stocks assessed by WGHANSA are unclear and further studies are needed.
- Preliminary results from a genetic study suggests that the boundaries of the sardine stocks in Subarea 7 and 8 might be misplaced. Considering that a stock ID workshop might be needed in the near future, studies using alternative methodologies to identify stock boundaries are needed to be able to apply a holistic approach in the delineation of the stocks. These complementary tools could include otolith-shape, otolith-microchemistry, isotope analysis, or the use of parasites as biological markers, to name a few.
- Some of the stocks assessed by WGHANSA (e.g. anchovy in Subarea 8 and sardine in divisions 8.a-b and 8.d) have shown clear trends in recent years in some biological parameters such as weight-at-age and maturity-at-age. While the underlying reasons have to be further studied, the potential continuation in time of these patterns need to be monitored in following years.
- Currently the recruitment index for sardine in divisions 8c and 9a is based on the age 0 biomass in the 9aCN from the IBERAS survey. Based on the most recent surveys, the representativeness of this area and the possibility to extent the index to a larger area needs to be evaluated.
- Sardine in divisions 8c and 9a is assumed to be in a low productivity regime. However, in the last years there are indications that the stock may be moving towards a higher productivity regime. More research is needed to re-assess the current productivity regime and to adjust the reference points and the advice accordingly.

- The transition to the Regional Database and Estimation System (RDBES) will require substantial work from regional and species working groups, beyond the usual terms of reference. This work will need to be planned and coordinated in the ICES community to ensure a smooth and efficient transition.

2 Anchovy General

This section of the report has not been updated.

3 Bay of Biscay anchovy

3.1 ACOM advice, STECF advice and political decisions

In 2013 and 2014, the STECF evaluated a set of harvest control rules for the management of the Bay of Biscay anchovy stock (STECF, 2013, 2014). The European Commission, EU Member States and stakeholders chose the harvest control rule named G4 with a harvest rate of 0.45. ICES reviewed this harvest control rule in 2015 and concluded that it was precautionary (Annex 5 in ICES (2015)). Subsequently, in December 2015, ICES advised that "when the management plan is applied, catches in 2016 should be no more than 25 000 tonnes". In January 2016 the Council established the TAC in 2016 for the Bay of Biscay anchovy stock at 25 000 tonnes (Council Regulation No 72/2016).

In May 2016, based on the good state of the stock, the South West Waters Advisory Council (SWWAC) asked for a change in the harvest control rule used for management to rule G3 with a rate of exploitation of 0.4 and an increase of the fishing opportunities for 2016 from 25 000 to 33 000 t (SWWAC Advice 101 released on 05/05/2016). In June, the Council increased the 2016 TAC to 33 000 t (Council Regulation No 891/2016), on the basis that "The stock biomass and recruitment of anchovy in the Bay of Biscay are among the highest in the historical time-series, thus allowing a higher precautionary TAC in 2016 in accordance with the management strategy assessed by the Scientific, Technical and Economic Committee for Fisheries (STECF) in 2014".

This new harvest control rule has formed the basis of the ICES advice and the TAC subsequently established by the Council from 2017 onwards.

In January 2023 the Council established a provisional TAC of 21 000 tonnes for the Bay of Biscay anchovy stock for the period from 1 January to 30 June 2023 (Council Regulation No 2023/194). The final TAC was set in March at 33 000 tonnes (Council Regulation No 2023/730) from which 90% corresponded to Spain and 10% to France. However, these percentages might be modified due to bilateral agreements be-tween countries.

According to the European Commission Regulation No. 185/2013, the deductions from the anchovy fishing quota allocated to Spain because of over-fishing of mackerel quota in 2009 shall be applied from 2016 to 2023. This supposes a reduction of 3696 tonnes in the 2023 Spanish quota of Bay of Biscay anchovy.

Regarding the landing obligation regulation that aims at progressively eliminate discards in all Union fisheries, in October 2014 the European Commission established a discard plan for certain pelagic species in southwestern waters (No. 1394/2014). This includes an exemption from the landing obligation for anchovy caught in artisanal purse-seine fisheries based on evidence of high survivability and de minimis exemptions both in the pelagic trawl fishery and the purse-seine fishery from 2015 to 2017. These exemptions have been extended until 2023 through various regulations (Commission Delegated Regulation 2018/188, Commission Delegated Regulation 2020/2015, Commission Delegated Regulation 2020/2015).

3.2 The fishery in 2022 and 2023

3.2.1 Fishing fleets

Two fleets operate on anchovy in the Bay of Biscay: Spanish purse-seines (operating mainly during spring) and the French fleet constituted of purse-seiners (the Basque ones operating mainly in spring and the Breton ones in autumn) and pelagic trawlers (operating mainly during the second half of the year but with decreasing catches along years).

Since the reopening of the fishery in 2010 the number of fishing licences for anchovy in Spain have been oscillating between 149 and 175. For France, the number of purse-seiners able to catch anchovy since 2016 is around 28. The exact number of vessels is not fixed, due to important movements in this fleet. Most of them are based in Brittany. The number of Basque French purse-seiners has decreased progressively and some of them joined the north of the Bay of Biscay in the last years. The real target species of these vessels is sardine, and anchovy is more opportunistic in summer or autumn.

The number of French pelagic trawlers decreased drastically during the closure of anchovy fishery (2005–2009) because they were targeting mainly anchovy and tuna. Currently around 12 pairs of trawlers (~24 vessels) are able to target anchovy. In the last years a shift has occurred on the French anchovy fishery. Pair pelagic trawlers mainly targeted tuna between July and October, and single pelagic trawlers didn't catch anchovy. In 2022, there were very low catches by the French fisheries (234 tonnes), 91.9% by purse-seiners and 8.1% by pelagic trawlers. According to the very low price (anchovies were too small for the market), vessels have dedicated their fishing effort to other species, particularly tuna and sardine.

A more complete description of the fisheries is available in the stock annex.

3.2.2 Catches

Historical catches are presented in Table **3.2.2.1** and Figure 3.2.2.1 Total catches in 2022 were 25 196 tonnes, from which 4992 corresponded to Spain and 234 to France. In 2020, the French landings of anchovy drastically decreased because vessels found only small or medium-size individuals, and the price was very low, so vessels stopped targeting an-chovy. From the Spanish catches, 8 tonnes corresponded to anchovy used as live bait for tuna fishing. Discards are less than 1% of the total catch and they are considered negligible for this stock.

The series of monthly catches are shown in Table **3.2.2.2**. In 2022, most of the catches occurred between April and May, where the bulk of the Spanish fishery occur. Although catches were recorded in all the months.

The quarterly catches by division in 2022 are given in Table 3.2.2.3. Most of the catches took place in the second quarter (72.1%), followed by the third quarter (13.9%) and with lower catches in first and fourth quarters (12.6% and 5.4% respectively). The major fishing activity of the Spanish fleet occurred in the second quarter (72.7%) followed by the third quarter (13.4%), whereas the French fleet operated mainly in the third quarter (70%). Re-garding fishing areas, most of the Spanish catches in the first semester corresponded to ICES division 8.c East, whereas in the second semester catches occurred in division 8.c East and West. All the French catches corresponded to ICES divisions 8.a and 8.b.

In previous years, non-negligible catches originate in divisions 7.h and 7.e (statistical rectangles 25E5 and 25E4) were reallocated to Division 8.a due to their very concentrated location at the boundary between 8.a, 7.h and 7.e in the same period. In 2022 around 60 tonnes have been declared in 25E5 and 25E4 and these catches have been reallocated to 8.a.

Table 3.2.2.1: Bay of Biscay anchovy: Annual catches (in tonnes) as estimated by the Working Group members.

COUNTRY	FRANCE	SPAIN	SPAIN	UNALLOCATED	OTHER COUNTRIES	INTERNATIONAL
YEAR	8ab	8bc	Live Bait Catches			8
1960	1 085	57 000	n/a			58 085
1961	1 494	74 000	n/a			75 494
1962	1 123	58 000	n/a			59 123
1963	652	48 000	n/a			48 652
1964	1 973	75 000	n/a			76 973
1965	2 615	81 000	n/a			83 615
1966	839	47 519	n/a			48 358
1967	1 812	39 363	n/a			41 175
1968	1 190	38 429	n/a			39 619
1969	2 991	33 092	n/a			36 083
1970	3 665	19 820	n/a			23 485
1971	4 825	23 787	n/a			28 612
1972	6 150	26 917	n/a			33 067
1973	4 395	23 614	n/a			28 009
1974	3 835	27 282	n/a			31 117
1975	2 913	23 389	n/a			26 302
1976	1 095	36 166	n/a			37 261
1977	3 807	44 384	n/a			48 191
1978	3 683	41 536	n/a			45 219
1979	1 349	25 000	n/a			26 349
1980	1 564	20 538	n/a			22 102
1981	1 021	9 794	n/a			10 815
1982	381	4 610	n/a			4 991
1983	1 911	12 242	n/a			14 153
1984	1 711	33 468	n/a			35 179
1985	3 005	8 481	n/a			11 486
1986	2 311	5 612	n/a			7 923
1987	4 899	9 863	546			15 308
1988	6 822	8 266	493			15 581
1989	2 255	8 174	185			10 614
1990	10 598	23 258	416			34 272
1991	9 708	9 573	353			19 634
1992	15 217	22 468	200			37 885
1993	20 914	19 173	306			40 393
1994	16 934	17 554	143			34 631
1995	10 892	18 950	273			30 115
1996	15 238	18 937	198			34 373
1997	12 020	9 939	378			22 337
1998	22 987	8 455	176			31 617
1999	13 649	13 145	465			27 259
2000	17 765	19 230	n/a			36 994
2001	17 097	23 052	n/a			40 149
2002	10 988	6 519	n/a			17 507
2003	7 593	3 002	n/a			10 595
2004	8 781	7 580	n/a			16 361
2005	952	176	0			1 128
2006	913	840	0			1 753
2007**	140	1	0			141
2008	0	0	0			0
2009	0	0	0			0
2010	4 573	5 744	n/a			10 317
2011	3 615	10 916	n/a			14 530
2012	5 975	7 896	n/a	531		14 402
2013	2 392	11 801	n/a			14 192
2014	4 012	16 114	n/a			20 126
2015	4 261	23 992	n/a		5	28 258
2016	2 300	18 060	310			20 670
2017	3 153	22 955	332	9		26 450
2018	3 151	27 607	15			30 773
2019	2 048	24 802	7			26 857
2020	138	25 661	24			25 823
2021	64	27 917	1			27 982
2022	234	24 953	8			25 196
2023 (Up to end of Octo	878	26 312				27 190
AVERAGE (1960-2004)	6 394	26 337				32 824
AVERAGE (2010-2022)	2 973	18 622	100			21 967

** : Experimental fishery

Table 3.2.2.2: Bay of Biscay anchovy: Monthly catches (Subarea 8) (without live bait catches).

YEAR\MONTH	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
1987	0	0	454	5246	5237	782	229	636	707	812	309	352	14763
1988	6	0	42	1657	4317	3979	584	1253	2423	445	136	246	15088
1989	706	73	36	588	4943	806	132	566	186	472	1619	301	10429
1990	80	6	2101	2658	11459	3083	1471	5132	5553	1570	652	92	33856
1991	1418	2175	626	2036	6913	1858	215	479	1621	822	238	882	19282
1992	2422	1864	1282	4241	13125	3448	719	1488	3291	3228	2489	89	37685
1993	1738	1864	3362	3260	7906	5927	2110	2979	4254	3342	3273	70	40086
1994	1972	1917	1591	5741	4761	7231	1796	2306	3382	3295	421	74	34487
1995	620	958	842	5967	12329	2764	439	1098	2155	1382	903	387	29843
1996	1132	647	752	1834	9763	6897	2449	2675	3617	2818	1575	17	34176
1997	2278	688	105	2782	2762	1985	1895	2400	3578	2381	921	185	21961
1998	1558	2363	1276	371	4839	2510	3943	5039	4298	2640	2500	104	31442
1999	2088	1360	626	4681	4282	2345	2052	948	4049	2130	2207	27	26794
2000	2219	948	925	1957	11922	4565	3148	3063	4043	2995	1210	0	36994
2001	960	565	479	2249	14428	4413	2514	3403	4435	3850	2852	1	40149
2002	1436	2561	1573	915	2506	2098	673	1034	2970	1152	578	0	17497
2003	39	2	0	1740	890	1403	294	2297	1602	1322	986	20	10595
2004	210	106	3	2377	3247	3241	902	2017	2886	557	813	2	16360
2005	363	17	35	4	183	525	0	0	0	0	0	0	1127
2006	1	0	33	124	630	870	95	0	0	0	0	0	1753
2007	0	0	0	39	57	45	0	0	0	0	0	0	141
2008	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	299	1324	2955	1532	75	632	2425	863	213	0	10317
2011	0	0	1586	4483	4492	351	2	176	815	1319	1258	47	14530
2012	0	0	68	1060	5663	1809	354	868	2352	1940	288	0	14402
2013	0	3	272	2226	5166	3269	312	316	1375	1069	185	1	14192
2014	0	0	0	3739	8604	1950	180	2081	2025	1188	357	0	20125
2015	0	0	1011	6089	4482	7833	505	1305	6331	590	106	0	28253
2016	41	11	1432	8746	3811	1339	657	1760	687	58	1758	62	20360
2017	21	16	1915	5854	9839	5118	559	937	1307	289	238	15	26108
2018	10	10	1498	8895	12956	2131	1736	1831	1166	508	9	8	30758
2019	7	8	2800	9743	8924	717	1863	1295	866	452	171	4	26850
2020	19	20	220	4090	9896	626	2670	3878	3729	224	405	24	25800
2021	1	1	7384	8512	7209	499	2632	1680	18	32	7	6	27981
2022	6	5	3164	10919	5973	1256	1582	1085	839	145	213	1	25188

Table 3.2.2.3. Bay of Biscay anchovy: Catches in the Bay of Biscay by country and divisions in 2022 (without live bait catches).

COUNTRIES	DIVISIONS	QUARTERS 1	2	3	4	CATCH (t) ANNUAL	%
SPAIN	8abd	146	10	189	18	364	1.5%
	8cE	3009	18030	2458	207	23703	95.0%
	8cW	15	101	695	75	886	3.6%
	TOTAL	3170	18141	3342	300	24953	100.0%
	%	12.7%	72.7%	13.4%	1.2%	100.0%	
FRANCE	8abd	5	7	164	59	234	100.0%
	8cE					0	0.0%
	8cW					0	0.0%
	TOTAL	5	7	164	59	234	100.0%
	%	2.0%	3.0%	70.0%	25.0%	100.0%	
INTERNATIONAL	8abd	150	17	353	77	598	2.4%
	8cE	3009	18030	2458	207	23703	94.1%
	8cW	15	101	695	75	886	3.5%
	TOTAL	3175	18148	3506	358	25188	100.0%
	%	12.6%	72.1%	13.9%	1.4%	100.0%	

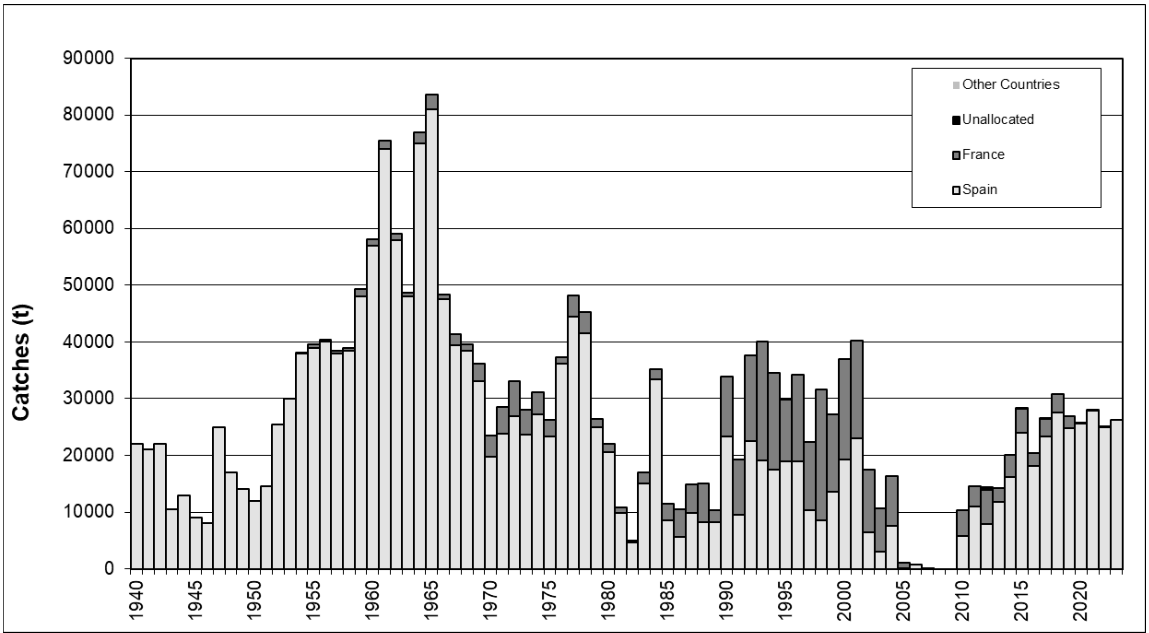


Figure 3.2.2.1. Bay of Biscay anchovy: Historical evolution of catches in Subarea 8 by countries. 2023 data are preliminary

3.2.3 Catch numbers-at-age and length

In 2022 there were no length and age samples available from the French fishery due to the low level of catches. Catch numbers-at-age of the French catches were estimated assuming that the percentage of numbers-at-age per quarter were equal to the percentage of numbers-at-age of the Spanish catches in divisions 8.a and 8.b, where the French fishery occurs.

Catch numbers-at-age by quarter in 2022 for Spain and France are given in Table 3.2.3.1. Age 1 individuals were predominant in the third quarter representing the 47.4% of total catches while age 2 individuals were predominant in the first and second quarters with a 63.5% and a 60.1% of total catches respectively for each quarter. Age 0 individuals appeared in third and fourth quarters, representing the 11.5% and 59.6% of the total of each quarter respectively.

Table **3.2.3.2.** records the age composition of the international catches since 1987, on a half-yearly basis. In 2022, the one-year-old anchovies dominated in the catches in the second semesters, representing the 45.0% while age 2 was dominant in the first semester representing the 61.3% of the catches in that semester.

See the stock annex for methodological issues.

Table 3.2.3.1: Bay of Biscay anchovy: Catch-at-age in thousands for 2022 and quarter (without the catches from the live bait tuna fishing boats).

	QUARTERS	1	2	3	4	Annual total
	AGE	8abc	8abc	8abc	8abc	VIIIabc
TOTAL Sub-area 8	0	0	0	21 726	14 039	35 765
	1	31 238	145 465	89 845	6 021	272 570
	2	97 577	463 356	69 686	2 903	633 522
	3	24 957	152 537	8 338	593	186 425
	4	0	0	51	0	51
	5	0	0	0	0	0
	TOTAL(n)	153 773	761 358	189 646	23 556	1 128 333
	W MED.	20.65	23.84	18.49	15.21	22.32
	CATCH. (t)	3175	18148	3506	358	25188
	SOP	3175	18149	3506	358	25188
	VAR. %	100.01%	100.00%	100.00%	99.99%	100.00%

Table 3.2.3.2. Bay of Biscay anchovy: Catches-at-age of anchovy of the fishery in the Bay of Biscay on half-year basis (including live bait catches up to 1999 and from 2016 onwards). Units: Thousands

INTERNATIONAL

YEAR	1987		1988		1989		1990		1991		1992		1993		1994		1995	
Age	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
0	0	38 140	0	150 338	0	180 085	0	16 984	0	86 647	0	38 434	0	63 499	0	59 934	0	49 771
1	218 670	120 098	318 181	190 113	152 612	27 085	847 627	517 690	323 877	116 290	1 001 551	440 134	794 055	611 047	494 610	355 663	522 361	189 081
2	157 665	13 534	92 621	13 334	123 683	10 771	59 482	75 999	310 620	12 581	193 137	31 446	439 655	91 977	493 437	54 867	282 301	21 771
3	31 362	1 664	9 954	596	18 096	1 986	8 175	4 999	29 179	61	16 960	1	5 336	0	61 667	1 325	76 525	90
4	14 831	58	1 356	0	54	0	0	0	0	0	0	0	0	0	0	0	4 096	7
5	8 920	0	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total #	431 448	173 494	398 971	529 130	294 445	219 927	915 283	615 671	663 677	215 579	1 211 647	510 015	1 239 046	766 523	1 049 714	471 789	885 283	260 719

YEAR	1996		1997		1998		1999		2000		2001		2002		2003		2004	
Age	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
0	0	109 173	0	133 232	0	4 075	0	54 357	0	5 298	0	749	0	267	0	7 530	0	11 184
1	683 009	456 164	471 370	439 888	443 818	598 139	220 067	243 306	559 934	396 961	460 346	507 678	103 210	129 392	50 327	133 083	254 504	252 887
2	233 095	53 156	138 183	40 014	128 854	123 225	380 012	142 904	268 354	64 712	374 424	98 117	217 218	77 128	44 546	87 142	85 679	20 072
3	31 092	499	5 580	195	5 596	3 398	17 761	525	84 437	18 613	19 698	5 095	37 886	3 045	34 133	11 459	12 444	1 153
4	2 213	42	0	0	155	0	108	0	0	0	4 948	0	76	0	887	1 152	4 598	16
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total #	949 408	619 034	615 133	613 329	578 423	728 837	617 948	441 092	912 725	485 584	859 417	611 639	358 390	209 832	129 893	240 366	357 225	285 312

YEAR	2005		2006		2007		2008		2009		2010		2011		2012		2013	
Age	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
0	0	0	0	0	0	0	0	0	0	0	0	16 287	0	4 656	0	3 761	0	10 343
1	7 818	0	48 718	3 894	0	0	0	0	0	0	125 198	135 570	164 061	159 675	56 013	167 935	84 863	81 392
2	32 911	0	17 172	991	0	0	0	0	0	0	77 342	13 864	214 454	11 080	254 863	69 396	223 958	45 177
3	6 935	0	6 465	320	0	0	0	0	0	0	10 897	815	7 161	503	5 055	1 115	87 493	5 559
4	586	0	49	2	0	0	0	0	0	0	1 711	189	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Total #	48 250	0	72 405	5 207	0	0	0	0	0	0	215 149	166 725	385 677	175 914	315 932	242 207	396 315	142 471

YEAR	2014		2015		2016		2017		2018		2019		2020		2021		2022	
Age	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
0	0	37 068	0	443	0	74 571	0	23 725	0	1 770	0	373	0	62 514	0	3 744	0	35 765
1	228 729	187 159	560 920	251 508	261 072	136 044	469 609	82 487	682 918	178 348	305 170	87 158	527 627	544 756	556 251	148 372	176 703	95 866
2	336 224	12 181	357 044	128 579	363 465	58 740	425 906	48 549	399 932	37 574	543 415	77 355	235 637	51 618	514 673	60 779	560 933	72 588
3	53 703	3 035	27 236	6 914	45 212	2 287	92 731	7 660	39 483	1 210	52 579	6 673	30 559	1 601	37 413	167	177 494	8 931
4	4 271	0	173	0	231	0	2 339	0	292	0	440	0	171	3	862	0	0	51
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total #	622 927	239 443	945 373	387 443	669 979	271 642	990 585	162 421	1 122 624	218 902	901 605	171 559	793 994	660 492	1 109 199	213 062	915 131	213 202

3.2.4 Weights and lengths-at-age in the catch

The series of mean weight-at-age in the fishery by half year, from 1987 to 2022, is shown in Table **3.2.4.1**. See the stock annex for methodological issues.

Table 3.2.4.1. Bay of Biscay anchovy: Mean weight-at-age (grammes) in the international catches on half-year basis. Units: grammes.

YEAR	1987		1988		1989		1990		1991		1992		1993		1994		1995	
Sources	Anon. (1989 & 1991)		Anon. (1989)		Anon. (1991)		Anon. (1991)		Anon. (1992)		Anon. (1993)		Anon. (1995)		Anon. (1996)		Anon. (1997)	
Periods	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
Age 0	na	11.7	na	5.1	na	12.7	na	7.4	na	14.4	na	12.6	na	12.3	na	14.7	na	15.1
1	21.0	21.9	20.8	23.6	19.5	24.9	20.6	23.8	18.5	25.1	19.6	23.0	15.5	20.9	16.8	25.3	22.5	26.9
2	32.0	34.2	30.3	30.4	28.5	35.2	28.5	27.7	25.2	29.0	30.9	28.8	27.0	29.4	26.8	28.1	32.3	31.3
3	37.7	39.2	34.5	44.5	29.7	42.7	44.8	40.8	28.2	39.0	37.7	27.4	30.5	na	30.7	30.0	36.4	36.4
4	41.0	40.0	37.6	na	27.1	na	na	na	na	na	na	na	na	na	na	na	37.3	29.1
5	42.0	0.0	48.5	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Total	27.3	20.8	24.6	10.7	23.9	15.6	21.3	24.0	22.1	21.1	21.7	22.5	19.6	21.2	22.3	24.3	26.9	25.0

YEAR	1996		1997		1998		1999		2000		2001		2002		2003		2004	
Sources:	Anon. (1998)		Anon. (1999)		Anon (2000)		WG data		WG data		WG data		WG data		WG data		WG data	
Periods	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
Age 0	na	12.0	na	11.6	na	10.2	na	15.7	na	19.3	na	14.3	na	9.5	na	15.4	na	15.5
1	19.1	23.2	14.4	20.3	21.8	23.7	17.1	27.0	21.7	28.2	22.7	27.5	25.0	28.8	21.0	25.4	21.7	24.9
2	29.3	27.7	26.9	30.1	24.3	27.7	29.8	33.5	29.1	33.0	31.8	31.1	31.6	33.4	36.2	29.5	35.7	33.5
3	35.0	35.7	32.0	29.7	31.9	28.7	34.7	38.9	32.8	36.9	36.3	38.6	42.8	36.5	40.3	36.4	39.3	40.7
4	46.1	39.7	na	na	31.9	na	55.9	na	na	na	40.7	na	45.6	na	36.9	37.9	44.0	42.8
5	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Total	22.2	21.6	17.3	19.1	22.5	24.3	25.4	27.7	24.9	29.0	27.1	28.2	30.9	30.6	31.4	27.1	26.0	25.2

YEAR	2005		2006		2007		2008		2009		2010		2011		2012		2013	
Sources:	WG data		WG data		WG data		WG data		WG data		WG data		WG data		WG data		WG data	
Periods	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
Age 0	na	na	na	na	na	na	na	na	na	na	na	14.4	na	8.9	na	12.6	na	12.0
1	19.3	na	20.3	17.8	na	na	na	na	na	na	25.0	25.9	22.5	20.5	16.7	22.3	20.8	21.9
2	24.5	na	27.7	19.7	na	na	na	na	na	na	32.1	27.4	32.4	27.3	28.9	25.9	28.8	28.7
3	27.6	na	31.3	19.7	na	na	na	na	na	na	43.7	43.2	36.4	34.8	38.7	26.5	31.5	31.6
4	24.5	na	37.3	34.3	na	na	na	na	na	na	43.0	44.4	na	na	na	na	na	na
5	na	na	na	na	na	na	na	na	na	na	55.7	na	na	na	na	na	na	na
Total	24.1	na	23.0	18.2	na	na	na	na	na	na	28.6	25.0	28.3	20.6	26.9	23.2	27.7	23.7

YEAR	2014		2015		2016		2017		2018		2019		2020		2021		2022	
Sources:	WG data		WG data		WG data		WG data		WG data		WG data		WG data		WG data		WG data	
Periods	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
Age 0	na	16.1	0.0	9.4	na	14.3	na	8.5	na	12.5	na	11.9	na	9.3	na	13.7	na	14.6
1	18.3	26.3	17.0	19.9	19.3	20.0	19.8	23.3	20.7	22.1	20.2	21.0	16.5	16.8	19.9	20.0	15.5	17.5
2	25.1	33.3	25.5	28.1	24.5	24.1	25.1	26.8	25.0	28.3	27.4	26.0	21.6	21.9	22.3	22.2	23.2	20.1
3	28.9	45.8	28.7	38.5	31.7	32.8	28.8	30.7	33.7	28.8	32.2	33.6	28.4	28.7	27.6	36.3	31.2	23.2
4	26.0	na	25.5	na	32.6	na	29.9	na	27.8	na	27.7	na	29.3	29.4	32.4	na	na	33.2
5	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Total	22.9	25.3	20.5	22.9	23.0	19.4	23.0	22.6	22.7	23.2	25.3	23.7	18.5	16.5	21.3	20.5	23.3	18.1

3.2.5 Preliminary fishery data in 2023

The provisional catches during the first semester of 2023 were 24 213 t, from which 24 208 t corresponded to Spain and 4 t to France. 62% of the catches (in mass) during the first semester were age 1. During the second semester provisional catches until the end of October were 2977 t, from which 2104 t corresponded to Spain and 874 t to France. Overall, the total catches in 2023 from France were low (878 t).

It must be emphasised that 2023 fishery data are preliminary. No age structure was available yet for the French catches in the first half of the year, and they were assumed to have the same age composition as the Spanish catches in April, when most of the catches of the first semester took place. For the assessment, 2023 November and December catches were assumed to be 635 t (2.3% of the total annual catch which is the average percentage of the catches in November and December in 2010–2022, after the re-opening of the fishery). Therefore, the total catch in November and December was estimated at 635 t, resulting in 3612 tonnes for the second semester 2023.

3.3 Fishery independent data

3.3.1 BIOMAN DEPM survey 2023

All the methodology for the survey and the estimates performance are described in detail in **annex A.5**_stock annex - Bay of Biscay Anchovy (Subarea 8). A detailed report of the survey and results 2023 is attached as a working document at ICES WGACEGG 2023 in **annex** 3 (Santos Mocoroa. M *et al*. BIOMAN 2023).

3.3.1.1 Survey description

The 2023 anchovy DEPM survey was carried out in the Bay of Biscay from the 3rd to the 26th of May, covering the whole spawning area of the species, following the procedures described in the **annex A.5**_stock annex- Bay of Biscay Anchovy (Subarea 8). Two research vessels were used at the same time and place: the RV Vizconde de Eza to collect plankton and adult samples and the RV Emma Bardán to collect adult samples. Some specifications of the sampling are given in **Table 3.3.1.1.1.**

Total number of PairoVET samples (vertical sampling) obtained was 778. From those, 584 had anchovy eggs (75%) with an average of 314 eggs m^{-2} per station in the positive stations, and a maximum of 4350 eggs m^{-2} in a station. A total of 18 039 anchovy eggs were encountered and classified. The number of CUFES samples (horizontal sampling) obtained was 1,824. Frome those 778 (63%) stations had anchovy eggs with an average of 30 eggs m^{-3} per station and a maximum of 845 eggs m^{-3} in a station in the positive stations.

This year 19% of the anchovy eggs abundance was found in the Cantabrian Sea, the eggs were distributed all over the area and beyond 200m depth isoline, the area surveyed limit was at 6º20'W. In the French platform there were eggs all over the platform and passed the 200 m depth isoline almost in all the area up to the limit of area ICES 8 (48ºN), except for the west part of the platform from 47º30 to 48ºN that arrived until 180m approximately. (**Figure 3.3.1.1.1**). The total area covered was 113 814Km^2 and the spawning area for anchovy was 77 312Km^2, 68% of the total.

In relation with the adult samples, 42 pelagic trawls were selected for the analysis. The spatial distribution of the samples and their species composition is shown in **Figure 3.3.1.1.2**. The most abundant species in the trawls ware: anchovy, sardine, blue whiting and mackerel. Anchovy adults were found in the same places where the anchovy eggs were found. This year the biggest anchovy was found in the Cantabrian Sea. The smallest anchovy was found around the mouth of the Gironde River. Spatial distribution of mean length and mean weight is shown in **Figure 3.3.1.1.3**

This year the mean sea surface temperature of the survey, 15.5 °C was lower than last year (16.7 °C), the minimum was 12.47 °C and the maximum 18.21 °C. The mean sea surface salinity (34.98) was lower than last year (34.8) with a minimum of 31.31 and a maximum of 35.96. There were atypical weather conditions this year during May, it was the warmest of this century and the second driest in the historical series.

Figure 3.3.1.1.4 shows the maps of sea surface salinity and temperature registered during the survey.

3.3.1.2 Total daily egg production estimate

The estimates of daily egg production(P_0), daily egg mortality rates (z) and total egg production (P_{tot}) are given in **Table 3.3.1.2.1** and the mortality curve model adjusted is shown in **Figure 3.3.1.2.1.** Total egg production in 2023 was estimated at 1.01 E+13 with a CV of 0.0949, lower than the last five years but still above the historical mean. **Figure 3.3.1.2.2** shows the historical series of P_0, z, spawning area and P_{tot}

3.3.1.3 Daily fecundity and total biomass

To estimate the total Biomass following the DEPM a daily fecundity (*DF*) estimate is necessary. To estimate the *DF* the sex ratio (*R*), the female mean weight (W_f), the batch fecundity (*F*) and the spawning fraction (*S*) estimates are required. The anchovy adults from the survey were used to estimate those parameters. This year there were no problems in estimating those parameters. The results of all those parameters are showed in **Table 3.3.1.3.1** and the historical series in **Figure 3.3.1.3.1**. The final **total biomass** obtained as the quotient between P_{tot} and *DF* was **160.549 t** with a **CV of 0.1178,** lower than the last five years but still above the historical mean.

3.3.1.4 Population at age

To estimate the numbers at age, the age readings based on 2813 otoliths from 42 samples, well distributed over the spawning area, were available. Six strata were defined based on the egg abundance, the adult distribution and the mean size, mean weight, and age of adult anchovy: Cantabrian (C), South (S), Centre (C), Garonne (G), West (W) and North (N) (**Figure 3.3.1.4.1**). 82% of the anchovy in numbers were estimated as individuals of age 1 (76% in mass), 15% of the individuals in numbers were of age 2 (20% in mass) and 3% of the individuals in numbers were of age 3 (5% in mass) (**Table 3.3.1.4.1**). This was a high year recruitment in relation with the historical series. The anchovy age composition by haul is showed in **Figure 3.3.1.4.2**. The time series of the numbers at age is shown in **Figure 3.3.1.4.3.** The historical series of the total biomass at age and weight at age that is downwards is showed in **Figure 3.3.1.4.4** and those parameters for this year and the length at age are showed in **table 3.3.1.4.1.**

Table 3.3.1.1.1: Bay of Biscay anchovy: Details of the DEPM survey BIOMAN 2023.

Parameters	Anchovy DEPM survey
Surveyed area	(43°18' to 48°00′N & 7° 36′ to 1°13' W)
R/V	*Vizcon de Eza* & *Emma Bardán*
Date	03-26/05/2023
Eggs	RV Vizconde de Eza
PairoVET stations (plankton)	778
% st with anchovy eggs	75%
Anchovy egg average by st	314 eggs/m^2
Max. anchovy eggs in a St	4,350 eggs/m^2
Total ANE egg collected&staged	18,039 eggs
North spawning limit	48°00′N
West spawning limit (Cantabrian)	6°20′W
Total area surveyed	113,814 Km^2
Spawning area for anchovy	77,312 Km^2
CUFES stations (plankton)	1,824
Adults	RV E.Bardán,Vizconde,Thalassa& PSeines
Pelagic trawls	40(EBardán)+5(thalassa)+5 (Vizconde)
Pelagic trawls with anchovy	35(EBardán)+3(Thalassa)+3(Vizconde)
Selected for analysis	41
Hauls from purse seines	1
Total adult samples for analysis	42

Table 3.3.1.2.1: Bay of Biscay anchovy: 2023 estimates for daily egg production (P0) (egg/m²/day), daily mortality rates (z) and total daily egg production (Ptot)(eggs/day) with its Standard error (S.e) and coefficient of variation (CV).

Parameter	Value	S.e.	CV
P_0	130.59	12.39	0.0949
z	0.28	0.056	0.2026
Ptot	1.01E+13	9.6E+11	0.0949

Table 3.3.1.3.1: Bay of Biscay anchovy: estimates of adult parameters for applying the DEPM for anchovy in the Bay of Biscay (ICES 8abcd): sex ratio (R) (% of females), spawning fraction (S) (% of females spawning per day), batch fecundity (F) (eggs/batch/mature female), female mean weight (Wf)(g) and daily fecundity (DF) (eggs/g/day) for the application of the DEPM and total biomass (B)(tons) with their standard error (S.e) and coefficient of variation (CV). Total egg production (Ptot)(eggs) estimate is showed as well.

Parameter	estimate	S.e.	CV
P_{tot} (eggs)	1.01E+13	9.6E+11	0.0949
R´(% of females)	0.53	0.0066	0.0123
S (% fem. spawning/day)	0.34	0.0181	0.0533
F (eggs/batch/mature fem.)	5,566	437	0.0786
W_f(g)	15.94	0.96	0.0599
DF (eggs/g/day)	63.21	4.42	0.0699
B (tons)	**160,549**	18,914	0.1178

Table: 3.3.1.4.1: Bay of Biscay anchovy: Anchovy total biomass (B), percentage at age, numbers at age, percentage at age in mass, total biomass at age in mass, mean weight at age (g), mean length at age(mm), with the correspondent standard error (S.e.) and coefficient of variation (CV) from BIOMAN 2023.

Parameter	estimate	S.e.	CV
BIOMASS (tons)	**160,549**	18,914	0.1178
total mean Weight (g)	13.32	0.73	0.0550
Population (millions)	12,071	1,657	0.1373
Percentage at age 1	0.82	0.021	0.0257
Percentage at age 2	0.15	0.016	0.1047
Percentage at age 3+	0.03	0.008	0.2412
Numbers at age 1	9,866	1,485	0.1506
Numbers at age 2	1,828	232	0.1272
Numbers at age 3+	377	93	0.2470
Percent. at age 1 in mass	0.76	0.024	0.0316
Percent. at age 2 in mass	0.20	0.018	0.0920
Percent. at age 3+ in mass	0.05	0.010	0.2042
Biomass at age 1 (tons)	121,532	15,359	0.1264
Biomass at age 2 (tons)	31,538	4,321	0.1370
Biomass at age 3+ (tons)	7,479	1,721	0.2301

Biological Features	estimate	S.e.	CV
Weight at age 1 (g)	12.3	0.64	0.0523
Weight at age 2 (g)	17.1	0.80	0.0467
Weight at age 3 (g)	19.6	1.12	0.0574
Length at age 1 (mm)	126.5	1.88	0.0148
Length at age 2 (mm)	141.0	1.82	0.0129
Length at age 3 (mm)	148.0	2.12	0.0143

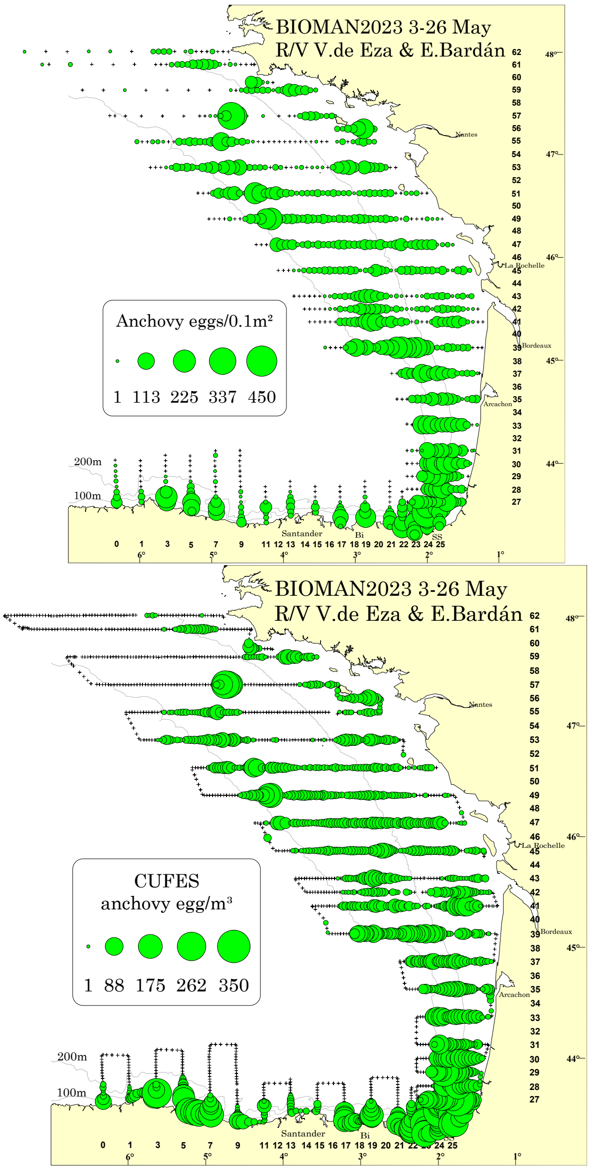


Figure 3.3.1.1.1: Bay of Biscay anchovy: Spatial distribution and abundance of anchovy egg obtained with PairoVET (vertical sampling net) (eggs per 0.1 m2) (left) and CUFES (horizontal sampling net) (egg/m³) obtained during the DEPM survey BIOMAN2023.

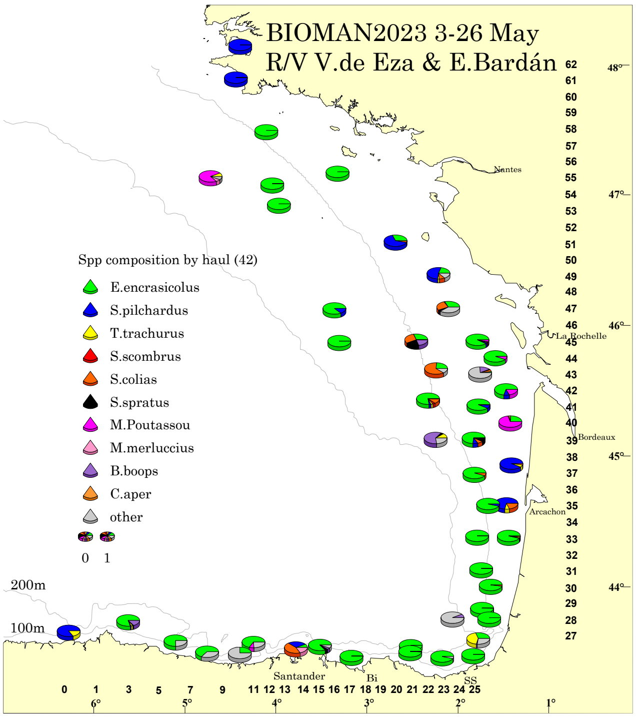


Figure 3.3.1.1.2: Bay of Biscay anchovy: Species composition of the 42 hauls obtained for the anchovy adult parameters analysis for the application of the DEPM.

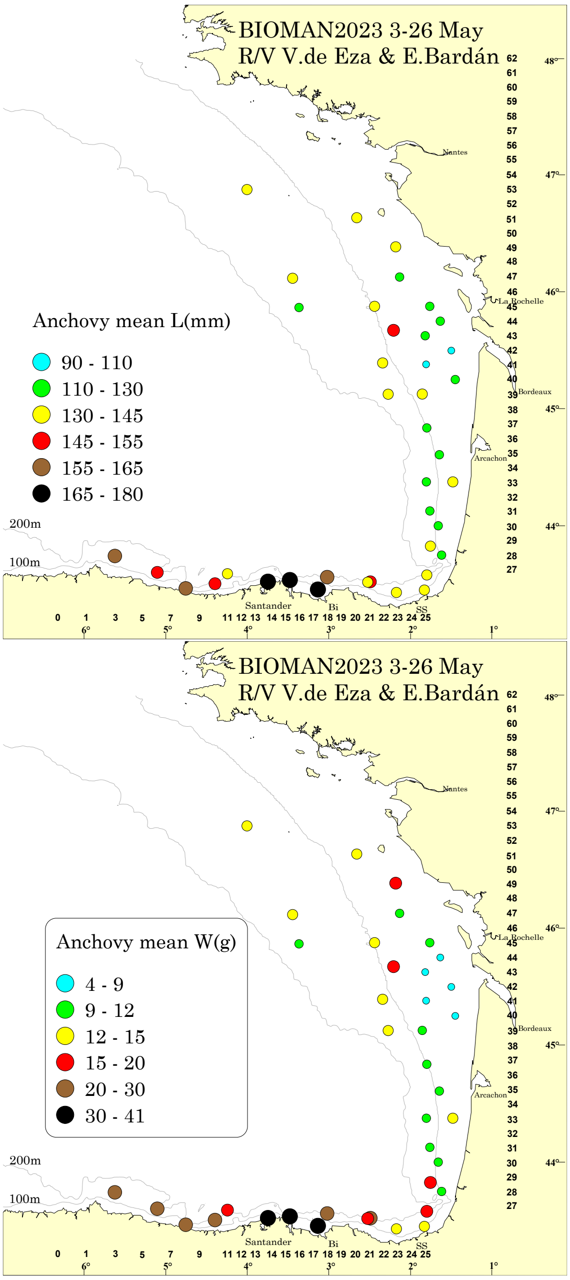


Figure 3.3.1.1.3: Bay of Biscay anchovy: Spatial distribution of anchovy mean length (left) and mean weight (right) (males and females) by haul during BIOMAN2023.

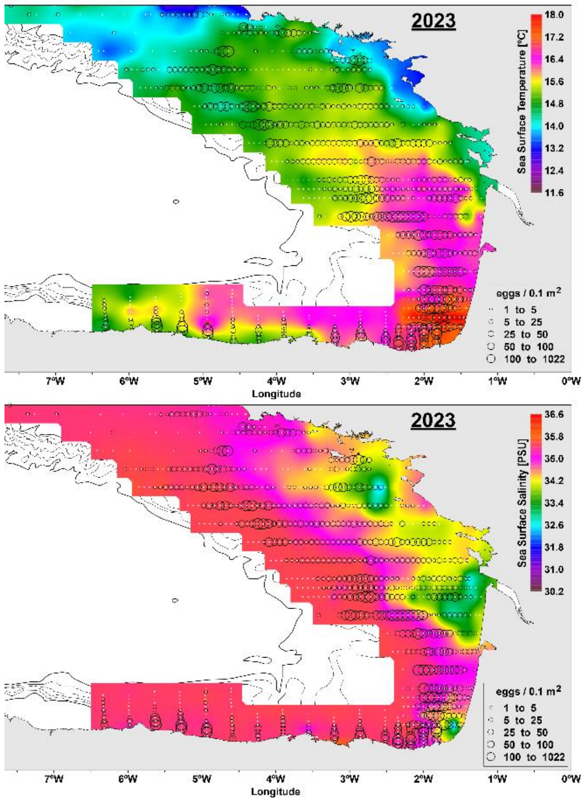


Figure 3.3.1.1.4: Bay of Biscay anchovy: Spatial distribution of sea surface temperature (left) and sea surface salinity (right) during BIOMAN 2023 with the anchovy egg abundances spatial distribution.

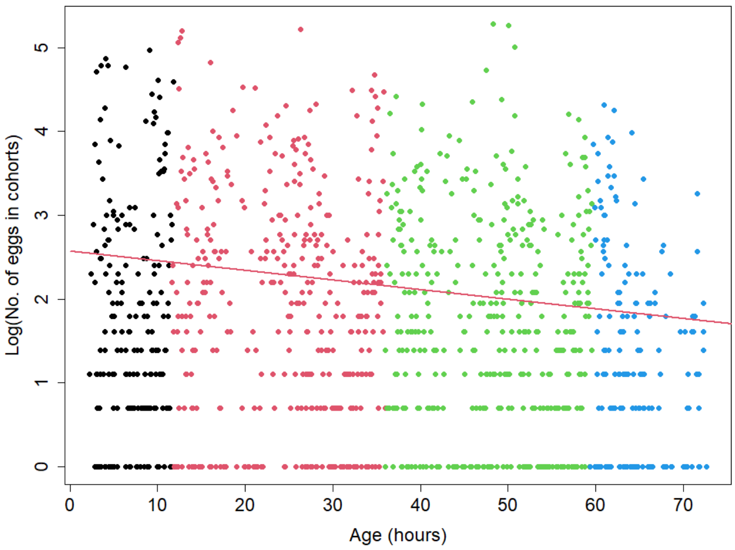


Figure 3.3.1.2.1: Bay of Biscay anchovy: Exponential mortality model in log scale adjusted applying a GLM to the data obtained in the Bayesian egg ageing (spawning peak at 23:00h GMT). The red line is the adjusted line. The coloured dots represent the different cohorts.

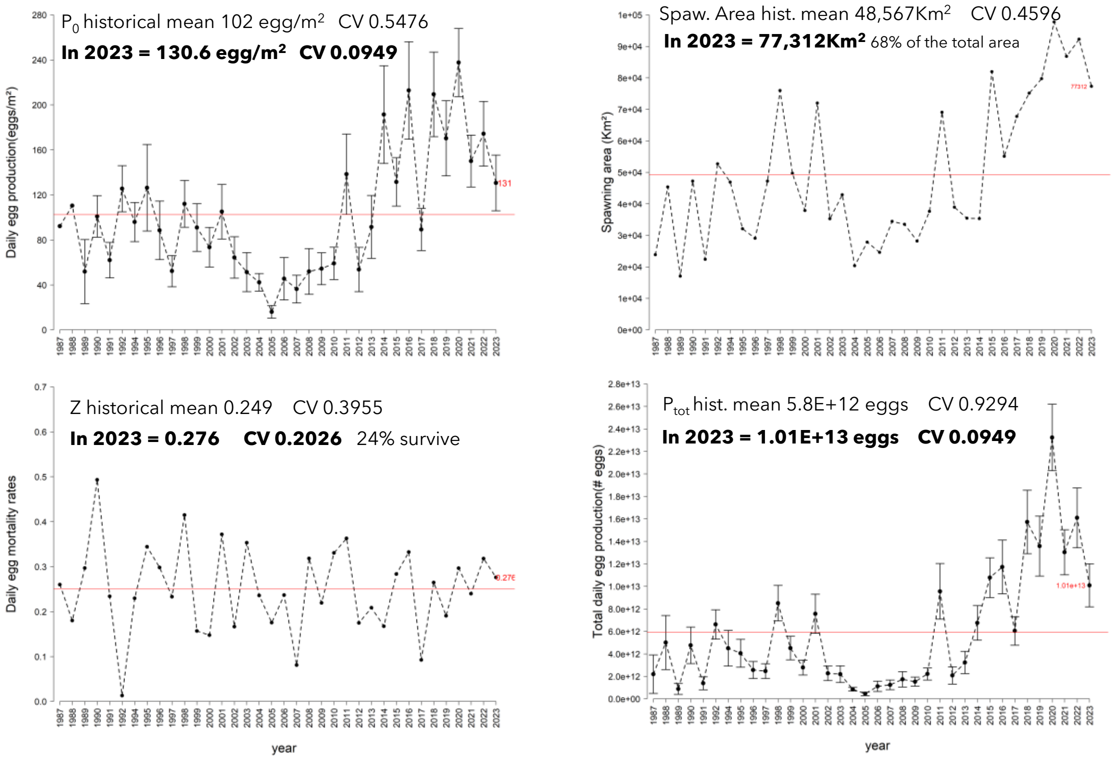


Figure 3.3.1.2.2: Bay of Biscay anchovy: historical series including 2023 estimates for daily egg production (P0) (egg/m²/day), spawning area (Km²), daily mortality rates (z) and total daily egg production (Ptot)(eggs/day) for anchovy in the Bay of Biscay (ICES 8abcd). The red line is the historical mean, the value showed in bold is the historical mean and CV is de coefficient of variation over time for each parameter.

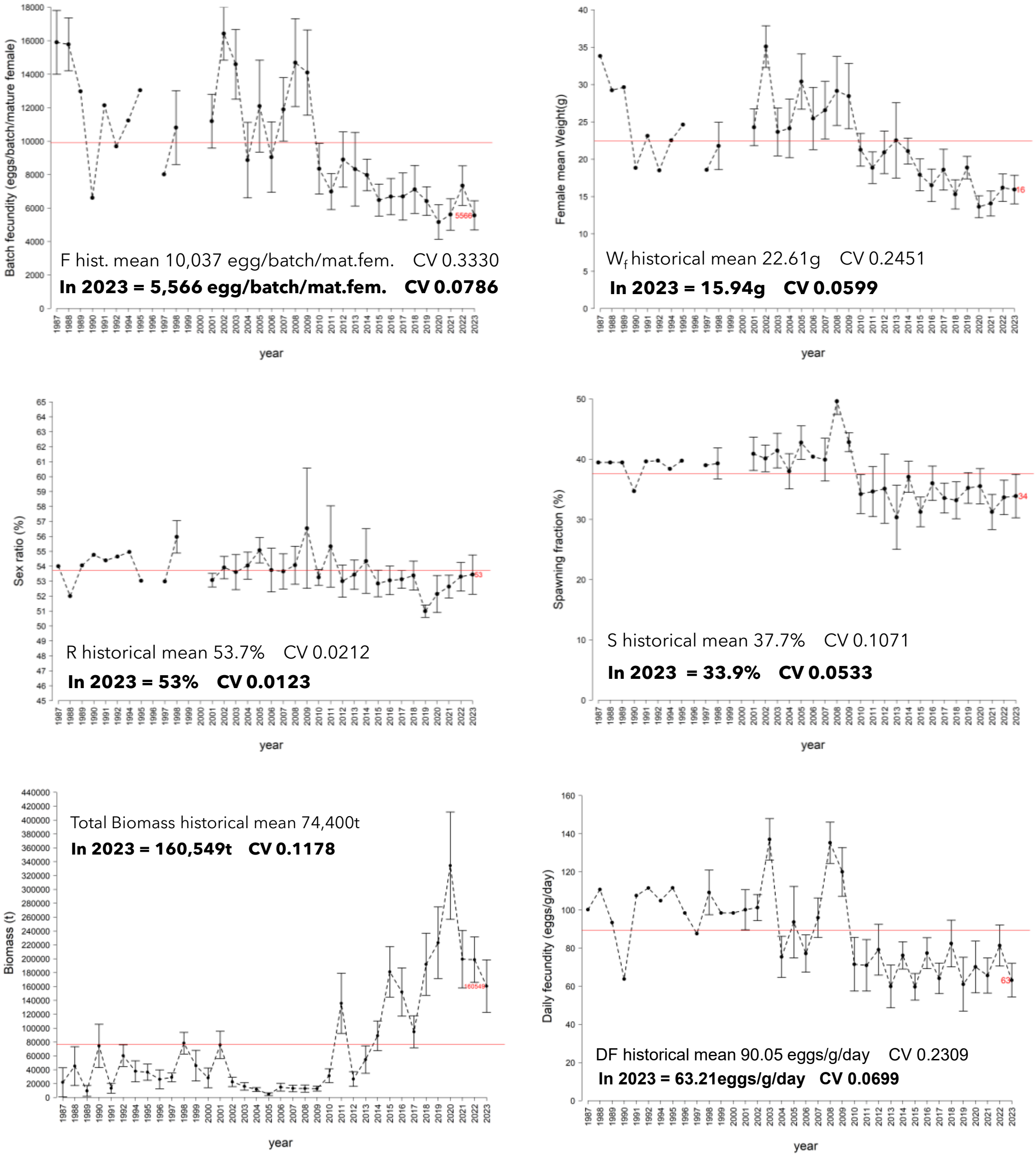


Figure 3.3.1.3.1: Bay of Biscay anchovy: historical series including 2023 estimates of the adult parameters for anchovy in the Bay of Biscay (ICES 8abcd): batch fecundity (F) (eggs/batch/mature female), female mean weight (Wf)(g), sex ratio (R) (% of females), spawning fraction (S) (% of females spawning per day), daily fecundity (DF) (eggs/g/day) for the application of the DEPM and the total biomass (B)(tons). The red line is the historical mean, the value showed in bold is 2023 value. The historical mean is as well showed with a CV as the coefficient of variation over time for each parameter.

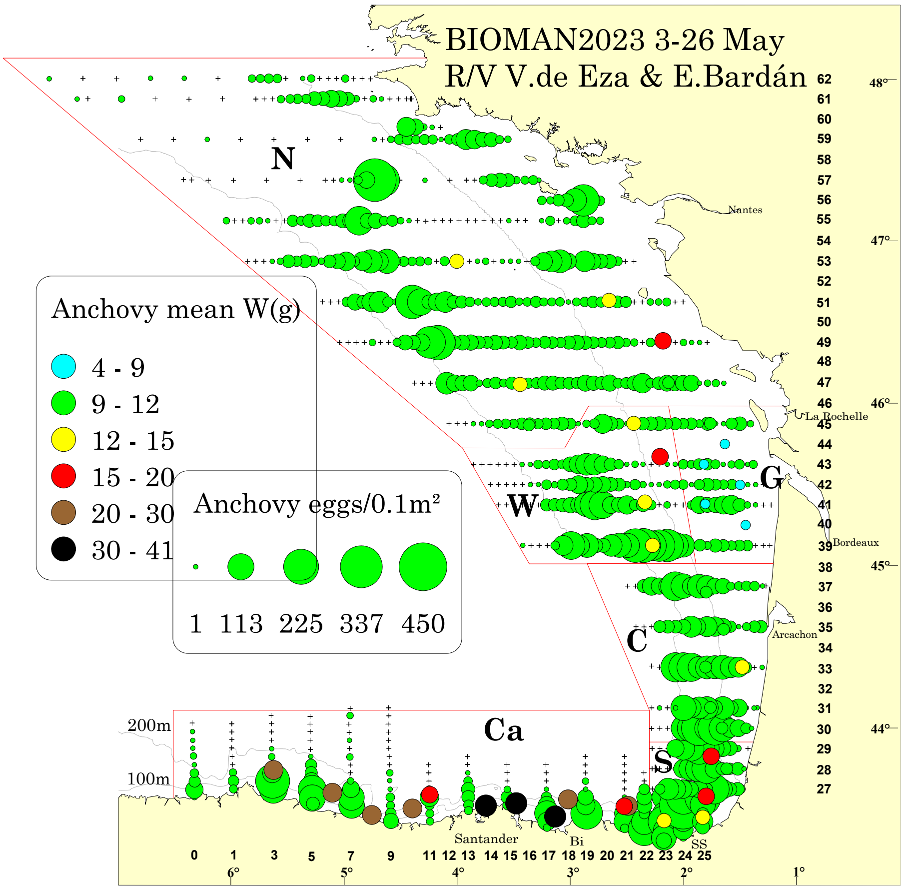


Figure 3.3.1.4.1: Bay of Biscay anchovy: 6 regions were defined to weight the adult samples to estimate anchovy numbers at age in 2023: Cantabrian (Ca), South (S), Centre (C), Garonne (G), West (W), and North (N). The red lines represent the border of the regions, the green bubbles the abundance of anchovy eggs (egg/0.1m2) in each station and the small colour bubbles represent the mean weight (g) of individuals within each haul.

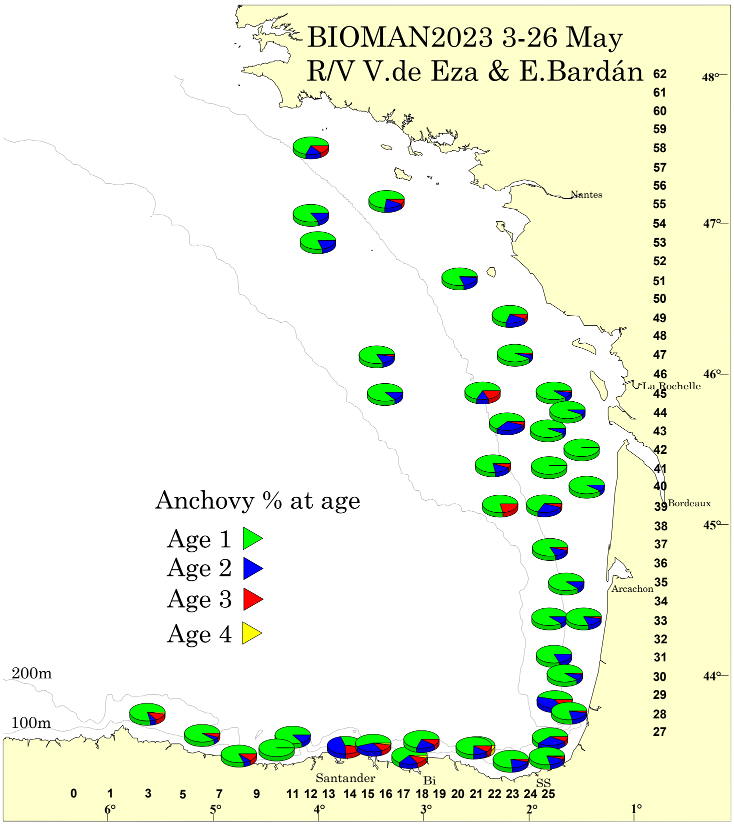


Figure 3.3.1.4.2: Bay of Biscay anchovy: Anchovy age composition in space by haul during BIOMAN2023.

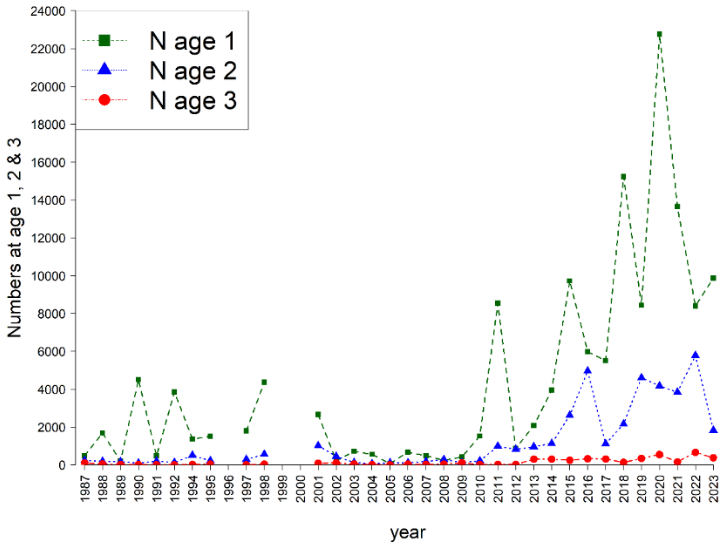
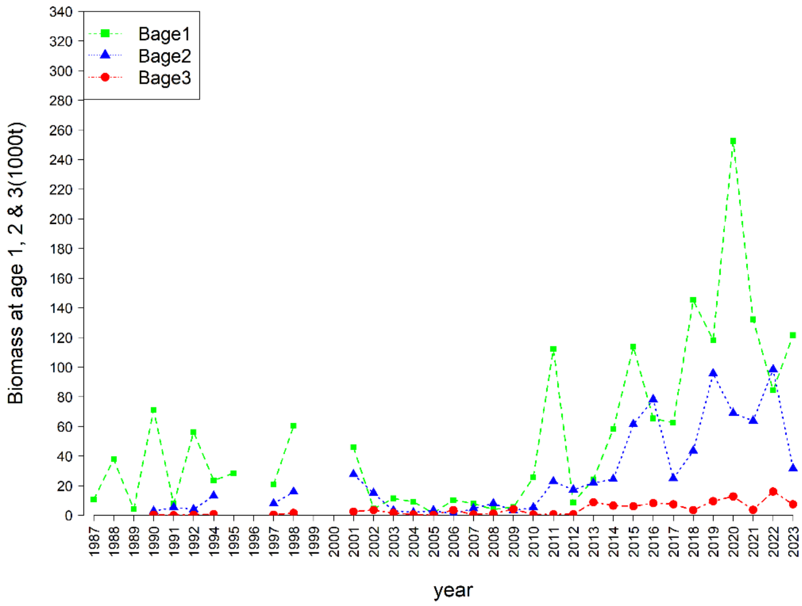


Figure 3.3.1.4.3: Bay of Biscay anchovy: Anchovy historical series of numbers at age from 1987 to 2023 from BIOMAN surveys.



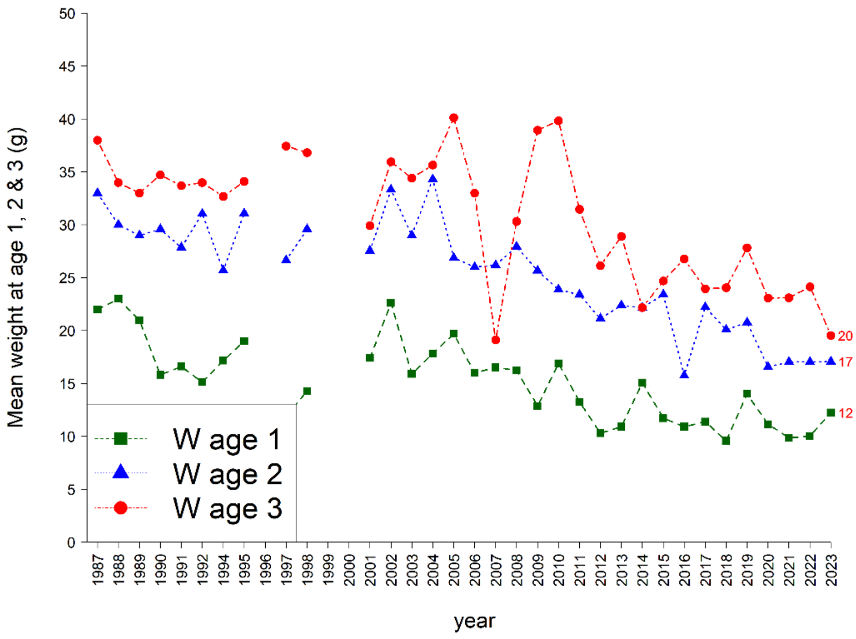


Figure 3.3.1.4.4: Bay of Biscay anchovy: Anchovy historical series (1987-2023) of total biomass at age and mean weight at age.

3.3.2 PELGAS spring acoustic survey 2023

An acoustic survey (PELGAS) is carried out every year in the Bay of Biscay in spring onboard the French research vessel Thalassa. The objective of PELGAS survey is to study the abundance and distribution of pelagic fish in the Bay of Biscay. The main target species are anchovy and sardine, but they are considered in a multi-specific context and within an ecosystem approach as they are located in the centre of pelagic ecosystem.

A consort survey is routinely organised since 2007 with French commercial vessels during 18 days. This approach is identical to last year's surveys, using the commercial vessel's hauls for echoes identification and biological parameters to complement hauls made by the R/V Thalassa.

Four commercial vessels (two pairs of pelagic trawlers) participated to PELGAS23 survey:

A total of 100 hauls (including not valid) were carried out during the consort survey including 56 hauls by the R/V Thalassa and 44 hauls by commercial vessels.

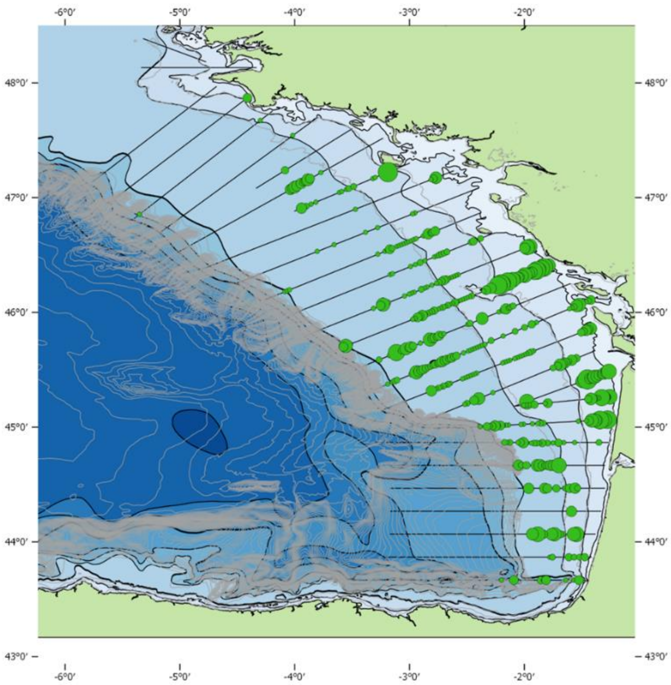


Figure 3.3.2.1: Bay of Biscay anchovy: total abundance of anchovy per ESDU in 2023.

The biomass estimate of anchovy observed during PELGAS2023 is 78 941 tonnes, which is about the average of the series, but far away the strong maximum as observed in 2021.

In the Gironde area, the configuration was very unusual in terms of energy compared to what is usually observed, with a very low energy attributed to anchovy. It may be linked with absence of river discharge this year.

The one-year-old anchovies were present in more coastal areas than older fishes (in terms of energy and, as well, biomass) and they were sometimes mixed. The average size of one year old fish was comparable the average size in recent years but shows a clear decreasing trend, year after year. Bigger (and older) fish appeared close to the surface or in midwater from the central part to the North of the Bay of Biscay.

The other picture of anchovy we can have in 2023, as explained previously, is the fact that we were able to scrutinise the lateral echograms and to have an idea, with the echointegration, of the amount of biomass we lose this year if we take into account only the vertical echograms. In 2023, 20% of the total index of biomass were localised close to the surface. The biomass of 79 000 tons doesn't take that in consideration.

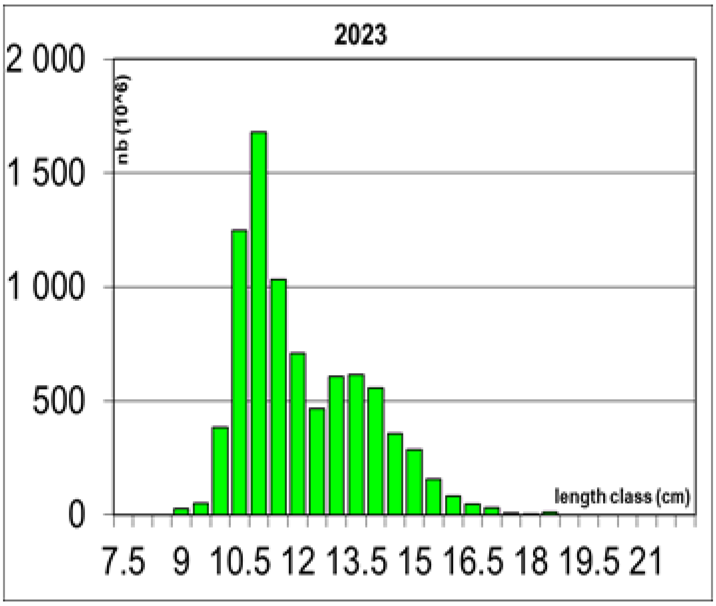


Figure 3.3.2.2: Bay of Biscay anchovy: length distribution of global anchovy as observed during PELGAS23 survey.

Globally we observe that length structure shows a classic distribution, with fish from 9 to 18 centimetres. It must be noticed that even if some individuals were small (less than 12 cm), almost all fishes were mature and in their spawning period (including individuals starting their maturation). This observation on maturity contrasted with the 2015 observation where a large proportion of the population was not spawning at the period of the survey.

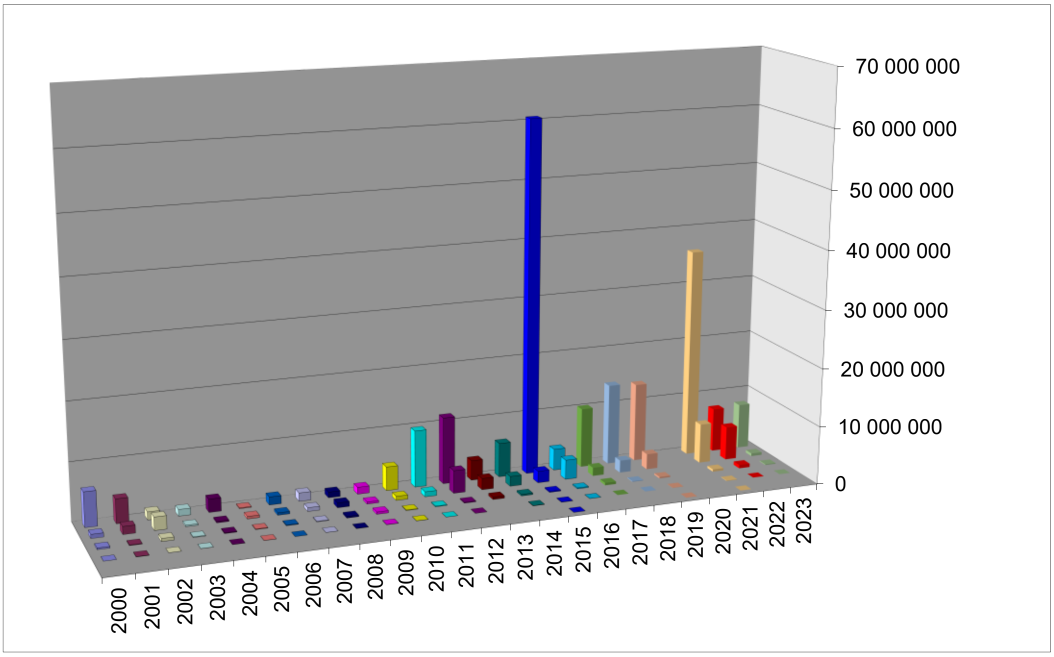


Figure 3.3.2.3: Bay of Biscay anchovy: Anchovy numbers at age as observed during PELGAS surveys since 2000.

The huge 2015 age class is not followed in 2016 and in 2017 as well (Figure 3.3.2.3). Once again, it could indicate that an overestimation occurred on the recruitment in 2015. Several investigations have been done to explain, without results for the time being.

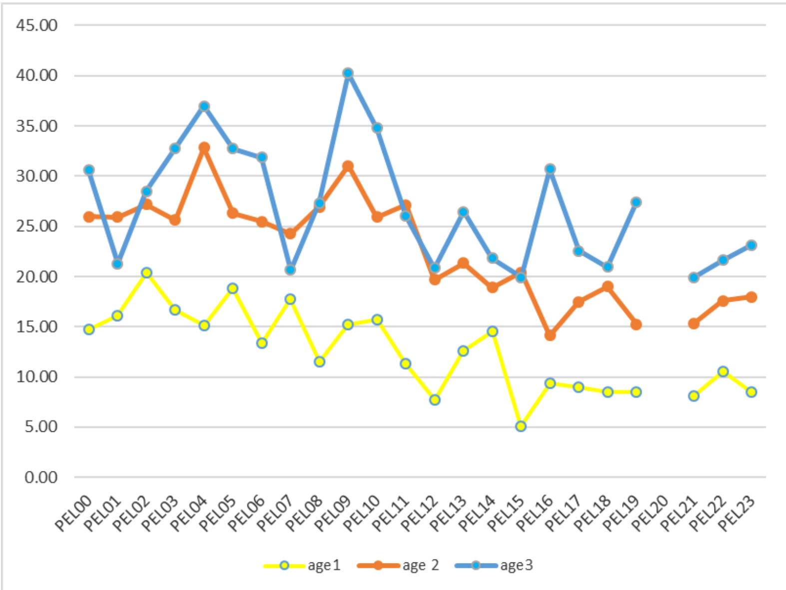


Figure 3.3.2.4: Bay of Biscay anchovy: evolution of mean weight at age (g) of anchovy along PELGAS series.

As previous years, we observe that globally the trend of the mean weight at age is a decrease (Figure 3.3.2.4). This trend is almost the same for sardine in the Bay of Biscay, even this trend seems to stop since 2016. Further investigates should be done. Potential hypothesis are related to an effect of density-dependence or a change in planktonic composition, although we do not have real explanation for the time being.

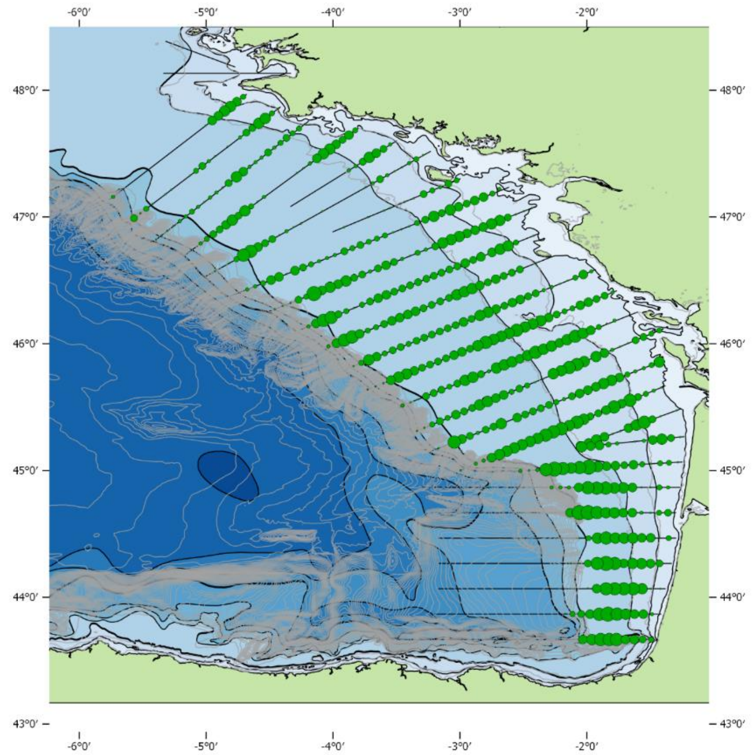


Figure 3.3.2.5: Bay of Biscay anchovy: Distribution of anchovy eggs observed with CUFES during PELGAS23.

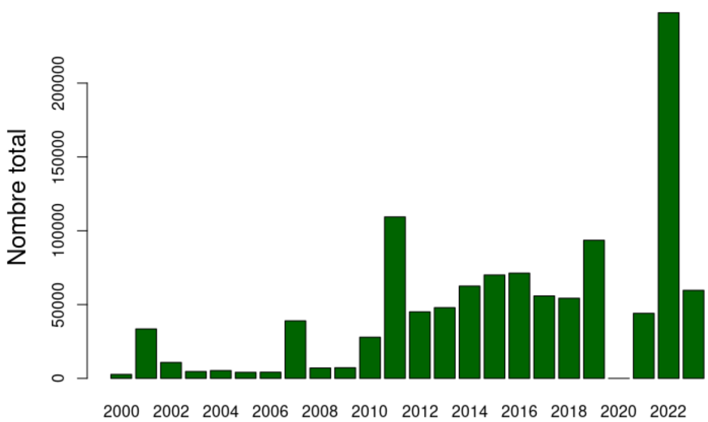


Figure 3.3.2.6: Bay of Biscay anchovy: Number of eggs observed during PELGAS surveys from 2000 to 2023

During this survey, in addition of acoustic transects and pelagic trawl hauls, 649 CUFES samples were collected and counted, 68 vertical plankton hauls and vertical profiles with CTD were carried out. Eggs were sorted and counted automatically with the zoocam system, and staged during the survey.

Between 2011 and 2021, the bay of Biscay marked by a large quantity of collected and counted anchovy eggs, with the same magnitude over the values, reaching the maximum in 2011 (Figure 3.3.2.6).The strong maximum appeared last year, and the total number of eggs reached the average of the series 2010-2021. Their spatial pattern of distribution was quite usual, with major part of the abundance South of 46°N (Figure 3.3.2.5). However, eggs are present almost everywhere in the bay of Biscay, according to the adults distribution. Eggs are particularly abundant on the platform, and were not present front of the Gironde.

Spawning occurred over the mid-shelf in the North, an area where eggs are observed rarely.

This very high abundance of eggs in 2022 could maybe be explained by their concentration just at the depth of the CUFES pump. This concentration never observed before and the fact that the water was strongly stratified may conduct the vertical model to maybe overestimate the Ptot. But this is just an hypothesis.

Globally, the total number of eggs seems to be around the average of the last 10 years, except last year when the number of eggs was exceptionally high. According to the level of biomass, the estimated fecundity seems to be high, but under the strong maximum of last year.

3.3.3 Autumn juvenile acoustic survey 2023 (JUVENA 2023)

The methodology of the autumn juvenile acoustic survey JUVENA is described in detail in the stock annex - Bay of Biscay Anchovy (Subarea 8). The results of the last survey in autumn 2023 were reported and discussed in ICES WGACEGG 2023 (Boyra et al., 2023, WD WGACEGG2023, ICES, 2023). Therefore, in this section only a short summary is provided, highlighting some issues of relevance for this assessment input.

The main objective of the JUVENA survey is estimating the abundance of the anchovy juvenile population and their growth condition at the end of the summer in the Bay of Biscay. In 2023, as in previous years, the survey was coordinated by AZTI and IEO. AZTI led the assessment studies whereas IEO led the ecological studies. The survey JUVENA 2023 took place between the 16th of August and 29th of September on board the chartered RV Angeles Alvariño and the RV Emma Bardán, both equipped with scientific echo sounders (Boyra et al., 2023; WD to WGACEGG). The sampling strategy followed an adaptive scheme with an inter-transect distance of 18 nm. The survey covered from 7º22′ W in the Cantabrian area to 47º39′ N in the French coast, with a total of 91 hauls to identify the species detected by the acoustic equipment, 57 of which were positive of anchovy (Figure **3.3.3.1**). As usual, most of the biomass of juve-niles was located off-the-shelf or in the outer part of the shelf in the first layers of the water column along the Cantabrian coast but on the French shelf this year was different from last year in that it was concentrated in the more coastal area of the shelf and was not observed in the more oceanic area (Figure **3.3.3.2**). The biomass of juveniles estimated for 2023 is around 531 000 tonnes (Table **3.3.3.1.**) and ~73 000 tonnes for adult anchovy, a bit lower than the mean of the temporal series. The combination of both results foresees a healthy and sustainable status of the overall anchovy stock for the next year (Figure **3.3.3.3.**). The mean size of anchovy was 7.4 cm long with a mean weight of 2.33 gr, both values are lower than in the previous year but still above the average of the time-series.

Table 3.3.3.1: Bay of Biscay anchovy. Summary of the estimates obtained in JUVENA autumn acoustic surveys from 2003 to 2022.

Year	Area+ (nm^2)	Size juv (cm)	Juveniles age 0
2003	3476	7.9	98601
2004	1907	10.6	2406
2005	7790	6.7	134131
2006	7063	8.1	78298
2007	5677	5.4	13121
2008	6895	7.5	20879
2009	12984	9.1	178028
2010	21110	8.3	599990
2011	21063	6	207625
2012	14271	6.4	142083
2013	18189	7.4	105271
2014	37169	5.9	723946
2015	21845	6.8	462340
2016	16933	7.3	371563
2017	19808	6.6	725403
2018	26787	6.3	489708
2019	20298	6.1	114074
2020	29849	6.1	228879
2021	26723	5.3	208241
2022	24354	8.6	481893
2023	13175	7.4	530,986

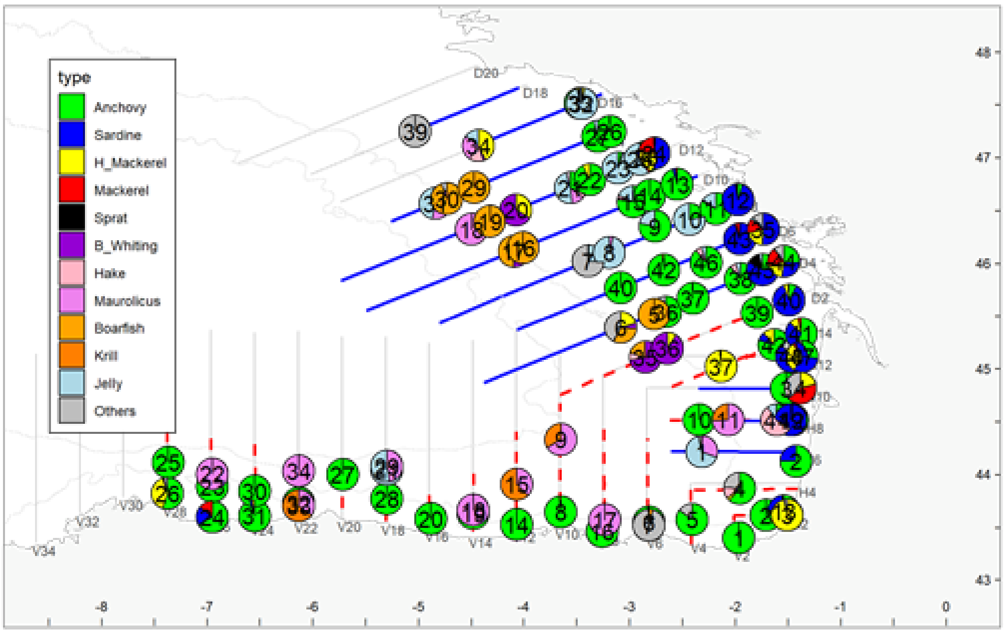


Figure 3.3.3.1: Bay of Biscay anchovy. Survey transects and species composition of the pelagic hauls in JUVENA 2023.

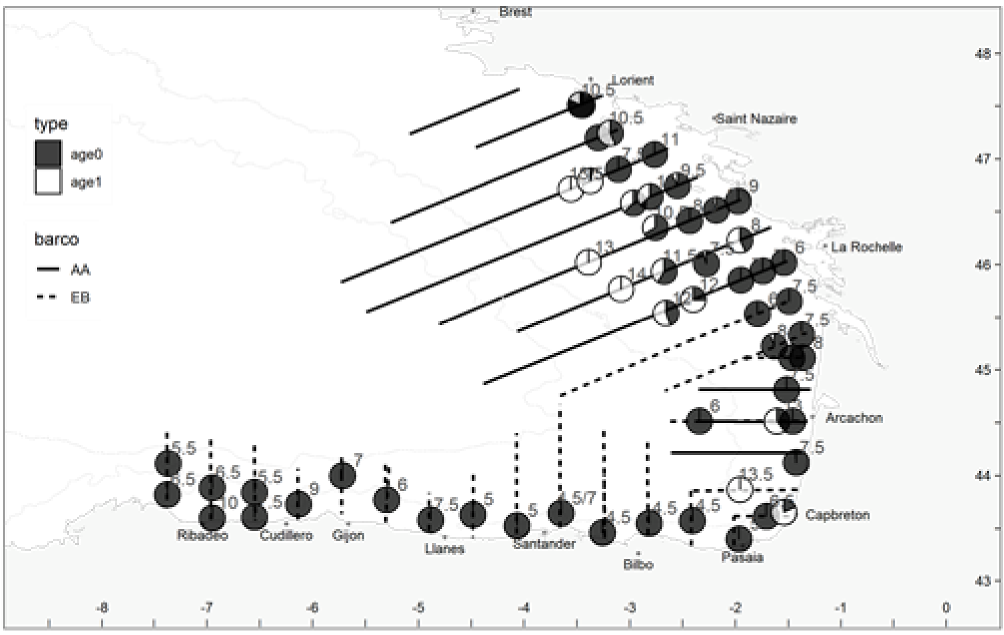


Figure 3.3.3.2: Bay of Biscay anchovy. Positive area of anchovy in JUVENA 2023. The pie charts show the percentage of juveniles (white) and adults (black) in the fishing hauls.

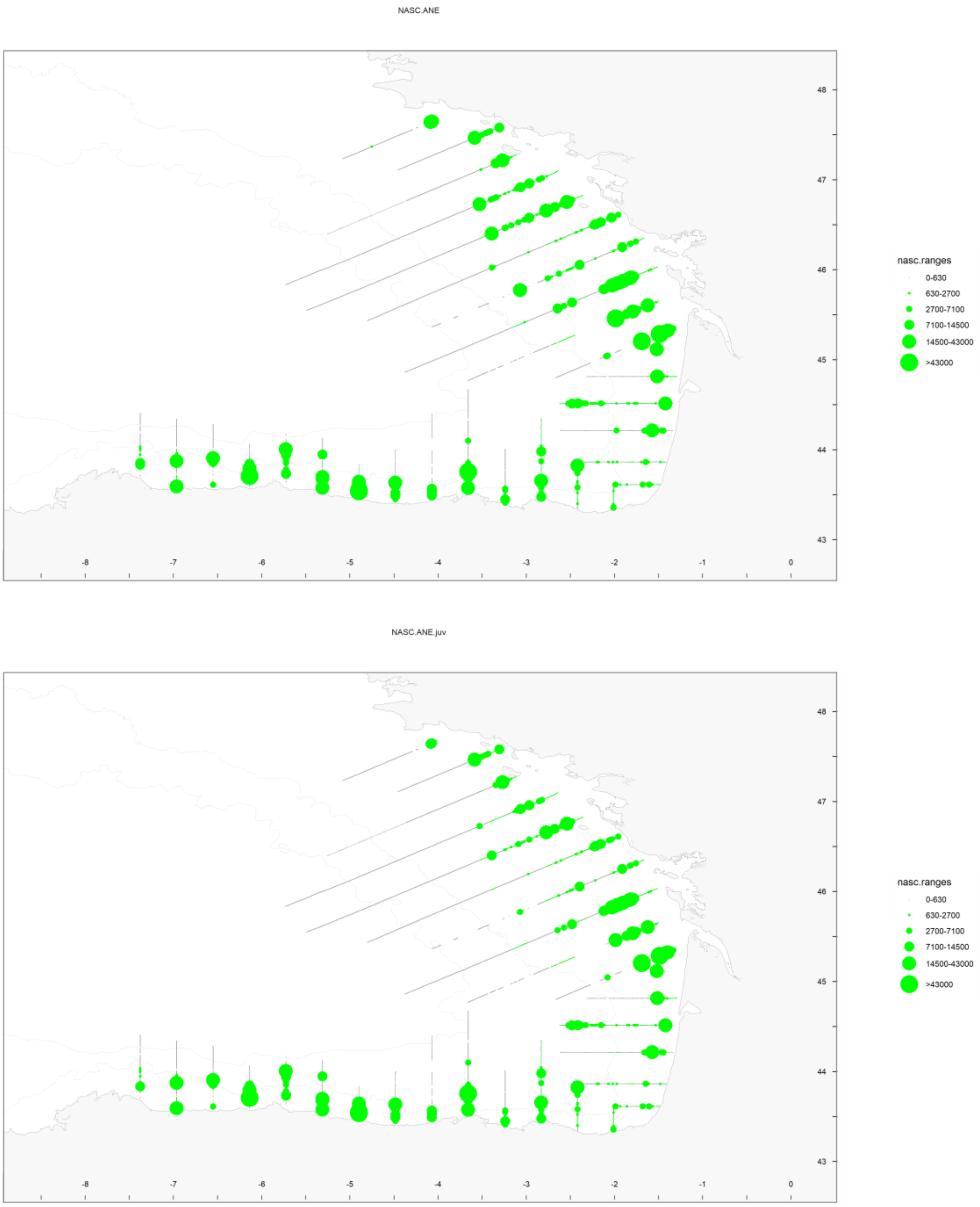


Figure 3.3.3.3: Bay of Biscay anchovy. Bubble maps representing acoustic backscattering by ESDU of 0.1 nm for total anchovy (top) and age 0 anchovy (bottom).

3.4 Biological data

3.4.1 Maturity-at-age

As reported in previous year reports, anchovies are fully mature as soon as they reach their first year of life, in spring the year after the hatch. See stock annex - Bay of Biscay Anchovy (Subarea 8) for details.

3.4.2 Natural mortality and weight-at-age in the stock

Natural mortality is fixed at 0.8 for age 1 and 1.2 for older individuals (age 2+).

In the CBBM assessment model the parameters G1 and G2+ representing the annual intrinsic growth of the population by age class are assumed constant along years and are estimated based on the weight-at-age data from the surveys.

See stock annex - Bay of Biscay Anchovy (Subarea 8) for further information.

3.5 State of the stock

According to the stock annex, the assessment of the Bay of Biscay anchovy can be conducted in June or November. The management plan currently in place is based on the November assessment. This year the final assessment of the stock was conducted in November 2023, and followed the methodology described in the stock annex.

3.5.1 Stock assessment

The input data entering into the assessment of the anchovy stock consist of:

- total biomass estimated by DEPM and acoustic surveys (BIOMAN and PELGAS) with their corresponding coefficients of variation;
- proportion of the biomass at-age 1 estimated by the DEPM and acoustic surveys (BIOMAN and PELGAS);
- juvenile abundance index from JUVENA;
- total catch by semester;
- proportion (in mass) of age 1 in the catch by semester (in 2023 only for the first semester);
- growth rates by age estimated from the weights-at-age of the stock.

The historical series of spawning–stock biomass (SSB) from the DEPM and acoustic surveys are shown in Figure 3.5.1.1. The trends in biomass from both surveys are similar. From 2003 to 2018, a parallel trend but with larger biomass estimates from the acoustic surveys is apparent, except in 2016 and 2018 that the DEPM biomass estimate was larger than the acoustic biomass. In 2020, the DEPM SSB estimate (around 334 300 t) was the largest of the historical time-series, well above the second highest value (223 200t) observed in 2019. The acoustic survey provided the largest SSB estimate of the historical time series in 2021 (451 660 t) with a much higher value than the DEPM SSB estimate for 2021 (199 490 t). In 2023 both the DEPM and the acoustic surveys provided lower SSB estimates than in 2022 (160 549 and 78 941t respectively) with a more pronounced decrease in the acoustic estimate (19% decrease in the DEPM and 56% decrease in the acoustic estimate). The largest discrepancy between the SSB estimates from the DEPM and acoustic surveys occurred in 1991, 2000, 2002, 2012, 2015, 2021 and 2023.

The agreement between both surveys is usually higher when estimating the relative age composition of the population. In 2023 the DEPM survey age 1 biomass proportion was around 0.76 and the acoustic age 1 biomass proportion was around 0.85 (Figure 3.5.1.2).

The historical series of the juvenile abundance index from the autumn acoustic survey JUVENA is shown in Figure 3.5.1.3. The 2023 survey index is well above the average value of the temporal time series and slightly above the index in 2022, with a higher value than the 2019, 2020 and 2021 index values that were slightly below the average.

In 2019 due to the bad weather conditions the JUVENA survey could not cover the region to the north of 46.6ºN. The 2019 juvenile abundance index was considered likely underestimated. This has been confirmed in next years by the BIOMAN and PELGAS surveys. Besides being among the largest SSB estimates of the BIOMAN and PELGAS surveys time series, the age 1 proportion estimates were above the average indicating large recruitments.

Due to the low total French landing in 2022 (234 t), length sampling was not available and age structure from Spanish catches in divisions 8.a and 8.b was used for catch-at-age calculations (see Section 3.2.3). Figure 3.5.1.4 shows the historical series of total catches by semester. In general, catches in the first semester are larger than in the second semester. The absence of catches from 2005 to 2009 corresponds to various consecutive fishery closures due to the low level of the population. The fishery was reopened in March 2010. In 2023, the preliminary total catch was around 24 213 t in the first half of the year and 3612 t in the second half. The latter was under the assumption that the November and December catches were 635t (2.3% of the total catch which is the average % of November and December catches in 2010–2022). Definitive 2023 catch estimates will be provided in WGHANSA 2024. Regarding the age structure of the catches, age 1 proportion in the catches in the first semester in 2023 was 0.61, which is above the average age 1 proportion in the time-series (Figure 3.5.1.5).

Historical series of intrinsic growth rates by age (computed from the weights-at-age of the stock) suggest a larger growth at-age 1 than at-age 2+ (Figure 3.5.1.6).

The data used for the November assessment are given in Table **3.5.1.1.**.

Figure 3.5.1.7 compares prior and posterior distribution of some of the parameters estimated. Summary statistics (median and 90% probability intervals) of the posterior distributions of the parameters estimated are given in Tables **3.5.1.2** and **3.5.1.3**. Recruitment (age 1 in mass at the beginning of the year), SSB (at spawn-ing time which is assumed to be 15th May), fishing mortality by semester and harvest rates (catch/biomass) from the final assessment are shown in Figure 3.5.1.8. The estimated level of SSB in 2023 is approximately 116 065t, which is among the four highest in the time-series, and the 90% probability interval is around 78 813t and 174 121t. This probability interval is among the widest in the time-series, accounting for the discrepancies observed in the surveys of the last years. The posterior median of recruitment in 2023 is around 83 436t and the 90% probability interval is between 35 363t and 189 329t. The posterior distribution of recruitment in 2023 is wide because only the JUVENA 2023 survey provides direct information about that recruitment (age 1 biomass) level. Assuming no fishing takes place in 2024, the SSB in 2024 is estimated around 134 560t with a 90% probability interval around 82 166t and 239 025t (Figure 3.5.1.9).

Overall, the Pearson residuals for all the observations used in the assessment are within -2 and 2, showing no major discrepancies between the observed and modelled quantities (Figure 3.5.1.10) and indicating that the model estimates are a compromise between all surveys inputs and catch estimates and all along the time-series. Since 2013, the time-series of biomass from the

DEPM has positive residuals, and for some years large negative residuals are observed for JUVENA recruitment index (e.g., 2020 and 2021), and for the acoustic index (e.g., 2023), which should be further investigated in next years.

Table 3.5.1.1. Bay of Biscay anchovy: Input data for CBBM.

	BIOMAN			**PELGAS**			**JUVENA**	**CATCH**				**GROWTH**	
	DEPM survey			Acoustic survey			Acoustic survey	Semester 1		Semester 2		G1	G2+
Year	Age 1 (tonnes)	Total (tonnes)	cv	Age 1 (tonnes)	Total (tonnes)	cv	Age 0 previous year (tonnes)	Age 1 (tonnes)	Total (tonnes)	Age 1 (tonnes)	Total (tonnes)	Age 1	Age 2+
1,987	10,637	21,943	0.480	NA	NA	NA	NA	4,561	11,719	2,219	2,666	0.405	0.141
1,988	37,813	45,230	0.310	NA	NA	NA	NA	6,739	10,002	4,018	4,404	0.266	0.125
1,989	4,128	9,477	0.410	6,476	15,500	NA	NA	3,026	7,153	643	1,086	0.323	0.129
1,990	71,142	74,371	0.208	NA	NA	NA	NA	17,337	19,386	12,080	14,347	0.566	0.130
1,991	7,821	13,295	0.271	28,322	64,000	NA	NA	6,150	15,025	2,743	3,087	0.626	0.198
1,992	56,202	60,332	0.125	84,439	89,000	NA	NA	19,737	26,381	9,939	10,829	NA	NA
1,993	NA	NA	NA	NA	NA	NA	NA	12,152	24,058	12,589	15,255	NA	NA
1,994	23,739	37,777	0.204	NA	35,000	NA	NA	8,236	23,214	8,849	10,408	0.594	0.283
1,995	28,416	36,432	0.159	NA	NA	NA	NA	11,600	23,479	4,961	5,629	NA	NA
1,996	NA	26,148	0.260	NA	NA	NA	NA	13,007	21,024	10,397	11,864	NA	NA
1,997	21,098	29,022	0.110	38,498	63,000	NA	NA	6,730	10,600	8,675	9,852	0.911	0.324
1,998	68,015	78,277	0.101	NA	57,000	NA	NA	9,620	12,918	14,811	18,481	NA	NA
1,999	NA	45,932	0.244	NA	NA	NA	NA	3,681	15,381	6,136	10,617	NA	NA
2,000	NA	28,321	0.245	89,363	113,120	0.064	NA	12,036	22,536	11,463	14,354	NA	NA

	BIOMAN			PELGAS			JUVENA	CATCH				GROWTH	
	DEPM survey			Acoustic survey			Acoustic survey	Semester 1		Semester 2		G1	G2+
Year	Age 1 (tonnes)	Total (tonnes)	cv	Age 1 (tonnes)	Total (tonnes)	cv	Age 0 previous year (tonnes)	Age 1 (tonnes)	Total (tonnes)	Age 1 (tonnes)	Total (tonnes)	Age 1	Age 2+
2,001	45,779	75,826	0.126	67,110	105,801	0.141	NA	10,379	23,095	13,828	17,043	0.649	0.266
2,002	4,330	22,462	0.147	27,642	110,566	0.113	NA	2,585	11,089	3,720	6,405	0.249	0.032
2,003	11,401	16,109	0.173	18,687	30,632	0.132	NA	1,055	4,074	3,376	6,405	0.769	0.206
2,004	9,042	11,496	0.117	33,995	45,965	0.167	98,601	5,467	9,183	6,285	7,004	0.410	0.157
2,005	1,441	4,832	0.202	2,467	14,643	0.171	2,406	146	1,127	NA	0	0.277	0.205
2,006	10,085	15,113	0.238	18,282	30,877	0.136	134,131	982	1,659	69	95	0.493	-0.307
2,007	7,946	13,060	0.178	26,230	40,876	0.100	78,298	42	141	NA	0	0.524	0.146
2,008	3,940	12,898	0.200	10,400	37,574	0.162	13,121	NA	0	NA	0	0.458	0.333
2,009	5,460	12,832	0.140	11,429	34,855	0.112	20,879	NA	0	NA	0	0.618	0.439
2,010	25,543	31,277	0.159	64,564	86,355	0.147	178,028	3,099	6,111	3,544	3,971	0.325	0.276
2,011	112,202	135,732	0.160	115,379	142,601	0.077	599,990	3,701	10,913	3,256	3,576	0.465	-0.123
2,012	8,936	26,663	0.202	73,843	186,865	0.046	207,625	948	8,600	3,869	5,753	0.777	0.307
2,013	24,090	54,686	0.179	42,508	93,854	0.128	142,083	1,759	10,928	1,722	3,144	0.670	0.013
2,014	59,283	91,299	0.125	86,670	125,427	0.063	105,271	4,188	14,274	4,752	5,278	0.427	0.101
2,015	113,677	181,063	0.101	313,249	372,916	0.074	723,946	9,524	19,416	4,976	8,838	0.257	0.143

	BIOMAN			PELGAS			JUVENA	CATCH				GROWTH	
	DEPM survey			Acoustic survey			Acoustic survey	Semester 1		Semester 2		G1	G2+
Year	Age 1 (tonnes)	Total (tonnes)	cv	Age 1 (tonnes)	Total (tonnes)	cv	Age 0 previous year (tonnes)	Age 1 (tonnes)	Total (tonnes)	Age 1 (tonnes)	Total (tonnes)	Age 1	Age 2+
2,016	65,312	152,049	0.114	35,604	89,727	0.130	462,340	5,024	15,380	2,501	3,991	0.765	0.456
2,017	62,488	94,759	0.122	83,713	134,500	0.154	371,563	9,316	22,763	1,705	3,248	0.567	0.079
2,018	145,159	192,088	0.116	136,397	185,524	0.070	725,403	14,138	25,499	4,095	5,236	0.773	0.325
2,019	118,102	223,210	0.115	129,269	183,166	0.053	489,708	6,164	22,760	1,842	4,085	0.167	0.105
2,020	252,547	334,283	0.116	NA	NA	NA	114,072	8,831	14,870	9,173	10,350	0.424	0.332
2,021	132,182	199,490	0.104	327,454	451,660	0.097	228,879	11,081	23,606	2,970	4,323	0.546	0.348
2,022	84,315	198,741	0.106	73,926	180,749	0.098	208,241	2,742	21,323	1,673	3,341	0.532	0.138
2,023	121,532	160,549	0.118	67,258	78,941	0.121	481,893	14,916	24,213	NA	3,612	NA	NA
2,024	NA	NA	NA	NA	NA	NA	530,986	NA	0	NA	0	NA	NA

Table 3.5.1.2. Bay of Biscay anchovy: Median and 90% probability intervals for some of the parameters estimated in the CBBM.

Notation	5%	Median	95%	Meaning of parameter
qdepm	0.714	0.875	1.071	Catchability of the DEPM B index
qac	1.224	1.471	1.771	Catchability of the Acoustic B index
qrobs	0.014	0.254	4.402	Parameter of the observation equation for the juvenile index
krobs	0.984	1.251	1.523	Parameter of the observation equation for the juvenile index
psidepm	1.926	3.283	5.437	Precision (inverse of variance) of the observation equation of DEPM B index
psiac	3.534	5.994	9.802	Precision (inverse of variance) of the observation equation of Acoustic B index
psirobs	1.113	2.086	3.627	Precision (inverse of variance) of the observation equation of juvenile index
xidepm	3.412	4.043	4.749	Variance-related parameter for the observation equation of DEPM age 1 proportion
xiac	2.757	3.320	3.857	Variance-related parameter for the observation equation of Acoustic age 1 proportion
xicatch	2.368	2.705	3.027	Variance-related parameter for the observation equation of age 1 proportion in the catch
B0	16,076	20,971	26,878	Initial biomass
mur	10.336	10.600	10.874	Median (in log scale) of the recruitment process
psir	0.818	1.223	1.754	Precision (in log scale) of the recruitment process
sage1sem1	0.395	0.460	0.540	Age 1 selectivity during the 1st semester
sage1sem2	0.848	1.021	1.220	Age 1 selectivity during the 2nd semester
G1	0.485	0.538	0.596	Intrinsic growth at age 1
G2	0.167	0.217	0.272	Intrinsic growth at age 2+
psig	21.154	29.708	40.141	Precision of the observation equations for intrinsic growth at ages 1 and 2+

Table 3.5.1.3. Bay of Biscay anchovy: Median and 90% probability intervals for recruitment, spawning–stock biomass, fishing mortalities by semester and harvest rates (Catch/SSB) as resulted from CBBM.

	R (tonnes)			SSB (tonnes)			fsem1			fsem2			Harvest rate		
Year	5%	Median	95%	5%	Median	95%	5%	Median	95%	5%	Median	95%	5%	Median	95%
1,987	12,082	15,772	21,056	15,743	20,587	27,067	0.965	1.263	1.625	0.270	0.381	0.539	0.531	0.699	0.914
1,988	25,708	31,082	38,026	23,283	28,537	35,614	0.826	1.061	1.332	0.306	0.413	0.556	0.405	0.505	0.619
1,989	6,468	9,101	12,831	10,520	15,183	21,361	0.718	0.992	1.375	0.138	0.204	0.317	0.386	0.543	0.783
1,990	58,777	67,106	77,564	45,148	52,622	62,349	1.029	1.269	1.546	0.591	0.782	1.024	0.541	0.641	0.747
1,991	17,483	22,933	30,459	21,681	28,970	38,594	0.905	1.191	1.567	0.214	0.302	0.442	0.469	0.625	0.835
1,992	67,379	85,773	108,572	52,229	69,852	91,586	0.927	1.251	1.684	0.287	0.411	0.619	0.406	0.533	0.712
1,993	52,313	66,097	81,189	60,972	72,688	86,665	0.711	0.892	1.123	0.464	0.603	0.789	0.454	0.541	0.645
1,994	33,600	41,453	51,658	38,850	47,513	58,370	0.952	1.192	1.469	0.493	0.663	0.896	0.576	0.708	0.865
1,995	33,886	44,708	58,369	28,197	39,493	54,064	1.173	1.605	2.182	0.269	0.402	0.635	0.538	0.737	1.032
1,996	40,834	50,734	62,514	38,127	46,596	57,558	0.993	1.279	1.640	0.551	0.761	1.035	0.571	0.706	0.863
1,997	30,808	39,820	52,286	34,146	44,458	58,695	0.499	0.670	0.889	0.431	0.622	0.909	0.348	0.460	0.599
1,998	71,444	93,286	120,868	69,933	91,790	119,180	0.347	0.469	0.625	0.368	0.527	0.778	0.263	0.342	0.449
1,999	31,035	45,206	64,871	51,450	68,651	90,231	0.399	0.539	0.732	0.309	0.435	0.626	0.288	0.379	0.505
2,000	74,824	91,407	110,956	76,732	93,383	112,329	0.579	0.724	0.912	0.309	0.407	0.544	0.328	0.395	0.481
2,001	62,087	73,470	87,417	77,714	89,405	104,767	0.558	0.676	0.817	0.424	0.532	0.664	0.383	0.449	0.516
2,002	9,304	12,887	17,986	31,332	37,749	46,361	0.458	0.568	0.691	0.411	0.533	0.680	0.377	0.463	0.558

	R (tonnes)			**SSB (tonnes)**			**fsem1**			**fsem2**			**Harvest rate**		
Year	5%	Median	95%	5%	Median	95%	5%	Median	95%	5%	Median	95%	5%	Median	95%
2,003	15,529	19,677	24,661	21,859	26,988	33,046	0.314	0.396	0.498	0.515	0.687	0.917	0.317	0.388	0.479
2,004	24,673	30,373	37,865	24,273	30,387	38,383	0.685	0.884	1.136	0.471	0.656	0.914	0.422	0.533	0.667
2,005	2,702	4,186	6,188	10,128	14,130	19,403	0.116	0.162	0.227	0.000	0.000	0.000	0.058	0.080	0.111
2,006	11,493	15,891	21,519	14,248	19,319	25,612	0.187	0.252	0.344	0.008	0.012	0.017	0.068	0.091	0.123
2,007	14,695	20,729	28,345	21,428	28,719	37,560	0.011	0.014	0.019	0.000	0.000	0.000	0.004	0.005	0.007
2,008	5,952	8,679	12,538	17,207	22,661	29,344	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2,009	6,704	9,527	13,670	14,493	18,924	24,615	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2,010	35,527	46,046	59,920	36,120	46,471	59,922	0.330	0.431	0.561	0.150	0.208	0.290	0.168	0.217	0.279
2,011	86,618	110,011	139,440	91,420	114,540	143,256	0.244	0.312	0.397	0.055	0.074	0.099	0.101	0.126	0.158
2,012	33,797	44,556	58,244	76,222	94,311	116,940	0.162	0.205	0.258	0.127	0.163	0.210	0.123	0.152	0.188
2,013	28,156	37,107	48,753	52,089	65,885	82,679	0.302	0.382	0.488	0.096	0.126	0.166	0.170	0.214	0.270
2,014	53,464	69,443	89,665	63,843	81,796	103,214	0.387	0.491	0.631	0.121	0.163	0.219	0.189	0.239	0.306
2,015	83,715	105,684	135,589	97,868	120,651	150,132	0.368	0.467	0.582	0.138	0.183	0.241	0.188	0.234	0.289
2,016	38,385	50,432	67,270	72,895	91,995	117,571	0.298	0.383	0.488	0.086	0.115	0.151	0.165	0.211	0.266
2,017	49,189	63,504	82,906	63,569	81,588	106,105	0.538	0.706	0.904	0.076	0.103	0.139	0.245	0.319	0.409
2,018	79,420	101,339	131,022	87,121	111,310	144,661	0.495	0.659	0.846	0.086	0.117	0.161	0.212	0.276	0.353
2,019	45,252	61,204	83,036	69,692	92,957	124,420	0.429	0.585	0.779	0.083	0.116	0.161	0.216	0.289	0.385

	R (tonnes)			SSB (tonnes)			fsem1			fsem2			Harvest rate		
Year	5%	Median	95%	5%	Median	95%	5%	Median	95%	5%	Median	95%	5%	Median	95%
2,020	78,938	104,290	139,318	96,003	125,293	166,147	0.254	0.342	0.454	0.149	0.207	0.285	0.152	0.201	0.263
2,021	80,828	105,992	140,816	104,285	137,584	184,420	0.340	0.457	0.608	0.057	0.079	0.108	0.151	0.203	0.268
2,022	30,053	42,062	59,686	64,313	89,420	124,558	0.365	0.508	0.699	0.071	0.102	0.148	0.198	0.276	0.383
2,023	70,266	105,404	156,052	74,813	116,065	174,121	0.412	0.606	0.917	0.049	0.077	0.125	0.160	0.240	0.372
2,024	35,363	83,436	189,329	82,166	134,560	239,025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

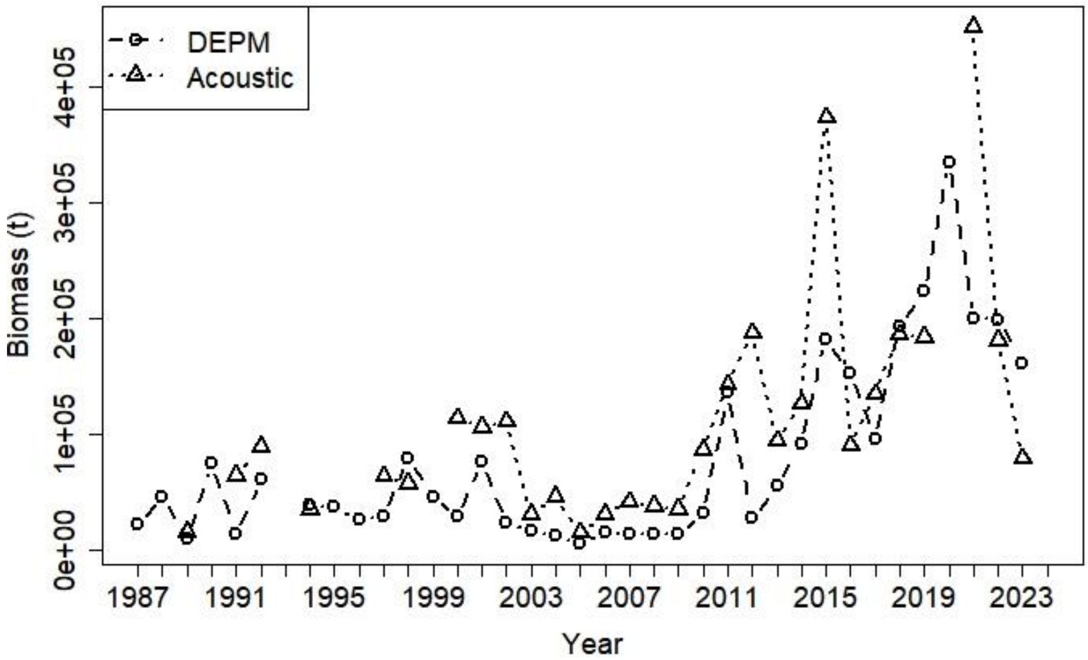


Figure 3.5.1.1: Bay of Biscay anchovy: Historical series of spawning–stock biomass estimates and the corresponding confidence intervals from DEPM (solid line and circles) and acoustics (dashed line and triangles).

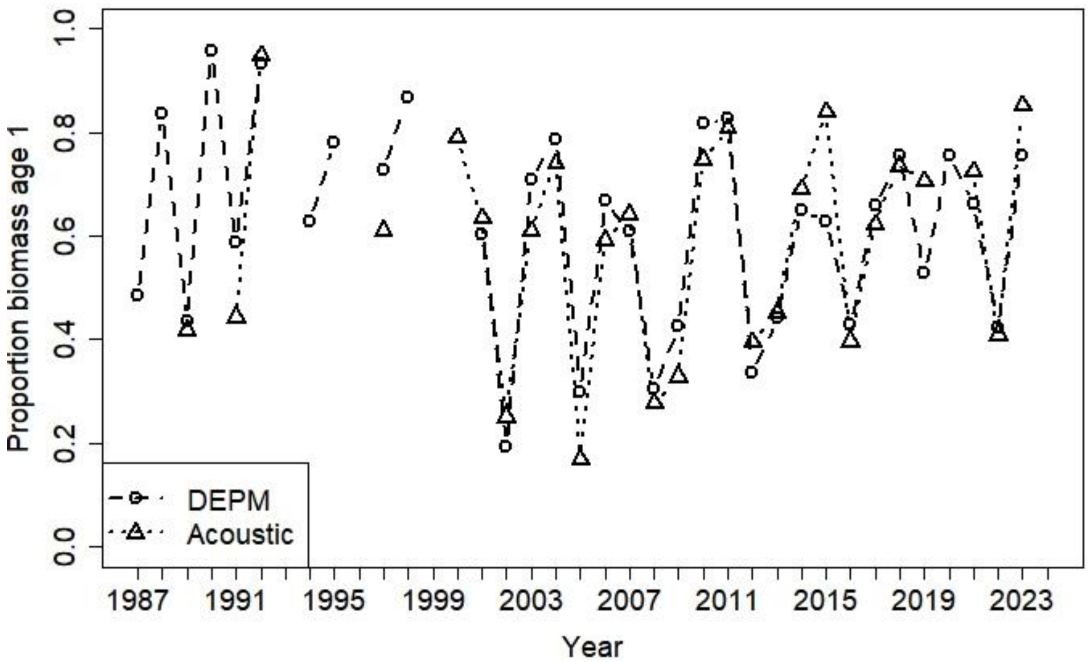


Figure 3.5.1.2: Bay of Biscay anchovy: Historical series of age 1 biomass proportion estimates from DEPM (dashed line and circles) and acoustics (dotted line and triangles).

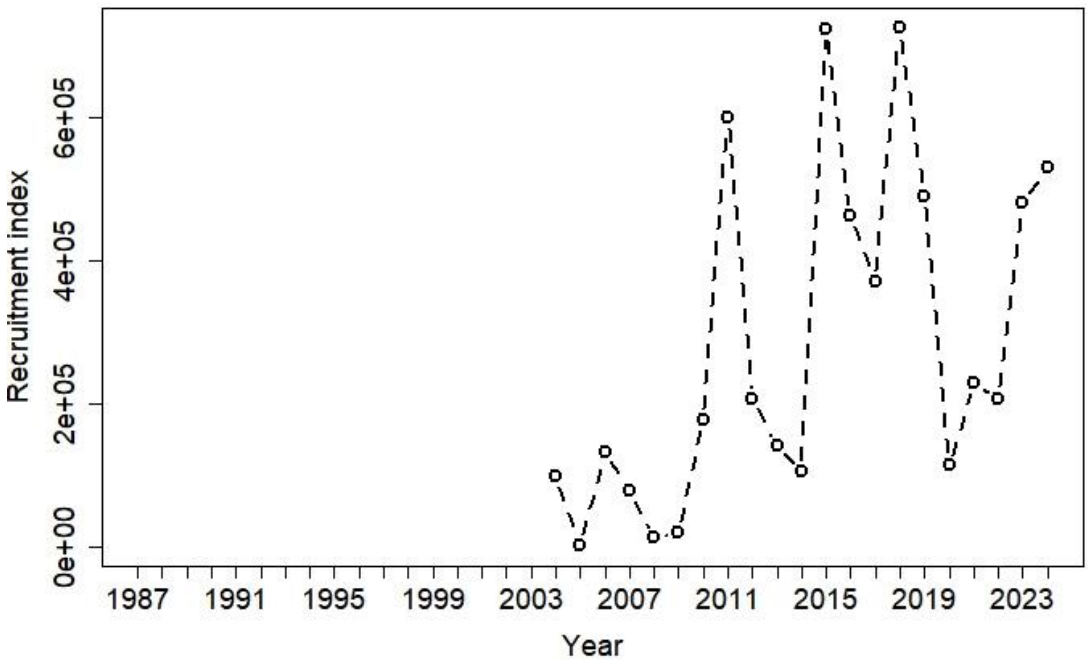


Figure 3.5.1.3: Bay of Biscay anchovy: Historical series of the juvenile abundance index from the autumn acoustic survey JUVENA that is related to recruitment (age 1) next year.

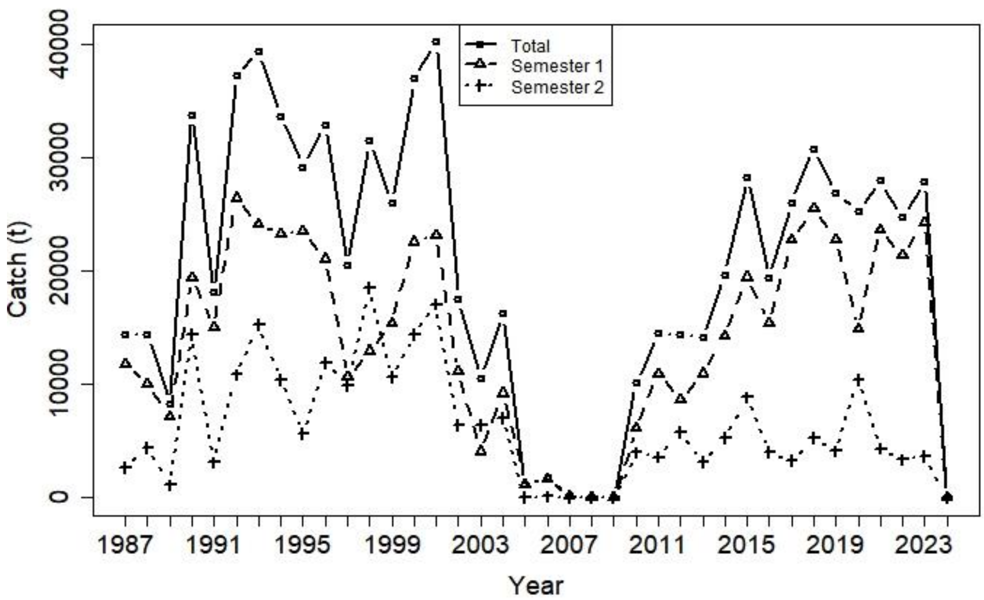


Figure 3.5.1.4: Bay of Biscay anchovy: Historical series of total catch (solid line) and catch by semesters (dashed and dotted lines for the first and second semester respectively). Note that the catch in 2023 is provisional and the catch in 2024 is set at zero.

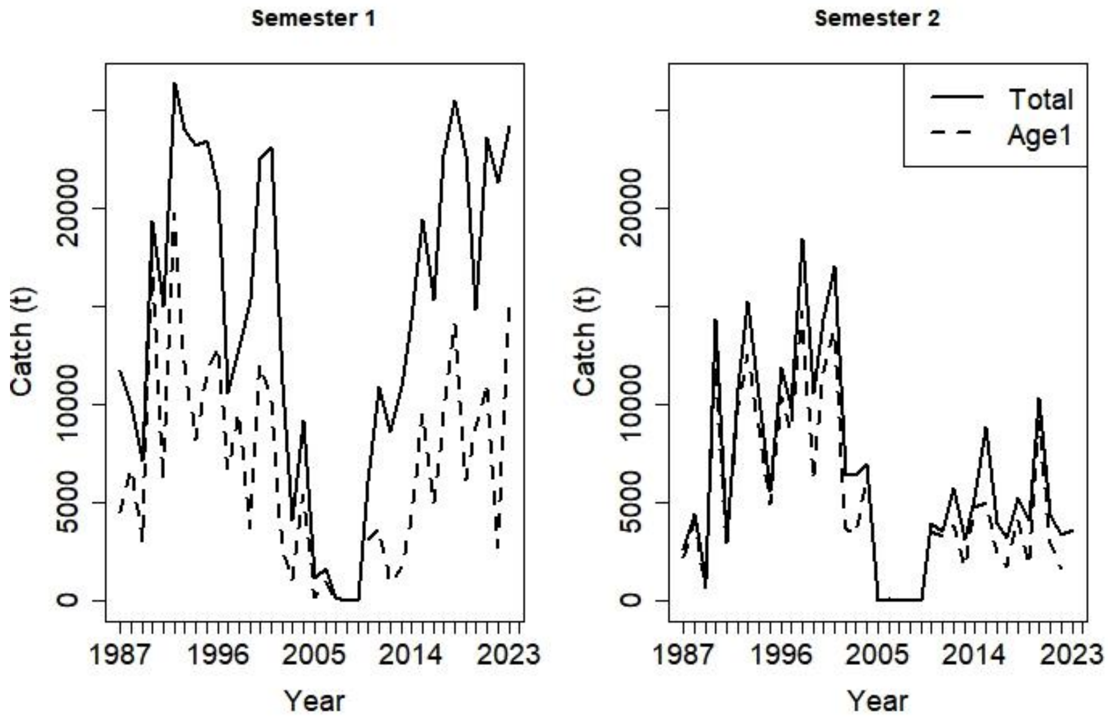


Figure 3.5.1.5: Bay of Biscay anchovy: Historical series of total (solid line) and age 1 (dashed line) catch (in tonnes). The left panel corresponds to the first semester and the right panel to the second semester. Note that the catch in 2023 is provisional.

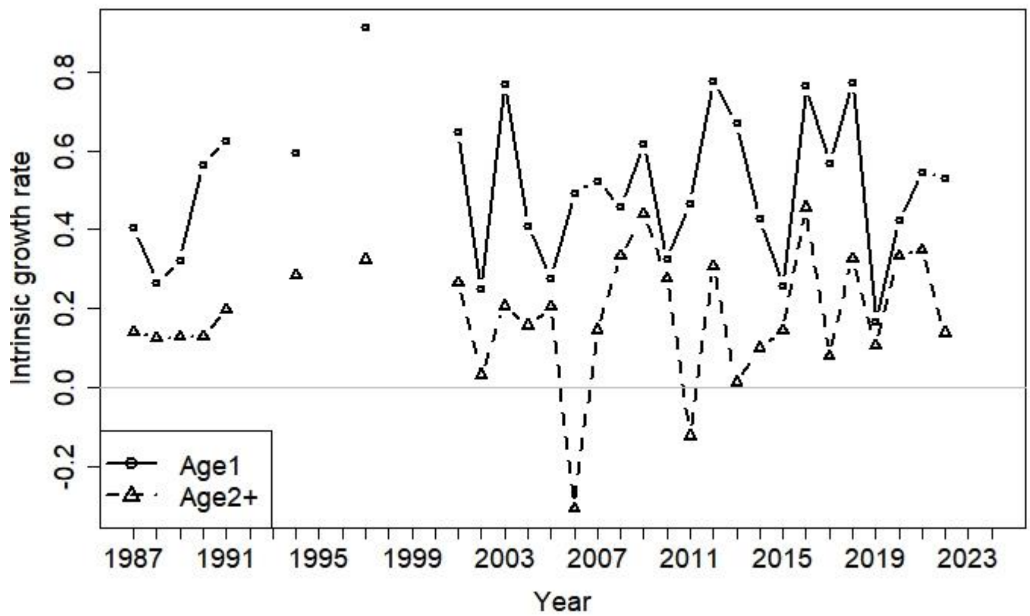


Figure 3.5.1.6: Bay of Biscay anchovy: Historical series of intrinsic growth rates by age as estimated from the mean weights-at-age of the stock.

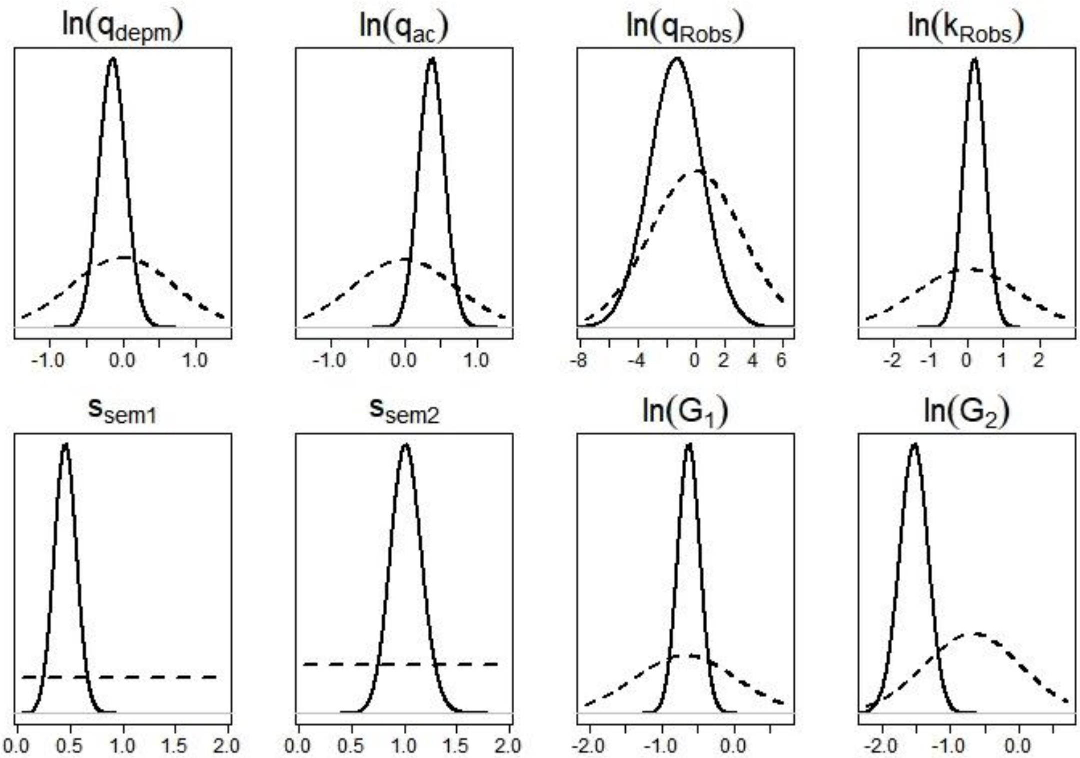
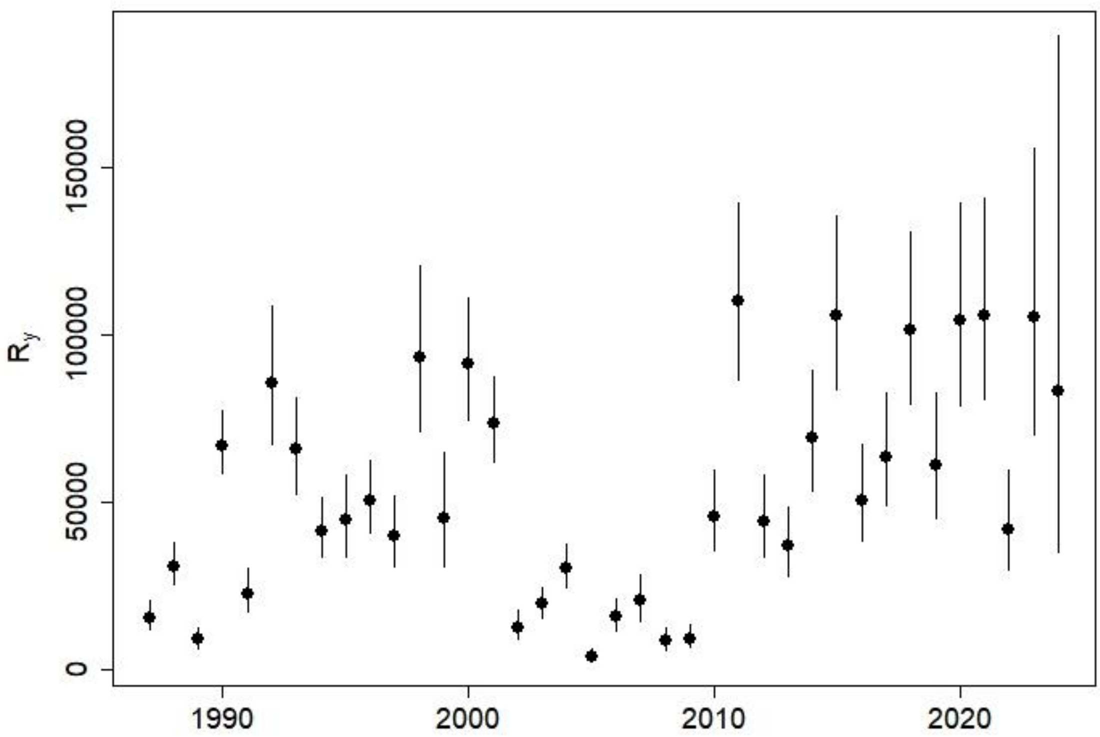
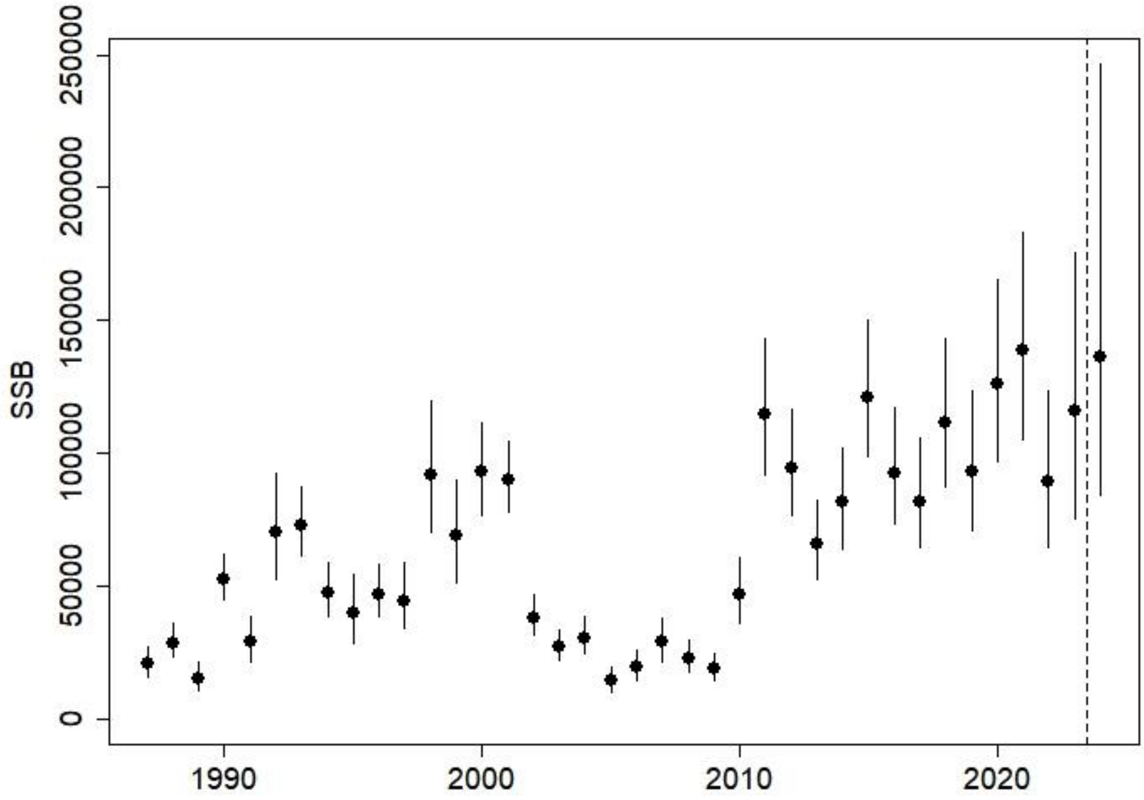
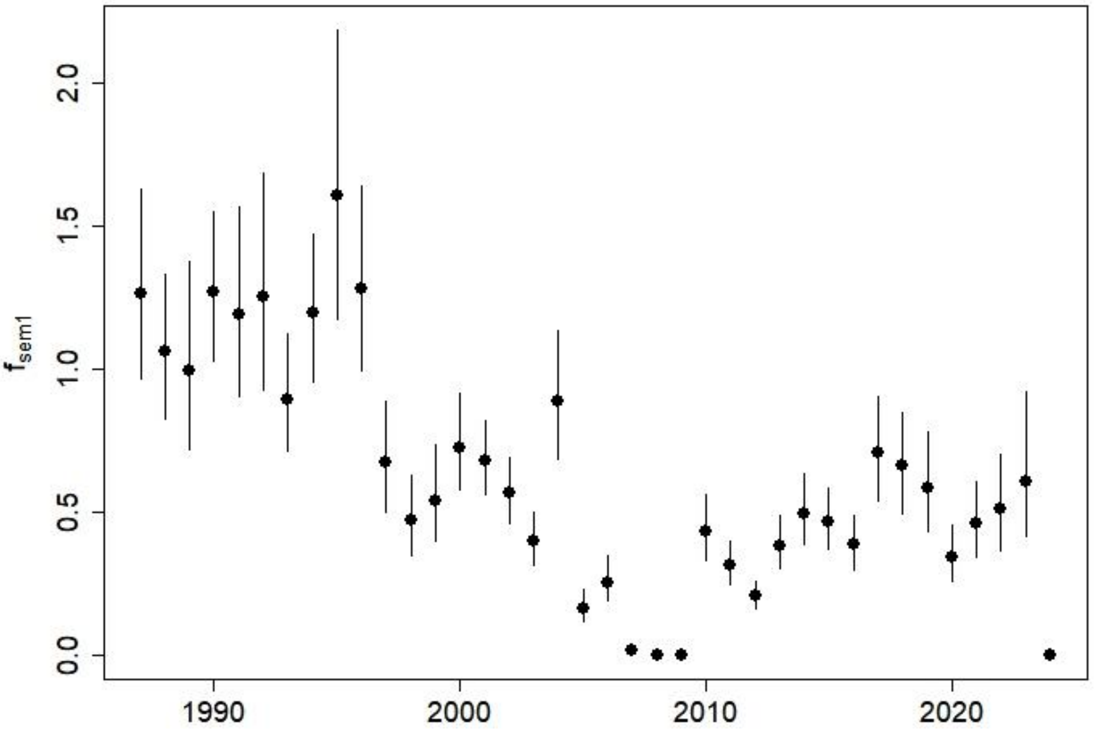
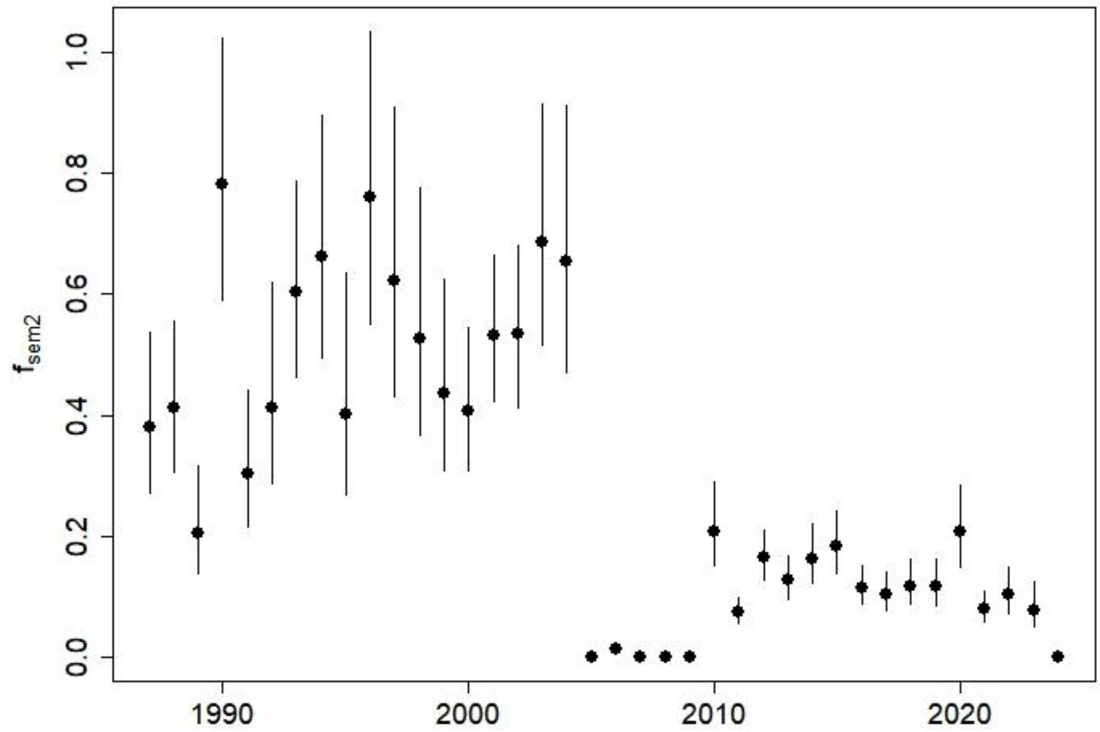


Figure 3.5.1.7: Bay of Biscay anchovy: Comparison between the prior (dotted line) and posterior distribution (solid line) for some of the parameters of CBBM.




SSB
0
50000
100000
150000
200000
250000
1990
2000
2010
2020


f_{sem1}
0.0
0.5
1.0
1.5
2.0
1990
2000
2010
2020



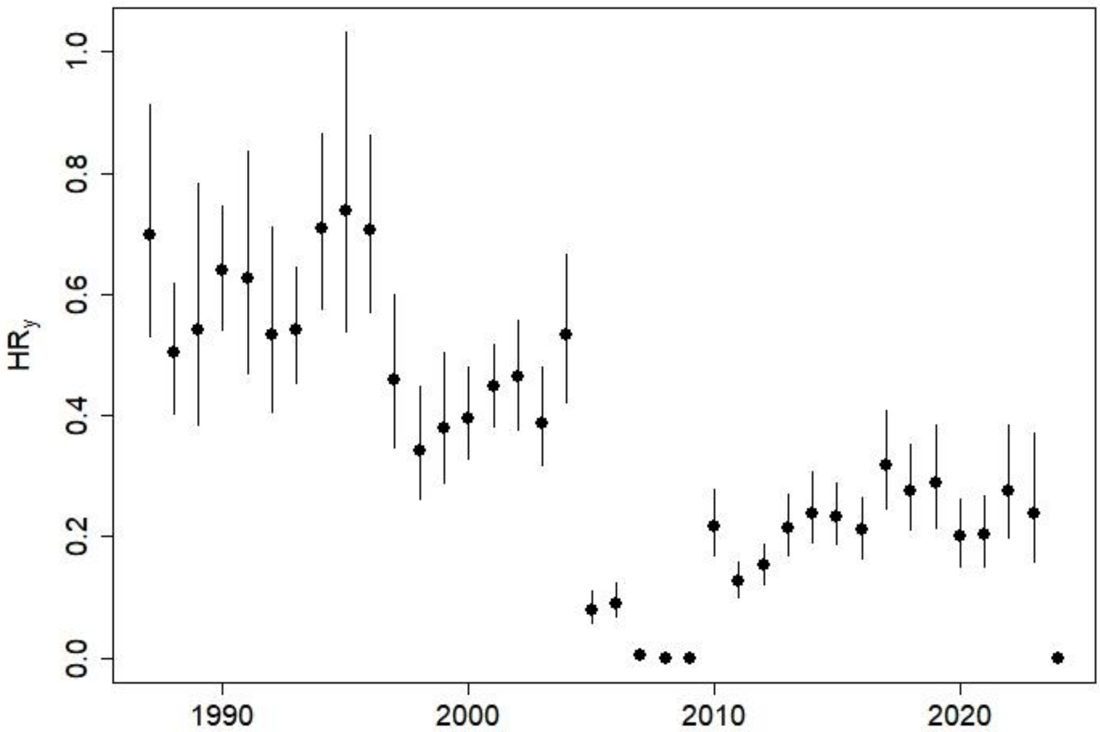


Figure 3.5.1.8: Bay of Biscay anchovy: Posterior median (bullet points) and 90% probability intervals (solid lines) for the recruitment (age 1 in mass in January), the spawning–stock biomass, the fishing mortality for the first and second semesters and the harvest rates (catch/biomass) from the CBBM. It must be taken into account that the fishing mortalities in 2024 are fixed at zero and SSB in 2024 results from no fishing in 2024.

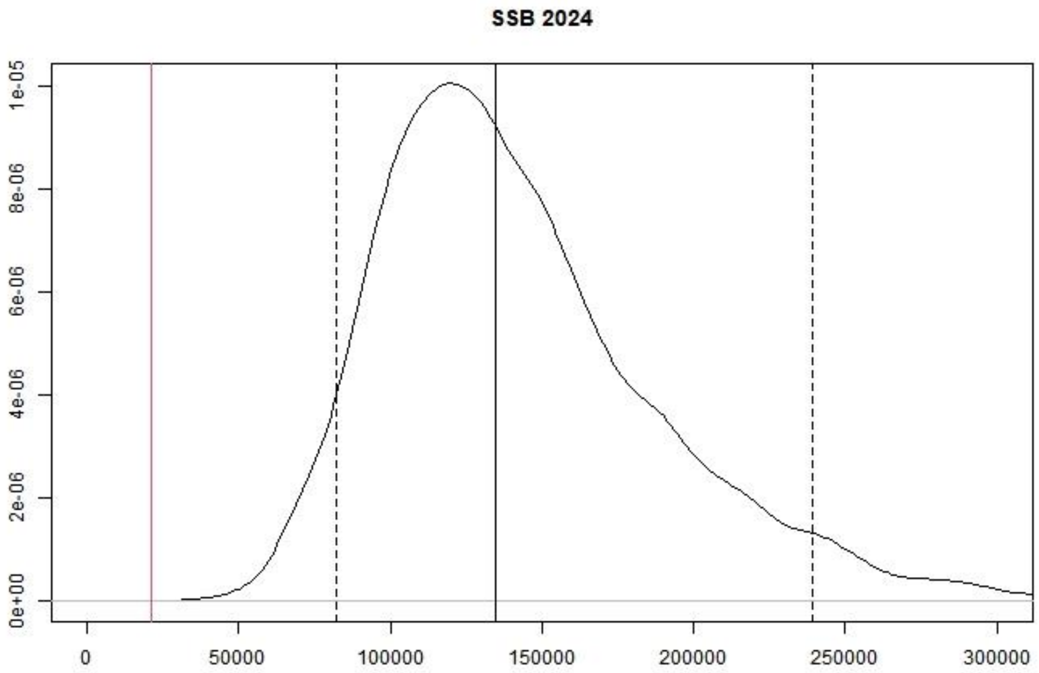


Figure 3.5.1.9: Bay of Biscay anchovy: Posterior distribution of SSB in 2024, under the assumption of no fishing during 2024. The red vertical line represents Blim at 21 000 tonnes.

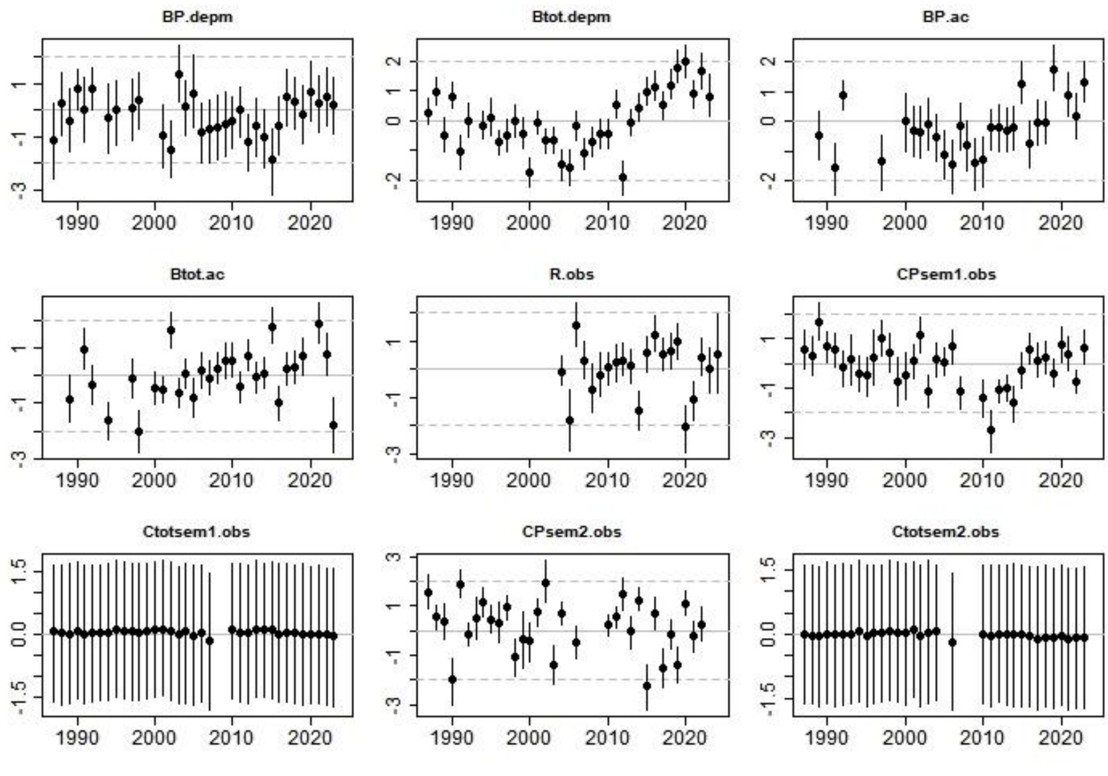
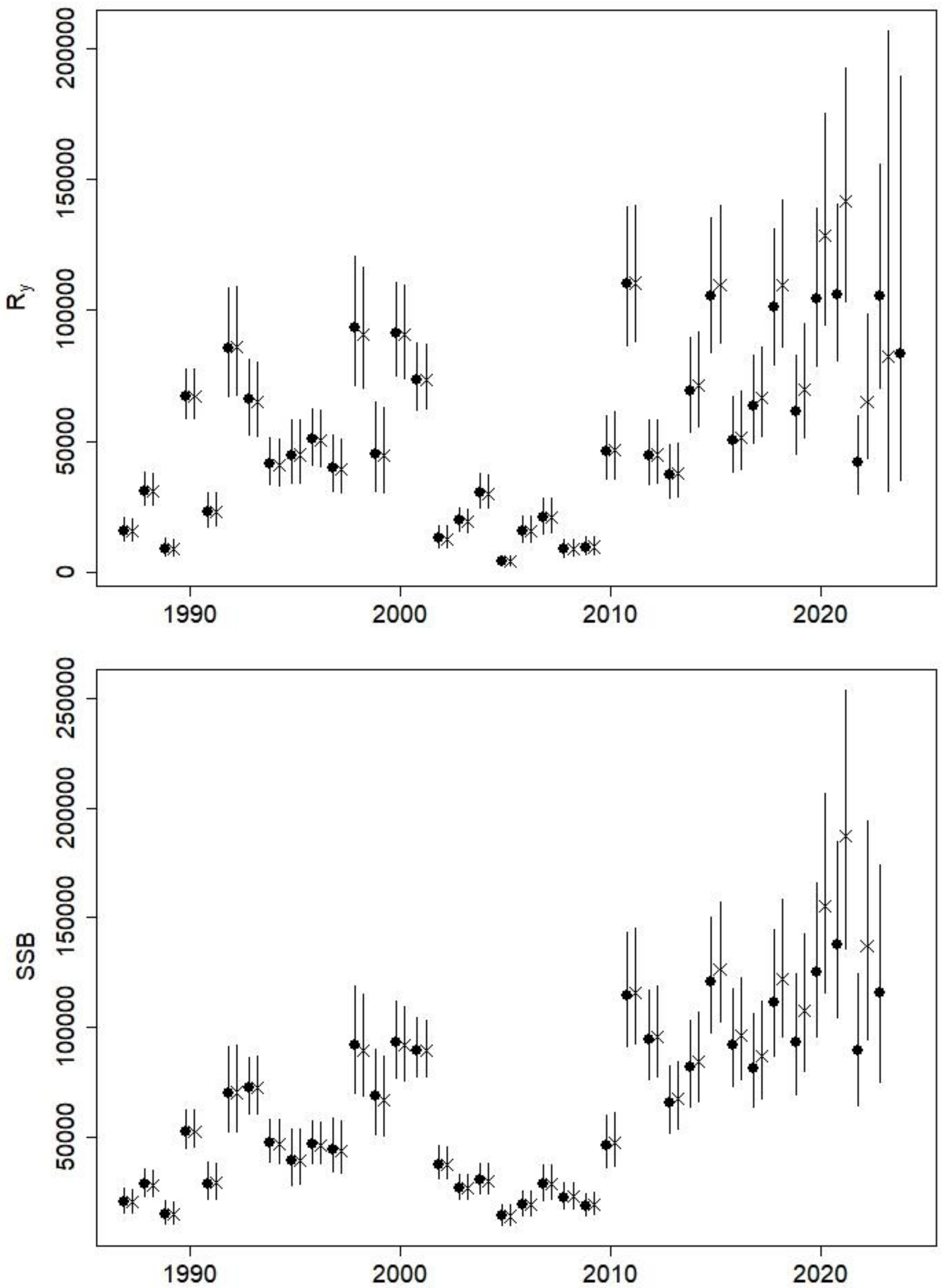
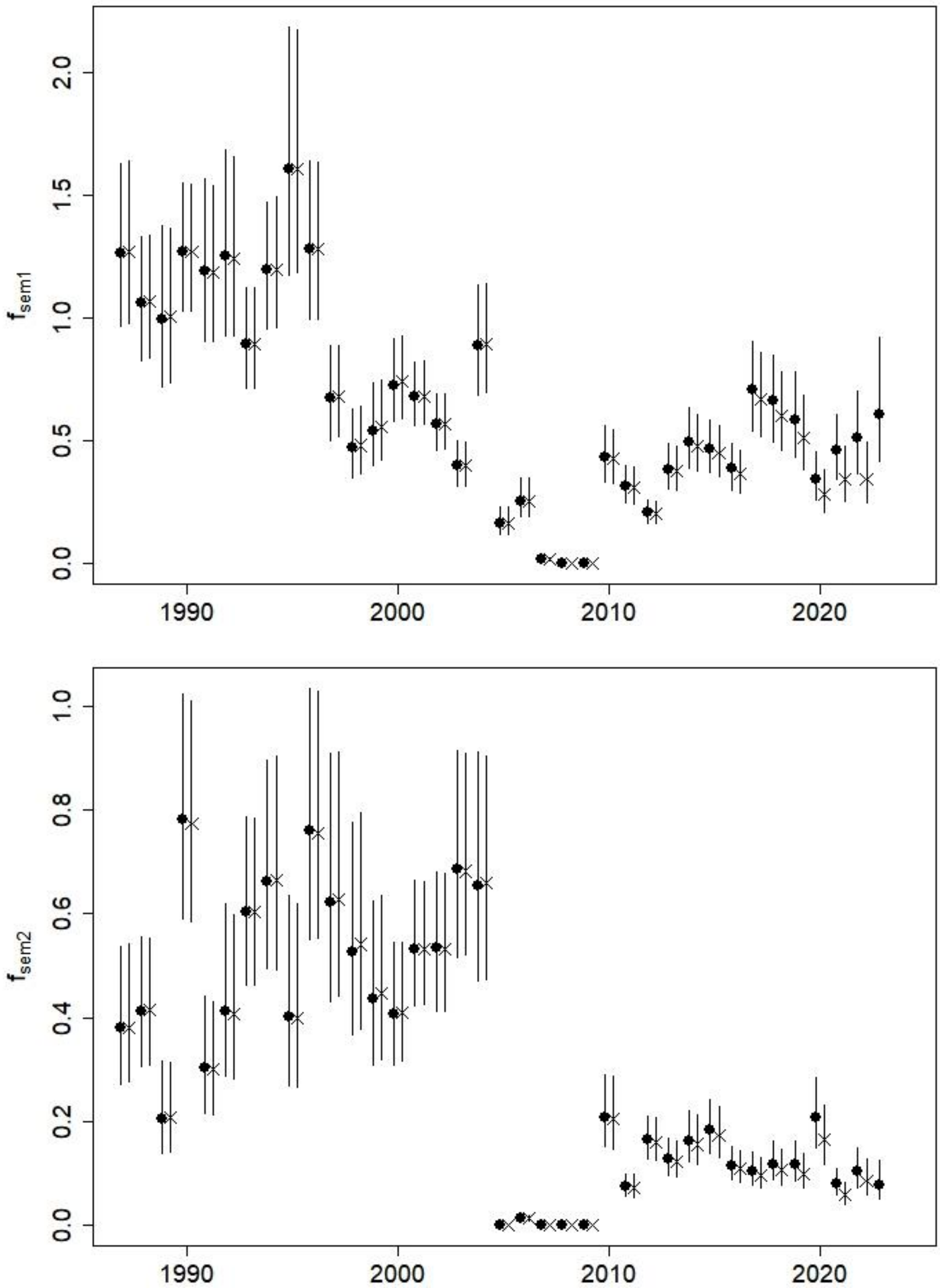


Figure 3.5.1.10: Bay of Biscay anchovy: Pearson residual medians and 90% probability intervals to the survey and catch observations used in the CBBM. From top to bottom and from left to right, residuals of the age 1 biomass proportion from the DEPM, total biomass from the DEPM, age 1 biomass proportion from the acoustic, total biomass from the acoustic, recruitment index, age 1 proportion in mass in the 1st semester catch, total catch in the 1st semester, age 1 proportion in mass in the 2nd semester catch and total catch in the 2nd semester.


R_y
200000
150000
100000
50000
0
1990
2000
2010
2020
SSB
250000
200000
150000
100000
50000
1990
2000
2010
2020


2.0
1.5
1.0
0.5
0.0
f_{sem1}
1990
2000
2010
2020
1.0
0.8
0.6
0.4
0.2
0.0
f_{sem2}
1990
2000
2010
2020

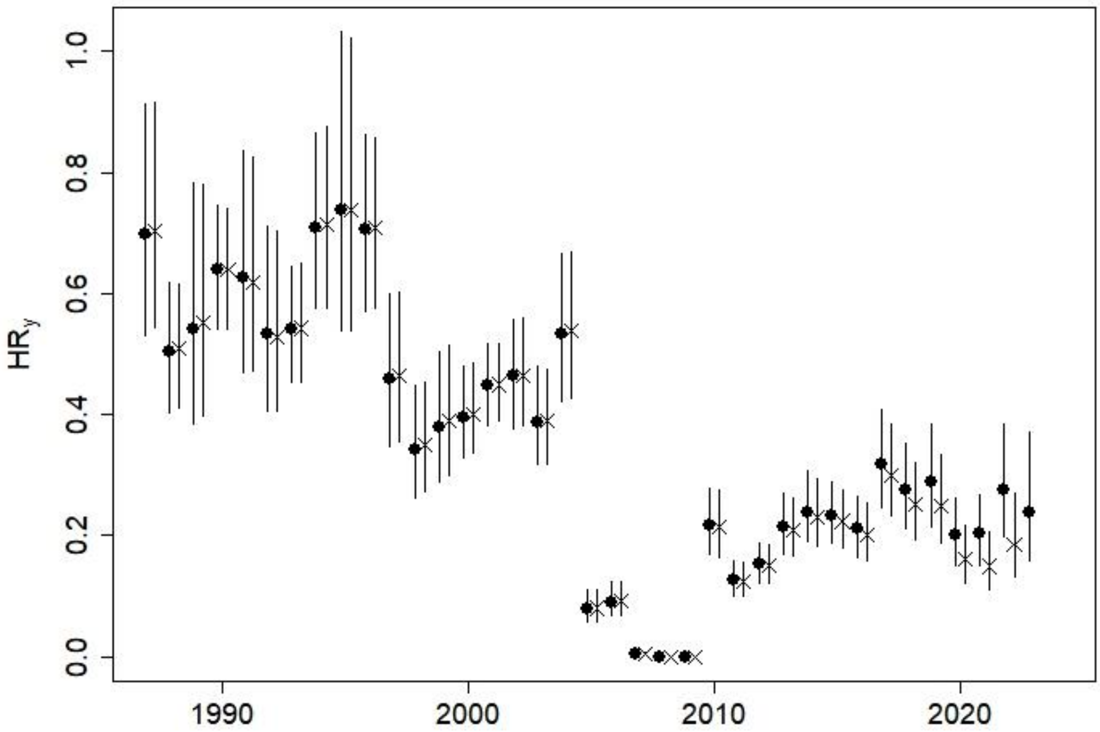


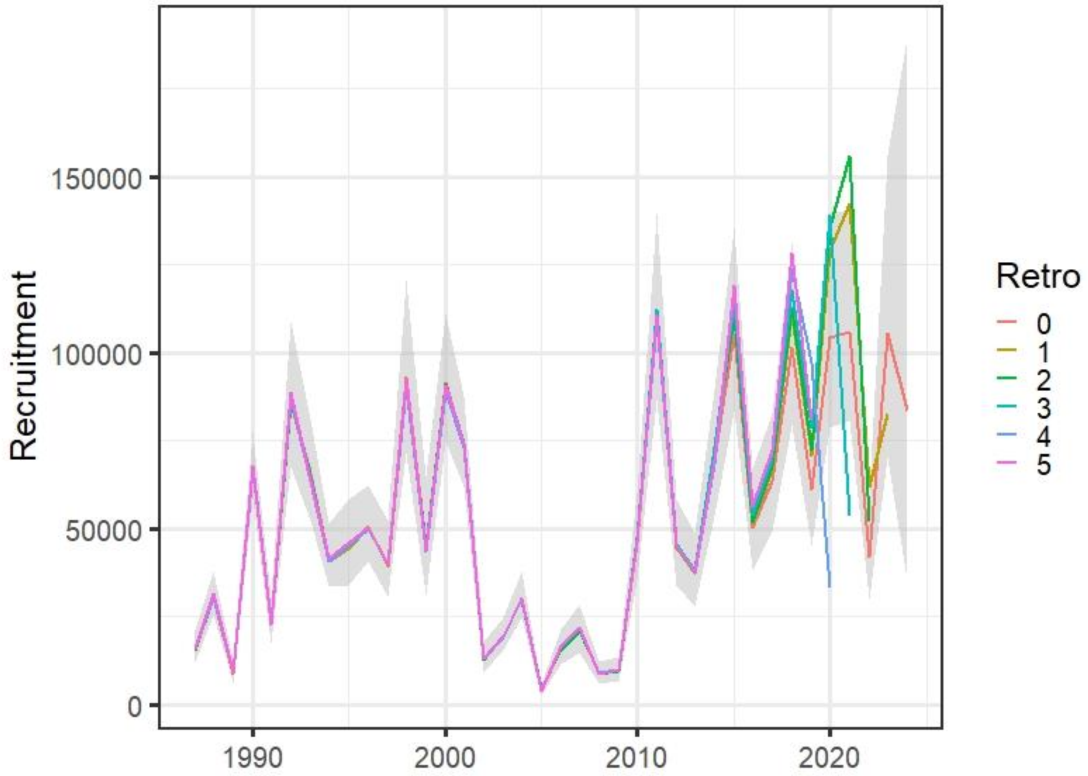
Figure 3.5.1.11: Bay of Biscay anchovy: From top to bottom comparison of the posterior median (points) and 90% probability intervals (solid lines) of the recruitment (age 1 in mass in January), the spawning–stock biomass, the fishing mortality in the first and in the second semester and the harvest rate assessed in WGHANSA 2022 (cross) and in WGHANSA 2023 (bullet).

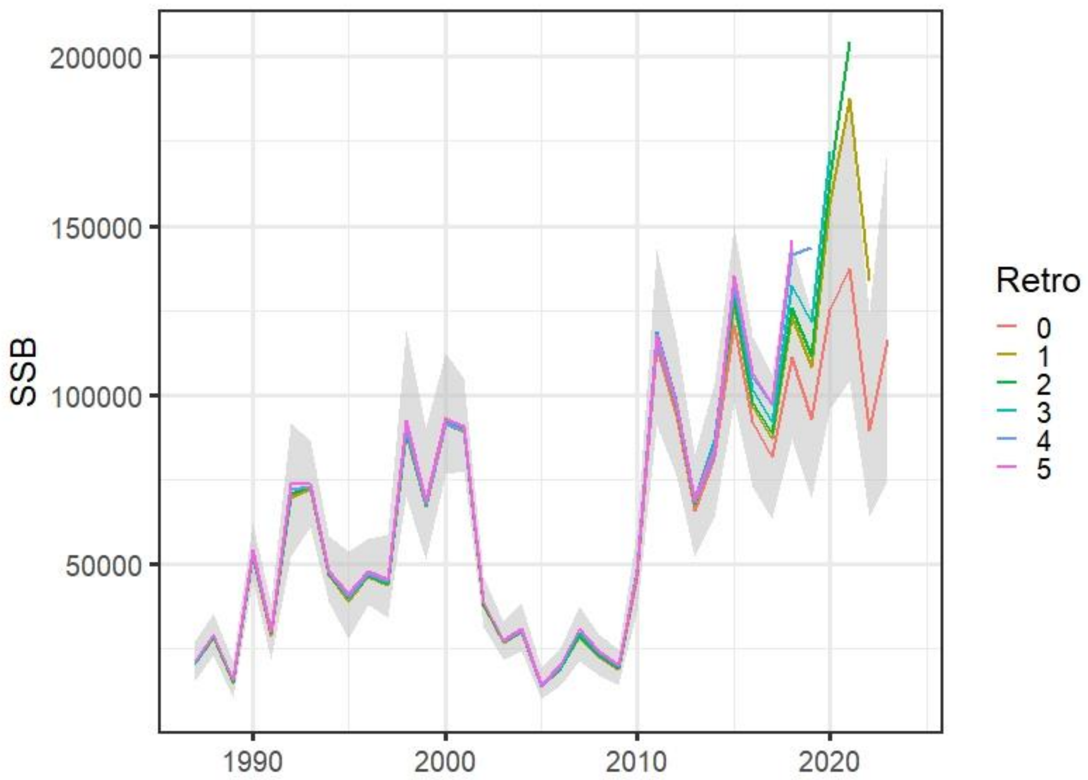
3.5.2 Retrospective pattern

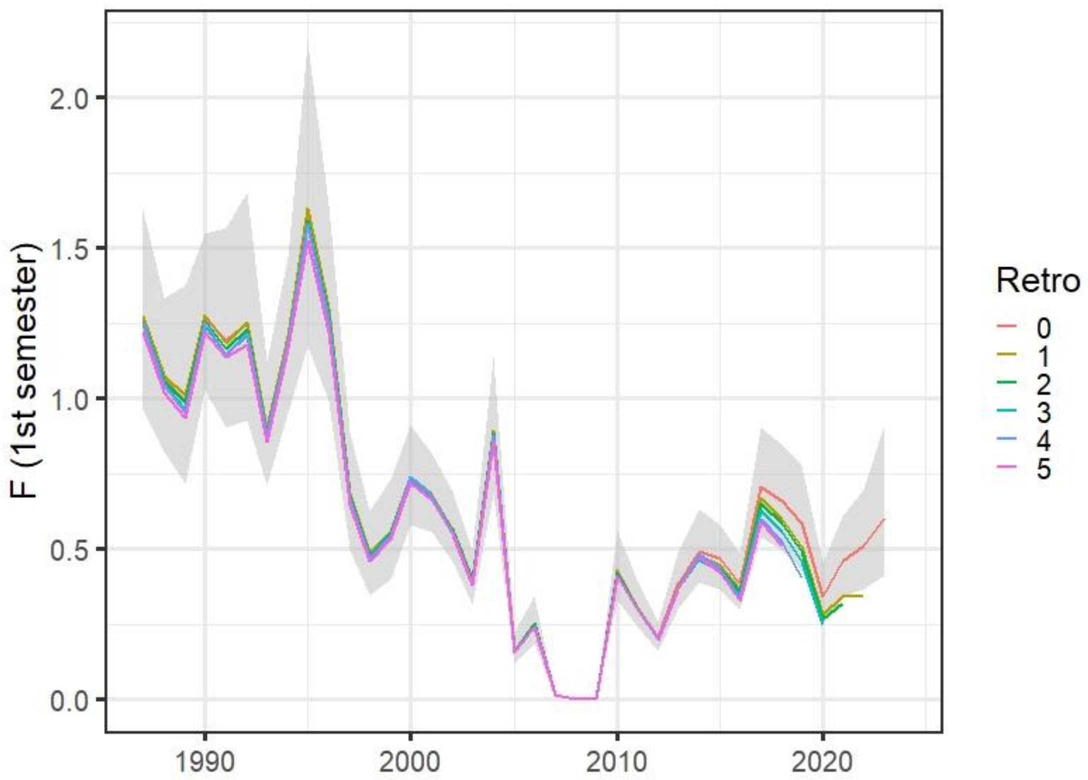
A five-year retrospective analysis of SSB, recruitment, fishing mortality by semester and harvest rate was conducted. For each run, assessment was conducted using DEPM and acoustic surveys data until the terminal year and recruitment survey data until the intermediate year. Catch data for the intermediate year were assumed to be zero, so that SSB and fishing mortality by semester for the intermediate year were not considered reliable, i.e. only estimates of recruitment in the intermediate year were analysed.

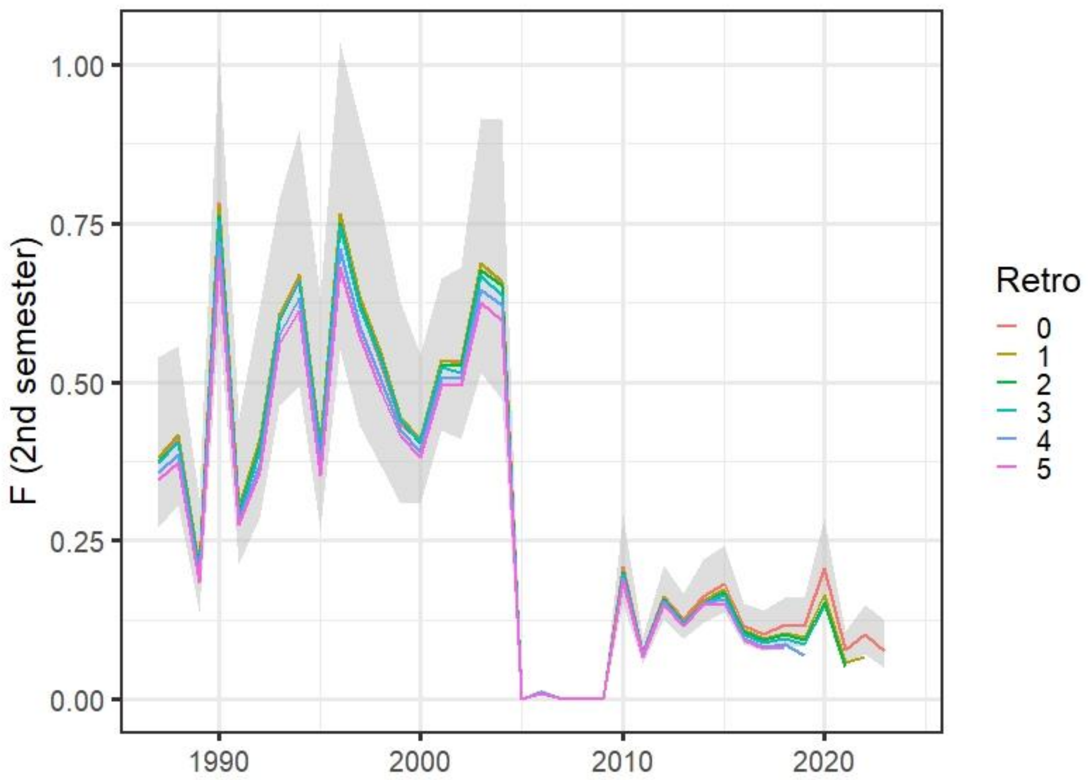
The trends for SSB, recruitment and fishing mortality by semester in the retrospective analysis are similar. However, looking at absolute values, the estimates from the retrospective analysis in general are not within the 90% probability interval of last year's assessment (Figure 3.5.2.1). Although results from assessments in 2018, 2019, 2020, 2021 and 2022 show similar time series, results in 2023 have been notoriously revised for the last 5 years estimates (Figure 3.5.2.1). Recruitment has been revised downwards (except for 2023) while fishing mortalities were revised upwards as noted in the previous section.

Retrospective bias was measured in terms of the Mohn's rho (Mohn, 1999) using the function mohn() in the R package icesAdvice (https://CRAN.R-project.org/package=icesAdvice). The relative bias for recruitment in the intermediate year was positive in 2019 and 2022, and negative in the other years, with high absolute values for 2020 and 2021 (Figure 3.5.2.2). It ranged between -0.7 and 0.3 and the Mohn's rho was calculated at -0.17. The relative bias for SSB in the terminal year was always positive (Figure 3.5.2.2). The relative bias for SSB ranged between 0.3 and 0.5, and the Mohn's rho was 0.44. Mohn's rho for the fishing mortality by semester and annual harvest rate was -0.28, -0.33 and -0.30 respectively. The relative bias for the three time-series was negative in all the years and ranged between -0.25 and -0.4 (Figure 3.5.2.2).


Recruitment
150000
100000
50000
0
1990
2000
2010
2020
Retro
0
1
2
3
4
5


SSB
200000
150000
100000
50000
1990
2000
2010
2020
Retro
0
1
2
3
4
5


F (1st semester)
2.0
1.5
1.0
0.5
0.0
1990
2000
2010
2020
Retro
0
1
2
3
4
5


F (2nd semester)
1.00
0.75
0.50
0.25
0.00
1990
2000
2010
2020
Retro
0
1
2
3
4
5

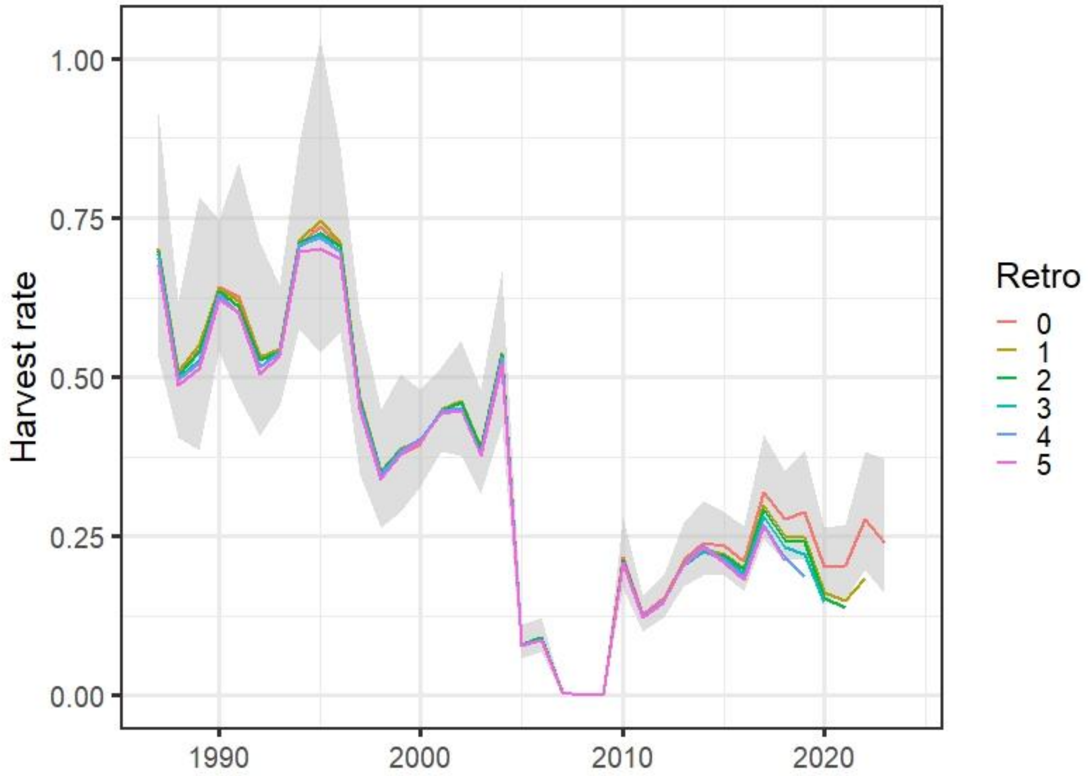
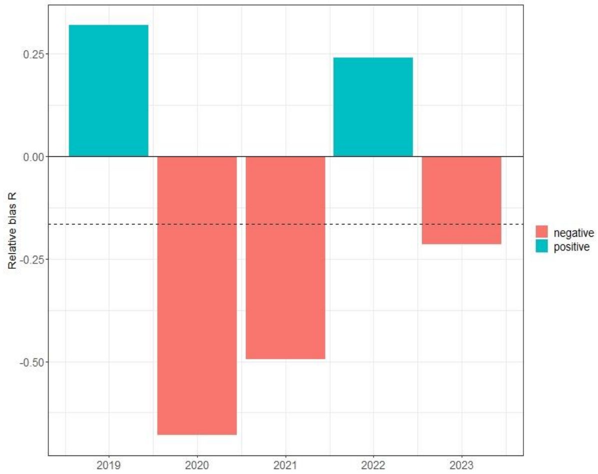
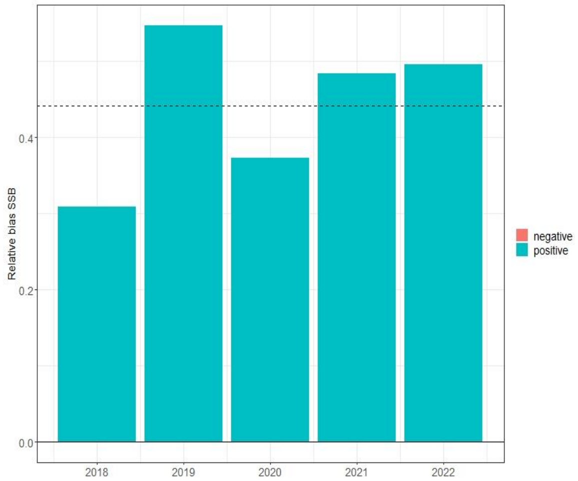
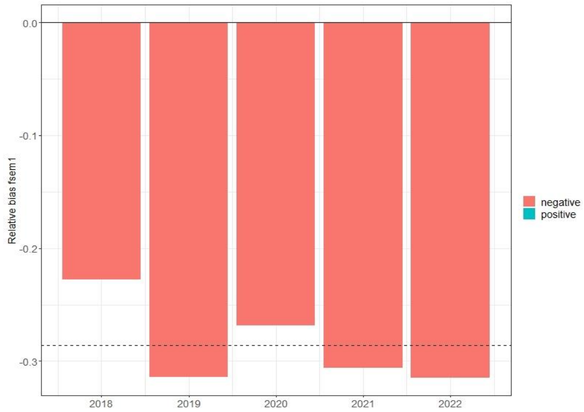


Figure 3.5.2.1: Bay of Biscay anchovy: From top to bottom retrospective pattern of recruitment (age 1 in tonnes on 1st January), SSB, fishing mortality on 1st and 2nd semesters and harvest rate. The shaded are represents the 90% probability intervals from this year's assessment.


Relative bias R
0.25
0.00
-0.25
-0.50
2019
2020
2021
2022
2023
negative
positive


Relative bias SSB
0.4
0.2
0.0
2018
2019
2020
2021
2022
negative
positive


Relative bias fsem1
0.0
-0.1
-0.2
-0.3
2018
2019
2020
2021
2022
negative
positive

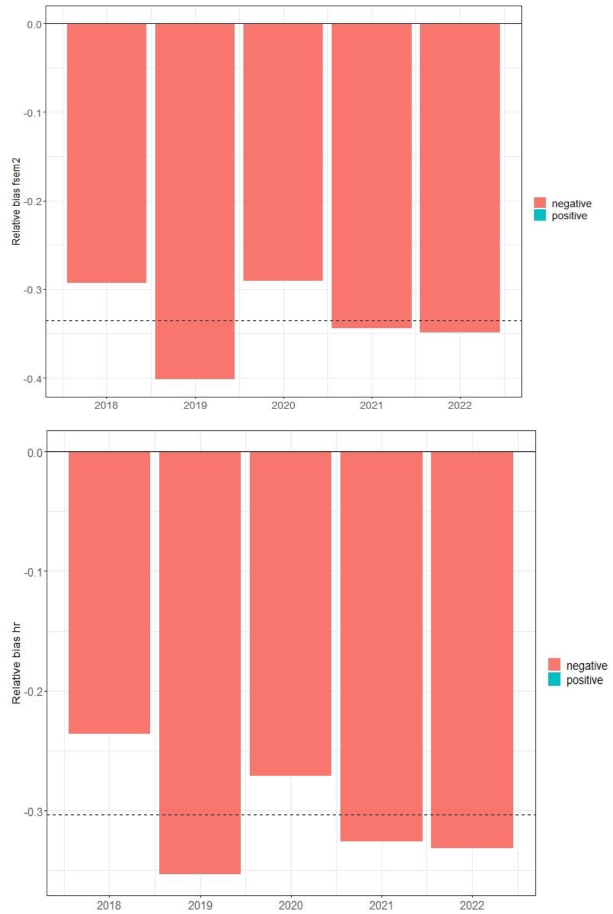


Figure 3.5.2.2: Bay of Biscay anchovy: From top to bottom relative bias of recruitment (age 1 in tonnes on 1st January), SSB, fishing mortality on 1st and 2nd semesters and harvest rate. The horizontal dashed lines represent the Mohn's rho statistic for each time-series.

3.5.3 Reliability of the assessment

Compared to commonly used assessment methods in ICES, the Bayesian two-stage biomass-based model (CBBM) entails changes in both the methodology used for projecting the population forward and establishing catch options and in the terminology in which the assessment and consequent advice is given. The state of the stock is given in terms of spawning biomass, recruitment is understood as biomass at-age 1 at the beginning of the year and management options may be given in terms of catches. Due to the Bayesian framework, all the results are given in stochastic terms and deterministic point estimates are replaced by summary statistics of the posterior distributions of the parameters, such as medians and percentiles.

The Pearson residuals for all the observations used in the assessment show no major discrepancies between the observed and modelled quantities (residuals within -2 and 2). However, the residuals of the age 1 proportion (in mass) in the catch of the first semester have been negative from 2010 (fishery reopening) to 2015, and the residuals of biomass from the DEPM have been positive since 2013. The former can be related to changes in the selection pattern of the fishery, while the later can be related to interannual changes in the percentage of biomass in the Cantabrian coast, which is not covered by the acoustic survey. In addition to these patterns in residuals, this year the assessment results have been revised greater than in previous years (downwards revision for the SSB for the most recent 4-5 years and upwards revision for fishing mortalities). This revision can be also related to the previously mentioned issues such as the conflicting signals in the surveys or incorrect model assumptions (constant growth). All these patterns and revisions should be further investigated in next years.

The catch data for 2023 are preliminary and the definite data will be available for WGHANSA 2024. As a result, the fishing mortality estimates in 2023 must also be considered as preliminary.

In 2015, the WG tested the sensitivity of the assessment to the reallocation of the French catches near the border of Subarea 8, and it was demonstrated that the influence was low. This should be further investigated in the next coming years, especially if the reallocated catches exceed the limits of the historical series.

The assessment scale is given by the survey catchability estimates. It therefore must be emphasized and admitted explicitly that the assessment should always be examined in relative terms, exploring the trends in biomass or harvest rates.

3.6 Short-term predictions

As the assessment, the short-term forecast for this stock can be conducted in June or in November. In June, there is no indication on next year recruitment, so the forecast has usually been based on an assumed undetermined recruitment scenario in which all the past recruitments were equally likely. In November, the forecast can be based on the next year recruitment distribution derived from the November assessment. The short-term prediction presented here, is based on the results from the final assessment conducted in November described in the previous section.

Recruitment in 2024 is estimated in the assessment and it is mainly informed by the latest JUVENA juvenile abundance index and the parameters of the JUVENA observation equations. Figure 3.6.1 shows the posterior distribution of recruitment in 2024 from the assessment in November. The median recruitment (age 1 biomass on 1st January) in 2024 for the November projections is around 83 436t.

The method for the short-term projections based on the November assessment is described in the stock annex approved in October 2013.

The European Commission requested ICES to provide advice based on the harvest control rule (HCR) named G3 with a harvest rate of 0.4 (STECF, 2013, 2014).

The full formulation of this HCR is as follows:

$$TAC_{Jan_y-Dec_y} = \begin{cases} 0 & if \widehat{SSB}_y \leq 24000 \\ -2600 + 0.4\widehat{SSB}_y & if 24000 < \widehat{SSB}_y \leq 89000 \\ 33000 & if \widehat{SSB}_y > 89000 \end{cases}$$

where $\widehat{SSB}_y$ is the expected spawning–stock biomass in year y. See also Figure 3.6.2 for a graphical representation.

In this rule, the TAC from January to December is based on the spawning biomass $\widehat{SSB}_y$ that will occur during the management year, which at the same time depends on the catches taken during the first semester of the management year. So, both parameters (catches and SSB) are inter-dependent and vary together. This leads to seek the value of fishing mortality during the first semester solving the system for the median values of recruitment 2024, biomass at-age 2+ at the beginning of 2024, the growth rates at-age 1 and 2+ and the selectivity at-age 1 in the first semester. The % of annual catches taken in the first semester was assumed to be 60% following STECF (2013; 2014). The simulations done by STECF for similar HCR suggested that the performance of the HCR was not dependent on the assumed split of the catches by semesters.

According to HCR G3 with harvest rate of 0.4, the TAC for the fishing season running from 1 January to 31 December 2024 should be established at 33 000 t. Under the assumption that 60%

of the annual catches are taken in the first semester, the deterministic SSB in 2024 is 119 026 t (Table **Error! Reference source not found.**). When the projection is stochastic, the median SSB in 2024 is around 120 858 t with a 90% probability interval between 68 537 t and 225 284 t (Figure 3.6.3). The probability of SSB in 2024 being below Blim is below 0.001.

Starting from the posterior distribution of recruitment (age 1 biomass) and biomass at-age 2+ on the 1st January 2024, the population was projected forward for one year. Total allowable catch during 2024 were explored from 0 (fishery closure) to 70 000 tonnes with a step of 5000 tonnes for a range of percentages of catches being taken in the first semester from 0 to 1 with a step of 0.1. Probability distributions of SSB in 2024 were derived for each of the catch options. For all cases, the probability of SSB in 2024 being below Blim is below 0.025 (Table **3.6.1** and Figure 3.6.4) and the corresponding median SSB values in 2024 are above 83 973t (Table **3.6.2** and Figure 3.6.4).

Under the assumption that 60% of the annual catches are taken in the first semester, the probability of SSB in 2024 being below Blim is lower than 0.05 for total catches up to 138 309 t (Table **3.6.1** and Figure 3.6.5). The harvest rate in 2023 was equal to 0.24. The same harvest rate in 2024 would lead to catches around 28 945 t and SSB around 120 735 t, with probability of SSB being below Blim lower than 0.001.

The final catch options table for 2024 is given in Table **3.6.3**.

Following the stock annex, the usual underlying assumption for the short-term projections is that 60% of the catches are taken in the first semester. This value corresponds to the average of the percentages of catches in the first semester from 1987 to 2004 before the fishery closure and it was also used in the evaluation of the management plan (STECF, 2013, 2014). However, the percentage of the catches taken in the first semester since the re-opening of the fishery has been 0.75. In 2020 a sensitivity analysis was carried out to test the potential influence of this assumption. In general, given the current high levels of biomass, the impact in the final catch option table was low.

Table 3.6.1. Bay of Biscay anchovy: Probability of SSB in 2024 of being below Blim under different catch options for 2024 and alternative catch allocation by semesters.

P(SSB < Blim)			% CATCHES IN THE FIRST SEMESTER 2024										
			0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
R estimated	TOTAL CATCH 2024	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		10000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		15000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		20000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		25000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002
		30000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004	0.0004
		35000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004	0.0005	0.0009
		40000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004	0.0007	0.0009	0.0013
		45000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004	0.0005	0.0009	0.0013	0.0022
		50000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004	0.0009	0.0013	0.0022	0.0031
		55000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004	0.0009	0.0011	0.0022	0.0025	0.0044
		60000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004	0.0009	0.0015	0.0024	0.0047	0.0095
		65000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0007	0.0011	0.0020	0.0035	0.0066	0.0155
		70000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0009	0.0015	0.0025	0.0047	0.0126	0.0246

Table 3.6.2. Bay of Biscay anchovy. Median SSB in 2024 under different catch options for 2024 and alternative catch allocation by semesters.

P(SSB < Blim)			% CATCHES IN THE FIRST SEMESTER 2024										
			0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
R esti-mated	TOTAL CATCH 2024	0	134,560	134,560	134,560	134,560	134,560	134,560	134,560	134,560	134,560	134,560	134,560
		5000	134,560	134,219	133,879	133,538	133,196	132,851	132,508	132,162	131,817	131,472	131,126
		10000	134,560	133,879	133,196	132,508	131,817	131,126	130,434	129,741	129,052	128,364	127,674
		15000	134,560	133,538	132,508	131,472	130,434	129,396	128,364	127,329	126,296	125,258	124,209
		20000	134,560	133,196	131,817	130,434	129,052	127,674	126,296	124,911	123,507	122,113	120,717
		25000	134,560	132,851	131,126	129,396	127,674	125,950	124,209	122,461	120,717	118,961	117,206
		30000	134,560	132,508	130,434	128,364	126,296	124,209	122,113	120,018	117,905	115,797	113,663
		35000	134,560	132,162	129,741	127,329	124,911	122,461	120,018	117,555	115,085	112,600	110,067
		40000	134,560	131,817	129,052	126,296	123,507	120,717	117,905	115,085	112,239	109,340	106,445
		45000	134,560	131,472	128,364	125,258	122,113	118,961	115,797	112,600	109,340	106,084	102,794
		50000	134,560	131,126	127,674	124,209	120,717	117,206	113,663	110,067	106,445	102,794	99,073
		55000	134,560	130,780	126,984	123,158	119,315	115,441	111,517	107,526	103,536	99,441	95,344
		60000	134,560	130,434	126,296	122,113	117,905	113,663	109,340	104,999	100,564	96,060	91,560
		65000	134,560	130,088	125,604	121,066	116,504	111,878	107,166	102,440	97,577	92,682	87,755
		70000	134,560	129,741	124,911	120,018	115,085	110,067	104,999	99,810	94,581	89,278	83,973

Table 3.6.3. Bay of Biscay anchovy: Catch options for 2024 under the assumption that 60% of the catches were taken in the first semester.

		STOCHASTIC	DETERMINISTIC	
Basis	Catch 2024	P(SSB 2024<Blim)	SSB 2024	Harvest rate 2024
G3 with hr=0.4	33,000	0.000	119,026	0.277
Zero catches	0	0.000	132,726	0.000
Same deterministic harvest rate as 2023	28,945	0.000	120,735	0.240
P(SSB2024<Blim)=0.05	138,309	0.050	71,729	1.928
Other options	10,000	0.000	128,621	0.078
Other options	20,000	0.000	124,476	0.161
Other options	30,000	0.000	120,291	0.249
Other options	40,000	0.000	116,062	0.345
Other options	50,000	0.000	111,789	0.447

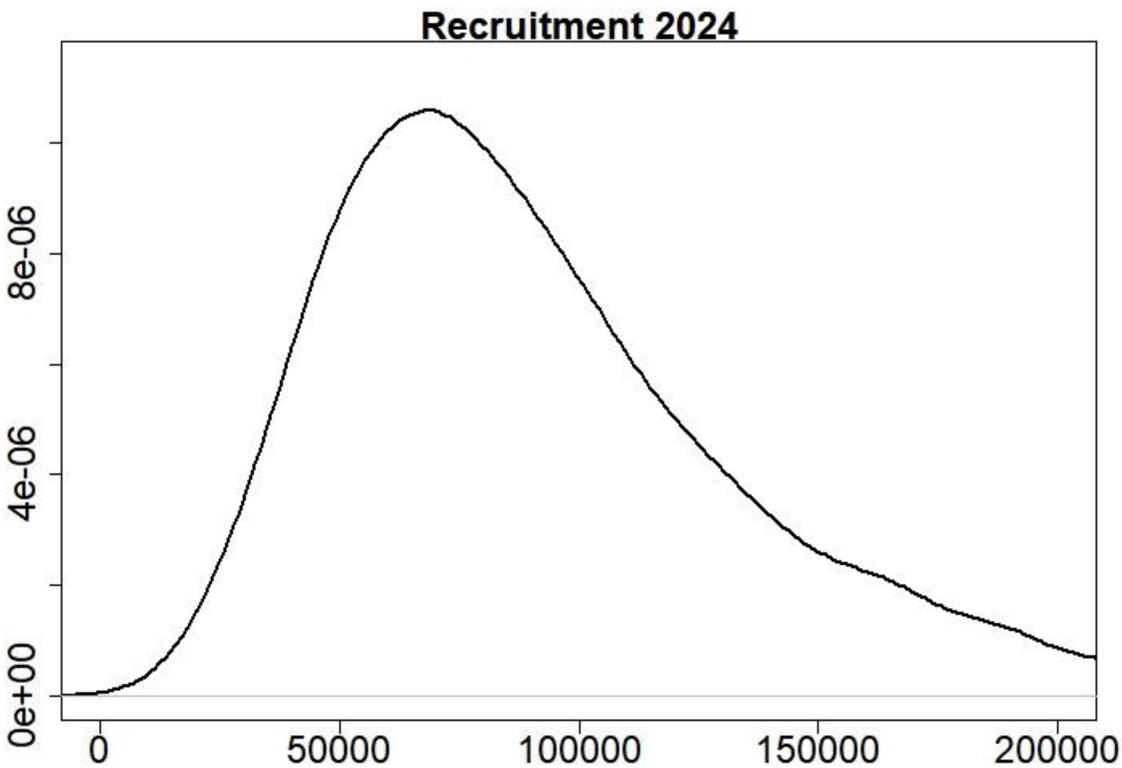


Figure 3.6.1: Bay of Biscay anchovy: Posterior distribution of recruitment (age 1 biomass at the beginning of the year) in 2024.

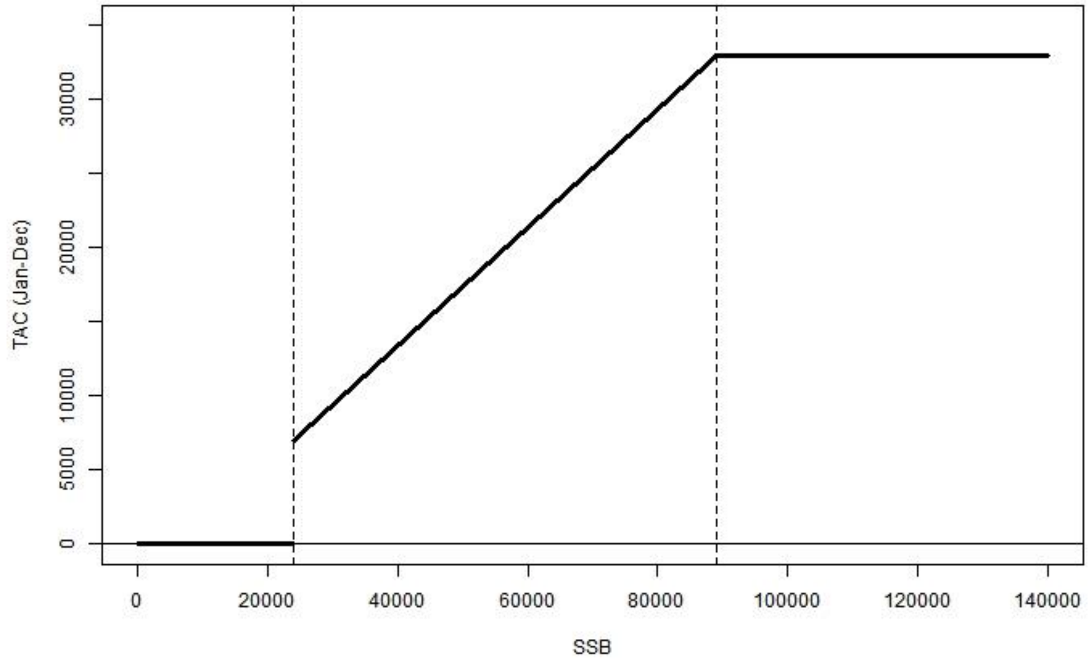


Figure 3.6.2: Bay of Biscay anchovy: Harvest control rule G3 with harvest rate of 0.4 according to which the TAC from January to December is set as a function of the expected spawning–stock biomass (on 15th May) in the management year.

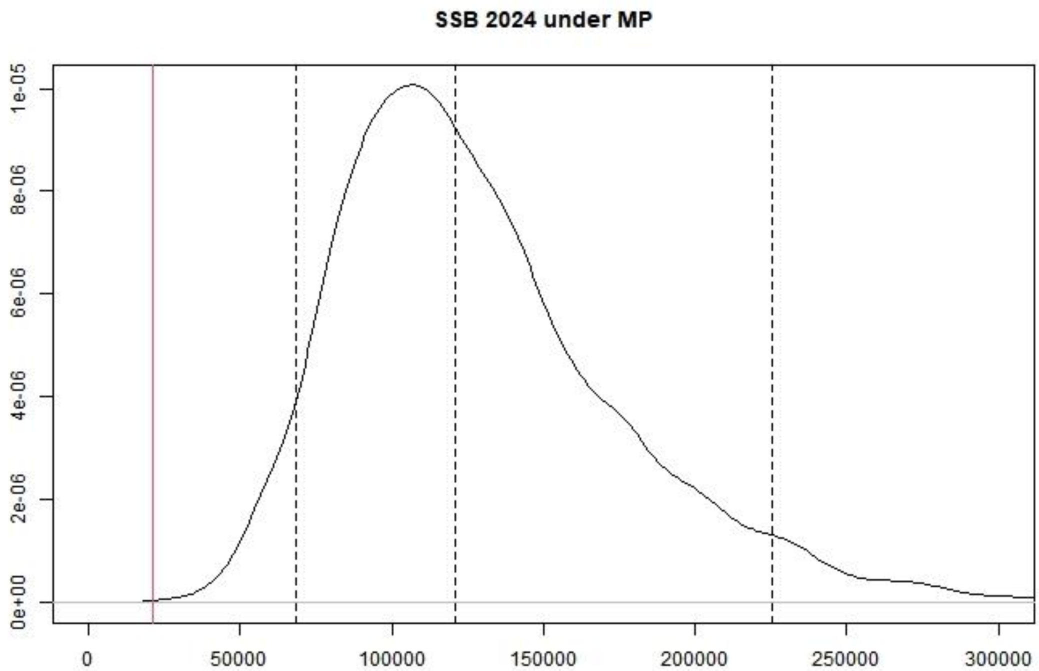


Figure 3.6.3: Bay of Biscay anchovy: Posterior distribution of SSB in 2024 if the annual catch is set according to the LTMP at 33 000 t and 60% of the catch is taken during the first semester. Vertical black dashed lines represent the 5, 50 and 95 posterior quantiles, whereas the red vertical line is Blim (21 000 t).

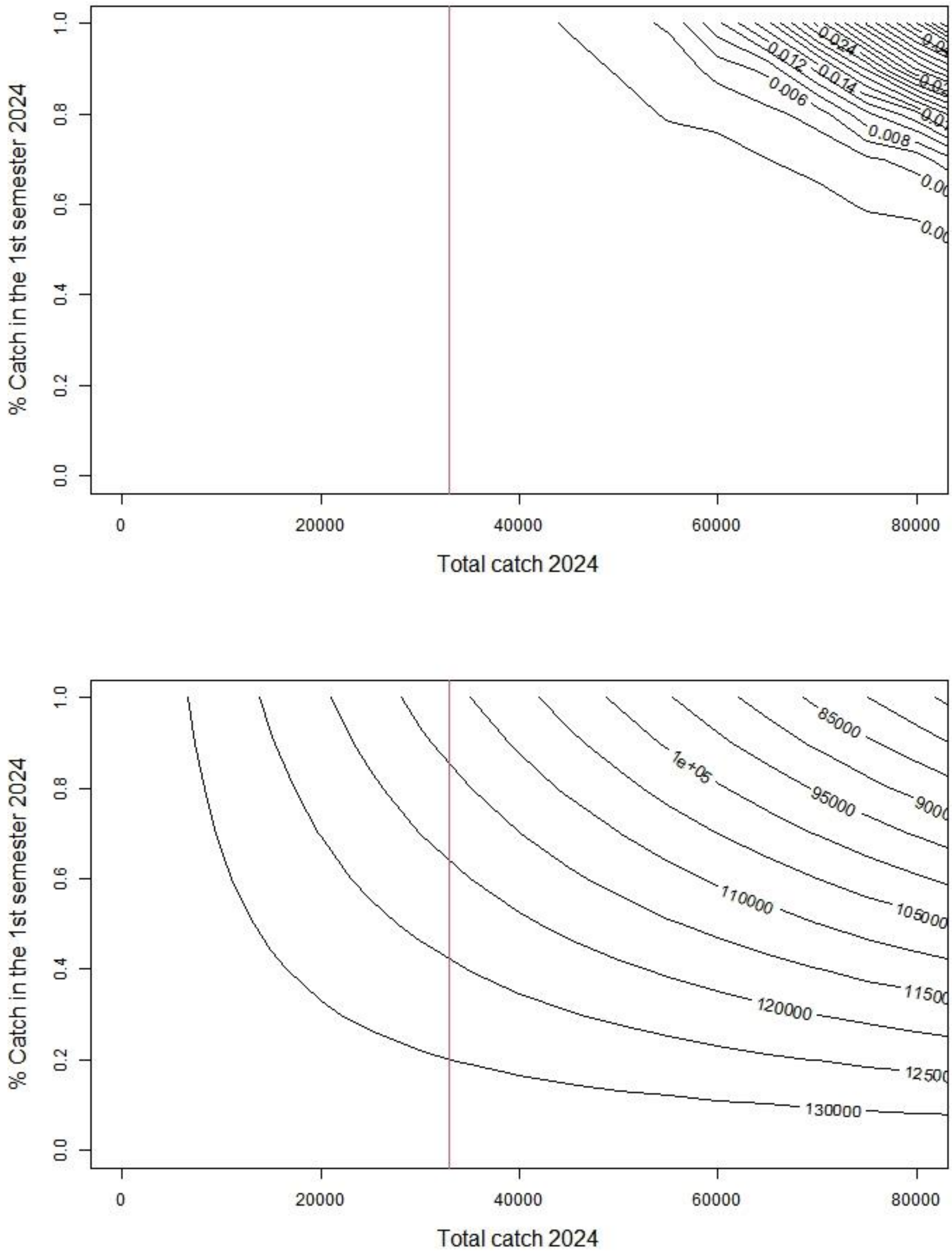


Figure 3.6.4: Bay of Biscay anchovy: Contour plots of probability of SSB in 2024 being below Blim (on the top) and median SSB in 2024 (on the bottom) depending on the total catch in 2024 (x-axis) and the % of the catch in the first semester (y-axis). The vertical red line is set at 33 000 t.

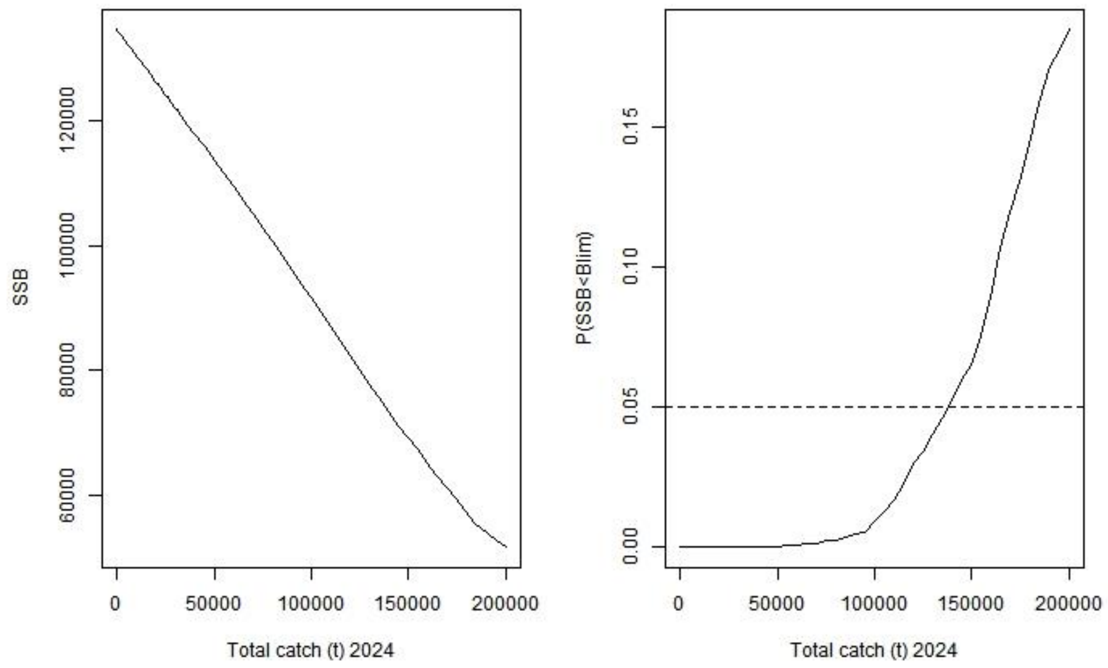


Figure 3.6.5: Bay of Biscay anchovy: SSB in 2024 (on the left) and probability of SSB in 2024 been below Blim (on the right) depending on the total catch taken in 2024 when 60% of the catch is taken during the first semester.

3.6.1 Evidence for changes in advice

A comparison of the input data used in the forecast from the current and previous assessments is provided in this section. In Figure **3.6.1.1** estimated time series for recruitment, SSB and fishing mortalities for first and second semester for previous and current assessments are shown. All estimated quantities for both assessments are compared in Table 3.6.1.1 and forecast assumptions from previous and current advice sheets are shown in Table 3.6.1.2.

The advice for 2024 is unchanged from the advice for 2023. In both years the SSB is above the upper trigger in the management plan, resulting in the maximum allowable catch under the management plan harvest control rule.

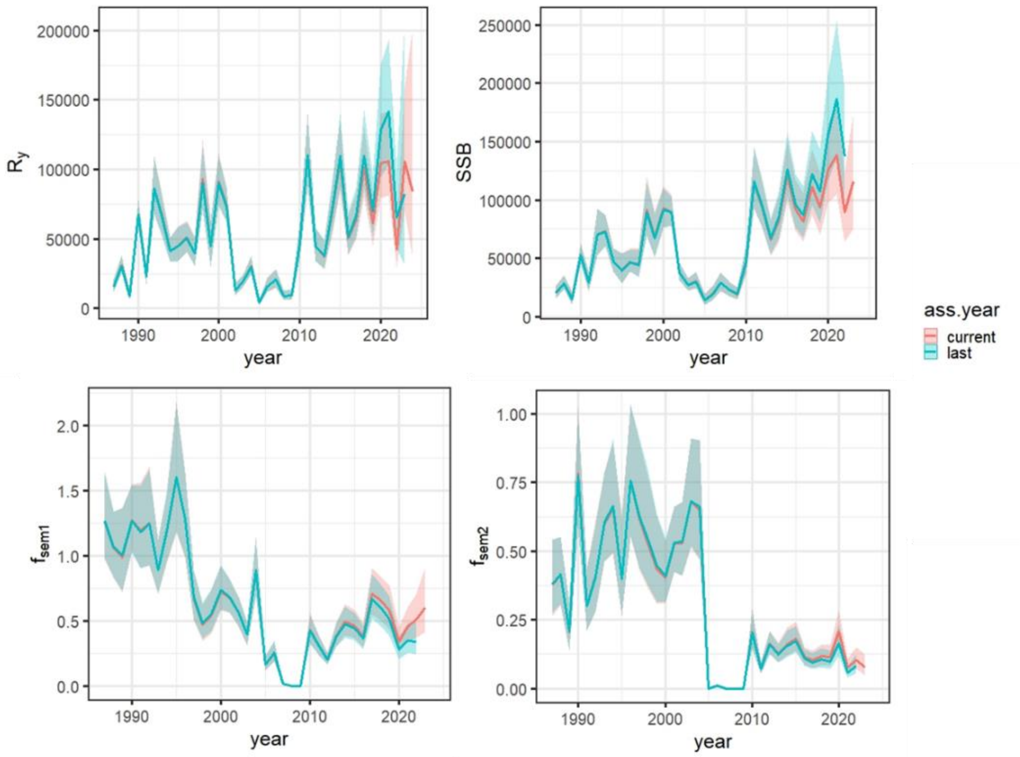


Figure 3.6.1.1: Bay of Biscay anchovy: Recruitment, SSB and fishing mortalities for first and second semester estimated in previous (last) and current assessments.

Table 3.6.1.1: Bay of Biscay anchovy: Estimated quantities in previous and current assessments.

Notation	2023 assessment			2022 assessment			Meaning of parameter
	5%	Median	95%	5%	Median	95%	
qdepm	0.714	0.875	1.071	0.684	0.831	1.007	Catchability of the DEPM B index
qac	1.224	1.471	1.771	1.223	1.452	1.722	Catchability of the Acoustic B index
qrobs	0.014	0.254	4.402	0.027	0.480	8.440	Parameter of the observation equation for the juvenile index
krobs	0.984	1.251	1.523	0.919	1.185	1.453	Parameter of the observation equation for the juvenile index
psidepm	1.926	3.283	5.437	2.325	4.013	6.836	Precision (inverse of variance) of the observation equation of DEPM B index
psiac	3.534	5.994	9.802	4.582	7.985	13.310	Precision (inverse of variance) of the observation equation of Acoustic B index
psirobs	1.113	2.086	3.627	0.962	1.801	3.139	Precision (inverse of variance) of the observation equation of juvenile index
xidepm	3.412	4.043	4.749	3.407	4.075	4.791	Variance-related parameter for the observation equation of DEPM age 1 proportion
xiac	2.757	3.320	3.857	2.816	3.393	3.945	Variance-related parameter for the observation equation of Acoustic age 1 proportion

Notation	2023 assessment			2022 assessment			Meaning of parameter
xicatch	2.368	2.705	3.027	2.354	2.693	3.015	Variance-related parameter for the observation equation of age 1 proportion in the catch
B0	16,076	20,971	26,878	16,046	20,858	26,452	Initial biomass
mur	10.336	10.600	10.874	10.329	10.613	10.884	Median (in log scale) of the recruitment process
psir	0.818	1.223	1.754	0.759	1.155	1.679	Precision (in log scale) of the recruitment process
sage1sem1	0.395	0.460	0.540	0.393	0.462	0.540	Age 1 selectivity during the 1st semester
sage1sem2	0.848	1.021	1.220	0.852	1.027	1.239	Age 1 selectivity during the 2nd semester
G1	0.485	0.538	0.596	0.487	0.541	0.599	Intrinsic growth at age 1
G2	0.167	0.217	0.272	0.175	0.227	0.285	Intrinsic growth at age 2+
psig	21.154	29.708	40.141	20.434	28.282	38.333	Precision of the observation equations for intrinsic growth at ages 1 and 2+
SSB_{ass_y}	74,813	116,065	174,121	94,268	137,278	194,166	Estimated SSB in the assessment year

Table 3.6.1.2: Bay of Biscay anchovy: Forecast assumptions from previous and current assessments.

	Year*	Current assessment (2023)	Previous assessment (2022)
Assumed recruitment	2022	42 062	98 865
	2023	105 404	82 389
	2024	83 436	
Catch	2022	25 196	25 496
HR	2022	0.28	0.19

***'2022' = Intermediate year in the previous assessment; '2023' = advice year in the previous assessment**

3.7 Reference points and management considerations

3.7.1 Reference points

The reference points and their definitions are found in the stock annex for this stock, which was approved in October 2013.

Bay of Biscay anchovy is a short-lived species classified in category 1. According to the guidelines, the classification of status of stock for short-lived species should be based directly on the distribution of SSB at spawning time relative to B_{lim}. B_{lim} is set at 21 000 tonnes. Given that the current assessment provides the probability distributions for SSB, the probability of SSB being below B_{lim} can be directly estimated and the definition of B_{pa} becomes irrelevant. Alternatively, F precautionary approach (PA) reference points don't need to be defined, since ICES does not use F reference points to determine exploitation status for short-lived species.

According to the recent advisory practice (ICES Advice 2019, Book1, Section 1.2 General context of ICES advice), the ICES MSY approach for short-lived stocks is aimed at achieving a target escapement (MSY Bescapement, the amount of biomass left to spawn), which is more robust against low SSB and recruitment failure than a fishing mortality approach. In addition, fishing mortality is not allowed to be higher than F_{cap}, a limit fishing mortality that constraints the exploitation rate when biomass is high. This applies to the Bay of Biscay anchovy. Hence, defining an FMSY is irrelevant, and advice aiming at MSY is equivalent to the precautionary approach advice. ICES advice for this stock is based on a management plan and MSY Bescapement and F_{cap} have not been defined for this stock.

3.7.2 Short-term advice

Providing a risk adverse advice according to the precautionary approach in the short-term perspective translates into recommending a TAC, which implies a low risk of leading below B_{lim}, for selected scenario(s) of recruitment.

The Bayesian assessment model provides estimates of the uncertainty, which are expressed as posterior distributions of the interest parameters. The posterior distributions express the uncertainty of the results given the uncertainty of the data and the prior assumptions, and presumably represent more realistic estimates of the uncertainty than the assumptions underlying the distance between B_{lim} and B_{pa} in the common deterministic framework.

According to the current stock annex, the assessment of this stock can be conducted at two points in time: in June when SSB is estimated based on the most recent spring surveys information and in November when the assessment can incorporate the most recent juvenile abundance index from JUVENA and any other updated data.

Similarly, the forecast can be given based either on the June or November assessment. In the former the assessment goes up to June, and given that there is no indication on the strength of the incoming year class, an undetermined scenario is assumed based on a mixture distribution of all the past recruitments. In the latter, the assessment covers the whole year up to December and the next year recruitment distribution is derived from the assessment which includes the latest juve-nile abundance index.

3.7.3 Management plans

A draft management plan was proposed by the EC in 2009 in cooperation between science (STECF) and stakeholders (Southwestern Waters AC). This plan was not formally adopted by the EU, but it was used from 2010 to 2014 for establishing the TAC for the period between 1st July and 30th June next year.

In February 2013, the Bay of Biscay anchovy stock was benchmarked in the Benchmark Workshop on Pelagic Stocks (WKPELA). The new stock annex for this stock was approved in October 2013 after further discussions held during WGHANSA 2013 and afterwards by correspondence.

Given that the 2009 long-term management plan proposal for the stock was based on the methods described in the previous stock annex (approved by WKSHORT 2009), STECF was requested to assess the harvest control rule and possible alternatives scoped with the stakeholders, and provide advice taking into account the long-term biological and economic objectives established in the plan. The STECF expert group met from 14 to 18 October 2013 and concluded that the change in the assessment methodology did not affect the usefulness of the LTMP proposal and that the HCR remained within the precautionary limits of risk.

In addition, the STECF expert group advised on a possible revision of the HCR (including changes regarding the HCR and the management calendar) and set the basis for conducting an impact assessment for the Bay of Biscay anchovy long-term management regulation (STECF, 2013).

The data analysis for support of the impact assessment for the management plan of Bay of Biscay anchovy was carried out by an STECF expert group that met from 10 to 14 March 2014 (STECF, 2014). A range of alternative HCR formulations were tested and they were considered to provide a sound base for developing options for fisheries management. In particular, for all the HCRs tested, the STECF noted that changing the management period to January–December reduced the risks of the stock falling below Blim, and leaded to a small increase in quantity and stability of catches compared with the management period July–June.

During the two expert group meetings, the STECF concluded that the HCR in the 2009 LTMP proposal remained appropriate as a basis for advising on TACs. Therefore, in July 2014, the TAC from July 2014 to June 2015 was set according to this draft plan.

In the second semester of 2014, managers and stakeholders agreed on adopting the HCR named G4 in the STECF report with a harvest rate of 0.45 (Figure **3.7.3.1**). According to this rule, the TAC for the management period from January to December is set as:

$$TAC_{Jan_y-Dec_y} = \begin{cases} 0 & if \widehat{SSB}_y \le 24000 \\ -3800 + 0.45\widehat{SSB}_y & if 24000 < \widehat{SSB}_y \le 64000 \\ 25000 & if \widehat{SSB}_y > 64000 \end{cases}$$

where is the expected spawning–stock biomass in year. In this rule, the TAC from January to December is based on the spawning biomass that will occur during the management year, which at the same time depends on the catches taken during the first semester of the management year. So, both parameters (catches and SSB) are interdependent and vary together. This leads to seek the value of fishing mortality during the first semester solving the system for the median values of incoming recruitment, biomass at-age 2+ at the beginning of the year, the growth rates at-age 1 and 2+ and the selectivity at-age 1 in the first semester. The % of annual catches taken in the first semester is assumed to be 0.6 according to STECF (2013; 2014).

Subsequently, the European Commission requested ICES to provide advice in December 2014 based on this new HCR, which was used to set a new TAC from January to December 2015. In 2015, ICES reviewed the selected harvest control rule and concluded that it was precautionary (Annex 5 in ICES, 2015a). Subsequently, ICES advice for year 2016 was again provided in accordance with this HCR. In May 2016, the SWWAC recommended to modify the management framework (SWW Opinion 101). Based on the good state of the stock, they asked to use the harvest control rule G3 with a rate of exploitation of 0.4 (Figure **3.7.3.1**), which sets the TAC for the management period from January to December as:

$$TAC_{Jan_y-Dec_y} = \begin{cases} 0 & if \widehat{SSB}_y \le 24000 \\ -2600 + 0.4\widehat{SSB}_y & if 24000 < \widehat{SSB}_y \le 89000 \\ 33000 & if \widehat{SSB}_y > 89000 \end{cases}.$$

This rule complies with the probability of risk of 5% as evaluated by STECF (2014) and has been assessed to conform to the ICES criteria for management plans (ICES, 2016, Annex 9). The SWWAC recommended an immediate application of this HCR and in June 2016 the European Commission increased the fishing opportunities for 2016 from 25 000 to 33 000 tonnes. The European Commission requested that this rule was used as the basis of the ICES advice from 2017 onwards.

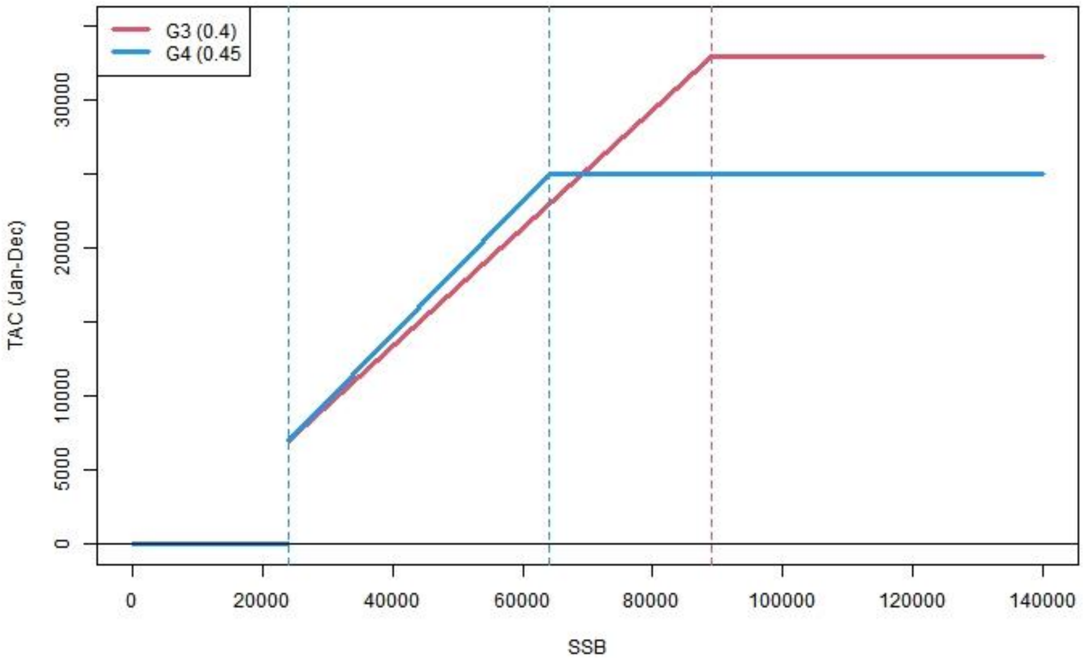


Figure 3.7.3.1: Bay of Biscay anchovy: Harvest control rules G4 with harvest rate of 0.45 (in red) and G3 with harvest rate of 0.4 (in blue) according to which the TAC from January to December is set as a function of the expected spawning–stock biomass (on 15th May) in the management year.

3.7.4 Species interactions effects and ecosystem drivers

Anchovy is a prey species for other pelagic and demersal species, and also for cetaceans and birds. Recruitment depends strongly on environmental factors, and several recruitment predictions have been proposed in the past based on environmental variables. However, their prediction capacity is still being tested.

3.7.5 Ecosystem effects of fisheries

These effects are not quantified.

3.8 References

ICES. 2015. Report of the working group on southern horse mackerel, anchovy and sardine (WGHANSA), 24-29 june 2015, lisbon, portugal. ICES CM 2015/ACOM:16. 612 pp.

STECF. 2013. Advice on the harvest control rule and evaluation of the anchovy plan COM(2009) 399 final (EWG 13-20). Publications Office of the European Union, Luxembourg, 2013, ISBN 978-92-79-34619-4.

STECF. 2014. Evaluation /scoping of management plans - data analysis for support of the impact assessment for the management plan of bay of biscay anchovy (COM(2009)399 final) (EWG 14-03). Publications Office of the European Union, Luxembourg, 2014, ISBN 978-92-79-37843-0.

4 Anchovy in Division 9.a

4.1 ACOM Advice Applicable to the management period July 2022–June 2023

The stock was benchmarked in February 2018 (WKPELA 2018 ICES, 2018a). WKPELA 2018 supported the proposal of considering two different components of the stock (western and southern component) due to the different dynamics of their fisheries and populations. However, until the stock structure along the division is properly identified, the provision of advice will still be given for the whole stock, but with separate catch advice for each stock component. Given the high natural mortality experienced by this stock, its high dependence upon recruitment (the fishery depends largely on the incoming year class, the abundance of which cannot be properly estimated before it has entered the fishery), and the large inter-annual fluctuations observed in the spawning stock, ICES is aware that the state of this resource can change quickly. Therefore, an in-year monitoring and management, or alternative management measures should be considered. However, such measures should take into account the data limitation of the stock and the need for a reliable index of recruitment strength.

From the above reasons, the management calendar for the application of the advice has been agreed to be the one from 1st July of year *y* to 30th June of year *y+1* since 2018 onwards.

ICES advised for the period 1st July 2022 to 30th June 2023 that when the precautionary approach is applied, catches from the western component should be no more than 14 083 t and catches from the southern component should be no more than 1694 t (no more than 15 777 t for the whole stock). The TAC for this same management period was initially agreed in 15 777 t (Portugal: 8231 t; Spain: 7546 t). After the application of inter-annual flexibility criteria and swaps the national quotas were finally adjusted to 8231 t for Portugal and 7968 t for Spain.

Official anchovy landings in the division in 2022 were of 10 299 t. Estimated total catches were 10 343 t. Provisional estimated catches for the current management calendar are 13 106 t (western component: 5869 t; southern component: 7237 t).

4.2 Population structure and stock identity

A review of the anchovy sub-stock structure in the Iberian Atlantic waters (Ramos, 2015) was submitted in 2015 to the ICES Stock Identification Methods Working Group SIMWG; ICES, 2015). At that time, SIMWG considered that there was evidence to support a self-sustained population of anchovy located in the Gulf of Cadiz (GoC, ICES Subdivision 9a South), but there was a lack of information regarding the origin of European anchovy in the western subdivisions (comprising subdivisions 9a North, 9a Central-North and 9a Central-South; **Figure 4.2.1**).

This stock was benchmarked at WKPELA in 2018 by ICES (ICES, 2018a) and an updated review of this issue was provided to this workshop, which included new available information of the potential connectivity of anchovy population of the 9a West subdivisions with the south Iberian population (Garrido *et al*., 2018a). Evidence shown at that time led to the decision of considering the anchovy populations inhabiting the southern and western Iberian regions as separate stock components for management purposes. The western component comprises the subdivisions 9a North, 9a Central-North and 9a Central-South. The southern component includes the Portuguese and Spanish waters of the Subdivision 9a South.

A Working Document was submitted and presented during WGHANSA-1 2022 with updated information on anchovy stock structure in the 9a area (Garrido *et al*. 2022). Anchovy spatial distribution in Division 9a provided by surveys shows a persistent discontinuity between the western and southern components of the stock for several life stages (eggs, juveniles and adults) and during different seasons of the year. Landings also show this discontinuity, with more than 90% of Portuguese landings occurring in Subdivision 9a C-N since 2017. No correlation was found between anchovy catches between the two areas, suggesting independent dynamics. The hypothesis that the western stock might come from migration from the southern component was not supported by the current data, since there was no correlation between anchovy abundance and landings in the western Iberia with anchovy abundance in the southern Iberia in the following year. The spatial discontinuity and the independent dynamics between the western and southern anchovy populations point to the presence of a self-sustained anchovy population in the western Iberia, independent of the southern component. A review of studies conducted in Portuguese estuaries have also shown the persistent presence of recruits in numerous estuaries, mainly in the Subdivision 9a C-N, which, agreeing with the concentration of eggs in this subdivision, points to the presence of a self-sustained population in this area. Morphometric and genetic studies seem to indicate a differentiation of the western and Cantabrian populations, as well as a separation with those from the Gulf of Cadiz, but additional analyses are needed as these conclusions might be affected by the presence of two ecotypes (marine and coastal), which are often not considered in these studies. From the evidence presented in that working document, WGHANSA supported the separation of the western and southern components of the anchovy 27.9.a into two stock units: the population in Subdivision 9a South and the populations from sub-divisions in the western coast (9a North, Central-North and Central-South). Such a proposal was then submitted to the ICES Stock Identification Methods Working Group (SIMWG) for consideration (ICES, 2022). SIMWG stated that the results of those studies detect differentiation between both stock components (e.g. Silva *et al*., 2014; Zarraonaindia *et al*., 2012) but may be biased by different (and unknown) proportions of each ecotype in the samples used. SIMWG advocates for the need for future monitoring programs to include sampling that considers the ecotypes presence and to further use genomic markers that display an appropriate level of resolution both geographic and genetic.

4.3 The fishery in 2022

4.3.1 Fishing fleets

Anchovy harvesting throughout the Division 9.a was carried out in 2022 by the following fleets in each stock component:

Western component

- Portuguese purse-seine fleet (PS_SPF_0_0_0).
- Portuguese multipurpose fleet (although fishing with artisanal purse-seines) (MIS_MIS_0_0_0_HC).
- Portuguese trawl fleet for demersal fish species (OTB_DEF_>=55_0_0).
- Spanish purse-seine fleet (PS_SPF_0_0_0).
- Spanish miscellaneous fleet (artisanal métiers accidentally fishing anchovy) (MIS_MIS_0_0_0_HC).

Southern component

- Portuguese purse-seine fleet (PS_SPF_0_0_0).
- Portuguese multipurpose fleet (although fishing with artisanal purse-seines) (MIS_MIS_0_0_0_HC).
- Portuguese trawl fleet for demersal fish species (OTB_DEF_>=55_0_0).
- Spanish purse-seine fleet (PS_SPF_0_0_0).
- Spanish bottom otter trawl directed to demersal fish in 9.a South (OTB_MCD_>=55_0_0 anchovy discards).

The Spanish fleet fishing anchovy in the Western component was composed in 2022 by a total of 36 vessels. From this total, 28 vessels (78%) were purse-seiners (**Table 4.3.1.1**). No information on the number of Portuguese vessels fishing anchovy in 2022 was available to the working group, but it may be assumed that the fleet operating in 2021 and 2022 should not be very different from the one in 2020. The Portuguese fleet targeting anchovy and operating in the Western component in 2020 was composed by a total of 113 vessels in the Subdivision 9.a Central North and 52 vessels in the Subdivision 9.a Central South (ICES, 2021a).

Number and technical characteristics of the purse-seine vessels operated by Spain targeting anchovy in their national waters off GoC (Southern component) are also summarised in **Table 4.3.1.1**. In 2022, GoC anchovy fishing was practised by 54 purse-seiners, 7 vessels less targeting anchovy than in 2021, and still lower than in previous years (74-78 vessels for the period 2016-2018). Details of the dynamics of this fleet in terms of number of operative vessels over time in recent years are given in ICES (2008a; WGANC 2008 report) and subsequent WGHANSA reports. The Portuguese fleet targeting anchovy and operating in the Southern component in 2020 was composed of a total of 22 vessels (ICES, 2021a).

4.3.2 Catches by stock component and division

4.3.2.1 Catches in Division 9.a

Anchovy total catch in 2022 was estimated at 10 343 t, which accounted for 42% decrease in relation to the time-series maximum (since 1989) of catches recorded in the previous year (17 837 t), and they represent a negative change in the recent period of consecutive high catch levels which started in 2016 (Table 4.3.2.1.1, Figure 4.3.2.1.1). The above estimate is the result from adding up 10 231 t of official landings and 112 t of discards (see Section 4.3.3).

As usual, the anchovy fishery in 2022 was almost exclusively harvested by purse-seine fleets (98.9% of the total catch). However, unlike the Spanish fleet fishing in the GoC, the remaining purse-seine fleets in the division (historically targeting sardine and fishing anchovy as a commercial by-catch) only have targeted anchovy when its abundance was high, as occurred in 2011 and in 2014–2022.

Provisional official landings during the first semester in 2023 amounted to 3502 t (updated until 30thApril for the Portuguese fishery and until 17th May for the Spanish one). Preliminary, 39% of the official landings from the Spanish fishery in 9a S in January–May (percentage estimated as the mean of those estimated for the period 2009–2022) were added to account for catches in June 2023 not yet reported. After such computations, the landings in the Spanish fishery in 9a S during the first semester in 2023 were estimated in 3836 t.

Provisional catches during the current management period (July 2022–June 2023), as the result of summing up total catches from the second semester in 2022 and provisional official (estimated) landings from the first semester in 2023, amounted to 13 106 t for the whole Division (5869 t from the western component and 7237 t from the southern component).

The contribution of each stock component to this total catch is described in the following sections.

4.3.2.2 Catches by stock component

The updated historical series of anchovy catches by subdivision are shown in table 4.3.2.1.1 (see also Figure 4.3.2.1.1). Table 4.3.2.2.1 shows the contribution of each fleet in the total annual catches by subdivision. The seasonal distribution of 2022 catches by subdivision is shown in Table 4.3.2.2.2.

Western component

The total catch in 2022 for this stock component was estimated at 3548 t, which accounted for 65% decrease on the 2021 catch (10 276 t; *i.e.* the historical maximum within its time-series), but still above the time-series average (2345 t). Catches from this component in 2022 accounted for 34% of the total catch in the division. The fractions composing this total catch in 2022 were: 3548 t of official landings and 0 t of discards.

Provisional official landings during the first semester in 2023 amounted to 3354 t.

Provisional catches during the current management period (July 2022–June 2023) amounted to 5869 t.

The distribution of these catches by subdivision is as follows:

Subdivision 9a North

In this Spanish subdivision a total of 15 t was caught in 2022, which accounted for 98% decrease in relation to the 2021 catches (747 t), 0.4% of the total catch estimated for the Western component and 0.1% for the whole division. These catches are well below the time-series average (387 t). Purse seiners were the main responsible for the fishery (99.9% of the total catch in the subdivision). The fishery was concentrated in the first quarter.

Provisional official landings during the first semester in 2023 amounted to 2683 t (up to 17th May 2023). Those ones corresponding to the current management calendar amounted to 2685 t.

Subdivision 9a Central-North

This subdivision concentrated a great part of the anchovy fishery in 2022 in the Western component (99%), but it was not the case for the whole division (34%): a total catch of 3509 t was estimated (with all of these catches corresponding to official landings; neither unallocated nor discarded catches were reported). These catches represented a 63% decrease regarding the catches estimated the previous year (9521 t), but they are still well above the time-series average (1901 t). Purse-seiners practically harvested the whole fishery, mainly during the first and third quarters in the year.

Provisional official landings during the first semester in 2023 amounted to 669 t (up to end of April). Official landings for the current management calendar were 3158 t.

Subdivision 9a Central-South

Anchovy catches from this subdivision were 24 t (all of them official landings), accounting for a 214% increase in relation to the catches in 2021 (8 t) but still staying this value below its time-series average (57 t). Such catches accounted only for 0.7% of the total catch in the Western component and 0.2% of the total catch in the division. The fishery was mainly harvested by purse-seiners, mostly during the third and fourth quarters.

Provisional official landings during the first semester in 2023 (up to end of April) in this subdivision amounted to only 2 t. Official landings for the current management calendar were 26 t.

Southern component

Subdivision 9a South

The total catch in 2022 of this stock component was estimated at 6795 t, which accounted for a 10% decrease with respect to the 2021 catch (7562 t), but above the time-series average (5106 t), and represented 66% of the total catch in the division. The fractions composing this total catch in 2022 were: 6683 t of official landings (Portugal: 0.1 t, Spain: 6683 t) and 112 t of (Spanish) discards.

Almost the whole of the total catch (98%) was captured by the purse-seine fleet.

The fishery was concentrated during the second and third quarters in the year.

As mentioned above, provisional official landings during the first semester in 2023 amounted to 3836 t, all of them fished by the Spanish fishery. Preliminary; 1076 t, corresponding to 39% of the Spanish official landings in January–May (mean 2009–2022), were added to the Spanish data to account for landings in June 2023 not yet reported. Official landings and total catches during 2022 in the subdivision for the current management calendar were 3357 t and 3401 t, respectively. Preliminary estimates for catches for the current management calendar (July 2022–June 2023) amounted to 7237 t (landings: 7193 t; discards: 44 t).

4.3.3 Discards

See the stock annex for previous available information on discards in the division.

General guidelines on appropriate discard sampling strategies and methodologies were established during the ICES Workshop on Discard Sampling Methodology and Raising Procedures (ICES, 2003).

Covid-19 disruption and the interruption of the IEO’s on-shore and at-sea sampling programs during the first semester in 2020 because administrative and budgetary reasons prevented from estimating discards during that semester in the Spanish fisheries in subdivision 9a N and 9a S. Sampling programs performed as planned in 2021.

Average discards estimates (in t) in subdivision 9a N for the available time-series (2014-2022) show that quarterly discards could be considered, for the time being, as negligible, almost null. The same considerations have also been applied to the discards in the Spanish fishery in 9a S.

Western component

Subdivision 9a North

No discards have been recorded during 2022 in the subdivision 9a N. The overall annual discard ratio for the Spanish fishery in this stock component in 2019 was 0.0006 (0.06%) and may be also considered in 2022 as negligible as described above.

Subdivisions 9a Central-North and Central-south

Regarding the Portuguese anchovy fishery in this stock component, the official information provided to the WG states that there are no anchovy discards in the fishery.

Southern component

Subdivision 9a South

No anchovy discards have been reported from the Portuguese fishery.

Discards in the Spanish fishery were recorded in the purse-seine (3 t) and the bottom-trawl fishery (109 t) mainly during the third quarter. The estimated discards (112 t) represented an annual discard ratio of 0.02 (1.7%) and may be considered as a very low ratio.

4.3.4 Effort and landings per unit of effort

Western component

CPUE indices are not considered for this stock component.

Southern component

Annual standardised landings per unit of effort, lpue, series for the whole Spanish purse-seine fleet fishing GoC anchovy (Subdivision 9.a-South) are routinely provided to this WG. An update of the available series (1988–2022) has been provided this year to this WG (**Figure 4.3.4.1**). Details of data availability and the standardisation process are commented in the stock annex. At present, the series of commercial lpue indices is only used for interpreting the Spanish purse-seine fleets' dynamics in Subdivision 9a S. The recent dynamics of fishing effort and lpue for this fleet has been described in previous WG reports. Fishing effort experienced a strong decrease since 2017, which was coupled to a parallel decrease in catches. A relatively stable trend in effort (with some increase in 2020 and 2021) has been recorded during the 2017-2022 period, which was coupled with steeply increasing catches resulting in an increasing trend in lpue in the very recent years (from less than 1 t to at around 1.2-1.9 t/fishing day). However, a probable overestimation of the annual estimates computed so far was suggested in previous WG reports because of a probable underestimation of the true exerted fishing effort on anchovy, since fishing trips targeting anchovy with zero anchovy catches are not considered in the effort measure.

4.3.5 Catches by length and catches-at-age by stock component

Length–frequency distribution (LFD) of catches and catch-at-age data from the whole Division 9.a are routinely provided to this WG from the Spanish fishery operating in the GoC (Subdivision 9.a S), since the anchovy fishery in the division is traditionally concentrated there. Data from the Spanish fishery in Subdivision 9.a N were usually not available since commercial landings used to be almost negligible. The same reason is also valid for the Portuguese subdivisions (included the Portuguese part of the 9.a S (Algarve)), although in this case anchovy was also a group 3 species in its national sampling program for DCF. Nevertheless, the local increases of anchovy abundance in subdivisions 9.a N and C-N recorded since 2014 have led to a circumstantial exploitation of the species by the fleets operating in those areas. The respective national sampling programmes accounted for this event those years but in an accidental way. A higher sampling effort has been made in the port of Matosinhos (9.a C-N) since 2018 to have monthly biological data of anchovy in that area that represents the bulk of catches in the western component.

Quarterly LFDs in 2022 have been provided for the Spanish fishery in subdivision 9.a N for the first quarter only. Landings of the remaining quarters were raised to the corresponding quarterly LFDs in the previous year. Quarterly ALKs were based on half-yearly ALKs made by combining *PELACUS* (April) survey samples and May and June commercial ones (for the first and second quarters), and July and September commercial samples (for the third and fourth quarters).

Quarterly LFDs and ALKs from the Spanish fishery in subdivision 9.a S were also available and showed a relatively good coverage. Nevertheless, no LFD was available for landings from the first quarter, being these landings raised to the LFD of the second quarter. LFDs from bottom-trawl and purse-seine discards were available in all of the quarters when they were estimated.

LFDs from the Portuguese fishery provided to this WG are the ones from the anchovy purse-seine fishery in Subdivision 9.a Central-North, given that only 0.7% and 0.003% of the Portuguese catches occurred in the 9.a Central-South and 9.a South (Algarve) subdivisions, respectively. Data was only available for the 1st, 3rd and 4th Quarters.

Catch-at-age data in 2022 have only been provided for the Portuguese fishery from subdivision 9.a C-N for the 3rd and 4th Quarters. No age structure is available for 2022 Portuguese anchovy catches in subdivisions 9.a C-S and 9 a. S (Algarve), related to the low catches observed in those areas.

4.3.5.1 Length distributions

Western component

Subdivision 9.a North

Quarterly and annual size composition of anchovy catches for the whole fishery in the Subdivision 9.a North in 2022 are shown in **Table 4.3.5.1.1**. Size range in catches from the whole fishery varied between 11.5 and 18.5 cm size classes (main mode at 16.5 cm size class and a secondary mode at 13.5 cm size class), with the annual mean size and weight in catches being estimated at 16.5 cm and 32.0 g, respectively.

Subdivision 9.a Central-North

The size composition of 2022 anchovy catches from the Subdivision 9.a Central-North is shown in **Table 4.3.5.1.2**. These length–frequency distributions (LFDs) correspond to catches landed by purse-seiners and polyvalent fleets throughout the year and incidental bottom-trawl catches in the second semester, hence the raising and further pooling processes applied in order to obtain overall LFDs by quarters for the whole fishery were done using the data from purse-seine fishery, that accounts for >99% of all catches. Anchovy size composition in catches from the whole fishery in 2022 ranged between 10.5 and 19.0 cm size classes (main mode at 16.5 cm size class and a secondary mode at 13.5 cm size class), with a mean size and weight in catches being estimated at 15.2 cm and 24.5 g, respectively.

Subdivision 9.a Central-South

No length composition is available from the Portuguese fishery in this subdivision since the catches were very scarce.

Southern component

Subdivision 9.a South

Quarterly LFDs from the Spanish catches in 2022 for the whole fishery is shown in **Table 4.3.5.1.3**. Size range of the exploited stock (landings plus discards) in the whole fishery varied between 4.5 and 18.0 cm size classes, with the main modal class located at the 12.5 cm size class and a secondary one at 9.5 cm. Anchovy mean length and weight in the Spanish 2022 annual catch (12.3 cm and 12.8 g) were the highest estimates in the time-series but they used to be the smallest anchovies in the division.

No length composition is available from the Portuguese fishery in this subdivision since the catches were very scarce.

4.3.5.2 Catch numbers-at-age

Western component

Subdivision 9.a North

Estimates from the fishery in this subdivision in 2022 are shown in **Table 4.3.5.2.1**. These estimates are shown together with the age structure of catches in previous years with available data in **Table 4.3.5.2.2** and **Figure 4.3.5.2.1**. The estimated total catch in numbers in 2022 was of 0.5 million fish, composed by ages 1, 2 and 3 anchovies, with ages 1 and 2 accounting for 60% and 33% of the total catch in numbers, respectively.

Subdivision 9.a Central-North

Estimates from the fishery in this subdivision in 2022 have been provided to the WG (**Table 4.3.5.2.3**, **Figure 4.3.5.2.2**).

The estimated total catch in numbers in 2022 was of 388 million fish, composed by 0, 1, 2 and 3 years old anchovies, which accounted for 16%, 65%, 17%, and 2% of the total catch, respectively.

Subdivision 9.a Central-South

No estimate from this subdivision in 2022 has been provided to this WG since the catches were very scarce.

Southern component

Subdivision 9.a South

Table 4.3.5.2.4 shows the quarterly and annual anchovy catches-at-age in the Spanish fishery in 2022. Total catches in the Spanish fishery in 2022 were estimated at 530 million fish, which accounted for 14% decrease in relation to the 618 million caught during the previous year. Such an increase was caused by 28%, 10% and 13% decreases of ages 0, 1 and 2, respectively. Age 1 group is the dominant age group (76% of the total catch in numbers). Age group 3 anchovies were absent in the fishery.

The recent historical series of annual landings-at-age in the Spanish fishery in 9.a South is shown in **Table 4.3.5.2.5** and **Figure 4.3.5.2.3**. Description of annual trends of landings-at-age data from the Spanish fishery through the available data series is given in previous WG reports.

No data are available from the Portuguese fishery in this subdivision since the catches were very low.

4.3.6 Mean length and mean weight-at-age in the catch

Western component

Subdivision 9.a North

The resulting estimates for the fishery in 2022 are shown in **Tables 4.3.6.1** and **4.3.6.2**. Anchovy mean length and weight in the catches were estimated at 16.5 cm and 32.0 g. The available series of estimates are shown in **Figure 4.3.6.1** and indicate that anchovies by age group from this subdivision are usually larger and heavier than those harvested in the southernmost areas. In 2022, all the age groups experienced a small increase in the mean length and weight in catches.

Subdivision 9.a Central-North

The available estimates for the fishery in 2022 are shown in **Tables 4.3.6.3** and **4.3.6.4**. A series of regular estimates is only available since 2017 in this subdivision. Anchovy mean length and weight in the catches from north-western Portugal in 2022 were estimated at 15.2 cm and 24.5 g (**Figure 4.3.6.2**).

Subdivision 9.a Central-South

No estimate from this subdivision is available.

Southern component

Subdivision 9.a South

The 2022 estimates of the mean length and weight-at-age of Gulf of Cadiz anchovy Spanish catches are shown in **Tables 4.3.6.5** and **4.3.6.6**. **Figure 4.3.6.3** shows the recent history of the evolution of such estimates. Anchovy mean length and weight in the Spanish 2022 annual catches were estimated at 12.3 cm and 12.8 g respectively, a slightly higher mean size and higher mean weight than those ones recorded in the previous year. In 2022, all the age groups experienced a small increase in the mean length and weight (but age-1 anchovies, which showed a smaller mean weight than in 2021) in catches.

4.4 Fishery-independent Information

Table 4.4.1 shows the list of acoustic and DEPM surveys providing direct estimates for anchovy in Division 9.a. The WG considers each of these survey series as an essential tool for the direct assessment of the population in their respective survey areas (subdivisions) and recommends their continuity in time, mainly in those series that are suffering from interruptions through its recent history.

4.4.1 DEPM-based SSB estimates

***BOCADEVA* series**

Anchovy DEPM surveys in the division are only conducted by IEO for the SSB estimation of Gulf of Cadiz anchovy (Subdivision 9.a-South, *BOCADEVA* survey series). The methods adopted for both the conduction of these surveys and the estimation of parameters are described in the stock annex and in ICES (2009) and Massé *et al*. (2018).

The series started in 2005 and their surveys are conducted with a triennial periodicity. Since 2014, this series has been financed by DCF. The last *BOCADEVA* survey was conducted in summer 2020. The next survey will be conducted in July 2023. The time-series of mean estimates and their associated variances for the egg and adult parameters, and the SSB are shown in **Table 4.4.1.1** and **Figures 4.4.1.1** and **4.4.1.2**.

4.4.2 Spring/summer acoustic surveys

General

A description of the available acoustic surveys providing estimates for anchovy in Division 9.a is given in the stock annex. Survey's methodologies deployed by the respective national Institutes (IPMA and IEO) are also thoroughly described in Massé *et al*. (2018) and Doray *et al.* (2021).

A summary list of the available acoustic and DEPM surveys providing direct estimates for anchovy in Division 9.a is given in **Table 4.4.1**. Detailed information in the present section will be provided for those surveys carried out during the elapsed time between 2022 and 2023 WGHANSA meetings.

***PELACUS* series**

PELACUS 0423

The Spanish *PELACUS* acoustic-trawl time-series started in 1984. Since 1998, survey strategies and methodologies, together with the Portuguese *PELAGO*, are standardized with the French one *PELGAS*. Moreover, since 2000 the three time-series are using CUFES to collect sub-surface sardine and anchovy eggs. *PELACUS* was carried out on board R/V *Thalassa* from 1997 to 2012 and since then is routinely conducted on board the Spanish R/V *Miguel Oliver*. An inter-calibration survey was done in April 2014 off Garonne mouth (*i.e.* at the spawning season and area of both sardine and anchovy). No significant changes in both fish availability (acoustic) or in fish accessibility, catchability or selectivity (trawl) were detected, and therefore similar performance for both vessels was assumed.

PELACUS 0423 was conducted between 7th and 30th April 2023 on board the R/V *Miguel Oliver*. Sampling grid this year was based on acoustic transects separated 10 nm, between 20 and 1000 m depth, and with random start in each of the geographical strata, which correspond to the ICES subareas. Detailed information on this survey was not available at the time of writing this report, namely the distribution and abundance of anchovy in subarea 8c (this information will be presented in the ICES WGACEGG meeting in November this year). The occurrence of anchovy in the subdivision 9a N increased since last year when the occurrence in this area was incidental. **Figure 4.4.2.1** shows the distribution area and density derived from the NASC values attributed to this fish species in the surveyed area by *PELACUS 0423* and *PELAGO 23* surveys (see below).

A total of 3223 t, corresponding to 168 million fish were estimated in the subdivision 9.a N (**Table 4.4.2.1**). Length composition and age structure of anchovy estimates were not available at the time of writing this report.-**Figure 4.4.2.2** shows the time series (1996-2023) of anchovy biomass estimates from *PELACUS* in area 9.a N.

PELAGO series

PELAGO 23

The *PELAGO 23* survey was conducted from 15th March to 4th April on board R/V *Miguel Oliver*. Seventy-one (71) transects were acoustically sampled between Caminha and Cape Trafalgar (30-200 m depth). A total of 40 pelagic trawl hauls were carried out by the research vessel; 28 additional hauls were done by 1 purse-seiner. The distribution and species composition of all of these hauls are shown in **Figure 4.4.2.3**.

Regarding the mapping of acoustic energy, anchovy was mainly concentrated in 9.a CN and in the 9.a S (CAD). The distribution along the 9.a CN extended further south, in the northern 9.a CS area, similarly to the previous year (**Figure 4.4.2.1)**.

Anchovy acoustic estimates for the whole surveyed area were 6590 million fish and 96 977 t (**Table 4.4.2.2**).

In 9.a Central-North were estimated a total of 3018 million fish and 69 825 t, estimates which represent the third highest peak of abundance and the second of biomass of the time series, respectively (34% and 36% decrease in abundance and biomass in relation to the 2022 estimates;

Table 4.4.2.2, **Figure 4.4.2.5**). The estimated population in this subdivision ranged between 12.5 and 18.5 cm size classes, with a mode at 16.5 cm size class (**Figure 4.4.2.4**).

Anchovy population in 9a Central-South was supported by 21 million fish and 366 t, entailing 89.3% and 89% decrease of abundance and biomass in relation to the 2022 estimates (**Table 4.4.2.2**, **Figure 4.4.2.5**). The population showed a size range between 11.5 and 17.0 size classes, with a 13.0 cm modal size (**Figures 4.4.2.4**).

In the Subdivision 9.a South, with values of 3551 million fish and 26 785 t (**Table 4.4.2.2**, **Figure 4.4.2.5**). The Spanish waters concentrated most of the population (99.6% and 98.6% of abundance and biomass, respectively). The above 2023 estimates accounted for 418% and 299% increases in relation to those estimated in the 2022 survey (**Figure 4.4.2.5**). In 9a South-Algarve were estimated a total of 14 million fish and 374 t representing a decrease of population levels in relation to the last years (**Table 4.4.2.2**, **Figure 4.4.2.5**). The estimated population in subdivision 9.a South-Algarve ranged between 14.5 and 19.0 cm size classes, with a mode at 16.5 cm size class (**Figure 4.4.2.4**). In 9a South-Cadiz were estimated a total of 3 537 million fish and 26 411 t, entailing strong 541% and 486% increases in abundance and biomass in relation to the previous year's estimates, respectively (**Table 4.4.2.2**, **Figure 4.4.2.5**). The estimated population in this subdivision 9.a South-Cadiz ranged between 8.0 and 18.0 cm size classes, with a main mode at 11.0 cm size class (**Figure 4.4.2.4**).

The age structure estimated for the *PELAGO 23* survey has not been included in the present report because some inconsistencies were found in the age readings. An intercalibration exercise including readers of Portugal and Spain will be conducted this year to determine the age of the PELAGO survey anchovies.

Table 4.4.2.2 and **Figure 4.4.2.5** track the historical series of anchovy acoustic estimates from *PELAGO* surveys in the Division 9.a. Anchovy experienced a huge outburst in 9.a Central-North in 2018, after the decreased biomass recorded in 2017, and reaching population levels even higher than the previous historical peaks recorded in the 2011 and 2016 outbursts. After a strong drop in 2019 the population has experienced consecutive increases in abundance and biomass which culminate in the historical maximum recorded in 2022. Anchovy in 9.a Central-South had low abundances in the past and had a 3 order of magnitude increased in number and biomass. Biomass levels in the subdivision 9.a South, after experiencing an increasing trend started in 2018 which peaked in 2020 have shown consecutive drops in 2021 and 2022 down to levels well below the historical average and an increase in 2023 (**Figure 4.4.2.5**).

Figure 4.4.2.6 shows the age structure of the population estimates in the western component. Age 2 anchovies constitute the bulk of the population in spring 2022 (68.8%), followed by age 1 (26.0%) and 3 (5.3%). Strong incoming recruitments seem to be inferred in in the period 2019-2022, in particular in 2020.

Size composition and age structure of the population estimated in the southern component through the time-series was described in previous reports. In **Table 4.4.2.4** and **Figure 4.4.2.7** we revisit the trends observed in the age structure of the population as estimated by the *PELAGO* and *ECOCADIZ* survey series. Age structure from the *PELAGO* 2023 survey is not considered for the abovementioned reasons. As described in previous reports, Portuguese acoustic estimates for anchovy until 2013 were not provided age-structured to the WG. As an alternative, this age structure was estimated by applying the Spanish Gulf of Cadiz commercial age–length keys for the second quarter in the year. It should also be taken into consideration that such keys are based on commercial samples from purse-seine catches and therefore they may result in a biased picture of the population structure because of a different catchability.

The population age structure in previous years suggests strong 2000, (exceptionally) 2001, and 2006-year classes, with the last one still being present in 2009 (as age 3 anchovies). The strength of the 2007, 2008- and 2009-year classes decreased in relation to that observed for the 2006 year-class: population numbers of age 1 anchovies in 2008, 2009 and 2010 showed 49.7%, 43.3% and 68.9% decreases in relation those ones estimated in 2007. Notwithstanding the above, the extreme situation that the population reached in spring 2011, when no anchovy was detected in the *PELAGO* acoustic survey, seems uncertain because the observation of high egg densities during the survey is not consistent with the null detection of biomass with acoustics and with the estimates provided by the *BOCADEVA* DEPM survey (32.7 kt) some months later. These reasons led to the WG to consider the 2011 acoustic estimate with caution. The population age structure in 2013 suggests a failed recruitment, which, however, seems to show clear signs of progressive recovery in the three following years, especially in 2016. The decreased population levels in 2017 pointed again to a failed incoming recruitment. The situation in 2018 and 2019 seems to be quite similar to the one occurring in 2015–2016. Conversely, the 2020- and 2021-year classes show again a low strength.

ECOCADIZ series

ECOCADIZ 2022-07

The 2022 survey was not conducted (neither the 2021 survey because a malfunctioning of the echo-sounder). The *ECOCADIZ 2022-07* survey was planned to be conducted during the usual dates (first fortnight of August) onboard R/V *Miguel Oliver*. However, the usual ship-time scheduled for *ECOCADIZ* was invested in 2022 in other surveys/compromises instead, and no other research vessel was available to conduct the survey. Given that there are two other acoustic-trawl series covering the Gulf of Cadiz on an annual basis (*PELAGO* in spring time and *ECOCADIZ-RECLUTAS* in autumn) and the lack of available ship time, this series has temporarily been suspended by IEO until further notice and its continuation is not still secured, as long as the surveyed area doesn`t cover the entire stock distribution of the Iberian-Atlantic sardine nor both stock components of the anchovy stock in 9a but southern stock component.

Notwithstanding the above, a combined *BOCADEVA-ECOCADIZ* DEPM-acoustic-trawl survey will be carried out in early August this year. Survey time allocated to the acoustic-trawl surveying (c.a. 7 days, the half of the usual survey's duration) will include not only the acoustic sampling and the conduction of ground-truthing hauls (including the collection of anchovy DEPM-based adult samples), but also some extra night hauls providing hydrated anchovy females.

Time-series of available estimates so far are shown in **Table 4.4.2.3** and **Figure 4.4.2.8**.

Table 4.4.2.4 shows the time-series of population estimates at age in the southern component estimated by *PELAGO* and *ECOCADIZ* surveys (see also **Figure 4.4.2.7**).

4.4.3 Recruitment surveys

***SAR, JUVESAR* and *IBERAS* autumn survey series**

The last survey in the *SAR* series (aimed to cover the sardine early spawning and recruitment season in the Division 9.a, but also covering the anchovy recruitment season) which provided anchovy estimates was carried out in 2007 (see **Table 4.4.1**). **Table 4.4.3.1** shows the historical series of anchovy acoustic estimates derived from this survey series in the Division 9.a available so far. The *JUVESAR* autumn survey series, an acoustic survey restricted to the Subdivision 9.a Central-North, the main recruitment area of sardine in Portuguese waters, started in 2013. The scarce presence and abundance of anchovy in the 2013 and 2014 surveys prevented the provision of acoustic estimates for the species. The last survey in this series was conducted in 2017 (*JUVESAR 17*), because in 2018 the *JUVESAR* acoustic sampling area was incorporated into the new *IBERAS* survey series, described below. Point estimates of anchovy abundance of the

JUVESAR/IBERAS series are at present scarce but the trend is so far not consistent with spring survey series.

IBERAS is a new acoustic-trawl time-series aiming to get a synoptic coverage of the Atlantic waters of the Iberian Peninsula and the Bay of Biscay targeting on Young of the Year (YoY) of sardine and anchovy. Since 2017, both the Bay of Biscay (*JUVENA*) and the Gulf of Cadiz (*ECOCADIZ-RECLUTAS*) were routinely prospected by R/V *Ramón Margalef* and the Northwest coast of Portugal (*JUVESAR*) by R/V *Noruega* since 2013. The idea is to fill the gap between both *JUVENA* and *ECOCADIZ-RECLUTAS* surveys and incorporate the *JUVESAR* series, following the same radials in Subdivision 9.a Central-North. This new time-series is being conducted either in the vessel R/V *Ángeles Alvariño* or in R/V *Ramón Margalef*, twin of the former. Both vessels have similar shape, with slight changes in the main engine but using the same equipment (acoustic and trawling devices). Together with this synoptic coverage, using similar vessel equipment will limit both the vessel and trawling effects on the overall precision and accuracy of the estimates. In 2018, due to the lack of available vessel time in September, the survey was delayed until November, but in 2019 the survey was planned in September, at the same time of *JUVENA* and previous to *ECOCADIZ-RECLUTAS* one (see **Table 4.4.3.2**).

The rationale of this new time-series is to track and assess early juveniles for predicting the strength of the recruitment previously to the incoming fishing season (e.g. next year) as this will heavily depend on the incoming year class. This strategy is of special interest to manage the fisheries for short-lived species because of the short time between spawning and the exploitation of subsequent emerging recruits. Due to the recent situation of the sardine stock, with the biomass at the lowest productivity ever recorded and with a continuous period since 2004 of bad recruitment as compared with previous periods, any recovery of the biomass will likely be triggered by the strength of the recruitment.

IBERAS 0922

R/V *Ramón Margalef* was not available for *IBERAS* and therefore R/V *Ángeles Alvariño* was assigned to perform *IBERAS 0922*. Due to additional unexpected problems in the diesel engines, the duration of the survey was shortened to 9 days including the days used for calibration. The surveyed area had to be reduced accordingly, to cover only the main recruitment area of sardine on the west Iberian coast from latitude 41.7 to 38.1ºN. The survey was conducted between 30th September and 8th October. The survey area (from 20 to 100 m isobath) covered 65 tracks with random start and evenly distributed each 8 nmi on those areas out of the main expected sardine recruitment areas and each 4 nmi on the main ones. (**Figure 4.4.3.1**). The vessel's acoustic equipment consisted of a *Simrad™ EK-80* scientific echosounder, operating at 18, 38, 70, 120 and 200 kHz, working in CW mode. All frequencies were calibrated according to the standard procedures (Demer *et al*., 2015) at the start of the survey. The backscattering acoustic energy from marine organisms was measured continuously during daylight.

A total of 16 pelagic hauls and 9 purse-seine hauls were done as shown in **Figure 4.4.3.1**. Anchovy occurred in 52% of the hauls, with a 10.8% contribution in the total catch.

Anchovy was present in 9a N contrary to the former year (**Figure 4.4.3.2**). The bulk of the estimated population was concentrated in the subdivision 9aCN, with the centre of gravity of its distribution being located in the coastal waters, but more offshore than in 2021 (c.a. 40 m depth). To be noted that in the northern part of 9aCN schools were distributed mainly offshore, therefore, as the outer shelf waters deeper than 120 m depth are not sampled in *IBERAS*, part of the population was probably not sampled.

Anchovy biomass in autumn 2022 experienced a decrease to 7.6 10^3 t (482 million fish). Anchovy recruits accounted for 70% of the total number of individuals estimated in the survey (**Table 4.4.3.2**; **Figures 4.4.3.3** and **4.4.3.4**).

***ECOCADIZ-RECLUTAS* survey series**

ECOCADIZ-RECLUTAS 2022-10

ECOCADIZ-RECLUTAS 2021-10 survey was conducted by IEO between 12th and 27th October 2022 in the Portuguese and Spanish shelf waters (20–200 m isobaths) off the Gulf of Cadiz on board the R/V *Angeles Alvariño*. The R/V *Ramón Margalef*, *i.e.* the vessel routinely used in this survey series, was not available because maintenance works at shipyard. The adjustment of the survey to the *Ángeles Alvariño*'s surveys calendar entailed a reduction of 3 days (14 days at sea) in relation to the usually planned days (17 days at sea). Half working day was also invested in engine repair at land. Results from this survey have been reported to this WG by Ramos *et al.* (WD 2023).

The 21 foreseen acoustic transects were sampled. A total of 18 valid fishing hauls were carried out for echo-trace ground-truthing purposes. Sardine and chub mackerel, were the most frequent captured species in the fishing hauls, followed by horse mackerel, anchovy, Mediterranean horse mackerel, bogue, Atlantic mackerel and blue jack mackerel. Sardine and chub mackerel showed the highest yields in these hauls, followed by anchovy and Mediterranean horse mackerel (**Figure 4.4.3.5**).

Total estimates of total NASC allocated to the "pelagic fish species assemblage" in this survey were 28% lower than those recorded last year. Such a decrease was more noticeable in Portuguese waters. By species, chub mackerel (21% of total NASC) and Mediterranean horse mackerel (20%) were the main contributors to the total back-scattered energy, followed by sardine (19%), anchovy (18%), and bogue (11%), with the remaining species showing relative contributions of acoustic energies lower than 6%.

GoC anchovy was mainly found in Spanish waters, with areas of high densities being observed between Isla Cristina and Bay of Cádiz (**Figure 4.4.3.5**). GoC anchovy acoustic estimates in autumn 2022 were of 1837 million fish and 11 912 t, accounting for 5% and 31% decreases in abundance and biomass, respectively, as compared to last year's estimates (1973 million, 17 512 t). Current overall estimates are also lower than the time-series average (*i.e.* 2851 million; 21 399 t; **Table 4.4.3.3**; **Figure 4.4.3.6**).

By geographical strata, the Spanish waters yielded 99% (1825 million) and 98% (11 719 t) of the total estimated abundance and biomass in the Gulf, highlighting the importance of these waters in the species' distribution. The estimates for the Portuguese waters were 11 million and 193 t (**Table 4.4.3.3**; **Figure 4.4.3.6**).

The size class range of the assessed anchovy population in autumn 2022 varied between the 5.0 and 16.0 cm size classes. The size distribution showed a mixed composition, with one main mode at 10.5 cm, a secondary mode at 9.0 cm, and with a small proportion of individuals being observed at 5.0 cm. It is noticeable the occurrence of this last modal size, a consequence of the record of very tiny juveniles in the coastal waters located between Guadalquivir river mouth and Rota. The size composition of anchovy throughout the surveyed area confirms the usual pattern exhibited by the species during the survey season, with the largest (and oldest) fish being distributed in the westernmost waters and the smallest (and youngest) ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters (**Table 4.4.3.3**; **Figure 4.4.3.6**).

The population was composed by fishes not older than 2 years. Age 0 fish accounted for 93% (1705 million) and 91% (10 797 t) of the total estimated abundance and biomass, respectively (**Table 4.4.3.3**; **Figure 4.4.3.7**). Spanish waters concentrated the bulk (99.8%) of this juvenile fraction. The estimates of age-0 fish experienced a similar trend than the one showed by the whole population in relation to the historical peak recorded in 2019 and the values recorded in 2020. Age-0 fish have shown 5% increase in number and 11% decrease in weight in relation to the estimates recorded in the previous year. The recent strong decreasing trends for the whole population and juveniles seem to have slowed down in 2022, although the 2022 estimates are still well below their time-series averages (**Table 4.4.3.3**). Age 1 fish represented 7% and 9% of the total abundance and biomass, while Age 2 fish accounted for <1% of the total abundance and biomass (**Figure 4.4.3.7**). The 2022 autumn estimates of mean size and weight of the whole population (10.3 cm, 6.5 g) were somewhat lower than their respective time-series averages (11.3 cm, 9.5 g).

The time-series of survey estimates is shown in **Figure 4.4.3.8**. **Figure 4.4.3.9** shows the correspondence between acoustic estimates of abundance of age-0 anchovies from *ECOCADIZ-RECLUTAS* surveys in the autumn of the year y against the abundance of age-1 anchovies estimated in spring of the following year (y+1) by the *PELAGO* survey and in summer by the *ECOCADIZ* survey. Some positive relationship seems to be suggested when the most recent *ECOCADIZ-RECLUTAS* and *PELAGO* surveys estimates are compared.

4.5 Biological data

4.5.1 Weight-at-age in the stock

Western component

Weight-at-age in the stock estimated from the combined *PELACUS* and *PELAGO* surveys are shown in **Table 4.5.1.1**

Southern component

Weight-at-age in the stock is shown in **Table 4.5.1.2**. See the stock annex for comments on their computation.

4.5.2 Maturity-at-Age

Maturity stage assignment criteria were agreed between national institutes involved in the biological study of the species during the Workshop on Small Pelagics (*Sardina pilchardus*, *Engraulis encrasicolus*) maturity stages (WKSPMAT; ICES, 2008 c).

See the stock annex for comments on computation of the maturity ogives in both stock components.

Due to some inconsistencies in the maturity ogives of anchovy in the southern component, not noticed during WKPELA 2018, we assume that all individuals with age 1 or higher (B1+), are mature for assessment purposes.

The macroscopic maturity scale used by IPMA (Soares *et al*., 2009) has been validated with histology (microscopic identification of macroscopic maturity stages). Results show that only histology allows the correct identification of mature and immature individuals macroscopically identified as stage 1 (Immature or Resting); therefore, the maturity ogive of this species must be obtained during the spawning season with histology.

4.5.3 Natural mortality

Western component

Natural mortality, M, is unknown for this stock component. It has been suggested in WKPELA 2018 to follow the M pattern at-age used for the anchovy in the Bay of Biscay, which is 1.2 for age 0, 0.8 for age 1 and 1.2 for older ages, for further modelling exercises. Recent work on growth estimates (Wise *et al*., 2022) estimated other values for the natural mortality (M0= 1.285; M1= 1.028; M2= 0.827; M3= 0.703; M4= 0.724).

Southern component

M is also unknown for this stock component. The following estimates for M at-age were finally adopted in WKPELA 2018: M0=2.21; M1=1.30; M2+=1.30 (similar at any older age; see ICES, 2018a). A description of the rationale and whole process for deriving the above estimates is shown in the stock annex.

4.6 Stock Assessment

Both components of the stock are assessed following the ICES framework for category 3 stocks with the assessment and advice based on survey trends.

A stock-specific management strategy evaluation (MSE) process was conducted this year to update the assessment method (see Pérez-Rodríguez *et al.*, WD 2023a,b and Wise *et al.,* WD 2023a,b). A constant harvest rate rule (*chr*, Method 3.2, ICES, 2022) was determined for each component. The *chr* rule was tested alongside the 1o2 with 80% uncertainty cap rule.

The *chr* rule is based on the stock biomass indicator of the current year, multiplied by a sustainable harvest rate, as follows:

$$A_{y+1} = HR_{MSYproxy} * I_{current}$$

where A_{y+1} and $I_{current}$ represent the catch advice for July to June of the following year and the stock biomass indicator of the current (*y*) year, respectively. For the Western component the stock biomass indicator input has been taken from the results of the acoustic spring surveys covering this area (by adding *PELAGO* and *PELACUS* estimates for areas 9a N, 9a C-N and 9a C-S), while for the Southern component the biomass indicator input has been obtained from the results of SSB estimates from the Gadget assessment model.

The *chr* rule was found to be more precautionary for both components than the current 1o2 rule. The *chr* rule of 25% was the maximum value estimated for the western component while a *chr* rule of 50% was the maximum value estimated for the southern component.

The basis of this procedure for both components was approved by WGHANSA-1 2023 and the methodology followed for its approval is described in Pérez-Rodríguez *et al.* (WD 2023a,b) and Wise *et al.* (WD 2023a,b).

4.6.1 Western component

The stock assessment procedure for this component is described in the stock annex.

4.6.1.1 Biomass survey trend as base of the advice

The anchovy biomass indicator for the Western component is computed as the sum of *PELACUS* (9a N) and *PELAGO* (9a C-N and 9a C-S) acoustic estimates of biomass.

4.6.2 Southern component

4.6.2.1 Model used as basis of the advice

The model used to provide the estimates of the SSB indicator is a Gadget model. Gadget is an age–length-structured model that integrates different sources of information in order to produce a diagnosis of the stock dynamics. It works making forward simulations and minimizing an objective (negative log-likelihood) function that measures the difference between the model and data. General model specifications are described in the Stock Annex, while details on data input, implementation and results up to 2023 are described in Rincón *et al*. (WD 2023).

4.6.2.1.1 Data input

Data input for optimization routines is summarized in **Table 4.6.2.1.1.1**. It corresponds to all the information of the fishery available until the end of June of 2023, together with data from *ECOCADIZ* and *PELAGO* survey series up to 2022 (no *ECOCADIZ* survey in 2021 and 2022).

Due to discrepancies on mean length and weight at age in *PELAGO* survey for 2023, a cross validation for age composition was required. This cross-validation reveals some mis-estimation in the otolith reading suggesting that more analysis is needed to agree on the definitive age composition. For this reason anchovy age structure from *PELAGO* survey in 2023 was removed from the model.

Catches (landings +discards, discards from 2014 onwards) from Spain and Portugal are assumed to be removed from the population by only one fleet from 1989 to the second quarter of 2023. For the first two quarters of year 2023, provisional catches estimations of Spanish (until May 17th) purse-seine fleet were used and catches for June were estimated as the 39% of January to May catches based on historical records from 2009 to 2022.

4.6.2.1.2 Model fit

A summary of the goodness of fit of model estimations compared with data is shown in **Figures 4.6.2.1.2.1**, **4.6.2.1.2.2**, **4.6.2.1.2.3** (length distributions), **4.6.2.1.2.5**, **4.6.2.1.2.6** and **4.6.2.1.2.7** (age distributions). These figures show that length and age frequency distributions of catches and surveys match reasonably well with available data. Goodness of fit for length distribution of catches (**Figure 4.6.2.1.2.1**) is better in the last 20 years compared to the first years, in coherence with the assumption of two different selectivity periods. The model seems to not capture well enough the fluctuating or sharp patterns of year 2013 for the *ECOCADIZ* survey (**Figure 4.6.2.1.2.2**) and for most of the years for *PELAGO* survey; in this survey series the length distribution fit is better for years 2000, 2005, 2008, 2017-2020 and 2022 (**Figure 4.6.2.1.2.3**). Age distributions present a very good fit in almost all the cases (**Figures 4.6.2.1.2.5**, **4.6.2.1.2.6** and **4.6.2.1.2.7**), except for some mismatch in years 2014, 2020, 2021 and 2022 for *PELAGO* survey (**Figure 4.6.2.1.2.7**). There are no remarkable differences compared with the fit of the 2018 model implementation.

Figure 4.6.2.1.2.4 shows the model residuals from the fit to the catch-at-length composition and the acoustic survey length composition, while **Figure 4.6.2.1.2.8** shows the model residuals from the fit to the catch-at-age composition and the acoustic survey age composition. In both cases the residuals from the present assessment are very similar to those in the benchmark model implementation.

Figure 4.6.2.1.2.9 presents the comparison between observed and estimated survey indices. It can be observed that the model assimilates the trend of survey indices in most of the years but in particular, it does not assimilate the first four years of the *PELAGO* series.

4.6.2.1.3 Model estimates

Parameter estimates after optimization are presented in **Table 4.6.2.1.3.1**, while **Figure 4.6.2.1.3.1** presents model annual estimates for abundance (removing Age-0 individuals to be accurate with the time of the assessment), recruitment, fishing mortality and catches at the end of the second quarter of each year. **Figure 4.6.2.1.3.2** shows annual estimates for biomass of individuals of Age-1+ at the end of the second quarter of each year. Due to some inconsistencies in the maturity ogives not noticed during WKPELA 2018, we assume that all individuals with Age 1 or older (B_{1+}) are mature, *i.e.* these biomass estimates result equivalent to spawning stock biomass estimates. The SSB estimate used for the advice was the estimate for year 2023 corresponding to 4402 t (**Figure 4.6.2.1.3.2**). Detailed model outputs are available at https://github.com/ices-taf/2023_ane.27.9a_south_assessment/tree/main/results, where each file corresponds to the following description:

- sidat: model fit to the survey indices.
- suitability: model estimated fleet suitability.
- stock.recruitment: model estimated recruitment.
- res.by.year: results by year.
- catchdist.fleets: data compared with model output for the length and age-length distributions.
- stock.full: modelled abundance and mean weight by year, step, length and stock.
- stock.std: modelled abundance, mean weight, number by age consumed by the fleet, stock and year.
- stock.prey: consumption of the fleet by length, year and step.
- fleet.info: information on catches, harvest rate and harvestable biomass by fleet, year and step.
- params: parameter values used for the fit.

4.7 Reference points

4.7.1 Western component

Reference points were not calculated for this area.

4.7.2 Southern component

A B_{lim} of 1226.13 and a B_{pa} of 2010.85 t were calculated with updated values of SSB following the procedure agreed at the most recent benchmark (**Figure 4.7.2.1**). B_{pa} is defined as the upper 95% of the distribution of the estimated SSB if the true SSB equals B_{lim} based on a terminal SSB coefficient of variation assumed as 0.3 as recommended by ICES (ICES, 2017b) for short-lived species.

4.8 State of the Stock

4.8.1 Western component

The stock size indicator (a combined index from *PELAGO* and *PELACUS* estimates for areas 9aN, 9aCN and 9aCS) was obtained this year.

4.8.2 Southern component

The SSB has been fluctuating without a trend over the time-series showing a increase in the last year, which is consistent with the trend of *PELAGO* survey biomass estimates, and with a decrease of F. Time series for recruitment and F are fluctuating with no clear trend (**Figures 4.6.2.1.3.1** and **4.6.2.1.3.2**).

4.9 Catch advice

4.9.1 Western component

The ICES framework for category 3 stocks was applied (Method 2.2: Constant harvest rate, *chr*, rule; ICES, 2022). The combination of anchovy biomass estimated in the PELACUS and PELAGO acoustic surveys is used as the index of stock development. The advice is based on the product of the last index value (73414) and the MSY proxy harvest rate (0.25).

4.9.2 Southern component

The ICES framework for category 3 stocks was applied (Method 2.2: Constant harvest rate, *chr*, rule; ICES, 2022). The SSB estimated by the assessment model was used as the index of stock size development. The advice is based on the product of the last index value (4402) and the MSY proxy harvest rate (0.5). The index ratio is estimated to have increased 30%.

4.10 Short-term projections

No short-term projections are presented for this stock.

4.11 Quality of the assessment

A MSE has been developed for each component resulting in a new assessment method that provides advice based on the application of constant harvest rate over the stock size indicators, as detailed in Pérez-Rodríguez *et al.* (WD 2023) and Wise *et al.* (WD 2023).

4.11.1 Western Component

This stock component is assessed based on survey trends. The acoustic spring surveys that cover the distribution area of this component (PELAGO and PELACUS) were normally carried out and it was possible to have estimates for this year.

4.11.2 Southern Component

The biomass estimates provided by the Gadget model are assumed as absolute. Even with some instability (as shown by the occurrence of a certain retrospective pattern) and also with a high estimated catchability for both surveys, the MSE simulations in Pérez-Rodríguez *et al*. (WD 2023) showed that the estimates are precautionary. In addition, a harvest rate of 0.5 over that biomass has proved to be sustainable and optimum in the short, medium and long term.

A comparison with last year's estimated time-series is presented in **Figure 4.11.2.1.** This figure shows the annual model estimates for relative SSB of individuals with more than one year of age, relative fishing mortality, recruitment and catches (in tons). Pink line corresponds to the current year's estimated time-series (the one estimated by the model described here), the green line, to the estimated in 2022 and the blue line, to the estimated in 2021.

4.12 Management considerations

ICES has agreed with the clients that the catch advice will be framed in a management calendar set from 1st July (*y*) to the following 30th June (*y+1*), instead of calendar years.

Other management considerations and the current management situation are described in the stock annex.

4.13 Ecosystem considerations

Ecosystem considerations are described in the stock annex and there have not been remarkable changes in the last year.

4.14 Deviations from stock annex caused by missing information

For this year assessment, there were some deviations for the southern component of the stock, but they were not related to the Covid-19 disruption. For the western component there were only deviations that were previously considered in the 2020 assessment. Those deviations in 2020 were related to missing survey data associated to *PELACUS* survey, details which were provided at ICES (2020b; WGHANSA 2020 report).

1. Stock: ane.27.9a. Anchovy 9.a southern and western components.
2. Missing or deteriorated survey data: YES. *ECOCADIZ 2022-07* acoustic-trawl survey was the Gulf of Cadiz pelagic ecosystem survey (20-200 m depth) to be conducted by IEO onboard RV *Miguel Oliver* (SGP) last year. The *ECOCADIZ 2022-07* survey was planned to be conducted during the usual dates (first fortnight of August) onboard R/V *Miguel Oliver*. However, the usual ship-time scheduled for *ECOCADIZ* was invested in 2022 in other surveys/compromises instead, and no other research vessel was available to conduct the survey. Given that there are two other acoustic-trawl series covering the Gulf of Cadiz on an annual basis (*PELAGO* in spring time and *EOCADIZ-RECLUTAS* in autumn) and the lack of available ship time, this series has temporarily been suspended by IEO until further notice and its continuation is not still secured, as long as the surveyed area doesn`t cover the entire stock distribution of the Iberian-Atlantic sardine nor both stock components of the anchovy stock in 9a but southern stock component.
3. Missing or deteriorated catch data: NO.
4. Missing or deteriorated commercial *LPUE/CPUE* data: NO.
5. Missing or deteriorated biological data: For the western component: missing length frequency distributions (LFD) for Spanish commercial catches in the second, third and fourth quarter (Q2, Q3, Q4) in 2022 in 9a N; missing age-length keys (ALK) for Spanish commercial catches in Q1 and Q4 in 9aN, but landings were very scarce in 2022. Missing LFD and ALK in Q1 and Q2 in 2022 for the Portuguese fishery in 9a CN. No data from the Portuguese fishery in 9a CS in 2022, but catches were very scarce in that subdivision.

For the southern component: missing LFD for the Spanish fishery in Q1 2022. Missing LFDs and ALKs for commercial catches from the Portuguese fishery, but landings were almost null (0.001% of total catches from this component in 2022). Discrepancies on the age structure in *PELAGO 2023* were found, mainly some inconsistencies on mean length- and weight-at-age compared to previous years as a consequence of an unusual high relative proportion of age-2 fish in the estimated population.

Brief description of methods explored to remedy the challenge: For the western component: 2021 Q2, Q3 and Q4 LFDs from 9a N were propagated to the corresponding 2022 quarterly catches in 9a N. Quarterly ALKs for Spanish commercial catches in 9a N were based in a combination of samples from commercial (May and June) and research (*PELACUS 0422*) samples (the same ALK for Q1 and Q2) and commercial (July and September) samples only (the same ALK for Q3 and Q4). Methods to remedy gaps of biological information in the Portuguese fishery have not been explored because the very low catches recorded in those quarters without biological data. For the southern component: Q2 2022 LFD from the Spanish fishery was propagated to their Q1 2022 catches; quarterly LFDs and ALKs from the Spanish fishery were propagated to the very low quarterly catches from the Portuguese fishery. The assessment model for this year did not include the missing data corresponding to 2021 and 2022 in the *ECOCADIZ* time series. No further analysis was performed to understand the effect of this missing data, but considering that *PELAGO* survey estimates were available and that estimated biomass was consistent with the last year estimates, it was assumed that *PELAGO* and fishery information was enough to provide an accurate biomass index for this year. A cross validation exercise of the age-readings from a sub-set of otoliths (images) used for the *PELAGO 2023* ALK was performed by IPMA and IEO assessment age-readers during the WG meeting. This exercise revealed certain disagreement between readers suggesting that a more detailed analysis is needed to agree a consistent ALK and the resulting age structure of the estimated population.

1. Suggested solution to the challenge, including reason for this selecting this solution: For the western component: 2021 Q2, Q3 and Q4 LFDs from 9a N were propagated to the corresponding 2022 quarterly catches in 9a N. Quarterly ALKs for Spanish commercial catches in 9a N were based in a combination of samples from commercial (May and June) and research (*PELACUS 0422*) samples (the same ALK for Q1 and Q2) and commercial (July and September) samples only (the same ALK for Q3 and Q4). Methods to remedy gaps of biological information in the Portuguese fishery have not been explored because the very low catches recorded in those quarters without biological data. For the southern component: Q2 2022 LFD from the Spanish fishery was propagated to their Q1 2022 catches; quarterly LFDs and ALKs from the Spanish fishery were propagated to the very low quarterly catches from the Portuguese fishery. The assessment model for this year did not include the missing data corresponding to 2021 and 2022 in the *ECOCADIZ* time series. No further analysis was performed to understand the effect of this missing data, but considering that *PELAGO* survey estimates were available and that estimated biomass was consistent with the last year estimates, it was assumed that *PELAGO* and fishery information was enough to provide an accurate biomass index for this year. The ALK from the *PELAGO 23* survey was removed as data input to the model, relying only on its length composition and abundance estimates for year 2023.

2. Was there an evaluation of the loss of certainty caused by the solution that was carried out? For the southern component: A comparison with last year model implementation was performed where it can be observed that estimated biomass without this survey was consistent with the previous estimated biomass time series.

4.15 Stock specific Management Strategy Evaluation

During WGHANSA meeting on May 2022, the working group agreed on proposing to conduct a dedicated workshop in 2023 to evaluate by Management Strategy Evaluation the performance of a constant harvest rate advice rule that could be used as an alternative to the current applied 1-over-2 advice rule.

The proposed draft Terms of Reference for such workshop were:

> The Workshop on the Management Strategy Evaluation of constant harvest rates strategies for anchovy in Division 9a (WKANEMSE), will meet to:
>
> a) develop a Management Strategy Evaluation framework to test alternative advice rules for anchovy in Division 9a (Iberian Atlantic waters);
> b) identify constant harvest rate rules that could be appropriate to provide advice for this stock and compare them with respect to the current basis for advice (1-over-2 rule with 80% uncertainty cap and biomass safeguard)

On the 5th of May 2023, the results and conclusions of a first group of simulations conducted with FLBEIA MSE framework separately to the anchovy 27.9a south and west components were presented by members of WGHANSA to the ICES designated external reviewers.

4.15.1 Western component

Following the stock-specific MSE work and considering the high sensitivity of the CHR advice rule to the value of the catchability of the survey index, it was recommended that the advice for Anchovy 9a west should be based on a CHR with a $HR_{msy.proxy}$ = 0.36 applied to the most recent survey-based biomass index derived by the combination of the PELACUS and PELAGO survey in sub-divisions 9aN, 9aCN and 9aCS. Advice should be applied in the current seasonal management calendar (July to June). In addition, a biomass safeguard factor based on $I_{trigger} = I_{minpa}$ = 1.64 * min(I_{hist}) = 2017 tonnes should be considered.

Other main results and conclusions included as part of that first MSE work (see Wise et al, 2023a in annex 6) were the following:

- In the long-term, when compared to the 1-over-2 rule, the CHR advice rule outperforms the 1-over-2 advice rule by allowing for higher relative yields with risks below 5%. For example, in the base case scenario a harvest rate of 0.5 has higher risks than the 1-over-2 rule but leads to 200% higher relative yields.
- In general, the change in selectivity pattern (allowing for 20% of age zero catches) increases risks. However, mean risk increases in the long-term is small (from 5% to 9%).
- The CHR advice rule is sensitive mainly to the management calendar (populations crash with the interim year advice) and the catchability of the survey index (risks increase sharply).
- The CHR advice rule is not very sensitive to the initial depletion level of the stock although risks may increase.

- The CHR advice rule is also sensitive to the standard deviation of the mean recruitment assumed. Risks almost double when the standard deviation increases from 0.5, to 0.75 and to 1.
- From the different options tested, the I_{minpa} biomass safeguard type is the one that is able to reduce risks the most both in the short and long terms.

During the online meeting, the external reviewers expressed their concerns and criticisms, which are compiled in the documents 2023_anchovy_9.a_MSE_review_SHF and 2023_anchovy_9.a_MSE_review_BE in annex 6.

During the meeting the 5th of May it was agreed that updates on the MSE framework and a second batch of simulations would be performed to deal with some of the main reviewer´s concerns. The methodology employed, the structure of the simulations, results and conclusions are described in Wise et al, 2023b (see annex 6). In this work, the main conclusions were:

- The CHR advice rule also outperforms the current 1-over-2 advice rule when additional uncertainty is included in the operating models.
- New values for B_{lim} were adopted according to the re-estimation of the reference points. For the base case productivity (h = 0.75) this means that now B_{lim} = 16 279 t is lower than previously assumed value (0.2B0 = 20 000 t) decreasing risks. The opposite behavior was observed for the other two scenarios of productivity.
- For the base case considered a harvest rate of 0.4 is considered to be precautionary by ICES standards in the medium and long terms. In this base case we take into account the high sensitivity of the CHR advice rule to the value of the catchability of the survey index (QIDX = 1.5).
- However, to account for possible shifts in productivity, we now support the harvest rate HR = 0.25 as the basis of advice for the CHR advice rule to be applied to the Anchovy 9a western.

During the WGHANSA meeting from May 29th to June 2nd 2023 it was agreed to support the proposal, for the western component of the 27.9.a anchovy, of a switch from the current 1-over-2 advice rule to a CHR advice rule with a HR_{MSY_proxy}=0.25.

4.15.2 **Southern component**

The main results and conclusions included as part of that first MSE work were (see Perez-Rodriguez et al, 2023a in annex 6):

- The sensitivity analysis showed that in order to account for uncertainty in the most relevant factors affecting the perception of stock status and behaviour of the commercial fleet, the final settings for the *MSE* framework should include:
  - Biomass safeguard in the *1over2* and *chr HCR*s
  - Assessment error with sporadic high error values.
  - Limitation to recruitment to the maximum observed in the historic period
  - Distribution of catches over the year as observed in the last 10 years of the historic period.
  - *OM* conditioned with input data from Gadget assessment model with survey catchability as approved in the ane27.9a_south component 2022 assessment (ICES, WGHANSA 2022). This is the most precautionary scenario regarding the uncertainty in survey catchability in the assessment model.
- With this configuration of the *MSE* framework, the maximum precautionary *HR* in a *chr* was 0.5. Accordingly, HR=0.5 applied to the estimated SSB (by the Gadget assessment model) could be proposed as the $HR_{MSYproxy}$ for the 27.9a_south anchovy.

- When compared to the *1-over-2* rule, the *chr* with a HR=0.5 produces higher yield while being precautionary.

During the online meeting, the external reviewers expressed their concerns and criticisms, which are compiled in the documents 2023_anchovy_9.a_MSE_review_SHF and 2023_anchovy_9.a_MSE_review_BE in annex 6. Reviewer´s concerns are summarized in Perez-Rodriguez et al, 2023b (see annex 6), where some extra clarifications were added.

During the meeting the 5th of May it was agreed that a second batch of simulations would be performed to deal with some of the main reviewer´s concerns. The methodology employed, the structure of the simulations, results and conclusions are described in Perez-Rodriguez et al, 2023b (see annex 6). In this work, the main conclusions are:

- Despite the increase in risk of being below Blim as result of higher uncertainty in the biological-fisheries elements simulated, the results of this second part of the MSE continues to support the harvest rate HR=0.5 as candidate reference point to be used on a constant harvest rate *chr* HCR, with a biomass safeguard $B_{trigger}$ = 1194.132 tons. This chr should be applied to the SSB estimated by the gadget assessment model approved by WKPELA 2018.
- The results of the first and second MSE exercises proved that the HCR *chr* with HR=0.5 overcome the performance of the 1over2 rule, reducing the risk of falling below Blim in the short term, while producing a higher yield in the short, medium and long term.

During the WGHANSA meeting from May 29th to June 2nd 2023 it was agreed to support the proposal, for the southern component of the 27.9.a anchovy, of a switch from the current *1over2* HCR to a *chr* HCR with a HR_{MSY_proxy}=0.5 and a biomass safeguard $B_{trigger}$ = 1194.132 tons.

4.16 References

Doray, M., Boyra, G., and van der Kooij, J. (Eds.). 2021. ICES Survey Protocols – Manual for acoustic surveys coordinated under the ICES Working Group on Acoustic and Egg Surveys for Small Pelagic Fish (WGACEGG). 1st Edition. *ICES Techniques in Marine Environmental Sciences* Vol. 64. 100 pp. https://doi.org/10.17895/ices.pub.7462

Garrido, S., Ramos, F., Silva, A., Angélico, M. M., Marques, V. 2018a. Population structure of the European anchovy (*Engraulis encrasicolus*) in ICES Division 9a: synopsis and updated information. Working document presented to the ICES Benchmark Workshop on Pelagic Stocks (WKPELA 2018). 12–16 February 2018. Copenhagen, Danmark.16 pp.

ICES. 2003. Report of the Workshop on Discard Sampling Methodology and Raising Procedures. Charlottenlund, Denmark, 2–4 September 2003.

ICES. 2004. Report of the Study Group on Assessment Methods Applicable to Assessment of Norwegian Spring-Spawning Herring and Blue Whiting Stocks (SGAMHBW). 19–22 February 2004, Lisbon, Portugal. ICES CM 2014/ACFM 145. 166 pp.

ICES. 2007. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 26–30 November 2007, Palma de Mallorca, Spain, ICES C.M. 2007/LRC:16. 167 pp.

ICES. 2008a. Report of the Working Group on Anchovy (WGANC), 13–16 June 2008, ICES Headquarters, Copenhagen. ICES CM 2008 ACOM:04. 226 pp.

ICES. 2008b. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 24–28 November 2008, Nantes, France. ICES CM 2008/LRC:17. 183 pp.

ICES. 2008c. Report of the Workshop on Small Pelagics (*Sardina pilchardus*, *Engraulis encrasicolus*) maturity stages (WKSPMAT), 10–14 November 2008, Mazara del Vallo, Italy. ICES CM 2008/ACOM:40. 82 pp.

ICES. 2009a. Report of the Working Group on Anchovy and Sardine (WGANSA), 15–20 June 2009, ICES Headquarters, Copenhagen. ICES CM 2009/ACOM:13. 354 pp.

ICES. 2009b. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 16–20 November 2009, Lisbon, Portugal. ICES CM 2009/LRC:20. 181 pp.

ICES. 2012. ICES Implementation of Advice for Data-limited Stocks in 2012 in its 2012 Advice. ICES CM 2012/ACOM:68. 42 pp.)

ICES. 2015. Interim Report of the Stock Identification Methods Working Group (SIMWG), 10–12 June 2015, Portland, Maine, USA. *ICES CM 2015/SSGEPI:13*. 67 pp.

ICES. 2017a. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8, and 9. WGACEGG Report 2016 Capo, Granitola, Sicily, Italy. 14–18 November 2016. ICES CM 2016/SSGIEOM:31. 326 pp.

ICES. 2017b. Report of the Workshop to review the ICES advisory framework for short-lived species, including detailed exploration of the use of escapement strategies and forecast methods (WKMSYREF5), 11–15 September 2017, Capo Granitola, Sicily. ICES CM 2017/ACOM:46 A. 63 pp.

ICES. 2018a. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA 2018), 12–16 February 2018, ICES HQ, Copenhagen, Denmark. ICES CM 2018/ACOM:32. 313 pp.

ICES. 2018b. Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9 (WGACEGG). ICES WGACEGG REPORT 2017 3–17 November 2017. pp. 388.

ICES. 2020b. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). *ICES Scientific Reports*. 2:41. 655 pp. http://doi.org/10.17895/ices.pub.5977

ICES. 2021a. Working Group on Southern Horse Mackerel Anchovy and Sardine (WGHANSA). *ICES Scientific Reports*. 3:55. 689 pp. https://doi.org/10.17895/ices.pub.8138.

ICES. 2021b. Tenth Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE X). *ICES Scientific Reports*. 2:98. 72 pp. http://doi.org/10.17895/ices.pub.5985

ICES. 2022. Stock Identification Methods Working Group (SIMWG). *ICES Scientific Reports*. 4:72. 66 pp. http://doi.org/10.17895/ices.pub.20937001.

Jiménez, M.P., Tornero, J., Villaverde, A., Llevot, M.J., Solla, A., Ramos, F. 2018. Anchovy spawning stock biomass of the Gulf of Cadiz in 2017. Working document presented in the ICES Working Group on Southern Horse Mackerel, Sardine and Anchovy (WGHANSA). Lisbon, Portugal, 26–30 June 2018.

Massé, J., Uriarte, A., Angélico, M. M., and Carrera, P. (Eds.) 2018. Pelagic survey series for sardine and anchovy in ICES subareas 8 and 9 – Towards an ecosystem approach. *ICES Cooperative Research Report* No. 332. 268 pp. https://doi.org/10.17895/ices.pub.4599.

Payne, M. R., L. W. Clausen, H Mosegaard. 2009. Finding the signal in the noise: objective data-selection criteria improve the assessment of western Baltic spring-spawning herring. *ICES Journal of Marine Science*, 66: 1673–1680.

Ramos, F., 2015. On the population structure of the European anchovy (*Engraulis encrasicolus*) in ICES Division IXa: a short review of the state of art. Working document presented in the ICES Stock Identification Methods Working Group (SIMWG). 10–12 June 2015.

Ramos, F., Tornero, J., Oñate, D., Jiménez, M.P. 2018a. Acoustic assessment and distribution of the main pelagic fish species in ICES Subdivision 9a South during the *ECOCADIZ 2017-07* Spanish survey (July–August 2017). Working document presented in the ICES Working Group on Southern Horse Mackerel, Sardine and Anchovy (WGHANSA). Lisbon, Portugal, 26–30 June 2018.

Ramos, F., Tornero, J., Oñate, D., Córdoba, P. 2018b. Acoustic assessment and distribution of the main pelagic fish species in ICES Subdivision 9a South during the *ECOCADIZ-RECLUTAS 2017-10* Spanish survey (October 2017). Working document presented in the ICES Working Group on Southern Horse Mackerel, Sardine and Anchovy (WGHANSA). Lisbon, Portugal, 26–30 June 2018.

Rincón, M M., Ramos, F., Tornero, J., Garrido, S., Elvarsson, B., Lentin, J. 2022. Gadget for anchovy 9a South: Model description and results to provide catch advice and reference points (WGHANSA 2022-1). Working Document presented in the ICES Working Group on Southern Horse Mackerel, Sardine and Anchovy (WGHANSA-1). On-line meeting. 23–27 May 2021. https://github.com/ices-taf/2022_ane.27.9a_south_assessment/blob/main/report/Assessment2022_May19.pdf

Silva, G., Horne, J. B., & Castilho, R. (2014). Anchovies go north and west without losing diversity: Post-glacial range expansions in a small pelagic fish. *Journal of Biogeography*, *41*(6), 1171–1182. https://doi.org/10.1111/jbi.12275.

Zarraonaindia, I., Iriondo, M., Albaina, A., Pardo, M. A., Manzano, C., Grant, W. S., Irigoien, X., & Estonba, A. (2012). Multiple SNP Markers Reveal Fine-Scale Population and Deep Phylogeographic Structure in European Anchovy (Engraulis encrasicolus L.). *PLoS ONE*, *7*(7), e42201. https://doi.org/10.1371/journal.pone.0042201.

Table 4.3.1.1. Anchovy in Division 9.a. Composition of the Spanish fleets operating in Southern Galician waters (Western component, subdivision 9.a North) and in the Gulf of Cadiz (Southern component, Subdivision 9.a-South) targeting anchovy in 2022. The categories include both single purpose purse-seiners, artisanal and trawl and artisanal vessels fishing with purse-seine in some periods through the year (multi-purpose vessels). Storage: catches are dry hold with ice (one fishing trip equals one fishing day). Similar tables for yearly data since 1999 are shown for the Gulf of Cadiz Spanish fleet in previous WG reports.

Subdivision 9.a North						
2021	Vessels targeting anchovy					
	Engine (HP)					
Length (m)	0–50	51–100	101–200	201-500	>500	Total
≤10	5					5
11–15	2	9	6			17
16–20			2	4		6
>20			1	5	2	8
Total	7	9	9	9	2	36
Subdivision 9.a South						
2021	Vessels targeting anchovy					
	Engine (HP)					
Length (m)	0–50	51–100	101–200	201-500	>500	Total
≤10						
11–15		3		1		4
16–20		6	21	9		36
>20			3	10	1	14
Total		9	24	20	1	54

Table 4.3.2.1.1. Anchovy in Division 9.a. Recent historical series of annual catches (t) by subdivision, stock component and total division since 1989 on (the period with available data for all the subdivisions). Catches in Subdivision 9.a South are also differentiated between Portuguese (PT) and Spanish (ES) waters. (-) not available data; (0) less than 1 tonne (from Pestana, 1989, 1996 and WGMHSA, WGANC, WGANSA and WGHANSA members). The rest of the historical series of catches is shown in the stock annex. Discards are considered negligible in both the Portuguese (9.a C-N to 9.a S (PT)) and Spanish (9.a N, 9.a S (ES)) fisheries. Notwithstanding the above, the estimates for the Spanish fishery include estimates of discarded (and unallocated) catches since 2014 on. Discards estimates for the Spanish fishery are not available for the first semester 2020 because Covid-19 disruption and interruption of the IEO's observers at-sea sampling program.

Year	9.a N	9.a C-N	9.a C-S	West. Comp.	9.a S (PT)	9.a S (ES)	South. Comp.	Total Division
1989	118	646	141	905	36	5330	5365	6270
1990	220	431	4	655	110	5726	5836	6491
1991	15	187	3	205	22	5697	5718	5924
1992	33	136	1	170	2	2995	2997	3167
1993	1	22	1	24	0	1960	1960	1984
1994	117	236	8	361	0	3035	3035	3397
1995	5329	2521	9	7859	0	571	571	8430
1996	44	2711	13	2768	51	1780	1831	4599
1997	63	610	8	682	14	4600	4614	5296
1998	371	894	153	1419	610	8977	9587	11006
1999	413	957	96	1466	355	5587	5942	7409
2000	10	71	61	142	178	2182	2360	2502
2001	27	397	19	444	439	8216	8655	9098
2002	21	433	90	543	393	7870	8262	8806
2003	23	211	67	301	200	4768	4968	5269
2004	4	83	139	226	434	5183	5617	5844
2005	4	82	6	92	38	4385	4423	4515
2006	15	79	15	110	14	4368	4381	4491
2007	4	833	7	844	34	5576	5610	6454
2008	5	211	87	303	37	3168	3204	3508
2009	19	35	5	59	32	2922	2954	3013
2010	179	100	2	281	28	2901	2929	3210
2011	541	3239	1	3782	78	6216	6294	10076
2012	39	521	220	779	56	4754	4810	5589
2013	69	192	131	392	67	5172	5240	5632

Year	9.a N	9.a C-N	9.a C-S	West. Comp.	9.a S (PT)	9.a S (ES)	South. Comp.	Total Division
2014	581	678	21	1281	118	8933	9051	10332
2015	173	2533	10	2717	2	6878	6880	9597
2016	222	6908	10	7140	19	6581	6599	13740
2017	1069	8854	170	10094	26	4585	4611	14705
2018	992	7871	370	9233	65	4433	4499	13732
2019	991	5205	4	6200	113	4701	4814	11014
2020	309	5327	2	5639	155	7163	7317	12956
2021	747	9521	8	10276	109	7452	7562	17837
2022	15	3509	24	3548	0	6795	6795	10343
2023*	2683	669	2	3354	0	3836	3836	7190

(*) Provisional official landings data for the 2023 first semester updated until 30th April (9a.CN, 9a.CS, 9a.S-ALG) – 17th May (9a.N, 9a.S-CAD).

Table 4.3.2.2.1. Anchovy in Division 9.a. Catches (t) by gear and subdivision in 1989–2022. Discards are considered negligible in both the Portuguese (9.a C-N to 9.a S (PT)) and Spanish (9.a N, 9.a S (ES)) fisheries. Notwithstanding the above, the estimates for the Spanish fishery include estimates of discarded catches by gear since 2014 on. Discards estimates for the Spanish fishery are not available for the first semester 2020 because Covid-19 disruption and interruption of the IEO's observers at-sea sampling program. Landings by gear in subdivisions 9.a C-N to S (PT) are not available by subdivision until 2009.

Subarea	Gear	1989	1990	1991	1992	1993	1994	1995*	1996	1997	1998	1999	2000
9.a N	Artisanal	0	0	0	0	0	0	0	0	0	0	0	0
	Purse-seine	118	220	15	33	1	117	5329	44	63	371	413	10
9.a C-N to 9.a S (PT)	Demersal Trawl	-	-	-	4	9	1	-	56	46	37	43	6
	P. seine polyvalent	-	-	-	1	1	3	-	94	7	35	20	7
	Purse-seine	-	-	-	270	14	233	-	2621	579	1541	1346	297
	Not different. By gear	496	541	210	-	-	-	7056	-	-	-	-	-
9.a S (ES)	Demersal Trawl	0	0	0	0	330	152	75	224	190	1148	993	104
	Purse-seine	5336	5911	5696	2995	1630	2884	496	1556	4410	7830	4594	2078

Subarea	Gear	2001	2002	2003	2004	2005	2006	2007	2008	2009
9.a N	Artisanal	0	0	4	1	0	0	0	1	0.1
	Purse-seine	27	21	19	2	4	15	4	4	18
9.a C-N to 9.a S (PT)	Demersal Trawl	16	13	7	5	7	27	14	9	4

Subarea	Gear	2001	2002	2003	2004	2005	2006	2007	2008	2009
	P. seine polyvalent	32	13	184	197	57	24	376	141	38
	Purse-seine	806	888	287	455	62	57	484	185	30
	Not different. By gear	-	-	-	-	-	-	-	-	-
9.a S (ES)	Demersal Trawl	36	23	14	6	0.2	0.4	0.3	0.1	0.02
	Purse-seine	8180	7847	4754	5177	4385	4367	5575	3168	2922

Sub-area	Gear	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
9.a N	Demersal trawl	0	0	0	0	0	0.2	0	7	0.6	0.6	0	0	0
	Artisanal	4	0	1	6	0	21	6	6	0.4	0.1	0.1	0.1	0.01
	Purse-seine	175	541	37	63	581	152	217	1057	991	990	309	747	15
9.a C-N	Demersal Trawl	5	4	1	0.5	2	3	2	2	0,3	0.2	2	2	5
	P. seine poly-valent	45	1116	177	17	9	150	294	332	403	34	122	400	126
	Purse-seine	50	2119	342	175	668	2381	6613	8521	7468	5170	5203	9119	3379
9.a C-S	Demersal Trawl	1	1	0.4	1	3	2	1	0.2	1	0.02	0.02	0.01	0
	P. seine poly-valent	0	0.1	17	4	1	0.4	4	13	14	1	2	2	0.1
	Purse-seine	1	0.4	202	127	18	8	5	157	355	4	0	5	24
9.a S (PT)	Demersal Trawl	8	13	16	2	5	1	3	6	1	0	0.1	0.1	0.04
	P. seine poly-valent	4	33	0.1	2	0.04	0.02	0.04	0	0	0	1	2	0
	Purse-seine	17	33	41	63	113	1	16	20	65	113	153	107	0.1
9.a S (ES)	Demersal Trawl	0	0	2	0	99	33	118	204	90	209	105	66	110
	Artisanal	0	0	0	0	0	0.1	0.1	0.01	0	0	0	0	0
	Purse-seine	2901	6216	4752	5172	8835	6845	6463	4381	4343	4492	7058	7387	6686

Table 4.3.2.2.2. Anchovy in Division 9.a. Quarterly anchovy catches (t) by subdivision in 2022.

Subdivision/ Component	QUARTER 1		QUARTER 2		QUARTER 3		QUARTER 4		ANNUAL (2022)	
	C(t)	%	C(t)	%	C(t)	%	C(t)	%	C (t)	%
9.a North	11	75,6	1	9,5	2	11,1	1	3,7	15	0,1
9.a Central North	1020	29,1	0,2	0,01	1860	53,0	628	17,9	3509	34,4
9.a Central South	0	0,0	0,1	0,2	18	75,3	6	24,5	24	0,2
Western Comp.	1032	29,1	2	0,05	1880	53,0	635	17,9	3548	34,8
9.a South (PT)	0	0,0	0	0,0	0,1	100,0	0	0,0	0,1	0,001
9.a South (ES)	532	7,2	3542	48,2	2659	36,2	609	8,3	7342	71,9
Southern Comp.	532	8,0	2862	43,0	2659	39,9	609	9,1	6662	65,2
TOTAL	1563	15,3	2864	28,0	2679	26,2	722	7,1	10210	100,0

Table 4.3.5.1.1. Anchovy in Division 9.a. Western Component. Subdivision 9.a North. Spanish fishery (all fleets). Seasonal and annual length distributions ('000) of anchovy catches in 2022. Discards were sampled but they were null, hence landings equals to catches.

2022	Q1	Q2	Q3	Q4	TOTAL
Length (cm)	9.a N	9.a N	9.a N	9.a N	9.a N
6	0	0	0	0	0
6.5	0	0	0	0	0
7	0	0	0	0	0
7.5	0	0	0	0	0
8	0	0	0	0	0
8.5	0	0	0	0	0
9	0	0	0	0	0
9.5	0	0	0	0	0
10	0	0	0	0	0
10.5	0	0	0	0	0
11	0	0	0	0	0
11.5	0	0	1	0	1
12	0	0	2	0	2
12.5	0	1	3	1	5
13	0	2	8	2	12

2022 **Length (cm)**	**Q1** **9.a N**	**Q2** **9.a N**	**Q3** **9.a N**	**Q4** **9.a N**	**TOTAL** **9.a N**
13.5	0	2	10	3	15
14	0	3	5	5	13
14.5	0	4	1	5	11
15	4	8	0	3	16
15.5	4	10	0	3	18
16	80	7	1	1	90
16.5	101	6	6	0	113
17	72	4	10	1	86
17.5	40	2	7	0	49
18	20	2	3	0	25
18.5	4	0	1	0	5
19	0	0	0	0	0
19.5	0	0	0	0	0
20	0	0	0	0	0
20.5	0	0	0	0	0
21	0	0	0	0	0
21.5	0	0	0	0	0
Total N	326	51	61	24	461
Catch (T)	11	1	2	1	15
L avg (cm)	16,9	15,7	15,3	14,7	16,5
W avg (g)	34,2	27,9	27,1	23,2	32,0

Table 4.3.5.1.2. Anchovy in Division 9.a. Western Component. Subdivision 9.a Central North. Portuguese fishery (purse-seine fleet). Seasonal and annual length distributions ('000) of anchovy catches in 2022. Discards are null, hence landings correspond to catches. Length frequency distributions were not available for other métiers. Only data for the 3rd and 4th Quarter LFDs from the métier PS_SPF_0_0_0 are available.

2022 Length (cm)	Q1 9.a CN	Q2 9.a CN	Q3 9.a CN	Q4 9.a CN	TOTAL 9.a CN
6	0	-	0	0	0
6.5	0	-	0	0	0
7	0	-	0	0	0
7.5	0	-	0	0	0
8	0	-	0	0	0
8.5	0	-	0	0	0
9	0	-	0	0	0
9.5	0	-	0	0	0
10	0	-	0	0	0
10.5	954	-	0	0	954
11	392	-	0	0	392
11.5	2692	-	0	0	2692
12	2300	-	0	177	2477
12.5	6793	-	0	89	6881
13	8192	-	0	527	8719
13.5	7514	-	0	1180	8694
14	6676	-	48	5295	12019
14.5	4885	-	48	4110	9043
15	4154	-	749	4066	8969
15.5	1176	-	4386	2027	7589
16	3815	-	7625	875	12315
16.5	1515	-	10959	1905	14379
17	784	-	13552	1884	16220
17.5	0	-	8967	1633	10600
18	0	-	4687	389	5076
18.5	0	-	1357	406	1764

2022	Q1	Q2	Q3	Q4	TOTAL
Length (cm)	9.a CN	9.a CN	9.a CN	9.a CN	9.a CN
19	0	-	121	0	121
19.5	0	-	0	0	0
20	0	-	0	0	0
20.5	0	-	0	0	0
21	0	-	0	0	0
21.5	0	-	0	0	0
Total N	51842	-	52498	24565	128905
Catch (T)	1019	0	1860	621	3500
L avg (cm)	13,9	-	17,1	15,4	15,5
W avg (g)	19,6	-	35,4	25,3	26,8

Table 4.3.5.1.3. Anchovy in Division 9.a. Southern component. Subdivision 9.a South (ES). Spanish fishery (all fleets). Seasonal and annual length distributions ('000) of anchovy catches in 2022. Discards were sampled and estimated.

2022	Q1	Q2	Q3	Q4	TOTAL
Length (cm)	9.a S (ES)	9.a S (ES)	9.a S (ES)	9.a S (ES)	9.a S (ES)
4	0	0	0	0	0
4.5	0	7	0	0	7
5	0	0	0	77	77
5,5	0	21	0	185	206
6	12	86	24	413	534
6.5	30	85	54	438	608
7	65	173	163	754	1155
7.5	66	264	314	740	1384
8	196	705	716	794	2411
8.5	260	458	1068	3152	4938
9	493	524	1473	7194	9684
9.5	918	1909	2593	16421	21840
10	693	3259	4333	8477	16762
10.5	2412	13403	5610	5977	27402

2022 Length (cm)	Q1 9.a S (ES)	Q2 9.a S (ES)	Q3 9.a S (ES)	Q4 9.a S (ES)	TOTAL 9.a S (ES)
11	3200	18665	11438	7254	40557
11.5	6620	36813	22848	5697	71978
12	5885	32479	28921	6078	73364
12.5	6238	33939	30422	13692	84292
13	5578	29822	28394	7088	70881
13.5	3832	20789	20806	2681	48107
14	1936	9876	15289	564	27664
14.5	1018	5058	7128	433	13638
15	562	2723	4677	433	8396
15.5	259	1288	1412	0	2959
16	20	0	1194	0	1214
16.5	11	0	0	0	11
17	0	0	0	0	0
17.5	9	0	0	0	9
18	19	0	0	0	19
18.5	0	0	0	0	0
19	0	0	0	0	0
19.5	0	0	0	0	0
20	0	0	0	0	0
20.5	0	0	0	0	0
21	0	0	0	0	0
21.5	0	0	0	0	0
Total N	39241	209629	186919	84477	520266
Catch (T)	532	2862	2679	722	6795
L avg (cm)	12,4	12,5	12,7	11,1	12,3
W avg (g)	11,5	13,6	14,2	8,3	12,8

Table 4.3.5.2.1. Anchovy in Division 9.a. Western component. Subdivision 9.a North. Spanish catches (all fleets) in numbers-('000) at-age of Galician anchovy in 2022 on a quarterly (Q), half-year (HY) and annual basis.

2022	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	0	0	0	0	0
	1	170	35	51	23	205	73	279
	2	128	14	10	1	141	11	152
	3	28	2	0	0	30	0	30
	Total (n)	326	51	61	24	377	84	461
	Catch (t)	11	1	2	1	13	2	15
	SOP	11	1	2	1	13	2	15
	VAR.%	1,00	0,99	1,00	1,00	1,00	1,00	1,00

Table 4.3.5.2.2. Anchovy in Division 9.a. Western component. Subdivision 9.a North. Spanish annual catches of anchovy in numbers ('000) at-age (only data for 2011–2012 and 2015–2022).

Year	Age 0	Age 1	Age 2	Age 3
2011	2725	23903	380	0
2012	0	668	599	7
2013	n.a	n.a	n.a	n.a
2014	n.a	n.a	n.a	n.a
2015	0	1667	6667	66
2016	4677	9206	881	1
2017	14116	21150	10310	184
2018	0	33336	8551	354
2019	0	3274	5942	196
2020	0	4091	4170	1526
2021	12697	12148	4331	30
2022	0	279	152	30

Table 4.3.5.2.3. Anchovy in Division 9.a. Western component. Subdivision 9.a Central-North. Portuguese catches (all fleets) of anchovy in numbers ('000) at-age in 2022 on a quarterly (Q), half-year (HY) and annual basis.

2022	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	36030	26185	0	62214	62214
	1	69111	23155	132676	27411	92266	160088	252354
	2	3667	0	31306	31407	3667	62713	66381
	3	4896	0	1632	234	4896	1866	6763
	Total (n)	77674	23155	201644	85238	100830	286882	387711
	Catch (t)	1020	0,2	1860	628	1021	2489	3509
	SOP	1	0,3	6	2336	2	8	9
	VAR.%	0,83	0,001	0,33	0,0003	0,67	0,31	0,37

Table 4.3.5.2.4. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. Spanish catches (all fleets) in numbers ('000) at-age of Gulf of Cadiz anchovy in 2022 on a quarterly (Q), half-year (HY) and annual basis.

2022	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	34856	69028	0	103884	103884
	1	37114	199275	146031	18917	236389	164948	401337
	2	3220	13069	7991	597	16289	8588	24877
	3	0	0	0	0	0	0	0
	Total (n)	40334	212344	188877	88542	252677	277420	530097
	Catch (t)	532	2862	2679	722	3394	3401	6795
	SOP	464	2880	2690	739	3344	3	6772
	VAR.%	1,15	0,99	1,00	0,98	1,01	0,99	1,00

Table 4.3.5.2.5. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. Spanish annual catches (all fleets) in numbers ('000) at-age of Gulf of Cadiz anchovy (1995–2022).

Year	Age 0	Age 1	Age 2	Age 3
1995	34497	33961	189	0
1996	484540	162483	2053	0
1997	333758	279641	44823	0
1998	436307	1015535	13260	0
1999	124784	472348	32279	0
2000	118808	197497	3844	0

Year	Age 0	Age 1	Age 2	Age 3
2001	158126	541331	23342	0
2002	74399	708070	17515	0
2003	71847	381407	13109	0
2004	105958	398862	2590	0
2005	37906	482256	3495	0
2006	11303	491307	5261	0
2007	61692	559217	7342	0
2008	57477	138295	30970	394
2009	9695	184941	20051	2673
2010	34462	210384	11118	257
2011	199191	406217	16117	0
2012	25265	335487	8348	0
2013	176169	300781	5950	0
2014	73210	808350	6155	0
2015	196337	460887	13667	0
2016	87979	460201	19758	0
2017	118554	402410	4339	8
2018	39467	316336	6450	0
2019	163216	265091	17311	0
2020	196225	373573	28237	1357
2021	144927	444421	28745	0
2022	103884	401337	24877	0

Table 4.3.6.1. Anchovy in Division 9.a. Western component. Subdivision 9.a North. Mean length (TL, in cm) at-age in the Spanish catches of Galician anchovy (all fleets) in 2022 on a quarterly (Q), half-year (HY) and annual basis.

2022	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	0	0		0	0
	1	16,7	15,4	14,9	14,6	16,5	14,8	16,0
	2	17,2	16,2	17,7	16,0	17,1	17,5	17,1
	3	17,7	17,7	0	0	17,7	0	17,7
	Total	16,9	15,7	15,3	14,7	16,8	15,2	16,5

Table 4.3.6.2. Anchovy in Division 9.a. Western component. Subdivision 9.a North. Mean weight (in kg) at-age in the Spanish catches of Galician anchovy (all fleets) in 2022 on a quarterly (Q), half-year (HY) and annual basis.

2022	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	0	0	0	0	0
	1	0,032	0,026	0,025	0,023	0,031	0,024	0,030
	2	0,035	0,031	0,039	0,029	0,035	0,038	0,035
	3	0,039	0,039	0	0	0,039	0	0,039
	Total	0,034	0,028	0,027	0,023	0,033	0,026	0,032

Table 4.3.6.3. Anchovy in Division 9.a. Western component. Subdivision 9.a Central-North. Mean length (TL, in cm) at-age in the Portuguese catches of Northwestern anchovy (all fleets) in 2022 on a quarterly (Q), half-year (HY) and annual basis.

2022	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	15,4	14,8	0	15,1	15,1
	1	12,9	13,4	16,0	15,7	13,0	16,0	14,9
	2	16,4	0	16,1	15,9	16,4	16,0	16,0
	3	15,9	0	15,9	16,9	15,9	16,1	15,9
	Total	13,3	13,4	15,9	15,5	13,3	15,8	15,2

Table 4.3.6.4. Anchovy in Division 9.a. Western component. Subdivision 9.a Central-North. Mean weight (in kg) at-age in the Portuguese catches of Northwestern anchovy (all fleets) in 2022 on a quarterly (Q), half-year (HY) and annual basis.

2022	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	0,025	0,022	0	0,024	0,024
	1	0,014	0,013	0,028	0,029	0,014	0,028	0,023
	2	0,030	0	0,032	0,030	0,030	0,031	0,031
	3	0,026	0	0,031	0,032	0,026	0,031	0,027

	Total	0,016	0,013	0,028	0,027	0,015	0,028	0,024

Table 4.3.6.5. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. Mean length (TL, in cm) at-age in the Spanish catches of Gulf of Cadiz anchovy (all fleets) in 2022 on a quarterly (Q), half-year (HY) and annual basis.

2022	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	11,1	10,6	0	10,8	10,8
	1	12,4	12,4	13,0	12,6	12,4	13,0	12,6
	2	12,8	13,9	14,4	14,1	13,7	14,4	13,9
	3	0	0	0	0	0	0	0
	Total	12,4	12,5	12,7	11,1	12,5	12,2	12,3

Table 4.3.6.6. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. Mean weight (in kg) at-age in the Spanish catches of Gulf of Cadiz anchovy (all fleets) in 2022 on a quarterly (Q), half-year (HY) and annual basis.

2022	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0,000	0,000	0,009	0,007	0	0,008	0,008
	1	0,011	0,013	0,015	0,012	0,013	0,015	0,014
	2	0,013	0,019	0,020	0,017	0,018	0,020	0,018
	3	0	0	0	0	0	0	0
	Total	0,012	0,014	0,014	0,008	0,013	0,012	0,013

5 Sardine General

This section has not been updated in this report.

6 Sardine in divisions 8a.b.d

6.1 Population structure and stock identity

Sardine in Celtic Seas (7a, b, c, f, g, j, k), English Channel (7d, e, h) and in Bay of Biscay (8a, b, d) are considered to belong to the same stock from a genetic point of view.

Therefore, it has been previously considered that the sardine stock in divisions 8a, b, d and in Subarea 7 as a single-stock unit. The assessment of this stock as a single unit assumed that the trends derived from the observations made in the Bay of Biscay through the scientific surveys (PELGAS, BIOMAN) could be extended to the Subarea 7.

Information from the ICES WKSAR workshop (ICES, 2016) suggests higher growth rates for the populations of the English Channel and Celtic Seas than for the Bay of Biscay but it is unknown if this results from different oceanographic conditions or from population characteristics. Furthermore, there is no information on connectivity between the Bay of Biscay and English Channel/Celtic Sea. Bordering catches in Subarea 7 (statistical rectangles 25E4, 25E5) to the Bay of Biscay are generally considered to be taken from sardine populations in the Bay of Biscay. The recent PELTIC surveys (abundance of eggs, larvae, recruits and adults in the Channel) and results from the calorimetry/growth analysis suggest that Channel/Celtic Sea can be a self-sustained population. In fact, there are historical (Wallace and Pleasants, 1972) and recent evidence (Coombs *et al*., 2009) that a significant spawning takes place regularly in Subarea 7. In a recent acoustic survey series in this area (PELTIC surveys) relevant concentrations of all life stages (eggs, juveniles and adults) have been found as well (van der Kooij *et al*. Presentation to WKSAR report ICES CM 2016/ACOM:41). Furthermore, the Cornish fisheries has been operating there for more than a century.

In terms of stock assessment, the availability of data strongly differs between the northern (Celtic Seas, English Channel) and the southern areas (Bay of Biscay). Additionally, each area presents different historical exploitation patterns. Therefore, analysis and management advice between the areas may differ.

The workshop concluded that in the absence of evidence of connectivity between the Bay of Biscay and Subarea 7 sardine populations, and taking into account the indications of shelf-sustained populations in each area (whereby all stages are found in substantial amounts in both regions) it would be preferable to deal with the Bay of Biscay and Subarea 7 separately.

6.2 Input data in 8a, b, d

6.2.1 Catch data in divisions 8a, b, d

Official landings per country are given in Table 6.2.1.1. Working group estimates are provided in Table 6.2.1.2. Differences are generally related to unallocated catches. Most of the landings correspond to France and Spain. As part of the interbenchmark process in 2019, French landings have been revised from 2013 to 2017 (ICES, 2019).

As in previous years, French sardine landings have been corrected for notorious misallocations between 7e,h and 8a. A substantial part of the French catches originates from divisions 7h and 7e, but these catches have been assigned to division 8a due to their very concentrated location at the boundary between 8a, 7h and 7e. French sardine landings declared in 25E5 and 25E4 have hence been reallocated to 8a. Those two rectangles use to typically account for 25% of the French sardine catches reported in the Bay of Biscay. In 2022, they accounted for 44%. This is one of the highest proportion of catches in 25E4-25E5 in the time-series.

The Spanish fishery takes place mainly during March and April and in the fourth quarter of the year. Spanish vessels are purse-seines from the Basque Country and other regions of the north of Spain, which operate mostly in division 8b. Spanish landings averaged around 4000 tonnes in the late 1990s early 2000s with peaks in 1998 and 1999 at almost 8 thousand tonnes. Catches have then decreased until 2010 to below 1 thousand tonnes. Since 2011, catches have raised again, reaching 16 237 tonnes in 2014. Landings in 2022 were 3 117tonnes.

French catches consistently increased from 1983 to 2008, with values ranging from 4367 tonnes in 1983 to 21 104 tonnes in 2008. Since 2009, French landings displayed an increasing trend which stopped in 2013 with 20 066 tonnes landed, which is close to the time-series maximum. In 2018, landings reached a new maximum with 25 195 tonnes. In 2022, 23 299 tonnes were landed. About 83% of French catches are taken by purse-seiners while the remaining 17% is reported by pelagic trawlers (mainly pair-trawlers). Both purse-seiners and pelagic trawlers target sardine in French waters. Average vessel length is about 18 m. Purse-seiners and trawlers operate mainly in coastal areas (<10 nautical miles. Both pair-trawlers and purse-seiners operate close to their base harbour when targeting sardine. The highest catches are usually taken in summer, even if sometimes catches can be important during winter. Almost all the catches are taken in southwest Brittany.

Table 6.2.1.1. Sardine in 8abd. Official landings (in tons) reported to ICES (1989–2022).

	8 a,b,d									
year	France	Spain	Netherlands	Ireland	UK	Denmark	Germany	Lithuania	Belgium	Total
1989	8811	0	0	0	0	0	0	0	0	8811
1990	8543	0	0	0	0	0	0	0	0	8543
1991	12482	35	0	0	0	0	0	0	0	12517
1992	8847	43	0	0	0	0	0	0	0	8890
1993	8805	45	0	0	0	308	0	0	0	9158
1994	8604	0	0	0	0	0	0	0	0	8604
1995	9877	0	24	0	0	0	0	0	0	9901
1996	8604	0	0	0	0	0	0	0	0	8604
1997	10706	0	26	0	0	0	0	0	0	10732
1998	9778	873	0	0	0	0	68	0	0	10719
1999	0	2384	0	0	0	124	11	0	0	2519
2000	10615	3158	34	0	0	0	38	0	0	12505
2001	10004	3720	333	0	0	0	135	0	0	10589
2002	11977	4428	23	19	276	0	4	0	0	15519
2003	9809	1113	68	1750	68	0	0	0	0	14925
2004	11155	342	6	1401	0	0	0	0	0	13231
2005	10975	898	1	974	0	0	54	0	0	17694
2006	10884	825	2	49	0	12	78	5	0	16986
2007	13231	1263	0	0	0	48	0	0	0	16814

	8 a,b,d									
year	France	Spain	Netherlands	Ireland	UK	Denmark	Germany	Lithuania	Belgium	Total
2008	18071	717	0	0	1	39	0	0	0	23133
2009	15847	228	0	0	0	0	0	0	0	21229
2010	12877	642	0	0	0	0	0	0	0	22432
2011	12469	5283	5	0	0	0	0	0	0	25155
2012	10854	14948	0	0	0	0	0	0	0	33100
2013	13614	12423	445	0	252	0	0	0	0	37291
2014	14730	16237	0	0	0	0	0	0	0	39829
2015	13132	13055	0	25	7	0	1	0	0	31574
2016	14320	6824	65	0	0	0	0	0	0	30122
2017	17265	6380	0	0	0	0	0	0	0	30249
2018	18161	7094	0	0	0	0	0	0	0	32289
2019	21099	3250	0	0	0	0	0	0	0	24349
2020	24596	6746	0	0	0	0	0	0	0	31342
2021	20239	5922	0	0	0	0	0	0	0	26161
2022	12907	3117	0	0	0	0	0	0	0	16024

Table 6.2.1.2. Sardine in 8abd. Sardine landings (in tons) by France (1983–2020) and Spain (1996–2020) in ICES divisions 8a,b,d as estimated by the WG.

Year	France	Spain	Total
1983	4367	n/a	
1984	4844	n/a	
1985	6059	n/a	
1986	7411	n/a	
1987	5972	n/a	
1988	6994	n/a	
1989	6219	n/a	
1990	9764	n/a	
1991	13965	n/a	
1992	10231	n/a	
1993	9837	n/a	
1994	9724	n/a	
1995	11258	n/a	
1996	9554	2053	11607
1997	12088	1608	13696
1998	10772	7749	18521
1999	14361	7864	22225
2000	11939	3158	15097
2001	11285	372	11657
2002	13849	4428	18277
2003	15494	1113	16607
2004	13855	342	14197
2005	15462	898	16360
2006	15916	825	16741
2007	16060	1263	17323
2008	21104	717	21821
2009	20627	228	20855
2010	19485	642	20127
2011	17925	5283	23208
2012	15952	14948	30900
2013	20515	12423	32938
2014	19467	16237	35704
2015	15701	13055	28756
2016	22930	6824	29754
2017	24055	6380	30435
2018	25195	7104	32299
2019	21300	3279	24579

Year	France	Spain	Total
2020	24593	6747	31340
2021	20370	5828	26198
2022	23299	3061	26360

6.2.2 Surveys in divisions 8abd

6.2.2.1 DEPM surveys in Divisions 8abd

The DEPM survey BIOMAN takes place annually in spring in the Bay of Biscay with the main objective of estimate the total biomass and distribution of anchovy as well as the numbers at age, percentage at age, length at age, weight at age and anchovy biomass at age in the Bay of Biscay (8abcd) and the egg abundance of sardine in 8abd. Triennially, the SSB of sardine is also included as an assessment index since 2011. Since 2020 the SSB for sardine is estimated annually as well as the numbers at age, percentage at age, weight at age and length at age to be available as inputs for future assessments. The daily egg production (P_0) (eggs /m²), daily mortality rates (z) and total daily egg production (P_{tot})(eggs) parameters were as well estimated for this year (**Table 6.2.2.1.1**) and for the historical series in all the area surveyed, in 8abd and in 8abd without part of the Northwest. Apart from the frequentist method that was applied up to now, to estimate $P_{0,}$ z and P_{tot}, a Bayesian method was applied (Citores et all, 2023 in press) with the aim to avoid incurring in incorrect sign for z (**Figure 6.2.2.1.1**). Currently, the input used for the assessment is the total egg abundance in the 8abd without the Northwest part to be consistent with the historical series and the triennial DEPM since 2011.

The survey took place from the 3rd to the 26th of May. All the methodology concerning the survey and the estimates performance, are described in detail in the annex A.5_stock annex - Bay of Biscay Anchovy (Subarea 8). A detailed report of the survey and results from 2023 are attached as a working document at ICES WGACEGG 2023 in **annex** 3 (**Santos Mocoroa. M *et al.* BIOMAN 2023).**

This year the sardine eggs were scarce in the Cantabrian Sea without reaching the 200m depth isoline. In the French platform, there were sardine eggs from South to North all along the East of the 100m depth isoline area in general. This distribution was similar to last year. (**Figure 6.2.2.1.2**)

In the sampling with the PairoVET net (vertical sampling) from 778 stations a total of 276 (35%) had sardine eggs with an average of 108 eggs m^{-2} per station in the positive stations, a maximum of 1640 egg m^{-2} in a station and a total number of 29 770 eggs m^{-2}. In the sampling with CUFES (horizontal sampling) a total of 607 stations (33%) had sardine from 1824 stations with an average of 4.3 eggs m^{-3} per station in the positive stations and a maximum of 78 egg m^{-3} in a station.

Total egg abundance for sardine was estimated as the sum of the number of eggs in each station multiplied by the area each station represents. This year sardine egg abundance estimates for assessment was 2.88E+12 eggs, considering the 8abd and removing part of the Northwest, to be consistent with the historical series. This estimate was below the time series average (5.68E+12) (**Figure 6.2.2.1.3, Table 6.2.2.1.2**).

To estimate the reproductive parameters for sardine in the Bay of Biscay from BIOMAN survey, 17 adult hauls were available. Mean weight and mean length are showed in **Figure 6.2.2.1.4**. Age composition is showed in **Figure 6.2.2.1.5**. BIOMAN survey produced DEPM spawning Biomass, it was reported in WGACEGG 2023 (Santos Mocoroa M. *et al*. BIOMAN survey 2023), and for the purpose of independent shelf documentation they are summarized in the Table 6.2.2.1.3. The age composition of the stock was estimated as well (**Table 6.2.2.1.4**). All the estimates were obtained from the mature population of the 17 samples that represent a 63 % of the individuals. This year one of the samples was pure immature and another one almost all immature and were eliminated for the SSB estimated. Another sample was eliminated for being outside the 8abd (**Table 6.2.2.1.5**).

Table 6.2.2.1.1. Sardine in 8abd. Daily egg production (P0) (eggs m-²), daily mortality rates (z) and total daily egg production (Ptot)(eggs) estimates and their corresponding standard error (S.e.) and coefficient of variation (CV) for all the area surveyed area, 8abd and 8abd without NW from BIOMAN 2023.

	ALL AREA			8abd			8abdwithoutNW		
Parameter	**Value**	**S.e.**	**CV**	**Value**	**S.e.**	**CV**	**Value**	**S.e.**	**CV**
P0	58.26	8.37	0.1436	63.66	9.53	0.1498	52.33	8.19	0.1565
z	0.27	0.101	0.3763	0.32	0.105	0.3290	0.22	0.112	0.5030
Ptot	2.1.E+12	3.1.E+11	0.1436	2.2.E+12	3.3.E+11	0.1498	1.5.E+12	2.4.E+11	0.1565

Table 6.2.2.1.2. Sardine in 8abd. Time-series for sardine, total egg abundances (Σ(egg St*area st)) in numbers of eggs, without the Northwest, the one adopted as an input for the assessment of sardine in 8abd.

year	totAb8abdwithoutNW
1999	1.06E+12
2000	5.03E+12
2001	2.20E+12
2002	7.82E+12
2003	3.26E+12
2004	7.83E+12
2005	1.09E+13
2006	3.84E+12
2007	2.33E+12
2008	9.37E+12
2009	6.05E+12
2010	1.03E+13
2011	4.29E+12
2012	5.60E+12
2013	5.47E+12
2014	8.21E+12
2015	5.52E+12
2016	8.56E+12
2017	5.99E+12
2018	4.67E+12
2019	4.49E+12
2020	3.75E+12
2021	4.02E+12
2022	3.29E+12
2023	2.88E+12

Table 6.2.2.1.3: Sardine in 8abd. Sardine spawning stock biomass (SSB) in Division 8abd, with the estimates of adult parameters for applying the DEPM: sex ratio (R) (% of females), spawning fraction (S) (% of females spawning per day), batch fecundity (F) (eggs/batch/mature female), female mean weight (Wf)(g) and daily fecundity (DF) (eggs/g/day) for the application of the DEPM with their standard error (S.e) and coefficient of variation (CV). Total egg production (Ptot)(eggs) estimate is showed as well.

Parameter	estimate	S.e.	CV
Ptot	2.19E+12	3.3E+11	0.1498
R'	0.53	0.007	0.0123
S	0.06	0.018	0.3163
F	17,399	2,246	0.1291
Wf	43.17	3.26	0.0756
DF	12.13	4.11	0.3387
SSB	**200,572**	74,269	0.3703

Table 6.2.2.1.4: Sardine in 8abd. Sardine spawning stock biomass (SSB) in Division 8abd, with information on the percentage at age, numbers at age, percentage at age in mass, spawning stock biomass at age in mass with the correspondent standard error (S.e.) and coefficient of variation (CV) from BIOMAN 2023. As well as the biological features mean weight at age(g) and mean length at age(mm).

SSB	**200,572**	74,269	0.3703
Wt	38.71	1.89	0.0489
Population (millions)	5,175	1865	0.3604
Percentage at age 1	0.18	0.079	0.4313
Percentage at age 2	0.39	0.076	0.1978
Percentage at age 3	0.26	0.056	0.2177
Percentage at age 4	0.08	0.038	0.4810
Percentage at age 5	0.07	0.036	0.5295
Percentage at age 6+	0.03	0.015	0.5627
Numbers at age 1	940	467.7	0.4973
Numbers at age 2	1,969	778.6	0.3954
Numbers at age 3	1,352	625.5	0.4627
Numbers at age 4	427	291.0	0.6809
Numbers at age 5	337	203.8	0.6043
Numbers at age 6+	148	111.3	0.7507
Perc. at age 1 in mass	0.14	0.066	0.4740
Perc. at age 2 in mass	0.37	0.084	0.2309
Perc. at age 3 in mass	0.28	0.050	0.1818
Perc. at age 4 in mass	0.09	0.041	0.4371
Perc. at age 5 in mass	0.09	0.043	0.5006
Perc. at age 6+ in mass	0.04	0.021	0.5370
SSB at age 1 (Tons)	27,279	13,380	0.4905
SSB at age 2 (Tons)	72,432	29,065	0.4013
SSB at age 3 (Tons)	56,386	26,286	0.4662
SSB at age 4 (Tons)	19,680	13,259	0.6737
SSB at age 5 (Tons)	16,509	9,954	0.6029
SSB at age 6+ (Tons)	8,285	6,290	0.7592

Biological Features	**estimate**	**S.e.**	**CV**
Weight at age 1 (g)	29.8	0.47	0.0157
Weight at age 2 (g)	37.3	0.89	0.0238
Weight at age 3 (g)	41.7	0.80	0.0191
Weight at age 4 (g)	45.3	0.91	0.0202
Weight at age 5 (g)	48.7	1.68	0.0344
Weight at age 6+ (g)	54.5	1.79	0.0328
Lenght at age 1 (cm)	160.5	0.47	0.0029
Lenght at age 2 (cm)	172.6	0.73	0.0042
Lenght at age 3 (cm)	180.4	1.62	0.0090
Lenght at age 4 (cm)	188.7	1.78	0.0094
Lenght at age 5 (cm)	192.9	2.85	0.0148
Lenght at age 6+ (cm)	200.9	2.54	0.0126

Table 6.2.2.1.5: Sardine in 8abd. Percentage of mature population within the 17 samples used for the DEPM estimates after eliminating 3 samples. And with all the samples obtained (20 samples)

% mature in numb	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
3 hauls eliminated	63%	97%	100%	100%	100%	100%	100%
All hauls	57%	98%	100%	100%	100%	100%	100%

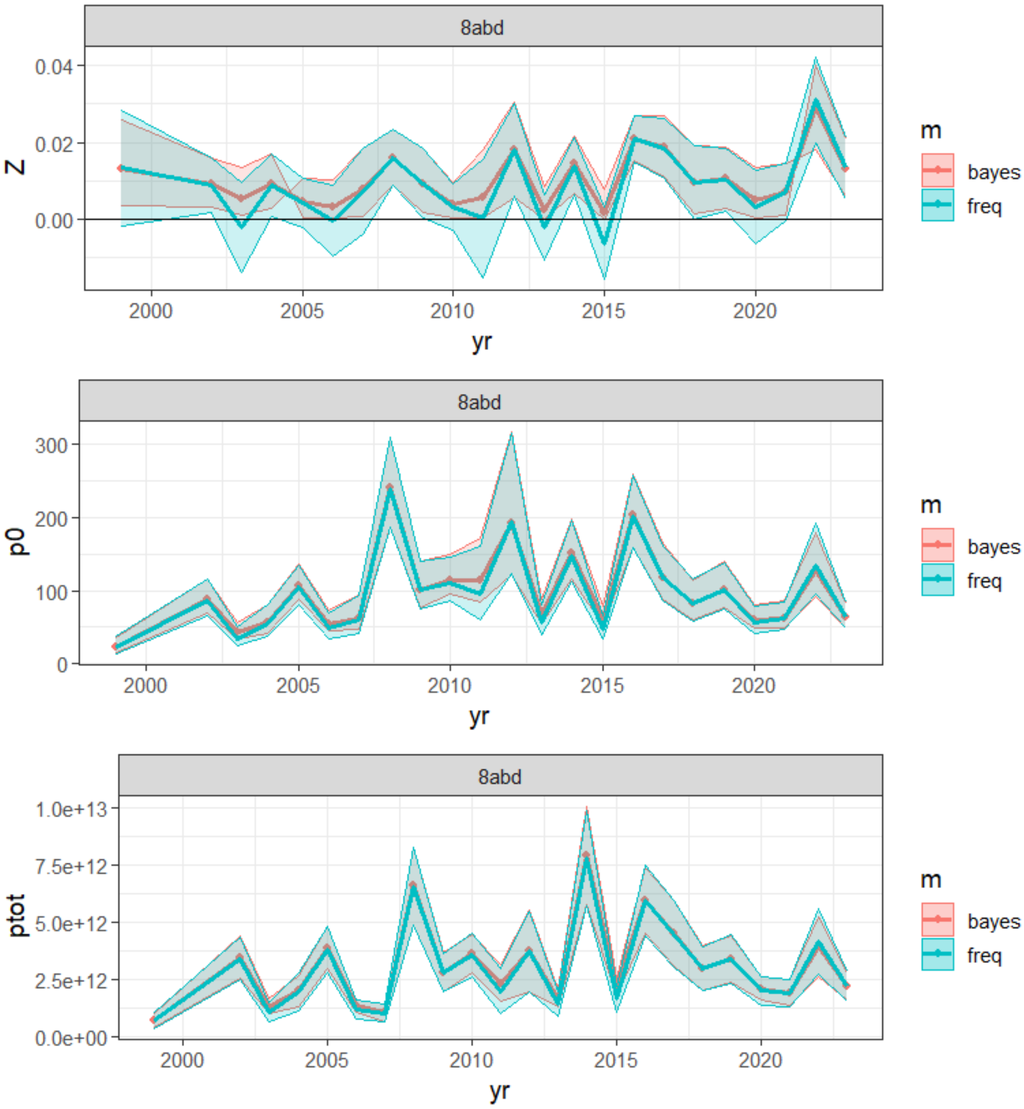


Figure 6.2.2.1.1. Sardine in 8abd. Point estimates (joined points) and 95% confidence intervals (shaded ribbons) for estimated parameters z, P0 and Ptot for all the historical series. Colours represent two different approaches: the Bayesian approach in red and the frequentist approach in blue. Frequentist confidence intervals are computed as mean ± 1.96se.

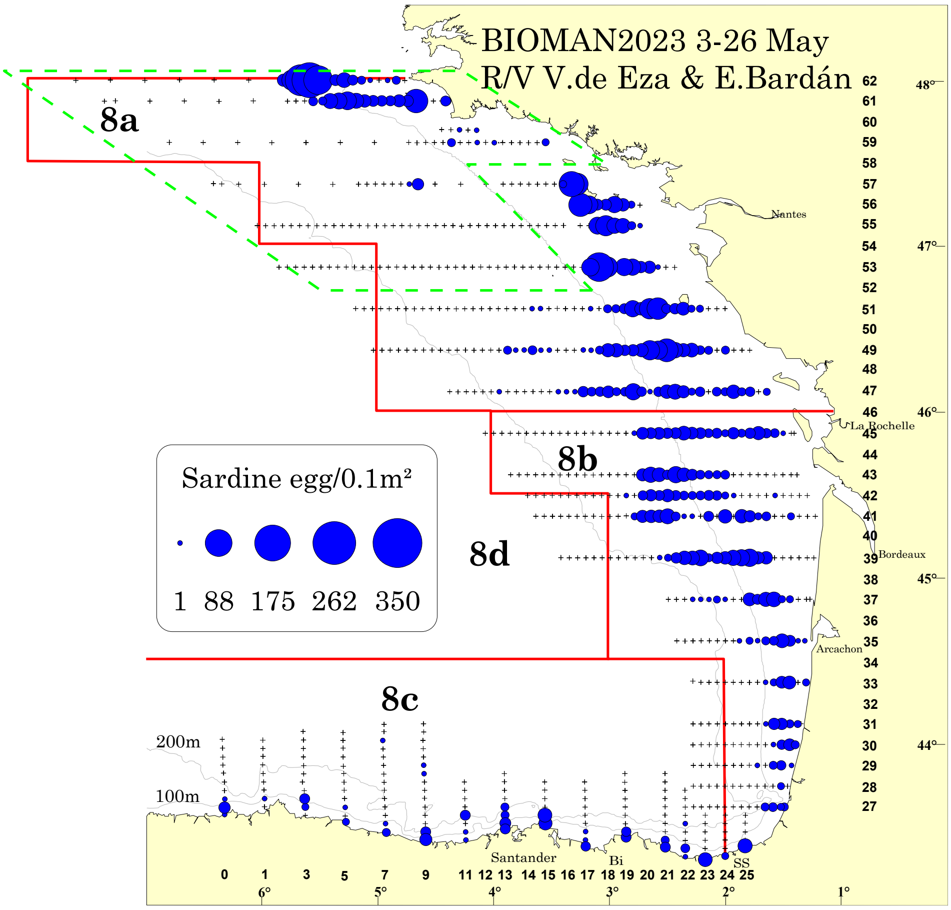


Figure 6.2.2.1.2. Sardine in 8abd. Spatial distribution and abundance of sardine eggs per 0.1m² from the DEPM survey BIOMAN2023 obtained with PairoVET (vertical sampling). The dash green line represents the stations removed for assessment propose in 8abd to be consistent with the historical series. Red lines represent the limits of 8abcd.

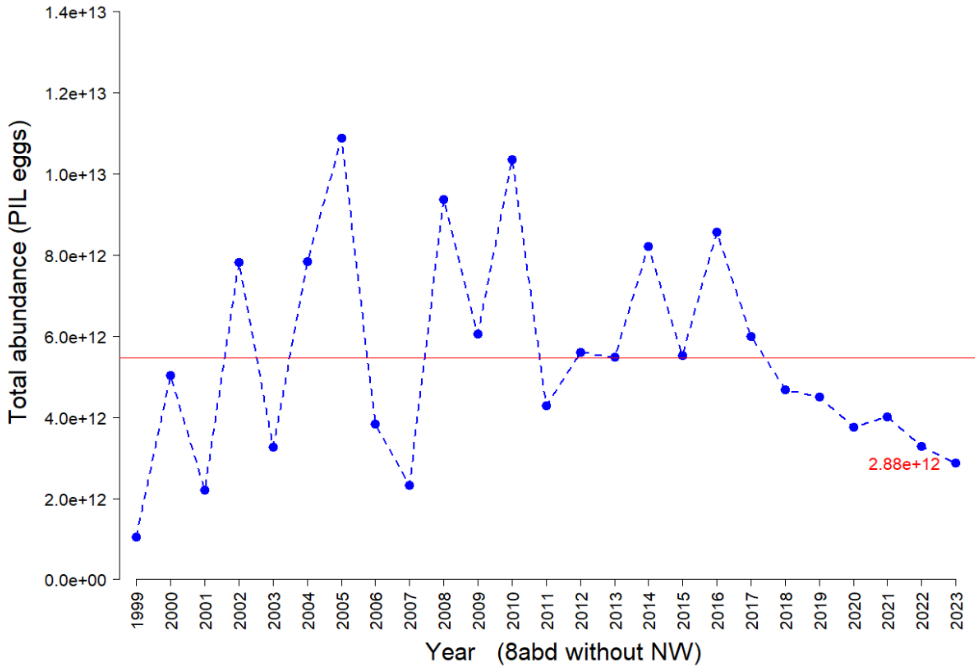


Figure 6.2.2.1.3. Sardine in 8abd. historical series for sardine egg abundances in 8abd without Northwest stations including 2023 value. The red line is the historical mean.

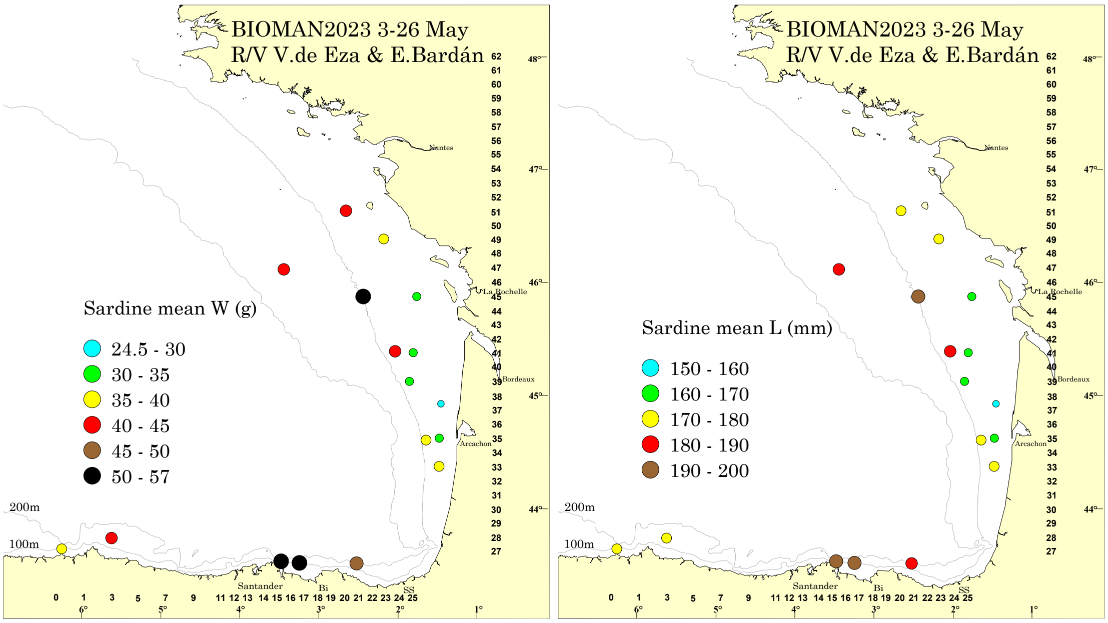


Figure 6.2.2.1.4. Sardine in 8abd. Sardine spatial distribution of mean weight (left) and mean length (right) in the Bay of Biscay from BIOMAN 2023 survey.

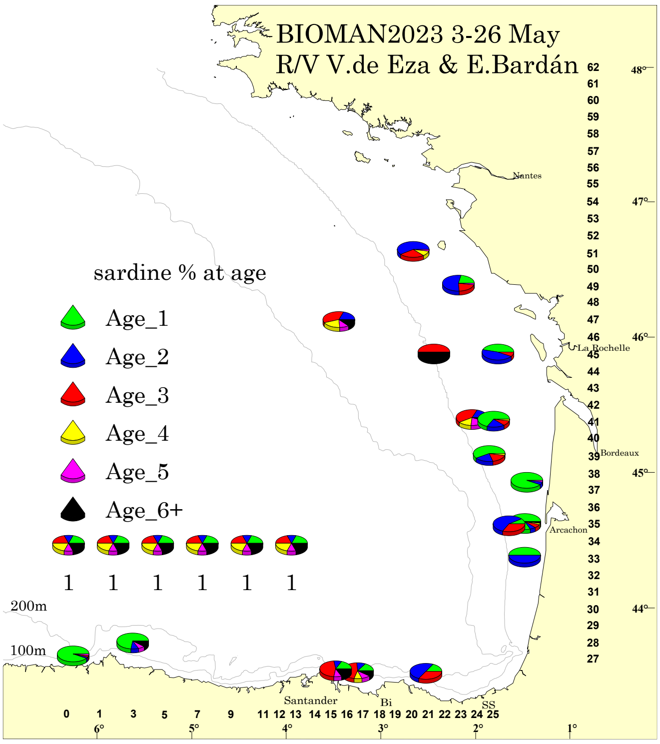


Figure 6.2.2.1.5. Sardine in 8abd. Sardine spatial distribution of percentage at age by haul in the Bay of Biscay from BIOMAN 2023 survey. The different colours are the different ages.

6.2.2.2 Acoustic spring survey (PELGAS): 8ab

The biomass of sardine estimated during PELGAS23 is **265 944** tonnes, which is a slight increase compared with the previous survey, the biomass reaching a medium level of the PELGAS series (around the average). It must be noticed that the sardine abundance index is very variable, and it could be explained that this survey doesn't cover the total area of potential presence of sardine, and it is possible that some years, this specie could be present up to the North, in the Celtic sea, SW of Cornouailles or Western Channel where some fishery (and the PELTIC survey) occurs. It is also possible that sometimes, a part of the population could be present in very coastal waters, when the R/V Thalassa is unable to operate in those waters. The estimate is representative of the sardine present in the survey area at the time of the survey and can be therefore considered as an estimate of the Bay of Biscay (8ab) sardine population.

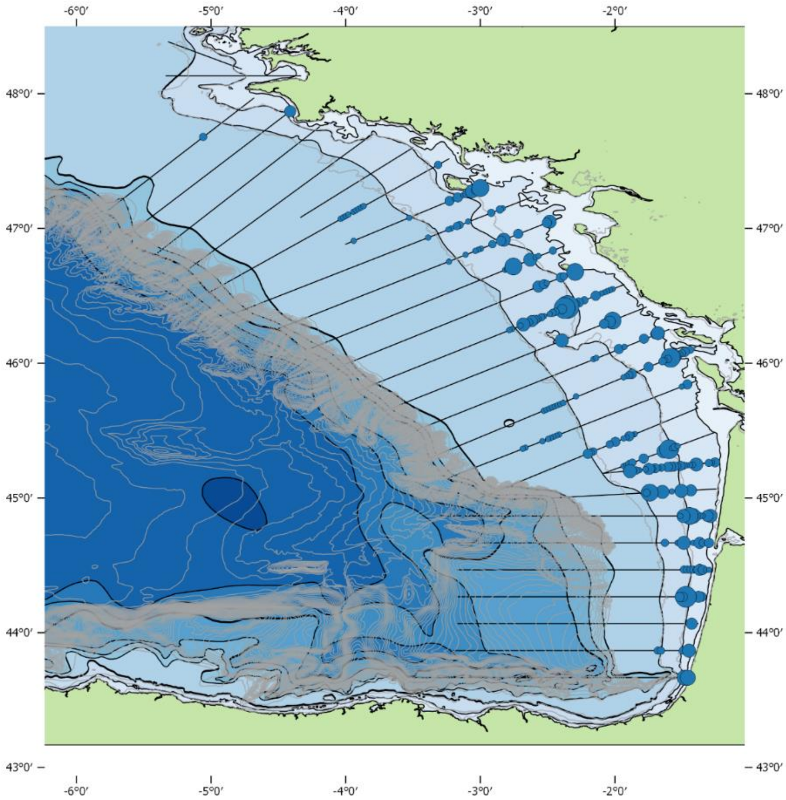


Figure 6.2.2.2.1. Sardine in 8abd. distribution of sardine observed by acoustics during PELGAS23.

Sardine was distributed all along the French coast of the Bay of Biscay, from the South to the Loire river (Figure 6.2.2.2.1). The small sardine was present this year, sometimes pure, and regularly mixed with anchovy. It must be noticed that one more year, no sardine at all were detected along the shelfbreak.

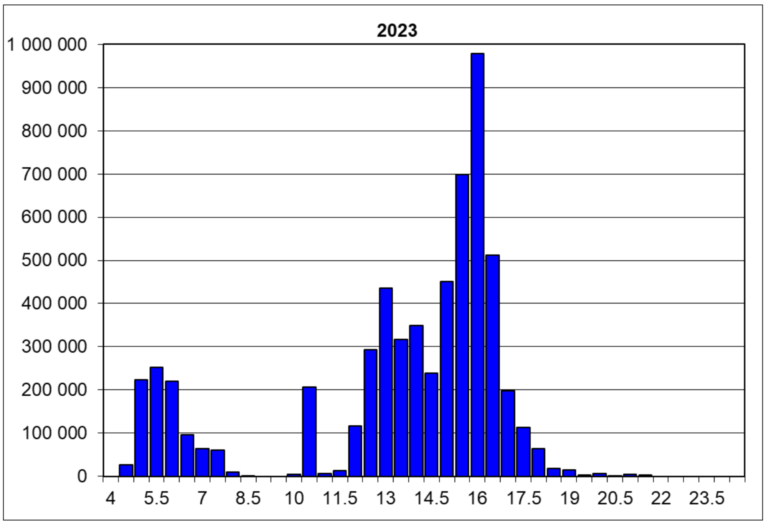


Figure 6.2.2.2.2. Sardine in 8abd. Length distribution of sardine as observed during PELGAS23.

Length distributions in the trawl hauls were estimated from random samples. The population length distributions have been estimated by a weighted average of the length distribution in the hauls. Weights used are the acoustic biomass estimated in the post-stratification regions comprising each trawl haul. The global length distribution of sardine is shown in Figure 6.2.2.2.2. We can see that this year, a mode about 6 centimetre is visible. It corresponds to juveniles, detected and caught particularly along the Brittany coast, at the end of the survey. Some of these fish have been aged by the daily ring method, and their age have been determined between 80 and 90 days, so with a probable birth at the end of February. These juveniles, largely underestimated because of the low catchability of the vessel on so small individuals, have been removed to keep the abundance index on adults (age 1+).

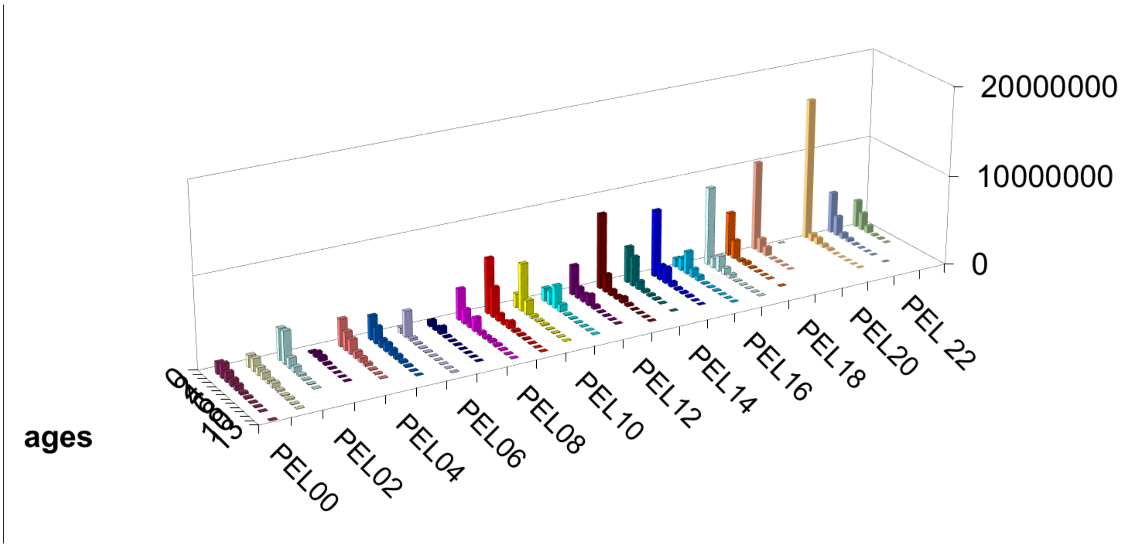


Figure 6.2.2.2.3. Sardine in 8abd. Age composition of sardine as estimated by acoustics since 2000

PELGAS series of sardine abundance at age (2000-2023) is shown in Figure 4.1.7. Cohorts can be visually tracked on the graph particularly in the past : the respectively very low and very high 2005 and 2008 cohorts denote atypical years in terms of environmental conditions, and therefore fish (and particularly sardine) distributions. This is no more true in recent years, with the good recruitment in 2013 which doesn't profit to incoming years, or the 2017 year class which seems to be one of the best recruitment ever and who seems to contribute not that much to the total abundance of sardine in 2018 (and 2019) in the bay of Biscay. 2021 seemed to be the best recruitment ever and the population appeared more and more young (88% of the fish were 1 year old). 2022 showed that this very strong cohort doesn't profit in 2022 to the population with an abundance at age 2 which is around the level of the series, and it is confirmed this year with only 13% of age 3. The population of sardine is still very young, with an age distribution largely dominated by age 1 and 2 groups (sum about 82% in numbers).

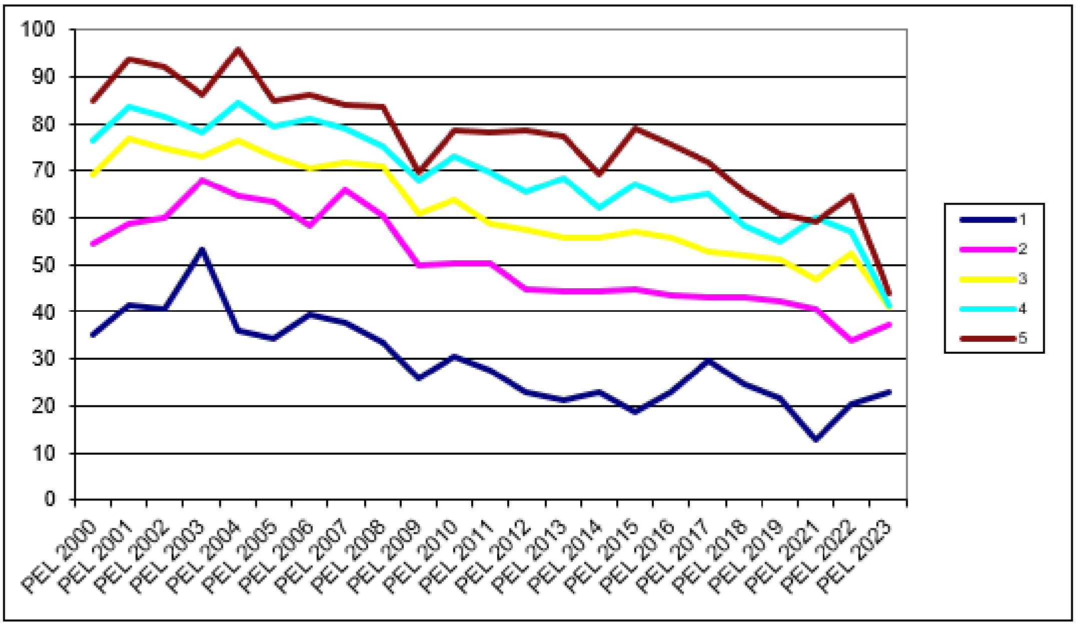


Figure 6.2.2.2.4. Sardine in 8abd. Evolution of mean weight at age (g) of sardine along PELGAS series.

The PELGAS sardine mean weights at age series (Figure 6.2.2.2.4) shows a clear decreasing trend, whose biological determinant is still poorly understood. Further studies are conducted, particularly on the nutritive quality of plankton. One year old sardines were about 40 grams in the beginning of the serie, and reach only 23 grams this year, with a strong minimum value in 2021 with 12.5 grams. Further work must be conducted to explore the causes of the fluctuation of mean weights at ages but recent works suggest that it could be caused by a modification of the plankton composition.

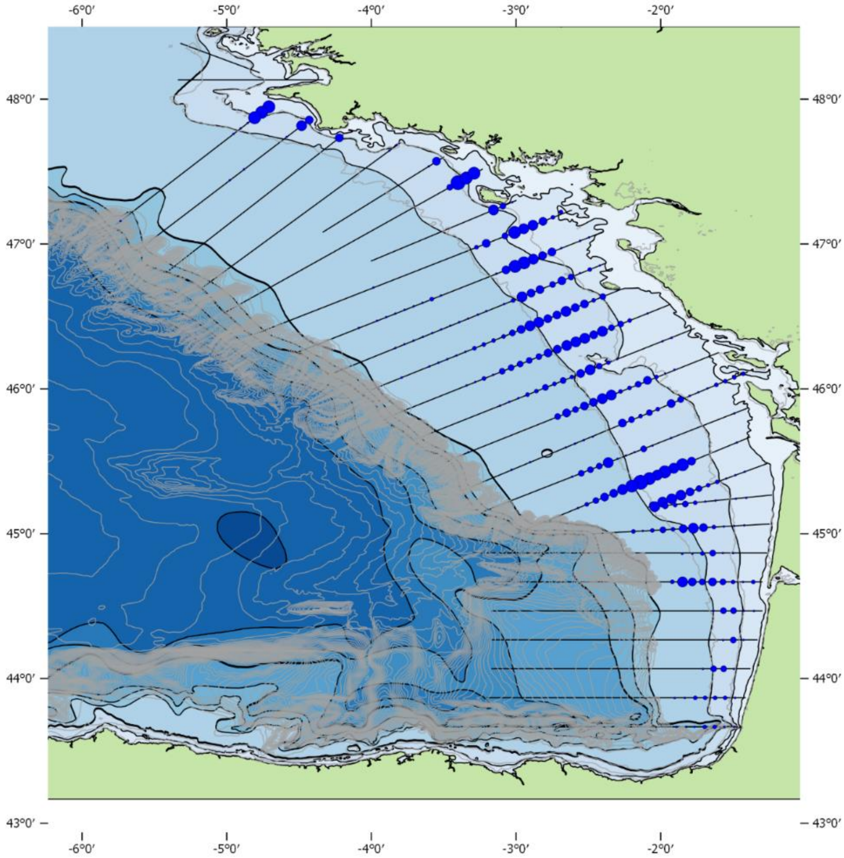


Figure 6.2.2.2.5. Sardine in 8abd. Distribution of sardine eggs observed with CUFES during PELGAS23.

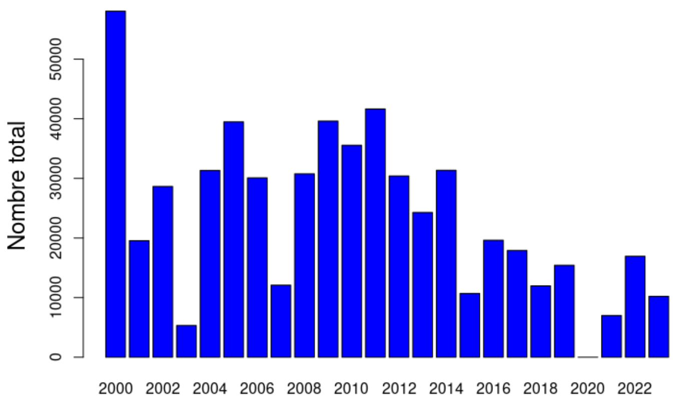


Figure 6.2.2.2.6. Sardine in 8abd. Number of eggs observed during PELGAS surveys from 2000 to 2023

2023 was marked by a low abundance of sardine eggs as compared to the PELGAS time-series (Figure 6.2.2.2.5 and Figure 6.2.2.2.6). It must be noticed that this year the one-year-old individuals were not fully mature: 57 % of the age 1 were totally immature (stage1) and 13 % were starting their maturation (stage 2 of the maturity scale) at the time of the survey. Only 27 % age 1 were fully mature. Almost all of the older individuals (age 2 and more) were spawning.

6.2.3 Biological data

6.2.3.1 Catch numbers-at-length and age

Catches were sampled, and numbers by length class for divisions 8a, b, d by quarter are shown in Tables 6.2.3.1.1 and 6.2.3.1.2, for France and Spain, respectively. Sardine caught in divisions 8a, b, d ranges from 12 to 24 cm (half cm bin). In 2022, a peak is observed in the catch-at size distributions around -17 cm length (half cm bin).

Table 6.2.3.1.3 and Table 6.2.3.1.4 shows the catch-at-age in numbers for each quarter of 2022 for Spanish and French landings respectively. Even if France and Spain are not fishing at the same place and at the same period, fish of age 2 dominated the fishery for both countries.

6.2.3.2 Mean length and mean weight-at-age

Mean length and mean weight-at-age by quarter in 2022 for France and Spain are shown in Tables 6.2.3.2.1 to 6.2.3.2.4.

Table 6.2.3.1.1. Sardine in 8abd. French Sardine catch at length composition (thousands) in ICES divisions 8a,b in 2022.

Length * (half cm)	Quarter 1	Quarter 2	Quarter 3	Quarter 4	All year
10					
10.5					
11					
11.5					
12		472			472
12.5					
13	162	472		284	919
13.5	162	1 416			1 578
14	325	3 775	2 086	284	6 470
14.5	1 136	4 247	1 147	284	6 815
15	1 639	9 438	1 774	569	13 420
15.5	3 349	9 271	3 548	853	17 021
16	3 998	27 831	16 070	6 824	54 723
16.5	2 652	34 943	40 479	16 776	94 850
17	3 612	27 025	48 398	23 884	102 920
17.5	2 815	6 273	52 880	18 482	80 449
18	2 907	1 096	34 002	14 501	52 506
18.5	5 428	1 568	29 412	7 961	44 369
19	7 484	1 096	16 689	2 559	27 828
19.5	7 562	2 193	6 049	3 981	19 785
20	6 681	472	3 234	1 137	11 524
20.5	4 454	1 096		853	6 403
21	2 876	548			3 424
21.5	982	1 644			2 626
22	951			284	1 236
22.5	131				131
23	263				263
23.5					
24					
24.5					
25					
Total number	59 732	134 878	255 768	99 518	549 896
Official catch (t)	3 135	4 875	11 026	4 263	**23 299**

Table 6.2.3.1.2. Sardine in 8abd. Spanish sardine catch-at-length composition (thousands) in ICES Division 8b in 2022.

Length * (half cm)	Quarter 1	Quarter 2	Quarter 3	Quarter 4	All year
10					
10.5					
11					
11.5	3				3
12	9				9
12.5	66				66
13	359				359
13.5	709			5	714
14	1 426			48	1 475
14.5	2 023			19	2 043
15	2 641	1		100	2 742
15.5	2 617	3		487	3 107
16	3 476	4		2 558	6 039
16.5	4 890	9		5 789	10 688
17	4 895	26	39	8 002	12 963
17.5	3 155	37	59	7 217	10 468
18	2 212	33	138	7 521	9 905
18.5	1 627	32	296	5 137	7 092
19	1 093	30	315	2 709	4 147
19.5	658	11	296	1 530	2 495
20	348	10	197	1 162	1 717
20.5	239	2	99	581	921
21	75	3	59	271	408
21.5	15	1	20	161	196
22	20		20	55	94
22.5	5				5
23	1		20		21
23.5					
24					
24.5					
25					
28					
Total number	32 563	202	1 557	43 354	77 676
Official catch (t)	1 066	8	84	1 898	**3 056**

Table 6.2.3.1.3. Sardine in 8abd. Spanish 2022 landings in ICES Division 8ab: Catch in numbers (thousands) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	0	0,00	0,00	171,94	171,94
1	13411,18	42,12	28,20	10046,12	23527,63
2	13369,94	87,84	290,25	17341,47	31089,50
3	4302,62	71,94	313,48	7867,65	12555,68
4	1312,10	24,00	497,68	5138,69	6972,47
5	358,93	10,40	197,84	1655,05	2222,22
6	0	0,00	230,00	1132,82	1362,82
7	0	0	0	0,00	0
8	0	0	0	0	0
9	0	0	0	0	0

Table 6.2.3.1.4. Sardine in 8abd. French 2022 landings in ICES Division 8b: Catch in numbers (thousands) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0			4273,82	1264,75	5538,57
1	6915,44	42025,03	111462,41	45524,21	205927,09
2	17980,05	78273,39	116982,07	44473,70	257709,21
3	19212,22	8499,30	15521,50	5218,35	48451,36
4	9716,42	3635,39	5234,43	1786,40	20372,64
5	4085,75	1045,00	2294,17	966,32	8391,23
6	1546,82	668,52		284,34	2499,67
7	215,78	731,04			946,82
8	59,45				59,45
9					0,00

Table 6.2.3.2.1. Sardine in 8abd. Spanish 2022 landings in divisions 8a,b: Mean length (cm) -at-age.

	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	0,00	0,00	0,00	14,87	14,87
1	15,68	15,16	17,60	16,89	16,20
2	16,93	17,82	18,63	17,69	17,37
3	18,49	18,89	19,09	18,36	18,42
4	18,73	19,16	19,56	19,12	19,08
5	20,48	20,49	19,91	19,39	19,62
6	0,00	0,00	20,71	20,46	20,50
7	0,00	0,00	0,00	52,00	
8	0,00	0,00	0,00	0,00	
9					

Table 6.2.3.2.2. Sardine in 8abd. Spanish 2022 landings in divisions 8a,b: Mean weight (kg) -at-age.

	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	0,00	0,00	0,00	0,03	0,03
1	0,03	0,03	0,04	0,04	0,03
2	0,03	0,04	0,05	0,04	0,04
3	0,04	0,05	0,05	0,05	0,05
4	0,04	0,05	0,05	0,05	0,05
5	0,06	0,06	0,06	0,05	0,05
6	0,00	0,00	0,06	0,06	0,06
7	0,00	0,00	0,00	0,00	
8					
9					

Table 6.2.3.2.3. Sardine in 8abd. French 2022 landings in ICES Division 8a,b: mean length (cm) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0			14,80	14,67	14,77
1	15,39	15,64	16,98	16,96	16,65
2	17,27	16,44	17,63	17,54	17,23
3	19,32	18,12	18,95	19,15	18,97
4	19,69	18,66	18,99	19,35	19,30
5	20,41	20,57	19,25	19,37	19,99
6	20,59	18,36		22,02	20,16
7	20,69	17,82			18,48
8	22,00				22,00
9					

Table 6.2.3.2.4. Sardine in 8abd. French 2022 landings in ICES Division 8a,b: mean weight (kg) -at-age.

Age	First Quarter		Third quarter	Fourth Quarter	Whole Year
0		0,03	0,03	0,03	0,03
1	0,03	0,04	0,04	0,04	0,04
2	0,04	0,05	0,04	0,04	0,04
3	0,06	0,05	0,06	0,06	0,06
4	0,06	0,07	0,06	0,06	0,06
5	0,07	0,05	0,06	0,06	0,07
6	0,07	0,05		0,09	0,07
7	0,07				0,05
8	0,09				0,09
9					

6.2.3.3 Maturity

The maturity ogive is provided yearly by the PELGAS survey, carried out in May, from the visual examination of gonads according a maturity scale (stage 1- 5). Age 1 is the only age group which has partial maturity, and usually it has been assessed to be about 0.7580 (mean of maturity in 2017-2019). In 2023 about 57% (49% in 2022) of age 1 fishes were immature (a value corresponding to the unweighted mean of the proportion age 1 fishes in stage 1 of maturity). This implies that only about 43%% of age 1 fishes were mature.

6.3 Stock assessment

6.3.1 Historical stock development

Model used: SS3

Since 2019 this stock is assessed using SS3. The procedure is described in the stock annex following the WKPELA benchmark (2017). It was updated in 2019 following the IBPSardine interbenchmark (ICES, 2019). The interbenchmark took place in 2019 and was tasked with evaluating the stock assessment focusing on retrospective bias, data revisions and updating reference points. Standard model diagnostics were used to evaluate a series of interventions designed to evaluate the models and to determine causes of and corrections for the retrospective bias.

The retrospective bias could be corrected by several straightforward interventions. First, fixing selectivity at asymptotic improved model fit and reduced bias. Second, invoking a very weak stock–recruitment relationship (steepness=0.99) and commensurate bias correction ramping on recruitment deviations coupled with not estimating terminal year recruitment, further reduced the bias. Such a treatment of terminal year recruitment and penalizing poorly informed recruitment deviations is common assessment practice.

Additional concerns were raised by the estimated catchability coefficients above one for the PELGAS and BIOMAN surveys. There are a number of reasons why these surveys could estimate higher abundance than the assessment model. These include mismatch of timing given the rapid population dynamics, overestimation of acoustic biomass, mismatch of assumed selectivity of the survey as well as many other common issues that support the standard practice of treating most surveys as relative rather than absolute. Once the decision to use these indices as relative inputs, the absolute value of catchability is meaningless as the index could simply be scaled to a mean of one with the same impact in the model.

Given the substantial reduction in retrospective bias achieved through straightforward model interventions and the solid diagnostic performance of the WG-preferred model, it was recommended the assessment be upgraded from category 2 to category 1.

Nonetheless, the model cannot estimate MSY-based reference points and this requires proxies. Based on considerations of life history, the WG recommends a proxy of SPR35% for B_{lim}. Recommendations for future work include explicitly modelling variability of growth reflecting the declines in mean weight-at-age, incorporating length composition and considering a management procedure approach as the majority of catch comes from ages 1 and 2 which are very poorly informed in catch projection due to the time-lag between the assessment and the provision of management advice.

This assessment is the fifth one following the interbenchmark in 2019.

6.3.2 State of the stock

Summary of the assessment is shown in Table 6.3.2.1 and in Figures 6.3.2.1–6.3.2.2.

The spawning–stock biomass (SSB) is above B_{lim} in 2023. SSB has decreased strongly from 2010 to 2012 to the lower value of the series and has been stable until 2017. SSB has since then had a decreasing trend with 2021 the lowest value of the time-series (50 141.7 t). In 2022, SSB showed a very small increase with a value of 62 534 tons. In 2023 SSB is still low (65 739.1 t), between B_{lim} and B_{pa}. The decrease after 2012 is not clearly related to the increase in fishing mortality in recent years, as F went up above F_{MSY} just after the drop in biomass assessed for January 2012. Landings were above 30 kt between 2012 and 2014, dropping for two years and then raising up again to 32 kt in 2018 for four consecutive years. Fishing mortality has been above 0.4 and above F_{MSY} since 2012. Recruitment has been variable over time. Recruitment in 2022 is lower than in 2021.

Table 6.3.2.1. Sardine in 8abd. Summary of the sardine 8abd stock assessment.

Year	Recruitment (thousand)	SSB (tonnes)	Total Catch (tonnes)	F(2–5)
2000	4283890	137384	15097	0.142
2001	5217970	155107	15005	0.147
2002	3466720	167625	18277	0.173
2003	3830320	176203	16607	0.140
2004	7050300	147215	14197	0.133
2005	2315340	174835	16360	0.131
2006	3549170	153863	16741	0.143
2007	6898540	137782	17323	0.152
2008	8421790	157741	21821	0.22
2009	3446070	134573	20855	0.174
2010	2629740	150268	20127	0.172
2011	4302210	120939	23208	0.23
2012	7495660	88575.9	30900	0.41
2013	5217100	94667.2	32938	0.45
2014	6964670	98405.7	35704	0.55
2015	2594530	88291.2	28756	0.47
2016	6356360	81001.1	29754	0.57
2017	4734390	101905	30435	0.56
2018	5259440	88288.4	32299	0.62
2019	4698900	71477	24579	0.47
2020	7163340	85450.4	32340	0.60
2021	5545550	53407.3	26198	0.52
2022	4816870	71639.3	26360	0.46
2023	*4767249	65739.1		

***Geometric mean (2002–2022).**

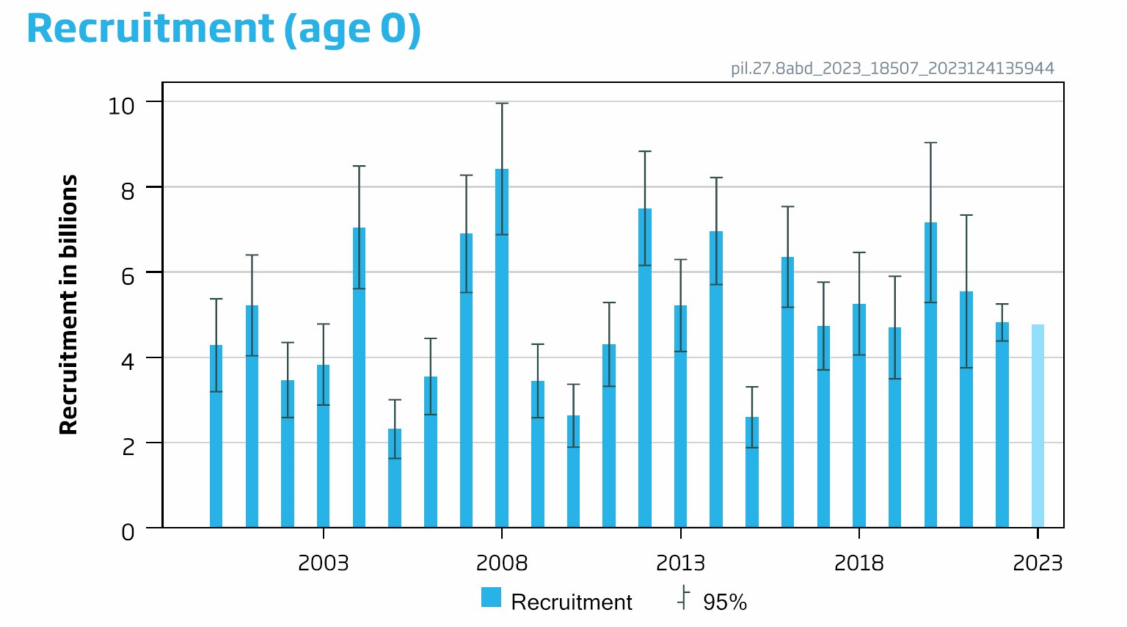


Figure 6.3.2.1. Sardine in 8abd. Recruitment estimates from SS3 outputs for sardine 8abd. Last year's value is estimated from the geometric mean (2002-2022).

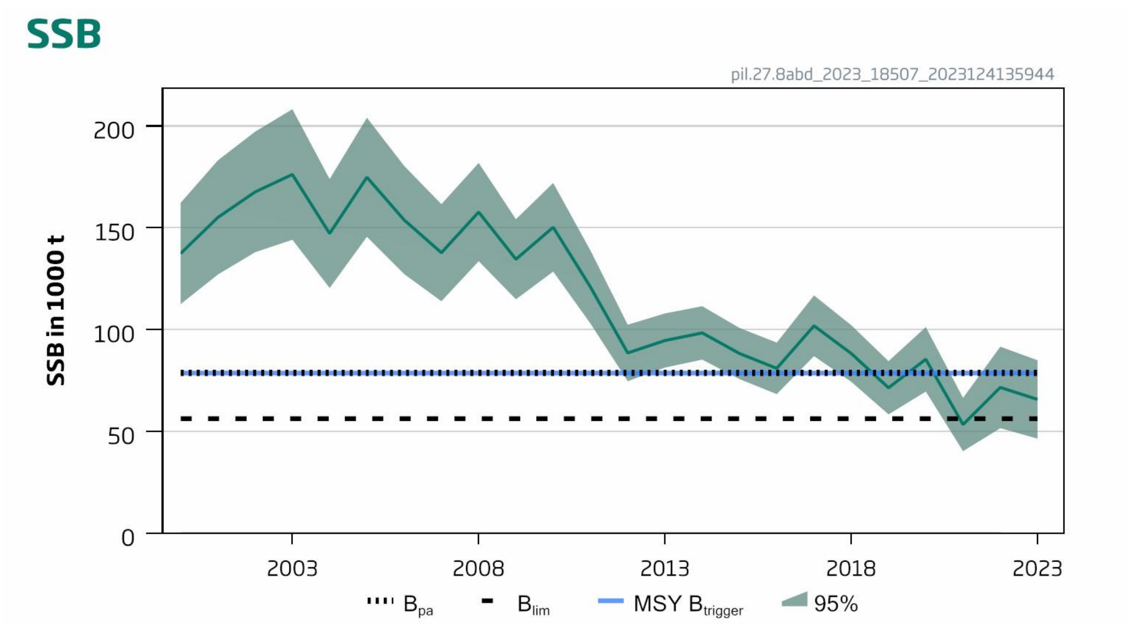


Figure 6.3.2.2. Sardine in 8abd. Spawning–stock biomass from SS3 outputs for sardine 8abd. Last year's value is estimated from the model.

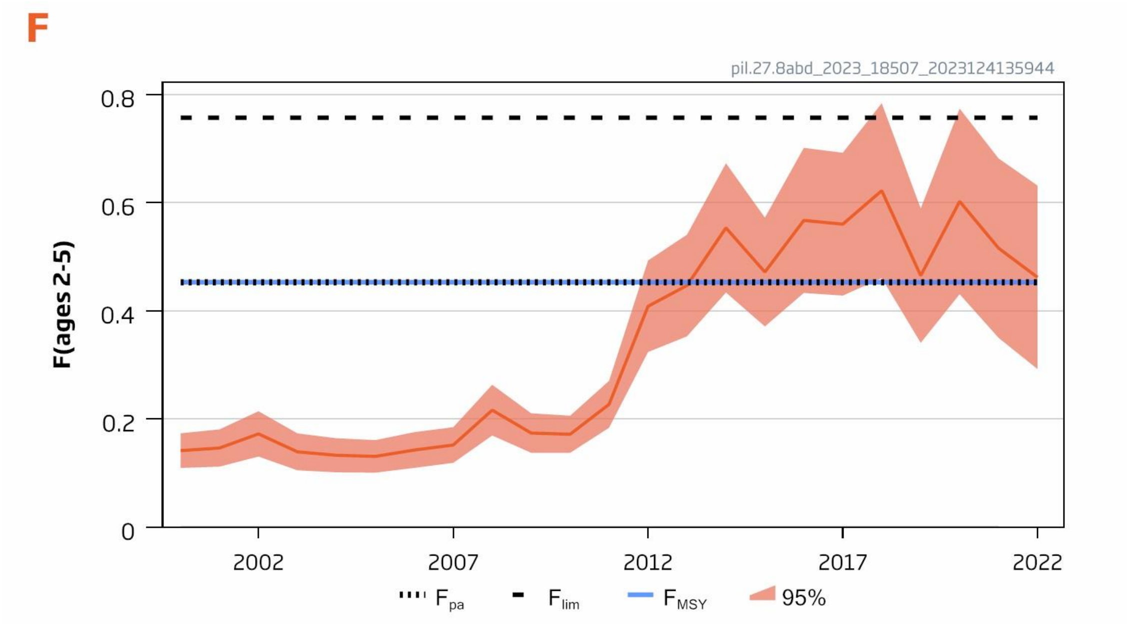


Figure 6.3.2.3. Sardine in 8abd. Fishing mortality for ages 2 to 5 derived from SS3 outputs for sardine 8abd.

6.3.3 Diagnostics

Residuals (Figures 6.3.3.1–6.3.3.2) and diagnostics do not highlight any problem regarding the input data and model fit. Some cohorts lead to some model over or underestimations. This phenomenon appears on some years for the PELGAS survey. For PELGAS, age 1 has positive residuals since 2011 and negative in earlier years.

For the commercial vessels, the cohort effect is less visible, but some years appears to have larger residuals than other (e.g. 2009). The model fit to the survey indices is within the confidence intervals of those indices.

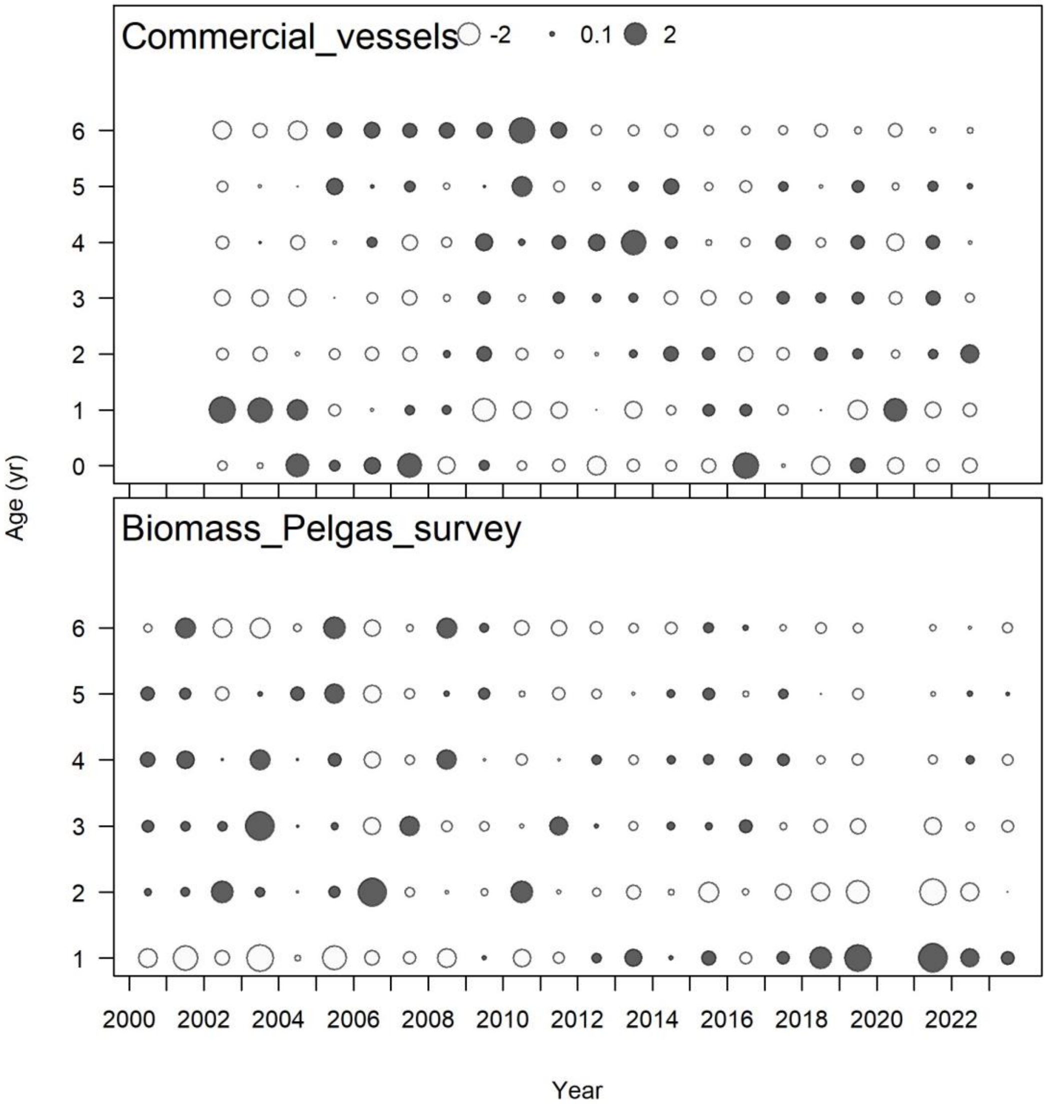


Figure 6.3.3.1. Sardine in 8abd. Fit between model and age composition from the PELGAS survey (bottom) and commercial vessels (top) up to 2023.

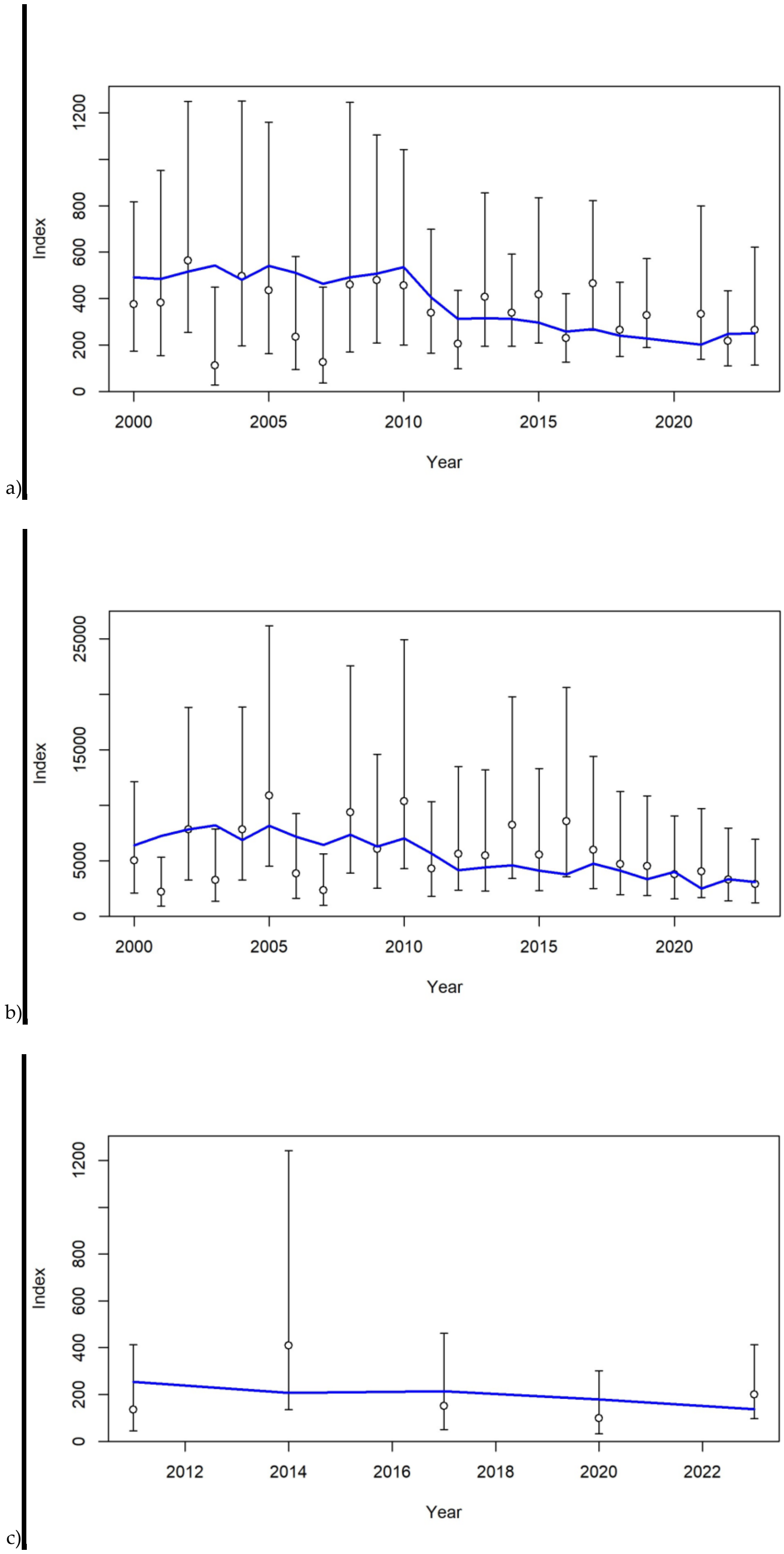


Figure 6.3.3.2. Sardine in 8abd. Fit between model and survey indices: a - Acoustic (PELGAS), b - egg count (BIOMAN), c - DEPM.

6.3.4 Retrospective pattern

Retrospective patterns for SSB, F_{bar}(2–5), apical F and recruitment were computed for years 2015–2023 (Figure 6.3.4.1) using the r4ss *do_retro()* function and Mohn's rho estimates were calculated using the same approach carried out during the interbenchmark and therefore values can be compared to the work made during the interbenchmark. For each run, assessment was performed including survey data until the last retrospective year and catch data until previous year, as done in the current assessment (2023).

Overall, SSB tends to be overestimated while F is underestimated. There is no clear patterns regarding recruits although the magnitude of sporadic stronger recruitment events tend to increase Mohn's rho estimates for recruits.

Absolute values of Mohn's rho estimates differ compared with previous assessment (especially for R) but on a lower extent than last year's assessment in regards to previous years:

- Mohn's rho for SSB is 0.24 (previously 0.372).
- Mohn's rho for F is -0.14 (previously -0.301).
- Mohn's rho for R is 0.29 (previously 0.080).

The reason for this might be that in 2020 and 2021, two effects might have impacted the assessment: 1) the strong downward deviation of the model in 2021 is related to the large number of age-1 individuals with low weight at age and low fecundity. This drives down the SSB in 2021. 2) The lack of stock structure input from PELGAS in 2020, cancelled due to COVID-19, possibly accounts for this issue as SS3 had to fill the gap possibly from the previous and next year internal estimates. This year's assessment seems to be less influenced by the lack of PELGAS survey in 2020 and the 2023 is more in line with the 2021 assessments in terms of stock structure. As in 2022 assessment, recruitment estimate in 2020 has been scaled down in the current assessment. This reduces the erratic pattern seen previously.

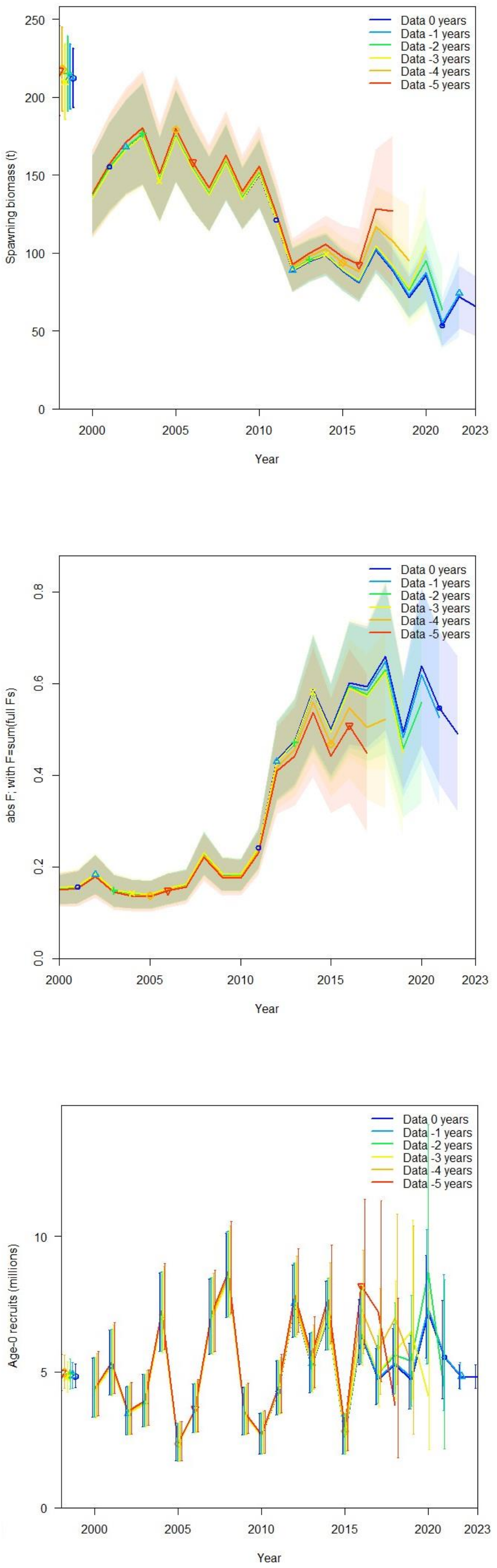


Figure 6.3.4.1. Sardine in 8abd. Summary of retrospective plots.

6.4 Short-term projections

The recruitment of sardine for the intermediate year is assumed to be the geometric mean of the time-series of recruitment. Short-term projections were performed using FLR libraries using the *fwd* function.The initial stock size corresponds to the assessment estimates for ages 1–6+ at the final year of the assessment. The maturity ogive is provided during the interim year in 2023 by the average of PELGAS survey for the last three years. F and M before spawning are zero, which correspond to the beginning of the year when the SSB is estimated by the model. Weights-at-age in the stock are provided during the interim year by the average of the PELGAS survey for the last 3 years. Weights-at-age in the catch are calculated as the arithmetic mean value of the last 3 years. The exploitation pattern is equal to the last year of the assessment.

Recruitment in the interim year and forecast year is set equal to the geometric mean of the time-series (2002-2022). Recruitment for 2023 was assumed to be 4767 million individuals. Assumption for the intermediate year are presented in Table 6.4.1.

Preliminary catches are estimated and used as assumption for the interim year. The *fwd* function is set to use the preliminary catch estimates (instead of F estimates). Preliminary catches were available for quarter 1 to 3. The assumption for the catch in 2023 relies on preliminary catch statistics available from Q1-Q3 of 2023. Q4 is estimated from the average proportion of Q4 catches in last 3 years (2020-2022). The assumed catches for 2023 are 26 441 tonnes. The catch assumption was also included as preliminary catches in the stock assessment model this year.

Input data for the short-term forecast are provided in Table 6.4.2. Table 6.4.3 provides alternative catch options for 2024.

Table 6.4.1. Sardine in 8abd. Assumptions for the intermediate year.

Variable	Value	Notes
Fages 2–5 (2023)	0.53	Based on assumed catches for 2023
SSB (2024)	64 331	Short term forecast; tonnes
Rage 0 (2023-2024)	4 767	Geometric mean (2002–2022); millions
Total catch (2023)	26 441	Preliminary value based on reported catches in Quarters 1 to 3 and assumed catches for Quarter 4; tonnes
Discards (202)	0	Negligible; tonnes

Table 6.4.2. Sardine in 8abd. Input data for the short-term forecast.

Year	Age	stock.n	stock.wt	catch.wt	Mat	M	F
2023	0	4767.25	0.00	0.02	0.00	1.07	0.01
	1	1639.55	0.02	0.04	0.55	0.69	0.22
	2	762.09	0.04	0.04	0.98	0.55	0.39
	3	379.83	0.05	0.05	1.00	0.48	0.50
	4	87.43	0.06	0.06	0.99	0.44	0.50
	5	36.30	0.06	0.06	0.99	0.41	0.50
	6+	20.12	0.07	0.07	1.00	0.40	0.50
2024	0		0.00	0.02	0.00	1.07	0.01
	1		0.02	0.03	0.46	0.69	0.22
	2		0.04	0.04	0.97	0.55	0.40
	3		0.05	0.05	1.00	0.48	0.51
	4		0.06	0.06	0.99	0.44	0.51
	5		0.06	0.06	0.99	0.41	0.51
	6+		0.07	0.06	1.00	0.40	0.51
2025	0		0.00	0.02	0.00	1.07	0.01
	1		0.02	0.03	0.46	0.69	0.22
	2		0.04	0.04	0.97	0.55	0.40
	3		0.05	0.05	1.00	0.48	0.51
	4		0.06	0.06	0.99	0.44	0.51
	5		0.06	0.06	0.99	0.41	0.51
	6+		0.07	0.06	1.00	0.40	0.51

Table 6.4.3. Sardine in 8abd. Catch option table for 2024.

Basis	Catch (2024)	F (2024)	SSB (2025)	% SSB change *	% catch change **	% advice change ***
ICES advice basis						
MSY approach: $F = F_{MSY} * SSB(2024)/MSY\ B_{trigger}$	19811	0.37	65284.12	1.48	-24.85	-7.8
Other scenarios						
F = 0	0.00	0.00	81322.04	26.41	-100.00	-100.0
$F = F_{pa} = F_{MSY}$	23566	0.45	62314.89	-3.13	-10.60	9.6
$F = F_{lim}$	35730	0.76	52890.51	-17.78	35.55	66.2
$SSB(2024) = B_{lim}$	31282	0.64	56300.00	-12.48	18.67	45.5
$SSB(2024) = B_{pa} = MSY\ B_{trigger}$	3192	0.05	78700.00	22.34	-87.89	-85.2
F = F(2023)	26759	0.53	59810.99	-7.03	1.51	24.5

* SSB 2025 relative to SSB 2024.

** Advised catch for 2024 relative to catch in 2022 (26 360 tonnes).

*** Advised catch for 2024 relative to advised catch for 2023 (21 497 tonnes).

The catch options for 2024 are slightly lower than the advice for 2023. Recruitment and SSB estimates from 2022 and 2023 assessments being quite similar.

Based on the GM recruitment and *catch assumption* in 2023. for all catch options for 2024. SSB in 2025 will stay above B_{lim} but is only above MSY $B_{trigger}$ in the case of targets of closure of the fishery (F=0). SSB in 2025 is expected to decrease compared with the one of 2024 for $F=F_{pa}$. $F=F_{lim}$. F=F(2023). B_{lim} target SSB expected to increase when catch options are the most limiting for 2024: closure, B_{pa} target and MSY approach.

6.4.1 Evidence for changes in advice

A comparison of the input data used in the forecast from the current and previous assessments is provided in this section. In Figures 6.4.1–6.4.3 estimated time series for recruitment, SSB and fishing mortalities for previous and current assessments are shown.

Uncertainties are generally higher for the last two years because the available data of the assessment year are limited to an assumption on preliminary catches and survey data. The data of the previous year are fully consolidated in terms of number and weight-at-age for the commercial fleets. The catches are also final rather than assumed.

This year, the run does not differ substantially from last year's run in terms of SSB, F and R. This is generally what has been observed in previous WGHANSA reports except in 2021 where the lack of PELGAS survey in 2020 was suspected to have a strong impact on the assessment. This year, the runs start to slightly diverge in 2020 for R.

Forecast assumptions from previous and current advice sheets are shown in Table.6.4.1.

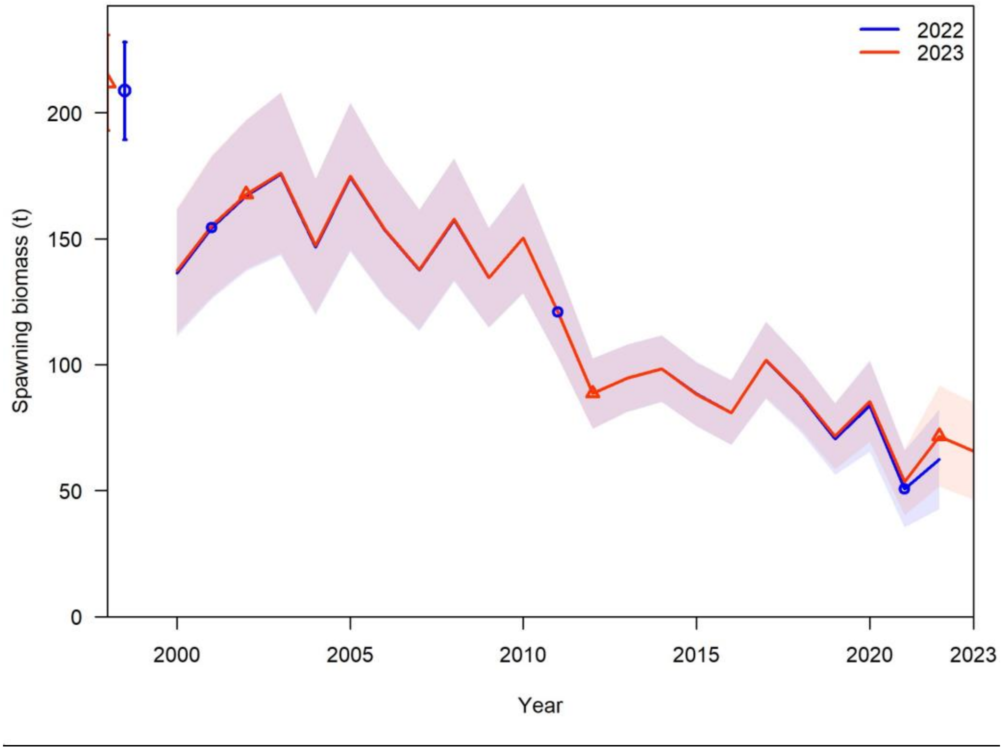


Figure 6.4.1. Sardine in 8abd. Comparison of SSB estimates between this year and the 2022 run.

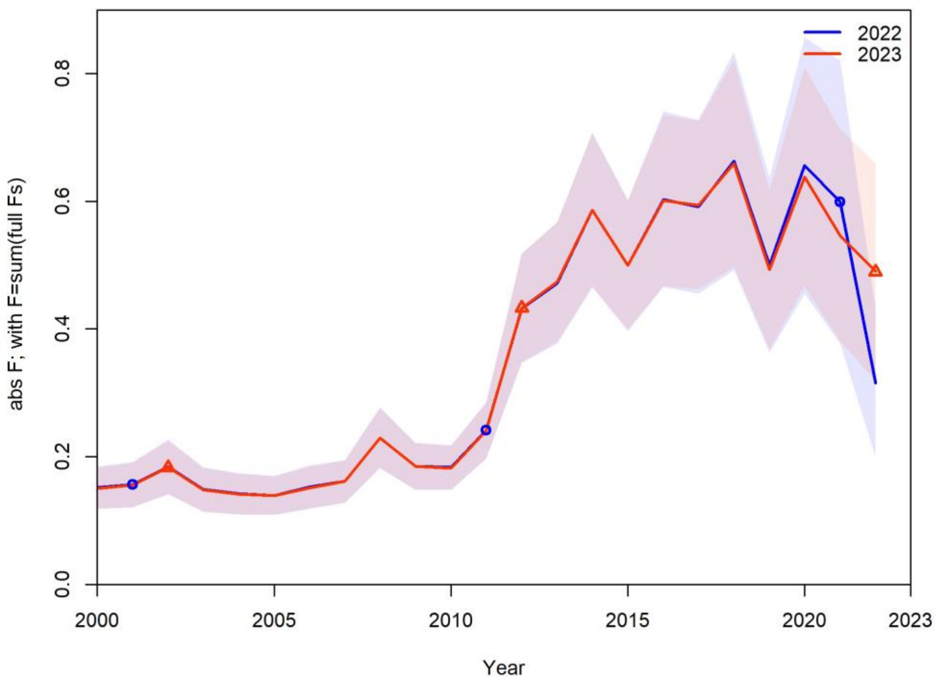


Figure 6.4.2. Sardine in 8abd. Comparison of fishing mortality estimates between this year and the 2022 run.

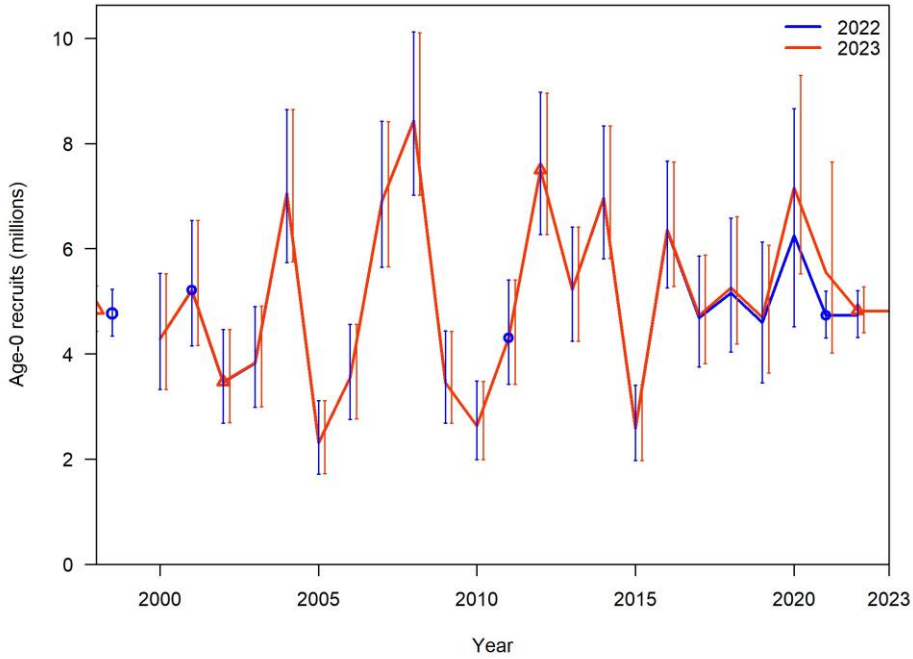


Figure 6.4.3. Sardine in 8abd. Comparison of Recruitment estimates between this year and the 2022 run.

Table 6.4.1. Sardine in 8abd. Forecast assumptions from previous and current assessments.

	Year*	Current assessment (2023)	Previous assessment (2022)
Assumed recruitment	2022-2023	4 816 870	4 680 980
	2023-2024	4 767 249	
Catch	2022	26 360	21 497
F	2021	0.52	0.60
	2022	0.46	
Target F for TAC	2023		0.40
	2024	0.37	

**'2022' = Intermediate year in the previous assessment; '2023' = advice year in the previous assessment*

6.5 Medium-term projection

No medium-term projections were carried out.

6.6 MSY and Biological reference points

As a result of the Inter-benchmark carried out in October 2019. the assessment of this sardine has been upgraded to category 1 and a set of new Biological reference points have been defined. In particular. B_{lim} has been proposed at 35%SBR (ICES 2019). based on considerations of life history and precautionary reference points (Myers *et al*.. 1999; Mace. 1994; Mace and Sissenwine. 1993) and proxies for F_{MSY} based on natural mortality rate (Zhou *et al*.. 2012).

The Inter-benchmark preferred this approach because for this stock 18 pairs of stock and recruitment estimates (2000–2017). covering a narrow range of biomasses (Min/Max=51%) and with no clear indications of impaired recruitment (Figure 6.6.1). Setting B_{pa}=B_{loss} led to infer B_{lim} (63 328 t) and afterwards F_{MSY} (0.27) which seemed to be respectively a bit high and low value respectively. On the one hand. such B_{lim} would be above the expected biomass at $F_{0.1}$ (as calculated for this stock in the deterministic yield-per-recruit) and on the other hand F_{MSY} at 0.27 results in a 61%SBR. which is well below the typical F_{MSY} proxies at %SBR of 40% or 50% (Mace. 1994; Horbowy and Luzenczyk. 2012). below $F_{0.1}$. and also below the alternative F_{MSY} proxy of 0.87*M (= 0.44). For these reasons. an alternative definition of B_{lim} from which derived F_{MSY} was looked for. based on %SPR.

Mace (1994) and Mace and Sissenwine (1993) pointed out that for stocks of unknown resilience a more prudent approach would be using F30%B0. Furthermore. in their analysis Mace and Sissenwine (1993) found that pelagic species that reach relatively small maximum size and/or mature at small size. seem to have high replacement %SPR. and the analysis by taxonomic groups suggested a mean replacement %SPR for cupleoids of about 37.5% higher than for other taxonomic groups. Myers *et al*. (1999) also found that the median steepness of cupleoids and engraulidae were intermediate (not in the upper range of values). Therefore. it can be deduced or presumed from a precautionary approach that small pelagic fish may have relatively lower resilience to fishing (Mace and Sinsenwine. 1993). This led the IBP group to set B_{lim} at 35%B0. which was equal to 56 300 t.

Following the ICES guidelines for stocks in Category 1 and 2. the remaining reference points were derived from the former value of B_{lim} (= 56 300 t). Bpa was derived as B_{pa} = B_{lim} x exp(1.645 σB). where σB is the standard deviation of ln(SSB) in the terminal year (2018) (σB = 0.204 rounded to 0.2). Thus. B_{pa} was set at 78 700 tonnes. As unconstrained F_{MSY} in Eqsim resulted in a value (0.621) conditioned to a hockey stick S–R relationship with inflection point at B_{lim} (Figure 6.6.2). Because this F_{MSY} value was higher than F_{pa} (0.539) and higher than $F_{p0.05}$ (0.453) the F_{MSY} value was reduced to $F_{p0.05}$. The final estimate of F_{MSY} (over ages 2–5) (= 0.453) has the property of being consistent with the ideas of Zhou *et al*. (2012) of setting F_{MSY} equal to 0.87·Natural Mortality (=0.44 for this sardine stock).

In 2021, ICES has been revising the definition of reference points. Fpa is now equal to $F_{p0.05}$. Therefore, that value has been updated and used in the short-term forecast this year.

The updated biological and MSY reference points in absolute terms are:

Table 6.6.1. Sardine in 8abd. Biological Reference points for sardine in 8abd as estimated in ICES 2019.

Framework	Reference point	Absolute value	Technical basis
MSY approach	MSY $B_{trigger}$	78 700	B_{pa}
	F_{MSY}	0.453	$F_{MSY} = F_{p.05}$. i.e. the F that leads to SSB >B_{lim} with probability 0.95 when including the ICES MSY advice rule
Precautionary approach	B_{lim}	56 300	35%SPR. i.e. equilibrium biomass at F that leads to 35% of spawner of recruit without fishing
	B_{pa}	78 700	$B_{pa} = B_{lim} \times \exp(+1.645 \times \text{sigma})$. where sigma=0.2
	F_{lim}	0.757	F that results in 50% probability that SSB is above B_{lim} in the long term. using segmented regression with B_{lim} (EqSim)
	F_{pa}	0.453	$F_{p0.5}$. The F that leads to SSB ≥ B_{lim} with 95% probability
Management plan	SSB_{MGT}	Not applicable	
	F_{MGT}	Not applicable	

All details of the calculations are described in the Inter-benchmark report (ICES, 2019) and in the stock annex. These values are expected to be updated every benchmark or after relevant changes in the selectivity of the fishery are detected.

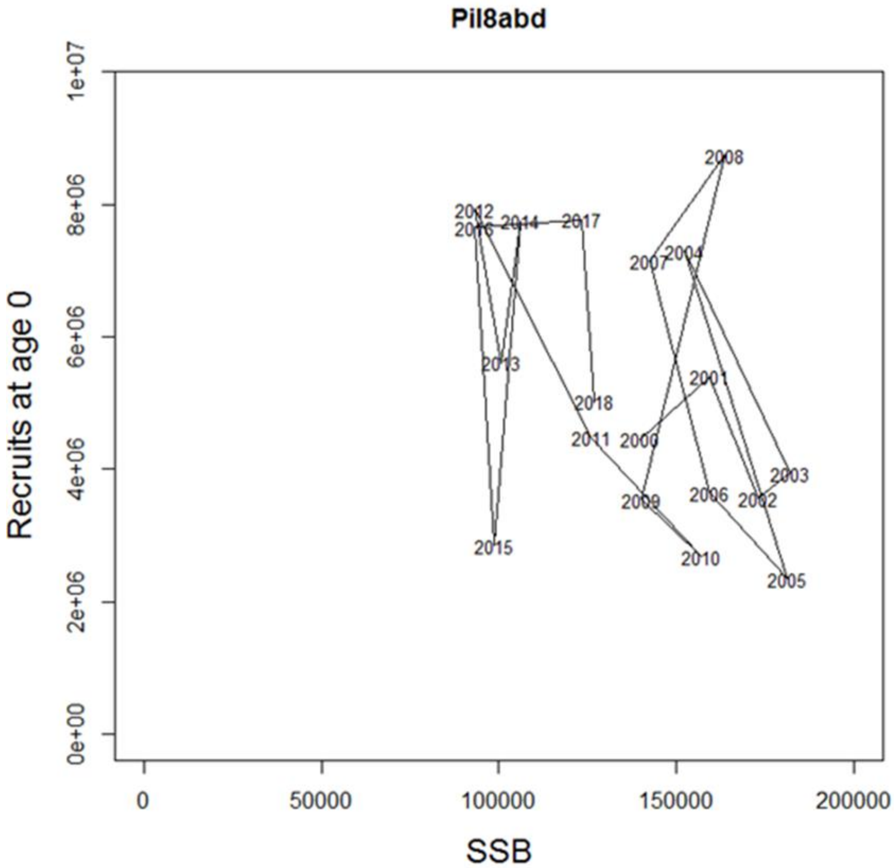


Figure 6.6.1. Sardine in 8abd. Stock–recruitment relationship for sardine in 8abd.

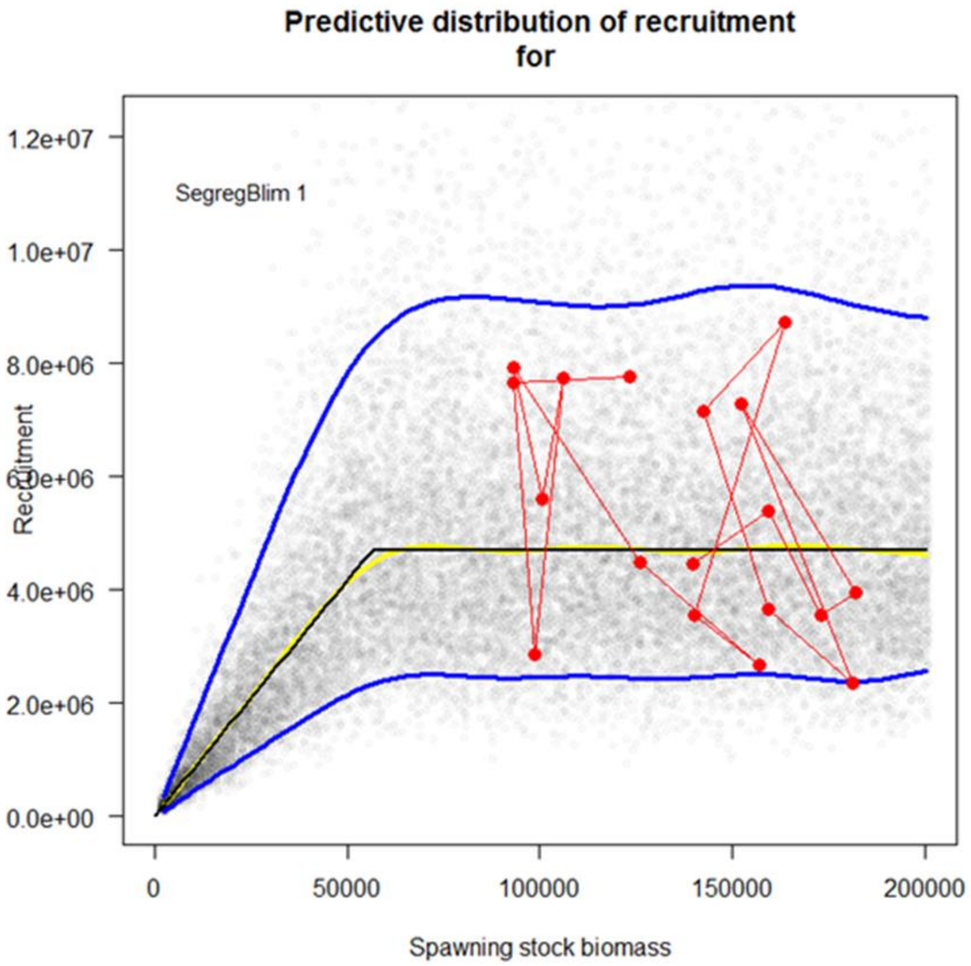


Figure 6.6.2. Sardine in 8abd. Segmented regression model with the breakpoint fixed at B_{lim} for sardine in 8abd.

6.7 Management plan

There are no specific management objectives or a management plan for this stock at the moment. There is ongoing discussion about a management plan or TAC through the SWWAC for this stock, but the plan has not been formalised yet.

6.8 Uncertainties and bias in assessment and forecast

Uncertainties in the assessment relate to the retrospective pattern and relative changes in the perception of the most recent years.

Most of the uncertainties in the forecast comes from the assumption in the intermediate year although the fishery is not expected to increase over the next years.

6.9 Management considerations

No TAC is currently set for this stock.

6.10 References

Beddington. J.R. and Cooke. J. 1983. The potential yield of previously unexploited stocks. FAO Fisheries Technical Paper No. 242. 63 pp.

Buckland S.T.. Burnham K.P.. Augustin N.H. 1997. Model selection: an integral part of inference. Biometrics 53:603–618.

Horbowy. J.. and Luzeńczyk. A. 2012. The estimation and robustness of FMSY and alternative fishing mortality reference points associated with high long-term yield. Canadian Journal of Fisheries and Aquatic Sciences. 69: 1468–1480.

ICES. 2017. ICES Advice technical guidelines. ICES Advice. Book 12.

ICES. 2016. Report of the Workshop to consider FMSY ranges for stocks in ICES categories 1 and 2 in western waters (WKMSYREF4). 13–16 October 2015. Brest. France. ICES CM 1025/ACOM:58.187 pp.

ICES. 2019. Inter-benchmark process on sardine (*Sardina pilchardus*) in the Bay of Biscay (IBPSardine). ICES Scientific Reports. 1:80. 34 pp. http://doi.org/10.17895/ices.pub.5552.

ICES. 2018. Report of the Working Group on Southern Horse Mackerel. Anchovy and Sardine (WGHANSA). 26–30 June 2018. Lisbon. Portugal. ICES CM 2018/ACOM:17. 639 pp.

ICES. 2019. Inter-benchmark process on sardine (*Sardina pilchardus*) in the Bay of Biscay (IBPSardine). ICES Scientific Reports. 1:80. 34 pp. http://doi.org/10.17895/ices.pub.5552

ICES. 2021. Working Group on Southern Horse Mackerel Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 3:55. 679 pp. https://doi.org/10.17895/ices.pub.8138

Mace. P.M. 1994. Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. Can. J. Fish. Aquat. Sci. 51(1): 110–122. doi:10.1139/f94-013.

Mace. P.M. and Sissenwine. M.P. 1993. How much spawning per recruit is enough? Risk Evaluation and Biological Reference Points for Fisheries Management (eds S.J. Smith. J.J. Hunt and D. Rivard). Canadian Special Publication in Fisheries and Aquatic Sciences No. 120. National Research Council of Canada. Ottawa. 101–118.

Myers. R.A.. Bowen. K.G.. and Barrowman. N.J. 1999. Maximum reproductive rate of fish at low population sizes. Can. J. Fish. Aquat. Sci. 56: 2404–2419. doi:10.1139/f99-201.

Zhou. S.. Yin. S.. Thorson. James T.. Smith. Anthony D. M.. Fuller. M.. and Walters. C. J. 2012. Linking fishing mortality reference points to life history traits: an empirical study. Canadian Journal of Fisheries and Aquatic Sciences. 69: 1292–1301.

7 Sardine in Subarea 7

7.1 Population structure and stock identity

Sardine stock in Subarea 7 has historically been assessed together with the Southern population in the Bay of Biscay (divisions 8.a, b and d) because no genetic differences were found between both areas (Shaw *et al*., 2012). However, research presented at ICES WKSAR workshop (ICES, 2016) showed that growth rates in the English Channel and Celtic Sea were higher than in the Bay of Biscay; there were separate spawning grounds; and all ages were present in significant abundance in both areas. This research suggests that sardine in the English Channel and Celtic Sea is a self-sustained population, and consequently sardine in Subarea 7 has been considered an independent stock since 2017 (ICES, 2017).

Nevertheless, the degree of mixing occurring with the Bay of Biscay, as well as the boundary between both stocks is still unknown. Similarly, little is known about the extension of the stock in the Eastern Channel and the North Sea. Until new insights are put forward, modelling the population in Subarea 7 as an independent stock seems to be the most appropriate option.

7.2 The fishery

7.2.1 Analysis of the catch

Sardine landing data in Subarea 7 is available since 1970 but their reliability is doubtful given their high variability across years and nations. Catch data were revised for the period 2002-2019 (ICES, 2021) and therefore data prior 2002 has been excluded from assessment. It must be also noted that French catches from ICES rectangles 25E5 and 25E4 (Subarea 7) have been allocated to Division 8.a, as they occur in the boundary between divisions and are considered to be more closely associated with the sardine stock in divisions 8.a-b and 8.d.

Below minimum size (BMS) landing data have been reported by some countries since 2015. They increased in 2019 and since continue to represent <7% of the total catch. Reported discards represent less than 1% of the catch, and they are considered negligible (Figure 7.2.1.1).

Annual landings (i.e. landings and BMS landings) have fluctuated between 6 157 and 29 287 t since 2002, being the highest values reported at the beginning of the reviewed time-series (Figure 7.2.1.2, Table 7.2.1.1). This large temporal fluctuation in landings is primarily explained by shifts in fleets activity and species targeted over the years (ICES, 2021). Sardine landings were dominated by France, followed by England, Netherlands, and Ireland in the 2000s. However, French landings decreased significantly since 2009 because of the closure of the fishery intended for human consumption in the Seine bay (Eastern Channel) due to PCB contamination. Landings remained lower than 10 000 t between 2009 and 2015 and increased again in 2016 due to a higher contribution from England, Netherlands, and Denmark. Landings from England remain quite stable since then (average English landings since 2016 is 8101t), whereas the contribution from the other countries has are more irregular/opportunistic. Landings in 2022 were 75% higher than in 2021, as UK, Irish and French landings were slightly higher and because the Danish sardine fishery was operating in 2022.

The fleet and seasonality of the fishery has also changed over the years. The main fleet in the 2000s was midwater otter trawlers, which fished in 7d throughout the whole year (Figures

7.2.1.3, 7.2.1.4. Table 7.2.1.2). Currently it is a seasonal fishery, and most of the sardine landings are caught by purse-seiners in the third and fourth quarters, mainly from 7e. A detailed description of the temporal evolution of the fishery can be found in the stock annex.

UK (England) has reported a minimum of 1600 tonnes caught each year since 2010 under the gear code "GNS_DEF_all_0_0_all", a gillnet gear code. Gillnets would catch at best a negligible quantity of Sardine due to the low catchability of sardine with this gear. This is a known error caused during the automated mapping between in UK catch reporting databases and as such landings under this gear have been interpreted instead as purse seine landings for the purposes of the ICES advice and reporting.

7.3 Biological data

7.3.1 Size composition of the catch

Historically, reported biological sampling of sardine from commercial catches has been almost non-existent. Dutch pelagic freezer trawlers operating in the English Channel provided length distribution in 1994, 1996 and annually from 2000; despite these vessels capturing substantial amounts of sardine, the species is not their main target, and the size composition of their catches may not be representative for the sardine population. Other countries have not provided regular comprehensive length or age information due to the lack of national biological sampling scheme and no DCF (data collection framework) requirement regarding the species in Subarea 7.

In 2017, the UK started a self-sampling programme involving the Cornish ringnet fleet, whose catches contribute to more than half of the total landings in recent years. Since fishing season 2017–2018, these vessels have recorded fishing trip information (haul locations, total catches, by-catch, discard, and effort) on dedicated logbooks. In addition, they were asked to collect individual lengths of a subsample approximately four times per month. In parallel, the main processors were asked to provide biological information (length and weight) for every catch.

Some of the data provided by the processors is measured with 1 cm precision whilst some is measured at 0.5 cm precision, which creates a sawtooth pattern in the distribution with multiple peaks in the length distributions for years 2017, 2019 and 2020. Figure 7.3.1.1 shows the combined size distribution provided by the fishing industry without applying a correction for this artefact. The mean size of fish in the landings between 2018 and 2023 was consistently between 18.8 cm - 19.5 cm, with the exception of 2021 when the mean size was lower (17.9 cm). On average, 12057 measurements have been provided each year by the industry. The number of sardine samples provided in 2021 was fewer than usual, from both fishers and processors.

7.4 Fishery-independent information

7.4.1 The PELTIC survey

The PELTIC, Pelagic Ecosystem Survey in the western Channel and Celtic Sea, is an autumn acoustic survey conducted by Cefas (UK) and provides biomass estimates for sardine and other small pelagics in Subarea 7. The first surveys (2012-2016) covered only the English waters of ICES areas 7e and all of 7f, but from 2017 survey coverage expanded to include also the French waters as well as one-off coverage of waters further north of the core area (2017), part of the eastern English Channel (2018) and Cardigan Bay in the southern Irish Sea (2020 and 2021). The survey follows a typical acoustic survey design with parallel equidistant transects which are covered during daylight only from 2014 onwards. A pelagic trawl is used opportunistically to validate the species and size composition of the acoustic marks detected on the echogram. The methodology used to estimate sardine biomass is described in the stock annex and ICES (2021).

Two biomass indices are calculated from PELTIC (Figure 7.4.1.1): one representing the consistently sampled "Core" Area of the whole time-series (2013 onwards): English waters of the western Channel (excluding the Isles of Scilly) and ICES division 7f (Bristol Channel in the Celtic Sea). The second time time-series, called 'Total area', is available from 2017 and represents full coverage of ICES divisions 7e (including the Isles of Scilly) and 7f.

The time-series of biomass estimated in the Core area significantly increased between 2017 and 2019, reaching the highest biomass in 2019 with 273 708 tonnes of sardine (Figure 7.4.1.2, Table 7.4.1.1). Biomass dropped in 2020 and 2021 but they are still the second highest values of the time-series. The temporal series of the biomass in the total area (including French side of division 7.e) was very similar, although it showed a slight drop in 2018 compared to 2017 and a 32% decline in 2021 that was not found in the Core area (Figure 7.4.1.2, Table 7.4.1.1).

In 2022 the survey coverage for the PELTIC survey was severely reduced for technical reasons (see Figure 7.4.1.1c). In addition, a survey transect was not covered in the stratum in the west of the survey area. To account for this missing transect a new survey stratum was created, departing slightly from the standard strata used in previous years. The area covered in 2022 is termed the restricted area and constitutes <30% of the standard survey area adopted for the assessment. The area covered is the area where a large proportion of the stock has been found in previous years. The estimated biomass in this restricted area was 175 896t (CV=0.26). There were a limited number of trawl hauls in this survey which limited the quantity of biological data available. However, the quantity of hauls was considered adequate. The most abundant age group in the survey was age 0 (2022 year class) with age 2 (2020 year class) at a higher abundance than the older of younger age group.

The 2023 PELTIC survey returned to complete coverage of the survey area and saw a record biomass index for sardine over the total area of 456 482 tonnes, more than double the biomass seen in the last 'complete' survey in 2021. The full area biomass index estimate of WGHANSA in 2022 for the 2022 PELTIC survey lies almost as a direct intersection between the 2021 and 2023 surveys.

7.5 Stock assessment

The stock was benchmarked in 2021 and upgraded from category 5 to category 3 as the time-series of biomass derived from PELTIC are considered reliable indicators of trends in stock biomass (ICES, 2021). Following the assessment methods described in the stock annex, a surplus production model in continuous time (SPiCT, Pedersen and Berg, 2017) has been run to provide an indication of the status of the stock. The catch advice has been then provided based on the 1-over-2 rule (ICES, 2020a).

7.5.1 SPiCT

As for each assessment year since the 2021 benchmark, a quarterly SPiCT model was again run using the settings described in the stock annex. The input data included the time-series of landings (landings and BMS landing) from 2013 to 2022 and the biomass derived from PELTIC for the core area from 2013 to 2023 (Figure 7.5.1.1, Table 7.5.1.1). A prior on the initial depletion level was added to inform the model that the fishery was operating before the beginning of the input data to the model.

A summary of the SPiCT outputs is given in Figure 7.5.1.2 and Table 7.5.1.2. The model indicates that fishing mortality is likely to be below F_{MSY} proxy and the biomass is above the reference B_{MSY}* 0.5 proxy. The confidence intervals of both reference points and the absolute values of biomass and fishing mortality remain high, as was the case when the model was run in the 2022 WGHANSA-2 meeting, and therefore these values are still not considered reliable.

The checklist described in Mildenberger et al. (2021) for acceptance of the assessment was followed. The diagnosis of the residuals shows the assumptions of the model are met: the catch and biomass data have normal distributions, and there are not autocorrelation or bias in the data (Figure 7.5.1.3). The retrospective patterns of the model could not be properly analysed given the short time time-series of data. Although the retrospective trajectories for the relative biomass and fishing mortality were inside of the confidence intervals and the Mohn's rho values were small (0.156 and -0.062, respectively), there is a tendency to overestimate biomass and underestimate the fishing mortality (Figure 7.5.1.4). Parameter estimates were influenced by initial values.

7.5.2 1-over-2 rule

Following the methods described in the stock annex, the catch advice for this stock is based on the 1-over-2 rule with a symmetric 80% uncertainty cap and a biomass safeguard (ICES, 2020a; ICES, 2020b). This harvest control rule is defined as:

$$C_y = \left\{ \begin{Bmatrix} 0.2C_{y-1} & if \ \dfrac{I_y}{(I_{y-1}+I_{y-2})/2} < 0.2 \\ C_{y-1}\dfrac{I_y}{(I_{y-1}+I_{y-2})/2} & if \ \ 0.2 \leq \dfrac{I_y}{(I_{y-1}+I_{y-2})/2} \leq 1.8 \\ 1.8C_{y-1} & if \ \dfrac{I_y}{(I_{y-1}+I_{y-2})/2} > 1.8 \end{Bmatrix} \right. \cdot \left[min\left(1, \frac{Icurrent}{Istat}\right) \right]$$

where C_y and I_y represent the advised catch and the biomass indicator for year y, respectively. The first and third cases of the formula correspond to the application of an 80% symmetrical uncertainty cap. The last term in the equation refers to the biomass safeguard based on a trigger index value (Istat). If the biomass index falls below Istat, the advised catch will be reduced in proportion to the drop of the biomass index in relation to Istat. The biomass estimates derived from PELTIC in the total area were used as the biomass index and the Istat has been estimated as 120 751 t (see section 7.7).

An overview of the application of the 1-over-2 rule is shown in Table 7.5.2.1. The index is estimated to have increased by 62% and thus the uncertainty cap was not applied. The biomass was estimated to be above Istat and the biomass safeguard was not applied. The resulting catch advice for 2024 is 13 459 tonnes, a 62% increase from 2023.

7.6 Short-term projections

No projections have been carried out for this stock.

7.7 Reference points

Table 7.1.1 summarizes the reference points for sardine in Subarea 7 and their technical basis. MSY reference points were not defined for this stock. The Istat reference point represents the biomass safeguard trigger applied into the 1-over-2 rule and is estimated using the biomass index in the total area from 2017 to 2021 (Ihist). This reference point was recalculated in 2022 (ICES, 2022) because the Ihist time-series was still short and it was judged convenient to include all years now available for its estimate. As of 2023, Istat has not been recalculated and it is not intended that it will be updated in successive years. This was decided on the basis that Ihist is now 5 years long, and including an additional year would mean including the 2022 PELTIC index. The 2022 PELTIC index was scaled up from limited survey coverage and no estimate exists for the confidence intervals (Figure 7.4.1.2).

7.8 Quality of the assessment

This stock was benchmarked in 2021 and the ICES framework for category 3 short-lived stocks using the 1-over-2 rule with an uncertainty cap of 80% and a biomass safeguard (ICES, 2020a) was considered the most appropriate method to provide advice. However, this harvest control rule leads to a decreasing trend of catch options in time after repeated applications and therefore should be considered as a provisional management approach (ICES, 2020a, ICES, 2020b).

The PELTIC survey in October 2022 only covered approximately 30% of the total area used for the estimation of sardine biomass due to technical issues. The total area accepted for use in the assessment has been sampled since 2017. The 2022 coverage was also slightly smaller than the 'core' area which has been sampled since 2013. An estimate of the biomass in the total area was undertaken by raising the area covered in 2022 to the 'core' area and then raising the core area estimate to the total area. This estimate utilized the available information to the WG and remains consistent with the PELTIC biomass increase seen between 2021 and 2023.

French catches from ICES rectangles 25E5 and 25E4 (Subarea 7) have been traditionally allocated to division 8.a, as they occur in the boundary between divisions, and are considered to be more closely associated with the sardine stock in divisions 8.a-b and 8.d. In 2022, 10 300 t were reallocated to Subarea 8, which is 73% of the remaining total catches in Subarea 7. However, the boundary between sardine stocks in Subarea 7 and 8 is unclear and further studies are needed to support this procedure to allocate catches. Results presented at WGACEGG indicate that the genetic identity of Sardine across subareas 7 and 8 is an active area of research, however it is expected that a multidisciplinary approach may also help improve certainty over stock boundaries. This process may benefit from studies on otolith microchemistry, drift modelling, morphometrics (including growth rates and life history parameters) or other similar indicative evidence.

7.9 Management considerations

This is a non-quota stock and there are no management measures implemented at international level. Nevertheless, the Cornish Sardine Management Association (a partnership between the owners of 15 vessels and four local seafood processors in England) has agreed specific regulations since 2018 for the sardine fishery around the Cornwall coast (UK) as it is subject to an MSC (Marine Stewardship Council) certification.

The 1-over-2 rule performs the best when there is no time-lag between the survey producing the biomass estimate and the TAC implementation (ICES, 2020a, ICES, 2020b). This is especially important for short-lived species, as part of the observed stock will not be available for the fishery when there is a large lag in time. The PELTIC survey is conducted in October and the biomass estimate is already incorporated in the catch advice for the following year, with a time-lag of only two months. Since 2021 the catch advice is provided annually.

7.10 References

ICES. 2016. Report of the Workshop on Atlantic Sardine (WKSAR), 26–30 September 2016, Lisbon, Portugal. ICES CM 2016/ACOM:41. 351 pp.

ICES. 2017. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA), 6–10 February 2017, Lisbon, Portugal. ICES CM 2017/ACOM:35. 278 pp.

ICES. 2020a. Tenth Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE X). ICES Scientific Reports. 2:98. 72 pp. http://doi.org/10.17895/ices.pub.5985

ICES. 2020b. Workshop on Data-limited Stocks of Short-Lived Species (WKDLSSLS2). ICES Scientific Reports. 2:99. 119 pp. http://doi.org/10.17895/ices.pub.5984

ICES. 2021. Benchmark Workshop on selected stocks in the Western Waters in 2021 (WKWEST). ICES Scientific Reports. 3:31. 504 pp. https://doi.org/10.17895/ices.pub.8137

ICES. 2022. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 4:51. 518 pp. http://doi.org/10.17895/ices.pub.19982720

Mildenberger, T.K., Kokkalis, A., Berg, C.W. 2021. Guidelines for the stochastic production model in continuous time (SPiCT). DTUAqua/spict: Surplus Production model in Continuous Time (github.com)

Pedersen, M. W., and Berg, C. W. 2017. A stochastic surplus production model in continuous time. Fish and Fisheries, 18: 226–243.

Shaw P., McKeown, N., Van der Kooij, J. 2012. Analysis of genetic population structuring of Sardine (*Sardina pilchardus*) in Eastern Atlantic waters using nuclear microsatellite DNA markers Working Document for WKPELA, 13-17/02/2012 Copenhagen

Table 7.2.1.1. Sardine in Subarea 7. Landings reported by country (tonnes)*

	France**	UK	Nether-lands	Ireland	Germany	Denmark	Lithuania	Belgium	Spain	Poland	TOTAL
1970	1014	890	38	0	2112	0	0	0	0	0	4054
1971	1350	1242	108	0	3362	0	0	0	0	0	6062
1972	1297	2190	54	0	1553	0	0	0	0	0	5094
1973	1603	2375	17	0	2577	0	0	0	0	0	6572
1974	833	1280	15	0	1826	0	0	0	0	0	3954
1975	678	6	561	0	4043	0	0	0	0	0	5288
1976	1284	3	127	0	2346	0	0	0	0	0	3760
1977	3544	10778	623	0	183	0	0	0	0	0	15128
1978	2773	549	1523	0	1463	0	0	0	0	0	6308
1979	3247	46	1321	0	1188	0	0	0	0	0	5802
1980	3573	753	1131	0	79	0	0	0	0	0	5536
1981	1125	35	553	0	0	4471	0	0	0	0	6184
1982	908	141	928	0	0	1311	0	0	0	0	3288
1983	802	6	795	0	19	4743	0	0	0	0	6365
1984	817	1	0	0	0	1210	0	0	0	0	2028
1985	2089	20	0	0	0	3111	0	0	0	0	5220
1986	2570	30	0	0	0	3602	0	0	0	0	6202
1987	965	124	0	0	0	1573	0	0	0	0	2662
1988	2586	0	0	0	0	3234	0	0	0	0	5820
1989	1219	1660	11	0	0	4667	0	0	0	0	7557
1990	1128	2078	6	0	107	6113	0	0	0	0	9432
1991	1963	2952	0	0	8	4462	0	0	0	0	9385
1992	1777	4493	41	0	4	17843	0	0	0	0	24158
1993	1135	4917	109	0	0	13395	0	0	0	0	19556
1994	1285	2081	20	0	2	20804	0	0	0	0	24192
1995	1282	7133	107	0	66	9603	0	0	0	0	18191
1996	1563	7304	48	0	0	1396	0	0	0	0	10311
1997	3346	7280	411	0	13	1124	0	0	0	0	12174
1998	1974	6873	1647	192	100	14316	0	0	0	0	25102
1999	119	4815	5166	2375	146	3490	0	0	8	0	16119
2000	4074	4353	6586	354	436	1682	0	0	0	0	17485
2001	8589	10375	6609	1060	454	0	0	0	0	0	27087
2002	7977	7858	1905	11417	130	0	0	0	10	0	29297
2003	8186	4150	6897	4030	13	0	0	0	0	0	23276
2004	7807	2389	2187	2046	60	0	0	0	0	0	14489
2005	10605	3457	2231	922	140	0	0	0	5	0	17360
2006	11120	1925	2287	2416	246	0	0	0	2	0	17996
2007	7315	2655	1106	28	0	4	0	0	0	0	11108
2008	8562	3470	2073	473	43	53	0	0	0	0	14674

	France**	UK	Nether-lands	Ireland	Germany	Denmark	Lithuania	Belgium	Spain	Poland	TOTAL
2009	3918	2568	3406	65	0	0	0	0	0	0	9957
2010	706	2540	6645	50	62	13	0	0	0	0	10016
2011	237	3614	513	1966	5	3	0	0	0	0	6338
2012	372	4423	1637	16	587	40	0	0	0	0	7075
2013	1703	3722	1739	473	214	40	0	0	0	0	7891
2014	1100	3893	193	0	18	953	0	0	0	0	6157
2015	1208	4301	1171	555	1551	1011	0	0	0	0	9797
2016	925	9389	4697	464	1941	2286	1	1	0	0	19704
2017	820	7596	0	329	1475	2460	0	0	0	0	12680
2018	606	8143	811	89	758	263	0	1	0	0	10671
2019	671	7050	90	33	53	0	40	0	0	0	7937
2020	592	9500	185	58	0	3217	0	0	0	1	13553
2021	743	7074	111	509	0	89	0	0	0	743	8524
2022	1393	8549	89	993	2	3151	0	1	0	0	14178

***Catch data prior 2002 has not been revised and they are not used in the assessment.**

****French catches from ICES rectangles 25E5 and 25E4 are not included.**

Table 7.2.1.2. Sardine in Subarea 7. Landings by ICES division (tonnes).

	7.d	7.e	7.f	7.g	7.h	7.j	7.a	7.b	Unallo-cated
2002	9756	18035	35	164	1253	44	0	0	0
2003	15478	6815	2	321	255	123	279	4	0
2004	10001	2450	158	552	90	36	856	346	0
2005	12561	3464	204	64	182	636	224	20	0
2006	14116	1950	395	250	394	786	78	24	0
2007	8480	1592	993	0	14	28	0	0	0
2008	9395	3225	1579	365	1	100	0	10	0
2009	6389	2568	932	0	2	63	0	2	0
2010	7123	1706	1083	0	55	36	14	0	0
2011	759	1639	1884	1394	89	129	443	0	0
2012	943	3609	1555	0	952	0	16	0	0
2013	2431	3549	1095	473	342	0	0	0	0
2014	1442	3018	1698	0	0	0	0	0	0
2015	1476	6635	1604	10	66	6	0	0	0
2016	1478	9868	3026	163	169	301	0	0	4697
2017	3226	7421	1704	281	1	48	0	0	0
2018	1335	6013	2413	79	10	10	0	0	811
2019	888	5009	2007	34	0	0	0	0	0
2020	640	7615	3638	58	1601	0	0	0	0
2021	867	3737	3305	76	97	441	0	0	0
2022	1981	6255	4227	379	718	616	1.8	0	0

Table 7.4.1.1. Sardine in Subarea 7. Time-series of biomass (t) and abundance (1000s individuals) estimated from the acoustic survey PELTIC in the core and total area.

	Core Area				Total Area			
	Biomass		Abundance		Biomass		Abundance	
	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV
2013	48391	0.33	924300	0.18				
2014	121171	0.32	3072930	0.23				
2015	134907	0.22	3332244	0.41				
2016	89918	0.34	2121684	0.23				
2017	95298	0.11	4101091	0.13	174637	0.20	10163984	0.16
2018	123003	0.14	3317972	0.14	145514	0.12	4300528	0.12
2019	273708	0.21	11256581	0.18	374617	0.19	15409434	0.15
2020	178781	0.31	3713016	0.29	332098	0.20	6476230	0.18
2021	174375	0.28	5977676	0.28	227117	0.19	8714354	0.26
2022*	222889				336 306			
2023	265223	0.224			456482	0.187		

*Biomass estimate raised from the restricted area coverage for the 2022 PELTIC survey and uncertainty estimates are not available.

Table 7.4.2.1. Sardine in Subarea 7. PELTIC survey biomass estimates and raising factors and used to estimate the core and total area for Sardine in Subarea 7 in 2022.

Year	Survey biomass (t) in core area	Survey biomass (t) in full area	Survey biomass (t) in restricted area	Multiplier (average 2020-2021) for re-stricted area to core area	Multiplier (average 2017-2021) for core area to total area
2013	48 391				
2014	121 171				
2015	134 907				
2016	89 918				
2017	95 298	174 637			
2018	123 003	145 514			
2019	273 708	374 617			
2020	178 781	332 098	157 799		
2021	174 375	227 117	124 433		
2022	222889*	336 306*	175 896	1.267	1.509

*Estimated values

Table 7.5.1.1. Sardine in Subarea 7. Assessment summary. The high and low columns represent the 95% confidence intervals of the biomass index. All values are in tonnes.

Year	Biomass index (total area)	High	Low	Landings	Discards	BMS landing
2002				29287	190	
2003				23276	10	
2004				14488	737	
2005				17354	377	
2006				17994	785	
2007				11108	15	
2008				14675	51	
2009				9957	40	
2010				10017	4	
2011				6337	275	
2012				7075	342	
2013				7891	91	
2014				6157	0	
2015				9783		15
2016				19634		68
2017	176696	248358	105035	12662	28	18
2018	143845	178548	109141	10670	16	1
2019	358028	490975	225081	7317	111	620
2020	285564	402929	168200	12852		701
2021	212772	292836	132707	8155		370
2022	336306*	**	**			
2023	456482	627206	285757			

* Raised estimate.

** No uncertainty estimates were available.

Table 7.5.1.2. Sardine in Subarea 7. Summary outputs of the SPiCT model.

```
Convergence: 0  MSG: relative convergence (4)
Objective function at optimum: 45.1683639
Euler time step (years):  1/16 or 0.0625
Nobs C: 40,  Nobs I1: 11

Residual diagnostics (p-values)
    shapiro  bias    acf   LBox shapiro bias acf LBox
 C   0.8785 0.522 0.1432 0.3222       -    -   -    -
 I1  0.9726 0.342 0.0771 0.1395       -    -   .    -

Priors
 logbkfrac  ~  dnorm[log(0.5), 0.5^2]
      logn  ~  dnorm[log(2), 2^2]
  logalpha  ~  dnorm[log(1), 2^2]
   logbeta  ~  dnorm[log(1), 2^2]

Model parameter estimates w 95% CI
            estimate       cilow        ciupp    log.est
 alpha  4.527978e+00    0.4833946 4.241376e+01  1.5102755
 beta   1.685339e+00    0.4126067 6.883960e+00  0.5219668
 r      1.399276e+00    0.0796013 2.459727e+01  0.3359551
 rc     7.762242e-01    0.0520766 1.156996e+01 -0.2533138
 rold   5.370800e-01    0.0290069 9.944373e+00 -0.6216082
 m      1.658280e+04 5193.5191255 5.294854e+04  9.7161213
 K      6.989912e+04 1773.1697288 2.755453e+06 11.1548083
 q      3.466595e+00    0.0732448 1.640702e+02  1.2431729
 n      3.605340e+00    0.6455266 2.013624e+01  1.2824161
 sdb    6.579080e-02    0.0072870 5.939918e-01 -2.7212750
 sdf    2.608805e-01    0.0738481 9.216028e-01 -1.3436928
 sdi    2.978994e-01    0.1788929 4.960737e-01 -1.2109995
 sdc    4.396721e-01    0.3327793 5.809002e-01 -0.8217259
 phi1   2.147878e-01    0.0748077 6.166986e-01 -1.5381048
 phi2   2.875900e-02    0.0156309 5.291300e-02 -3.5488051
 phi3   9.842170e-01    0.3530998 2.743369e+00 -0.0159089

Deterministic reference points (Drp)
           estimate       cilow        ciupp   log.est
 Bmsyd 4.272683e+04  967.5633348 1.886783e+06 10.662582
 Fmsyd 3.881121e-01    0.0260383 5.784981e+00 -0.946461
 MSYd  1.658280e+04 5193.5191255 5.294854e+04  9.716121
Stochastic reference points (Srp)
           estimate       cilow        ciupp    log.est rel.diff.Drp
 Bmsys 4.248629e+04  959.3639040 1.881544e+06 10.6569368 -0.005661512
 Fmsys 3.854563e-01    0.0254895 5.828931e+00 -0.9533274 -0.006890050
 MSYs  1.637597e+04 5208.4977340 5.148748e+04  9.7035703 -0.012630066

States w 95% CI (inp$msytype: s)
                   estimate       cilow        ciupp    log.est
 B_2023.75      5.888108e+04 1204.3463036 2.878724e+06 10.9832750
 F_2023.75      2.040421e-01    0.0047089 8.841399e+00 -1.5894287
 B_2023.75/Bmsy 1.385884e+00    1.0289558 1.866625e+00  0.3263383
 F_2023.75/Fmsy 5.293522e-01    0.1479031 1.894577e+00 -0.6361013

Predictions w 95% CI (inp$msytype: s)
                 prediction       cilow        ciupp    log.est
 B_2025.00      5.603645e+04  931.0530291 3.372615e+06 10.9337576
 F_2025.00      2.040423e-01    0.0045102 9.230870e+00 -1.5894281
 B_2025.00/Bmsy 1.318930e+00    0.8504684 2.045433e+00  0.2768208
 F_2025.00/Fmsy 5.293525e-01    0.1308790 2.141016e+00 -0.6361007
 Catch_2024.00  1.185644e+04 5641.8498167 2.491652e+04  9.3806268
 E(B_inf)       6.213738e+04           NA           NA 11.0371030
```

Table 7.5.2.1. Sardine in Subarea 7. The basis for the catch scenarios*.

Index A (2023)	456482 tonnes
Index B (2021–2022)	281711 tonnes
Index ratio (A/B)	1.62
Biomass safeguard (Istat)	Not applicable
Uncertainty cap	Not applied
Catch advice 2023	8306 tonnes
Discard rate	Negligible
Catch advice 2024 **	13459 tonnes
% advice change ^	+62 %

* The figures in the table are rounded. Calculations were done with unrounded inputs, and computed values may not match exactly when calculated using the rounded figures in the table.

**[Advice for 2023] x [Index ratio]

Table 7.7.1. Sardine in divisions 8.a–b and 8.d. Reference points, values, and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	Not defined		
	F_{MSY}	Not defined		
Precautionary approach	I_{stat}	120 751 tonnes	Geomean(Ihist) × exp(−1.645 × sd(log(Ihist)); Ihist is the available historical series of the abundance index (2017–2021)	(ICES, 2022)
	B_{lim}, B_{pa}	Not defined		
	F_{lim}	Not defined		
	F_{pa}	Not defined		
Management plan	SSB_{MGT}	Not defined		
	F_{MGT}	Not defined		

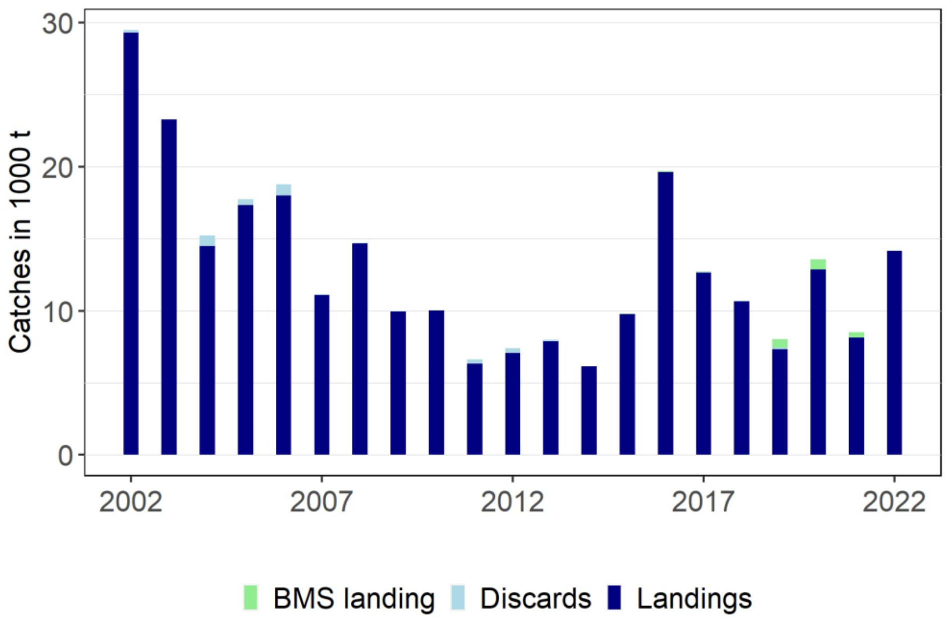


Figure 7.2.1.1. Sardine in Subarea 7. Catches by category (tonnes).

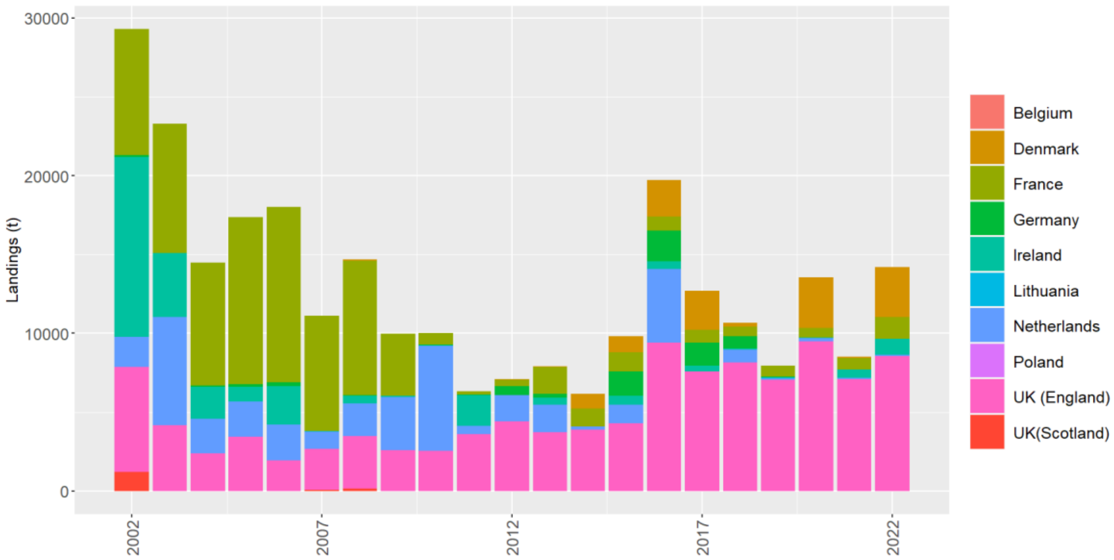


Figure 7.2.1.2. Sardine in Subarea 7. Landings reported by country (tonnes).

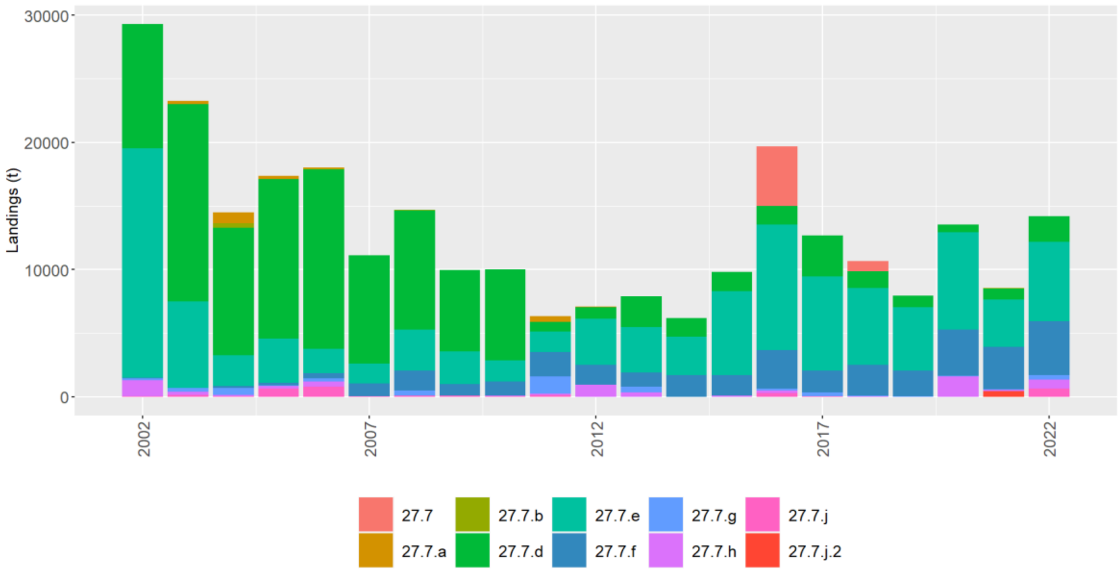


Figure 7.2.1.3. Sardine in Subarea 7. Landings by ICES division (tonnes).

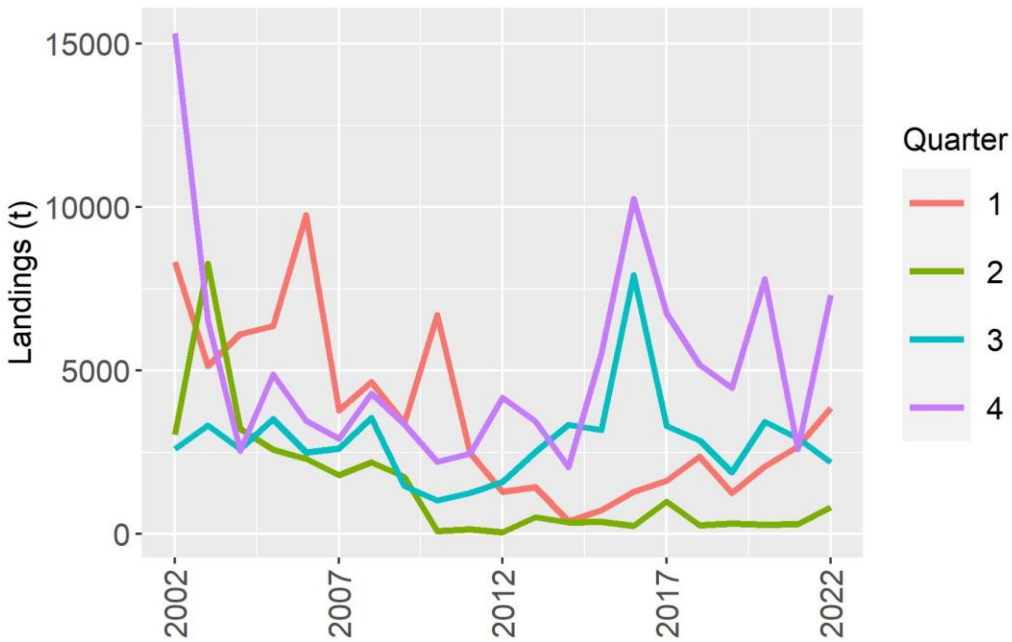


Figure 7.2.1.4. Sardine in Subarea 7. Landings by quarter (tonnes).

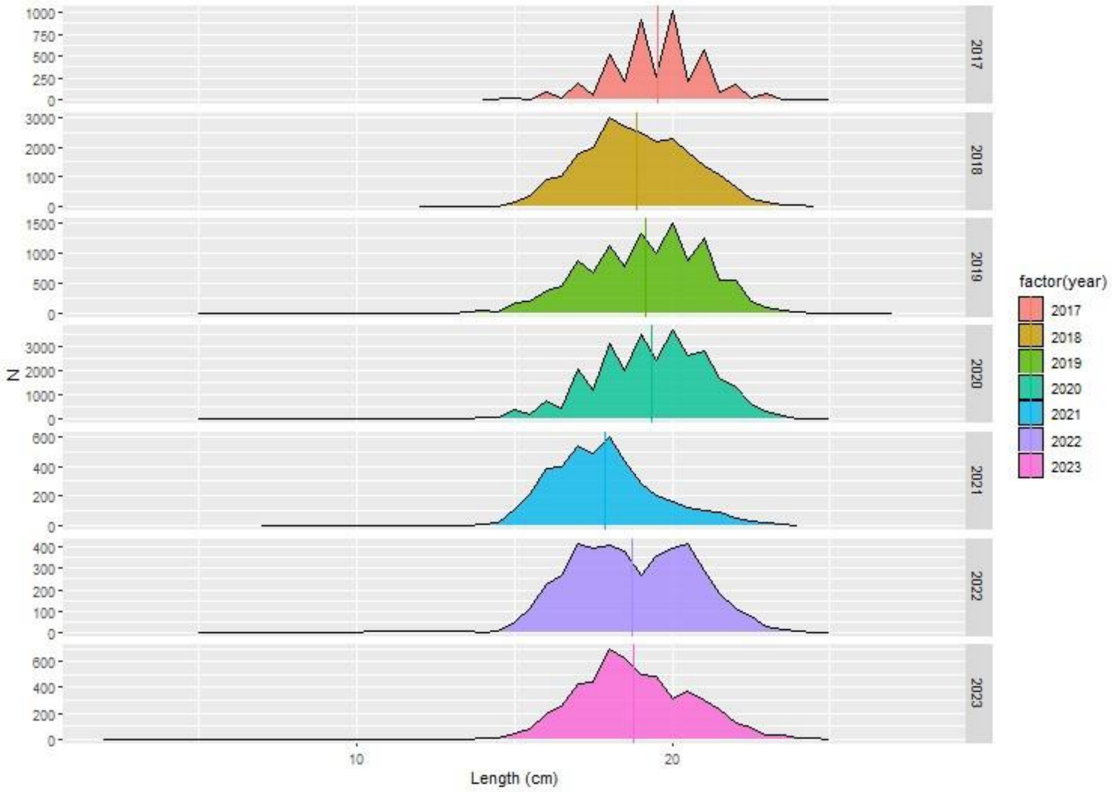


Figure 7.3.1.1. Sardine in Subarea 7. Length distribution of landings provided by the English fishing industry.

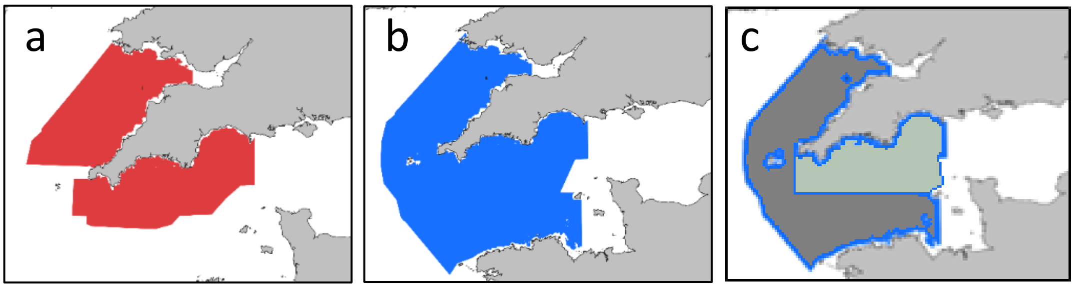


Figure 7.4.1.1. Sardine in Subarea 7. PELTIC coverage of core area a. 2013-2023, b. total area 2017-2023 and c. reduced survey extent in 2022.

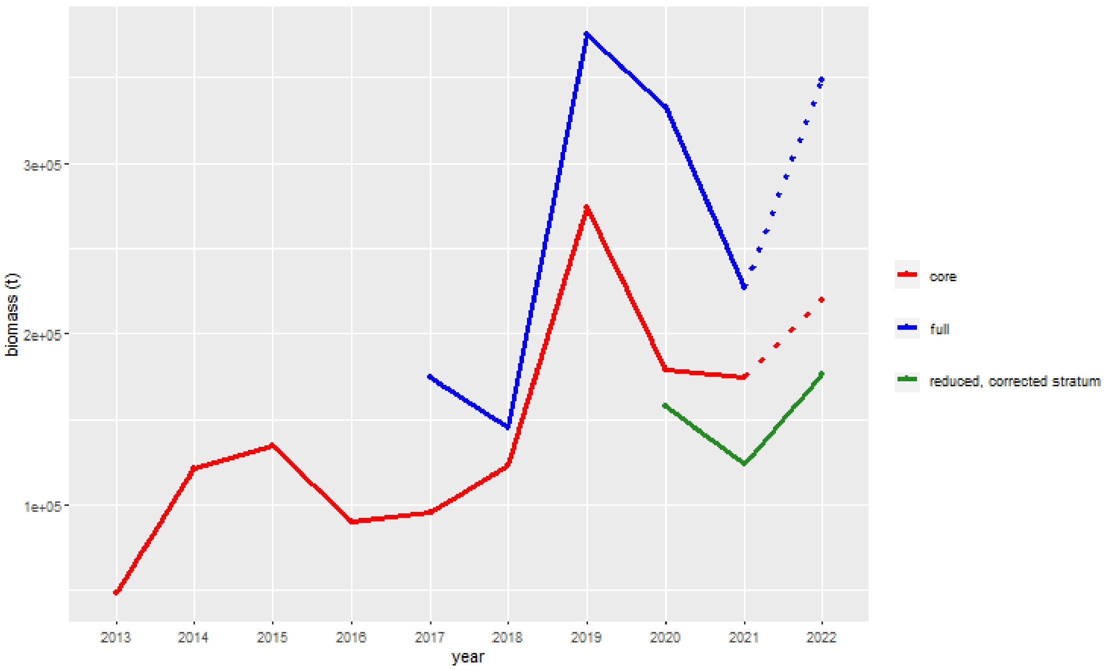


Figure 7.4.1.2. Sardine in Subarea 7. Sardine biomass in tonnes estimated from PELTIC survey in the core area (red line), covering division 7.f and English waters of 7.e, in the total area (blue line), covering division 7.f and 7.e (also French side), and in the restricted area covered in 2022 (green line). Dashed red and blue lines are the estimated values.

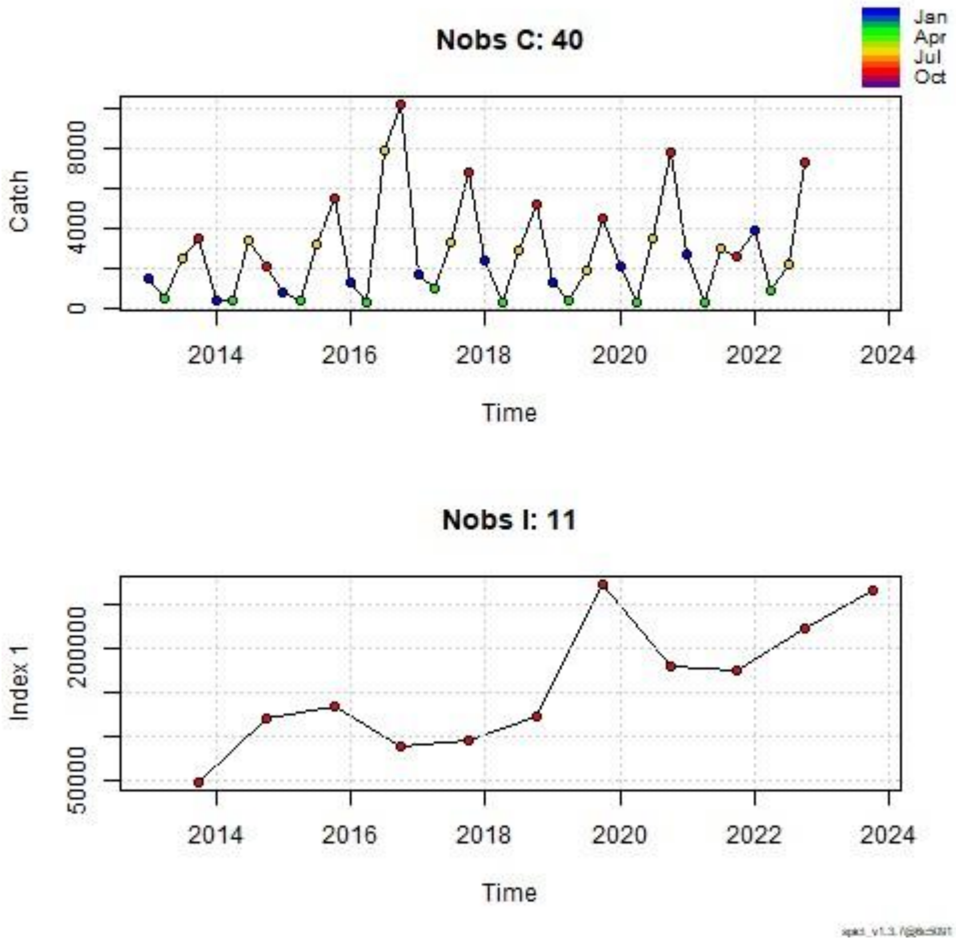


Figure 7.5.1.1. Sardine in Subarea 7. Input data of the SPiCT model. Top: landings by quarter (2013-2021). Bottom: biomass estimates in the core area (2013-2021). Blue represents quarter 1, green represents quarter 2, yellow represents quarter 3, and red represents quarter 4.

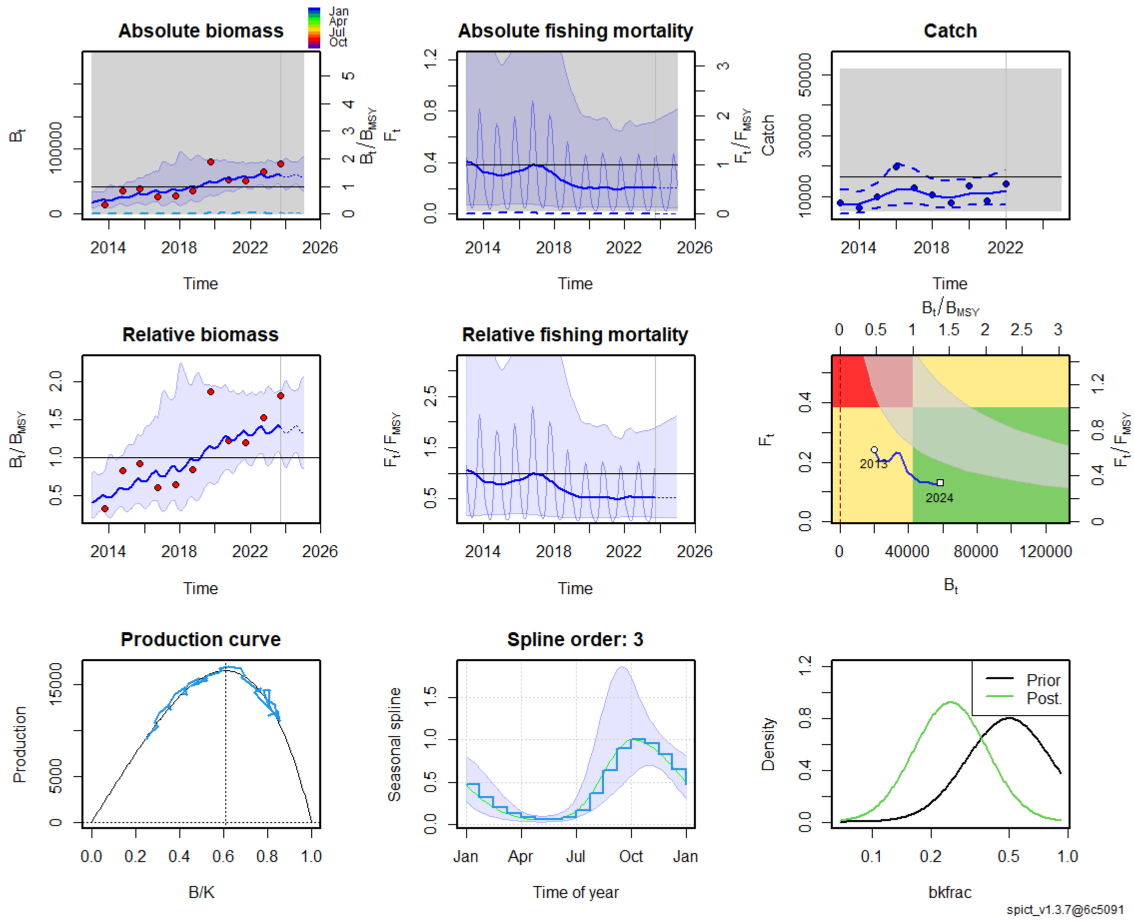


Figure 7.5.1.2. Sardine in Subarea 7. SPiCT model results. Top row: absolute biomass, absolute F estimates, and fitted catch. Middle row: relative biomass and F, and a Kobe plot comparing biomass and F. The grey area in the Kobe plot represents the uncertainty in the relative biomass and F estimates. Bottom row: production curve, seasonality of fishing mortality, and prior and posterior parameter distributions. The dashed lines are 95% CI bounds for absolute estimated values, shaded blue regions are 95% CIs for relative estimates, shaded grey regions are 95% CIs for estimated absolute reference points (horizontal lines).

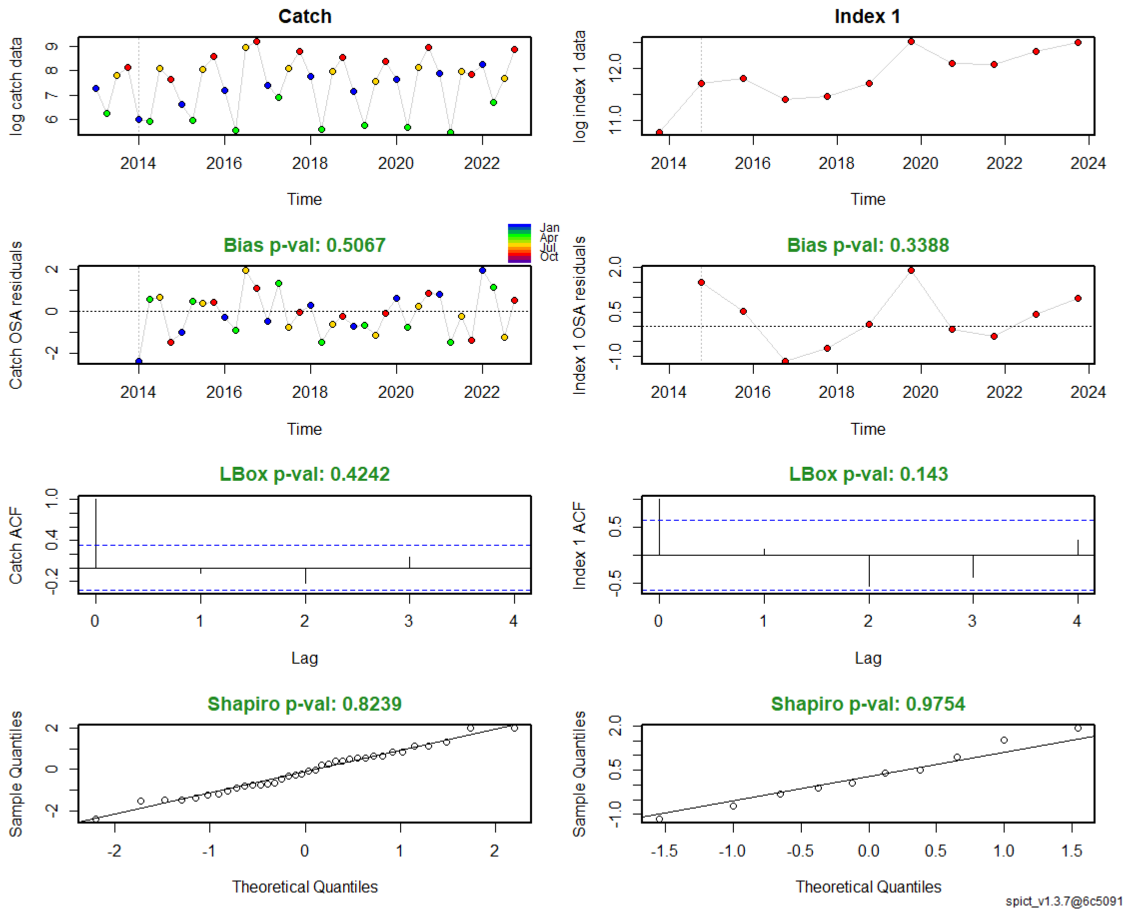


Figure 7.5.1.3. Sardine in Subarea 7. SPiCT model diagnosis.

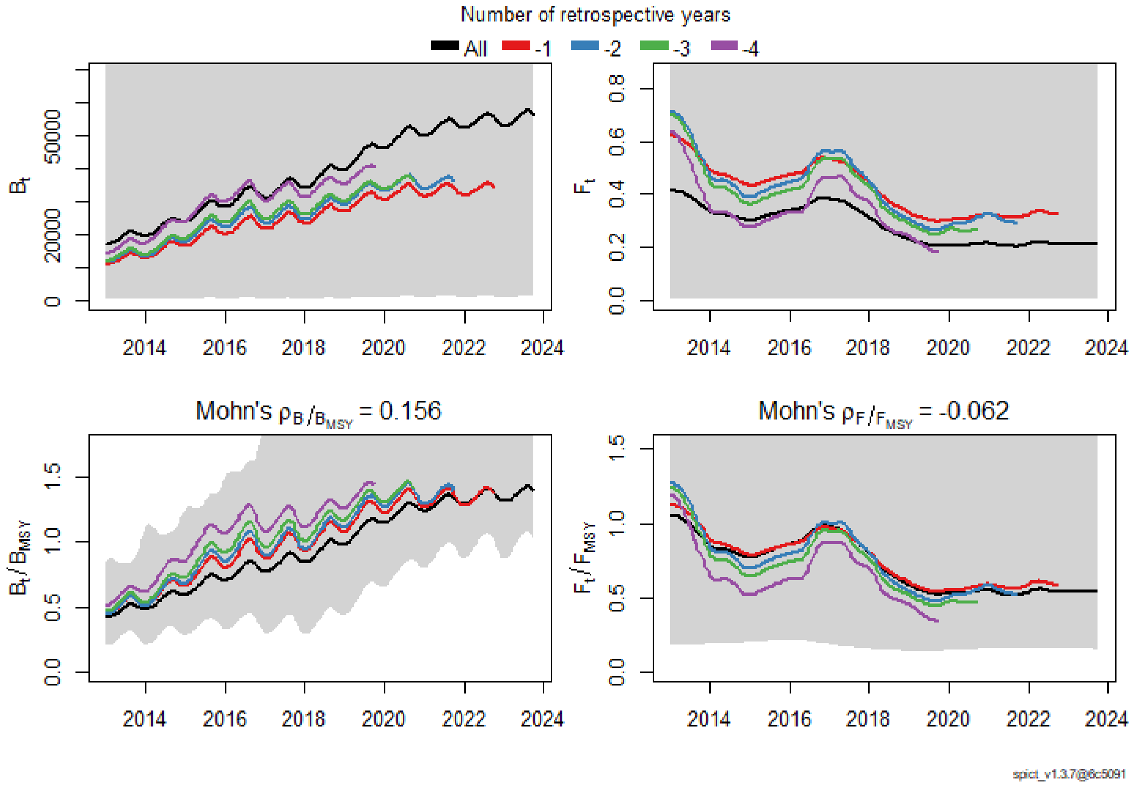


Figure 7.5.1.4. Sardine in Subarea 7. Retrospective analysis of the SPiCT model. Top row: absolute biomass and absolute F; bottom row: relative biomass and relative F.

8 Sardine in 8c and 9a

8.1 ACOM Advice Applicable to 2023, STECF advice and Political decisions

ICES advises that when the MSY approach is applied, catches in 2023 should be no more than 43 841 tonnes (ICES, 2022).

In 2023 the fishery was managed according to a bilateral agreement between Portugal and Spain (Despacho n.º 5059-A/2023; BOE-A-2023-7472). Portugal and Spain agreed to implement a total catch of 56 604 tonnes, based on the harvest control rules assessed as precautionary by ICES (ICES, 2021c) and within the Management Plan but without the cap.

In 2023, the Spanish fishery opened on the 20th March, two weeks earlier than last year, with a quota allowing to catch 18 962 tonnes (BOE-A-2023-7472). In August and in the framework of the usual negotiations between Member States, 2 100 tonnes of Spanish swordfish quota (SWO/AN05N) was exchanged by Portuguese sardine quota (stock pil.27.8c9a), this is known as quota swapping (BOE-A-2023-18183). This represents an increase in the Spanish quota of 42% when compared to 2022.

In Portugal, the purse-seine sardine fishery was closed since the 17th December of 2022 (Despacho n.º 43/DG/2022, Despacho n.º 6/DG/2023), to account for the protection of the reproductive individuals. However, 10% of accessory catches was allowed while targeting other species from the the 17th of December until the 31st of March 2023. In 2023, the sardine fishery opened on May 2nd with a quota allowing a total catch of 37 642 tonnes (Despacho n.º 5059-A/2023). If we take into account the quota swapping with Spain, this represents an increase in the Portuguese quota of 21%.

By the end of October preliminary catch information indicated that less than 42 000 tonnes had been taken by the two countries. While Spain had almost reached its quota, Portugal still had available 40% of its quota.

8.2 The fishery in 2022

8.2.1 Fishing fleets in 2022

Sardine is taken in purse-seine throughout the stock area and the fleet has remained relatively constant in recent years. In Spain (Gulf of Cadiz and northern waters), data from 2022 indicate that the number of purse-seiners taking sardine were 446, with mean power of 229 Kw.

In Portuguese waters, fleet data indicate that 172 vessels landed sardine with mean vessel tonnage of 70.0 GT and engine power category of 353 Kw.

8.2.2 Catches by fleet and area

The WG estimates of landings and catches are shown in Tables 8.2.2.1 and 8.2.2.2.

Total sardine landings in 2022 are shown in Tables 8.2.2.1, 8.2.2.2 and Figure 8.2.2.1. Total 2022 landings in divisions 8c and 9a were of 40 429 tonnes, showing stability compared to the previous year (40 685 tonnes). The bulk of the landings (99%) were made by purse-seiners.

In Spain, sardine landings, 15 764 tonnes, represent a 14% increase in relation to values from 2021 (13 835 tonnes). Catches experienced an increment in northern areas (by 20% in 8c west and by 31% in 9aNorth) and showed a decrease in the south (by 18% in 9aSouth-Cadiz).

In Portugal, sardine landings were of 24 665 tonnes, which represents an 8% decrease compared to 2021 landings (26 851tonnes). The decrease was caused by the reduction of catches in the areas of high recruitment (by 20% in 9aCN and by 18% in 9aSouth-Algarve), where there had been a very large increase in the previous year. On the other hand, in the 9aCS subdivision landings showed an increase of 11%.

Table 8.2.2.1 summarises the quarterly landings and their relative distribution by ICES subdivisions. In 2022, due to management regulations implemented in Spain and Portugal the sardine fishery opened late in the year (at the end of the first quarter in Spain and in the second quarter in Portugal). For that reason, the sums of the second and third quarter landings represent almost 78% of the annual catches.

The relative contribution of the different areas to the total catch was similar to 2021, being the western Portuguese Atlantic coast (9aCN and 9aCS subdivisions) the areas that obtained 49% of the total catches of the stock.

Figure 8.2.2.2 shows the historical relative contribution of the different subareas to the total catches.

Discards are negligible for this stock.

8.2.3 Effort and catch per unit of effort

No new information on fishing effort has been presented to the WG.

8.2.4 Catches by length and catches-at-age

Tables 8.2.4.1.a,b,c and d show the quarterly length distributions of landings from each subdivision. Annual length distributions in Spain (Table 8.2.4.1.) were unimodal in 8cW subdivision, with a mode at 21 cm. In 8cE, 9aN and 9aS-Cadiz subdivisions, size distributions had a main mode (at 19.5, 19 and 17 cm) and a secondary, smaller mode at 14, 13 and 12.5 cm, respectively.

For Portugal, sardine annual length distributions were unimodal in 9aS-Algarve, with mode at 18 cm. For the remaining areas, length distributions were bimodal, with modes at 18.5 and 14.5 cm in 9aCN and at 20 and 13 cm in 9aCS subdivision.

Table 8.2.4.2 shows the catch-at-age in numbers for each quarter and subdivision and Table 8.2.4.3. shows the historical catch-at-age data. In Table 8.2.4.4 and Figure 8.2.4.1. the relative contribution of each age group in each subdivision is shown as well as their relative contribution to the catches.

2022 still showed a clear dominance in catches of age-3 (2019 strong year class) individuals in the Cantabrian Sea (8c Division) and in the northern area of the Atlantic façade. In Cadiz, as in the previous years, the most important age class was age-0 (representing 35% of the catches). For Portugal, age-2 was dominant in the 9aCN and the Algarve (9aS subdivision). Age-3 had the higher contribution, with a 30% to the total biomass in catches, followed by age-2, representing 28% of the catches. By areas, age-0 showed a clear predominance in 9aS-Cádiz and older individuals (age-5 and age-6+) were mainly landed in the 9aCS subdivision.

8.2.5 Mean length and mean weight-at-age in the catch

Mean length and mean weight-at-age by quarter and subdivision are shown in Tables 8.2.5.1 and 8.2.5.2.

8.3 Fishery-independent information

Figures 8.3.1, 8.3.2 and 8.3.3 show the time-series of fishery-independent information for the sardine stock.

8.3.1 Iberian DEPM survey (PT-DEPM-PIL+SAREVA)

As part of the Iberian DEPM survey, surveys are carried out every three years by Portugal (IPMA) and Spain (IEO). As described in the Stock Annex, the total spawning biomass (SSB) from the two surveys is used in the assessment.

The DEPM surveys comprise ichthyoplankton, fish and hydrographic sampling. Plankton samples are collected, along a grid of parallel transects perpendicular to the coast, for spawning area estimation and daily egg production calculation. Concurrently, fishing hauls are carried out for estimation of daily fecundity (sex ratio, female weight, batch fecundity and spawning fraction) for the mature sardines in the population.

Survey design, laboratory and estimation analyses are described in detail in the TIMES survey manual (*in press*) and in Massé *et al*. 2018.

In 2023 both surveys were conducted on board R/V Vizconde de Eza. Portuguese survey PT-DEPM23-PIL was carried out between 10th and 24th February and Spanish survey SAREVA between 10th and 30th April.

In 2023 due to logistic issues (reduced number of vessel days) the initial grid of stations for PairoVET was altered. The number of transects and distance between PairoVET stations along the transects was reduced. From the planned 8x3 nm (transects x stations) it was changed to 10x4nm. However, during the SAREVA survey it was possible to carry out sampling according to the usual grid from 7.5º W to the east, only the Galician coast was covered with the adjusted grid.

Fish samples for IPMA survey were collected by a hired purse-seiner apart from 3 samples obtained in Cadiz with the R/V. Fish samples for IEO DEPM survey were collected during PELACUS acoustics survey, which took place in the same area simultaneously.

Sampled area for both plankton and adult stations during DEPM surveys in 2023, and main results are shown in Figure 8.3.1.1 and Table 8.3.1.1. Despite the increase of the spawning biomass in subdivisions 9aCN and 9aCS, the steep decline of the spawning biomass in the Gulf of Cadiz and the Algarve means that the overall values for 2023 are very similar to overall values of the last DEPM survey carried out in 2020. 9aN and 8c subdivisions could not be sampled in 2020 due to the outbreak of the COVID pandemic and the contribution of the Spanish survey was estimated based on the relative contribution over the historical series. In 2023, the estimated SSB value in this area has been higher than in the previous survey carried out in 2021.

The value of the DEPM index used in the assessment (combined SSB for the whole stock, 640 793 tonnes) showed a 1.6% increase compared to the last DEPM estimation, corresponding to 2020, Figure 8.3.1.2.

8.3.2 Spring Iberian acoustic survey (PELACUS-PELAGO)

As part of the Iberian acoustic survey, surveys are carried out each year by Portugal and Spain to estimate small pelagic fish abundance in divisions 8c and 9a. The Iberian acoustic survey is planned and discussed within WGACEGG (e.g WGACEGG, 2023). As described in the Stock Annex, the total numbers of individuals and numbers-at-age from the two surveys are used as input to the assessment.

There are two annual surveys carried out to estimate small pelagic fish abundance in 9a and 8c using acoustic methods: PELAGO and PELACUS. For the first time, in 2021, both surveys were carried out on the same vessel, R/V Miguel Oliver. The PELAGO survey was carried out in March, followed by the PELACUS survey.

Both surveys were conducted following the methodology applied in previous years and agreed and revised at the WGACEGG.

8.3.2.1 Portuguese spring acoustic survey

The PELAGO acoustic surveys have sampled the Portuguese and Bay of Cadiz continental shelves, since 1995 and until 2019 with the R/V Noruega, a 49 m trawl vessel. Since 2020 this survey was planned on-board R/V Miguel Oliver.

During PELAGO2023 survey, conducted between the 15th of March and the 4th April, seventy-one (71) transects were acoustically sampled between Caminha and Cape Trafalgar.

Figure 8.3.2.1.1 shows the acoustic transect along the surveyed area and Figure 8.3.2.1.2 shows the fishing operations conducted during the survey and the proportion of species in each fishing station. A total of 40 pelagic trawl hauls (3 null) were carried out by the research vessel and 28 additional hauls were done by purse-seiners. Sardine was present in most of the fishing hauls (92%) and the energy attributed to this species was distributed throughout the coast, with the highest concentrations in the north, in 9aCN subdivision (between Porto and Figueira da Foz) and in Algarve (9aS subdivision), Figure 8.3.2.1.3.

Figures 8.3.2.1.4., 8.3.2.1.5. and Table 8.3.2.1.1. show the abundance in number and biomass by length and age class, respectively. During 2023 PELAGO survey, age 0 sardine individuals were not detected. For all areas sampled, the size distributions were bimodal, but with modes at different sizes in the different locations. The smallest individuals were found in Cadiz (9aS subdivision) with modes at 12 and 17.5 cm, but the largest abundances were detected in area 9aCN, where modes were at 15 and 19 cm. In 9aCN, 9aCS and Algarve, the modal age corresponds to age 2 (2021 cohort), while in Cadiz, age 1 was the most representative in the population. For the total area sampled, age 2 accounted for 39% in abundance, corroborating the strong age class of 2021, already detected in the previous PELAGO survey. 2022 recruitment represents 36% of the sardine abundance in the survey and was detected mainly in Cadiz and in the 9aCN subdivision.

In relation to total abundance in PELAGO2022 (18907 million individuals), sardine estimation in 2023 showed an important decrease by 27%.

The sardine B1+ was estimated to be 436.3 thousand tonnes for the whole area, representing a significant decline by 46% in relation to the PELAGO2022 survey.

8.3.2.2 Spanish spring acoustic survey

The Spanish PELACUS0423 survey was carried out from 25th March to 18th April in the R/V Miguel Oliver. Sampling design and methodology was similar to that of the previous surveys and is summarised in Massé *et al.* (2018) with supplementary material available online. Tracks were placed at 10 nmi, with a random start and only steamed during day hours. The survey progressed eastwards (Figure 8.3.2.2.1).

A total of 34 fishing stations were carried out, yielding about 13 kt of fish. Of them, 9 corresponding to sardine (74% in number). Big sardine (>16 cm) was present in 68% of hauls and small sardine was caught in 44% of fishing stations. In 9aN a very significant increase of sardine schools was recorded. Figure 8.3.2.2.2 shows the species proportion (% in number) in the fishing stations, with circles proportional to the total catch in weight.

The amount of backscattering energy allocated to sardine is the highest of the time series in Spanish waters. The bulk of the small sardine NASC distribution was recorded in 9aN subdivision and bigger sardine (>16 cm) was widely distributed in the sampled area, with higher concentration in Galicia (9aN and 8cW subdivisions) and the western area of the Cantabrian Sea (Figure 8.3.2.2.3.).

A total of 689 thousand tonnes, corresponding to 13 351 million fish were estimated, most of them in the western part (79% in 9aN) (Table 8.3.2.2.). Age group 1 represents 23% of the total biomass (42% in abundance) and the signal from the 2019 cohort (age 4), which accounted for 37% of the abundance (and 48% of the biomass), was very strong. Although this cohort has been very well mapped out by the PELACUS survey over the years, age-4 abundance values in the 2023 PELACUS survey are higher than those estimated in 2022 for age 3 (Figure 8.3.2.2.4.).

8.3.3 Autumn acoustic survey index

For the major recruitment area in Portugal, from 1997 (SAR-PT-AUT time series) and in the recent period, from 2013 (JUVESAR time series) juvenile surveys were carried out from Lisbon to the Portuguese–Spanish border, to assess the abundance of recruits in that particular area. Since 2018, as a result of a collaboration between IPMA and IEO, the survey IBERAS estimates a recruitment index in Atlantic waters of the Iberian Peninsula, aiming to improve the estimation of the strength of the recruitment for both Ibero-Atlantic sardine and the western component of the south anchovy population.

In October 2021, an Inter-benchmark (ICES, 2021a) was accomplished for this stock and the juvenile index from autumn acoustic surveys since 1997, for the 9aCN subdivision, was decided to be included in the assessment model.

Last IBERAS survey, in 2023, was carried out between 12th and 25th September, on board Ramón Margalef R/V, with the collaboration of a purse seiner for additional samples in 9aCN and 9aCS.

Survey methods were similar to those undertook in the previous years (Massé *et al.*, 2018), with a survey track between 20 and 100 m, with a systematic random start and transects 6-8 nmi apart (Figure 8.3.3.1).

A total of 25 fishing stations were carried out and additional samples were obtained from 12 fishing stations carried out by purse seiner vessels. Sardine accounted for 34% of the abundance in the fishing hauls, but in large sizes. Small sardines (age 0, recruitment) were very rare in the catches (less than 10%) (Figure 8.3.3.2).

In terms of acoustic energy and biomass, the central area of the usual distribution of juveniles showed an almost total absence of age-0 sardine (Figure 8.3.3.3). Age-0 sardine was located in Southern Galicia (9aCN) and the northern part of subdivision 9aCS, areas that are not included in the recruitment index used in the sardine assessment.

2023 recruitment index (9aCN subdivision), was estimated to be 61 011 10^3 age-0 individuals (1624 tonnes) and represents the lowest value in the time series (Figure 8.3.3.4, Table 8.3.3.1.).

8.3.4 Other regional indices

Although not included as an input in the sardine assessment, ECOCADIZ survey (fully described in Section 4, Anchovy in 9a division), provides sardine abundance and biomass estimates in the Gulf of Cadiz and Algarve (9aS subdivision) in the summer, which can be compared with the results obtained by the spring Portuguese acoustic survey in the same area. For both surveys, trends in abundance (and biomass) are broadly similar (specially for age-0 individuals), although they have interannual differences (see WGHANSA2021 report, ICES 2021b).

In 2021 and 2022, ECOCADIZ survey could not be carried out due to logistical problems.

In addition, during autumn, ECOCADIZ-RECLUTAS gives (since 2012) an estimation of sardine recruitment in the Gulf of Cadiz, one of the main recruitment areas for this stock.

8.3.5 Mean weight-at-age in the stock and in the catch

Mean weight-at-age in the catch are shown in Table 8.3.5.1a.

According to the stock annex, mean weights-at-age in the stock (Table 8.3.5.1b) come from the DEPM surveys. See Annex 3.

- For years with no DEPM survey, a linear interpolation of the data from two consecutive surveys is carried out to obtain the estimates of mean weight-at-age.
- For the period 1978–1998 (before the DEPM series started) it was decided to consider the two closest DEPM surveys, and assume for that period the average between 1999 and 2002 estimates.
- For the years after the last DEPM survey, the estimates of the last DEPM survey are assumed.

8.3.6 Maturity-at-age

Following the stock annex, maturity ogive from the stock comes from the DEPM surveys.

- For years with no DEPM survey, a linear interpolation of the data between two consecutive surveys is carried out to obtain the estimates of maturity-at-age.
- For the period 1978–1998 (years before starting the DEPM series), constant proportions of maturity-at-age were assumed, based on the average of the estimates obtained from the six DEPM surveys of the 1999–2014 period, thus including both years of strong year classes and years of low recruitment.
- For the years after the last DEPM survey, the estimates of the last DEPM survey are assumed.

8.3.7 Natural mortality

Following the stock annex, natural mortality is:

M, year^{-1}	
Age 0	0.98
Age 1	0.61
Age 2	0.47
Age 3	0.40
Age 4	0.36
Age 5	0.35
Age 6	0.32

8.3.8 Catch-at-age and abundance-at-age in the spring acoustic survey

The historical series of catches-at-age and abundance-at-age in the spring acoustic survey are presented in Figures 8.3.8.1 and 8.3.8.2.

8.4 Assessment Data of the state of the stock

8.4.1 Stock assessment

The table below presents an overview of the assessment model settings. Additional details on the input data used in the stock assessment model can be found in the stock annex (See Annex 3).

Input data	WGHANSA 2021
Catch	Catch biomass 1978–2023 (tonnes)
	Catch-at-age 1978–2022 (thousands of individuals)
Spring acoustic survey (Joint SP+PT) *	Total numbers 1996–2023 (thousands of individuals)
	Numbers-at-age 1996–2023 (thousands of individuals)
DEPM survey (Joint SP+PT)	SSB 1997, 1999, 2002, 2005, 2008, 2011, 2014, 2017, 2020, 2023 (tonnes)
Weight-at-age in the catch	Yearly averages 1978–2022 (constant up to 1989), kg
Weight-at-age in the stock	From DEPM surveys in DEPM years, linear interpolation for years in-between (constant 1978–1998), kg

Input data	WGHANSA 2021
Maturity-at-age	From DEPM surveys in DEPM years, linear interpolation for years in-between (constant 1978–1998), proportions
Model structure and assumptions:	
M	M-at-age 0=0.98, M-at-age 1=0.61, M-at-age 2=0.47, M-at-age 3=0.40, M-at-age 4=0.36, M-at-age 5=0.35, M-at-age 6+=0.32
Recruitment	Density-dependent R model; annual recruitments are parameters, defined as lognormal deviations from Beverton–Holt stock–recruitment model, penalized by a sigma of 0.74, and an input steepness of 0.71.
Initial population	N-at-age in the first year are parameters derived from an input initial equilibrium catch of 135 000 tons, equilibrium recruitment and selectivity in the first year and adjusted by recruitment deviations estimated from the data on the first years of the assessment. Equilibrium assumed to take place in 1972.
Fishery selectivity-at-age	S-at age are parameters, each estimated as a random walk from the previous age; S-at-age 0 used as the reference; S-at-ages 4 and 5 assumed to be equal to S-at-age 3.
Fishery selectivity over time	Three periods: 1978–1987, 1988–2005 and 2006–onwards. Selectivity-at-age is estimated for each period and within each period assumed to be fixed over time.
Spring acoustic survey selectivity-at-age	Selectivity assumed to be equal at all ages.
Autumn acoustic survey selectivity-at-age	Selectivity tailored to young fish (age 0)
Fishery catchability	Scaling factor, median unbiased
Spring acoustic survey catchability	Simple model with extra standard error parameter
DEPM catchability	Simple model with extra standard error parameter
Autumn acoustic survey catchability	Power model with extra standard error parameter
Log-likelihood function:	
Weights of components	All components have equal weight
Data weights	Sample size of age compositions by year (50 in 1978-1990 and 75 in 1991-onwards for the fishery, 25 for the acoustic survey; Acoustic and DEPM abundance observations with equal weight = CV = 25%; age reading uncertainty; user input sample sizes and survey CV are used as inverse weights of likelihood components.

Table 8.4.1.1 shows the parameters estimated by the assessment model. Fishing mortality-at-age and numbers-at-age are presented in Tables 8.4.1.2 and 8.4.1.3. Virgin recruitment was estimated to be $R_{0,2023}$ = 20 208 000 (CV = 4%) and the initial F was estimated as $initF_{2023}$ = 0.41 $year^{-1}$. Catchability parameters are close to 1 for both the acoustic (Q = 1.31, RMSE = 0.36) and the DEPM (Q=1.19, RMSE=0.27) surveys. Catchability parameter for the recruitment index is 4.7e-08 (RMSE = 1.08). The extra standard deviation parameters are low for the spring acoustic and the DEPM surveys (0.11 and 0.02 respectively) but higher for the recruitment index (0.83). Correlations between the assessment parameters range from -0.99 to 0.46 although the majority are very close to zero. Negative correlations below -0.50 are observed between the two parameters of the power model of $Q_{recruitment\ index}$ (-0.99), R_0 and $Q_{acoustic\ survey}$ (-0.59), R_0 and $Q_{DEPM\ survey}$ (-0.53)and between selectivity parameters from the first period (four cases) and one case in the last period.

The assumed standard error for the acoustic and the DEPM index, all years = 0.25, is consistent with the residual mean square errors estimated by the model, 0.36 and 0.27. The harmonic mean of the fishery age composition sample size, 67, is consisted with the current assumption of 75. In the case of the spring acoustic survey survey, the sample size of 25 is consistent with the precision indicated by the model (the harmonic mean for the acoustic survey is estimated to be 25).

Figures 8.4.1.1, 8.4.1.2 and 8.4.1.3 show the fit of the model to the three indices of abundance, which are similar to the fit of the 2022 assessment model. The assessment of 2023 shows a poor fit to the 2022 and the 2023 point estimate of the acoustic survey index. It is observed that in previous years, high values of the point estimate of the acoustic surveys have poorer fits, i.e., positive residuals for the estimates in the surveys. It seems that the model has a tendency to underestimate abundance in years when the survey index is large.

Figure 8.4.1.4 shows the model residuals from the fit to the catch-at-age composition (top panel) and the acoustic survey age composition (bottom panel). Catch-at-age residuals in 2022 have increased, when compared to 2021, for the younger ages (until age 2) and increased for the older ages. Residuals are positive for ages 2, 4 and 5 and negative for all the other ages. The acoustic survey residuals in 2023 are positive for age two and four and negative for all other ages.

The fishery selectivity patterns estimated in the present assessment show less abrupt changes over time and through ages (particularly at the age-6+ group) (Figure 8.4.1.5). The patterns over age are dome-shaped in the three periods with the early (1978–1987) and recent periods (2006–2022) showing higher selectivity at ages 1–2 than the middle period (1988–2005), in agreement with the higher fraction of the catches coming from recruitment areas in those periods. The increase of age 0 selectivity estimated in the most recent period is consistent with large catches of this age group in a period that recruitment is at a very low level.

The summary of the 2023 assessment results is shown in Table 8.4.1.4 and Figure 8.4.1.5 (in the Figure compared to the 2022 assessment model results). The estimate of B1+ in 2023 assumes stock weights are equal to the mean in the last six years, the same assumption taken in the short term forecast, and in accordance to the stock annex. By the end of October, preliminary catch information indicates that less than 42 000 tonnes had been taken by the two EU Member states. For the interim year and based on reported catches in November and December for both countries in the past 5 years, it was considered that 50 000 tonnes is a realistic 2023 catch assumption for 2023 (see Section 8.1). The model estimates standard errors of SSB, recruitment and Apical F (maximum F over age within years). We assume the CVs of SSB and Apical F apply to B1+ and F(2–5), respectively.

B1+ in 2023 is predicted to be 480 817 t (CV = 15%), assuming that the stock weights are equal to the mean of the last six years. This represents an increase of 0.3% when compared with B1+ in 2022 = 479 464 t (CV = 15%). B1+ is above B_{lim} = 196 334 t, B_{pa} = 252 523 t and MSY $B_{trigger}$ = 252 523 t of the current low productivity regime of the stock (see Section 8.7).

$F_{bar\ 2–5}$ in 2022 is estimated to be 0.081 year^{-1} (CV = 15%) which represents an decrease of 1% when compared to $F_{bar\ 2-5}$ in 2021. $F_{bar\ 2–5}$ is below F_{MSY} and F_{pa} .

In summary, the stock is not overfished and is in a healthy condition.

The series of historical recruitments 1978–2023 shows a marked downward trend until 2006 and from then had been fluctuating around historically low values. Since 2018 that recruitment estimates had been above the mean values of the low productivity regime (since 2006). The 2023 recruitment estimate (R_{2023} = 4 260 090, CV = 49%) represents a decreased of 71% when compared to the recruitment estimate of 2022.

8.5 Retrospective pattern

Retrospective patterns for Biomass 1+, $F_{ages2-5}$ and recruitment were computed for years 2019–2023. For each run, assessment was performed including survey data until the terminal year and catch data until the previous year, as done in the current assessment (2023). This range of runs include runs prior and after the Inter-benchmark (ICES, 2021a). The potential retrospective bias in the assessment was quantified using an approach based on the Mohn's rho (Mohn, 1999), following ICES guidelines, and was computed using the function mohn() available in the R package called icesAdvice.

Results are shown in absolute terms (Figure 8.5.1). The model underestimates Biomass 1+ (Mohn's rho of -0.363) and recruitment (Mohn's rho of -0.138) while it overestimates $F_{ages2–5}$ (Mohn's rho of 0.457). Differences in the estimation of these parameters between runs are more pronounced for recruitment and, in all cases, in the last portion of the time-series. Most probably, changes in the most recent years are a consequence of the model fit to the most recent data. Overall, trends do not change between runs with the exception of some recruitment data points in the most recent part of the time series. This might be a consequence of the changes in the model after the Inter-benchmark Finally, the retrospective plots indicate that the model is robust.

8.6 Short-term predictions

The short-term forecast assumptions were updated in 2021 after Inter-benchmark of October 2021 (ICES, 2021a) and are specified in the stock annex (Annex 3).

Catch predictions were carried out following the stock annex, Annex 3. Recruitment in the interim year (2023) is now the estimate from the assessment model and in the forecast year (2024) was set to the geometric mean of the last five years (2019–2023), R_{2024} = 12 161 380 thousand individuals. Fishing mortality in the interim year is the fishing mortality that corresponds to a catch constrain. The catch assumption for 2023 was assumed to be 50 000 tonnes based on the total catches reported by the end of October and the November to December catches reported in the last five years. This corresponds to the HCR with a cap included in the Management Plan of the Iberian sardine and is equivalent to a $F_{ages2–5}$, 2023 = 0.107.

Table 8.6.1 shows input data of the short-term forecast. Table 8.6.2 shows the results of the short-term forecast. The complete set of results for fine steps of F scenarios is stored in file pil.27.8c9a_scenarios in the WGHANSA SharePoint.

8.6.1 Evidence for change in advice

A comparison of the input data used in the forecast from the current and the previous assessments is presented in this sub-section. In Figure 8.6.1.1 input data used for the short-term forecast on last year's advice is compared with the input data used for this year's short-term forecast and in Figure 8.4.1.5 it was already showned the summary for the previous and current assessments.

Figure 8.6.1.2 compares the predicted stock numbers at age at the start of the advice year from the previous advice and the estimate of stock numbers at age for the same year from the current assessment. Table 8.6.1.1 shows the numbers and biomass at age estimated in the current assessment divided by the numbers and biomass at age estimated in the previous assessment for the years 2020, 2021 and 2022.

Forecast assumptions from previous and current assessments are shown in Table.8.6.1.2

8.7 Reference points

Reference Points for this stock were re-evaluated at the beginning of 2021, during the **Workshop for the evaluation of the Iberian sardine HCR (WKSARHCR; ICES, 2021c).**

ICES adopted new reference points for the stock based on data from the period 2006–2019 which is considered representative of a low productivity state. The recomputed values, using the management strategy evaluation framework, are presented in Table 8.7.1.

Table 8.7.1. Sardine in 8c and 9a. Reference Points. The biological reference points were estimated during WKSARHCR (ICES, 2021c) based on the state of low productivity (2006–2019). Weights are in tonnes.

BRP	2006-2019	Technical basis
B_{lim}	196 334	B_{lim} = Hockey-stick change point
B_{pa}	252 523	$B_{pa} = B_{lim} * \exp(1.645 * \sigma)$, $\sigma = 0.17$ (ICES, 2021d)
F_{lim}	0.26	Stochastic long-term simulations (50% probability SSB < B_{lim}) (MSE)
$B_{trigger}$	252 523	$B_{trigger} = B_{pa}$
F_{pa}	0.092	$Fp_{.05}$; the F that leads to SSB ≥ B_{lim} with 95% probability (MSE).
F_{MSY}	0.22	Median F_{target} which maximizes yield without $B_{trigger}$ (MSE)
Adopted F_{MSY}	0.092	If $F_{pa} < F_{MSY}$ then $F_{MSY} = F_{pa}$

8.8 Management considerations

A new management and recovery plan for the Iberian sardine stock (divisions 8.c and 9.a) (Multiannual Management Plan for the Iberian Sardine 2021–2026) was developed by Spain and Portugal. In February 2021, ICES received a request from Portugal and Spain EU members to evaluate a generic harvest control rule (HCR) within that management plan. The new HCR is defined by three reference levels for fishing mortality, F = 0, F = 0.064 and F = 0.12 and, three reference levels for B1+, B_{low} = 112 943 t, defined as the lowest observed time series B1+ according to the 2018 assessment (ICES, 2018), MSY $B_{trigger}$ = 252 523 t, under a low productivity regime and MSY $B_{trigger}$ = 446 331 t, under a medium productivity regime (Figure 8.8.1.).

The proposed HCR was described as follows:

i) If B1+ ≤ 112943 t, then F = 0
ii) If 112943 t < B1+ ≤ 252 523 t, then F increases linearly from 0 to 0.064
iii) If 252 523 t < B1+ ≤ 446 331 t, then F increases linearly from 0.064 to 0.12
iv) If B1+ > 446 331 t, then F = 0.12

Conditions ii) to iv) are overridden if the forecast catch in any given year exceeds the maximum allowed catches of 30 to 50 kt.

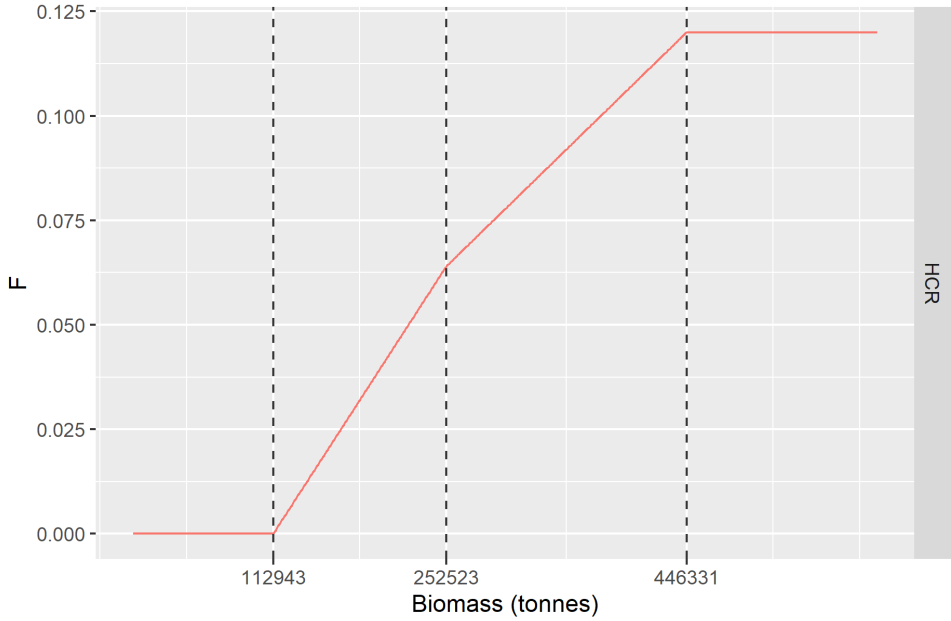


Figure 8.8.1. Proposed HCR. The biomass reference levels of biomass (B1+) reported correspond to $B_{loss(2018)}$ = 112 943 t, MSY $B_{trigger\_low}$ = B_{pa_low} = 252 523 t and MSY $B_{trigger\_medium}$ = B_{pa_medium} = 446 331 t.

ICES found that the generic harvest control rule was precautionary in a persistent low productivity regime with maximum allowed catches between 30 and 50 kt (ICES, 2021d). For 2023, the EU Commission requested ICES to provide advice based on the MSY approach. The precautionary generic harvest control rule should be included in the catch scenario table of the Advice Sheet.

8.9 References

Direcção Geral de Recursos Naturais, Segurança e Serviços Marítimos. 2022. Despacho n.º 43/DG/2022. Determina o fecho da pesca dirigida à sardinha exceto, a título acessório, até 10% do total desembarcado em cada maré.

Direcção Geral de Recursos Naturais, Segurança e Serviços Marítimos. 2023. Despacho n.º 6/DG/2023. Alarga o período em que se não se permite capturar sardinha exceto, a título acessório, até 10% do total desembarcado em cada maré.

ICES. 2021a. Inter-Benchmark Protocol for Iberian sardine (IBPIS). ICES Scientific Reports. 3:108. 57 pp. https://doi.org/10.17895/ices.pub.8144

ICES. 2021b. Working Group on Southern Horse Mackerel Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 3:55. 689 pp. https://doi.org/10.17895/ices.pub.8138

ICES. 2021c. The Workshop for the evaluation of the Iberian sardine HCR (WKSARHCR). ICES Scientific Reports. 3:49. 115 pp. https://doi.org/10.17895/ices.pub.7926

ICES. 2021d. Request from Portugal and Spain to evaluate a new Harvest Control Rule for the management of the Iberian sardine stock (divisions 8.c and 9.a). In Report of the ICES Advisory Committee, 2021. ICES Advice 2021, sr.2021.05. https://doi.org/10.17895/ices.advice.816

ICES. 2022. Sardine (Sardina pilchardus) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters). In Report of the ICES Advisory Committee, 2022. ICES Advice 2022, pil.27.8c9a. https://doi.org/10.17895/ices.advice.19772455

ICES. 2023. Working Group on Acoustic and Egg Surveys for small pelagic fish in NE Atlantic

Massé, J., Uriarte, A., Angélico, M. M., and Carrera, P. (Eds.) 2018. Pelagic survey series for sardine and anchovy in ICES subareas 8 and 9 – Towards an ecosystem approach. ICES Cooperative Research Report No. 332. 268 pp. https://doi.org/10.17895/ices.pub.4599

Ministerio de Agricultura, Pesca y Alimentación. 2023. BOE-A-2023-7472. Resolución de 17 de marzo de 2023, de la Secretaría General de Pesca, por la que se establecen disposiciones de ordenación de la pesquería de la sardina ibérica («Sardina pilchardus») que se pesca en aguas ibéricas de la zona CIEM 8c y 9a.

Ministerio de Agricultura, Pesca y Alimentación. 2023. BOE-A-2023-18183. Resolución de 4 de agosto de 2023, de la Secretaría General de Pesca, por la que se lleva a cabo el reparto de las cuotas adicionales de sardina ibérica (stock PIL/8C9A) obtenidas para 2023 por intercambio con Portugal.

Ministério da Agricultura e Alimentação. 2023. Despacho n.º 5059-A/2023, de 28 de abril de 2023 Determina a reabertura, a partir das 00:00 horas do dia 2 de maio de 2023, da pesca da sardinha (Sardina pilchardus). Diário da República, 2.ª série https://diariodarepublica.pt/dr/detalhe/despacho/5059-a-2023-212378755

Mohn, 1999. The retrospective problem in sequential population analysis; An investigation using cod fishery and simulated data. ICES Journal of Marine Science, 56: 473–488.

8.10 Tables

Table 8.2.2.1: Sardine in 8c and 9a: Quarterly distribution of sardine catches (t) in 2022 by ICES Subdivision. Above absolute values; below, relative numbers.

Sub-Div	1st	2nd	3rd	4th	Total
8cE	56	588	170	106	**920**
8cW	211	1722	2506	564	**5002**
9aN	32	2064	3817	787	**6701**
9aCN		2218	5604	2551	**10374**
9aCS		3048	3958	2763	**9769**
9aS-Algarve		1108	2619	796	**4522**
9aS-Cadiz	58	1013	1343	727	**3141**
Total	**357**	**11761**	**20017**	**8295**	**40429**

Sub-Div	1st	2nd	3rd	4th	Total
8cE	0.14	1.45	0.42	0.26	**2.28**
8cW	0.52	4.26	6.20	1.39	**12.37**
9aN	0.08	5.11	9.44	1.95	**16.58**
9aCN	0.00	5.49	13.86	6.31	**25.66**
9aCS	0.00	7.54	9.79	6.83	**24.16**
9aS-Algarve	0.00	2.74	6.48	1.97	**11.19**
9aS-Cadiz	0.14	2.51	3.32	1.80	**7.77**
Total	**0.88**	**29.09**	**49.51**	**20.52**	

Table 8.2.2.2. Sardine in 8c and 9a: Iberian Sardine Landings (tonnes) by subdivision for the period 1940-2022.

Year	Subdivision					
	8c	9a North	9a Central North	9a Central South	9a South Algarve	9a South Cadiz
1940	66816		42132	33275	23724	
1941	27801		26599	34423	9391	
1942	47208		40969	31957	8739	
1943	46348		85692	31362	15871	
1944	76147		88643	31135	8450	
1945	67998		64313	37289	7426	
1946	32280		68787	26430	12237	
1947	43459	21855	55407	25003	15667	
1948	10945	17320	50288	17060	10674	
1949	11519	19504	37868	12077	8952	
1950	13201	27121	47388	17025	17963	

Year	Subdivision					
	8c	9a North	9a Central North	9a Central South	9a South Algarve	9a South Cadiz
1951	12713	27959	43906	15056	19269	
1952	7765	30485	40938	22687	25331	
1953	4969	27569	68145	16969	12051	
1954	8836	28816	62467	25736	24084	
1955	6851	30804	55618	15191	21150	
1956	12074	29614	58128	24069	14475	
1957	15624	37170	75896	20231	15010	
1958	29743	41143	92790	33937	12554	
1959	42005	36055	87845	23754	11680	
1960	38244	60713	83331	24384	24062	
1961	51212	59570	96105	22872	16528	
1962	28891	46381	77701	29643	23528	
1963	33796	51979	86859	17595	12397	
1964	36390	40897	108065	27636	22035	
1965	31732	47036	82354	35003	18797	
1966	32196	44154	66929	34153	20855	
1967	23480	45595	64210	31576	16635	
1968	24690	51828	46215	16671	14993	
1969	38254	40732	37782	13852	9350	
1970	28934	32306	37608	12989	14257	
1971	41691	48637	36728	16917	16534	
1972	33800	45275	34889	18007	19200	
1973	44768	18523	46984	27688	19570	
1974	34536	13894	36339	18717	14244	
1975	50260	12236	54819	19295	16714	
1976	51901	10140	43435	16548	12538	
1977	36149	9782	37064	17496	20745	
1978	43522	12915	34246	25974	23333	5619

Year	Subdivision					
	8c	9a North	9a Central North	9a Central South	9a South Algarve	9a South Cadiz
1979	18271	43876	39651	27532	24111	3800
1980	35787	49593	59290	29433	17579	3120
1981	35550	65330	61150	37054	15048	2384
1982	31756	71889	45865	38082	16912	2442
1983	32374	62843	33163	31163	21607	2688
1984	27970	79606	42798	35032	17280	3319
1985	25907	66491	61755	31535	18418	4333
1986	39195	37960	57360	31737	14354	6757
1987	36377	42234	44806	27795	17613	8870
1988	40944	24005	52779	27420	13393	2990
1989	29856	16179	52585	26783	11723	3835
1990	27500	19253	52212	24723	19238	6503
1991	20735	14383	44379	26150	22106	4834
1992	26160	16579	41681	29968	11666	4196
1993	24486	23905	47284	29995	13160	3664
1994	22181	16151	49136	30390	14942	3782
1995	19538	13928	41444	27270	19104	3996
1996	14423	11251	34761	31117	19880	5304
1997	15587	12291	34156	25863	21137	6780
1998	16177	3263	32584	29564	20743	6594
1999	11862	2563	31574	21747	18499	7846
2000	11697	2866	23311	23701	19129	5081
2001	16798	8398	32726	25619	13350	5066
2002	15885	4562	33585	22969	10982	11689
2003	16436	6383	33293	24635	8600	8484
2004	18306	8573	29488	24370	8107	9176
2005	19800	11663	25696	24619	7175	8391
2006	15377	10856	30152	19061	5798	5779

Year	Subdivision					
	8c	9a North	9a Central North	9a Central South	9a South Algarve	9a South Cadiz
2007	13380	12402	41090	19142	4266	6188
2008	13636	9409	45210	20858	4928	7423
2009	11963	7226	36212	20838	4785	6716
2010	13772	7409	40923	17623	5181	4662
2011	8536	5621	37152	13685	6387	9023
2012	13090	4154	19647	9045	2891	6031
2013	5272	2128	15065	9084	4112	10157
2014	4344	1924	6889	6747	2398	5635
2015	1916	1946	7117	4848	1812	2956
2016	2886	2887	7695	4031	1972	3233
2017	2251	2225	5182	6676	2836	2742
2018	2764	856	3579	4759	1400	1704
2019	1608	1076	3520	4290	1986	1280
2020	2822	1950	5049	7560	2807	1955
2021	4918	5109	13031	8767	5052	3808
2022	5922	6701	10374	9769	4522	3141

Table 8.2.4.1: Sardine in 8c and 9a: Sardine length composition (thousands), mean length (cm) and catch (t) by ICES sub-division in 2022.

Length	8c E	8c W	9a N	9a CN	9a CS	9a S	9a S (Ca)	Total
6.5								
7							10	10
7.5								
8							271	271
8.5							205	205
9							347	347
9.5							680	680
10							1 241	1 241
10.5							1 702	1 702

Length	8c E	8c W	9a N	9a CN	9a CS	9a S	9a S (Ca)	Total
11							1 919	1 919
11.5			31		200		1 879	2 110
12			392	152	799		2 790	4 133
12.5	183		1 618	551	1 997		5 482	9 830
13	617		3 579	782	2 796		2 700	10 475
13.5	1 251		3 611	2 185	2 596		4 038	13 681
14	1 237		1 346	4 886	599		1 419	9 487
14.5	709		509	7 577	599		1 445	10 839
15	154		206	4 756	200		841	6 157
15.5	228		63	1 046	200	145	1 179	2 861
16	329			522		540	2 924	4 314
16.5	544		87	2 208	399	1 108	5 924	10 271
17	616	127	276	11 324	47	7 509	10 032	29 931
17.5	713	86	1 550	22 379	562	9 816	9 420	44 526
18	808	910	6 190	36 030	1 642	26 056	9 593	81 230
18.5	1 196	880	13 706	41 386	4 011	13 531	7 669	82 379
19	1 540	4 286	18 730	29 615	12 144	13 282	4 358	83 955
19.5	1 775	5 726	16 477	16 203	22 756	5 253	2 278	70 468
20	1 697	12 963	12 567	6 698	30 098	2 137	1 088	67 248
20.5	1 346	8 700	8 054	3 570	24 155	305	752	46 883
21	737	13 523	4 878	1 279	15 684	68	218	36 385
21.5	408	4 065	2 864	1 315	8 604	17	7	17 278
22	324	6 004	1 833	245	3 648		5	12 059
22.5	171	1 035	1 264	888	1 261		3	4 623
23	97	1 585	593	699	377			3 351
23.5	63	504	248		366			1 181
24	18	606	66		126			816
24.5		76	10					86
25		34	3					37

Length	8c E	8c W	9a N	9a CN	9a CS	9a S	9a S (Ca)	Total
25.5								
26		34						34
26.5								
27								
27.5								
Total	16 761	61 143	100 753	196 294	135 865	79 767	82 420	673 003
Mean L	18.1	20.9	19.1	18.3	19.9	18.5	16.2	18.7
sd	2.75	1.14	2.25	1.63	2.05	0.80	2.82	2.30
Catch	920	5002	6701	10374	9769	4522	3141	40429

Table 8.2.4.1a: Sardine in 8c and 9a: Sardine length composition (thousands), mean length (cm) and catch (t) by ICES subdivision in the first quarter 2022.

First Quarter								
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S (Ca)**	**Total**
6.5								
7								
7.5								
8								
8.5								
9								
9.5								
10								
10.5								
11								
11.5								
12								
12.5	7						4	10
13	29							29
13.5	81							81
14	77						4	80
14.5	150						1	151
15	82						10	93
15.5	191						7	198
16	240						9	249
16.5	345						87	432

First Quarter								
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S (Ca)**	**Total**
17	240						129	369
17.5	140						115	256
18	71	392	55				209	727
18.5	66	2	9				174	252
19	31	789	117				174	1 111
19.5	18	12	12				136	177
20	7	2 356	324				58	2 746
20.5	7	8	7				14	36
21		399	58				52	509
21.5	5	3	3				7	18
22		3	2				5	10
22.5			1					1
23		2						2
23.5								
24								
24.5								
25								
25.5								
26								
26.5								
27								
27.5								
Total	1 787	3 967	589				1 194	7 537
Mean L	16.4	20.0	20.0				18.6	18.9
sd	1.46	0.79	0.82				1.31	1.82
Catch	**56**	**211**	**32**				**58**	**357**

Table 8.2.4.1b: Sardine in 8c and 9a: Sardine length composition (thousands) , mean length (cm) and catch (t) by ICES subdivision in the second quarter 2022.

Second Quarter								
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
7							10	10
7.5								
8							5	5
8.5								
9								
9.5								
10							1	1

				Second Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
10.5							4	4
11							10	10
11.5							27	27
12							10	10
12.5							32	32
13							29	29
13.5							12	12
14							17	17
14.5	1						50	51
15	4						103	107
15.5	8						299	307
16	13			331		272	243	860
16.5	29		18	1 831		372	709	2 959
17	137	126	48	8 083	21	2 374	1 731	12 520
17.5	249	86	147	11 134	158	2 869	2 555	17 198
18	434	421	1 337	10 820	762	4 639	3 727	22 140
18.5	696	805	3 949	6 241	1 907	3 835	4 077	21 510
19	895	2 727	5 411	3 084	3 818	3 518	1 863	21 317
19.5	1 291	4 331	4 972	2 831	5 905	1 705	1 320	22 354
20	1 341	4 541	4 356	474	8 409	731	801	20 653
20.5	1 170	3 038	3 155	447	8 973	201	593	17 577
21	667	2 847	2 382		6 231	54	120	12 302
21.5	367	943	1 462	102	3 304	12		6 191
22	305	1 253	754		1 967			4 280
22.5	133	184	361		328		3	1 010
23	97	461	85		198			841
23.5	59	34	28		160			280
24	18	34	12		44			109
24.5		75						75

				Second Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
25		34						34
25.5								
26		34						34
26.5								
27								
27.5								
Total	7 916	NA	NA	45 377	42 186	20 583	NA	184 867
Mean L	20.1	NA	NA	18.2	20.5	18.5	NA	19.4
sd	1.31	NA	NA	0.85	0.99	0.90	NA	1.44
Catch	**588**	**1 722**	**2 064**	**2 218**	**3 048**	**1 108**	**1 013**	**11 761**

Table 8.2.4.1c: Sardine in 8c and 9a: Sardine length composition (thousands) , mean length (cm) and catch (t) by ICES subdivision in the third quarter 2022.

				Third Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
6.5								
7								
7.5								
8							13	13
8.5							83	83
9							194	194
9.5							417	417
10							1 056	1 056
10.5							1 582	1 582
11							1 546	1 546
11.5			31				1 093	1 124

				Third Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
12			392	152			1 176	1 720
12.5	176		1 618	551			1 314	3 658
13	588		3 579	603			994	5 765
13.5	1 170		3 611	1 762			2 839	9 382
14	1 160		1 346	3 131			1 016	6 653
14.5	554		509	3 514			960	5 538
15	50		206	2 050			370	2 676
15.5			63	22		145	833	1 064
16				63		268	2 547	2 878
16.5	8		70	160		736	4 930	5 903
17			229	3 241	26	4 747	6 933	15 175
17.5	8		1 106	9 822	26	4 878	4 482	20 323
18	35	68	4 185	21 467	598	17 150	3 181	46 682
18.5	211	73	8 088	26 415	333	7 110	849	43 079
19	396	701	10 957	18 797	3 124	7 696	697	42 369
19.5	263	1 192	9 966	6 601	12 613	2 255	80	32 970
20	225	5 330	6 606	2 095	15 965	1 018	98	31 336
20.5	93	4 869	3 590	639	9 463	104		18 758
21	26	8 486	1 774	187	5 247	14		15 734
21.5	12	2 234	1 037	828	2 828	5		6 944
22		3 747	759	149	881			5 537
22.5	25	497	514	728	252			2 016
23		832	166	699	178			1 875
23.5	4	409	74					487
24		473						473
24.5								
25								
25.5								
26								

				Third Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
26.5								
27								
27.5								
Total	5 005	28 912	60 475	103 675	51 535	46 125	39 283	335 009
Mean L	15.4	21.2	18.5	18.3	20.4	18.4	15.5	18.5
sd	2.58	0.99	2.56	1.67	0.76	0.78	2.63	2.36
Catch	**170**	**2 506**	**3 817**	**5 604**	**3 958**	**2 619**	**1 343**	**20 017**

Table 8.2.4.1d: Sardine in 8c and 9a: Sardine length composition (thousands) by ICES subdivision in the fourth quarter 2022.

				Fourth Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
6.5								
7								
7.5								
8							253	253
8.5							122	122
9							153	153
9.5							263	263
10							184	184
10.5							115	115
11							363	363
11.5					200		759	959
12					799		1 604	2 403
12.5					1 997		4 133	6 130
13				179	2 796		1 677	4 651
13.5				423	2 596		1 187	4 206

				Fourth Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
14				1 755	599		383	2 737
14.5	4			4 062	599		434	5 099
15	18			2 706	200		358	3 281
15.5	29			1 025	200		40	1 293
16	75			128			125	328
16.5	161			218	399		198	976
17	239					388	1 239	1 866
17.5	315		296	1 423	377	2 069	2 269	6 749
18	269	30	613	3 744	282	4 267	2 476	11 681
18.5	223		1 661	8 730	1 770	2 586	2 568	17 537
19	218	69	2 245	7 734	5 201	2 069	1 623	19 159
19.5	203	191	1 527	6 771	4 239	1 293	742	14 967
20	124	735	1 281	4 129	5 724	388	132	12 514
20.5	76	785	1 302	2 484	5 719		146	10 511
21	43	1 791	664	1 091	4 206		46	7 841
21.5	24	884	361	385	2 472			4 126
22	19	1 000	319	95	799			2 232
22.5	14	353	387	160	681			1 595
23		290	342					632
23.5		61	147		207			414
24		99	53		82			235
24.5			10					10
25			3					3
25.5								
26								
26.5								
27								
27.5								

				Fourth Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
Total	2 053	6 289	11 213	47 242	42 144	13 059	23 591	145 591
Mean L	18.5	21.5	20.1	18.4	18.7	18.6	15.5	18.3
sd	1.43	.98	1.39	2.05	3.12	.7	3.09	2.83
Catch	**106**	**564**	**787**	**2 551**	**2 763**	**796**	**727**	**8 295**

Table 8.2.4.2: Sardine in 8c and 9a: Catch in numbers (thousands) at age by quarter and by subdivision in 2022.

								First Quarter
Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-C	Total
0								
1	506	200	6				65	777
2	1 073	257	29				886	2 244
3	185	3 362	475				181	4 204
4	17	136	67				137	357
5	4		7				31	43
6	1	40	5					46
7			1					1
8								
9								
10								
11								
12								
Total	1 787	3 995	589				1 300	7 671
Catch (Tons)	56	211	32				58	357

								Second Quarter
Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-C	Total
0								
1	244	278	394	7 200	398	1 952	1 078	11 544
2	1 537	875	1 437	15 768	6 061	10 407	13 294	49 378
3	3 902	16 858	21 600	22 009	7 748	5 511	2 090	79 718
4	1 261	2 010	3 101	401	11 431	2 002	1 760	21 966
5	701	739	784		3 762	668	199	6 853
6	226	991	939		11 235	44		13 434
7	32	224	221		1 448			1 925
8	13				53			66
9					50			50
10								
11								
12								
Total	7 916	21 976	28 476	45 377	42 186	20 583	18 421	184 935
Catch (Tons)	588	1 722	2 064	2 218	3 048	1 108	1 013	11 761

								Third Quarter
Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-C	Total
0	3 699	26	11 175	11 816			16 947	43 663
1	191	677	3 082	29 024	5 941	13 497	15 407	67 819
2	493	8 450	19 736	52 838	4 820	17 657	4 238	108 232
3	447	13 873	24 843	8 158	15 033	11 330	2 194	75 877
4	135	2 523	1 353	1 139	12 690	3 346	334	21 520
5	30	2 092	130	699	10 797	182	163	14 094
6	5	844	116		1 201	113		2 279
7	5	428	36		1 053			1 522
8								
9								
10								
11								
12								
Total	5 005	28 912	60 472	103 675	51 535	46 125	39 283	335 006
Catch (Tons)	170	2 506	3 817	5 604	3 958	2 619	1 343	20 017

								Fourth Quarter
Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-C	Total
0	73	7	164	6 658	10 144		12 090	29 137
1	496	103	981	7 426	8 116	465	5 525	23 113
2	985	1 666	4 409	11 769	2 993	5 366	2 472	29 660
3	364	2 878	5 125	20 646	4 069	5 495	2 200	40 776
4	101	738	377	625	7 116	1 539	917	11 412
5	26	555	67	99	5 145	194	387	6 473
6	6	226	58	19	3 678			3 987
7	2	115	31		884			1 032
8								
9								
10								
11								
12								
Total	2 053	6 289	11 213	47 242	42 144	13 059	23 591	145 591
Catch (Tons)	106	564	787	2 551	2 763	796	727	8 295

								Whole Year
Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-C	Total
0	3 772	34	11 339	18 475	10 144		29 037	72 801
1	1 437	1 257	4 464	43 650	14 455	15 914	22 075	103 253
2	4 089	11 247	25 611	80 376	13 873	33 430	20 889	189 514
3	4 898	36 972	52 043	50 812	26 850	22 336	6 665	200 575
4	1 515	5 407	4 898	2 165	31 237	6 887	3 147	55 256
5	760	3 387	989	798	19 704	1 044	780	27 463
6	237	2 102	1 118	19	16 114	157		19 746
7	39	767	289		3 385			4 480
8	13				53			66
9					50			50
10								
11								
12								
Total	16 761	61 171	100 750	196 294	135 865	79 767	82 594	673 203
Catch (Tons)	920	5 002	6 701	10 374	9 769	4 522	3 141	40 429

Table 8.2.4.3: Sardine 8c and 9a: Historical catch-at-age data.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6+
1978	869437	2296650	946698	295360	136661	41744	16468
1979	674489	1535560	956132	431466	189107	93185	36038
1980	856671	2037400	1561970	378785	156922	47302	30006
1981	1025960	1934840	1733730	679001	195304	104545	76466
1982	62000	795000	1869000	709000	353000	131000	129000
1983	1070000	577000	857000	803000	324000	141000	139000
1984	118000	3312000	487000	502000	301000	179000	117000
1985	268000	564000	2371000	469000	294000	201000	103000
1986	304000	755000	1027000	919000	333000	196000	167000
1987	1437000	543000	667000	569000	535000	154000	171000
1988	521000	990000	535000	439000	304000	292000	189000
1989	248000	566000	909000	389000	221000	2.00E+05	245000
1990	258000	602000	517000	707000	295000	151000	248000
1991	1580580	477368	436081	406886	265762	74726	105186
1992	498265	1001860	451367	340313	186234	110932	80579
1993	87808	566221	1081820	521458	257209	113871	120282
1994	120797	60194	542163	1094440	272466	112635	72091
1995	30512	189147	280715	829707	472880	70208	64485
1996	277053	101267	347690	514741	652711	197235	46607
1997	208570	548594	453324	391118	337282	225170	70268
1998	449115	366176	501585	352485	233672	178735	105884
1999	246016	475225	361509	339691	177170	105518	72541
2000	489836	354822	313972	255523	194156	97693	64373
2001	219973	1172300	256133	195897	126389	75145	49547
2002	106882	587354	753897	181381	112166	55650	40219
2003	198412	318695	446285	518289	114035	61276	51172
2004	589910	180522	263521	386715	377848	78396	55312
2005	169229	1005530	266213	206657	191013	116628	46087
2006	18347	250200	777315	128695	108244	121043	81149
2007	199364	82084	313453	535706	80348	82713	120821
2008	298405	219205	182636	370253	411611	65397	108832
2009	378304	353839	195618	125324	251973	197185	83887
2010	278311	516544	263334	136037	82831	129434	182722
2011	341535	452259	383353	122136	87976	40949	110734
2012	220164	193884	168105	122976	94143	48700	52645
2013	280544	232934	155842	87924	48492	26591	27635
2014	63949	189093	109802	54550	35237	19462	21688
2015	68371	98936	84313	47069	20960	13656	11242
2016	172202	215051	58288	40726	15422	9815	8424
2017	35329	198627	126003	39727	15971	8393	10853
2018	37222	49140	88410	33715	19257	9003	9140
2019	53515	85035	49870	40297	13422	4307	3429
2020	41356	270602	83327	36914	20026	5690	5725
2021	87950	153333	393524	55831	38306	21632	4755
2022	72801	103253	189514	200575	52256	27463	24342

Table 8.2.4.4: Sardine 8c and 9a: Relative distribution of sardine catches. Upper panel relative contribution of each age group within each subdivision. Lower panel, relative contribution of each subdivision within each age group.

Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-S-C	Total
0	23%	0%	11%	9%	7%	0%	35%	11%
1	9%	2%	4%	22%	11%	20%	27%	15%
2	24%	18%	25%	41%	10%	42%	25%	28%
3	29%	60%	52%	26%	20%	28%	8%	30%
4	9%	9%	5%	1%	23%	9%	4%	8%
5	5%	6%	1%	0%	15%	1%	1%	4%
6+	2%	5%	1%	0%	14%	0%	0%	4%
	100%	100%	100%	100%	100%	100%	100%	100%

Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-S-C	Total
0	5%	0%	16%	25%	14%	0%	40%	100%
1	1%	1%	4%	42%	14%	15%	21%	100%
2	2%	6%	14%	42%	7%	18%	11%	100%
3	2%	18%	26%	25%	13%	11%	3%	100%
4	3%	10%	9%	4%	57%	12%	6%	100%
5	3%	12%	4%	3%	72%	4%	3%	100%
6+	1%	12%	6%	0%	81%	1%	0%	100%

Table 8.2.5.1: Sardine 8c and 9a: Sardine Mean length (cm) at age by quarter and by subdivision in 2022.

						First Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0							
1	15.0	18.2	18.9				16.7
2	16.7	18.5	18.9				18.4
3	18.2	20.1	19.9				19.3
4	19.4	20.5	20.3				19.9
5	20.3	22.9	21.4				21.0
6	20.8	21.3	21.6				
7		23.3	22.3				
8							
9							
10							
11							
12							

						Second Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0							
1	18.9	18.1	18.8	17.6	19.0	17.1	16.5
2	18.8	19.2	19.0	17.7	19.2	18.2	18.3
3	20.1	20.2	19.8	18.6	20.2	18.9	19.1
4	20.5	21.4	20.8	21.0	20.5	19.7	19.5
5	21.4	22.3	21.8		20.7	19.8	19.4
6	21.7	22.4	22.0		21.0	19.8	
7	23.6	23.9	22.3		22.5		
8	23.2				23.8		
9					23.3		
10							
11							
12							

						Third Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0	13.9	18.4	13.6	14.4			13.0
1	19.3	20.0	19.0	18.4	19.5	17.7	17.3
2	19.4	20.8	19.9	18.8	19.7	18.5	17.5
3	19.8	21.0	20.2	19.5	20.4	18.8	17.8
4	20.0	21.9	21.4	22.1	20.4	19.5	19.0
5	20.6	22.5	22.8	23.3	20.7	19.9	18.8
6	22.7	23.0	22.7		21.6	20.3	
7	23.0	23.7	23.7		21.7		
8							
9							
10							
11							
12							

						Fourth Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0	15.8	18.3	18.0	14.7	13.5		12.7
1	17.7	19.9	19.3	16.7	19.2	17.5	17.9
2	18.3	21.0	19.8	19.1	20.0	18.2	18.5
3	19.7	21.2	20.2	19.7	20.6	18.8	18.8
4	20.3	22.2	22.1	20.8	20.3	19.4	19.3
5	20.8	22.5	23.1	22.7	20.8	20.3	19.3
6	22.1	22.9	23.1	22.3	21.6		
7	22.8	23.5	23.8		22.6		
8							
9							
10							
11							
12							

Table 8.2.5.2: Sardine 8c and 9a: Sardine Mean weight (kg) at age by quarter and by subdivision in 2022.

						First Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0							
1	0.024	0.041	0.045				0.033
2	0.033	0.043	0.046				0.042
3	0.041	0.054	0.053				0.049
4	0.049	0.057	0.055				0.052
5	0.056	0.077	0.064				0.061
6	0.059	0.063	0.065				
7		0.081	0.072				
8							
9							
10							
11							
12							

						Second Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0							
1	0.061	0.051	0.059	0.045	0.059	0.044	0.040
2	0.059	0.063	0.061	0.045	0.061	0.052	0.053
3	0.074	0.074	0.070	0.052	0.070	0.057	0.062
4	0.080	0.091	0.083	0.071	0.072	0.063	0.066
5	0.093	0.104	0.098		0.074	0.064	0.066
6	0.097	0.108	0.100		0.077	0.063	
7	0.127	0.135	0.105		0.092		
8	0.121				0.106		
9					0.100		
10							
11							
12							

						Third Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0	0.022	0.054	0.020	0.025			0.019
1	0.064	0.071	0.063	0.054	0.068	0.050	0.044
2	0.064	0.082	0.071	0.057	0.070	0.057	0.047
3	0.069	0.083	0.075	0.065	0.077	0.060	0.049
4	0.072	0.096	0.090	0.096	0.077	0.067	0.061
5	0.079	0.105	0.109	0.112	0.080	0.071	0.059
6	0.108	0.113	0.109		0.091	0.075	
7	0.112	0.125	0.123		0.091		
8							
9							
10							
11							
12							

						Fourth Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0	0.028	0.048	0.045	0.025	0.024		0.013
1	0.044	0.067	0.061	0.039	0.066	0.053	0.045
2	0.049	0.083	0.067	0.059	0.074	0.058	0.051
3	0.065	0.085	0.072	0.065	0.082	0.062	0.053
4	0.072	0.101	0.100	0.078	0.079	0.067	0.059
5	0.080	0.107	0.118	0.102	0.084	0.074	0.060
6	0.099	0.114	0.119	0.096	0.093		
7	0.110	0.125	0.132		0.107		
8							
9							
10							
11							
12							

Table 8.3.2.1. Sardine in 8c and 9a: Summary of DEPM survey results in 2023.

Institute	**IPMA**	**IPMA**	**IEO**	**TOTAL**
Survey area (stratum)	9.a South	9.a West	9.a North & 8.c	
Survey area (Km2)	18144	36396	41673	96213
Positive area (Km2)	5114	10656	15615	31385
Z (hour-1)(CV%)	-0.029 (7.6)	-0.02 (6.0)	-0.021 (5.7)	
P0 (eggs/m2/day)(CV%)	319.08 (18)	276.46 (12)	151.65 (11)	747.19 (8)
P0 tot (eggs/day) (x1012) (CV%)	1.63 (18)	2.95 (12)	2.37 (11)	6.96 (8)
Female Weight (g)	43.39 (15)	36.7 (10)	58.31 (6)	
Batch Fecundity	18172 (15)	15388 (10)	23718 (6)	
Sex Ratio	0.422 (12)	0.556 (4)	0.516 (6)	
Spawning Fraction	0.041 (41)	0.044 (18)	0.089 (14)	
Spawning Biomass (tons) (CV%)	226326 (51)	287593 (26)	126874 (21)	640793 (22)

Table 8.3.2.1. Sardine in 8c and 9a: sardine abundance in number (millions of fish) and biomass (tons) by age groups and ICES subdivision in PELAGO2023. Mean Weight in grams and Mean Length in cm.

AREA 9aCN									
AGE	1	2	3	4	5	6	7	8	TOTAL
Biomass (ton)	87267	116554	17203	77362	9394	2657	-	-	310438
% Biomass	28.1	37.5	5.5	24.9	3.0	0.9	-	-	100
Abundance (N in 10^3)	3387384	3691559	347476	1569389	182780	46020	-	-	9224608
% Abundance	36.7	40.0	3.8	17.0	2.0	0.5	-	-	100
Mean Weight (kg)	24.1	29.0	47.4	46.8	48.7	55.4	-	-	30.7
Mean Length (cm)	15.3	16.3	19.1	19.0	19.2	20.0	-	-	16.6
AREA 9aCS									
AGE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**TOTAL**
Biomass (ton)	9793	24108	5853	3345	3970	2291	931	404	50696
% Biomass	19.3	47.6	11.5	6.6	7.8	4.5	1.8	0.8	100
Abundance (N in 10^3)	430308	903044	139551	62288	69319	38693	15616	7102	1665920
% Abundance	25.8	54.2	8.4	3.7	4.2	2.3	0.9	0.4	100
Mean Weight (kg)	21.5	25.1	38.6	51.4	55.1	57.0	57.4	54.5	27.8
Mean Length (cm)	14.7	15.5	18.0	19.9	20.4	20.6	20.7	20.3	16.1

AREA 9aS-Algarve									
AGE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**TOTAL**
Biomass (ton)	3191	14431	9866	10992	11831	1299	1259	-	52870
% Biomass	6.0	27.3	18.7	20.8	22.4	2.5	2.4	-	100
Abundance (N in 10^3)	196429	526110	233318	238072	262290	28552	26741	-	1511512
% Abundance	13.0	34.8	15.4	15.8	17.4	1.9	1.8	-	100
Mean Weight (kg)	14.4	24.4	40.4	44.2	43.0	43.5	45.3	-	31.0
Mean Length (cm)	13.1	15.7	18.7	19.3	19.1	19.2	19.4	-	17.1
AREA 9aS-Cádiz									
AGE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**TOTAL**
Biomass (ton)	12999	3863	4474	916	-	-	-	-	22251
% Biomass	58.4	17.4	20.1	4.1	-	-	-	-	100
Abundance (N in 10^3)	973675	180374	127673	26409	-	-	-	-	1308130
% Abundance	74.4	13.8	9.8	2.0	-	-	-	-	100
Mean Weight (kg)	13.0	20.7	34.9	34.5	-	-	-	-	15.9
Mean Length (cm)	12.7	14.9	17.8	17.8	-	-	-	-	13.6
TOTAL PELAGO									
AGE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**TOTAL**
Biomass (ton)	113249	158956	37397	92615	25196	6247	2191	404	436255
% Biomass	26.0	36.4	8.6	21.2	5.8	1.4	0.5	0.1	100
Abundance (N in 10^3)	4987796	5301087	848018	1896158	514388	113265	42357	7102	13710170
% Abundance	36.4	38.7	6.2	13.8	3.8	0.8	0.3	0.1	100
Mean Weight (kg)	25.1	32.9	50.6	54.4	56.8	63.1	62.0	65.8	34.3
Mean Length (cm)	14.6	16.0	18.6	19.0	19.3	20.0	19.9	20.3	16.3

Table 8.3.2.2. Sardine in 8c and 9a: sardine abundance in number (millions of fish) and biomass (tons) by age groups and ICES subdivision in PELACUS0423. Mean Weight in grams and Mean Length in cm.

AREA 8cE									
AGE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**TOTAL**
Biomass (ton)	9737	3566	5995	33657	18580	12699	8578	442	93256
%Biomass	10	4	6	36	20	14	9	0	100
Abundance (N in 103)	302772	74868	93188	442480	215186	137782	84905	4198	1355380
% Abundance	22	6	7	33	16	10	6	0	100
Mean Weight (gr)	30.2	45.3	61.1	72.9	82.9	88.8	97.3	101.8	62.7
Mean Lenght (cm)	16.2	18.3	20.1	21.2	22.1	22.5	23.2	23.5	20.2

AREA 8cW									
AGE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**TOTAL**
Biomass (ton)	29042	3077	5247	21653	3189	1121	374	2	63705
%Biomass	46	5	8	34	5	2	1	0	100
Abundance (N in 103)	886316	68542	83680	314718	40811	12589	3976	18	1410651
% Abundance	63	5	6	22	3	1	0	0	100
Mean Weight (gr)	31.1	42.2	60.0	65.9	74.9	85.7	90.7	101.8	42.0
Mean Lenght (cm)	16.3	17.9	20.0	20.6	21.4	22.3	22.7	23.5	17.8

AREA 9aN									
AGE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**TOTAL**
Biomass (ton)	122999	24287	75802	278741	26430	2899	795	41	531994
%Biomass	23	5	14	52	5	1	0	0	100
Abundance (N in 103)	4377467	446543	1231254	4122640	362005	36580	7596	392	10584476
% Abundance	41	4	12	39	3	0	0	0	100
Mean Weight (gr)	27.8	53.9	61.3	67.4	72.7	79.0	104.4	105.4	47.3
Mean Lenght (cm)	15.8	19.3	20.1	20.7	21.2	21.7	23.7	23.8	18.6

TOTAL PELACUS23									
AGE	**1**	**2**	**3**	**4**	**5**	**6**	**7**		**TOTAL**
Biomass (ton)	161779	30931	87044	334051	48199	16720	9746	485	688955
%Biomass	23	4	13	48	7	2	1	0	100
Abundance (N in 103)	5566556	589953	1408122	4879838	618001	186951	96477	4608	13350506
% Abundance	42	4	11	37	5	1	1	0	100
Mean Weight (gr)	27.3	49.6	59.1	65.6	74.6	86.0	97.3	101.8	46
Mean Lenght (cm)	15.7	18.8	19.9	20.5	21.4	22.3	23.2	23.5	18.4

Table 8.3.3.1. Sardine in 8c and 9a: sardine abundance in number (millions of fish) and biomass (tons) by age groups and ICES subdivision in IBERAS23. Mean Weight in grams and Mean Length in cm. In bold, values of recruitment index used in the assessment (age-0 in 9aCN).

AREA 9aN											
AGE	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**TOTAL**
Biomass (ton)	2780	24739	16344	38763	8457	4661	2499	265	0	0	98507
%Biomass	3	25	17	39	9	5	3	0	0	0	100
Abundance (N in 10^3)	118276	552886	253300	537007	102393	57636	29744	2764	0	0	1654006
%Abundance	7	33	15	32	6	3	2	0	0	0	100
Mean Weight (gr)	24	45	65	72	83	81	84	96	0	0	60
Mean Length (cm)	14	17	19	20	21	21	21	22	0	0	19

AREA 9aCN											
AGE	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**TOTAL**
Biomass (ton)	**1624**	167625	23306	34663	3558	1809	703	0	0	0	233288
%Biomass	**1**	72	10	15	2	1	0	0	0	0	100
Abundance (N in 10^3)	**61011**	4250779	375721	511958	46145	23292	8740	0	0	0	5277645
%Abundance	**1**	81	7	10	1	0	0	0	0	0	100
Mean Weight (gr)	**27**	39	62	68	77	78	80	0	0	0	44
Mean Length (cm)	**15**	16	19	20	21	21	21	0	0	0	17

AREA 9aCS											
AGE	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**TOTAL**
Biomass (ton)	23086	2118	2260	6207	2290	1077	556	145	53	0	37792
%Biomass	61	6	6	16	6	3	1	0	0	0	0
Abundance (N in 10^3)	2543150	55700	34362	84040	26250	12580	6452	1516	478	0	2764529
%Abundance	92	2	1	3	1	0	0	0	0	0	0
Mean Weight (gr)	9	38	66	74	87	86	86	96	110	0	14
Mean Length (cm)	10	16	19	20	21	21	21	22	23	0	11

Table 8.4.1a. Sardine in 8c and 9a: Mean weights-at-age (kg) in the catch. Weights-at-age in 1978-1990 are fixed.

Year	Age						
	0	1	2	3	4	5	6+
1990	0.020	0.039	0.054	0.060	0.066	0.073	0.090
1991	0.020	0.030	0.053	0.058	0.070	0.071	0.094
1992	0.018	0.044	0.052	0.061	0.066	0.077	0.089
1993	0.017	0.038	0.053	0.058	0.065	0.070	0.084
1994	0.020	0.036	0.057	0.060	0.067	0.072	0.089
1995	0.025	0.046	0.057	0.064	0.065	0.078	0.093
1996	0.019	0.037	0.048	0.054	0.062	0.070	0.082
1997	0.023	0.031	0.049	0.059	0.064	0.070	0.079
1998	0.024	0.041	0.055	0.061	0.064	0.067	0.073
1999	0.025	0.043	0.056	0.065	0.070	0.073	0.077
2000	0.025	0.037	0.056	0.066	0.071	0.074	0.077
2001	0.023	0.042	0.059	0.067	0.075	0.079	0.085
2002	0.027	0.045	0.057	0.068	0.074	0.079	0.082
2003	0.024	0.044	0.059	0.067	0.079	0.084	0.091
2004	0.020	0.040	0.056	0.066	0.072	0.082	0.089
2005	0.023	0.037	0.055	0.068	0.074	0.075	0.087
2006	0.031	0.042	0.056	0.068	0.073	0.078	0.082
2007	0.028	0.054	0.071	0.074	0.085	0.086	0.089
2008	0.025	0.043	0.066	0.074	0.075	0.083	0.085
2009	0.020	0.041	0.065	0.075	0.079	0.082	0.090
2010	0.026	0.046	0.061	0.075	0.082	0.084	0.081
2011	0.024	0.045	0.064	0.073	0.077	0.077	0.079
2012	0.031	0.056	0.065	0.078	0.083	0.086	0.090
2013	0.025	0.052	0.069	0.077	0.085	0.090	0.094
2014	0.030	0.046	0.061	0.076	0.080	0.089	0.093
2015	0.025	0.049	0.073	0.079	0.089	0.090	0.097
2016	0.018	0.046	0.062	0.074	0.084	0.092	0.098
2017	0.022	0.039	0.058	0.072	0.083	0.086	0.095
2018	0.031	0.047	0.062	0.080	0.088	0.094	0.099
2019	0.028	0.050	0.059	0.074	0.084	0.094	0.097
2020	0.031	0.042	0.057	0.065	0.075	0.084	0.095
2021	0.034	0.044	0.055	0.065	0.077	0.080	0.100
2022	0.021	0.052	0.059	0.068	0.077	0.084	0.089

Table 8.4.1b. Sardine in 8c and 9a: Mean weights-at-age (Kg) in the stock. Weights-at-age in 1978-1998 are fixed (see Stock Annex).

Year	Age						
	0	1	2	3	4	5	6+
1978	0	0.027	0.041	0.050	0.059	0.060	0.063
1979	0	0.027	0.041	0.050	0.059	0.060	0.063
1980	0	0.027	0.041	0.050	0.059	0.060	0.063
1981	0	0.027	0.041	0.050	0.059	0.060	0.063
1982	0	0.027	0.041	0.050	0.059	0.060	0.063
1983	0	0.027	0.041	0.050	0.059	0.060	0.063
1984	0	0.027	0.041	0.050	0.059	0.060	0.063
1985	0	0.027	0.041	0.050	0.059	0.060	0.063
1986	0	0.027	0.041	0.050	0.059	0.060	0.063
1987	0	0.027	0.041	0.050	0.059	0.060	0.063
1988	0	0.027	0.041	0.050	0.059	0.060	0.063
1989	0	0.027	0.041	0.050	0.059	0.060	0.063
1990	0	0.027	0.041	0.050	0.059	0.060	0.063
1991	0	0.027	0.041	0.050	0.059	0.060	0.063
1992	0	0.027	0.041	0.050	0.059	0.060	0.063
1993	0	0.027	0.041	0.050	0.059	0.060	0.063
1994	0	0.027	0.041	0.050	0.059	0.060	0.063
1995	0	0.027	0.041	0.050	0.059	0.060	0.063
1996	0	0.027	0.041	0.050	0.059	0.060	0.063
1997	0	0.027	0.041	0.050	0.059	0.060	0.063
1998	0	0.027	0.041	0.050	0.059	0.060	0.063
1999	0	0.030	0.043	0.050	0.054	0.059	0.062
2000	0	0.027	0.041	0.050	0.059	0.060	0.063
2001	0	0.024	0.039	0.051	0.064	0.061	0.064
2002	0	0.022	0.037	0.052	0.069	0.062	0.066
2003	0	0.021	0.041	0.054	0.068	0.065	0.072
2004	0	0.020	0.045	0.056	0.067	0.068	0.079
2005	0	0.019	0.049	0.058	0.066	0.072	0.086
2006	0	0.024	0.052	0.060	0.067	0.072	0.084
2007	0	0.029	0.054	0.062	0.069	0.072	0.081
2008	0	0.033	0.057	0.064	0.070	0.072	0.079
2009	0	0.030	0.054	0.063	0.070	0.069	0.075
2010	0	0.027	0.051	0.062	0.070	0.067	0.072
2011	0	0.024	0.048	0.061	0.070	0.064	0.068
2012	0	0.027	0.048	0.062	0.068	0.068	0.073
2013	0	0.030	0.049	0.063	0.067	0.073	0.077
2014	0	0.032	0.049	0.065	0.066	0.077	0.081
2015	0	0.030	0.048	0.063	0.066	0.073	0.077
2016	0	0.029	0.046	0.062	0.065	0.070	0.072
2017	0	0.027	0.045	0.060	0.065	0.066	0.068
2018	0	0.027	0.044	0.056	0.063	0.066	0.071
2019	0	0.027	0.043	0.053	0.060	0.067	0.074

Year	Age						
	0	1	2	3	4	5	6+
2020	0	0.027	0.042	0.050	0.058	0.068	0.078
2021	0	0.026	0.043	0.051	0.058	0.065	0.074
2022	0	0.024	0.043	0.052	0.058	0.062	0.071
2023	0	0.023	0.044	0.053	0.058	0.060	0.068

Table 8.4.1.1. Parameters and asymptotic standard deviations estimated in the 2023 assessment model.

Label	Value	Parm_StDev	Phase	Min	Max	Init
Label	Value	Parm_StDev	Phase	Min	Max	Init
SR_LN(R0)	16.822	0.040	1	1	20	16.844
Early_InitAge_4	0.086	0.539	2	-5	5	0
Early_InitAge_3	0.159	0.444	2	-5	5	0
Early_InitAge_2	0.369	0.289	2	-5	5	0
Early_InitAge_1	0.809	0.197	2	-5	5	0
Main_RecrDev_1978	0.975	0.164	2	-5	5	0
Main_RecrDev_1979	1.087	0.158	2	-5	5	0
Main_RecrDev_1980	1.186	0.148	2	-5	5	0
Main_RecrDev_1981	0.666	0.174	2	-5	5	0
Main_RecrDev_1982	0.003	0.240	2	-5	5	0
Main_RecrDev_1983	1.534	0.112	2	-5	5	0
Main_RecrDev_1984	0.260	0.187	2	-5	5	0
Main_RecrDev_1985	0.132	0.181	2	-5	5	0
Main_RecrDev_1986	−0.015	0.193	2	-5	5	0
Main_RecrDev_1987	0.818	0.127	2	-5	5	0
Main_RecrDev_1988	0.201	0.161	2	-5	5	0
Main_RecrDev_1989	0.170	0.159	2	-5	5	0
Main_RecrDev_1990	0.233	0.155	2	-5	5	0
Main_RecrDev_1991	1.333	0.090	2	-5	5	0
Main_RecrDev_1992	0.885	0.102	2	-5	5	0
Main_RecrDev_1993	0.036	0.144	2	-5	5	0
Main_RecrDev_1994	−0.088	0.137	2	-5	5	0
Main_RecrDev_1995	−0.309	0.138	2	-5	5	0
Main_RecrDev_1996	0.063	0.112	2	-5	5	0
Main_RecrDev_1997	−0.344	0.131	2	-5	5	0
Main_RecrDev_1998	−0.024	0.116	2	-5	5	0
Main_RecrDev_1999	−0.289	0.135	2	-5	5	0
Main_RecrDev_2000	0.899	0.089	2	-5	5	0
Main_RecrDev_2001	0.319	0.110	2	-5	5	0
Main_RecrDev_2002	−0.246	0.144	2	-5	5	0
Main_RecrDev_2003	−0.454	0.160	2	-5	5	0
Main_RecrDev_2004	0.985	0.080	2	-5	5	0
Main_RecrDev_2005	−0.070	0.113	2	-5	5	0
Main_RecrDev_2006	−1.260	0.171	2	-5	5	0
Main_RecrDev_2007	−0.878	0.135	2	-5	5	0
Main_RecrDev_2008	−0.596	0.115	2	-5	5	0
Main_RecrDev_2009	−0.403	0.102	2	-5	5	0
Main_RecrDev_2010	−0.910	0.124	2	-5	5	0

Label	Value	Parm_StDev	Phase	Min	Max	Init
Main_RecrDev_2011	−1.006	0.131	2	-5	5	0
Main_RecrDev_2012	−0.798	0.118	2	-5	5	0
Main_RecrDev_2013	−0.645	0.114	2	-5	5	0
Main_RecrDev_2014	−0.933	0.137	2	-5	5	0
Main_RecrDev_2015	−0.305	0.116	2	-5	5	0
Main_RecrDev_2016	−0.096	0.121	2	-5	5	0
Main_RecrDev_2017	−0.954	0.161	2	-5	5	0
Main_RecrDev_2018	−0.213	0.138	2	-5	5	0
Main_RecrDev_2019	0.906	0.115	2	-5	5	0
Main_RecrDev_2020	−0.170	0.163	2	-5	5	0
Main_RecrDev_2021	−0.257	0.194	2	-5	5	0
Main_RecrDev_2022	−0.059	0.226	2	-5	5	0
Main_RecrDev_2023	−1.368	0.470	2	-5	5	0
InitF_seas_1_flt_1purse_seine	0.410	0.061	1	-1	2	0.395
LnQ_base_Acoustic_survey(2)	0.273	0.100	1	-3	3	0.293
Q_extraSD_Acoustic_survey(2)	0.107	0.060	1	0	1	0.079
LnQ_base_DEPM_survey(3)	0.176	0.113	1	-3	3	0.199
Q_extraSD_DEPM_survey(3)	0.021	0.067	1	0	1	0.054
LnQ_base_Rec_survey(4)	−16.869	7.003	1	-30	3	-13.274
Q_power_Rec_survey(4)	1.024	0.457	1	0	3	0.8
Q_extraSD_Rec_survey(4)	0.833	0.203	1	0	3	0.758
AgeSel_P2_purse_seine(1)	1.638	0.153	2	-3	3	1.636
AgeSel_P3_purse_seine(1)	0.742	0.137	2	-4	4	0.738
AgeSel_P4_purse_seine(1)	−0.244	0.169	2	-4	4	-0.254
AgeSel_P7_purse_seine(1)	−0.650	0.445	2	-4	4	-0.694
AgeSel_P2_purse_seine(1)_BLK1delta_1988	−0.330	0.183	2	-4	4	-0.328
AgeSel_P2_purse_seine(1)_BLK1delta_2006	0.098	0.136	2	-4	4	0.093
AgeSel_P3_purse_seine(1)_BLK1delta_1988	−0.005	0.167	2	-4	4	-0.002
AgeSel_P3_purse_seine(1)_BLK1delta_2006	−0.142	0.131	2	-4	4	-0.187
AgeSel_P4_purse_seine(1)_BLK1delta_1988	0.888	0.191	2	-4	4	0.896
AgeSel_P4_purse_seine(1)_BLK1delta_2006	−0.613	0.133	2	-4	4	-0.596

Table 8.4.1.2. Sardine in 8c and 9a: Fishing mortality-at-age estimated in the assessment. RefF is equal to $F_{bar(2–5)}$, the reference fishing mortality, corresponding to the average F of ages 2 to 5 years.

Year	refF	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1978	0.275	0.030	0.156	0.328	0.257	0.257	0.257	0.134
1979	0.228	0.025	0.129	0.272	0.213	0.213	0.213	0.111
1980	0.232	0.026	0.132	0.277	0.217	0.217	0.217	0.113
1981	0.228	0.025	0.130	0.272	0.213	0.213	0.213	0.111
1982	0.226	0.025	0.129	0.270	0.212	0.212	0.212	0.111
1983	0.232	0.026	0.132	0.277	0.217	0.217	0.217	0.113
1984	0.234	0.026	0.133	0.280	0.219	0.219	0.219	0.114
1985	0.219	0.024	0.125	0.262	0.205	0.205	0.205	0.107
1986	0.284	0.031	0.162	0.339	0.266	0.266	0.266	0.139
1987	0.331	0.037	0.188	0.396	0.310	0.310	0.310	0.162
1988	0.403	0.031	0.115	0.240	0.457	0.457	0.457	0.208
1989	0.390	0.030	0.111	0.233	0.443	0.443	0.443	0.202
1990	0.425	0.033	0.121	0.253	0.482	0.482	0.482	0.220
1991	0.391	0.030	0.111	0.233	0.444	0.444	0.444	0.202
1992	0.287	0.022	0.082	0.171	0.326	0.326	0.326	0.149
1993	0.277	0.021	0.079	0.165	0.314	0.314	0.314	0.143
1994	0.233	0.018	0.066	0.139	0.264	0.264	0.264	0.120
1995	0.232	0.018	0.066	0.138	0.264	0.264	0.264	0.120
1996	0.314	0.024	0.090	0.187	0.356	0.356	0.356	0.162
1997	0.423	0.033	0.121	0.252	0.481	0.481	0.481	0.219
1998	0.479	0.037	0.137	0.286	0.544	0.544	0.544	0.248
1999	0.440	0.034	0.125	0.262	0.499	0.499	0.499	0.227
2000	0.391	0.030	0.112	0.233	0.444	0.444	0.444	0.202
2001	0.370	0.029	0.106	0.220	0.420	0.420	0.420	0.191
2002	0.309	0.024	0.088	0.184	0.351	0.351	0.351	0.160
2003	0.276	0.021	0.079	0.164	0.313	0.313	0.313	0.143
2004	0.305	0.024	0.087	0.182	0.347	0.347	0.347	0.158

Year	refF	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
2005	0.303	0.023	0.086	0.180	0.344	0.344	0.344	0.157
2006	0.178	0.024	0.096	0.174	0.180	0.180	0.180	0.144
2007	0.216	0.029	0.117	0.211	0.218	0.218	0.218	0.175
2008	0.346	0.046	0.186	0.338	0.348	0.348	0.348	0.280
2009	0.391	0.052	0.211	0.382	0.394	0.394	0.394	0.317
2010	0.486	0.064	0.262	0.475	0.490	0.490	0.490	0.394
2011	0.575	0.076	0.310	0.562	0.580	0.580	0.580	0.466
2012	0.458	0.061	0.247	0.447	0.461	0.461	0.461	0.371
2013	0.428	0.057	0.231	0.418	0.431	0.431	0.431	0.347
2014	0.268	0.036	0.145	0.262	0.271	0.271	0.271	0.218
2015	0.161	0.021	0.087	0.157	0.162	0.162	0.162	0.130
2016	0.156	0.021	0.084	0.152	0.157	0.157	0.157	0.126
2017	0.125	0.017	0.068	0.122	0.126	0.126	0.126	0.101
2018	0.066	0.009	0.035	0.064	0.066	0.066	0.066	0.053
2019	0.045	0.006	0.024	0.044	0.045	0.045	0.045	0.036
2020	0.054	0.007	0.029	0.052	0.054	0.054	0.054	0.044
2021	0.082	0.011	0.044	0.080	0.083	0.083	0.083	0.067
2022	0.081	0.011	0.044	0.079	0.082	0.082	0.082	0.066

Table 8.4.1.3. Sardine in 8c and 9a: Numbers-at-age, in thousands, at the beginning of the year estimated in the assessment.

Year	Age						
	0	1	2	3	4	5	6+
1978	39428400	12588700	3717130	1313990	624607	332575	440145
1979	45398800	14355600	5851540	1673990	681318	337081	460803
1980	51164700	16615400	6853430	2787180	906962	384200	491418
1981	30869800	18716400	7912110	3247000	1503770	509305	536537
1982	15821300	11297200	8932310	3766020	1758240	847520	638463
1983	71560900	5791120	5396760	4260240	2042530	992512	898318
1984	20659700	26178600	2758310	2558090	2299400	1147410	1145720
1985	17980100	7555500	12449300	1303150	1377130	1288380	1391370
1986	15190500	6586410	3623760	5987710	711438	782507	1647140
1987	33970900	5524790	3044540	1612990	3076400	380444	1463700
1988	18457900	12291000	2486300	1281050	792998	1574180	1100700
1989	17645500	6715540	5953300	1222310	543535	350192	1351070
1990	18494000	6426240	3264530	2948920	526126	243506	960235
1991	54784700	6717300	3093200	1584050	1220420	226624	665665
1992	37247100	19950800	3264760	1531590	681318	546337	497362
1993	16203900	13673000	9987350	1719450	740951	343060	589146
1994	14113700	5953150	6865530	5293570	841972	377632	547375
1995	11070900	5202900	3027080	3735850	2725250	451155	556818
1996	15568600	4081330	2645860	1647530	1924090	1460880	602858
1997	10120700	5703340	2027680	1371600	773355	940034	1093060
1998	13370100	3676430	2746410	984766	568601	333680	1047310
1999	10193200	4835880	1742320	1290080	383106	230232	729986
2000	32034000	3698100	2317910	838020	525021	162275	520772
2001	19184300	11665400	1797170	1147450	360287	234933	382219
2002	10999200	6997570	5703580	901018	505385	165162	337988
2003	8934000	4030940	3481400	2965390	425309	248293	291142

Year	Age						
	0	1	2	3	4	5	6+
2004	36770300	3282520	2024620	1846360	1453750	217013	311289
2005	13148600	13479100	1634780	1054890	875097	717138	301145
2006	4204280	4820960	6718110	853138	501506	433010	545404
2007	5998610	1541180	2379510	3528140	477893	292388	597779
2008	7606130	2187910	745256	1204100	1902050	268152	530020
2009	8659060	2727110	986589	332285	569686	936633	424184
2010	5003420	3085970	1199870	420728	150153	267936	669243
2011	4108640	1760880	1289910	466305	172752	64169	443290
2012	4525610	1429060	701541	459559	175043	67495	227237
2013	5117790	1598770	606642	280385	194228	76999	143851
2014	3945040	1815100	689670	249612	122111	88041	109093
2015	7246550	1428980	853293	331601	127656	64999	111059
2016	9927710	2662590	712051	455912	189081	75761	109769
2017	4596960	3650040	1330180	382225	261218	112757	115889
2018	9556250	1696970	1853770	735663	225846	160645	146073
2019	30514000	3555580	889985	1086660	461571	147483	206535
2020	12126100	11384300	1885590	532312	696108	307745	243922
2021	11450900	4518860	6009020	1118250	338017	460065	375013
2022	14737900	4251140	2348710	3465460	689910	217052	553130
2023	4260090	5472150	2210790	1355890	2140270	443477	516967

Table 8.4.1.4. Sardine in 8c and 9a: Summary table of the WGHANSA 2023 assessment. Coefficient of variation (CV) are presented for SSB, Recruitment and Apical F (maximum F-at-age by year); biomass and landings in tonnes, recruits in thousand of individuals, F in year-1. Catches for 2023 are an assumption.

Year	Biomass 1+	SSB	CV SSB	Recruits	CV recruits	F(2-5)	FApical	CV FApical	Landings
1978	642533	588461	0.17	39428400	0.178	0.275	0.328	0.168	145609
1979	800668	737394	0.169	45398800	0.169	0.228	0.272	0.159	157241
1980	976489	903174	0.16	51164700	0.156	0.232	0.277	0.148	194802
1981	1145170	1062400	0.149	30869800	0.18	0.228	0.272	0.139	216517
1982	1054360	1000240	0.149	15821300	0.246	0.226	0.27	0.13	206946
1983	827293	798732	0.159	71560900	0.108	0.232	0.277	0.126	183837
1984	1224510	1117030	0.111	20659700	0.187	0.234	0.28	0.122	206005
1985	1025790	983118	0.107	17980100	0.179	0.219	0.262	0.094	208439
1986	818488	788518	0.107	15190500	0.191	0.284	0.339	0.119	187363
1987	651192	626049	0.11	33970900	0.122	0.331	0.396	0.121	177696
1988	708430	656779	0.096	18457900	0.16	0.403	0.457	0.109	161531
1989	624718	591902	0.097	17645500	0.159	0.39	0.443	0.107	140961
1990	560947	531977	0.098	18494000	0.157	0.425	0.482	0.106	149429
1991	514930	484968	0.104	54784700	0.088	0.391	0.444	0.109	132587
1992	853418	770350	0.081	37247100	0.1	0.287	0.326	0.1	130250
1993	966040	901361	0.071	16203900	0.144	0.277	0.314	0.094	142495
1994	813719	783041	0.072	14113700	0.136	0.233	0.264	0.081	136582
1995	674319	650481	0.073	11070900	0.139	0.232	0.264	0.076	125280
1996	540206	521235	0.076	15568600	0.111	0.314	0.356	0.08	116736
1997	476598	451757	0.076	10120700	0.133	0.423	0.481	0.082	115814
1998	380654	363202	0.082	13370100	0.115	0.479	0.544	0.089	108924
1999	364031	352617	0.083	10193200	0.137	0.44	0.499	0.093	94091
2000	310306	293195	0.091	32034000	0.086	0.391	0.444	0.096	85786
2001	470430	398641	0.076	19184300	0.11	0.37	0.42	0.093	101957
2002	479251	417566	0.075	10999200	0.144	0.309	0.351	0.093	99673
2003	453540	417811	0.078	8934000	0.16	0.276	0.313	0.085	97831
2004	396905	368620	0.085	36770300	0.073	0.305	0.347	0.084	98020

Year	Biomass 1+	SSB	CV SSB	Recruits	CV recruits	F(2-5)	FApical	CV FApical	Landings
2005	532680	423212	0.072	13148600	0.109	0.303	0.344	0.081	97345
2006	626825	574821	0.063	4204280	0.171	0.178	0.18	0.097	87023
2007	494379	482752	0.065	5998610	0.132	0.216	0.218	0.077	96469
2008	386065	378756	0.067	7606130	0.109	0.346	0.348	0.078	101464
2009	292342	285902	0.07	8659060	0.096	0.391	0.394	0.09	87740
2010	247247	244161	0.068	5003420	0.124	0.486	0.49	0.099	89571
2011	178964	177204	0.079	4108640	0.132	0.575	0.58	0.113	80403
2012	133832	132403	0.101	4525610	0.131	0.458	0.461	0.13	54857
2013	125064	123465	0.118	5117790	0.138	0.428	0.431	0.153	45818
2014	131777	131777	0.135	3945040	0.169	0.268	0.271	0.169	27937
2015	126440	125587	0.151	7246550	0.153	0.161	0.162	0.174	20595
2016	163733	163733	0.148	9927710	0.163	0.156	0.157	0.175	22704
2017	213644	212314	0.152	4596960	0.195	0.125	0.126	0.179	21911
2018	208593	206739	0.159	9556250	0.174	0.066	0.066	0.175	15062
2019	244722	237611	0.155	30514000	0.149	0.045	0.045	0.16	13759
2020	493513	470744	0.139	12126100	0.185	0.054	0.054	0.157	22143
2021	508698	501131	0.138	11450900	0.216	0.082	0.083	0.156	40686
2022	479464	471719	0.146	14737900	0.242	0.081	0.082	0.151	40429
2023	480817	480894	0.151	4260090	0.488				50000

Table 8.6.1. Sardine in 8c and 9a: Input data for short-term catch predictions. Number-at-age for 2023 and recruitment for 2024. Input values for stock weight, catch weight, natural mortality (M) and fishing mortality (F) at-age. Input units are thousands and kg.

Year = 2023						
Age	Numbers	Stock weights	Catch weights	Maturity	M	F
0	4260090	0.000	0.029	0.000	0.98	0.014
1	5472150	0.023	0.046	0.955	0.61	0.058
2	2210790	0.044	0.057	0.991	0.47	0.105
3	1355890	0.053	0.066	0.998	0.40	0.108
4	2140270	0.058	0.076	1.000	0.36	0.108
5	443477	0.060	0.083	0.999	0.35	0.108
6	516967	0.068	0.095	0.998	0.32	0.087
Recruitment in 2024 = 12161380 Weights, maturity and mortality in 2024 are the same as in 2023						

Table 8.6.2. Sardine in 8.c and 9.a: Output data for short-term catch predictions.

B1+ 2023 = 480 817tonnes; Catch 2023 = 50 000 tonnes ; F 2023 = 0.107					
Catch (2024)	F (2024)	B1+ (2025)	[1]% Change in B1+	[2]% Change Quota	[3]% Change Advice
103030	0.26	344786	-13	82	135
245005	0.74	252517	-36	333	459
335577	1.175	196427	-50	493	665
45091	0.107	383503	-3	-20	3
38992	0.092	387606	-2	-31	-11
103030	0.26	344786	-13	82	135
44450	0.105	383934	-3	-21	1
30000	0.07	393667	-1	-47	-32
35000	0.082	390296	-1	-38	-20

[1]Biomass 1+ in 2025 relative to Biomass 1+ in 2024 (395 984 tonnes).

[2]Catches in 2024 compared to quota legislated for 2023 (56 604 tonnes)

[3]Advised catches in 2024 compared to 2023 catches (43 841 tonnes) .

Table 8.6.1.1 Sardine in 8.c and 9.a: Ratio of the numbers-at-age and the biomass-at-age estimated in the current assessment and the previous assessment.

Numbers			Biomass		
2020	2021	2022	2020	2021	2022
1.34	1.05	0.76	NaN	NaN	NaN
1.17	1.34	1.05	1.17	1.28	0.95
1.15	1.17	1.35	1.15	1.20	1.34
1.16	1.15	1.19	1.16	1.18	1.11
1.13	1.17	1.17	1.13	1.17	1.09
1.13	1.14	1.19	1.13	1.09	1.09
1.12	1.13	1.15	1.12	1.08	1.13

Table 8.6.1.2 Sardine in 8.c and 9.a: Forecast assumptions from previous and current assessments. Recruitment in millions, catch in tonnes.

Variable	Year	Previous	Current
Recruitment	Intermediate	19424400	4260090
	Advice	13330753	12161380
Catch	Intermediate	44262	50000
	Advice	43841	38992
F target	Intermediate	0.101	0.107
	Advice	0.092	0.092

8.11 Figures

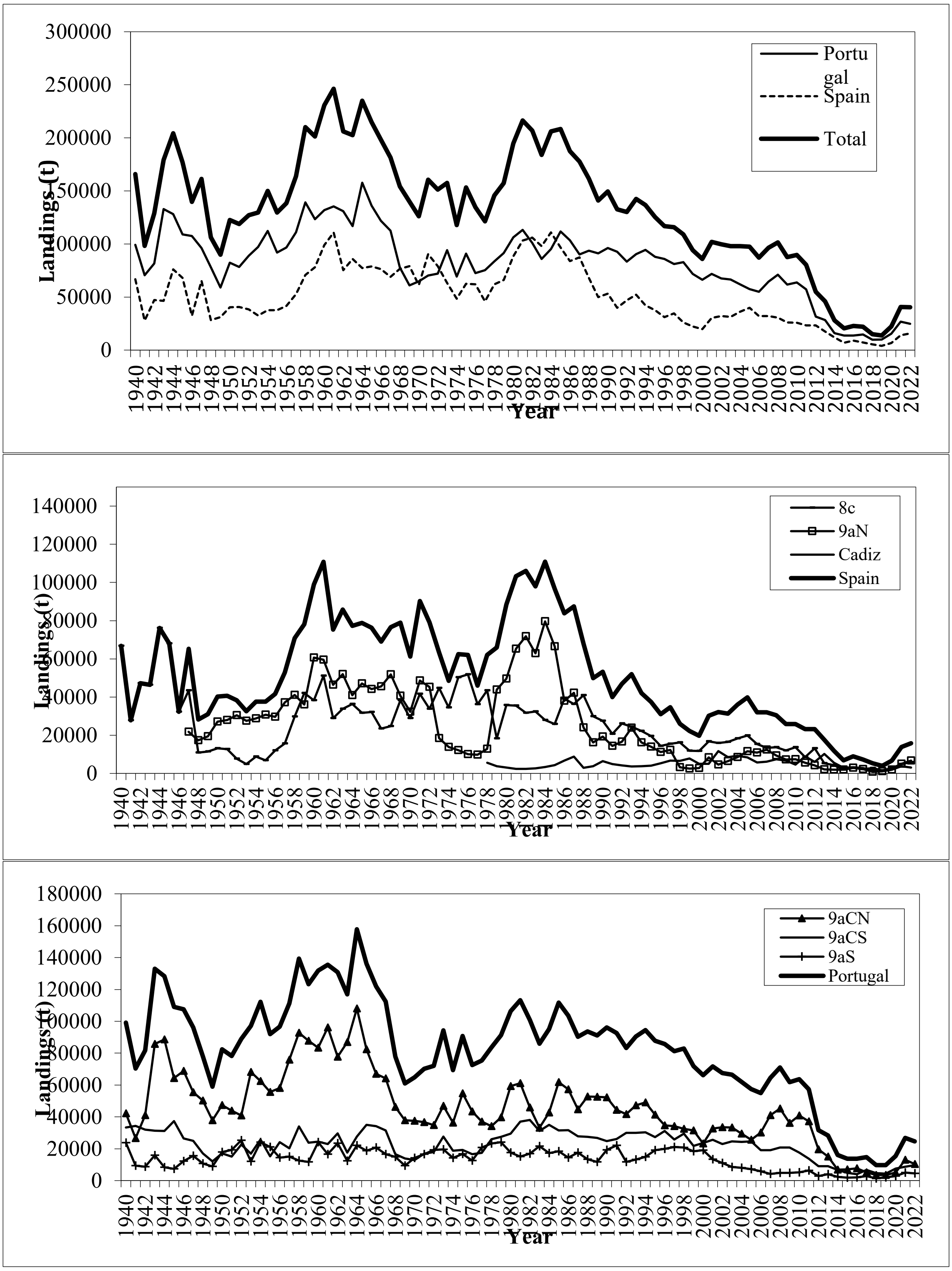


Figure 8.2.2.1: Sardine in 8c and 9a: WG estimates of annual landings of sardine, by country (upper pannel) and by ICES subdivision and country.

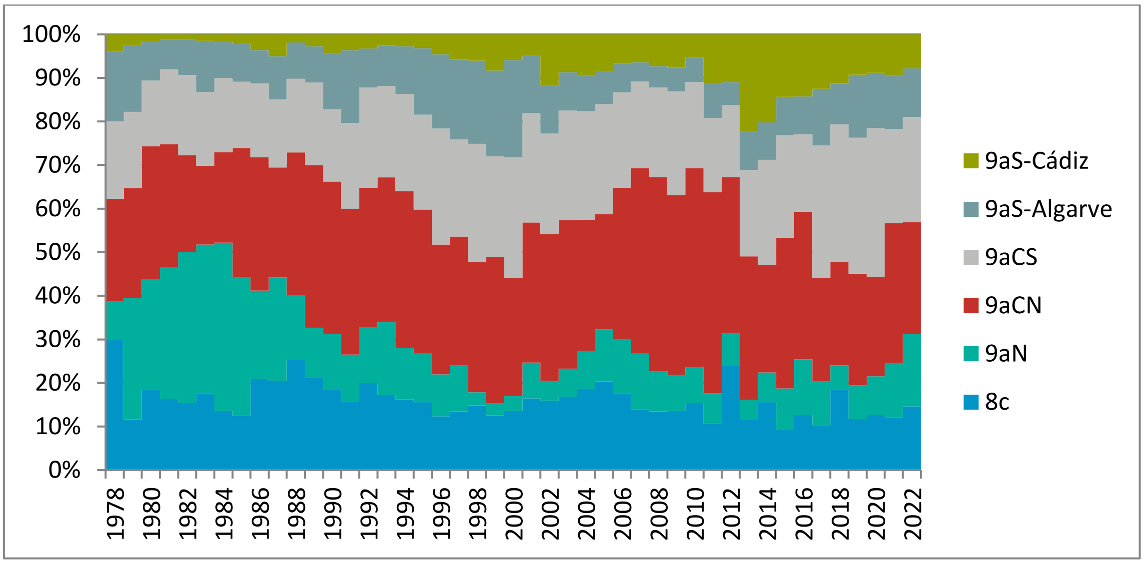


Figure 8.2.2.2: Sardine in 8c and 9a: Historical relative contribution of the different subdivisions to the total catches (1978-2022).

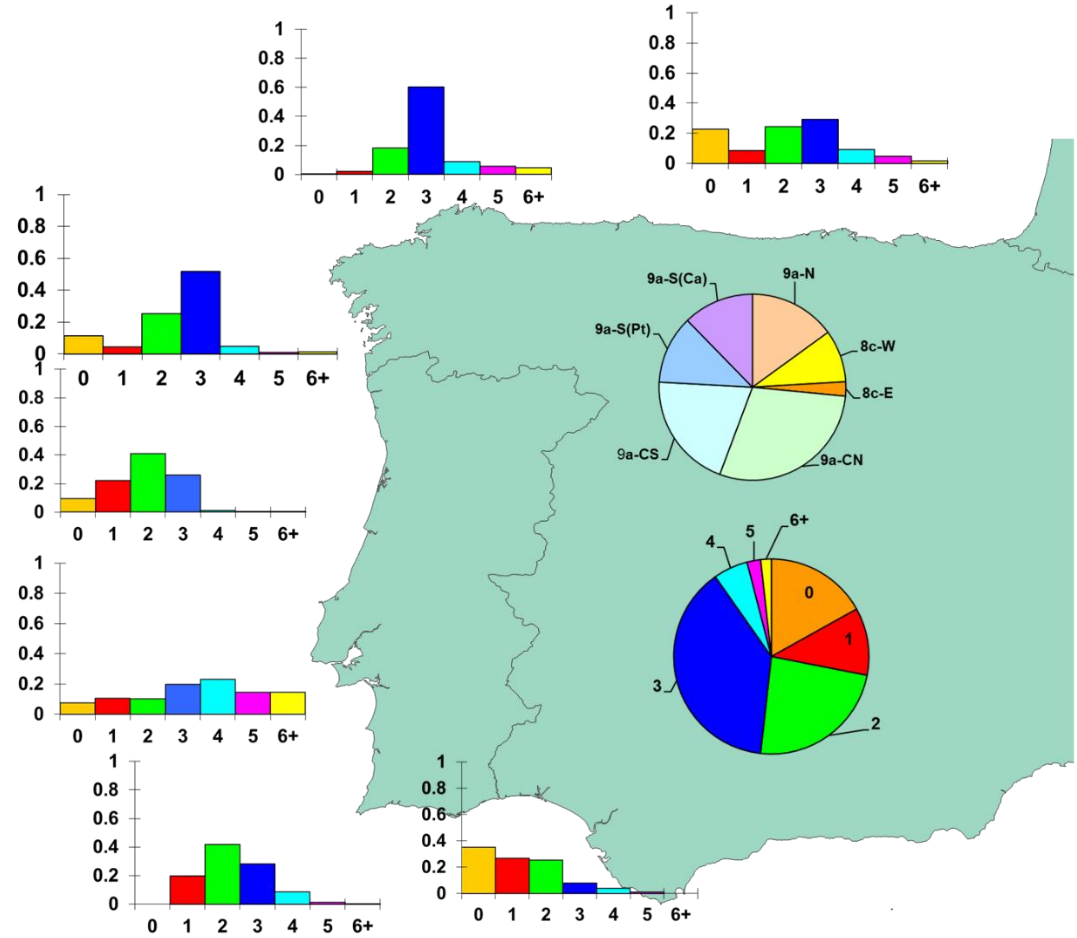


Figure 8.2.4.1.: Sardine in 8c and 9a: Relative contribution of each age-class by subdivisions as well as their relative contribution to the 2022 catches (pie-chart).

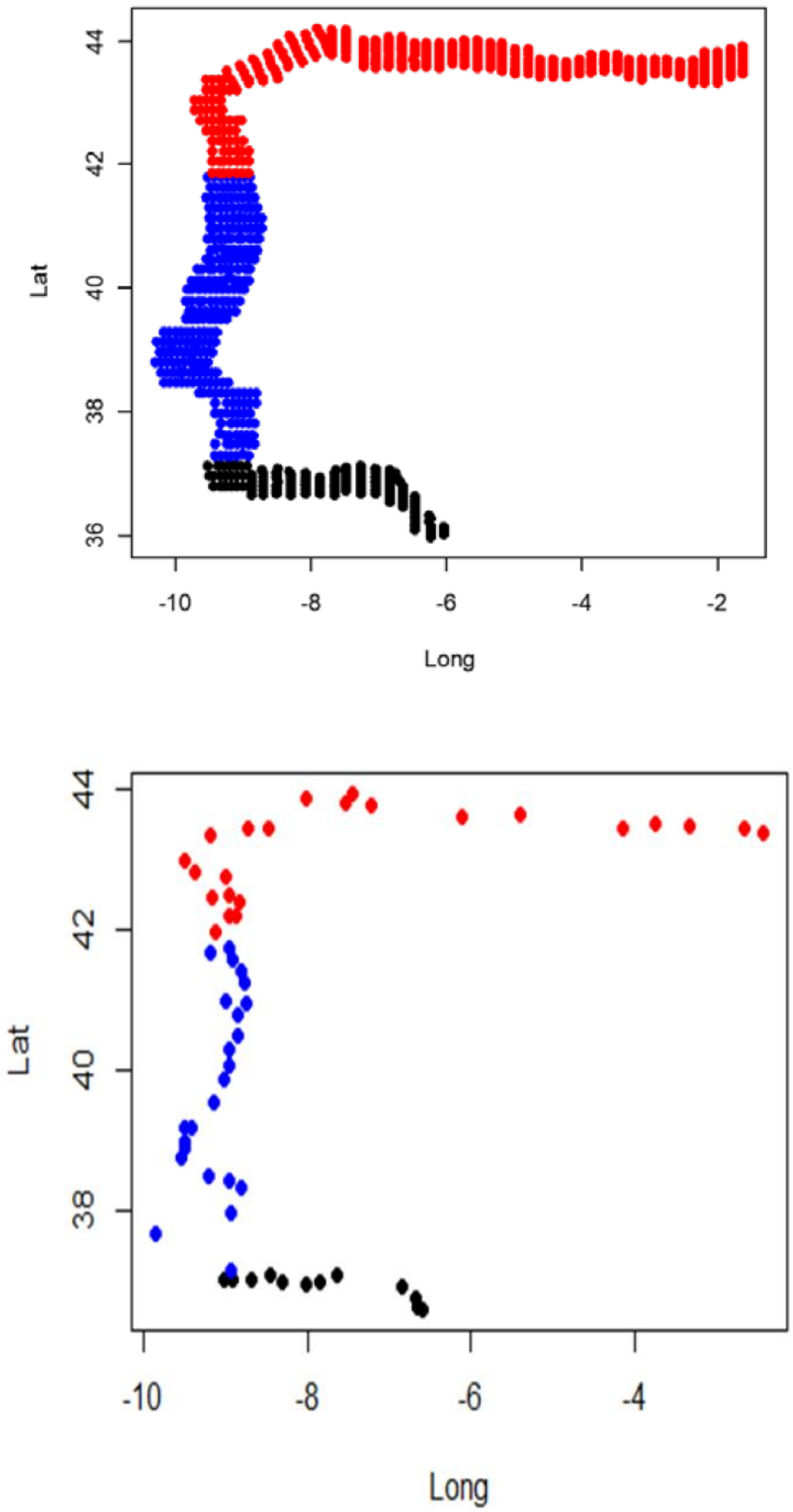
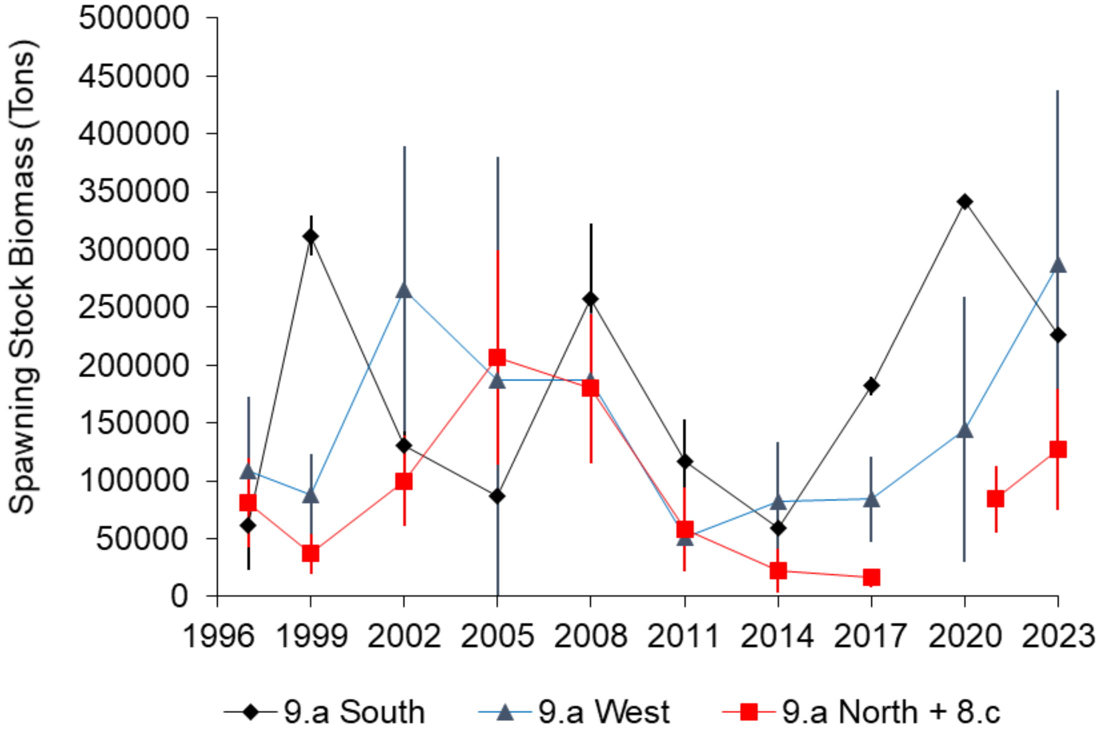


Figure 8.3.1.1. Sardine in 8c and 9a: Sampled area for both plankton and adult stations during DEPM surveys in 2023. Top) Plankton stations (South-black, west-blue and north-red strata) Bottom) Fishing stations (South-black, west-blue and north-red strata).



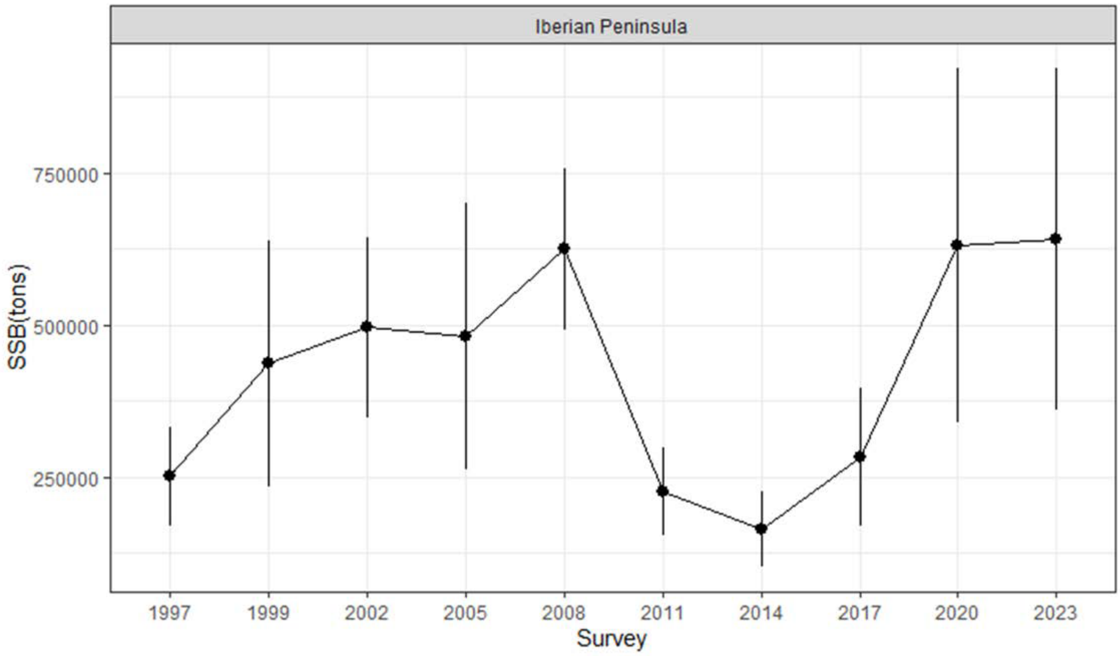


Figure 8.3.1.2. Sardine in 8c and 9a: Spawning stock biomass estimated by DEPM along the time series Top) SSB estimated by strata (South-black, west-blue and north-red) Bottom) SSB index for sardine assessment model, whole stock.

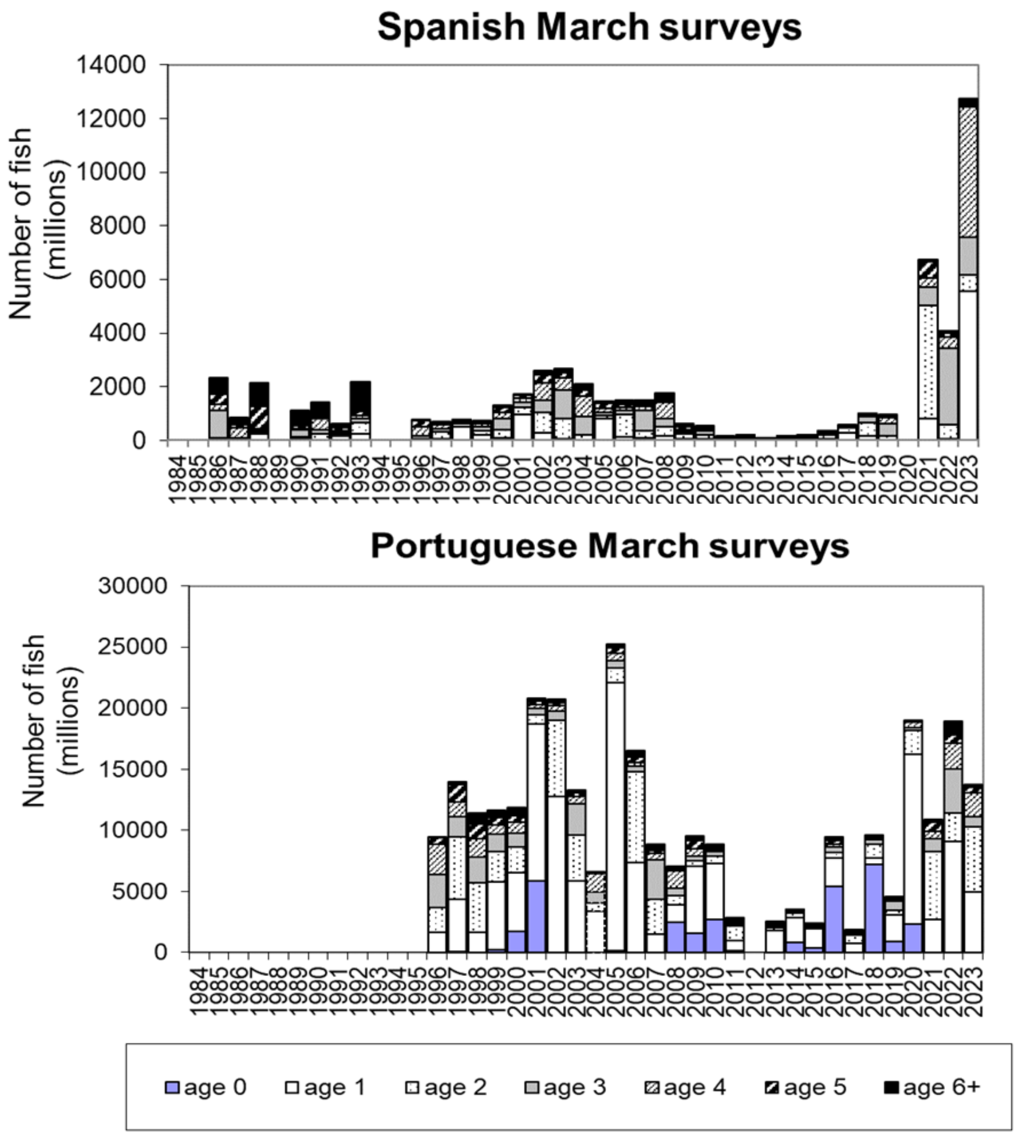


Figure 8.3.1: Sardine in 8c and 9a: Total abundance and age structure (numbers) of sardine estimated in the acoustic surveys. The Spanish March survey series covers area 8c and 9a-N (top panel) and the Portuguese March surveys covers 9aCN, 9a-CS, 9aS-Algarve and 9aS-Cadiz subdivisions (bottom panel). Portuguese acoustic survey in June 2004 was only considered as indications of the population abundance and is not included in assessment. Estimates from Portuguese acoustic surveys are not available for 2012 and for Spanish survey in 2020 (years without survey).

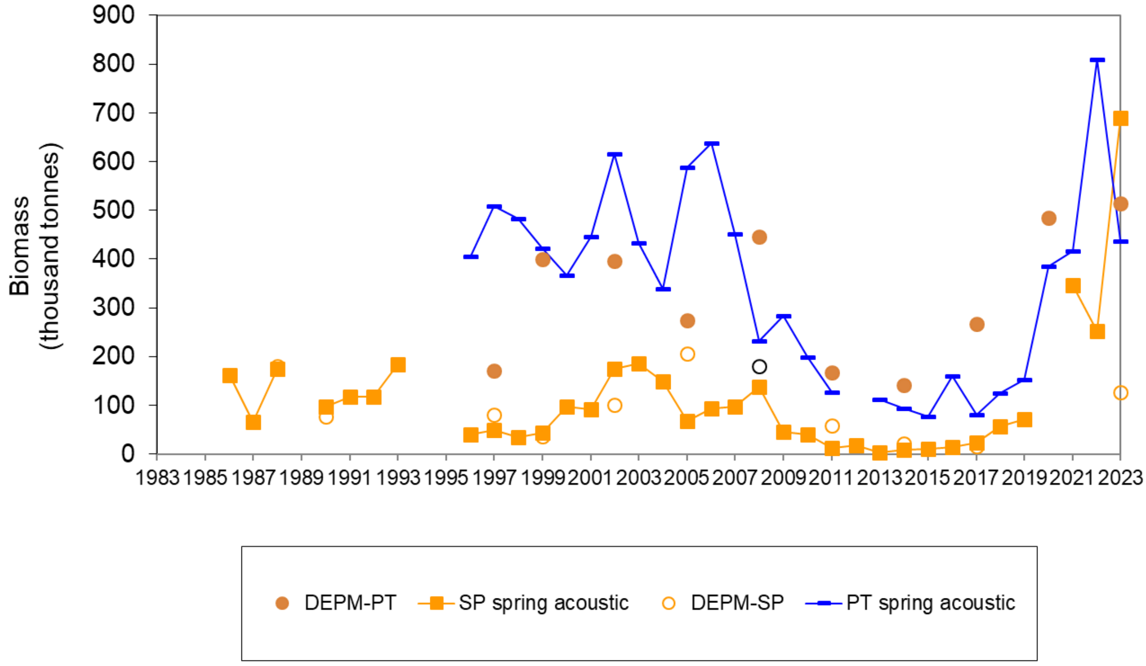


Figure 8.3.2: Sardine in 8c and 9a: Total sardine biomass (thousand tonnes) estimated in the different series of acoustic surveys and SSB estimates from the DEPM series covering the northern area and the west and southern area of the stock.

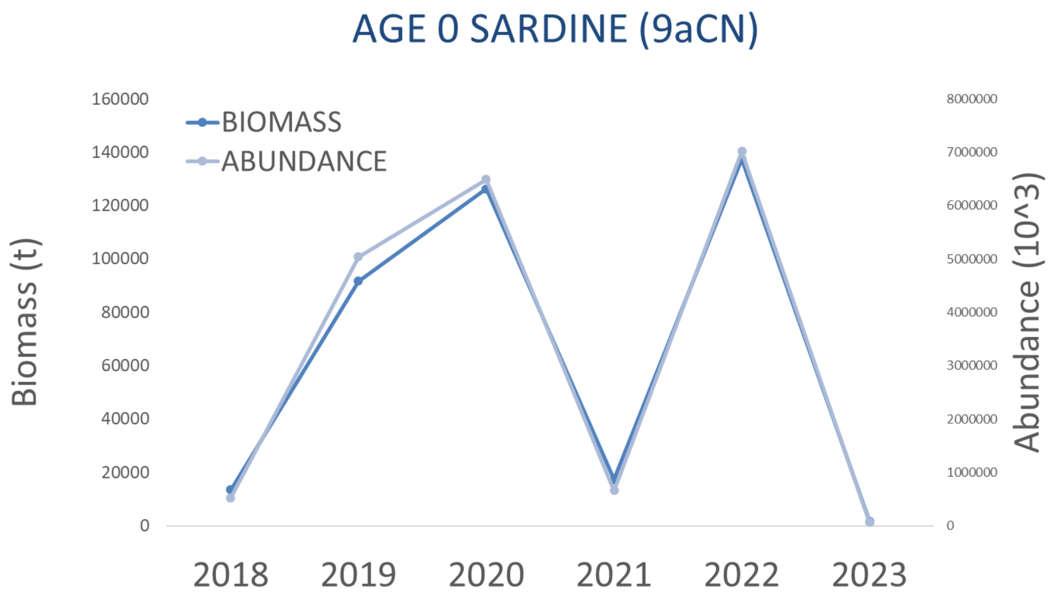


Figure 8.3.3: Sardine in 8c and 9a. Recruitment index. Age 0 Individuals (thousands) estimated in IBERAS autumn acoustic survey time series 2018-2023 (thousand tonnes) in 9aCN subdivision.

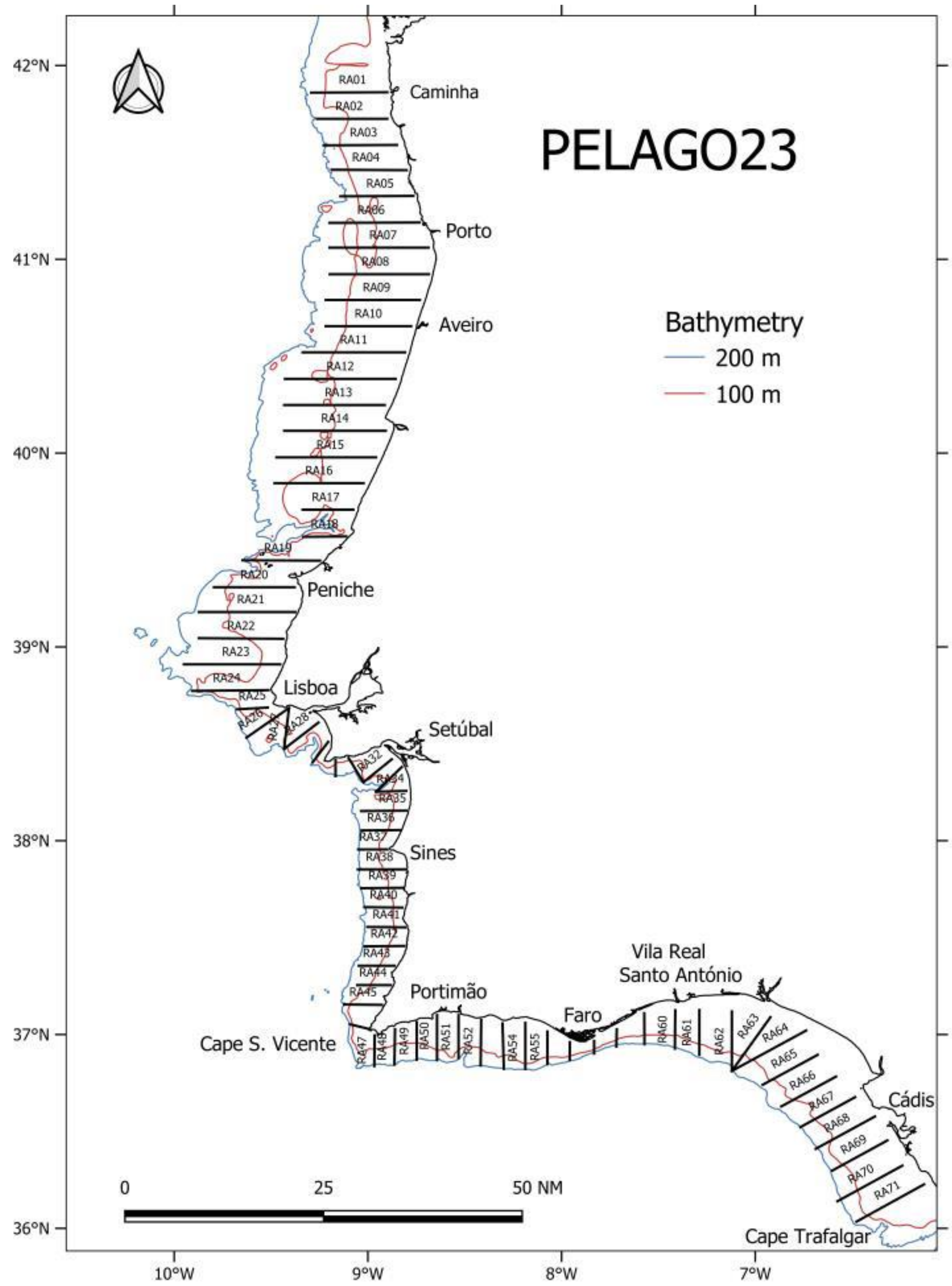


Figure 8.3.2.1.1. Sardine in 8c and 9a: acoustic transects during PELAGO 2023 survey.

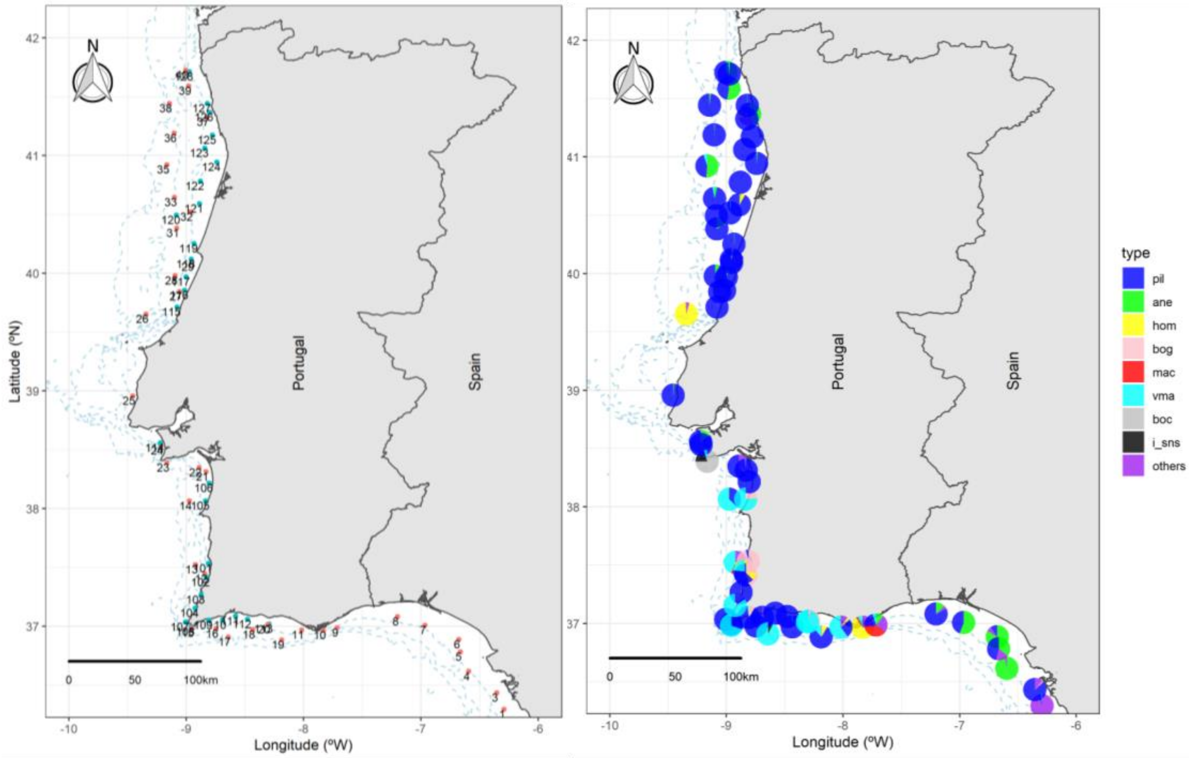


Figure 8.3.2.1.2: Sardine in 8c and 9a: Fishing haul operations during PELAGO 2023 survey. Left) Purse seiners hauls (blue) and research vessels hauls (red). Right) Species composition in the catches, sardine in dark blue..

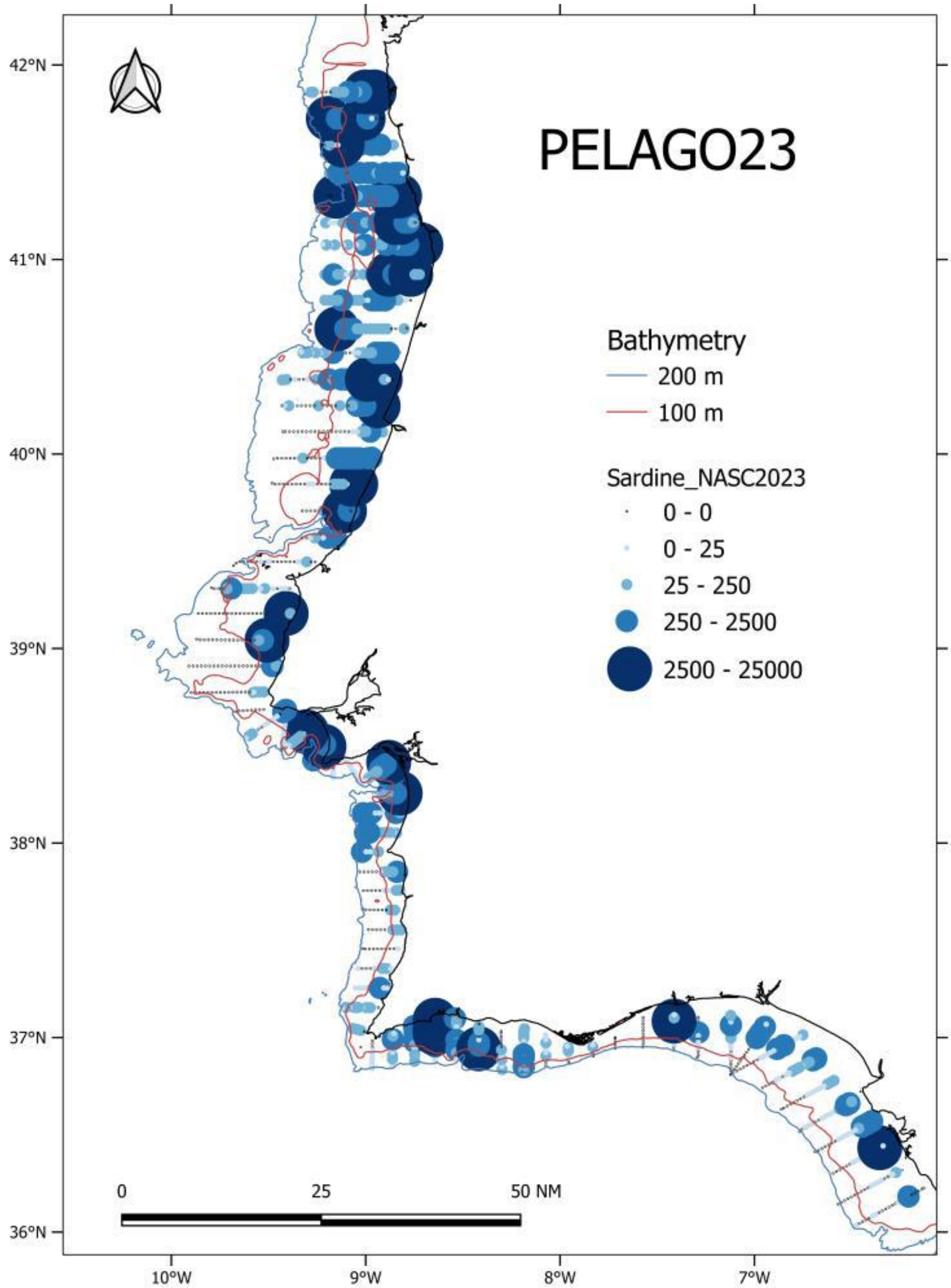


Figure 8.3.2.1.3: Sardine in 8c and 9a: Acoustic energy during PELAGO2023.

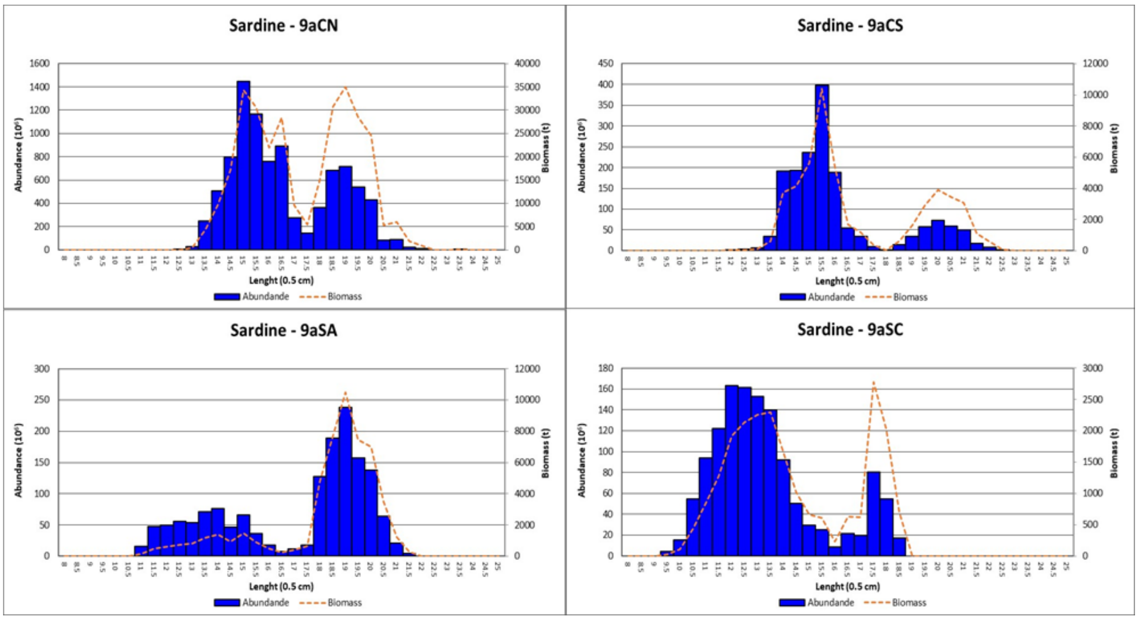


Figure 8.3.2.1.4: Sardine in 8c and 9a: Size composition during PELAGO2023.

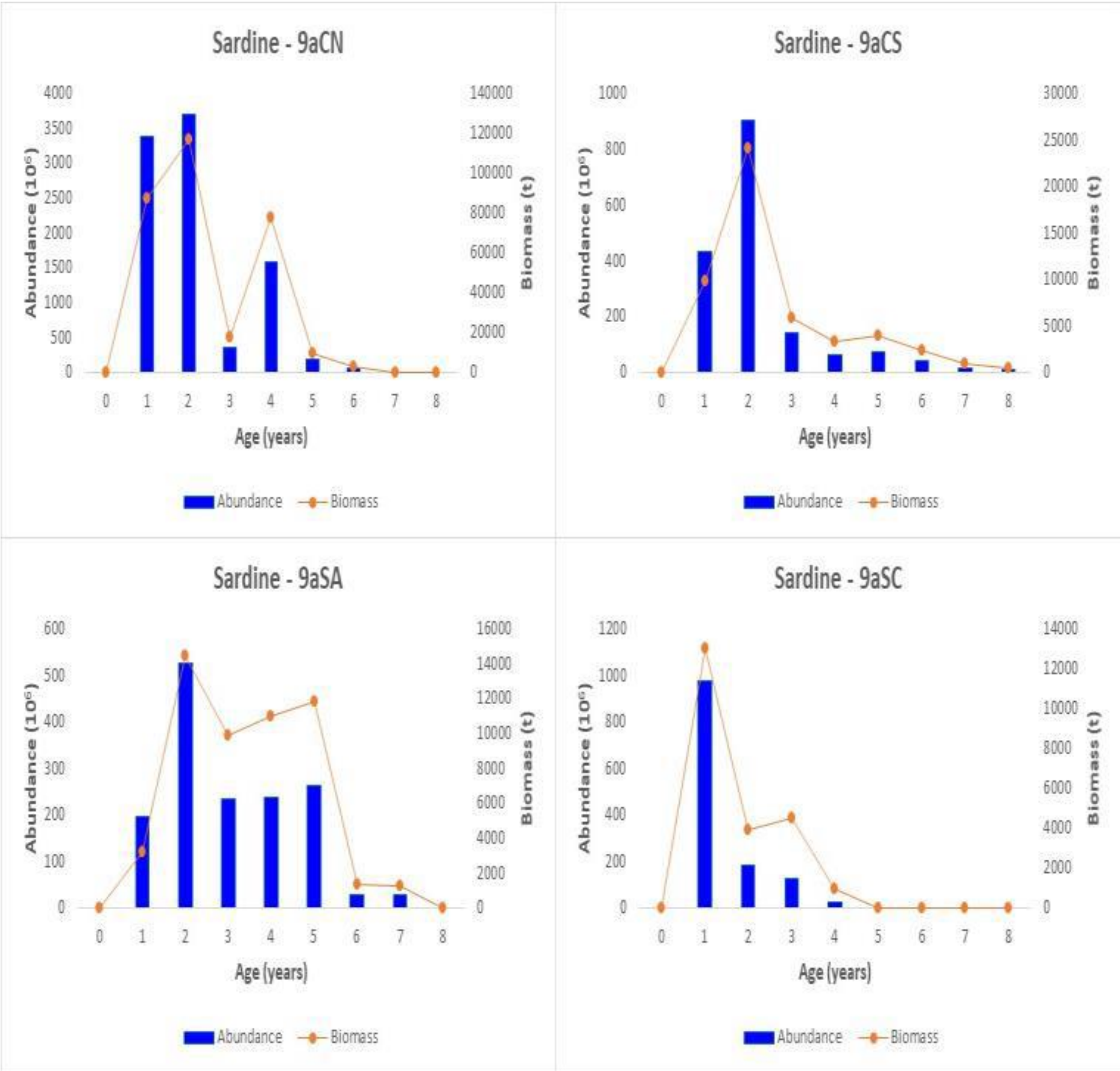


Figure 8.3.2.1.5: Sardine in 8c and 9a: Age composition during PELAGO2023.

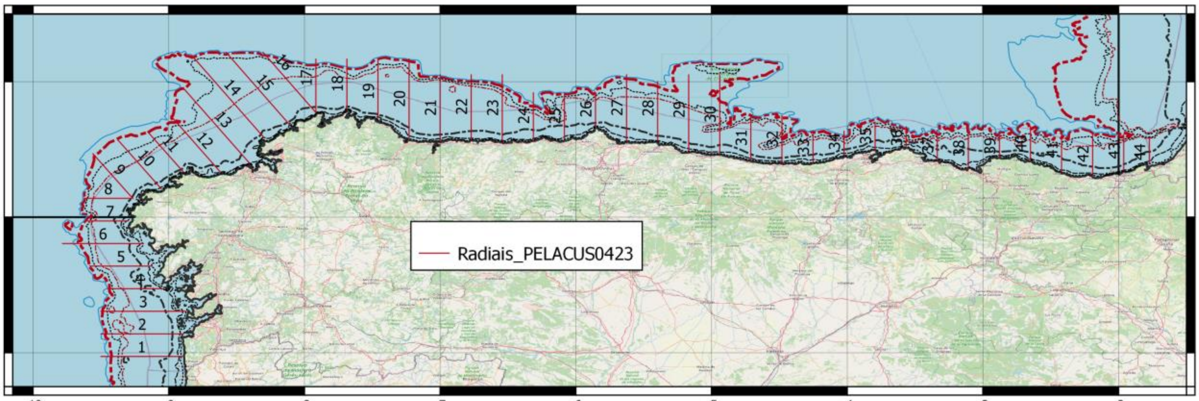


Figure 8.3.2.2.1 Sardine in 8c and 9a: Survey track of PELACUS0423 survey.

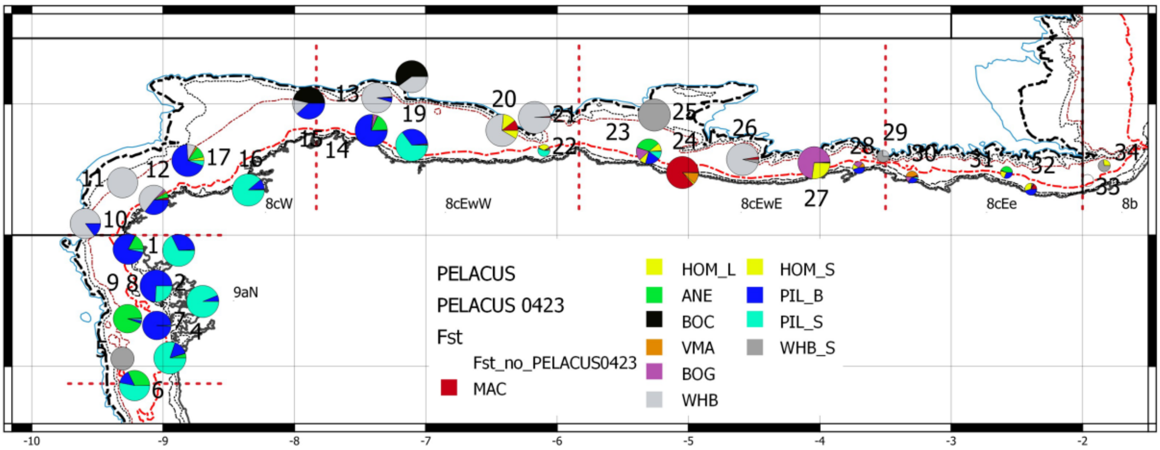


Figure 8.3.2.2.2. Sardine in 8c and 9a: Fishing stations and catch composition (% in number of fish caught) in PELACUS0423 survey. Big sardine (>16 cm) in dark blue, and small sardine (<16 cm) in light blue.

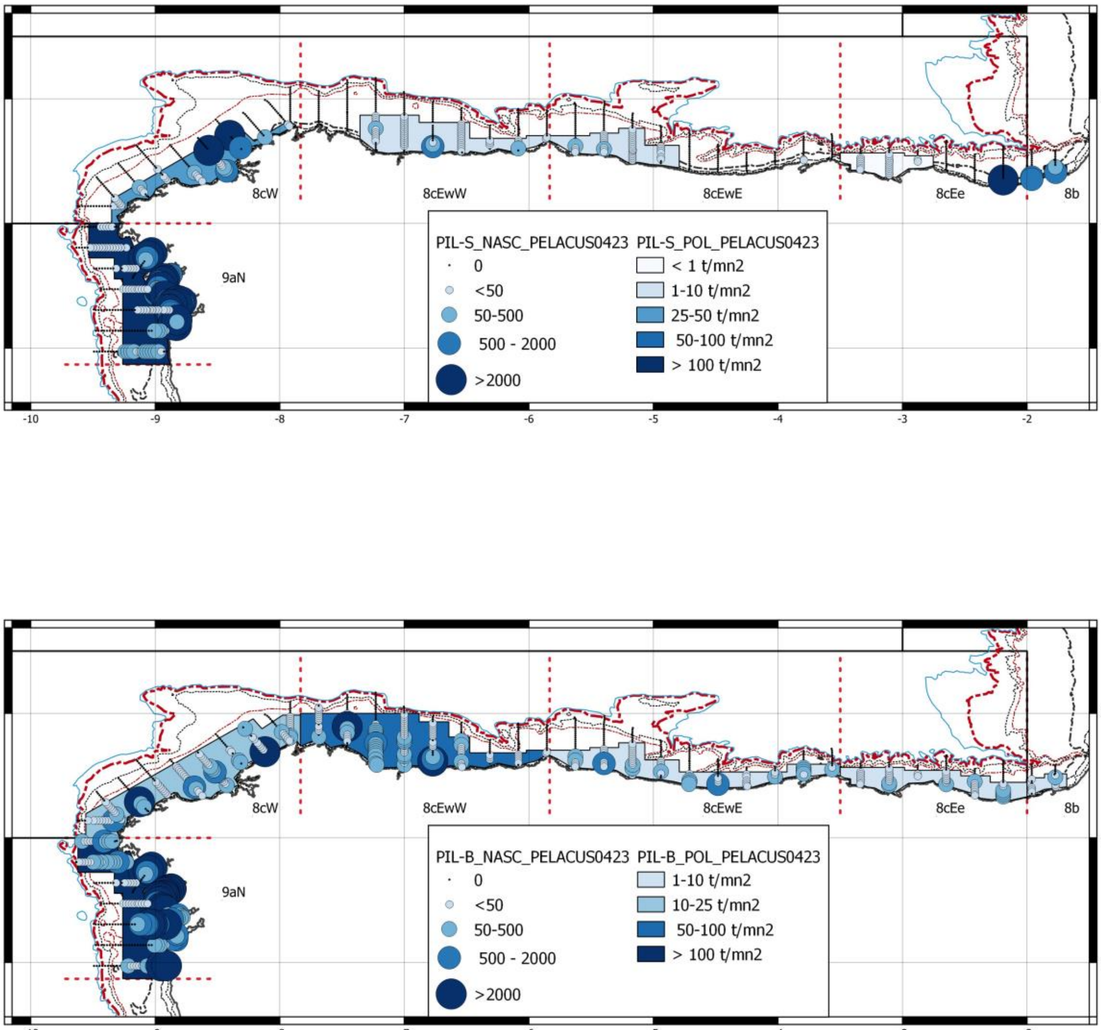


Figure 8.3.2.2.3. Sardine in 8c and 9a: Sardine spatial distribution in PELACUS0423 survey. Top panel (small sardine, <16 cm), bottom pannel, big sardine (>16 cm).

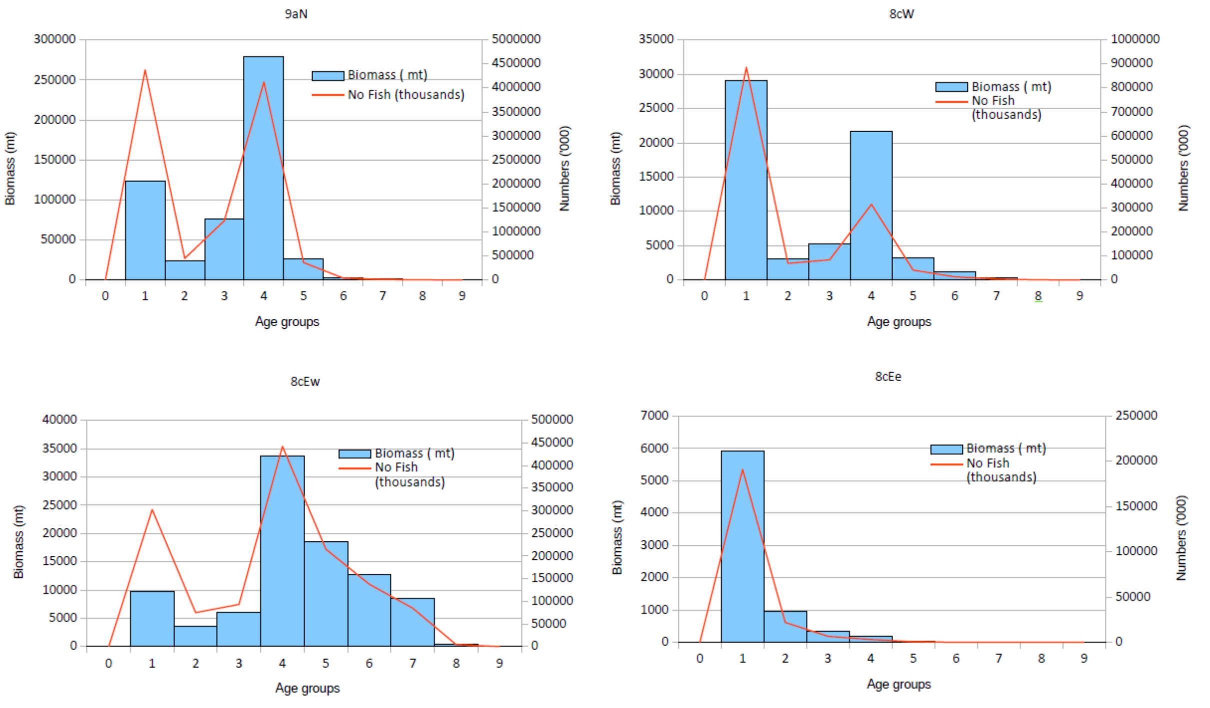


Figure 8.3.2.2.4. Sardine abundance by age group and area, estimated in PELACUS 0423.

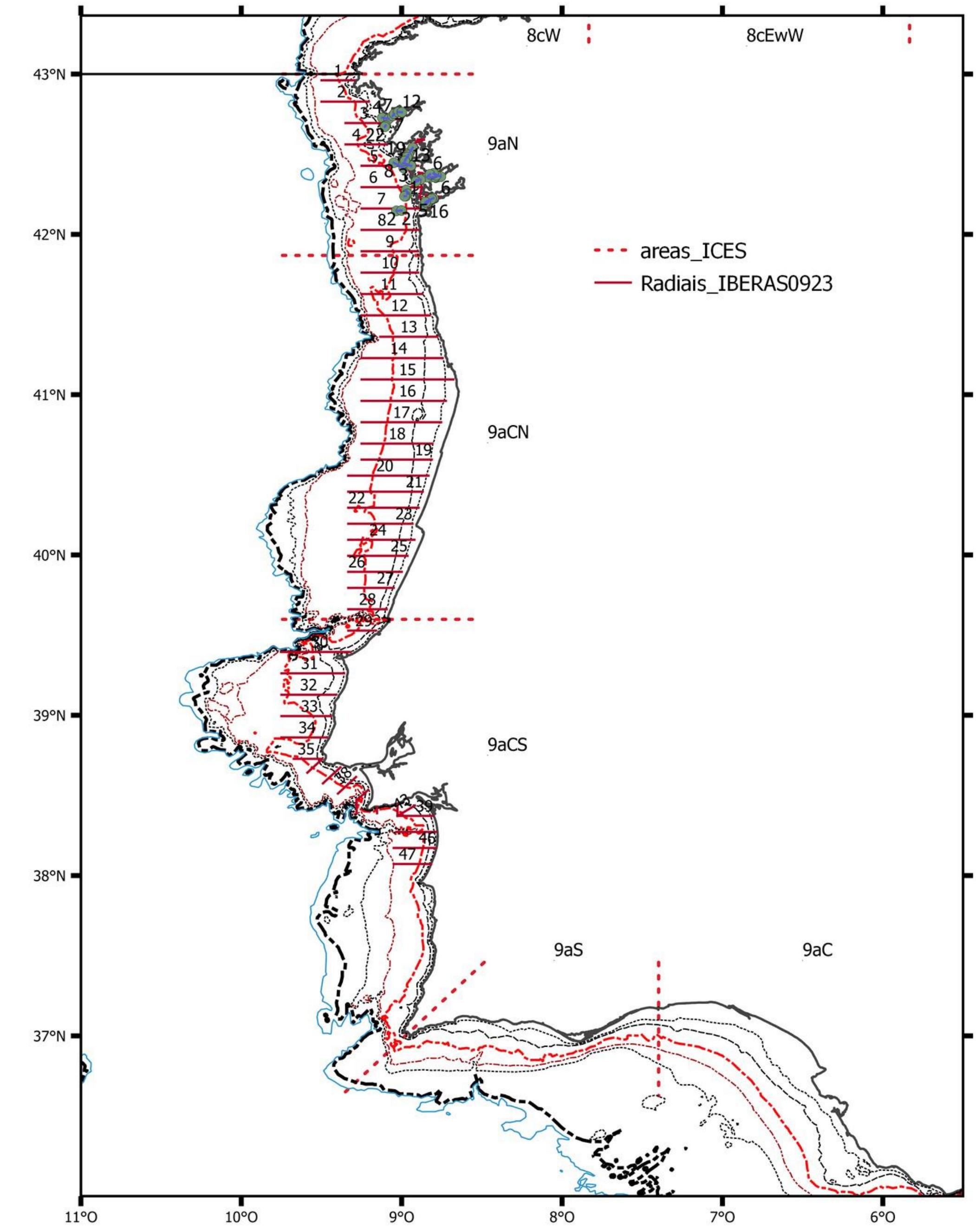


Figure 8.3.3.1. Sardine in 8c and 9a: Survey track of IBERAS0923 survey.

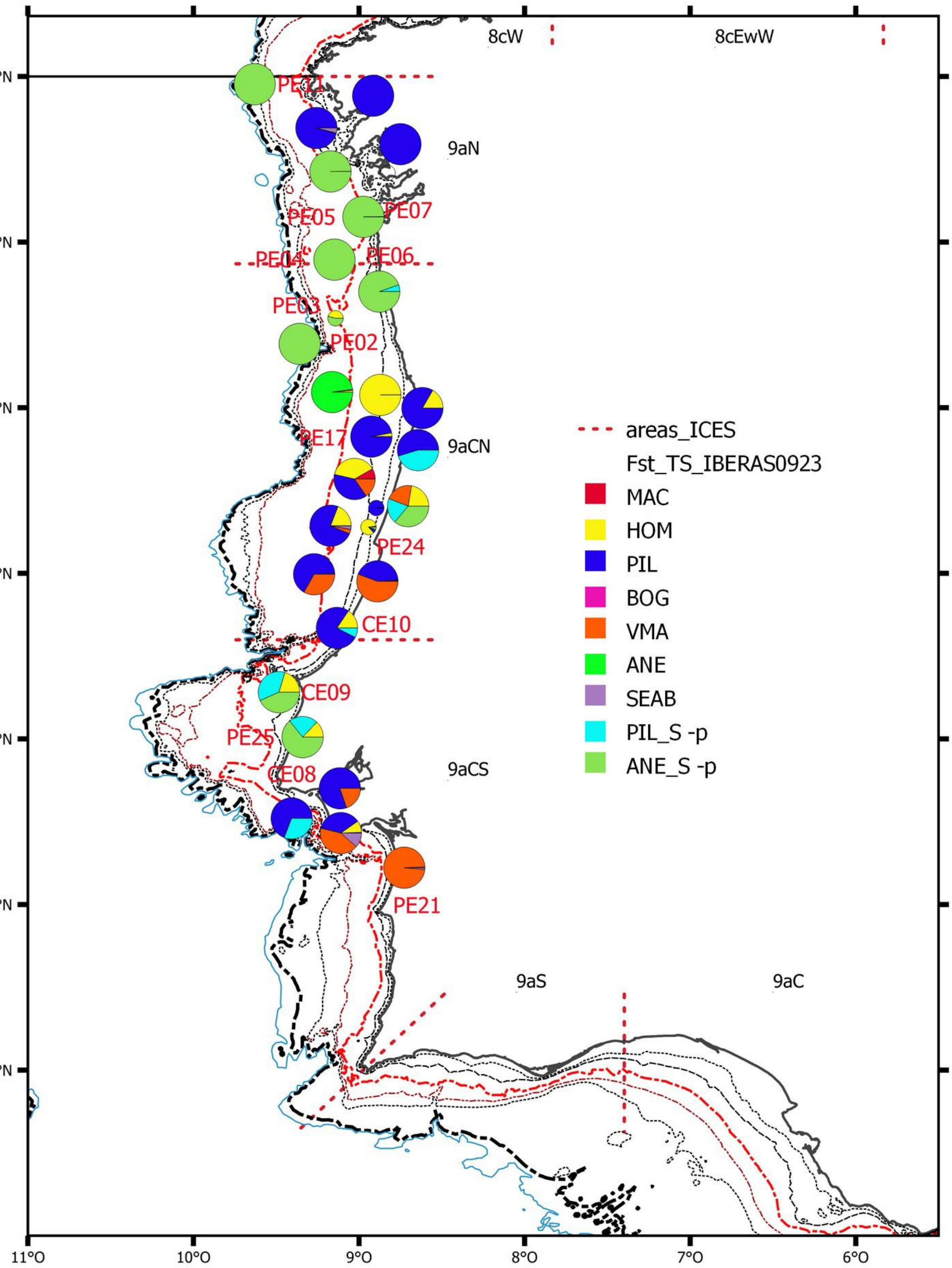


Figure 8.3.3.2. Sardine in 8c and 9a: Fishing stations and catch composition (% in number of fish caught) in IBERAS2023 survey ;PIL-adult sardine (dark blue); PIL_S: juvenile sardine (light blue).

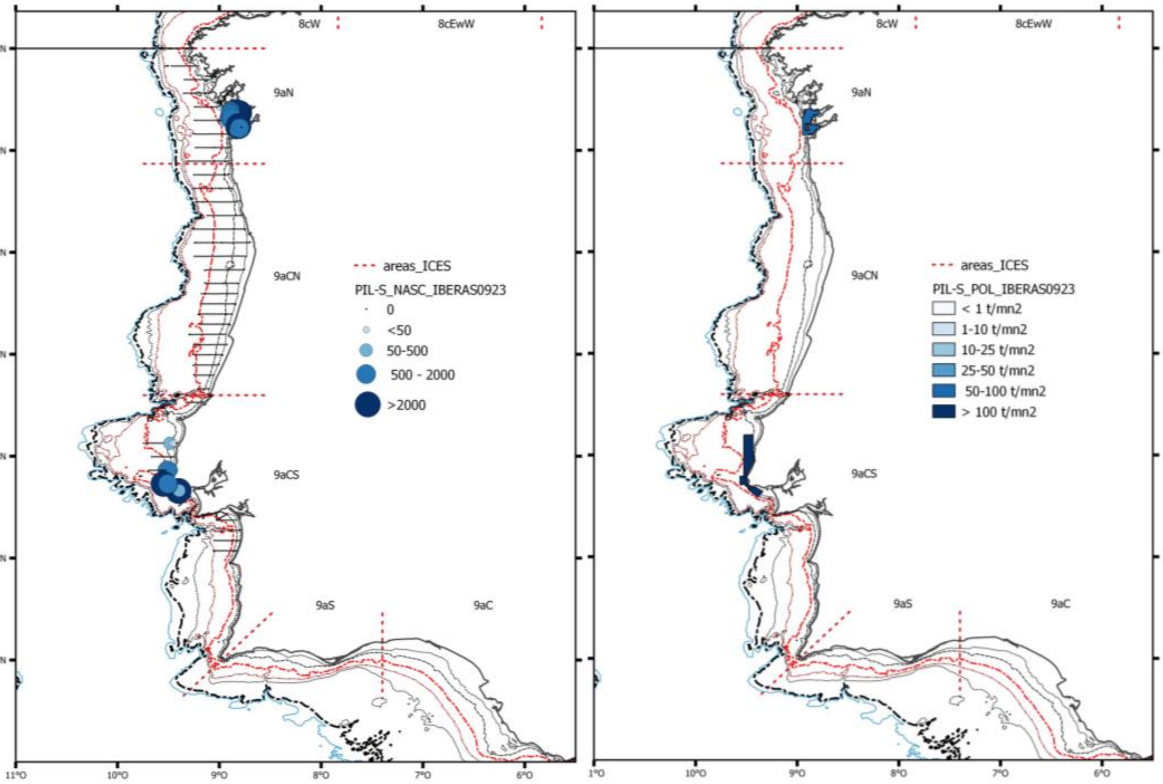


Figure 8.3.3.3. Sardine in 8c and 9a: Sardine juvenile spatial distribution in IBERAS2023 survey, a) Allocated NASC b) Conversion to biomass.

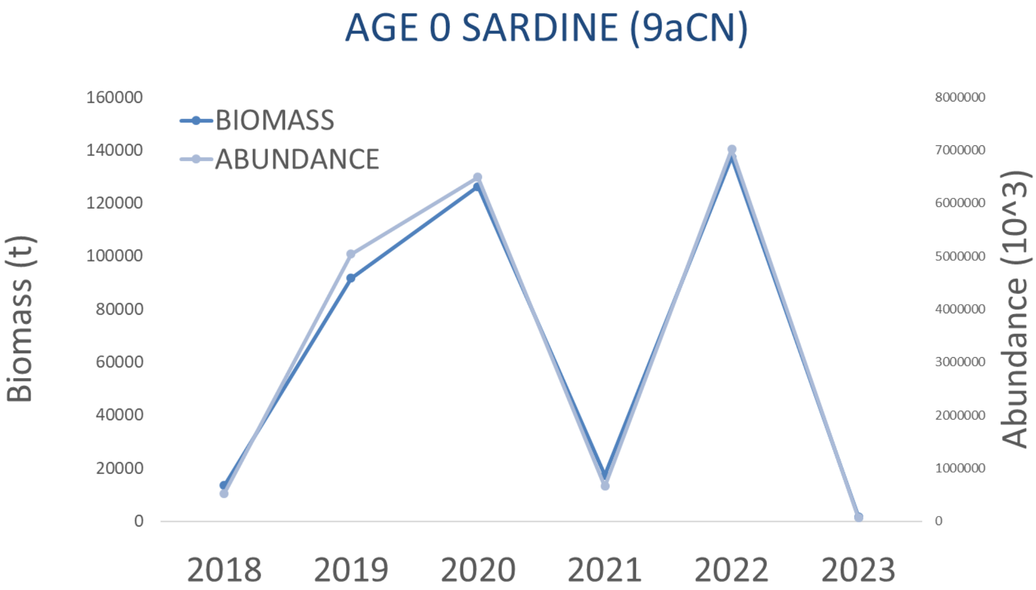


Figure 8.3.3.4. Sardine in 8c and 9a: Age 0 Sardine abundance and biomass in the IBERAS time series.

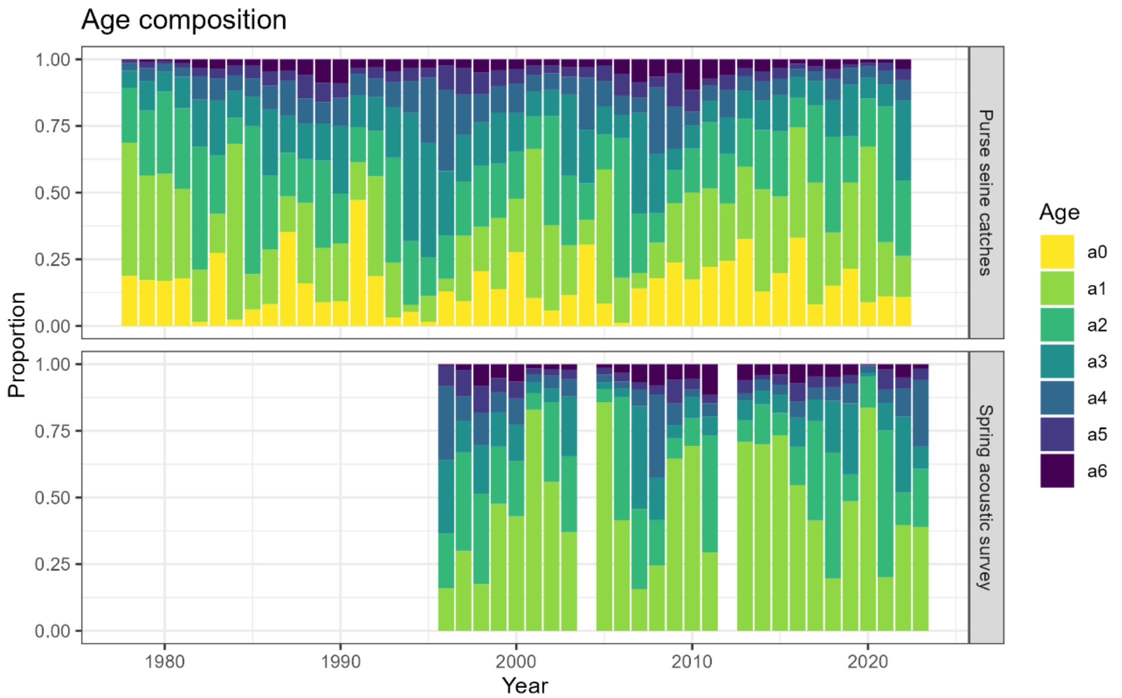


Figure 8.3.8.1. Sardine in 8c and 9a: Catches-at-age for 1978–2023 (top panel) and abundance-at-age in the joint Spanish-Portuguese spring acoustic survey 1996–2023 (bottom panel).

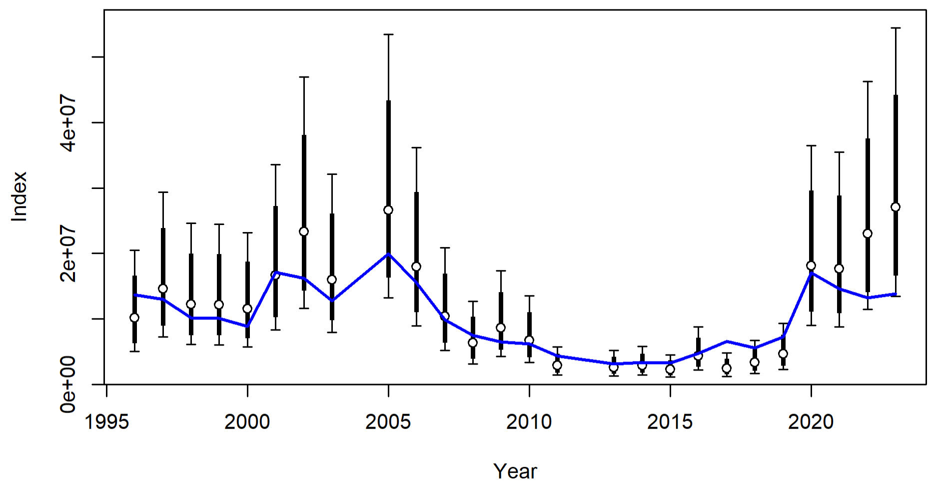


Figure 8.4.1.1. Sardine in 8c and 9a: Model fit to the acoustic survey series. The index is total abundance (in thousands of individuals). Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

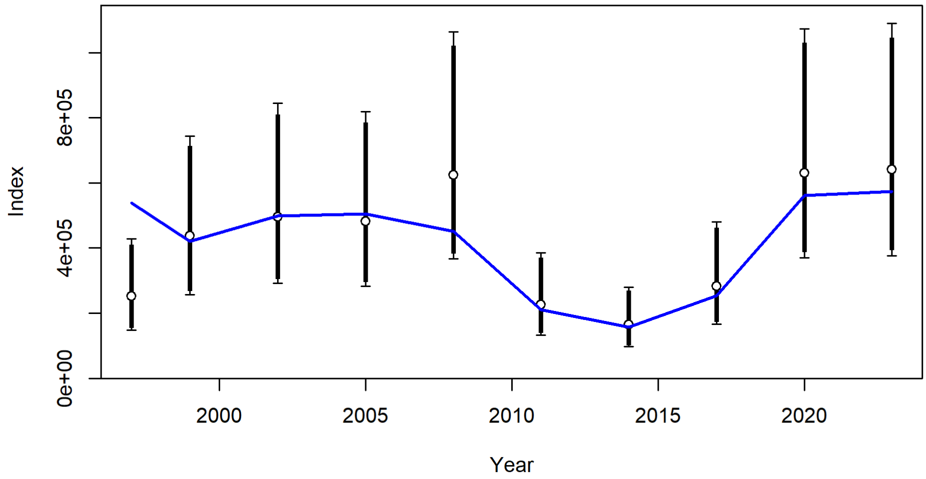


Figure 8.4.1.2. Sardine in 8c and 9a: Model fit to the DEPM survey series. The index is SSB (in thousand tonnes). Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

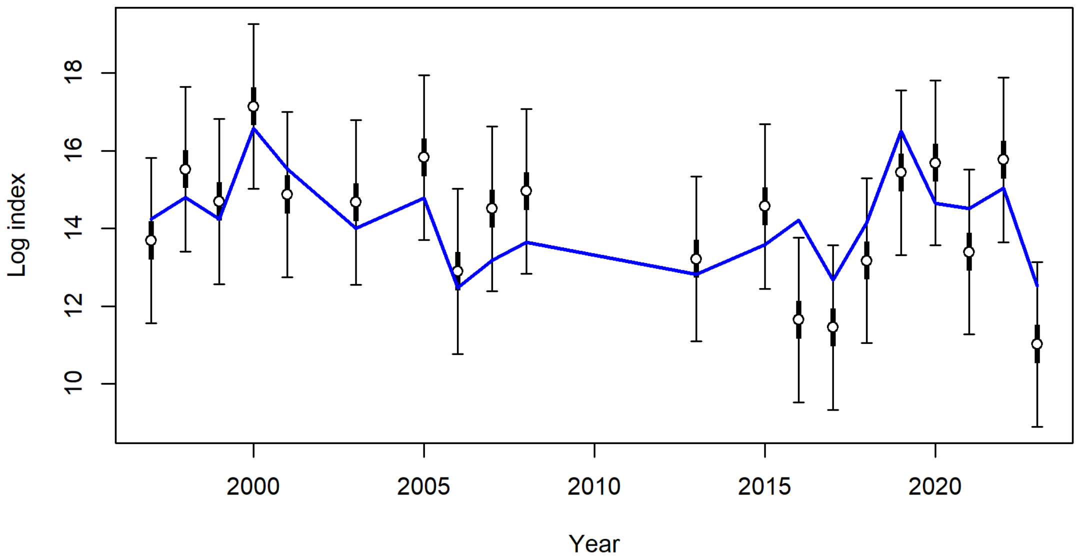
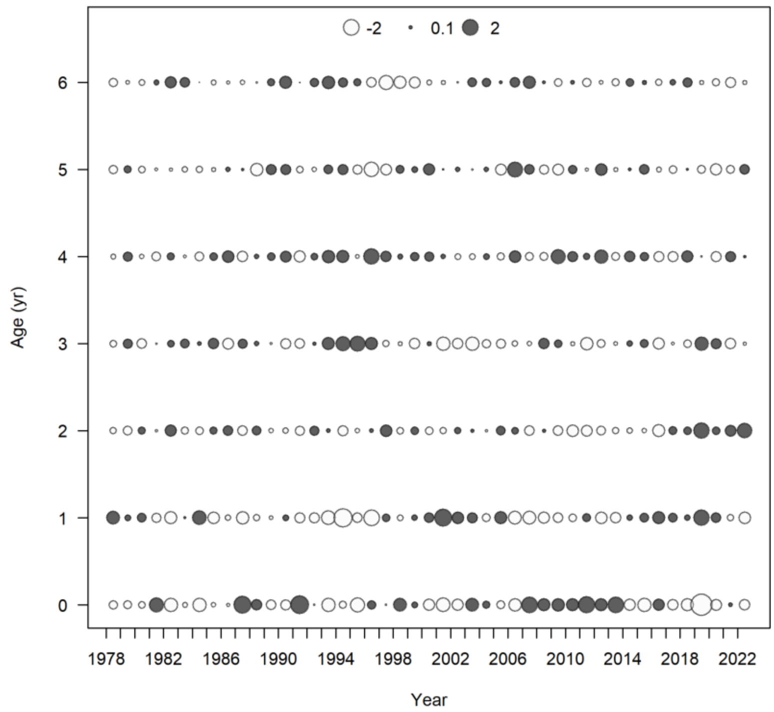


Figure 8.4.1.3. Sardine in 8c and 9a: Model fit to the log autumn acoustic survey series data on log scale. The index is age 0 abundance in subarea 9aCN (in thousand individuals). Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.



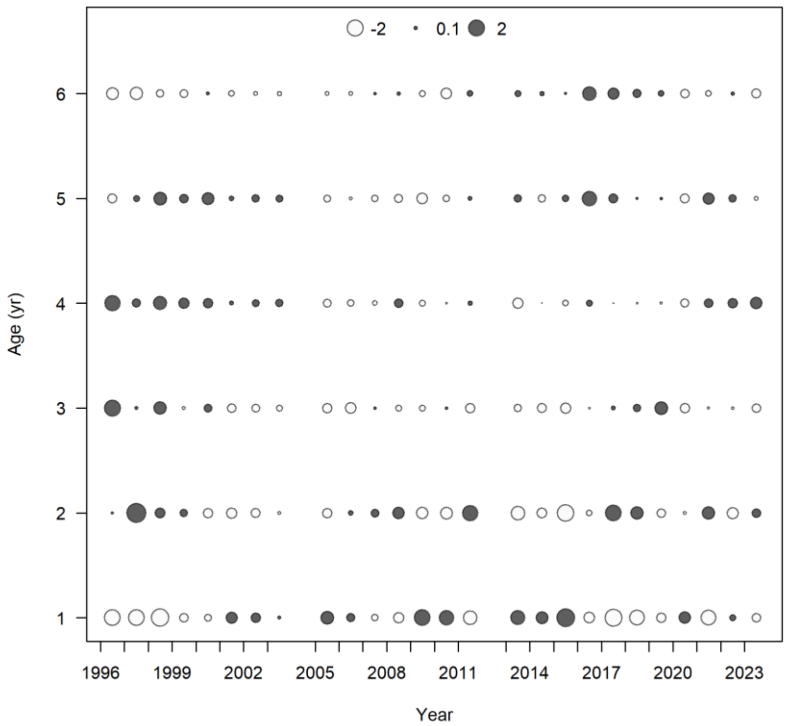


Figure 8.4.1.4. Sardine in 8c and 9a: Model residuals from the fit to the catch-at-age composition (top) and the acoustic survey age composition (bottom).

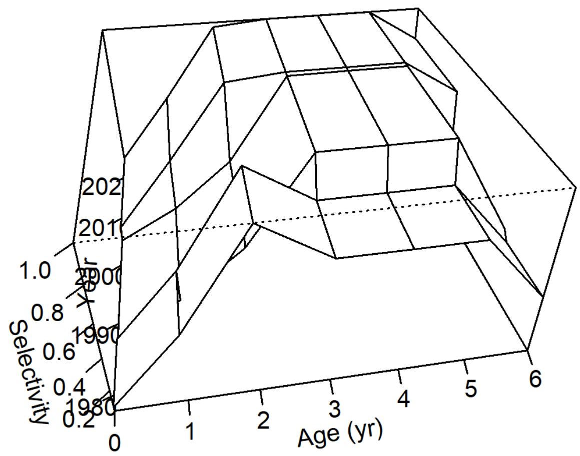


Figure 8.4.1.5. Sardine in 8c and 9a: Selectivity-at-age in the fishery showing the three blocks of fixed selectivity, 1978–1987, 1988–2005 and 2006–2022.

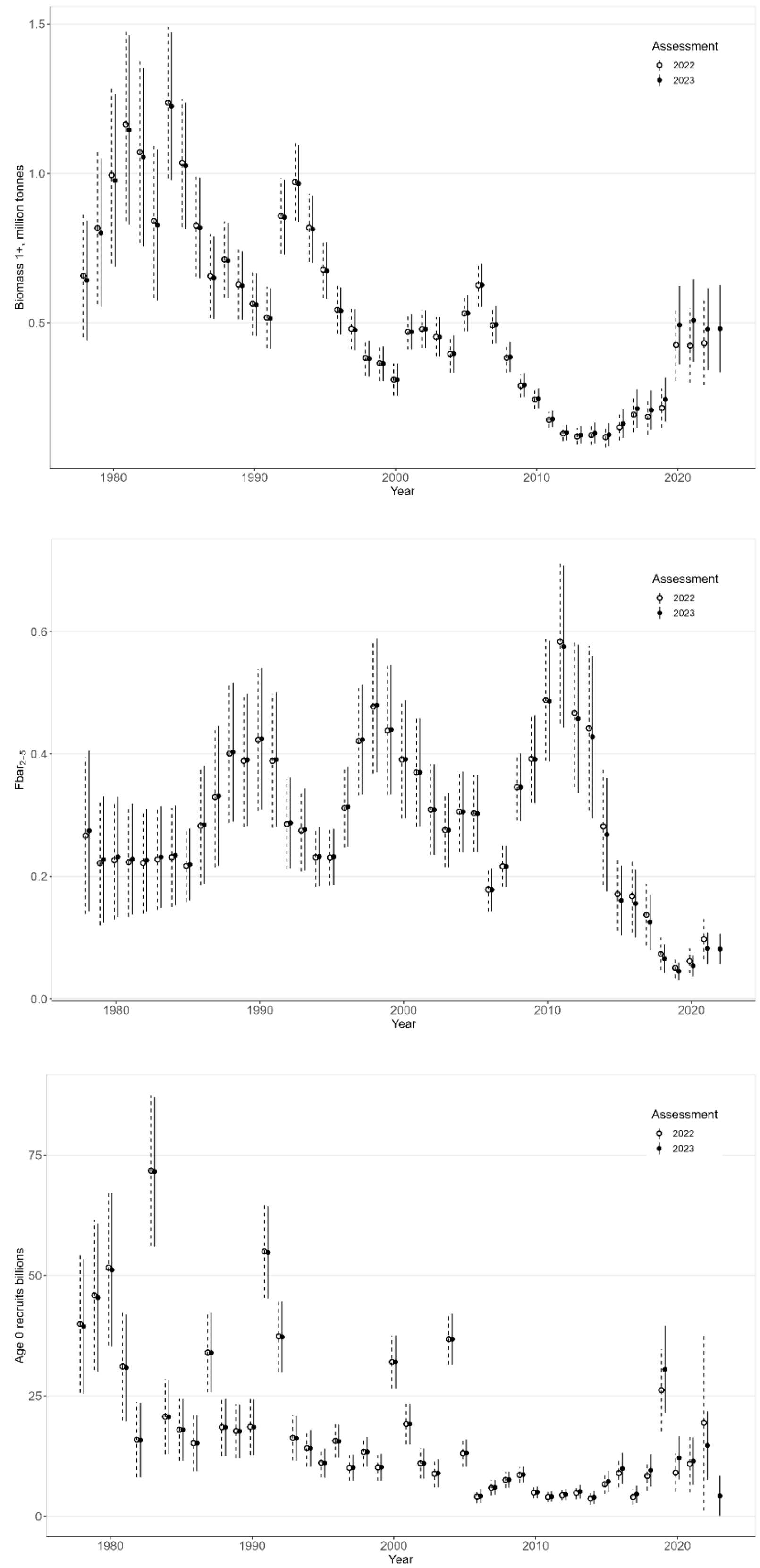


Figure 8.4.1.6. Sardine in 8c and 9a: Historical B1+ (top), $F_{bar(2–5)}$ (middle) and recruitment (bottom) trajectories in the period 1978–2023 (B1+ and recruitment is estimated up to 2023). The assessment of 2022 is shown for comparison (open dots and dashed lines).

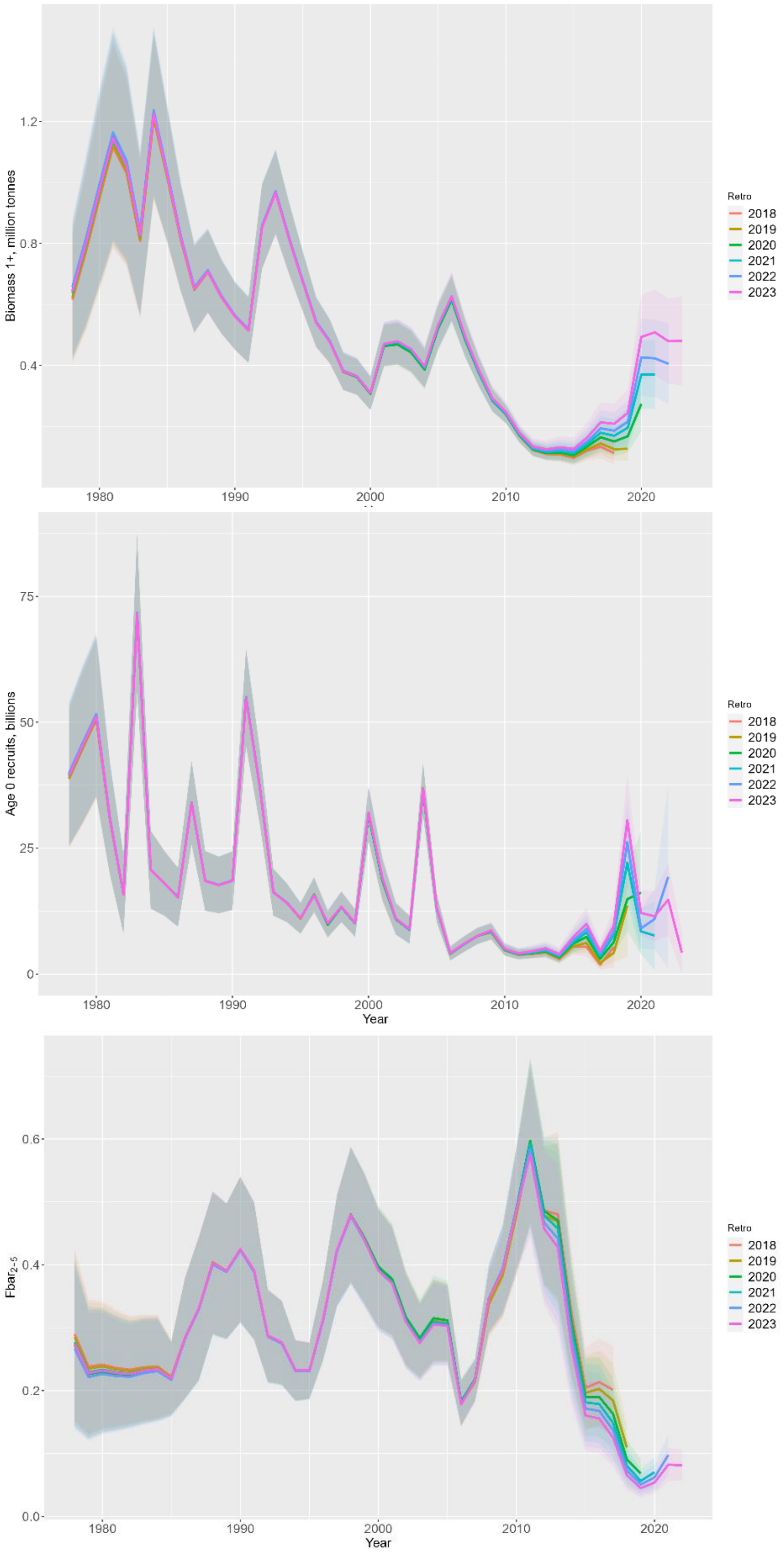


Figure 8.5.1. Sardine in 8c and 9a: Retrospective error for Biomass 1+ (top), recruitment (middle) and $F_{bar\ 2\text{-}5}$ (bottom) in the assessment.

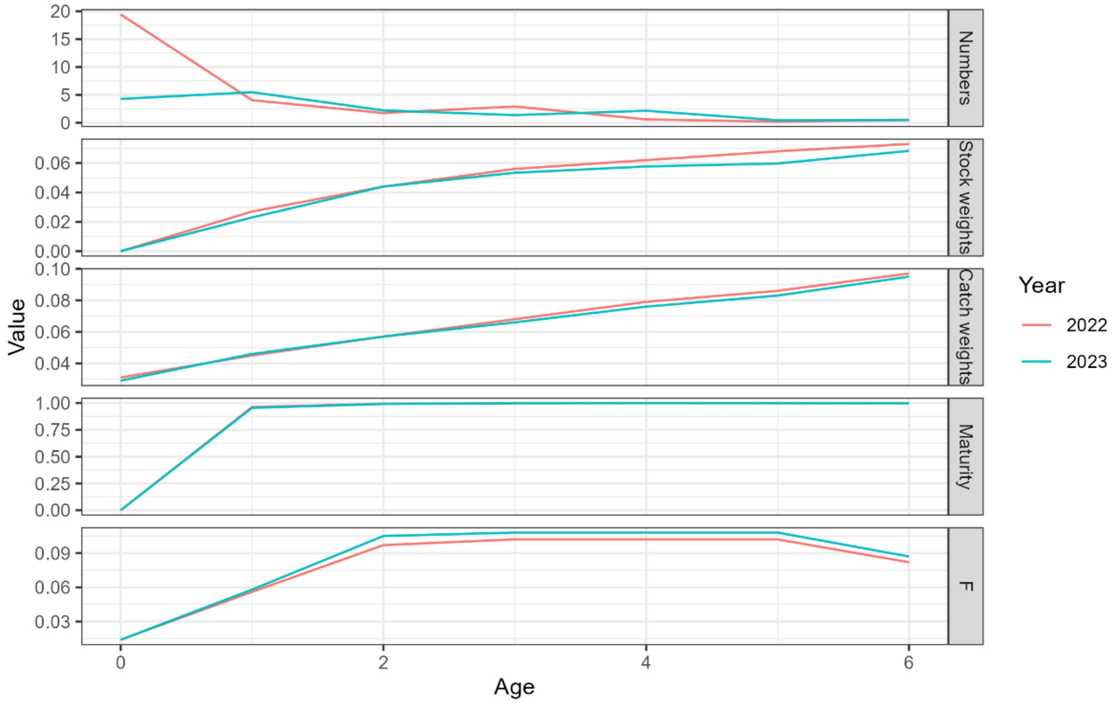


Figure 8.6.1.1 Sardine in 8c and 9a: Comparison of input data used for the short-term forecast on last year's advice (red) with the input data used for this year's short-term forecast (blue). From top to bottom: Numbers-at-age (millions), stock weights at age (in Kg), catch weights at age (in Kg), maturity at age (%) and Fbar at age.

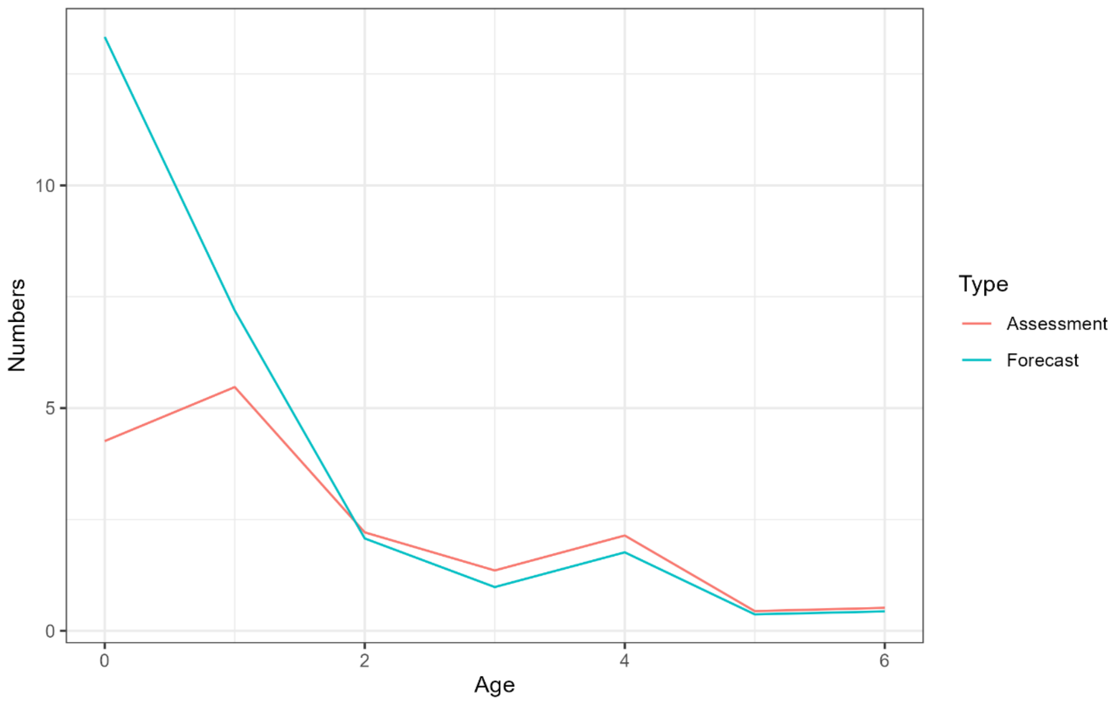


Figure 8.6.1.2 Sardine in 8c and 9a: Predicted stock numbers at age at the start of the advice year from the previous advice (blue) and the estimate of stock numbers at age for the same year from the current assessment (red).

9 Horse mackerel in Division 9.a (hom.27.9a)

9.1 ACOM Advice Applicable to 2023, STECF advice and Political decisions

The fishing mortality (F) has been below F_{MSY} over the whole time-series and the spawning–stock biomass (SSB) is above MSY $B_{trigger}$, relatively stable over the entire time-series and with a steep increase in the last years. Recruitment (R) in 2011–2021 has been estimated above the time-series average.

The ICES advice was based on the MSY approach with a revised F_{MSY} = 0.15. ICES therefore recommended that catches in 2023 should not exceed 165 173 t. ICES also recommended that the TAC for this stock should only apply to *Trachurus trachurus*. The TAC of 165 173 t in 2023 has been set for *Trachurus spp*.

In 2019 and 2020 the Portuguese survey was not carried out. Because this survey represents 87% of the total coverage and traverse the majority of the stock area, the combined survey index could not be estimated.

There has been a continued and significant shift in relative catch contribution from bottom trawls to purse-seines in the last few years. This has led to a change in the age composition of catches, with an increase in the proportion of age-1 individuals. This may lead to inconsistency in estimating selectivity in the last period of the assessment.

9.2 The fishery in 2022

9.2.1 Fishing fleets in 2022

The southern horse mackerel fisheries in Division 9.a are composed by six fleets. These fleets are defined by the gear type (bottom trawl, purse-seine and artisanal) and country (Portugal and Spain). Portuguese bottom-trawl and purse-seine fleets and Spanish purse-seine fleet show a similar exploitation pattern with a great presence of juveniles and lower abundance of adults. In the last years the Spanish purse-seine fleet had a significant increase of individuals from ages 1 and 2 in the catches. In 2022 overall landings and catches from the Spanish purse seine fleets decreased. Portuguese purse-seiners had an increase in catches for 2022 (+37%). The Portuguese artisanal fleet is mainly composed by small size vessels licensed to operate with several gears (gill and trammel nets, purse-seine and lines). Catches of horse mackerel from the Portuguese artisanal fleet are mainly from trips operating with nets showing the presence of larger/adult fish while the catches from trips operating with purse-seine show the presence of small/juveniles. The Spanish bottom trawl fleet catches mainly adults and also showed a significant decrease in 2022. Horse mackerel is one of the main target species in the Portuguese bottom trawl fleet representing almost half of this fleet catches (46%), however in 2022 catches decreased and accounted for 28% of the horse mackerel Portuguese catches, while purse seine accounted for 64%. In Spain, main catches are from the purse-seine fleet (92%). Portuguese catches from the artisanal fleet are very small (7%) and Spanish artisanal fishery is negligible (1%). In recent years, and due to the lower catch opportunities for the Iberian sardine stock (pil27.8c9a), the relative importance in the annual catches of the purse-seine fleet has increased. Description of the Portuguese and Spanish fleets is available in Stock Annex.

9.2.2 Catches by fleet and area

The catches of horse mackerel in Division 9.a comprise the following four subdivisions: 9.aNorth (9.a.n: Spain - Galicia), 9.aCentral-North (9.a.c.n: Portugal – Caminha to Figueira da Foz), 9.aCentral-South (9.a.c.s: Portugal – Nazaré to Sines) and 9.aSouth (9.a.s: Portugal – Sagres to V. Real Santo António) and are allocated to the Southern horse mackerel stock (hom.27.9a). The definition of the ICES subdivisions was set in 1992 and some of the previous catch statistics came from an area that comprises more than one subdivision. In the years before 2004 the catches from Division 8.c were also considered to belong to the southern horse mackerel stock. These catches were removed from previous total catches to obtain the current historical series of stock catches. Previous catch statistics came from areas as the Galician coasts that comprised more than one subdivision, the Subdivision 8.c West and Subdivision 9.a North and that is the reason why the time-series of catch statistics used in the assessment of southern stock is from 1992 onwards. Although Portuguese catches are available since 1927, in the case of Spanish catches the allocation of catches to Subdivision 9.a North and Subdivision 8.c West before 1992, has not yet been possible (Figure 9.2.2.1). Spanish catches from the Gulf of Cádiz (Subdivision 9.a.s) are available since 2002 but they are scarce, representing less than the 2% of the total catch and, therefore, are not included in the assessment to avoid a possible bias in the assessment results.

The catch time-series used in the assessment (1992–2022) shows a peak in 1998, of 41 564 t, a steady increase since 2011 to 2016 and in recent years a decrease is observed since 2019, with catches in 2022 of 25 515 t (Table 9.2.2.1, Figure 9.2.2.2). The minimum catch, of 18 887 t, was observed in 2003. The relative contribution of each gear to the total catch is given in Table 9.2.2.2. Until 2011 the highest contribution to the total catches was, in general, from the trawl fleets but since 2012 there has been a continued and significant shift in relative catch contribution from bottom trawls to purse-seines. In recent years, and due to the lower catch opportunities for the Iberian sardine stock (pil27.8c9a), the relative importance in the annual catches of the purse-seine fleet has increased substantially from 33% in 2011 to 73% in 2022 (Table 9.2.2.1 and Figure 9.4.2.5).

The Spanish purse seine contributions to catches remained high but decreased from last year (-19%). Catches from the Spanish bottom trawl are relatively low and decreased 30% from 2021 to 2022. Catches from the Portuguese purse seine has a significant 37% increase and bottom trawl decreased in 30% from 2021 to 2022. The contribution of the artisanal fleet from both Portugal and Spain is very small and in 2022 increased 4% and decreased 9%, respectively, when compared to 2021.

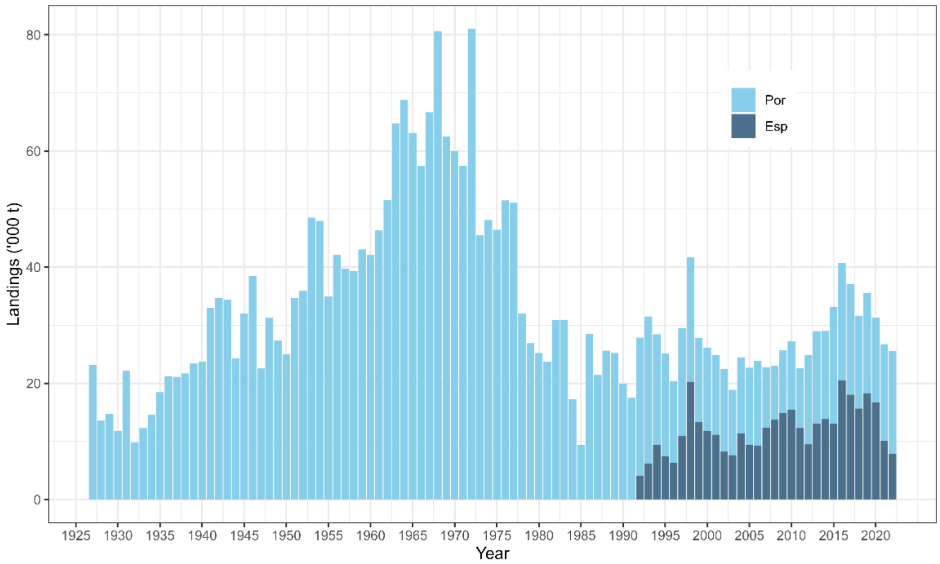


Figure 9.2.2.1. Horse mackerel in Division 9.a. Historical time series of landings (1927-2022) for southern horse mackerel (Div. 27.9.a). Light blue bars are Portuguese landings and dark blue bars are Spanish landings.

Table 9.2.2.1. Horse mackerel in Division 9.a. Time-series of southern horse mackerel historical catches (in tonnes).

Year	Total Catch
1991	34,992
1992	27,858
1993	31,521
1994	28,4411
1995	25,147
1996	20,4001
1997	29,491
1998	41,564
1999	27,733
2000	26,160
2001	24,910
2002	22,506 // (23,663)*
2003	18,887 // (19,566)*
2004	23,252 // (23,577)*
2005	22,695 // (23,111)*
2006	23,902 // (24,558)*

Year	Total Catch
2007	22,790 // (23,424)*
2008	22,993 // (23,593)*
2009	25,737 // (26,497)*
2010	26,556// (27,216)*
2011	21,875// (22575)*
2012	24,868//(25316)*
2013	28,993//(29,382)*
2014	29,017//(29,205)*
2015	32,723///(33,178)*
2016	40,741////(41,081)*
2017	36,946///(37,088)*
2018	31,661///(31,920)*
2019	35,520///(36,536)*
2020	30,177///(31,344)*
2021	26,320///(26,745)*
2022	24,997///(25,515)*

(*) In brackets: the Spanish catches from Subdivision 9a South are also included. These catches are only available since 2002 and are not included in the assessment data until the rest of the time-series is completed.

(1) These figures have been revised in 2008.

Table 9.2.2.2. Horse mackerel in Division 9.a. Southern horse mackerel landings by gear in the period 1992–2022 (in tonnes and in percentage, showing the contribution of each gear to total landings).

Year	Bottom trawl	Purse seine	Artisanal
1992	14,651	9,763	3,445
	52.6%	35.0%	12.4%
1993	20,660	7,004	3,841
	65.6%	22.2%	12.2%
1994	13,121	12,093	3,202
	46.2%	42.6%	11.3%
1995	15,611	7,387	2,137
	62.1%	29.4%	8.5%

Year	Bottom trawl	Purse seine	Artisanal
1996	13,379	5,727	1,228
	65.8%	28.2%	6.0%
1997	14,576	13,161	1,800
	49.3%	44.6%	6.1%
1998	16,943	22,359	2,287
	40.7%	53.8%	5.5%
1999	10,106	15,781	1,855
	36.4%	56.9%	6.7%
2000	12,697	11,237	2,227
	48.5%	43.0%	8.5%
2001	12,226	11,048	1,637
	49.1%	44.3%	6.6%
2002	12,307	8,230	1,969
	54.7%	36.6%	8.7%
2003	10,116	6,523	2,248
	53.6%	34.5%	11.9%
2004	16,126	5,700	2,658
	65.9%	23.3%	10.9%
2005	14,029	6,040	2,621
	61.8%	26.6%	11.6%
2006	15,019	5,430	3,445
	62.9%	22.7%	14.4%
2007	13,705	6,775	2,308
	60.1%	29.7%	10.1%
2008	12,380	7,670	2,949
	53.8%	33.3%	12.8%
2009	15,075	6,669	3,984
	58.6%	25.9%	15.5%
2010	16,062	6,847	4,308
	59.0%	25.2%	15.8%

Year	Bottom trawl	Purse seine	Artisanal
2011	11,038	7,301	3,530
	50.40%	33.30%	16.40%
2012	7,839	12,897	4,579
	30.97%	50.95%	18.09%
2013	9,221	16,774	2,687
	33.77%	57.09%	9.14%
2014	12,573	14,114	2,330
	43.33%	48.64%	8.03%
2015	13,310	16,937	2,932
	40.12%	51.05%	8.84%
2016	19,172	19,083	2,485
	47.06%	46.84%	6.10%
2017	16,931	18,038	2,120
	45.65%	48.64%	5.72%
2018	9,824	20,187	1,651
	31.03%	63.76%	5.21%
2019	9,542	24,190	1,788
	26.86%	68.10%	5.03%
2020	10,961	17,588	1,617
	36.34%	58.31%	5.36%
2021	8,074	16,869	1,378
	30.68%	64.09%	5.23%
2022	5,310	18,139	1,549
	21.24%	72,56%	6.19%

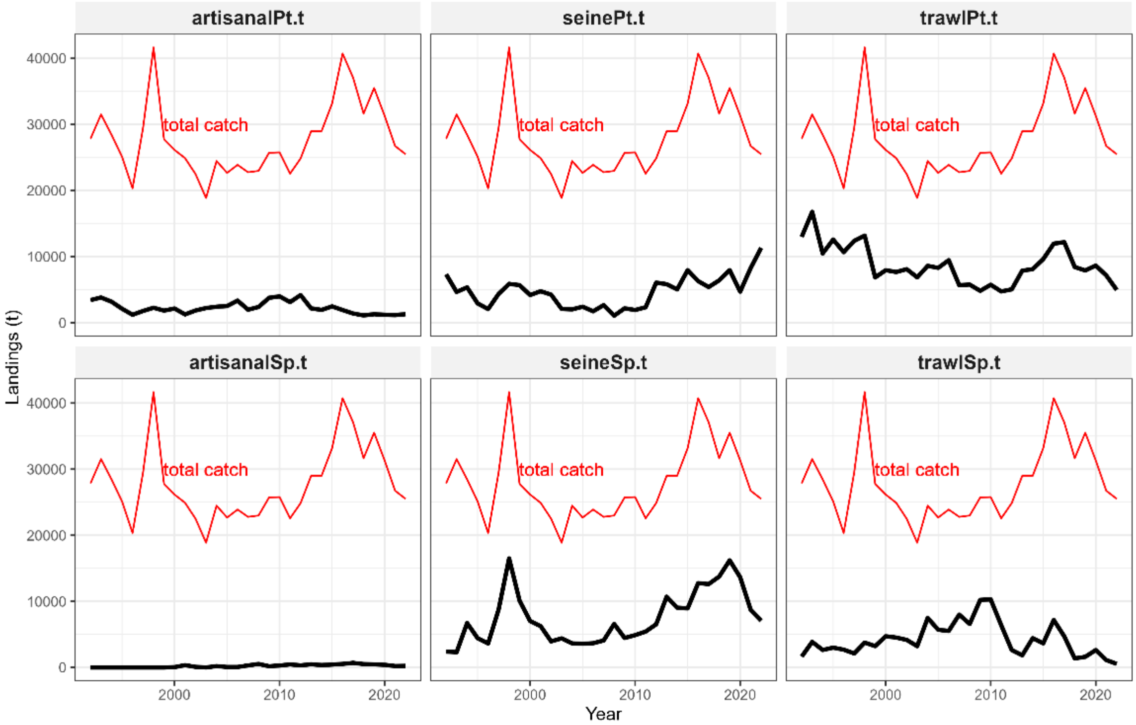


Figure 9.2.2.2. Horse mackerel in Division 9.a. Time-series (1992-2022) of southern horse mackerel catches (in tonnes) by country (Pt – Portugal; Sp – Spain) and gear (artisanal, purse seine, trawl).

Discards are estimated by both countries (Portugal since 2004, Spain since 2003) from national at-sea sampling programme (DCF) on board commercial vessels operating in ICES Division 9a. Discards for this species are usually very low and not frequent, thus being considered negligible. The frequency of occurrence of horse mackerel discards is too low and is considered zero because such low frequency will result in highly biased estimates (Portuguese discards are usually estimated when frequency of species occurrence is above 30%). The horse mackerel Spanish discards come mainly from the bottom trawl fleet operating in ICES subdivision 27.9.a.s (286.4 t), the total discards from the Spanish fleets were estimated at 293.9 t.

Table 9.2.2.3. Horse mackerel in Division 9.a. Discard estimates (tonnes) of southern horse mackerel in 2022 by country (SP – Spain, PT - Portugal), fleet/metier, ICES subdivision and quarter.

Country	Fleet	Metier	Fishing Area	Q 1	Q 2	Q 3	Q 4	Total
SP	artisanal	GNS_DEF_80-99_0_0	27.9.a.n	0.0	0.0	0.0	0.0	0.0
SP	purse seine	PS_SPF_0_0_0	27.9.a.s	0.0	0.0	0.0	0.0	0.0
SP	trawl	OTB_DEF_>=55_0_0	27.9.a.n	0.1	4.6	0.7	1.2	6.5
SP	trawl	OTB_MPD_>=55_0_0	27.9.a.n	0.0	0.0	0.0	0.0	0.0
SP	trawl	PTB_MPD_>=55_0_0	27.9.a.n	0.0	0.9	0.0	0.0	0.9
SP	trawl	OTB_MCD_>=55_0_0	27.9.a.s	189.1	29.4	19.7	48.3	286.4
PO	trawl	OTB_CRU>=55_0_0 (Loa>=12m)	27.9.a	0	0	0	0	0
PO	trawl	OTB_DEF_>=55_0_0 (Loa >=25m)	27.9.a	0	0	0	0	0

9.2.3 Effort and catch per unit of effort

A preliminary CPUE (catch per unit effort) is developed using data from the Portuguese trawl logbooks provided by the Portuguese fisheries administration (Directorate-General for Natural Resources, Safety and Maritime Services – DGRM) for the period 1992-2022. This study estimated a nominal CPUE and a standardized CPUE for horse mackerel using a Tweedie Generalized Linear Model to handle the null observations and improve the abundance indices available for this stock. The preliminary results from this index are shown in a following section of this report (section 9.8). This index still needs evaluation under the ICES benchmark procedures. Currently, no series of catch per unit of effort (CPUE) is available to be used for stock assessment.

9.2.4 Catches by length and catches-at-age

Sampling method for the catches by length is described in the Stock Annex. Catch-at-age data have been obtained by applying a semester ALK to each of the catch length distribution estimated by fleet segment (bottom trawl, purse-seine and artisanal) and country from the samples of each subdivision. The catch in numbers-at-age used in the assessment is the combined Portuguese and Spanish catch-at-age from 1992–2022, with age range 0–11+.

In general, catches are dominated by juveniles and young adults in the available time series (1992-2022). However, in 2021 and 2022 catches at these younger ages (age-0 to age-3) have decreased that could be a consequence of the steep decrease in Spanish purse seine catches and targeting of older individual by the Portuguese purse seine fleet (Table 9.2.4.1, Figure 9.2.4.1 and Figure 9.2.4.2).

Table 9.2.4.1. Horse mackerel in Division 9.a. Southern horse mackerel catch-at-age data in the period 1992–2022 (thousands).

	Ages											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
1992	11684	95186	145732	40736	12171	9102	5018	6864	5155	4761	13973	14354
1993	6480	66211	137089	100515	35418	13367	12938	10495	6597	5552	4497	14442
1994	12713	63230	86718	96253	28761	7628	4398	3433	5209	4834	6047	12264
1995	7230	55380	31265	52030	28199	11010	4003	3139	2720	3352	2530	31343
1996	69651	13798	14021	28125	33937	9861	6611	4501	4164	5504	3306	14243
1997	5056	295329	112210	26236	17168	12886	7780	7169	3938	3867	2425	8847
1998	22917	95950	320721	68438	18770	11317	9712	20627	12760	6686	6212	11323
1999	51659	29795	26231	66704	42960	15700	13840	7555	4175	4790	2475	7417
2000	12246	72936	23547	41618	35968	18643	17254	12118	7915	5227	3124	3557
2001	105759	77364	31261	24104	23721	16794	15391	14964	9795	3310	2023	3989
2002	18444	94402	84379	26482	13161	11396	10263	12501	10156	7525	3607	4433
2003	40033	6830	36754	28559	21931	12790	14751	13582	10631	6492	3531	2333
2004	7101	126797	58054	18243	8328	13586	11836	14878	10542	3876	5258	5318
2005	21015	108070	49197	24289	17877	11334	11179	7927	9124	7445	5502	11420
2006	3329	92563	92896	22665	6738	13176	11892	6029	7303	8070	8947	15322
2007	2885	16419	27667	44357	20534	8187	4459	3563	5975	4748	4943	30001
2008	48380	54167	31951	28058	16616	7194	4782	3660	4579	3975	4537	24990
2009	22618	85415	32416	8482	9774	7162	3289	2860	2791	3579	4236	39096
2010	81048	102016	33906	17496	11979	7569	3847	3942	2452	2671	2977	32284
2011	85973	23285	20987	19082	15047	7199	4272	3511	2885	5250	4639	22097

	Ages											
Year	0	1	2	3	4	5	6	7	8	9	10	11+
2012	201691	119136	30060	13964	14547	7693	5322	4373	2731	3218	4373	14562
2013	35849	123495	109557	30511	17468	9670	4085	3600	3123	2763	2488	17864
2014	22723	51727	89258	37772	18645	5573	2493	2899	1886	2137	2533	17588
2015	66497	92922	49067	50211	45753	16675	10529	5163	4253	4730	5149	13182
2016	15223	116079	122297	49145	28523	31170	14561	15087	11210	5823	7138	20703
2017	25212	192125	75227	48553	31124	12862	7701	9156	10323	4694	4846	19138
2018	71977	182113	69396	52508	26314	12485	11555	6753	6050	3463	2517	4554
2019	27706	146270	116225	48796	20638	25280	11293	9325	7943	4022	5208	4361
2020	18471	143836	57686	58352	24715	18078	8181	8553	5985	7025	3035	9365
2021	26901	60128	48825	46934	39919	17747	9263	6191	5077	10801	7100	8451
2022	7119	68831	44548	37500	28994	24289	13127	9842	6773	3021	1683	1958

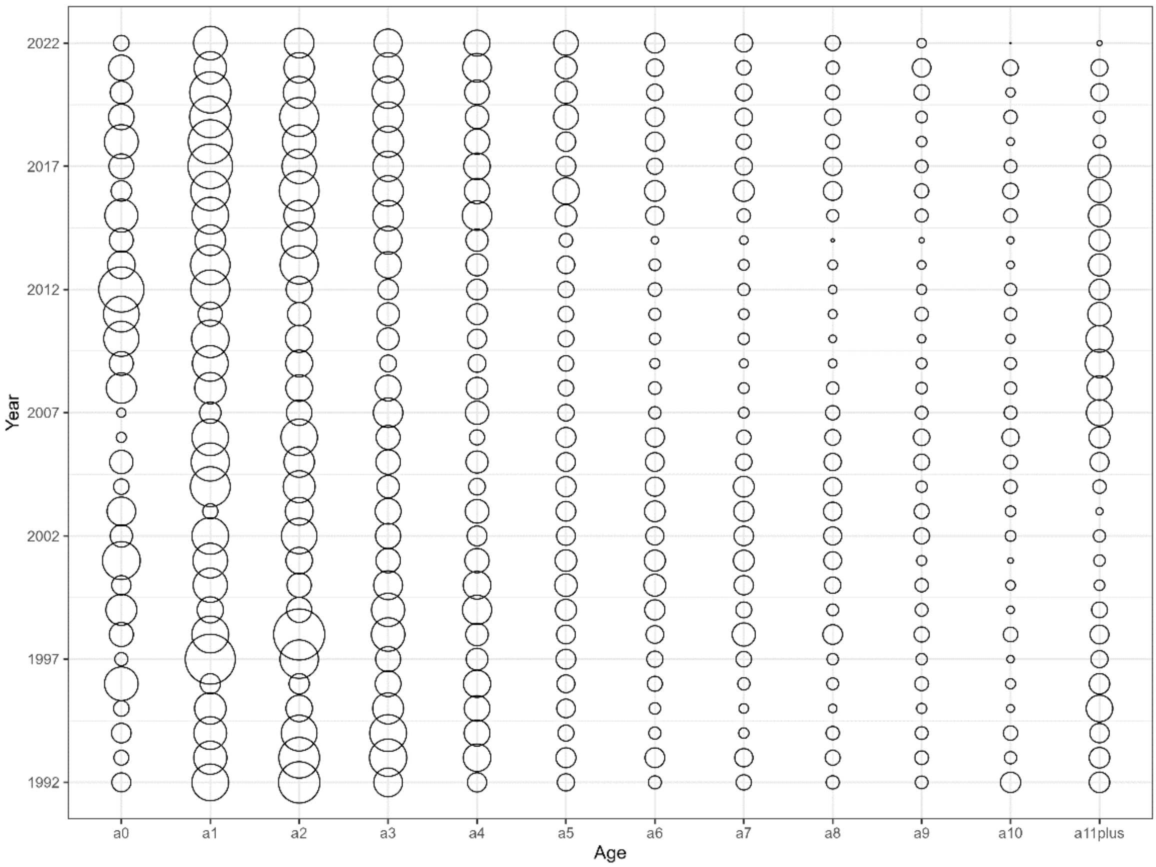


Figure 9.2.4.1. Horse mackerel in Division 9.a. Bubble plot of proportions of southern horse mackerel catch in numbers-at-age in each year (1992–2022).

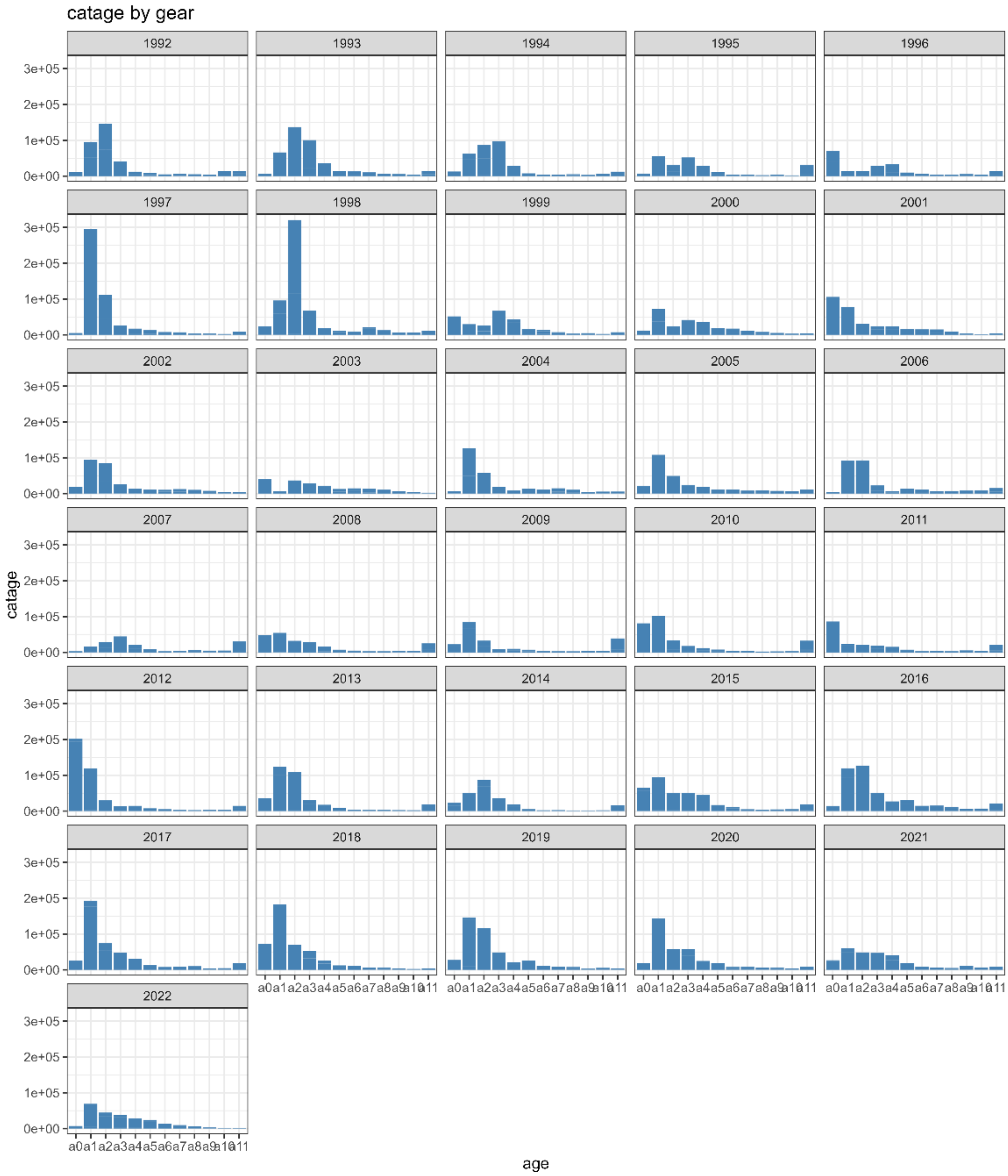


Figure 9.2.4.2. Horse mackerel in Division 9.a. Southern horse mackerel catch in numbers-at-age in each year (1992–2022).

Table 9.2.4.2 presents the southern horse mackerel catch in numbers-at-age by fishing fleet and Figure 9.2.4.3 shows the proportion of catch-at-age by fleet and country in the period 1992–2022. The Portuguese and Spanish purse-seine fleet and the Portuguese trawl and artisanal fleets caught mainly juveniles and young adults. In 2021 and 2022 catches at these younger ages (age-0 to age-3) have decreased from the steep decrease in Spanish purse seine catches and what seems to be a targeting of older individual by the Portuguese purse seine fleet. The pattern for the remainder of ages is similar to other years but showing a decrease in the most larger individuals (age-9 to age-11+).

Table 9.2.4.2. Horse mackerel in Division 9.a. Southern horse mackerel catch in numbers-at-age (thousands) by fleet (bottom trawl, purse-seine and artisanal) in the period 1992–2022.

	Ages										
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
Bottom trawl												
1992	98	8739	40094	78016	28660	10904	10401	8174	5166	3923	3319	9412
1993	3413	16252	37679	55079	16322	3926	2138	1559	2530	2200	2207	5223
1994	3917	12983	18292	22807	11447	5375	2541	2280	2299	2739	2138	25610
1995	30763	10340	10123	19245	23331	6326	4524	3063	2772	3245	2211	8611
1996	2828	180543	68330	15055	7846	4536	2087	1216	811	801	608	4360
1997	4444	36544	205609	32994	7151	3427	2487	3562	3100	2418	2724	7225
1998	28176	11492	16059	23745	8653	2914	3643	2570	1650	1932	1614	5525
1999	1106	35946	13685	18085	10763	7890	9180	7657	5546	4146	2544	2516
2000	39871	25245	10861	9401	8291	6329	8686	10261	7644	2630	1556	2606
2001	3572	59041	49402	12288	4796	4461	5100	7280	6068	5197	2671	3156
2002	14581	2077	18079	12556	13025	7525	7410	6940	6045	3966	2255	1526
2003	1352	77529	44171	12649	4758	9114	7787	9616	6875	2366	3823	3958
2004	2956	50643	30389	15100	12246	6636	6997	6190	7047	5546	3710	6705
2005	1666	59477	61175	14915	3798	9822	9492	3762	3871	4302	4908	9981
2006	19	2444	14853	31470	10967	2932	1983	1461	2681	2644	3135	21375
2007	5512	12787	21078	21828	10408	2984	1695	1166	1918	1678	2373	16881
2008	4552	19630	14558	5033	4758	4463	1581	1070	1183	1830	2579	27993
2009	10832	46074	15193	11434	6888	3661	1723	1728	1417	1531	1897	25218
2010	5984	3440	9440	9357	6696	2999	1871	1655	1426	3414	2876	16256
2011	7674	20041	14102	4899	4089	1915	2101	1356	987	1094	1799	7586
2012	6928	23225	29279	11222	3625	1573	903	1283	1357	1233	1170	11420
2013	7734	14850	18232	8434	5210	2040	987	1207	888	1072	1726	13972
2014	7845	18476	19923	11544	12206	5060	3228	2033	2411	3671	4417	13825
2015	4707	43326	72194	19569	7265	6349	3562	4339	3125	2623	7008	6134
2016	2461	26151	47865	29405	9083	11260	6151	5604	4336	4022	6322	16970
2017	2044	15323	21678	22423	15581	6110	3779	5644	6386	3311	3584	14874

Year	Ages 0	1	2	3	4	5	6	7	8	9	10	11+
2018	2622	23258	19042	20477	8998	4346	5413	3186	3190	1885	1351	2775
2019	494	6704	24021	18825	5382	8234	4354	3588	3030	1533	2064	2593
2020	340	12702	19697	19380	7833	5031	3057	3304	2480	4485	2220	7690
2021	2004	10941	10811	14478	12692	4563	2702	2080	2222	4432	2789	3793
2022	1398	11245	10072	5932	6221	5072	2412	2570	2496	1311	917	942
Purse seine												
Year	**Ages 0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
1992	6977	51859	73537	21162	4860	2677	1362	1973	1299	1204	2572	2402
1993	6293	51337	83236	16597	4355	795	512	819	544	862	667	1842
1994	7634	45429	45987	39236	11267	2838	1379	1036	1640	1691	2550	3530
1995	3311	42111	12457	27030	14822	4224	854	445	163	362	217	2247
1996	38888	3446	3801	8189	8955	2917	1621	1107	1022	2003	891	4301
1997	2211	114184	42908	9797	6407	5775	4380	5300	2707	2831	1539	3672
1998	18294	59225	112386	34393	9893	6028	5838	15381	8920	3621	2760	2041
1999	23481	18237	9440	41032	31471	10684	7777	3835	2092	2465	764	1328
2000	11068	35861	8832	22508	23779	9645	5890	2291	876	338	172	231
2001	65468	51105	20260	14164	14394	9020	5035	3008	1170	290	227	644
2002	13660	32185	34516	13604	7895	6041	3804	3510	2435	1141	359	116
2003	22915	4609	17093	15338	7464	3944	5188	3784	2554	1447	675	260
2004	5258	42114	12332	5137	2673	3042	2600	2603	958	489	980	929
2005	17856	56690	18512	8881	5272	3365	2539	799	904	848	600	1026
2006	1637	27295	29845	7133	2103	2210	1506	1225	1638	1804	2037	1514
2007	2863	13802	12416	11231	8019	3800	1912	1712	2799	1667	1323	4186
2008	42868	41050	9766	4672	3729	2223	2138	1918	2063	1877	1707	3544
2009	18016	65130	17157	2736	3551	2078	1139	1206	1041	1168	1136	3200
2010	70206	41433	11571	2766	2058	1531	1038	904	446	377	561	1598
2011	76225	18619	10553	7915	5197	1941	1480	719	315	707	723	1881

	Ages											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
2012	193478	96833	12558	5530	7261	3945	1375	1991	1106	1282	1279	1268
2013	28908	98794	77552	17612	12427	7287	2665	1692	1196	1033	730	2644
2014	14794	35667	68564	27850	12383	3078	1272	1316	712	699	384	540
2015	56896	73247	28072	34914	28163	10304	6699	2790	1444	860	524	1110
2016	11898	93528	78720	19246	16407	17104	7090	8488	6186	1451	414	876
2017	18888	172613	50320	23723	13874	6068	3386	2839	3275	1080	880	2560
2018	61071	155490	48838	30137	15822	7290	5295	3079	2427	1288	911	1003
2019	22771	130029	88205	28013	14267	15732	6347	5175	4360	2087	2655	1407
2020	14992	127345	34698	35464	15550	12088	4628	4832	3191	1995	508	962
2021	7867	30985	35744	30786	26247	12552	6161	3864	2678	6008	3993	4077
2022	2378	52118	30526	28618	20126	18011	10349	6901	4032	1511	640	696
Artisanal												
	Ages											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
1992	0	0	1	5	45	76	93	553	731	935	4393	5818
1993	89	6135	13760	5902	2402	1668	2025	1501	886	766	511	3187
1994	1666	1549	3052	1939	1171	863	882	839	1039	943	1290	3511
1995	2	286	516	2193	1929	1410	608	415	258	252	175	3485
1996	0	11	97	692	1651	618	465	331	370	255	205	1330
1997	17	602	972	1384	2915	2575	1313	653	420	235	278	814
1998	180	181	2726	1051	1726	1861	1387	1684	740	647	728	2056
1999	2	67	731	1927	2836	2102	2420	1151	433	394	98	564
2000	73	1129	1030	1024	1425	1108	2184	2171	1494	743	408	810
2001	420	1014	140	539	1036	1445	1671	1695	981	390	240	739
2002	1212	3176	461	591	471	895	1358	1711	1653	1187	578	1161
2003	2537	144	1581	665	1442	1320	2152	2858	2032	1079	601	547
2004	491	7154	1552	457	897	1429	1449	2659	2709	1021	455	431
2005	203	738	295	308	359	1332	1643	938	1174	1051	1193	3689

	Ages											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
2006	26	5790	1875	617	837	1144	894	1041	1793	1964	2002	3826
2007	3	173	398	1656	1548	1456	563	390	496	438	486	4440
2008	0	330	1108	1557	2479	1987	948	576	599	420	456	4564
2009	49	654	701	713	1465	621	569	585	567	581	521	7903
2010	10	14509	7141	3295	3033	2378	1087	1309	589	763	519	5469
2011	3764	1226	992	1810	3153	2258	920	1137	1144	1126	1039	3156
2012	539	2263	3401	3535	3197	1833	1846	1026	637	843	1295	5708
2013	14	1477	2726	1677	1416	810	516	625	570	497	588	3800
2014	0	73	178	221	350	275	155	195	164	208	242	1399
2015	103	2468	2215	3186	4380	1564	773	404	449	378	424	3072
2016	69	200	520	1265	1511	2037	1391	1164	802	410	453	2431
2017	4280	4189	3229	2407	1669	683	537	673	663	302	382	1704
2018	8284	3365	1516	1894	1495	849	847	488	433	291	255	776
2019	4441	9536	3999	1959	989	1314	591	562	553	402	488	361
2020	3138	3789	3291	3508	1332	959	496	417	315	545	306	713
2021	17031	18202	2270	1670	980	632	400	247	177	361	317	582
2022	3343	5468	3949	2950	2647	1205	365	371	245	199	126	320

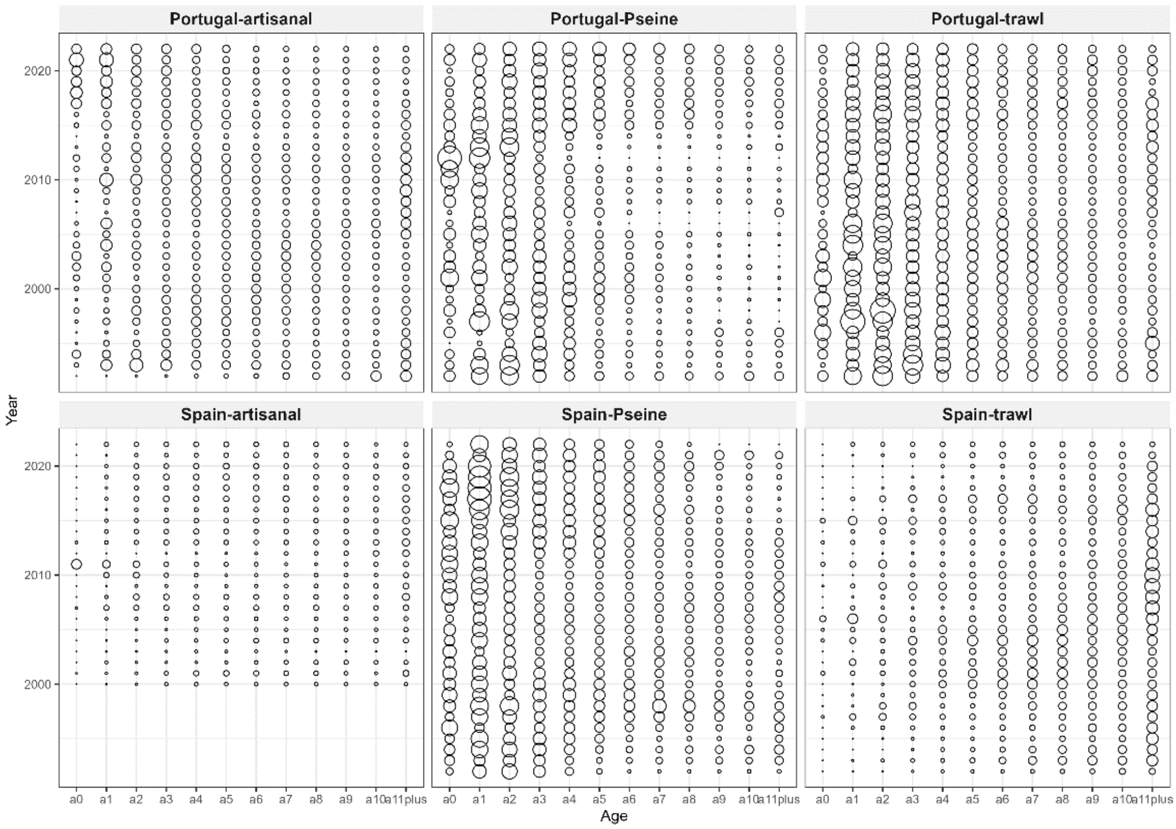


Figure 9.2.4.3. Horse mackerel in Division 9.a. Bubble plot of proportions of southern horse mackerel catch in numbers-at-age by country and fleet in each year (1992-2022).

9.2.5 Mean weight-at-age in the catch

Detailed information on the methodology to calculate mean weight-at-age and mean length-at-age is provided in the Stock Annex. Tables 9.2.5.1 and 9.2.5.2 show the mean weight-at-age in the catch and the mean length-at-age in catch, respectively, from 1992 to 2022.

The mean weight-at-age is of a similar magnitude to previous years in all ages with a slight decrease in the age 11+ plus group (Figure 9.2.5.1, Table 9.2.5.1) and the variations of mean length-at-age are of a similar scale along the temporal series (Table 9.2.5.2). Otoliths from older fish become thicker with time and thus presenting more difficulties for age determination at groups older than 11. Mean length-at-age from 2019 onward is only shown for 0 to 11+, plus group used for assessment.

Figure 9.2.5.2. shows the observed mean age in the catch (0 to 11+) with 95% confidence intervals and the mean age fitted by the assessment model (AMISH, red line) from 1992-2022. The mean age composition fluctuates around ages 2 to 4 in the available time series. From 2019 to 2022 there is a slight increase in the mean age.

Table 9.2.5.1. Horse mackerel in Division 9.a. Southern horse mackerel mean weight-at-age (kg) in the catch (1992-2022).

	Ages											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
1992	0.03	0.03	0.04	0.07	0.1	0.13	0.15	0.17	0.19	0.2	0.23	0.3
1993	0.02	0.03	0.04	0.07	0.09	0.13	0.17	0.21	0.24	0.24	0.25	0.3
1994	0.04	0.04	0.06	0.07	0.09	0.13	0.16	0.19	0.23	0.25	0.27	0.34
1995	0.04	0.03	0.06	0.08	0.1	0.12	0.16	0.17	0.2	0.22	0.23	0.31
1996	0.02	0.05	0.07	0.09	0.11	0.14	0.17	0.19	0.22	0.24	0.26	0.31
1997	0.03	0.03	0.05	0.07	0.11	0.14	0.17	0.2	0.24	0.26	0.26	0.36
1998	0.03	0.03	0.04	0.07	0.1	0.13	0.17	0.21	0.17	0.24	0.25	0.35
1999	0.02	0.04	0.06	0.08	0.11	0.14	0.16	0.19	0.22	0.25	0.27	0.36
2000	0.02	0.03	0.05	0.09	0.11	0.13	0.16	0.19	0.22	0.24	0.25	0.31
2001	0.02	0.03	0.07	0.08	0.09	0.13	0.16	0.18	0.2	0.23	0.24	0.31
2002	0.03	0.03	0.04	0.07	0.1	0.12	0.15	0.17	0.2	0.23	0.25	0.31
2003	0.02	0.03	0.05	0.06	0.09	0.12	0.15	0.18	0.2	0.23	0.25	0.31
2004	0.04	0.03	0.05	0.08	0.12	0.16	0.18	0.21	0.23	0.25	0.27	0.33
2005	0.02	0.03	0.04	0.07	0.12	0.15	0.17	0.18	0.22	0.24	0.25	0.3
2006	0.03	0.03	0.05	0.06	0.09	0.13	0.14	0.17	0.19	0.23	0.25	0.33
2007	0.03	0.05	0.06	0.07	0.09	0.11	0.16	0.19	0.23	0.22	0.24	0.3
2008	0.02	0.05	0.06	0.08	0.11	0.13	0.15	0.17	0.20	0.21	0.23	0.32
2009	0.02	0.03	0.06	0.09	0.11	0.13	0.15	0.17	0.18	0.21	0.24	0.36
2010	0.02	0.04	0.06	0.08	0.11	0.14	0.16	0.18	0.19	0.2	0.24	0.38
2011	0.03	0.06	0.07	0.08	0.11	0.13	0.17	0.18	0.19	0.22	0.26	0.35
2012	0.02	0.03	0.07	0.10	0.13	0.16	0.18	0.19	0.21	0.24	0.28	0.37
2013	0.05	0.04	0.05	0.09	0.13	0.16	0.18	0.20	0.21	0.23	0.26	0.33
2014	0.03	0.05	0.06	0.09	0.12	0.15	0.18	0.19	0.21	0.23	0.27	0.36
2015	0.03	0.04	0.06	0.09	0.11	0.14	0.17	0.19	0.21	0.24	0.26	0.35
2016	0.02	0.04	0.06	0.08	0.11	0.13	0.16	0.18	0.19	0.22	0.26	0.38
2017	0.02	0.04	0.07	0.09	0.12	0.15	0.18	0.20	0.21	0.25	0.28	0.35
2018	0.02	0.04	0.06	0.09	0.12	0.15	0.19	0.24	0.27	0.30	0.34	0.44
2019	0.02	0.04	0.06	0.08	0.12	0.14	0.17	0.22	0.24	0.34	0.37	0.46

	Ages										
Year	0	1	2	3	4	5	6	7	8	9	10	11+
2020	0.02	0.04	0.06	0.07	0.10	0.13	0.16	0.20	0.22	0.25	0.30	0.39
2021	0.01	0.03	0.05	0.08	0.10	0.13	0.15	0.18	0.23	0.25	0.28	0.33
2022	0.016	0.047	0.062	0.09	0.115	0.143	0.177	0.207	0.224	0.274	0.325	0.408

Table 9.2.5.2. Horse mackerel in Division 9.a. Southern horse mackerel mean length-at-age (cm) in the catch from 1992-2022 (age range: 0–11+ and older).

Year/ Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1992	14.9	15.6	17.5	19.8	23.2	25.8	27.4	28.6	29.6	31.2	31.5	32.6	33.3	33.9	34.7	36.8
1993	14.0	15.5	17.4	18.9	21.3	28.2	29.6	31.1	31.7	31.7	32.1	32.5	34.1	34.7	35.8	37.2
1994	13.4	14.6	18.1	21.1	22.7	24.8	27.0	29.5	31.2	31.7	32.4	32.2	33.3	34.2	34.4	36.5
1995	16.0	15.4	19.9	21.8	23.1	24.5	28.6	26.5	30.1	30.9	31.6	32.6	33.9	34.0	35.2	36.9
1996	13.3	19.0	19.7	21.8	24.7	26.3	28.0	28.6	30.3	30.7	31.5	32.0	33.4	32.5	36.2	37.0
1997	13.4	15.8	18.9	20.7	24.3	26.3	27.6	29.5	31.2	32.4	31.9	33.1	34.6	34.8	35.4	38.5
1998	14.5	13.9	15.9	20.4	23.5	25.5	28.3	30.3	26.9	31.7	32.0	32.7	33.4	34.5	36.4	39.1
1999	13.4	16.4	19.0	22.3	24.5	26.2	27.5	29.0	30.3	31.7	32.7	33.3	33.9	34.7	37.3	39.6
2000	13.6	16.4	18.4	21.7	24.8	26.0	27.2	28.6	30.2	30.8	31.5	32.3	32.7	34.2	34.5	35.0
2001	14.1	15.6	20.2	21.9	22.5	25.4	27.4	28.7	29.6	30.9	31.2	33.0	32.8	34.0	34.7	38.2
2002	15.0	15.7	17.5	20.3	23.1	25.4	26.6	28.0	29.6	30.9	31.8	32.6	34.2	34.7	35.4	36.9
2003	13.0	15.7	18.8	20.7	23.1	26.1	26.7	29.2	30.0	31.2	32.0	32.9	33.6	33.9	38.9	35.3
2004	16.2	14.4	17.2	21.2	24.0	26.7	28.1	29.4	30.5	31.6	32.3	32.2	33.0	32.2	36.4	35.9
2005	12.5	13.9	16.6	20.1	23.5	25.9	27.1	28.1	30.0	31.1	31.6	32.8	32.6	33.5	32.6	37.2
2006	14.6	14.7	17.0	19.2	22.2	24.6	25.6	27.2	28.7	30.3	31.5	33.2	34.0	35.9	36.7	37.0
2007	14.6	17.5	18.5	20.0	22.1	23.6	26.9	28.7	30.6	30.3	30.9	31.8	33.4	32.2	34.5	35.7
2008	13.0	17.3	20.5	22.3	24.0	25.4	26.5	27.7	28.8	29.6	30.5	31.3	32.2	33.5	35.6	37.2
2009	13.0	17.3	20.5	22.3	24.0	25.4	26.5	27.7	28.8	29.6	30.5	31.3	32.2	33.5	35.6	37.2
2010	13.1	15.8	18.4	20.8	23.4	25.4	26.9	27.8	28.6	29.2	31.2	31.7	33.5	34.7	36.7	38.0
2011	15.1	18.4	19.5	21.3	23.3	25.2	27.4	28.1	28.6	30.2	32.0	33.3	34.2	35.0	36.5	39.0
2012	15.7	15.8	18.4	22.8	24.9	26.5	27.8	28.8	29.9	31.1	33.2	34.4	35.5	36.7	39.4	39.8
2013	16.8	16.8	17.9	21.4	24.6	26.2	27.5	28.3	29.1	29.7	31.0	32.5	34.7	35.7	37.9	36.3

Year/ Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2014	13.9	18.7	20.4	21.4	23.0	25.2	26.5	27.5	28.5	28.9	31.2	32.9	34.5	35.4	36.6	38.0
2015	15.6	15.9	18.3	21.6	23.0	25.4	27.4	27.8	28.7	30.3	31.4	31.6	33.9	34.3	36.2	38.4
2016	13.8	16.1	18.7	20.6	23.1	25.0	26.5	28.0	28.5	30.1	31.9	33.7	36.2	36.8	37.1	39.3
2017	13.2	15.8	19.7	21.9	24.4	25.9	28.2	28.9	29.2	30.9	32.3	33.1	34.2	34.8	36.6	40.6
2018	12.9	16.2	19.4	22.1	24.1	25.9	28.4	30.7	31.7	33.0	34.4	37.3	37.9	38.9	38.5	39.2
2019*	13.5	16.3	19.2	21.3	24.2	25.5	27.3	29.8	30.7	34.0	35.1	38.5	-	-	-	-
2020	13.7	16.6	19.2	20.9	23.1	25.1	26.6	28.7	29.9	30.8	32.3	36.1	-	-	-	-
2021	12.1	14.5	18.4	20.9	22.7	25.0	26.5	28.2	30.1	31.1	32.4	34.3	-	-	-	-
2022	12.6	17.3	19.4	22.1	23.9	25.7	27.5	28.9	29.7	31.7	33.4	36.1	-	-	-	-

*** Mean length-at-age from 2019 onward is only shown for 0 to 11+, plus group used for assessment.**

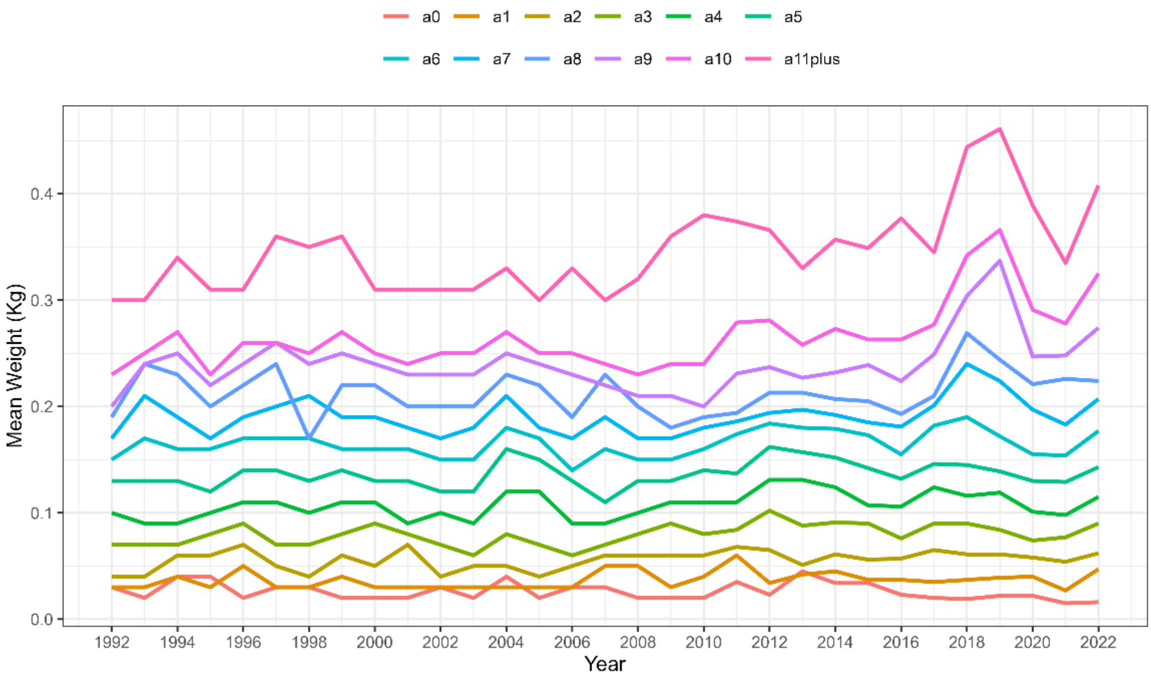


Figure 9.2.5.1. Horse mackerel in Division 9.a. Southern horse mackerel mean weight-at-age (kg) in the catch (age range: 0 to 11+, plus group) (1992-2022).

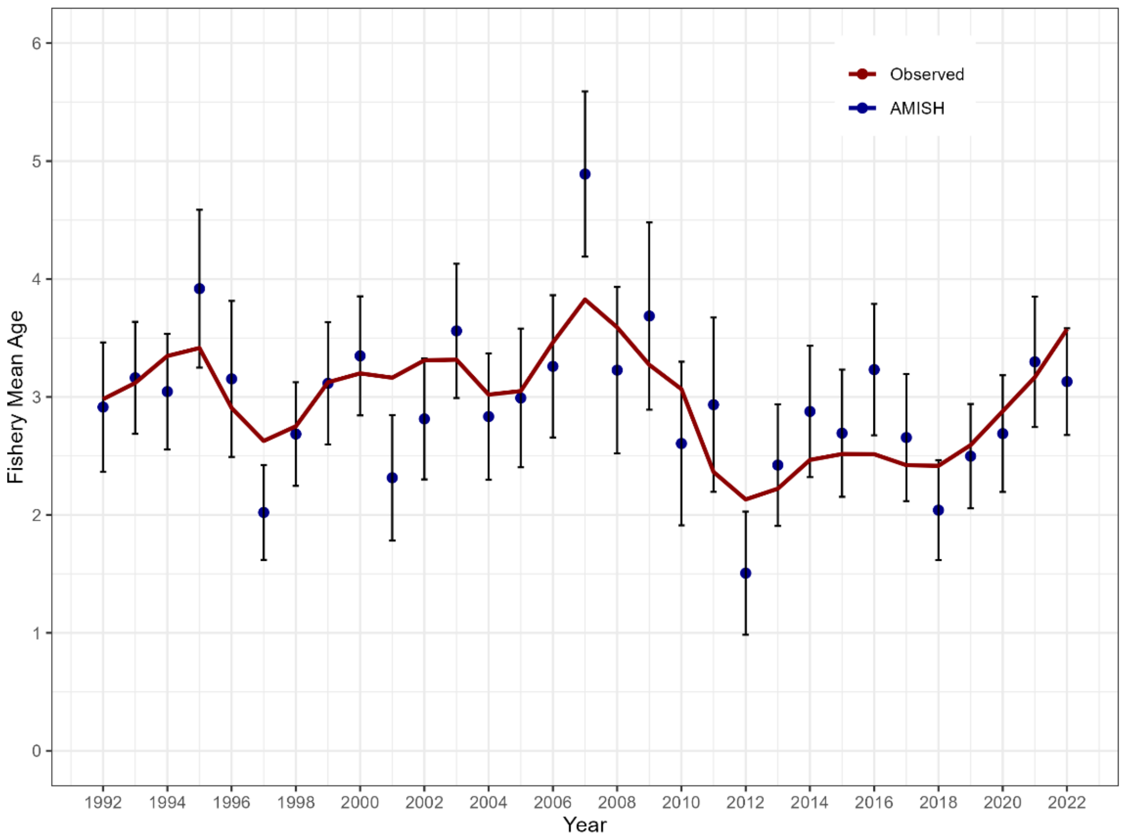


Figure 9.2.5.2. Horse mackerel in Division 9.a. Southern horse mackerel mean age in the catch in the period 1992–2022 (age range: 0 to 11+, plus group).

9.3 Fishery-independent information

The survey datasets currently available for the assessment of southern horse mackerel are those from the bottom-trawl surveys carried out in the 4th quarter (October) by Portugal (Pt-GFS-WIBTS-Q4 - G8899) and Spain (Sp-GFS-WIBTS-Q4 - G2784) in ICES Division 9.a. Both IBTS surveys cover the bulk of the geographical distribution of the southern horse mackerel stock at the same time but do not cover the southernmost part of the stock distribution area, corresponding to the Spanish part of the Gulf of Cadiz. In that area another bottom-trawl survey is carried out (Sp-GFS-caut-WIBTS-Q4 - G4309), usually in November. As explained in the Stock Annex, the survey series is shorter in time (only since 1998) and the raw data were unavailable in time for the WKPELA benchmark (ICES, 2017) to investigate the effect of merging it with the datasets from the other areas.

During the benchmark horse mackerel estimations from Portuguese spring acoustic surveys were also analysed to investigate the spatial distribution of juveniles and as a possible indicator of the recruitment strength for this species, which could prove to be useful for short-term forecasts (ICES, 2017). However, the analysis did not reveal any relationship between the estimates of recruitment from the acoustic survey and the stock assessment. Acoustic estimates require further analysis to be used as auxiliary information for recruitment strength.

SSB estimates from DEPM surveys require further analysis from ICES WGMEGGS to be used as external auxiliary information according to the Stock Annex.

9.3.1 Bottom-trawl surveys

IBTS data provides a good sampling of this species with valuable information on horse mackerel distribution, abundance, age–length distributions also providing a good signal of cohort dynamics (ICES, 2017). Several alternative methods for calculating indices of abundance-at-age were explored to improve the precision of the current survey tuning index, the diagnostics of stock assessment model fit, the uncertainty in the estimates of the key parameters fishing mortality, recruitment and spawning–stock biomass, as well as to evaluate the stock trends (ICES, 2017).

Different methods of obtaining an abundance index by age and year were explored. The "standard" stratified mean was an acceptable method to deal with the non-normal abundance distribution and the variability in the survey data. This estimator, described in the Stock Annex, was found adequate to deal with the data from the current classical stratified survey methodology applied in IBTS surveys and was thus adopted for tuning the assessment.

The abundance indices from both surveys are shown in Table 9.3.1.1. There is a strong variability of age 0 abundance that may be explained by the greater aggregation tendency of these small fish in dense shoals. This feature results in a rather noisy time-series at age 0. The abundance-at-age from 2022 onward is only shown for 0 to 11+, plus group used for assessment. The combined survey abundance-at-age for tuning the assessment excluding age 0 is presented in Table 9.3.1.2.

Figure 9.3.1.1. shows the observed mean age in the survey (with age ranges used in the assessment 1 to 11+) with 95% confidence intervals and the mean age fitted by the assessment model (AMISH, green line) from 1992-2022. The mean age composition in the survey shows lower variability than the catch (Figure 9.2.5.2) as catchability from the survey is expected to be more consistent. The mean age fluctuates around ages 2 to 3 in the available time series. From 2018 to 2022 (no available information in 2019 and 2020) there is a slight increase in the mean age.

The Portuguese IBTS was not conducted in 2012, 2019 and 2020. Because this survey traverses the majority of the stock area, the combined survey abundance-at-age index could not be estimated for 2012, 2019 and 2020.

Table 9.3.1.1. Horse mackerel in Division 9.a. CPUE-at-age (number/hour) by the Portuguese and Spanish surveys, in the period 1992–2022 (age range: 0 to 11+, plus group). The Portuguese IBTS (October) survey was not conducted in 2012, 2019 and 2020.

Portuguese October Survey

YEAR \ AGES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1992	452.2	488.2	145.8	26.8	13.2	5.9	4.0	4.3	2.4	2.2	3.0	0.5	0.6	0.2	0.1	0.1
1993	1645.8	183.8	212.2	148.0	32.5	2.0	1.5	0.7	0.5	0.7	0.4	1.0	0.3	0.2	0.0	0.0
1994	3.7	8.0	62.9	36.1	15.2	4.2	2.0	1.7	0.8	0.5	0.3	0.1	0.0	0.0	0.0	0.0
1995	15.8	61.2	89.7	49.7	23.9	6.5	1.4	1.2	0.5	0.2	0.2	0.3	0.3	0.5	0.1	0.1
1996*	1214.1	6.3	8.7	13.5	14.0	3.6	1.7	0.6	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0
1997	2094.7	97.4	69.0	20.4	45.0	55.4	14.9	10.9	4.5	5.3	1.8	0.1	0.0	0.1	0.1	0.0
1998	86.4	33.2	161.7	17.4	2.2	1.4	0.9	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999*	159.5	20.2	31.8	34.8	2.8	1.0	0.5	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2000	2.4	13.7	17.1	19.8	11.9	6.6	4.0	1.3	0.7	0.1	0.1	0.1	0.0	0.0	0.0	0.0
2001	1292.7	1.1	8.8	3.9	6.9	13.8	12.2	11.2	6.6	2.5	1.2	0.2	0.1	0.1	0.0	0.0
2002 [1]	21.1	1.5	11.4	10.0	5.5	2.8	1.0	0.7	0.5	0.3	0.6	0.2	0.1	0.1	0.0	0.0
2003*	56.5	9.1	8.2	10.2	8.8	3.3	2.3	1.2	0.7	0.4	0.1	0.0	0.0	0.0	0.0	0.0
2004	58.6	37.1	111.8	38.0	6.7	3.0	1.4	3.5	5.0	0.9	0.2	0.0	0.0	0.0	0.0	0.0
2005	351.9	1188.6	162.2	45.2	21.7	10.4	13.7	14.4	11.7	6.6	4.1	4.6	4.1	0.9	1.0	0.3
2006	65.1	84.6	181.8	46.6	3.4	10.3	7.4	6.6	2.7	1.4	0.4	0.1	0.0	0.0	0.0	0.0
2007	36.2	2.0	22.6	31.5	25.1	9.2	2.5	1.2	0.1	0.4	1.3	1.1	0.5	0.2	0.2	0.4
2008	47.6	28.2	39.7	20.6	26.7	17.3	2.2	0.8	1.2	1.8	1.3	1.0	0.5	0.9	0.5	1.8
2009	1245.2	79.5	147.0	52.4	44.7	11.6	2.8	1.7	1.4	0.9	0.7	0.4	0.7	1.7	0.4	0.8
2010	83.3	36.8	32.8	25.6	38.3	14.1	5.2	7.0	4.7	4.6	1.6	1.8	1.5	1.9	2.1	3.0
2011	132.8	33.1	24.5	16.2	4.7	1.1	0.3	0.4	0.2	0.4	0.5	0.2	0.3	0.4	0.2	0.2
2012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2013	12.5	363.7	820.0	105.4	18.9	3.0	2.5	2.7	2.2	2.2	1.5	0.8	1.2	0.4	0.3	0.2
2014	53.6	33.3	24.1	69.2	25.6	5.2	1.6	1.5	0.9	1.2	2.2	2.6	3.0	2.5	0.9	0.6
2015	900.2	160.3	112.5	46.6	38.0	4.5	2.3	1.0	0.8	0.9	0.7	0.5	0.4	0.5	0.3	0.5
2016	1.6	17.1	23.1	76.8	53.6	7.6	4.3	6.0	2.4	1.3	1.6	2.0	2.7	1.7	0.2	1.7
2017	68.2	440.0	584.2	263.0	177.1	27.9	3.5	13.5	19.2	2.4	2.1	1.6	1.0	0.9	0.0	0.0
2018	124.5	192.6	177.3	96.7	12.5	14.2	19.9	9.4	10.0	3.5	0.3	0.1	0.1	0.0	0.0	0.0
2019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2020	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2021***	180.3	288.5	74.8	123.3	78.4	58.2	29.6	5.5	4.4	3.6	5.4	0.9	0.5	0.0	0.0	0.1
2022	122.4	101.9	70.0	42.1	56.4	34.6	12.9	2.3	0.4	1.2	0.7	2.3	-	-	-	-

Spanish October Survey (only Subdivision IXa North)

YEAR \ AGES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1992	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	1.0	0.4	0.5	0.3	0.1	0.6
1993	33.1	0.4	1.2	0.9	0.1	0.0	0.6	2.5	2.6	3.6	2.2	4.2	0.8	0.5	0.1	0.2
1994	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.6	0.0	3.7	3.0	0.3	1.5
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.6	1.0	2.2	0.6	0.5
1996	8.4	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.7	0.2	0.1	0.5	0.7	0.3	1.1
1997**	0.5	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.5	0.2	0.1	0.1	0.2	0.3	0.7
1998	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.6	0.9	0.7	1.3	0.5	0.4	0.1
2000	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.8	1.0	0.9	0.2	0.2	0.1	0.1	0.1	0.2
2001	3.4	0.8	0.0	0.0	0.0	0.1	0.1	0.7	1.2	1.1	0.9	0.5	0.3	0.3	0.0	0.1
2002	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.4	2.1	2.0	2.5	2.9	1.0	1.2	0.4	0.6
2003	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.2	0.1	0.1	0.0	0.0	0.2
2004	24.1	0.3	0.7	4.3	1.4	1.2	0.5	0.4	0.2	0.1	0.2	0.0	0.1	0.0	0.0	0.0
2005	938.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.2	0.1	0.1	0.0	0.0
2006	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1
2007	0.4	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.4	0.2	0.2	0.2	0.0	0.1	0.1	0.0
2008	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1
2009	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.1
2010	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.3	0.3
2011	0.4	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.3	0.3	0.0	0.0	0.0	0.1	0.2
2012	12.9	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.2
2013	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.3	7.5	1.2	8.5	8.0	2.6	0.4	0.2	0.2	0.2	0.2	0.1	0.9	0.0	0.0	0.0
2015	6.6	0.0	0.1	1.9	2.8	1.0	0.1	0.2	0.0	0.1	0.2	0.0	0.1	0.0	0.1	0.2
2016	11.9	2.8	20.0	3.2	4.0	11.0	4.6	2.2	0.5	0.3	0.1	0.0	0.0	0.0	0.1	0.1
2017	4.9	27.1	171.7	84.1	48.6	13.4	17.7	0.4	0.7	0.1	0.4	0.1	0.0	0.0	0.0	0.0
2018	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2019	0.6	0.3	0.1	0.1	0.4	2.1	0.3	0.1	0.1	0.0	0.5	0.2	0.2	0.0	0.0	0.1
2020	12.5	37.4	121.3	32.8	5.1	0.7	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
2021	0.9	0.0	0.1	0.0	0.6	0.8	0.8	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
2022	5.5	0.2	0.5	0.5	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	-	-	-	-

* Surveys with a different research vessel (R/V Capricórnio)
** Since 1997 another stratification design was applied in the Spanish surveys
*** Since 2021 hte Portuguese survey is carried out with a new research vesse (R/V Mário Ruivo)
1 In 2002 started a new series in which the duration of the trawling per haul has changed from one hour to thirty minutes

Table 9.3.1.2. Horse mackerel in Division 9.a. Stratified mean abundance-at-age (number/hour) in the period 1992–2022. There were no Portuguese surveys in 2012, 2019 and 2020 and therefore the combined survey indices for 2012, 2019 and 2020 are not estimated.

	Ages										
Year	**0***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
1992	454.5	488.2	145.8	26.8	13.2	5.9	4.0	4.4	2.4	2.3	4.0	3.4
1993	1678.9	184.2	213.3	148.8	32.6	2.0	2.1	3.2	3.1	4.3	2.6	7.3
1994	3.8	8.0	63.0	36.1	15.2	4.2	2.0	1.7	0.9	0.8	0.9	8.7
1995	15.8	61.2	89.7	49.7	23.9	6.5	1.4	1.2	0.6	0.3	0.4	6.2
1996	1222.5	6.3	8.7	13.5	14.0	3.6	1.7	0.6	0.4	0.8	0.2	2.8
1997	2095.3	97.4	69.0	20.4	45.0	55.4	15.0	11.2	4.8	5.8	2.1	1.7
1998	86.6	33.2	161.7	17.4	2.2	1.4	1.0	1.2	0.3	0.1	0.0	0.1
1999	159.5	20.2	31.8	34.8	2.8	1.0	0.6	0.2	0.2	0.7	0.9	3.0
2000	2.5	13.7	17.1	19.8	11.9	6.6	4.1	2.1	1.7	1.0	0.3	0.9
2001	1296.1	1.8	8.8	3.9	6.9	13.8	12.3	11.9	7.8	3.7	2.1	1.6
2002	21.2	1.5	11.4	10.0	5.5	2.8	1.2	1.1	2.6	2.3	3.1	6.6
2003	58.9	9.1	8.2	10.2	8.8	3.3	2.4	1.3	0.7	0.6	0.4	0.5
2004	82.7	37.4	112.4	42.4	8.1	4.2	1.9	3.8	5.1	1.0	0.4	0.2
2005	1290.0	1188.6	162.2	45.2	21.8	10.5	13.8	14.5	11.8	6.7	4.1	11.3
2006	72.6	84.6	181.8	46.6	3.4	10.4	7.4	6.7	2.7	1.4	0.5	0.3
2007	36.6	2.0	22.6	31.5	25.1	9.2	2.7	1.6	0.6	0.6	1.4	2.9
2008	52.6	28.2	39.7	20.6	26.8	17.3	2.2	0.8	1.3	1.9	1.4	5.0
2009	1268.3	79.5	147.0	52.4	44.7	11.6	2.8	1.7	1.4	0.9	0.7	4.6
2010	83.4	36.8	32.8	25.6	38.3	14.1	5.2	7.0	4.7	4.6	1.8	11.6
2011	133.2	33.1	24.5	16.2	4.7	1.2	0.4	0.6	0.4	0.7	0.8	1.6
2012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2013	12.6	363.8	820.0	105.4	18.9	3.0	2.5	2.7	2.2	2.2	1.5	2.9
2014	53.9	40.8	25.4	77.7	33.6	7.8	2.1	1.7	1.2	1.4	2.4	10.5
2015	906.8	160.3	112.6	48.5	40.9	5.5	2.4	1.2	0.9	1.0	0.9	2.6
2016	13.6	19.9	43.1	80.0	57.6	18.6	8.8	8.1	3.0	1.6	1.7	8.6
2017	73.04	467.1	755.9	347.1	225.7	41.3	21.1	13.9	19.9	2.5	2.5	3.7

	Ages											
Year	**0***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
2018	124.5	192.6	177.3	96.7	12.5	14.2	19.9	9.4	10.0	3.5	0.3	0.1
2019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2020	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2021	178.6	276.6	92.5	120.2	79.00	59.01	30.4	5.4	4.4	4.3	5.2	1.6
2022	127.9	102.1	70.6	42.5	56.4	34.8	12.9	2.3	0.4	1.1	0.7	2.3

***age 0 is not used in the stock assessment.**

9.3.2 Mean length and mean weight-at-age in the stock

Taking into consideration that the spawning season is very long, from September to June, and that the whole length range of the species has commercial interest in the Iberian Peninsula, with scarce discards, there is no special reason to consider that the mean weight-at-age in the catch is significantly different from the mean weight-at-age in the stock.

9.3.3 Maturity-at-age

The maturity ogive corresponds to females. Horse mackerel is a multiple spawner (ICES, 2008) and hence maturity ogives should be based on histological analysis of the gonads which provide a correct and precise means to follow the development of both ovaries and testes (Costa, 2009). Maturity ogive estimation procedures are detailed in Stock Annex. The predicted proportion-at-age is given in the text table below (7+: age 7 and older fish) and was adopted by WKPELA for the assessment period (1992–2022).

Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7+**
Proportion mature	0.0	0.0	0.36	0.82	0.95	0.97	0.99	1.0

During the benchmark it was also agreed to estimate a maturity ogive every three years with the data collected during the triennial DEPM surveys. The maturity ogive will be updated only in the case there is strong evidence that the proportion of fish mature at age has changed.

9.3.4 Natural mortality

The natural mortality (M) used in the assessment is presented in the text table below (5+: age 5 and older fish).

Age	**0**	**1**	**2**	**3**	**4**	**5+**
M	0.9	0.6	0.4	0.3	0.2	0.15

The procedure in the estimation of natural mortality rate and considerations for adopting the current values are detailed in Stock Annex.

9.4 Stock assessment

9.4.1 Model assumptions and settings and parameter estimates

The stock assessment has been performed for the period 1992–2022 with the method and settings agreed during the benchmark (ICES, WKPELA 2017) and described in the Stock Annex. Table 9.4.1.1 presents the input data type, model assumptions and settings adopted by the benchmark.

The assessment was tuned with the stratified mean abundance-at-age estimated for the combined Portuguese and Spanish IBTS survey for the age range 1–11+. In 2012, 2019 and 2020 the Portuguese survey was not carried and, hence, the combined survey indices for 2012, 2019 and 2020 could not be estimated. Benchmark discussions also concluded that it was appropriate to adopt only one time-block for the survey selectivity given that the survey characteristics (e.g. survey design, surveyed area, research vessels and fishing gear) were relatively unchanged along the assessment period.

The three time-blocks for the catch selectivity accommodates the recent changes in the fishery due to the strong year classes of 2011, 2012 , 2015 and subsequent years, and the increase of horse mackerel catches by purse-seiners, following the Iberian sardine crisis. This pattern is persistent in the recent years being more pronounced in the Portuguese and Spanish purse seine fleets.

Table 9.4.1.1. Horse mackerel in Division 9.a. Input data type, model assumptions and settings for the assessment of southern horse mackerel with data series 1992-2022.

Name	Year range	Age range	Assumptions/settings
Catch in weight	1992–2022		Variable in time
Catch-at-age	1992–2022	0–11+	Variable by age and time; assuming a constant CV of 5%
IBTS (Spanish-Portuguese) mean stratified abundance-at-age	1992–2022 (except 2012, 2019,2020)	1–11+	Variable by age and time; assuming a constant CV of 30%
Mean weight-at-age (catch & stock)	1992–2022	0–11+	Variable by age and time
Proportion of F and M before spawning	1992–2022	0–11+	Fixed at 0.04 (mid-January)
Natural Mortality	1992–2022	0–11+	Age-dependent; time invariant
Catch-at-age selectivity	1992–2022	0–11+	Dome-shaped; constant at age 7+ Three blocks 1992–1997; 1998–2011; 2012–2022
Initial parameter vector		0–11+	0.2,0.7,1,1,0.8,0.5,0.5,0.2,0.2,0.2,0.2,0.2
Survey abundance-at-age selectivity	1992–2022 (except 2012, 2019,2020)	1–11+	Dome-shaped; constant at age 7+ One time-block 1992–2012 (no survey index in 2012, 2019 and 2022)

Name	Year range	Age range	Assumptions/settings
Initial parameter vector		1–11+	1,1,0.7,0.5,0.4,0.3,0.2,0.2,0.2,0.2,0.2
Proportion-at-age in the catch	1992–2022	0–11+	Multinomial distribution
Proportion-at-age in the survey	1992–2022	1–11+	Multinomial distribution
Effective sample size catch			100
Effective sample size survey			10

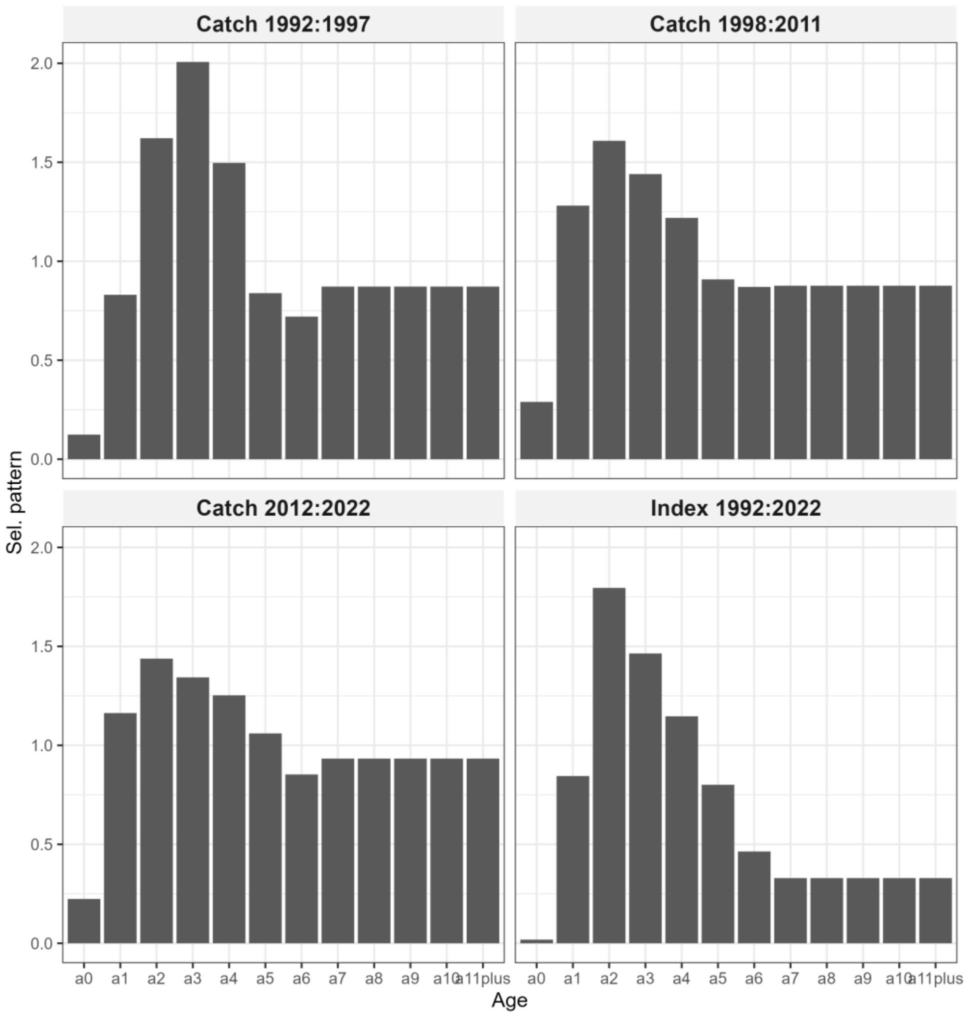


Figure 9.4.1.1. Horse mackerel in Division 9.a. Estimated selectivity for the catch-at-age (three time blocks) and for the IBTS combined stratified mean abundance-at-age (one time block).

The summarised results of the stock assessment are shown in Table 9.4.1.2 and Figure 9.4.1.2.

Table 9.4.1.2. Horse mackerel in Division 9.a. Final assessment (1992-2022). Stock summary table (SSB at spawning time in mid January).

Year	Recruits (10*3)	SD	CV	SSB (ton.)	SD	CV	$F_{2\text{-}10}$	SD	CV	Catch (ton.)
1992	4482820	921096	0.21	313108.7	79616.82	0.25	0.082533	0.019808	0.24	27937
1993	3133310	676582	0.22	334365.9	87474.34	0.26	0.087803	0.021951	0.25	31736.5
1994	3092330	673459	0.22	356728.5	97010.26	0.27	0.07173	0.01865	0.26	28608.5
1995	4226970	894732	0.21	340183.8	95583.72	0.28	0.068706	0.018551	0.27	25196.1
1996	11384700	2196920	0.19	361669.1	104517.3	0.29	0.050086	0.013523	0.27	20364.8
1997	3733280	785080	0.21	380571.6	110218.1	0.29	0.069311	0.018714	0.27	29394.5
1998	2387040	535580	0.22	383811	109619	0.29	0.092232	0.024903	0.27	41850.7
1999	3637770	778967	0.21	436031.9	127840.2	0.29	0.056858	0.01592	0.28	27786.7
2000	3316550	727628	0.22	420472.4	125991.6	0.3	0.05875	0.01645	0.28	26142.5
2001	3909550	852647	0.22	403447.1	123596.2	0.31	0.058018	0.016245	0.28	24823.5
2002	2204010	520495	0.24	390215.9	121242.1	0.31	0.056458	0.015808	0.28	22458.7
2003	4368740	962351	0.22	390054.6	122582.7	0.31	0.0477	0.013356	0.28	18848.9
2004	4812490	1058490	0.22	441494.4	139863.3	0.32	0.051947	0.014545	0.28	24406.2
2005	3013020	696671	0.23	403206.7	128612.8	0.32	0.053215	0.0149	0.28	22630.7
2006	1560650	399411	0.26	390629.4	124749.1	0.32	0.05882	0.017058	0.29	23874.6
2007	2299120	568168	0.25	392929.6	127135.5	0.32	0.056284	0.016322	0.29	22781.6
2008	3615430	880997	0.24	386255.3	127484.6	0.33	0.058311	0.017493	0.3	22929.8
2009	3333110	852298	0.26	386195.8	130380.6	0.34	0.066383	0.020579	0.31	25666.5
2010	4108790	1080100	0.26	386296.6	133307.4	0.35	0.066215	0.020527	0.31	27183.8
2011	10057800	2565500	0.26	386671	136095	0.35	0.042515	0.013605	0.32	21861
2012	11798500	3020740	0.26	406574.9	142853.6	0.35	0.045465	0.014549	0.32	24800.3
2013	6438350	1738950	0.27	407689.2	140713.7	0.35	0.045101	0.014883	0.33	28960.8
2014	8591460	2305920	0.27	505640.9	169725.6	0.34	0.040236	0.013278	0.33	29048.8
2015	9370680	2561970	0.27	549476.6	182166.1	0.33	0.04462	0.014725	0.33	32716.2
2016	10400200	2909840	0.28	577847.2	192070.2	0.33	0.054128	0.017862	0.33	40724.7
2017	13605100	3863760	0.28	670697.3	225377.2	0.34	0.042901	0.014157	0.33	36936.1
2018	12227000	3574840	0.29	814188.1	273766.4	0.34	0.030872	0.010188	0.33	31674
2019	10735400	3230710	0.3	899356.2	299144.4	0.33	0.031328	0.010338	0.33	35540.5
2020	7533870	2417200	0.32	876497.3	289835.3	0.33	0.027963	0.009228	0.33	30181.5
2021	8809300	3006750	0.34	930637.9	307220.3	0.33	0.025552	0.008177	0.32	26330.2
2022	2281870	1468730	0.64	1147452	379835.9	0.33	0.019955	0.006386	0.32	25001.7
Average	**5950620**	**1571825**	**0.26**	**499045.1**	**159859**	**0.32**	**0.05**	**0.02**	**0.3**	**27690.24**

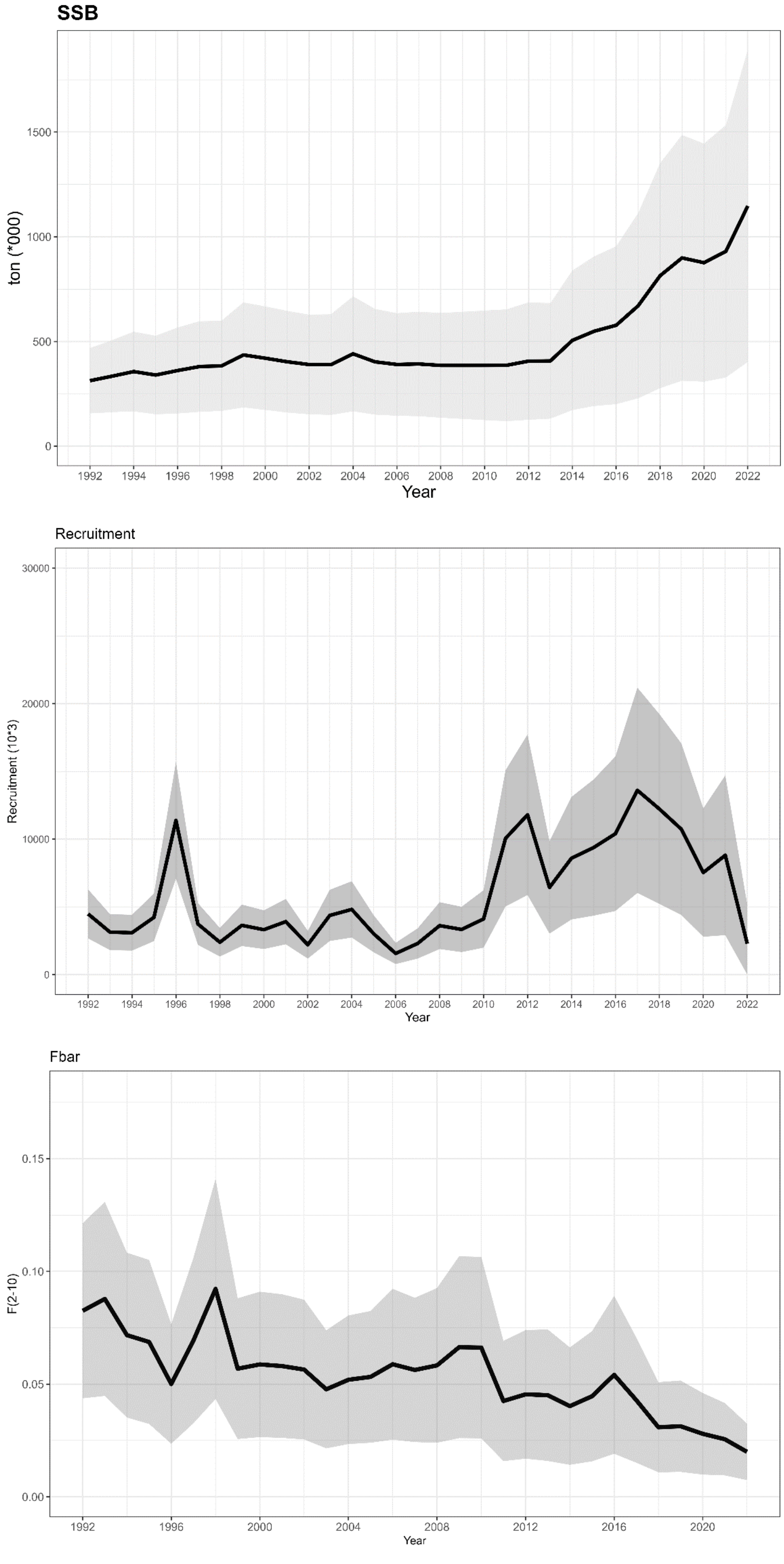


Figure 9.4.1.2. Horse mackerel in Division 9.a. Final assessment (1992-2022). Plots of SSB (top), Recruitment (middle) and Fishing mortality (bottom, mean F_{2-10}). Grey shaded area shows 95% confidence bounds and average CV is 32% for SSB, 30% for F_{2-10} and 26% for Recruitment. SSB and are in thousand tonnes and recruitment in thousands.

The estimated SSB shows a significant increase from 2013 to 2022 from 408 thousand tonnes to 1 147 thousand tonnes. Confidence intervals of SSB are in the range 25-35% with an average 26%. The fishing mortality has been below F_{MSY} over the whole time-series and after the slight increase in 2016, showed a decrease in 2017-2022. F_{2-10} in 2022 was estimated at 0.02 lower than the observed value in 2021. Confidence intervals of F are in the range 24-33%.

The stock showed a strong recruitment in 1996 and above average recruitments in the most recent years, with high values in 2011, 2012, 2017 and 2018. Recruitment estimates in the more recent years presents a high uncertainty showed in the wide confidence intervals (Figure 9.4.1.2). In 2022, recruitment showed a strong decrease and was estimated at 228 million individuals but with high uncertainty.

Figure 9.4.1.3 shows the scatterplot of the estimated spawning–stock biomass and recruitment in the period 1992–2022.

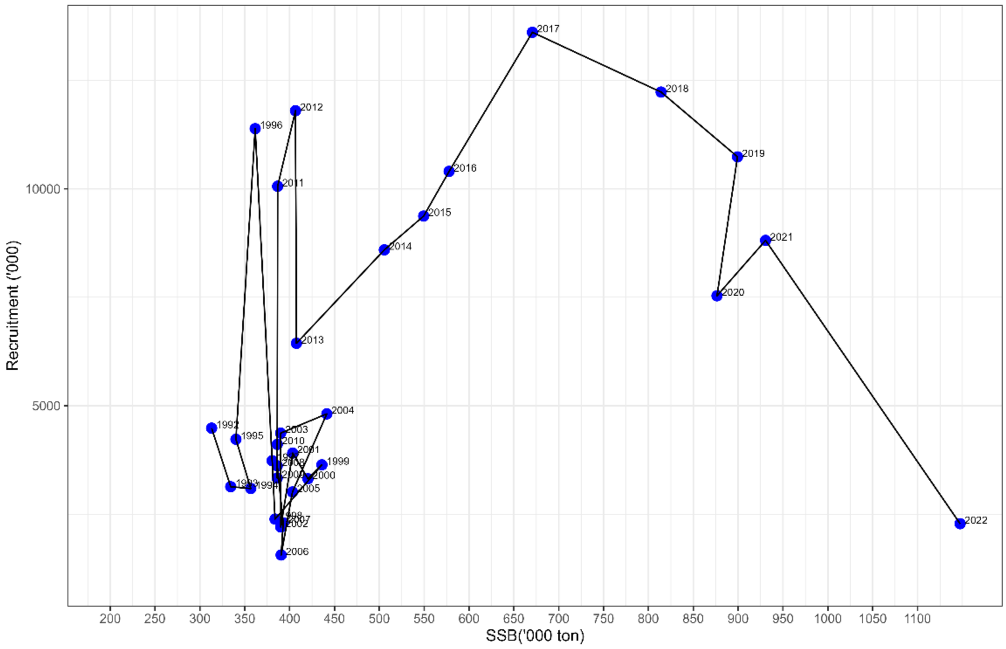


Figure 9.4.1.3. Horse mackerel in Division 9.a. Stock–recruitment data for southern horse mackerel (1992-2022).

9.4.2 Reliability of the assessment

The landings of this stock are believed to be fairly accurate, given the good sampling coverage, few discards (according to on-board observers) and the existence of well-defined ageing criteria. Therefore, a higher weight is given to the data series of landings in weight, which was very well fitted by the model (Figure 9.4.2.1).

The assessment is also tuned with the stratified mean abundance-at-age estimated for the combined Portuguese and Spanish IBTS surveys. The model down-weighted the high biomass observed in 2005. However, the 2013 and 2017 survey index were the highest in the time series which contributed for a steady increase of the fitted survey biomass index from 2013 to 2018, reaching values 2 times above the average (Figure 9.4.2.1). In 2019 and 2020 the survey was not carried out in the Portuguese area of Division 9.a. As this part of the survey covers 87% of the total stock area, the combined survey index could not be estimated. Because of this, the stock assessment was performed without the 2019 and 2020 survey index values which might have led to an increased uncertainty of these year-classes in the present spawning biomass estimates. In 2021 and 2022, the Portuguese Bottom Trawl Survey was carried out and the combined survey index estimate was used in the assessment. However, the assessment stills shows high uncertainty, reflected in the large confidence intervals for SSB and recruitment (Figure 9.4.1.2).

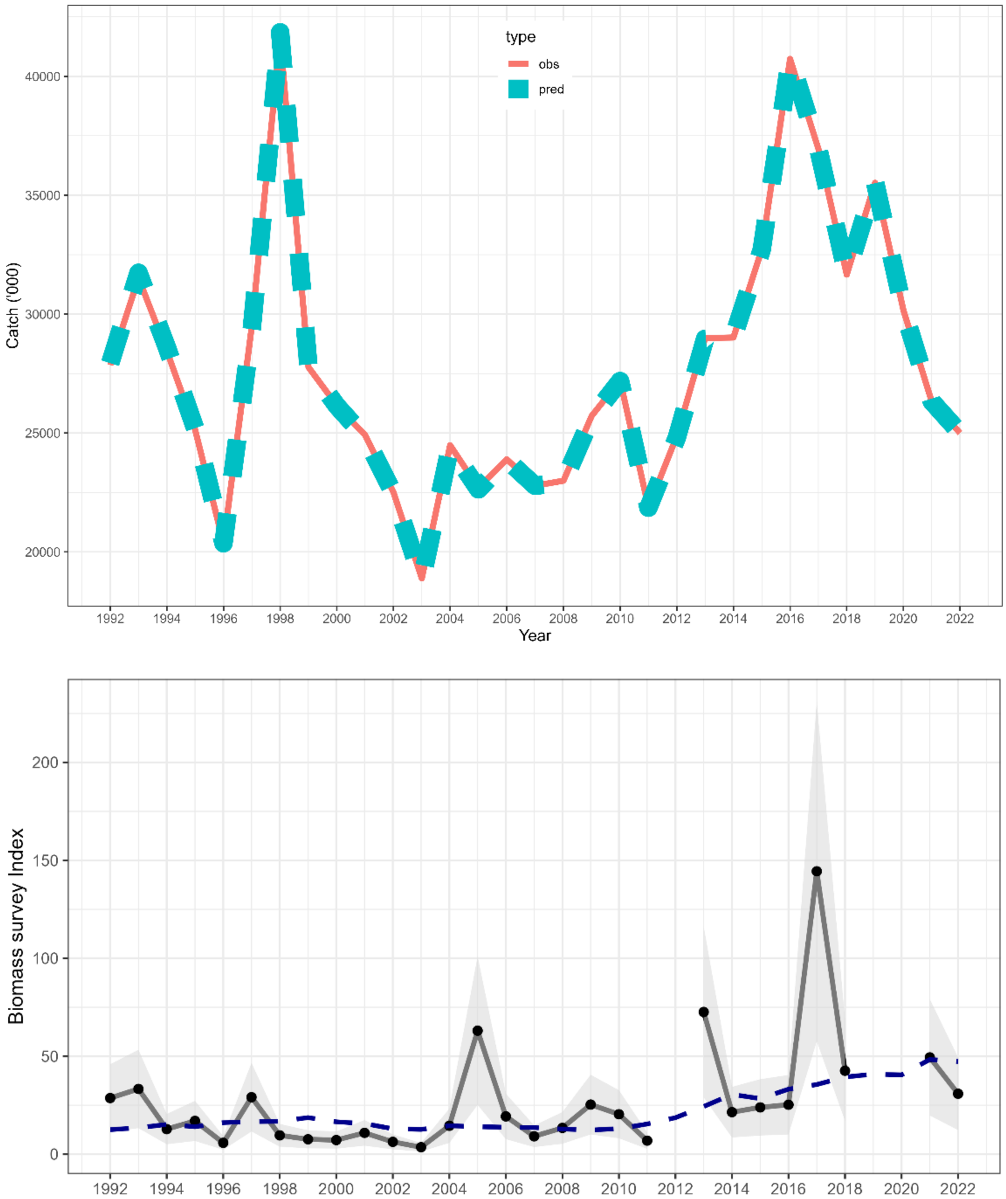


Figure 9.4.2.1. Horse mackerel in Division 9.a. Catch biomass (top) and survey biomass index (bottom): observed (solid black line) and estimated values (dashed blue line). (grey shaded area shows 95% confidence bounds of survey biomass index).

A good fit was obtained for the proportions-at-age of the catch in numbers (Figure 9.4.2.2) and, overall for the abundance indices in number/hour from the IBTS combined survey (Figure 9.4.2.3). The bubble plots of the residuals corresponding to the fitting of those data are shown in Figure 9.4.2.4.

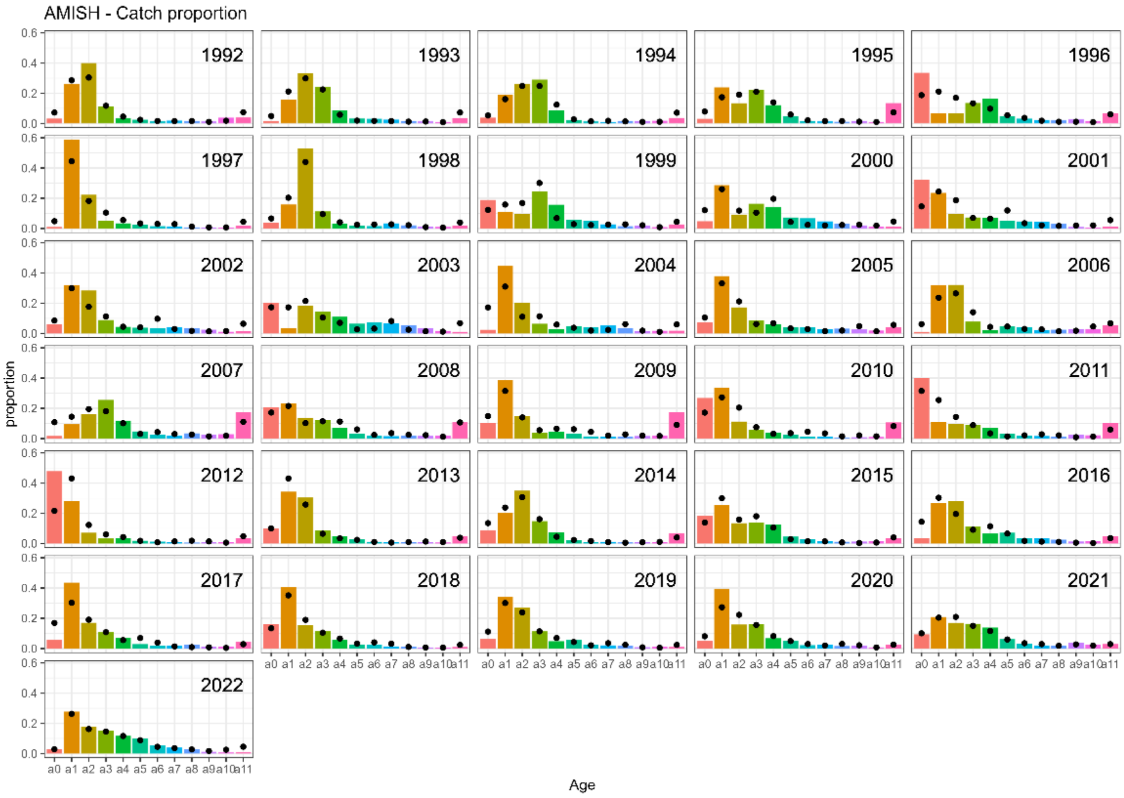


Figure 9.4.2.2. Horse mackerel in Division 9.a. Comparison of proportions-at-age of the observed and fitted catch data (observed values=dots; fitted values=solid lines).

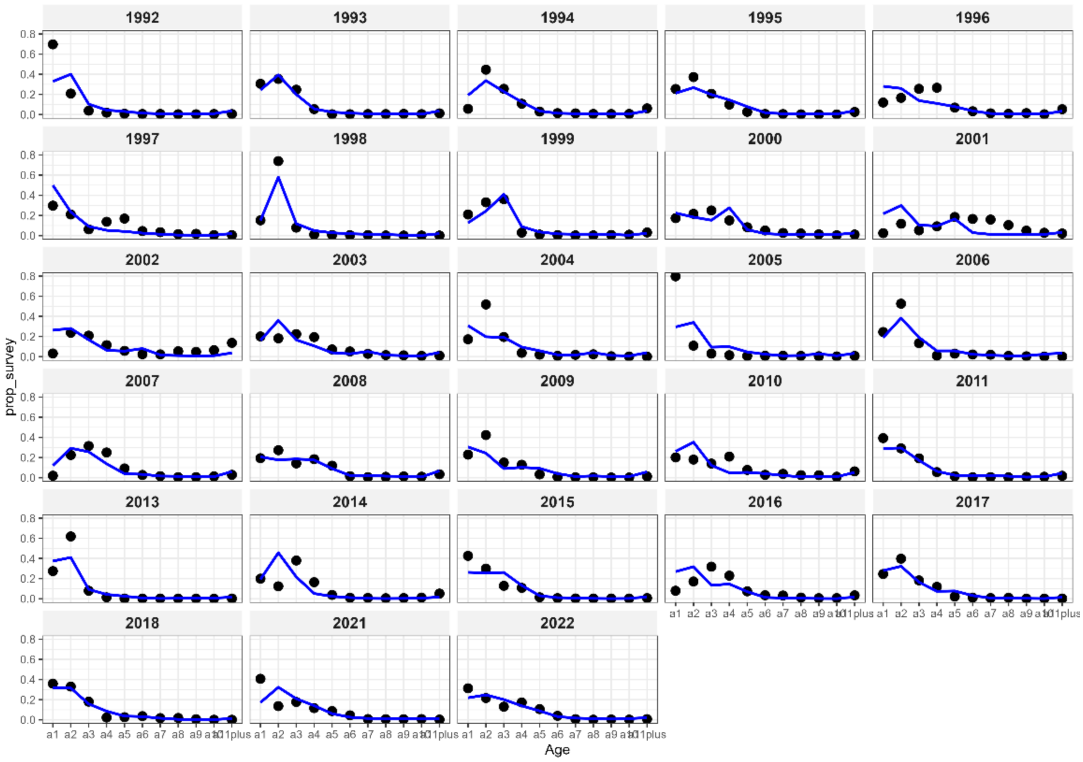


Figure 9.4.2.3. Horse mackerel in Division 9.a. Comparison of proportions-at-age of the observed and fitted survey data (observed values=dots; fitted values=solid lines).

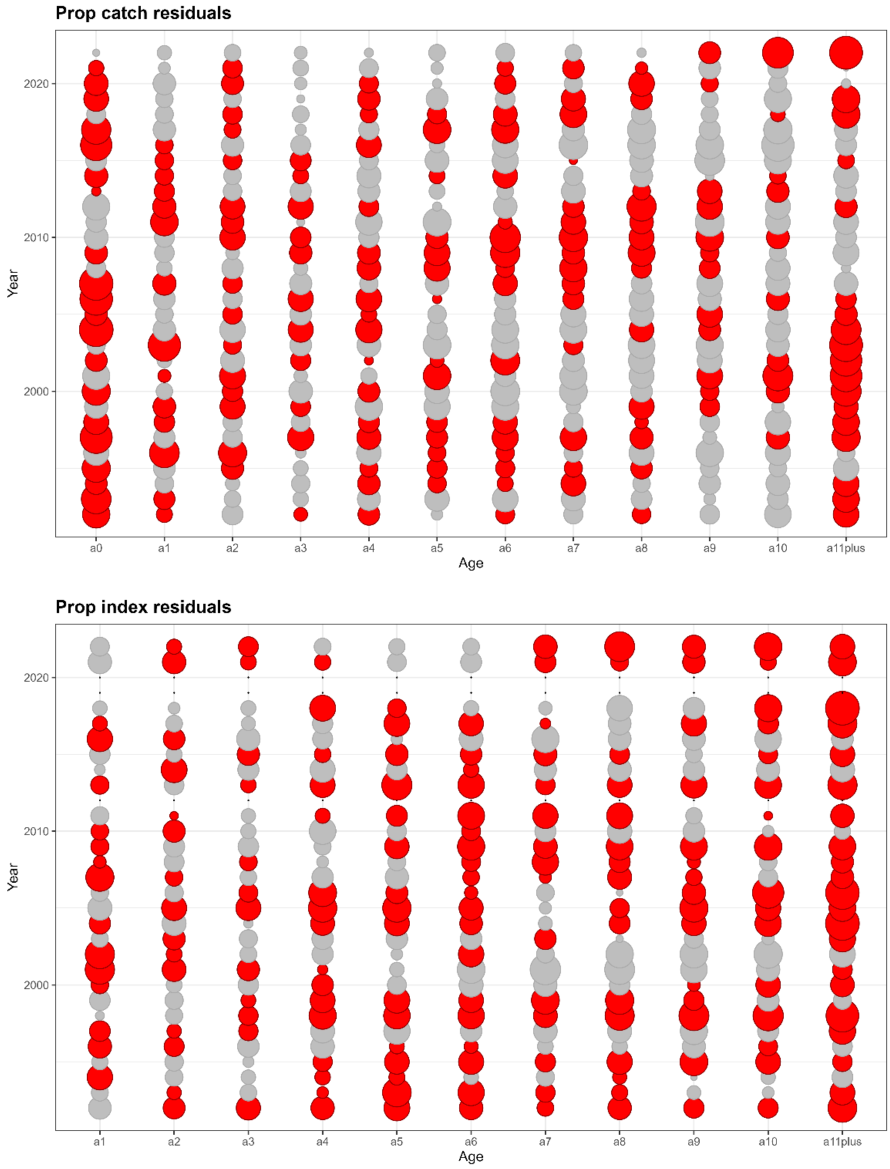


Figure 9.4.2.4. Horse mackerel in Division 9.a. Bubble plot of catch (top, age range 0–11+) and survey (bottom, age range: 1–11+) proportion-at-age residuals (negative residuals=red bubbles).

The significant increase in SSB in recent years is reflecting the contribution of the survivors of the above average recruitment in recent years. The uncertainty in SSB in most recent years is around 33% (coefficient of variation). The slight decrease in catches observed in 2022 and the continuous increase in estimated stock abundance in the last few years resulted in a lower estimate of F_{bar} in 2022 than in the previous year. The uncertainty in the estimated F_{bar} is of similar magnitude (coefficient of variation around 32%). In 2019 and 2020 the survey was not carried out in the Portuguese area of Division 9.a. In 2021 and 2022, the combined survey index estimate was used in the assessment but recruitment (and SSB) estimates shows high uncertainty, reflected in the large confidence intervals in 2021 and 2022 with 34% and 64%, respectively (Table 9.4.1.2).

Besides the above-mentioned issues, there has also been a continued and significant shift in relative catch contribution from bottom trawls to purse-seines in recent years. The relative importance in the annual catches of the purse-seine fleet has increased substantially from 33% in 2011 to 73% in 2022. Changes in the relative contribution to the catch from bottom trawls and purse-seines (Figure 9.4.2.5) have led to changes in the age composition of catches. This may lead to inconsistency in estimating selectivity for the last period of the assessment. WGHANSA performed exploratory analysis using different selectivity patterns, the results are shown in a following section of this report (section 9.8) and should be further explored when revising the stock methodology in the future benchmark.

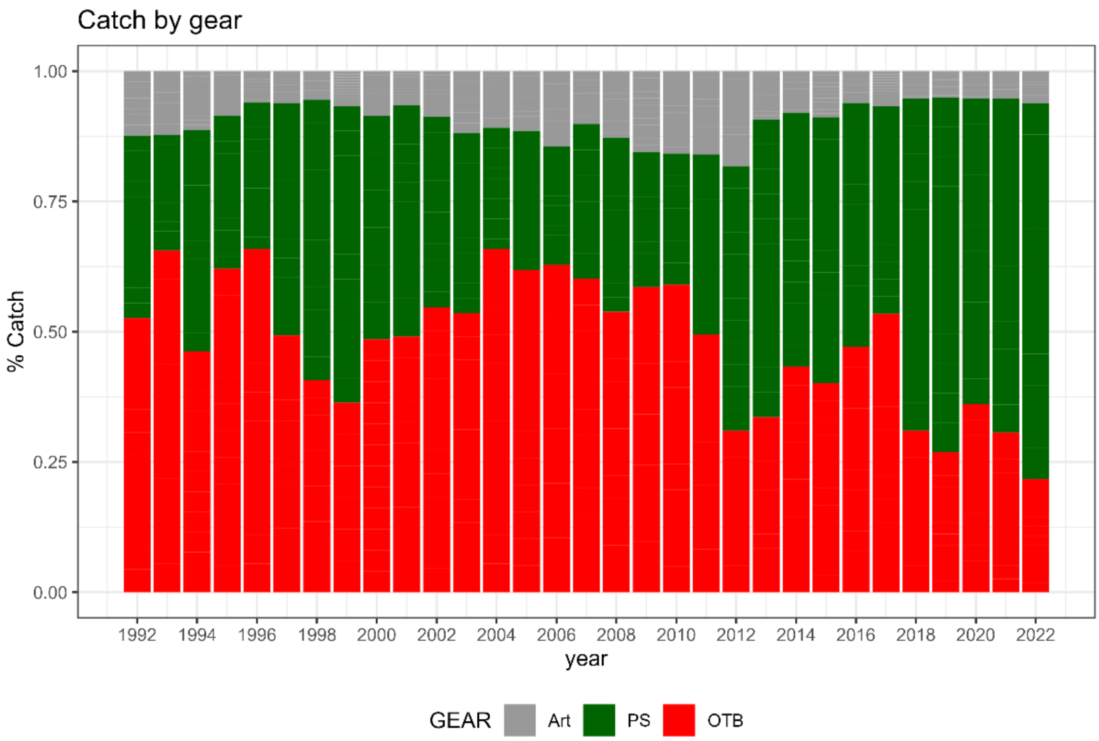


Figure 9.4.2.5. Horse mackerel in Division 9.a. Contribution of southern horse mackerel catches by gear (PS – Purse seine, OTB – bottom trawl, Art – Artisanal) from 1992-2022.

The retrospective analysis on SSB, recruitment and F_{bar} (mean F ages 2–10) was performed for a five-year period, from 1992–2017 to 1992–2022 time-series. The Mohn´s rho estimated for each retrospective peel and the 5-year average Mohn´s rho are shown in Table 9.4.2.1 and indicate a minor overestimation of the SSB (0.08) and overestimation of F (-0.08) and a slight overestimation of Recruitment (0.19). Because of the very high uncertainty observed in the last recruitment estimate (also not used in the short term forecast), the Mohn´s rho for recruitment is calculated without the terminal year. The Mohn´s rho results are below the suggested critical value (± 0.30) and the observed retrospectives are mostly inside the confidence bounds of the last assessment estimates (Figure 9.4.2.6).

Table 9.4.2.1. Horse mackerel in Division 9.a. Input to the calculations of Mohn’s rho from the most recent assessments and 5 retrospective assessments. The last assessment estimates (*base*) compared to each retrospective assessment (*retro*) and the relative bias in each year. The adopted Mohn´s rho is the average of the five last year relative bias.

F Mohn´s rho	Base	Retro	Relative Bias
2017	0.043	0.044	0.027
2018	0.031	0.029	-0.048
2019	0.031	0.028	-0.096
2020	0.028	0.024	-0.13
2021	0.026	0.022	-0.132
Average rho			**-0.0757**

SSB Mohn´s rho	Base	Retro	Relative Bias
2017	691.882	737.556	0.066
2018	762.296	888.422	0.165
2019	856.724	992.092	0.158
2020	963.31	983.374	0.021
2021	1066.534	1066.96	0
Average rho			**0.0821**

Recruitment Mohn´s rho*	Base	Retro	Relative Bias
2016	10400.2	11141.4	0.071
2017	13605.1	13087.8	-0.038
2018	12227	16394.6	0.341
2019	10735.4	15326.4	0.428
2020	7533.87	8679.67	0.152
Average rho			**0.1907**

*** Mohn´s rho for recruitment is estimated without the terminal year**

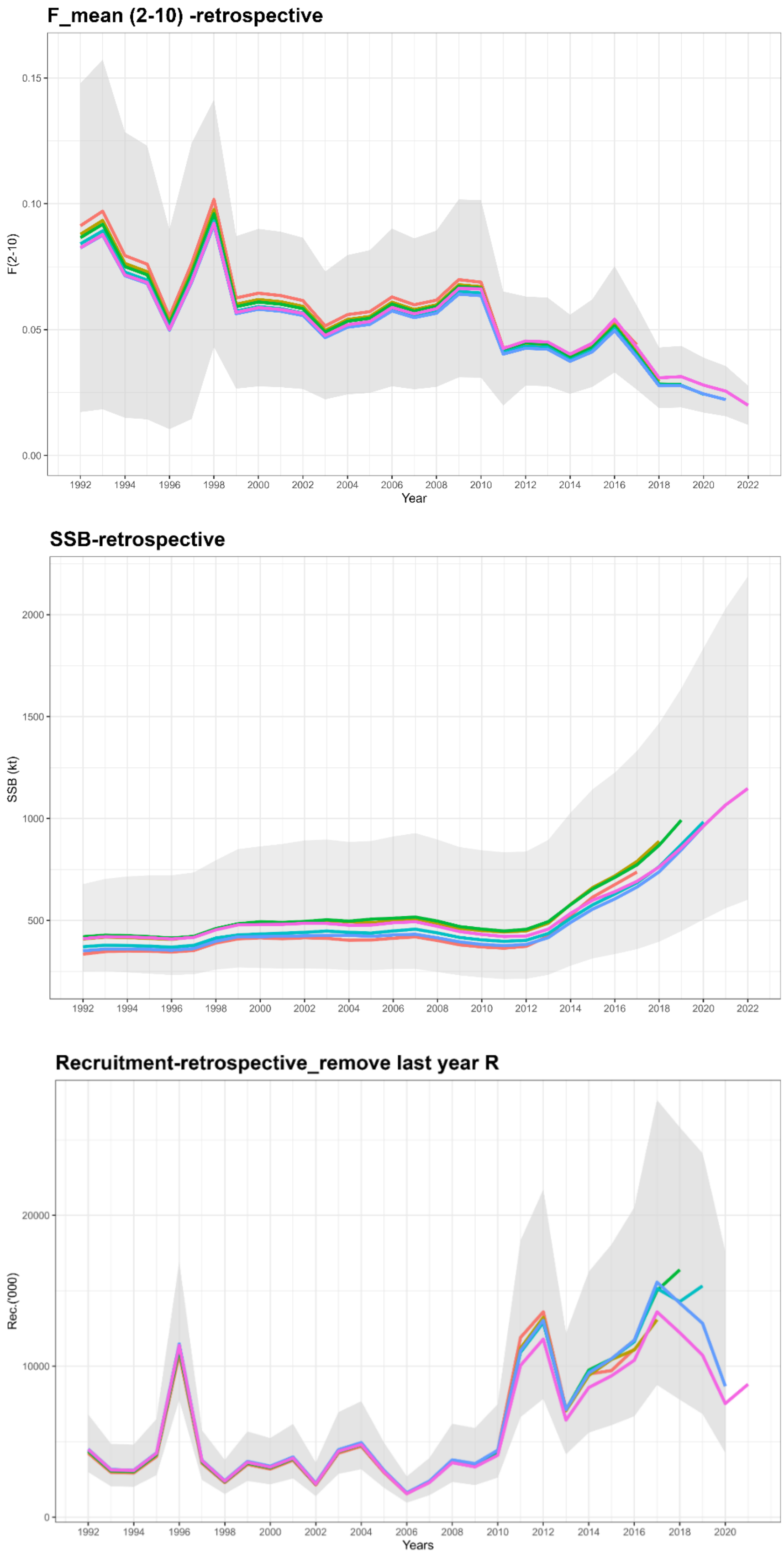


Figure 9.4.2.6. Horse mackerel in Division 9.a. Retrospective analysis results. Trajectories of SSB, Recruitment and Fbar (grey=95% confidence intervals) for the current assessment and the retrospective assessments.

9.5 Short-term predictions

Deterministic short-term forecasts were carried out with R using the Fisheries Library in R (FLR) "FLAssess" (Version 2.6.3) and "Flash" (Version 2.5.1), following assumptions and settings agreed during the benchmark (ICES, 2017) and described in the Stock Annex. Recruitment is assumed for 2022 and 2023, corresponding to the geometric mean recruitment of 1992–2021 (5 096 million fish). The abundance-at-age-1 in 2023 are the survivors of the geometric mean recruitment assumed for 2022. Weight-at-age in the catch and in the stock and fishing mortality for the interim year are assumed equal to those of the last assessment year.

Figure 9.5.1 shows the trajectories of SSB, Recruitment and Fbar from last year assessment and the current assessment. The estimates and trajectories of the key parameters are very similar between both assessments. Table 9.5.1 also shows that the numbers and biomass-at-age estimates for 2020, 2021, and 2022 are very similar. However, there are differences in the estimates for age-0 and age-1 in 2022 (intermediate year in last year forecast). These differences are explained by the high uncertainty observed in the last recruitment estimate which is replaced by the geometric mean. The estimated abundance-at-age-1 used in the forecasts is also replaced by the survivors of the assumed recruitment. The differences in age-1 biomass are bigger because of the differences between the assumed weight at age-1 used in last year forecast and the observed estimate in 2022 (Table 9.5.2). The remaining weight and fishery-at-age used in last year assessment forecasts and current stock assessment forecast are similar (Table 9.5.2). Last year forecast assumptions in F, catch and recruitment are very similar to this year observed estimates (Table 9.5.3)

Table 9.5.4 shows the management options table from the deterministic short-term forecasts at fishing mortalities levels used for the different catch scenario options in the advice. The management options table include forecasts of SSB at spawning time (assumed mid-January) and catch at current fishing mortality (F_{bar} of 0.020), F_{MSY}, F_{lim}, the F based on the management plan and the F_{pa} as the maximum value of F applied when SSB > MSY Btrigger that will result in SSB ≥ Blim with a 95% probability in a stochastic long-term simulation. Forecast of catches at the F level that produces SSB=B_{lim} and SSB=MSY $B_{trigger}$ are also showed.

The forecasts are deterministic and, therefore, no estimates of uncertainty are calculated. Sources of uncertainty in the outcomes is the recruitment assumed for 2022-2024, the assumptions on a stable mean fishing mortality and the observed changes in the fishery selection pattern in most recent years.

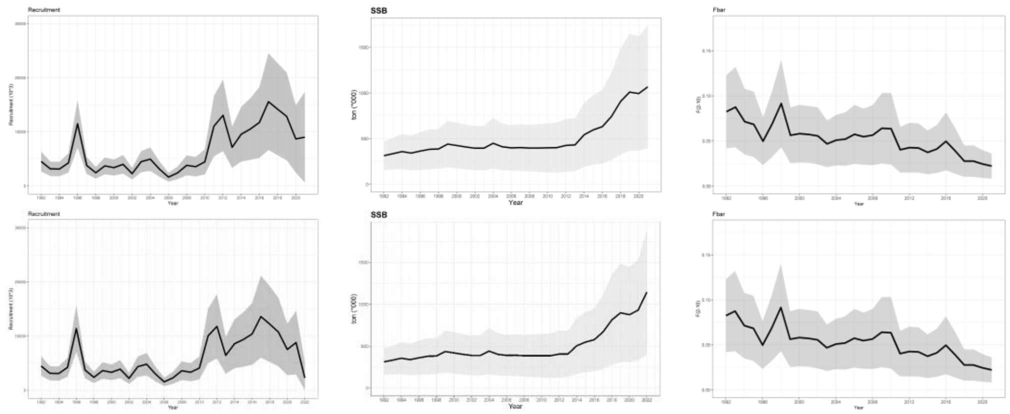


Figure 9.5.1. Horse mackerel in Division 9.a. Trajectories of SSB, Recruitment and Fbar (grey=95% confidence intervals) for last year assessment (top) and the current assessment (bottom).

Table 9.5.1. Horse mackerel in Division 9.a. Comparison of numbers and biomass-at-age in 2020, 2021 and 2022 between last year outputs and current stock assessment. 2022 estimates in the previous assessment from short term forecast/assumptions.

Age	Numbers 2020	Numbers 2021	Numbers 2022	Biomass 2020	Biomass 2021	Biomass 2022
0*	0.87	1.66	0.96	0.87	1.66	1.02
1*	0.83	0.87	1.66	0.83	0.87	2.89
2	0.86	0.83	0.86	0.86	0.83	0.99
3	0.86	0.85	0.83	0.86	0.85	0.97
4	0.87	0.86	0.85	0.87	0.86	0.99
5	0.87	0.87	0.85	0.87	0.87	0.95
6	0.87	0.86	0.86	0.87	0.86	0.99
7	0.87	0.87	0.86	0.87	0.87	0.97
8	0.87	0.87	0.87	0.87	0.87	0.86
9	0.88	0.87	0.87	0.88	0.87	0.96
10	0.89	0.88	0.87	0.89	0.88	1.02
11+	0.94	0.93	0.91	0.94	0.93	1.10

*** Recruitment is assumed for terminal and interim year in the forecast. The abundance-at-age-1 in interim year used in the forecasts are the survivors of the assumed recruitment.**

Table 9.5.2. Horse mackerel in Division 9.a. Comparison of weight (kg) and fishery-at-age used in last year assessment forecasts (2022-forecast) and current stock assessment (2022-estimated).

Age	weight 2022-forecast	weight 2022-estimated	F-at-age 2022-forecast	F-at-age 2022-estimated
0	0.015	0.016	0.004	0.004
1	0.027	0.047	0.023	0.022
2	0.054	0.062	0.028	0.027
3	0.077	0.09	0.027	0.025
4	0.098	0.115	0.025	0.023
5	0.129	0.143	0.021	0.020
6	0.154	0.177	0.017	0.016
7	0.183	0.207	0.021	0.017
8	0.226	0.224	0.021	0.017
9	0.248	0.274	0.021	0.017

Age	weight 2022-forecast	weight 2022-estimated	F-at-age 2022-forecast	F-at-age 2022-estimated
10	0.278	0.325	0.021	0.017
11+	0.335	0.408	0.021	0.017

Table 9.5.3. Horse mackerel in Division 9.a. Forecast assumptions for last year assessment forecasts (2022) and current stock assessment forecast (2023).

	Year	Current assessment (2023)	Previous assessment (2022)
Assumed recruitment (millions)	2022	5310	5096
	2023	5310	5096
Catch (tonnes)	2022	24997	26254
F	2022	0.020	0.022
Target F for TAC	2023	0.15	0.15

Table 9.5.4. Horse mackerel in Division 9.a. Short-term forecast (2023–2025) for southern horse mackerel management options. Catch and SSB (at spawning time) in tonnes.

	F 2-10 (2024)	Catches (2024)	SSB (2024)	SSB (2025)
F_{MSY}	0.150	173873	1244544	1111216
F_{sq}	0.020	24551	1250810	1262369
$F = F_{sq} \times 1.2$	0.024	29407	1250618	1257430
$F = F_{sq} \times 1.6$	0.032	39064	1250232	1247611
$F = F_{sq} \times 2.0$	0.040	48651	1249847	1237871
F_{pa}	0.150	173873	1244544	1111216
F_{lim}	0.190	216303	1242624	1068557
F_{MP}	0.110	129845	1246468	1155622
SSB (2025) = B_{lim}	2.643	1254759	1130454	103000
SSB (2025) = B_{pa} = MSY $B_{trigger}$	2.047	1156759	1156945	181000

9.6 Biological reference points

Biological Reference Points for southern horse mackerel (B_{lim}, B_{pa}, MSY $B_{trigger}$, F_{lim}, F_{pa} and F_{MSY}) estimated in the 2016 Assessment Working Group (ICES, WGHANSA 2016), were approved by ICES and adopted for the development of the management plan for this stock in the PELAC October 2016 meeting (Table 9.6.1). The biological reference points were re-evaluated during the 2017 benchmark (WKPELA). However, the new estimates resulted in very similar values and it was agreed not to revise the previously accepted BRP´s from both ICES and PELAC (ICES, 2017).

ICES redefined F_{pa} as $F_{p0.5}$ (the F that leads to SSB ≥ Blim with 95% probability) in 2021 and this led to a change in F_{MSY} value that is no longer constrained by F_{pa} from 0.11 to 0.15 (ICES, 2021).

Table 9.6.1. Horse mackerel in Division 9.a. Biological Reference points for southern horse mackerel. Values and the technical basis (weights in thousand tonnes).

BRP	Value	Technical basis
B_{lim}	103	$B_{lim} = B_{pa} * \exp(-1.645\ \sigma)$ σ = 0.32 (0.34)
B_{pa}	181	$B_{pa} = B_{trigger}$
MSY $B_{trigger}$	181	Lower bound (average) of 90%CI of $SSB_{1992-2015}$
F_{lim}	0.19	Stochastic long-term simulations (50% probability SSB > B_{lim})
F_{pa}	0.15	F that leads to SSB ≥ Blim with 95% probability (update ICES, 2021).
F_{MSY}	0.15	Stochastic long-term simulations

9.7 Management considerations

The traditional fishery across several fleets has for a long time targeted juvenile age classes. This exploitation pattern combined with a fishing mortality well below F_{MSY} over the whole time-series does not seem to have been detrimental to the dynamics of the stock. Spawning–stock biomass has been above MSY $B_{trigger}$ over the whole time-series with a continuous increase in the last five years and is currently at its highest level. Recruitment since 2011 has been above the time-series average.

The basis for the advice is the same as last year: the MSY approach (F=0.15) and gives estimated catches in 2024 of 173 873 tonnes. The catch advice for 2024 under the MSY approach, represents a significant increase of 596% in comparison with catches observed in 2022. The difference between the advised TAC and the observed catches is notably dissimilar in recent years (Figure 9.7.1).

There is a MP for this stock, developed within the PELAC-SWWAC framework, that has been evaluated as precautionary by ICES with Ftarget=0.11 (previous F_{MSY}). The management strategy includes a +/- 15% stability clause which is only implemented after the first year of the plan being applied. Since the plan has not previously been applied, the 2024 TAC is not based on the plan and the stability clause does not apply. Last year, ICES redefined Fpa as Fp0.5 (the F that leads to SSB ≥ Blim with 95% probability) (ICES, 2021) and this led to a redefinition of F_{MSY} to 0.15. This updated F_{MSY} differs from the Ftarget considered in the management plan that was evaluated in ICES (2018).

The advice pertains to *T. trachurus*, while the total allowable catch (TAC) is set for all *Trachurus* species, including *T. picturatus* (blue jack mackerel) and *T. mediterraneus* (Mediterranean horse mackerel). Part of the catches consist of other *Trachurus* spp. than *T. trachurus*, and this percentage can vary from year to year. Estimates indicate that in 2022, 14% of the catch consisted of *Trachurus* spp. (3592 t, mostly *T. picturatus*) other than *T. trachurus*. ICES considers that management of several species under a combined TAC prevents effective control of the single-species exploitation rates, and could lead to overexploitation of any of the species.

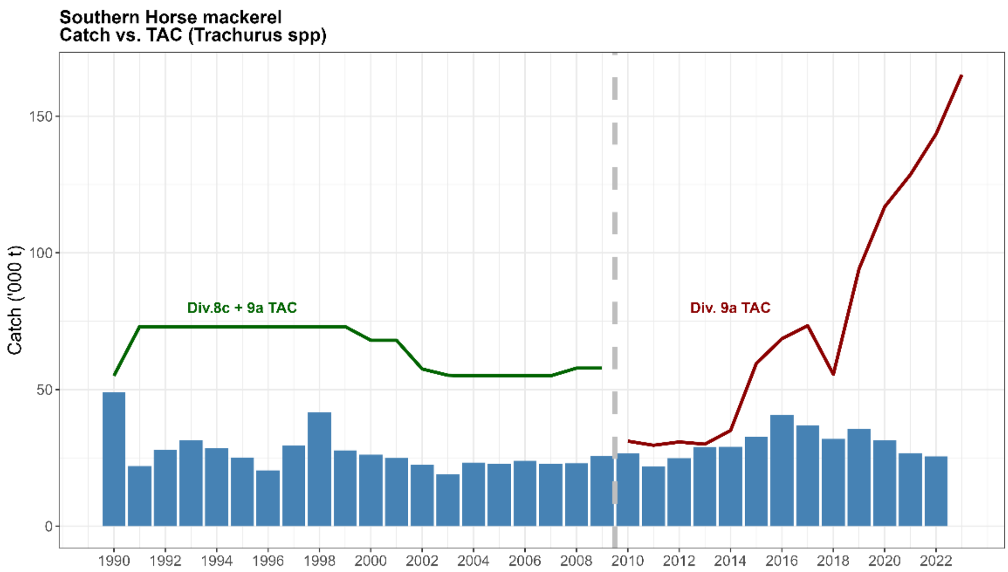


Figure 9.7.1. Horse mackerel in Division 9.a. Catch and TAC for southern horse mackerel. Blue bars show catches for southern horse mackerel, green line shows combined TAC for horse mackerel in division 8c and 9a and red line shows TAC for horse mackerel in division 9a.

9.8 Preliminary analysis in preparation for benchmark

9.8.1 Exploratory analysis on the selectivity pattern

As showed in the previous sections, there has been a continued and significant shift in relative catch contribution from bottom trawls to purse-seines in recent years. The relative importance in the annual catches of the purse-seine fleet has increased substantially from 33% in 2011 to 73% in 2022. Changes in the relative contribution to the catch from bottom trawls and purse-seines have led to changes in the age composition of catches. This may violate the assumption of constant selectivity (3-blocks) used in the current model and contribute to uncertainty in the assessment. WGHANSA performed exploratory analysis using different selectivity patterns with an updated version of the model AMISH, which we will designate AMAK2. The updated model uses ADMB translation and it is very flexible with regards to the functional forms that can be used for the biological processes and the fishery (selectivity), including a more flexible time-varying selectivity, as well as to the number of parameters that can be estimated and multi–stock assessment. The updated software is used within the South Pacific Regional Fishery Management Organization (SPRFMO) for the assessment of the Chilean Jack mackerel (https://sprfmo.int/meetings/scientific-committee/sc-workshops/scw14-jack-mackerel).
In this sensitivity analysis, we tested a new selectivity option that offers greater flexibility compared to the current fixed 3-block selectivity setting used in horse mackerel assessment (section 9.4.1). The time-varying selectivity using random walks can account for this time changing

process and allows for sufficient flexibility, based on the observed catch-at-age patterns for this stock. The selectivity was permitted to vary by year and between age-0 and age-6. Furthermore, an additional exploratory assessment trial was conducted using a constant dome-shaped selectivity. Selectivity was fixed for age 7+ in all exploratory runs to facilitate better comparison with the current assessment and the exploitation pattern for these older individuals.

Figure 9.8.1.1 illustrates the estimated selectivity patterns for the proposed time-varying, 3-block (current assessment) and fixed selectivity. The pattern demonstrated by the time-varying selectivity is more variable when compared to the other exploratory runs.

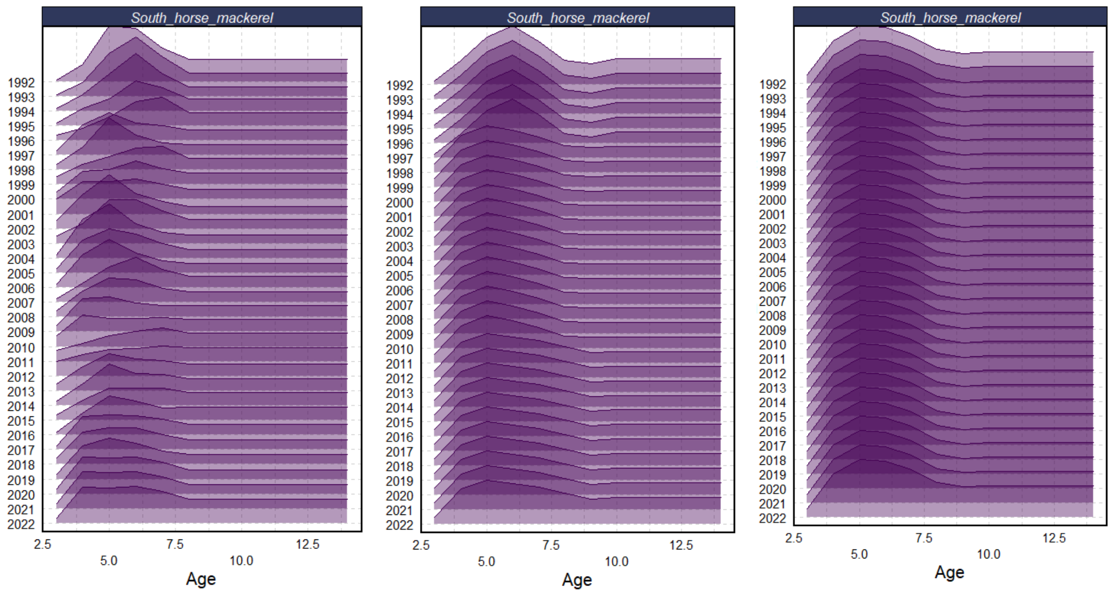


Figure 9.8.1.1. Horse mackerel in Division 9.a. Time varying selectivity (left panel), current 3-block selectivity (middle panel) and dome-shaped fixed selectivity pattern (right panel). Selectivity was fixed for age 7+.

Figure 9.8.1.2 shows the comparative trajectories of F_{bar}, recruitment, SSB and total stock biomass for the time varying (*amak2_time var*), fixed selectivity (*amak2_fixed sel*) and the AMISH assessment runs. Similar trajectories are evident but the biomass estimates for the time-varying selectivity run are lower, also showing a much lower uncertainty in all the estimates. The mean CV in SSB was estimated at 17% when compared to the fixed selectivity (31%) and the current AMISH assessment (32%).

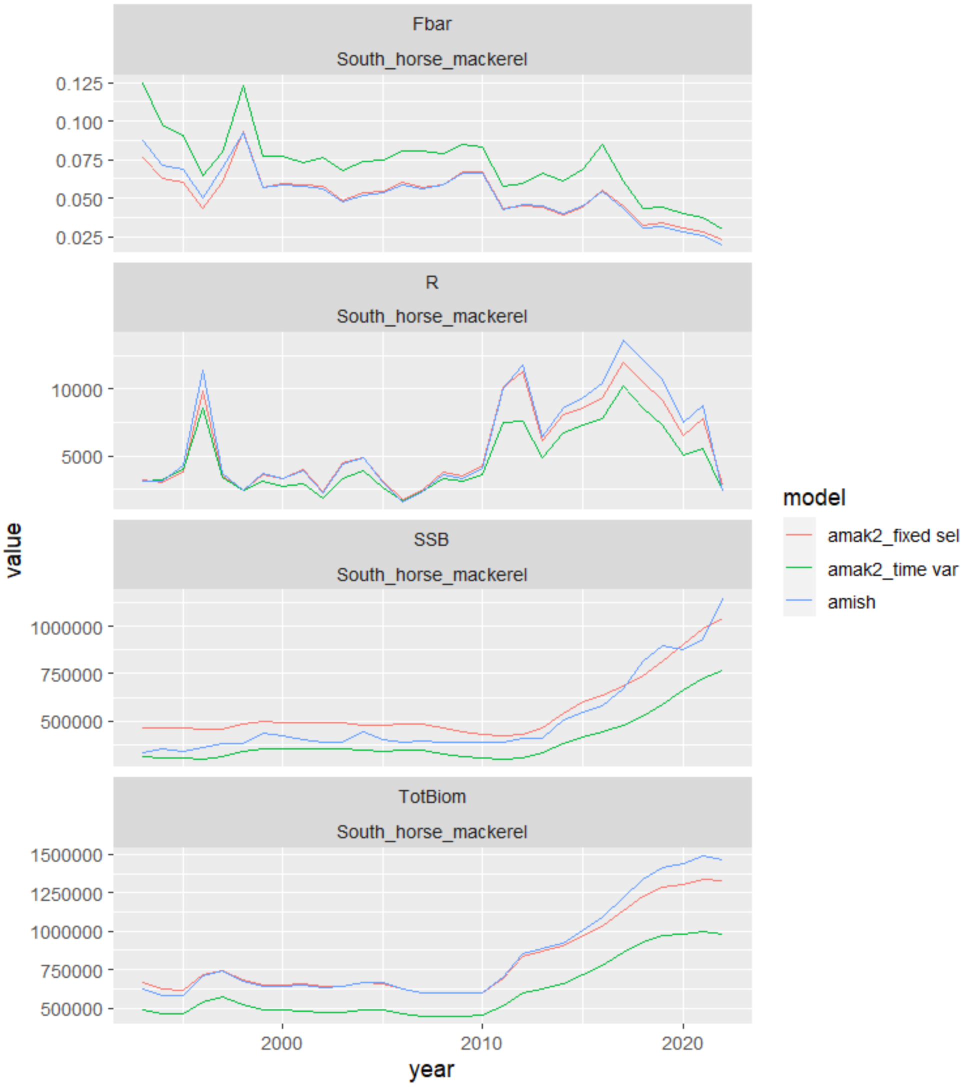


Figure 9.8.1.2. Horse mackerel in Division 9.a. Trajectories of F_{bar}, Recruitment, SSB and total biomass for the current assessment (*amish*, blue line), time varying (*amak2_time var*, green line) and fixed selectivity (*amak2_fixed sel*, red line) exploratory assessment runs.

The substantial decrease in SSB and total biomass estimates observed in the flexible selectivity assessment, as compared to the current assessment, should be further analysed in the benchmark process to evaluate potential changes in the selectivity pattern that could accommodate the observed variations in catch-at-age composition. While several mechanisms for the varying selectivity are understood for this stock, causes for changes in specific time periods are often not. Discussing whether it accurately reflects changes in the population and/or fishery has to be further explored.

The estimated SSB in the terminal year of this exploratory assessment is 33% lower than that estimated by the current assessment, which has significant implications for management advice and should be carefully considered.

9.8.2 Proposed abundance index from the commercial fleet

A commercial CPUE (catch per unit effort) was developed using revised and compiled data (Silva et al., 2022) from the Portuguese trawl logbooks provided by the Portuguese fisheries administration (Directorate-General for Natural Resources, Safety and Maritime Services – DGRM) for the period 1988-2022.

After a first exploratory data analysis, records with trawl duration greater than 20 hours and horse mackerel catches above 806 kg/h (above the 99th percentile) were removed from the dataset. The number of vessels, the total number of fishing days recorded, trawling hours, average vessel engine power, average total and horse mackerel catches and the percentage zero horse mackerel catches covered in the analysis varied between years (Table 9.8.2.1). The final dataset included an average 44% of zero horse mackerel catches and was composed of 415,068 records.

Table 9.8.2.1. Horse mackerel in Division 9.a. Summary of the data obtained from the Portuguese trawl logbooks for standardization of horse mackerel CPUE (Adapted from Silva et al. 2022).

Year	No. vessels	No. days	Trawling hour	Average power	Average Tot. Catch	Average horse mackerel catch	Percent zeros
1988	33	3510	47314	528.1	1307.8	460.9	45.9
1989	18	1551	21535	547.7	1643.5	323.5	64.4
1990	52	5799	73902	540.1	1527.9	594.1	34.1
1991	54	4360	54692	543.6	1329.3	633.4	33.1
1992	47	6865	84681	525.6	1012.5	561.4	31.1
1993	67	11795	143123	514.7	923.6	720.1	22.5
1994	73	11433	136307	524	795.4	487.7	32.2
1995	73	11473	142938	522.7	808	429.5	33.7
1996	76	11418	142961	523.6	775.5	341.2	36
1997	77	13910	177987	517.7	739.7	429.2	29.8
1998	79	13766	179457	528.5	871	539.3	32.7
1999	87	11966	150213	517.4	845	341.6	42.1
2000	69	12950	167689	522.2	1055.7	362.6	46.2
2001	35	6117	79877	551.4	1190.9	487.1	39
2002	61	7212	83520	564.3	1125.1	462.3	45.2
2003	84	14065	178966	490.8	836.1	252.7	48
2004	65	12357	151956	511.9	874.4	339.8	32.7
2005	85	8872	110068	495.4	948.8	410.5	37.5
2006	87	8300	106832	462.8	740.8	322.5	54.2
2007	88	17010	211633	474.4	847.8	276.2	51.9
2008	94	16061	207743.41	469.8	1043.7	308.6	48.3
2009	90	15558	201094.01	453.2	900.4	273.3	53.7
2010	76	14317	185807.48	439.4	928.6	357.2	51.1
2011	79	13629	180373	441	929.8	297.5	50.2
2012	75	13950	164507.346	457.8	925.2	306	49
2013	80	13869	156900.5	446.7	1139.9	493.3	47.6
2014	79	13367	151643.653	429	1067.4	557.4	47.1
2015	80	14391	160368.916	430.4	1099.9	570.9	47.7
2016	79	14804	164698.586	427.2	1288.7	649.4	45.3
2017	78	14750	166259.466	416.6	1315.6	667.6	48.1
2018	82	15509	177187.833	423.3	1037.3	439.7	52.9
2019	81	15070	171379.866	420.7	1114.3	431.3	51.6

Year	No. vessels	No. days	Trawling hour	Average power	Average Tot. Catch	Average horse mackerel catch	Percent zeros
2020	82	14850	166246.616	407.7	1083.8	509	47.5
2021	80	16254	188131.55	409.1	1009.8	374.4	50.8
2022	80	13960	173805.3	414.8	956.8	298.7	52.7

In multispecies fisheries where horse mackerel is caught, data sets contain a large number of zero catches (44%). Using traditional GLM model fitting techniques, such as log transformation or collapsing strata to eliminate zero catch observations, may introduce bias in estimating the year effect and hide important information about annual levels of abundance. Various methods have been proposed to address the issue of zero-catch data, including adding a constant variable, modulating catch with Negative-Binomial error, using a delta-type two-step model, or employing a zero-inflated model. We used the approach developed by Shono (2008) with a GLM Tweedie distribution model, which directly estimates the response distribution with a Poisson-Gamma family without requiring previous estimates and offering greater parsimony handling data where the ratio of zero catch is high.

The variables considered in the analysis included year, zone, day, month, total catch, proportion of horse mackerel in the catches, LOA, gross tonnage, engine power and trawl metier. Potential collinearity between the independent variables (e.g. vessels characteristics) was analyzed and interdependence between the response and the predictor variables (e.g. proportion of horse mackerel in catch) was also explored. All significant variables ($p<0.05$) and with explained deviance >1% were retained. The best model was selected based on the explained deviance, the Akaike Information Criterion (AIC) and residual diagnostics. The selected model has the following formula:

GLM(CPUE ~ year + zone + metier + engine.power, family = (tweedie(var.power = p, link.power = 0)),

where the link.power = 0 specifies a log link function. Some exploratory models were also tested using mixed models with vessel as random effects, but no apparent improvement was observed. However, further analyses are required to accurately assess the performance prediction of these models.

The 1988-2022 estimates of the standardized CPUE of horse mackerel were obtained with least-squares means and are shown in Figure 9.8.2.1 (right panel). For comparison purposes the nominal CPUE is also presented (left panel).

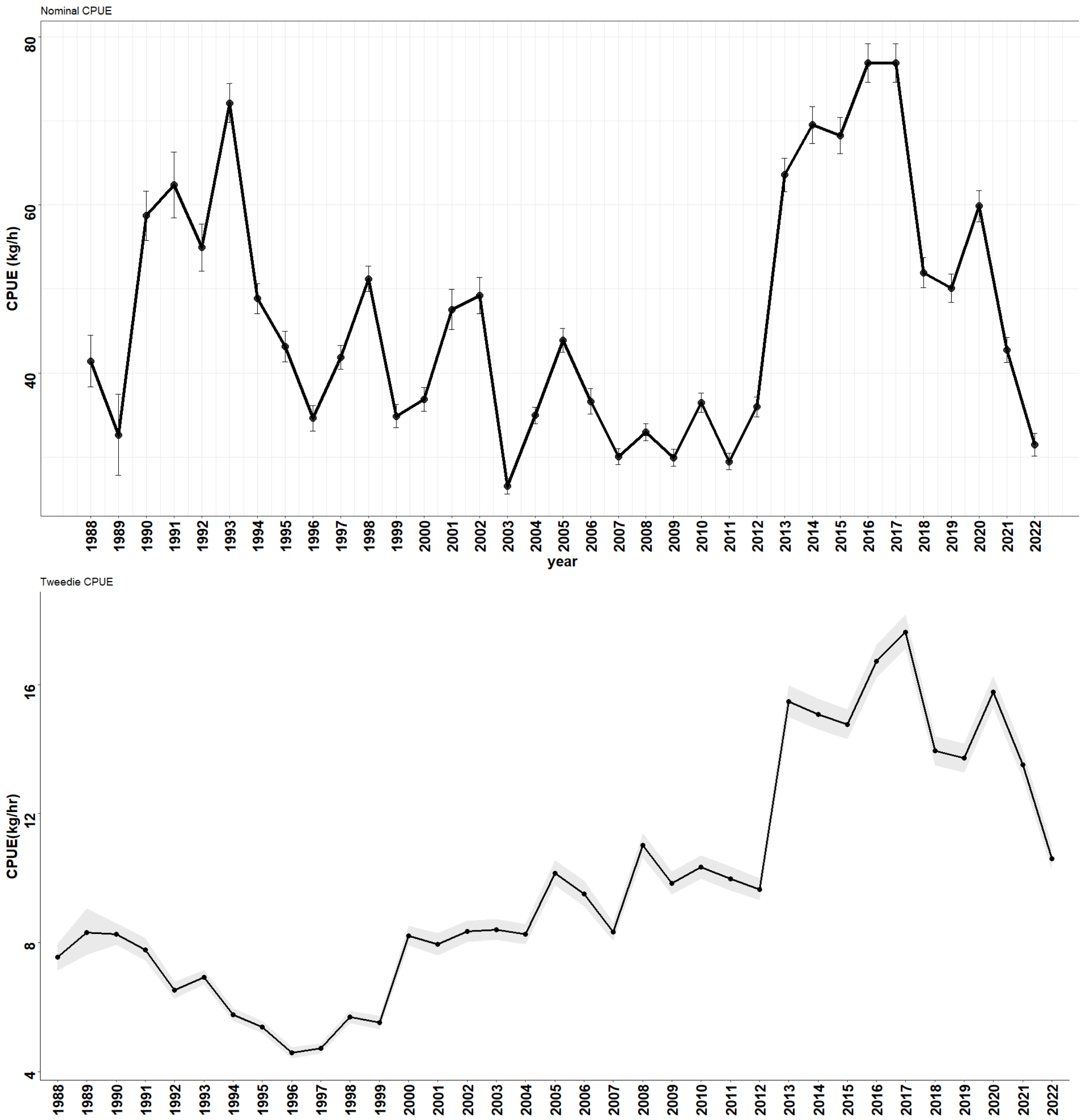


Figure 9.8.2.1. Horse mackerel in Division 9.a. Nominal CPUE (upper panel) and standardized CPUE (lower panel) for the Portuguese commercial trawl fleet from 1988 to 2022.

The predicted year estimates of the standardized CPUE using the proposed Tweedie Generalized Linear Model and the nominal CPUE show notable differences at the beginning of the time series, which correspond to higher variability in the percentage of zeros in the data. However, in the last period of high abundance, the estimates appear to coincide in both CPUE series also showing a steep decrease in the last few years.

When comparing the nominal and the standardized CPUE with the current assessment estimates of spawning stock biomass, the correlation coefficients are found to be p=0.37 and p=0.61, respectively. Besides providing the best fit to the SSB estimates, the Tweedie distribution offers advantages in handling zero catch data in a unified manner. This capability proves to be highly significant for species like horse mackerel that are explored with several gears in a multispecies fishery.

This proposed index still needs evaluation under the ICES benchmark procedures. Currently, no series of commercial catch per unit of effort (CPUE) is available to be used for stock assessment.

9.9 References

Costa, A. M. 2009. Macroscopic vs. microscopic identification of the maturity stages of female horse mackerel. ICES Journal of Marine Science, 66: 509–516.

ICES. 2008. Report of the Workshop on Sexual Maturity Staging of Mackerel and Horse Mackerel (WKMSMAC), 26-29 November 2007, Lisbon, Portugal. ICES CM 2007/ACFM:26. 52 pp.

ICES. 2016. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA), 24–29 June 2016, Lorient, France. ICES CM 2016/ACOM:17.

ICES. 2017. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA), 6–10 February 2017, Lisbon, Portugal. ICES CM 2017/ACOM:35. 294 pp.

ICES. 2018. Report on the Assessment of a Long-term Management Strategy for Southern Horse Mackerel (hom27.9a), 15–16 February 2018. Manuela Azevedo, Hugo Mendes, Gersom Costas, Ernesto Jardim, Iago Mosqueira, Finlay Scott. ICES CM 2018/ACOM:42. 36 pp.

ICES. 2021. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES Scientific Reports 3:55. 689 pp. https://doi.org/10.17895/icces.pub.8138.

Silva, A.V., Mendes, H., Silva, C. (2022). Standardization of the Portuguese trawl fleet LPUE for Iberian hake. Working Document to ICES Benchmark Workshop on anglerfish (Lophius budegassa, Lophius piscatorius) and hake (Merluccius merluccius).

Shono, H. (2008). Application of the Tweedie distribution to zero-catch data in CPUE analysis. Fisheries Research, 93: 154–162.

10 Blue Jack Mackerel Azores

This section has not been updated from the previous report, since the advice is biannual.

The blue jack mackerel, *Trachurus picturatus* Bowdich, 1825 (*Carangidae*), is the only species of genus *Trachurus* that occurs in the Azores region (northeastern Atlantic). It is a pelagic species found around the islands' shelves, banks, and seamounts up to 300 m in depth. However, a different size structure was observed between the islands' shelf and offshore areas. The island shelf areas seem to function as nursery or growth zones, while the seamount/bank offshore areas act as feeding zones where adults predominate (Menezes et al., 2006).

In the Azores, the *T. picturatus* is exploited by different fleets and métiers. The main catches are those of the artisanal fleet that operates with several types of surface nets, the most important being the purse-seines. Also, bottom longline and handline fisheries catch this species, but not as a target species. Purse-seines are also used by the tuna bait boat fleet, which targets the *T. picturatus* to be used as live bait for tuna. The blue jack mackerel is also popular among recreational anglers who fish along the islands' coast.

The *T. picturatus* landings were considerably high during the 1980s. However, changes in the local markets lead to a substantial reduction in the catches afterwards. This reduction was accompanied by a sharp decrease in the fleet targeting small pelagic fishes. Since then, the yields have maintained a low level due to a voluntary auto regulation adopted by the fishermen's associations and later (since 2014) limited by local regulations with conditioned daily catch limits. Despite this landings reduction, this fishery still strongly impacts some fishers communities, which directly depend on this fishery's income.

10.1. Blue Jack Mackerel in ICES areas

The blue jack mackerel has a broad geographical distribution within the Eastern Atlantic waters and can be found from the southern Bay of Biscay to south Morocco, including the Macaronesia archipelagos, Tristan de Cunha and Gough Islands and also in the western part of the Mediterranean Sea and the Black Sea (Smith-Vaniz, 1986). It's a pelagic fish species whose characteristic habitat includes the neritic zones of island shelves, banks, and seamounts (Smith-Vaniz, 1986). It has a shoal behaviour and preys mainly on crustaceans—common in Madeira, the Azores, the Canaries and Portuguese continental waters.

So far, no studies have been attempted to address distinct populations in this species' distribution range. Some studies on growth and biological characteristics from Madeira, Azores, and the Canary islands (Garcia et al., 2015; Isidro, 1990; Jesus, 1992; Gouveia, 1993; Vasconcelos *et al.*, 2006; Jurado-Ruzafa & Santamaría, 2013) indicated similar growth-rates and reproductive season. However, biological differences in age at first maturity seem to exist between individuals from the Azores compared with those from the Madeira and Canary Islands (Jesus, 1992; Jurado-Ruzafa & Santamaría, 2013). The morphometric studies on *T. picturatus* from the Azores archipelago (Isidro, 1990), the west coast coast of Portugal (Mendes et al., 2004) and the western Mediterranean (Merella et al., 1997) revealed similar population parameters for the estimated relationships. On the contrary, some variation was found between different geographic areas in the number of soft spines from the second dorsal fin (Shaboneyev & Kotlyar 1979; Smith-Vaniz, 1986). However, meristic characters are heavily influenced by the environmental conditions experienced by the fish while in the larval stages. Therefore, in the case of migratory oceanic species, such as *T. picturatus*, they are usually considered of reduced utility for identifying stock units.

Several studies have successfully used parasites as biological markers. Gaevskaya and Kovaleva (1985) conducted a research survey on the parasites of *T. picturatus* from the Azores and Western Sahara. Their study identified some protozoan and helminth parasites showing differences in prevalence. The myxosporean *Kudoa nova* was found in Western Sahara samples but not in the Azores archipelago banks. Similarly, some digeneans (Platyhelminths: *Digenea*) found in the Azores banks were not observed in the samples from Western Sahara and vice-versa. The apicomplexan, *Goussia cruciata*, which is common in *T. picturatus* from the Mediterranean (Kalfa-Papaioannou & Athanassopoulou-Raptopoulou, 1984) and more recently from Madeira waters (Gonçalves, 1996), was not found in the Azores or Western Sahara. These variations in the occurrence of parasites could indicate the existence of different populations of *T. picturatus*. Further studies on helminth parasite occurrence showed differences in species diversity and parasitic infection levels (Costa *et al*. 2000, 2003).

The blue jack mackerel is an economically vital resource, especially in the Macaronesian islands of Azores and Madeira, where it is the main pelagic fish species caught by the local (artisanal) fisheries. The hypothesis that the fluctuations in landings can be due to changes in availability or abundance, and not just by changes in fishing effort, is supported for the Portuguese mainland by observing fluctuations in the abundance indices obtained from demersal research surveys.

10.2. The fishery in 2021

Official landings for 2021 include commercial landings from small purse-seiners (and other surrounding nets), landings from hooks and lines *métiers*, and unsold purse-seine landings withdrawn at the port (daily catch limits) and used as bait on longline and handline fisheries.

Other catches include longline bait, tuna (live) bait, and recreational catches. In 2021 estimates of recreational catches are available for recreational boat fishing. Estimates for shore recreational anglers are still unavailable.

10.2.1 **Fishing Fleets**

Trachurus picturatus is mostly landed by the artisanal fleet, using purse-seines and other surrounding nets, targeting juveniles. In 2021, the total number of vessels licensed to small pelagic fish was 179, and the landings of this fleet represented around 85% of total blue jack mackerel (official) landings in the Azores.

Despite having a license to fish small pelagics, many of these vessels carry out multipurpose artisanal fishing, which varies between lifting gears, hook gears and, often, even traps and gillnets. They are often (and for this reason) classified as polyvalent vessels and not as vessels mainly using purse-seines.

The artisanal purse-seines fleet comprises small open deck vessels, mostly with less than 12 meters of overall length, targeting juveniles of *T. picturatus*. Included in this group of vessels (licensed for this fishing gear) is the proper "mackerel fleet" – vessels dedicated exclusively to capturing small pelagics and of which the blue jack mackerel is the predominant target species. The active "Mackerel fleet" composition shows a regular decrease in recent years, from around 50 vessels in 2010 to 24 in 2021. The number of small purse-seine vessels and the number of vessels of the "Mackerel fleet" for the last twenty-five years is shown in Figure 10.2.1.1.

The longline and handline fleets catch around 15% of the total official landings of *T. picturatus*. These fleets catch the adult stock mainly to use it as bait to catch other demersal species with high economic value. Only the excedent is landed.

10.2.2 Catches

Catches of blue jack mackerel, including landings (from artisanal purse-seines, longliners & handliners) and other catches (longline bait plus discards from the longline fishery, tuna live bait, and recreational catches) from 1978 to 2021, are presented in Table 10.2.2.1. Purse-seine catches over daily sales limits are withdrawn from the human consumption market and recorded as fish for bait (but also with daily limits). These catches have been included in official landings only since 2018.

Total average yearly catches of blue jack mackerel in the Azores for the period 2000-2021 are shown in Figure 10.2.2.1. The average annual catches of blue jack mackerel in the Azores for 2000-2021 are around 1700 tonnes, while official landings in the same period are, on average, 1000 tonnes. Despite this relative stability, there has been a downward trend in official landings over the last ten years, which average around 800 tons.

In the tuna fleet, live bait catches (*Trachurus picturatus*) are related to the occurrence of tuna – years with a shortage of tuna will reflect small catches of live bait. Concerning longliners, the changes in yields observed in recent years are mainly related to the use and even preference of this species for bait (since the quality of the bait is high) and not to landings (since the market price for adults tends to be lower).

The year 2019 stands out as a year in which a value was higher than the average of the last ten years, which is due, in particular, to the great abundance of juveniles that year. This resulted in significant landings exceeding the established daily sales limits, so excedent catches were withdrawn from the human consumption market and stored as bait fish. Some decrease that occurred in 2020 is justified by the pandemic experienced worldwide caused by COVID-19, which caused several stoppages in the fisheries sector. In 2021, this situation seems to have been overcome, with the values regularising to the last decade's average values.

10.2.3 Effort

The nominal fishing effort (number of fishing days) for the main fleet (active artisanal purse-seiners – "Mackerel fleet") for 2010 – 2021 is presented in Figure 10.2.3.1. In 2021, the number of trips of only 21 of these vessels represented 95% of the total number of official landings of blue jack mackerel in the Azores. The landings of these 21 vessels represented about 70% of the value and weight (official) of blue jack mackerel landed.

Nominal LPUE (landings per unit effort) for the Sao Miguel and Terceira islands purse-seine fleet, which represents, on average, 90% of the landings of the artisanal purse-seine fleet, has increased slightly in the last years (Figure 10.2.3.2). However, the validity of these indices needs to be further studied.

10.3. Basis of the advice

In 2018, the stock category of *Trachurus picturatus* in 10.a.2 changed from category 3 to category 5, and a precautionary buffer of 20% was applied to the advised catches. The reasons pointed out were that:

(i) Different length-based reference points were explored but were not found appropriate since catches from the different fisheries do not represent the full-length composition of the stock;

(ii) stock size indicators previously used (directed fishery from artisanal purse-seiners and bait for tuna fishery) target only juveniles, thus probably are not reflecting the whole dynamics of the stock;

(iii) handliners and longliners were targeting adults, although they seem minor compared to purse-seiners;

(iv) and no data available from tuna bait, recreational fishery, and longline (bait) fisheries were available in the previous assessment for 2016 and 2017.

Since then, the advice for blue jack mackerel in Azores grounds is based on the ICES framework for category 5 stocks (ICES, 2012) and it's provided every two years.

10.4. Catch scenarios for 2023 and 2024

The advice for this stock is biennial, so the 2022 advice is valid for 2023 and 2024: *ICES advises that when the precautionary approach is applied, catches should be no more than 702 tonnes in each of the years 2023 and 2024.*

ICES framework for category 5 stocks was applied (ICES, 2012). ICES cannot assess the stock and exploitation status relative to MSY and precautionary approach (PA) reference points because the information to define reference points is not available. For stocks without information on abundance or exploitation, ICES considers that a precautionary reduction of catches should be implemented where there is no ancillary information clearly indicating that the current level of exploitation is appropriate to the stock. The PA buffer was not applied since 2018 and therefore was applied this year.

10.5. Management considerations

The Azores Administration put in place in October 2014 (and last updated in 2018) a specific management measure (local regulations with daily catch limits) for the purse-seine fleet and human consumption, primarily to regulate markets. This measure allows only 200kg or 300kg of catch per vessel, per day, depending on the island (Sao Miguel or Terceira islands – once the landings of juvenile blue jack mackerel on these islands represent more than 95% of the total landings of the artisanal purse-seine fleet). It also states that fishing and consequent landings shall be forbidden on weekends and set quantities for unsold purse-seine landings withdrawn at the port.

10.6. Suggested inter-seasonal work

In 2019, the Working Group discussed different (or complementary) approaches that could have been taken into account for the 2020 assessment and proposed intersessional work. However, due to COVID-19, much of the work was not put into practice. The 2022 Working Group updated the suggestions for intersessional work:

- Continue track of (Catch, effort) CPUE indexes of different fleets;
- Explore alternative indicators for the purse-seiners, e.g. the number of times the maximum daily catches were reached, etc.;
    - Use the market selling records of the small purse-seiners targeting blue jack mackerel to compute indicators of availability as the number of days when the maximum daily allowable catch of blue jack mackerel is landed by the vessels

(per month or annually) in relation to the number of fishing days by month of every particular vessel;

- Relate the former to the maximum catch of other species being landed so that some definition of métier might be derived or inferred for the daily fishing trips. This can potentially distinguish the number of fishing days targeting blue jack mackerel from those targeting other species.

- Monitor and track in time catch length distributions (for any purpose, including landings or selling as live bait, bait for hooks or discards) of different fleets;
- To assess growth (Von Bertalanffy) parameters of blue Jack mackerel;
- Try length-based methods, but with some changes from what has been done in the past: for example, (i) using the longline length distribution series to verify stability in the length or age distribution; (ii) use any trends in mean length or age composition as an indicator of overall population mortality; (iii) use these series as an indicator of global (medium-term) changes in overall exploitation on the stock.
- Check whether other fisheries may or may not serve as an overall mortality indicator or an alarm indicator if normal series variability deviates.

10.7. References

Garcia A., Pereira J., Canha Â, Reis D. and Diogo H. (2015). Life history parameters of blue jack mackerel Trachurus picturatus (Teleostei: Carangidae) from Northeast Atlantic. Journal of the Marine Biological Association of the UK, 95(2), 401-410.

Gouveia M.E.P. 1993. Aspectos da biologia do chicharro, Trachurus picturatus (Bowdich, 1825) da Madeira. Dipl. thesis, Univ. Lisboa, Lisboa, 153 pp.

Isidro H. A. 1990. Age and growth of Trachurus picturatus (Bowdich, 1825) (Teleostei: Carangidae) from the Azores. Arquipel. Cienc. Biol. Mar. 8, 45–54.

Jesus G. T. 1992. Study of the growth and reproduction of Trachu-rus picturatus (Bowdich, 1825) in Madeira. Doc. No XIV/C/1-1991/03 (DG XIV/CE). 66, p.

Jurado-Ruzafa A. and Santamaria M. T. 2013. Reproductive biology of the blue jack mackerel, Trachurus picturatus (Bowdich,1825), off the Canary Islands. J. Appl. Ichthyol. 29: 526–531.

Mendes B, Fonseca P, Campos A. 2004. Weight/length relationship for 46 species of the Portuguese west coast. J Appl Ichthyol 20: 355–361.

Menezes G. M., Sigler M. F., Silva H. M. and Pinho, M. R. 2006. Structure and zonation of demersal fish assemblages off theAzores Archipelago (mid-Atlantic). Mar. Ecol. Prog. Ser. 324, 241–260.

Shaboneyev I. Y. and Kotlyar A. N. 1979. A comparative morphoeco-logical analysis of the Eastern Pacific forms of Trachurus symmetricus and the Atlantic Oceanic horse mackerel, Trachurus picturatus. J. Ichthyol. 19, 24–29.

Smith-Vaniz W.F. 1986. Carangidae. p. 815-844. In P.J.P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nielsen and E. Tortonese (eds.) Fishes of the northeastern Atlantic and the Mediterranean. UNESCO, Paris. vol. 2.

Vasconcelos J., Alves A., Gouveia E., Faria G. 2006: Age andgrowth of the blue jack mackerel, Trachurus picturatus Bowdich,1825 (Pisces: Teleostei) off Madeira archipelago. Arquipel.Cienc. Biol. Mar. 23, 47–57.

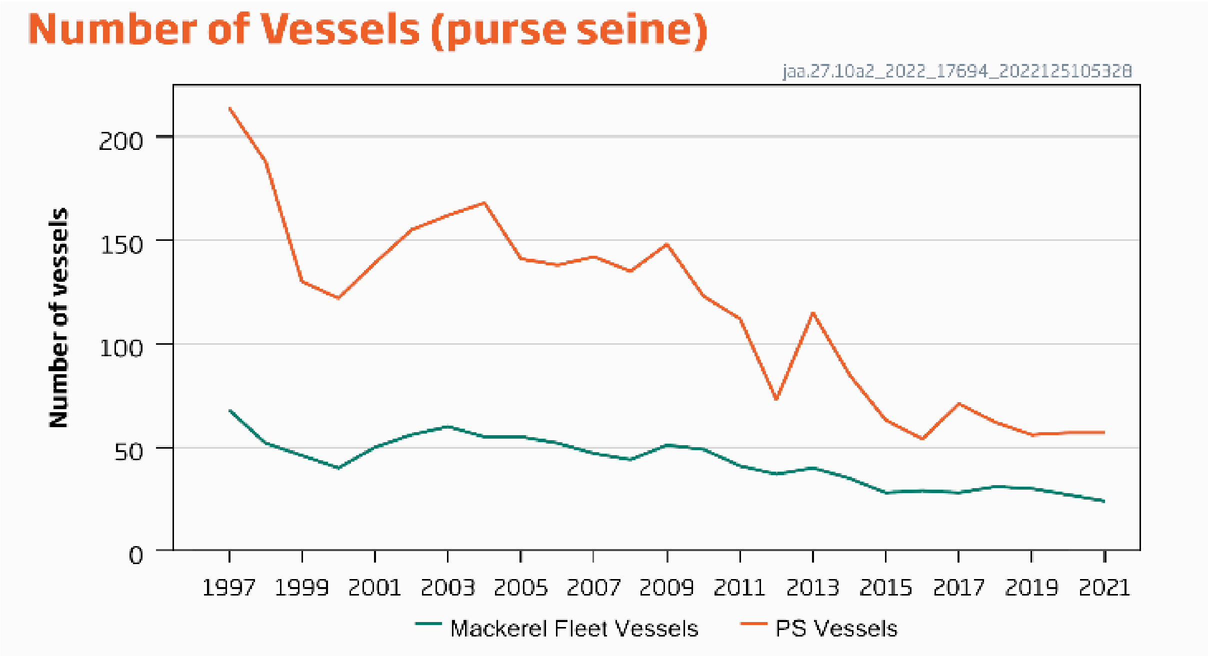


Figure 10.2.1.1. Blue jack mackerel in Azores grounds. Number of small purse-seine vessels and the number of vessels of the "Mackerel fleet" in the Azores (ICES Subdivision 10.a2) from 1997 to 2021.

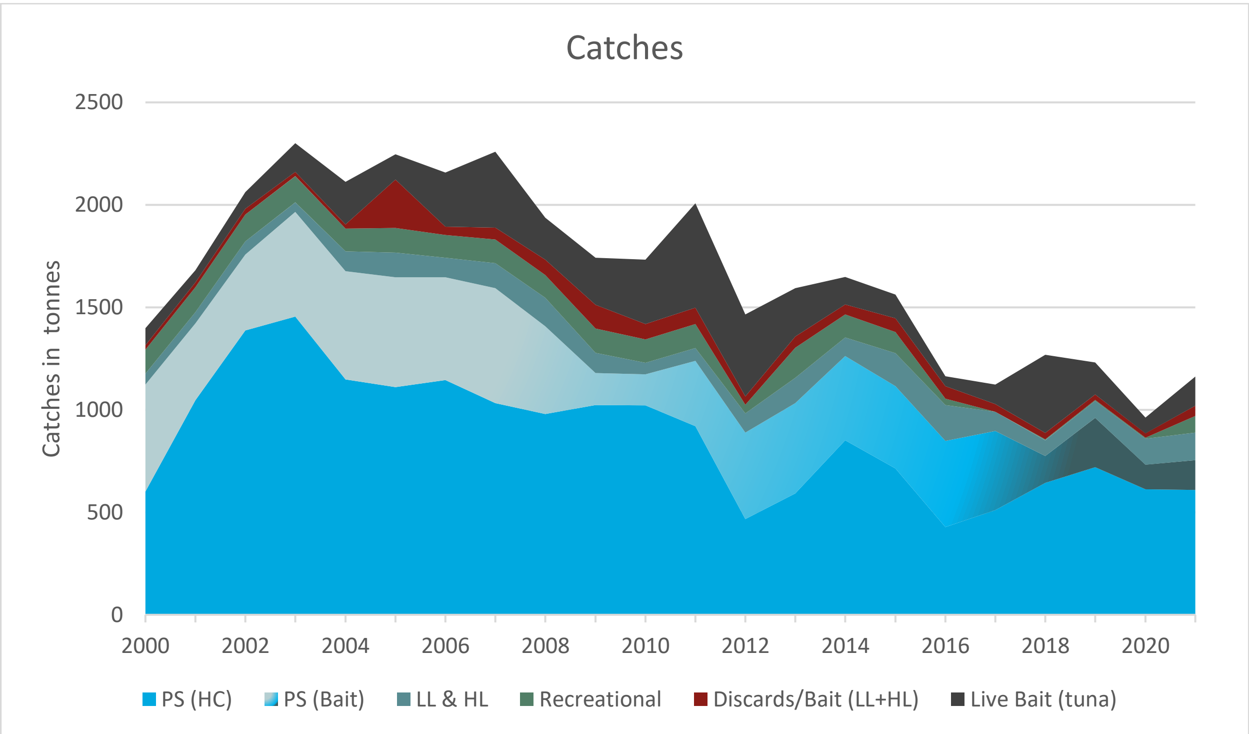


Figure 10.2.2.1. Blue jack mackerel in Azores grounds. Landings and other catches. Landings include purse-seine catches for human consumption – PS (HC) – purse-seine catches for bait – PS (Bait) – and have unsold purse-seine landings withdrawn at the port as well as longline and handline landings (LL & HL). Other catches include recreational catches, discards/longline bait, and tuna live bait.

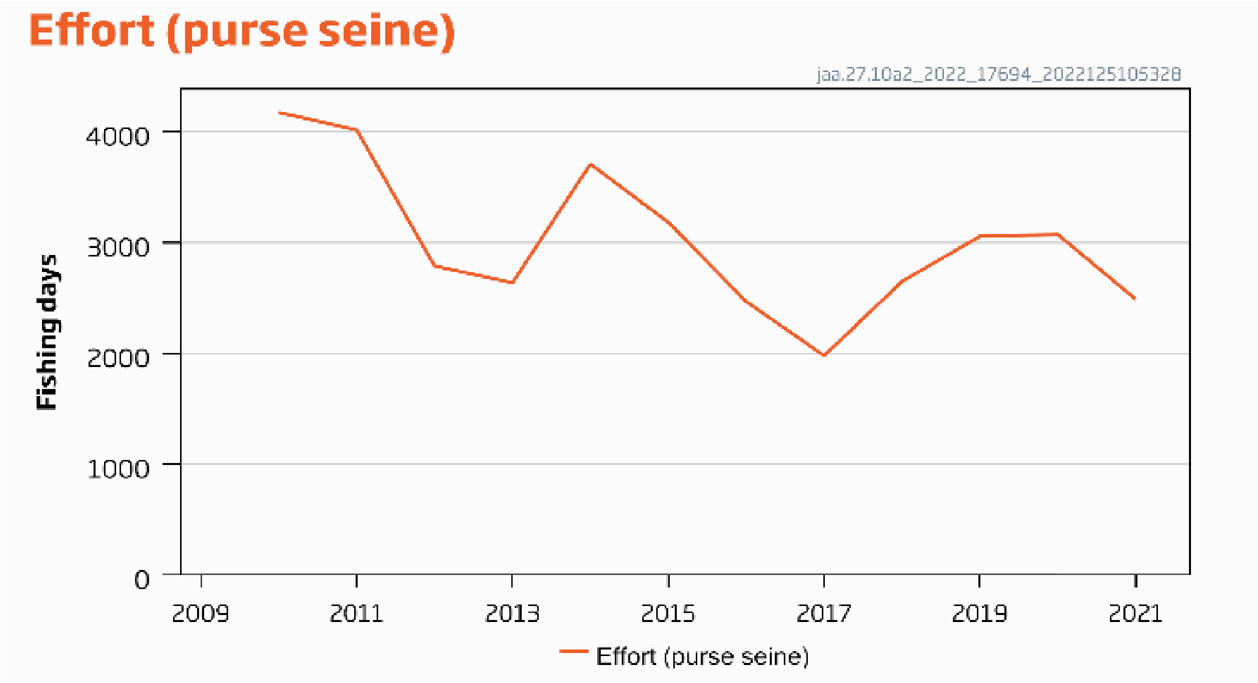


Figure 10.2.3.1. Blue jack mackerel in Azores grounds. Nominal effort (number of Fishing days) of the "Mackerel fleet" for 2010 – 2021.

Table 10.2.2.1. Blue jack mackerel in Azores grounds. History of catches (in tonnes) of blue jack mackerel (*Trachurus picturatus*) in Subdivision 10.a.2.

	Official landings			**Additional catches**				**Total**
Year	Purse-seine (human consumption)	Purse-seine (withdrawn at the port and used for bait)*	Longline + handline	Recreational	Longline (discards and used for bait)	Tuna bait	Purse-seine (withdrawn at the port and used for bait)[1]	ICES catches
1978	2657		78	129	15	115	0	2995
1979	4114		61	130	15	118	0	4439
1980	2920		70	132	22	210	0	3354
1981	2104		39	135	9	229	0	2516
1982	2429		43	142	10	239	0	2862
1983	3711		67	142	21	231	0	4172
1984	3180		62	135	17	295	0	3689
1985	3442		60	136	11	303	0	3952

	Official landings			**Additional catches**				**Total**
Year	Purse-seine (human consumption)	Purse-seine (withdrawn at the port and used for bait)*	Longline + handline	Recreational	Longline (discards and used for bait)	Tuna bait	Purse-seine (withdrawn at the port and used for bait)[1]	ICES catches
1986	3282		58	135	9	433	0	3918
1987	2974		53	139	8	491	0	3666
1988	3032		55	143	8	586	0	3824
1989	2824		50	138	9	352	0	3373
1990	2472		48	117	11	345	584	3577
1991	1247		33	115	6	242	421	2064
1992	1226		35	121	6	249	486	2123
1993	1684		70	130	22	375	742	3023
1994	1745		59	125	18	264	636	2847
1995	1769		79	119	24	474	688	3153
1996	1642		123	110	38	351	656	2920
1997	1849		72	110	31	259	599	2920
1998	1387		120	111	52	308	606	2584
1999	609		84	119	37	141	565	1555
2000	602		53	117	23	83	521	1399
2001	1046		55	121	24	59	376	1681
2002	1387		63	132	28	82	371	2063
2003	1455		47	128	21	140	510	2301
2004	1148		98	111	19	208	528	2112
2005	1111		120	120	236	124	536	2247
2006	1145		96	111	40	264	501	2157
2007	1032		122	115	58	370	562	2259
2008	980		139	110	75	205	428	1937
2009	1023		98	119	115	230	157	1742
2010	1021		57	114	75	313	152	1732

	Official landings			Additional catches				Total
Year	Purse-seine (human con-sump-tion)	Purse-seine (with-drawn at the port and used for bait)*	Longline + handline	Recrea-tional	Longline (discards and used for bait)	Tuna bait	Purse-seine (with-drawn at the port and used for bait)[1]	ICES catches
2011	920		62	118	79	510	319	2008
2012	467		94	42	41	399	422	1465
2013	592		123	147	54	237	441	1594
2014	852		91	112	49	134	410	1648
2015	714		160	103	67	116	402	1562
2016	428		174	32	61	48	421	1164
2017	511		95	N/A	37	96	385	1124
2018	643	132	77	4	31	381		1268
2019	720	241	83	5	26	156		1231
2020	613	119	127	5	21	77		962
2021	609	145	135	81	57	143		1170

*** Purse seine catches in excess of daily sales limits are withdrawn from the human consumption market but are recorded as fish for bait. Starting in 2018, these catches are included in official landings.**

Annex 1: List of participants

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Annex 2: Working Documents

The following working documents were presented to WGHANSA-1 2023 and are presented in full in Annex 2:

Ramos, F., Córdoba, P., Tornero, J., Canseco, J. A., Martínez Cedeira, J. A., Sánchez, M. J., Navarro, R. Acoustic assessment and distribution of the main pelagic fish species in ICES Subdivision 9a South during the ECOCADIZ-RECLUTAS 2022-10 Spanish acoustic-trawl survey (October 2022).

Rincón M.M, Ramos F., Tornero J., Garrido S., Elvarsson B., Lentin J. Gadget for anchovy 9.a South: Model description and results to provide catch advice and reference points (WGHANSA-1 2023).

Additional working documents related to the evaluation of management strategies for anchovy in 9.a are provided in Annex 6.

In addition, the following presentations were done in WGHANSA-2 2023:

- del Rio-Lavín A., Díaz-Arce N., Rodriguez-Ezpeleta N. et al. Population structure of European anchovy in the NorthEast Atlantic based on genomic markers

  "While correct assessment of fish stocks require an accurate stock delimitation which would ideally match biological populations, there are big uncertainties about the population structure of the European anchovy in the NorthEast Atlantic. We present a comprehensive study of anchovy genetic diversity covering most of its distribution in the North East Atlantic based on >10,000 single nucleotide polimorphisms (SNPs). Our results show: i) a clear population connectivity break at the South of Portugal which separates a northern population mainly inhabiting in the Bay of Biscay, North of Portugal and Irish Waters, ii) that there is transition zone between the Southern and Mediterranean populations at the Alboran Sea, iii) the Bay of Biscay Area and Mediterranean Sea are genetically more similar between them than they are with the population present in the South of Portugal and Morocco, and that iv) signal of genetic adaptation in the English Channel. These results confirm that current stock delimitation considered for the assessment do not match with natural populations observed from genomic markers."

- Garrido S., Machado A. and Sakamoto T. Anchovy dispersion patterns under anomalous oceanic conditions in the northern Iberia & Eye lens isotopic composition: migration and connectivity patterns

  "Two different methods were used to study the connectivity of Iberian anchovy populations. In the first study, a set of different models to simulate the dispersion and survival of anchovy early life stages in the Iberian region for the years preceding the increase of anchovy abundance in the western Iberia were conducted. An ocean model simulation provided the fields used as background for Lagrangian simulations coupled to an Individual-Based Model of anchovy eggs and larvae. Results show that in 2014 and 2015, anomalous upper-ocean circulation pattern with strong and persistent eastward currents transported a large number of eggs and larvae from the Bay of Biscay (BoB) eastward along the Northern Iberian margin. The maximum transport occurred in June/July 2015 when 8%/4%, respectively, of the eggs spawned in the BoB potentially reached the Iberian west coast as larvae. This process might explain the increase in anchovy abundance in the Western Iberian ecosystem. A second study used the isotopic composition of eye lenses of adult and juvenile sardine and anchovy collected during different years from 2016 off northern, western and southern Iberia. Preliminary results show that isotopic composition of the eye lenses of sardine and anchovy juveniles is significantly different from the west and south coasts and similar for the anchovy from the Bay of Biscay and Western Iberia. Results for the adults show very high mixing for sardines in the Iberia whereas for the anchovy the separation of the western and southern populations persisted. This work will be continued to further understand the mixing and migration rates per year and age groups."

- Bordes A., Huret M., Rivot E., Andrieux C., Doray M., Edeline E. and Olmos M. Unraveling the natural mortality, growth and recruitment processes underlying the population dynamics of a small pelagic system. Work also presented at the ICES ASC 2023.

  "Understanding ecological processes driving populations dynamics within fish ecosystems is critical to support ecosystem-based management. In this paper, we aimed to unravel the mechanisms linking density, size and environment to natural mortality, pseudo growth and recruitment processes within a small pelagic fish system of the Bay of Biscay (French Atlantic coast). We modeled population dynamics of two species likely to interact, anchovy (Engraulis encrasicolus) and sardine (Sardina pilchardus), and built a two-species life-cycle model in a state-space framework, using Bayesian inference. We found no evidence of interaction between these two species but intraspecific density dependence occurring at different life-stages. We highlighted density-dependent effects on natural mortality of age-1 and age-2 for anchovies, and of age-1, age-3 and on recruitment for sardines. Also, age-1 anchovy natural mortality is size-dependent. We found environment factors such as, zooplankton, temperature, global indicators Atlantic Multidecadal Oscillation (AMO) and North Atlantic Oscillation (NAO), impacting age-3 natural mortality and recruitment in both species populations and age-1 natural mortality in anchovy population. We found no effect on pseudo-growth, as it results of both individual growth and size-selective mortality inside a life-stage, two phenomena that are likely to offset each other. Our results provide new information on the mechanisms that govern the dynamics of sardines and anchovies at population level, which we discussed by proposing hypothetical interpretations of the mechanisms underlying the three processes investigated."

- Ibaibarriaga L., Citores L., Garcia D., Wise L., Riveiro I., Sánchez-Maroño S., Silva A. and Uriarte A. Regime-shifts for Iberian sardine: a multi-model approach. Work also presented at the ICES ASC 2023

  "Traditionally stock-recruitment models are assumed to be stationary or time-invariant. However, several meta-analyses have shown that regime-shifts are frequent in stock-recruitment models. Furthermore, in some case studies stock-recruitment models that have inter-annual variation in some of the productivity parameters have performed better than static productivity regimes. In the context of the ecosystem-based fisheries management, understanding changes in stock productivity and properly accounting for them is crucial for an adequate advice.

  In 2019 ICES established that the Iberian sardine (*Sardina pilchardus*) stock was in a low productivity regime since 2006, but the higher recruitments estimated in recent years have re-opened the debate about the current productivity of the stock. In this work we revisit stock-recruitment models for sardine for the period 1978-2021 and we analyse potential changes in the stock productivity regime using a variety of non-stationary recruitment models. Based on the latest stock assessment estimates, we first tested the existence of changepoints and/or trends in the time series of recruits and of recruits per spawner (i.e., with and without accounting for the parental stock size). Then, we implemented time-varying Ricker models (allowing for changes in the productivity parameter, the density dependent parameter and both) and regime-switching models (including changepoint models with fixed number of shifts, random switching models and changepoint models with unknown number of shifts). The models were compared using leave-one-out cross-validation and their predictive capabilities were tested in a hindcasting procedure. Although the underlying mechanisms and model assumptions were different, all the models confirmed the low productivity regime since 2006 onwards. Additional regime shifts, though of less intensity, were also identified around 1993 and 2015. This latter shift agreed with the increase in the productivity parameter observed in the time-varying Ricker model, suggesting the stock is moving towards a higher productivity period. These results pose the question on the most appropriate timing and procedure to account for the observed productivity changes within the current management advisory process."

- Uriarte A., Citores L., Ibaibarriaga L., Riveiro I., Sánchez-Maroño S., Wise L. and Silva A. Dynamic harvest control rules based on recruitment levels to manage stocks of uncertain productivity: application to Iberian sardine.

  "Two Dynamic harvest control rules are proposed to manage stocks showing uncertain or changing regimes of productivity, basically accounting for the most recent recruitment levels. For a given functional S-R relationship, every recruitment realization can be seen as the effect of a different yearly change on the average productivity, affecting the steepness of the relationship for that year. And as steepness is directly related to sustainable fishing levels, every recruitment level can be used to define an FMSY level. In present work, two dynamic harvest control rule which set the target fishing mortality according to a weighted mean of recruitment-based FMSY estimates inferred from the assessment of the recruits of the preceding years, were proposed and tested. The averages are geometric weighted means of those past recruitment-based FMSY with weights being a decreasing function of the time elapsed between the year when every cohort was born and the interim year of the assessment, according the presumed duration of homogeneous productivity regimes. The rules are the Two Recruitment level based F rule (2RLb) and the Multiple Recruitment level based F rule (MRLb). Their performance in the long term (years 41-50 of projections) were compared with the currently applied HCR (current HCR), agreed between Portugal and Spain, and an ICES Fmsy type HCR (but with Ftarget at 0.125, instead of the current official Fmsy or 0.92 of the ICES low Productivity regime) (ICESvarian). The management strategy evaluation covered a range of 7 productivity scenarios for the Iberian sardine stock, of which two were those covered formerly by ICES when evaluating the current HCR (ICES WKSARHCR 2021) corresponding to low or low-Medium productivity Hockey-Stick models, and the rest were new stock-recruitment relationships (Ricker type) covering a single or two recruitment levels models (Much and Kottas 2009) and including two which allowed changes in the productivity at year 25 of the projections.

Results showed that the two dynamic HCRs were able to accommodate fishing mortality to to the changing productivity of the stock within its environment, with performances rather similar to that of the current HCR. They would overcome the current rule only if productivity would be increasing beyond historical levels. OF the two dynamic HCRs, the 2RLbMK can exceed the catches of the current HCR, but with occasional higher risks under poor or changing productivity scenarios (up to 0.085 without TACmax; or up to 0.06 if limited to a TACMAX ≤100 kt,). The MRLbMK HCR produce sustainable catches at any TACmax or without any restrictions. It would produce catches similar to the current rule and to the maximum sustainable catches, except at low productivity (REClowmed y REClow, when recommended catches would be ~15 kt less than for the current HCR). These two dynamic HCRs would have produced higher catch advises than those given by ICES since 2021. The Current rule (as agreed by the Portugal and Spain) was shown to be robust to every productivity scenarios, even unconstrained by a TACmax. Limiting current rule with a TACmax of 50 kt (as initially proposed) seems to be too restrictive. Our analysis suggest that if applied with maximum TAC limits of 60 or 80 kt , or perhaps a 100 kt, the current rule would not exceed in the long term the reference risk level of 0.05 (of falling below medium Blim), conditional to assuming recruitment dynamics corresponding to the entire series of recruitments from the available assessment (until 2021). Current results were provisional, requiring still verification under a full MSE including the actual ICES assessment in the management projection loop, because the testing was made based on perfect observation (neglecting the actual observation error). Essays on the effect of including the actual assessment errors lead to infer that the reported risks can be under-estimated by about 2%. Those full MSE runs are to be taken in the next coming months."

Working document presented in the ICES Working Group on Southern horse mackerel, Anchovy and Sardine (WGHANSA-1). On-line meeting, 29 May – 02 June 2023.

Working document presented in the ICES Working Group on Acoustic and Egg Surveys for small pelagic fish in NE Atlantic (WGACEGG). Dates and venue of the 2023 meeting to be determined.

Acoustic assessment and distribution of the main pelagic fish species in ICES Subdivision 9a South during the *ECOCADIZ-RECLUTAS 2022-10* Spanish acoustic-trawl survey (October 2022).

By

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ABSTRACT

This working document summarizes the main results obtained during the *ECOCADIZ-RECLUTAS 2022-10* Spanish (pelagic ecosystem-) acoustic-trawl survey, conducted by IEO between October 12th and 27th 2022 in the Portuguese and Spanish shelf waters (20-200 m isobaths) off the Gulf of Cádiz (GoC) onboard the R/V *Angeles Alvariño*. The R/V *Ramón Margalef*, *i.e.* the vessel routinely used in this survey series, was not available because maintenance works at shipyard. The adjustment of the survey to the *Ángeles Alvariño*'s surveys calendar entailed a reduction of 3 days (14 days at sea) in relation to the usually planned days (17 days at sea). Half working day was also invested in engine repair at land. The survey's main objective is the acoustic assessment of anchovy and sardine juveniles (age 0 fish) in the GoC recruitment areas. The 21 foreseen acoustic transects were sampled. A total of 18 valid fishing hauls were carried out for echo-trace ground-truthing purposes. Sardine and chub mackerel, were the most frequent captured species in the fishing hauls, followed by horse mackerel, anchovy, Mediterranean horse mackerel, bogue, Atlantic mackerel and blue jack mackerel. Longspine snipefish and pearlside showed an incidental occurrence in the hauls performed in the surveyed area. Sardine and chub mackerel showed the highest yields in these hauls, followed by anchovy and Mediterranean horse mackerel. Total estimates of total NASC allocated to the "pelagic fish species assemblage" in this survey were 28% lower than those recorded last year. GoC anchovy was mainly found in Spanish waters with areas of high densities observed between Isla Cristina and Bay of Cádiz. Anchovy acoustic estimates in autumn 2022, 11 911 t and 1836 million fish, in abundance and biomass, respectively, were 5% and 31% lower than last year's estimates and they continue to be lower than their time-series averages. The population was composed by fishes not older than 2 years. As usual, the bulk of the population, including juveniles, was located in Spanish waters. Age-0 anchovies accounted for 93% (1705 million) and 90% (10 797 t) of the total estimated abundance and biomass, respectively. Age-0 estimates followed the same decreasing trend as last years and in relation to the historical peak recorded in 2019, but with values close to the time-series average. GoC sardine was widely distributed all over the surveyed area (also avoiding the easternmost waters) in autumn 2022 possibly related to the high density areas recorded throughout the GoC. Abundance (1085 million fish) and biomass (20 909 t) estimates showed a sharp decrease (63% in abundance and 86% in biomass), when compared to last

year's estimates, the second-lowest values within the standard survey series. Age-5 group was the oldest age group in the population, although the occurrence of fishes older than 4 years was incidental. The population was mainly composed by fishes belonging to the age-0 to age-2 groups. This year, Juvenile sardines (age-0 group) were the dominant group, accounting for 91% (992 million) and 77% (16 177 t) of the total abundance and biomass, respectively. Sardine juvenile fraction was widely distributed in the GoC. Chub mackerel was restricted to the area between Cape San Vicente and Cape Santa María, where high density areas were recorded, whereas in the rest of the surveyed areas was almost absent. Chub mackerel estimated biomass and abundance were 15 500 t and 246 million, respectively, which were 18% and 132% higher than last year's estimates. This year's abundance and biomass were above the time series average. The population was composed by fishes not older than 3 years, with the age-0 group being the dominant one (65%, 163 million, and 52%, 8 198 t).

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INTRODUCTION

The abundance of Gulf of Cádiz (GoC) anchovy and sardine recruits started to be acoustically assessed by the IEO in autumn 2009. However, that survey was considered a pilot experience due to a series of events that vastly reduced the area covered, making it impossible to achieve the survey's main objectives (Ramos *et al.*, 2010). This autumn survey was conducted again in 2012 as *ECOCADIZ-RECLUTAS 1112;* it was financed by the Spanish Fisheries Secretariat and planned and conducted by the IEO to obtain an autumn estimate of GoC anchovy biomass and abundance. That survey was carried out onboard R/V *Emma Bardán*, but restricted to the Spanish waters only (Ramos *et al.*, 2013). *ECOCADIZ-RECLUTAS 2014-10* re-started the series two years later, with the surveys being conducted with the R/V *Ramón Margalef* and covering both the GoC Portuguese and Spanish waters as the agreed standard sampling scheme. Since 2014 on the series should therefore be considered as the standard one. The 2017 survey is not included in the series since it suffered from an unexpected breakdown of the research vessel, leading to an earlier survey's ending and an incomplete coverage of the survey area (only the seven easternmost transects were sampled). As commented below, the 2022 survey was conducted on board R/V *Ángeles Alvariño* (the twin vessel of R/V *Ramón Margalef*).

The general objective of these surveys is the acoustic assessment by vertical echo-integration and mapping of the abundance and biomass of recruits of small pelagic species (especially anchovy and sardine), as well as the mapping of both the oceanographic and biological conditions featuring the recruitment areas of these species in Division 9a. The long-term objective of the surveys is to assess the strength of the incoming recruitment to the fishery of these species the following year.

The present Working Document reports the main results from the *ECOCADIZ-RECLUTAS 2022-10* survey (the eighth survey within its standard series), namely the acoustic estimates of abundance and biomass (age-structured for anchovy, sardine and chub mackerel) and the spatial distribution of the assessed species.

MATERIAL AND METHODS

The *ECOCADIZ-RECLUTAS 2022-10* survey was conducted on board Spanish IEO R/V *Ángeles Alvariño* since the R/V *Ramón Margalef*, i.e. the vessel routinely used in this survey series, was not available because maintenance works at shipyard. The adjustment of the survey to the *Ángeles Alvariño*'s surveys calendar entailed a reduction of 3 days (14 days at sea) in relation to the usually planned days (17 days at sea). Half working day was also invested in engine repair at land. The survey was conducted between the 12th and 27th of October covering a survey area which comprised the GoC waters, both Spanish and Portuguese, between the 20 m and 200 m isobaths. The survey design consisted in a systematic parallel grid with 21 transects equally spaced by 8 nm, normal to the shoreline (**Figure 1**).

Because the above mentioned shortage of days the acoustic equipment was not calibrated (the calibration values obtained in the previous survey, following the ICES standard procedures, were used instead; Demer *et al.*, 2015; see also Foote *et al.*, 1987), neither the evaluation of vessel's self-noise was carried out, nor the sampling of the RH03 transect of CTD-LADCP stations. The number of pelagic trawl fishing hauls was also somewhat lower than usual.

Echo-integration was carried out with a *Simrad™ EK80* echo-sounder working in the multi-frequency fashion (18, 38, 70, 120, 200, 333 kHz) and in CW mode. Average survey speed was about 10 knots and the acoustic signals were integrated over 1-nm intervals (EDSU). Raw acoustic data were stored for further post-processing using the *Echoview™* software package.

Survey execution and abundance estimation followed the methodologies firstly adopted by the *ICES Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX* (ICES, 1998) and the recommendations given later by the *Working Group on Acoustic and Egg Surveys for Small Pelagic Fish in NE Atlantic* (WGACEGG; ICES, 2006a,b; see also ICES TIMES 64 report, Doray *et al.*, 2021).

Fishing hauls for echo-trace ground-truthing were opportunistic, according to the echogram information, and they were carried out using a *Gloria HOD 352* pelagic trawl gear (ca. 10 m-mean vertical opening net) at an average speed of 4-4.5 knots. Gear performance and geometry during the effective fishing was monitored with *Simrad™ Mesotech FS20* trawl sonar, a *Marport™ Narrow Band Trawl Eye* and *Scanmar™* trawl door sensors for inter-doors distance and depth. Trawl sonar data from each haul were recorded and stored for further analyses.

Ground-truthing haul samples provided biological data on species and they were also used to identify fish species and to allocate the back-scattering values into fish species according to the proportions found at the fishing stations (Nakken and Dommasnes, 1975).

Length frequency distributions (LFD) by 0.5-cm class were obtained for all the fish species in trawl samples (either from the total catch or from a representative random sample of 100-200 fish). Only those LFDs based on a minimum of 30 individuals and showing a normal distribution were considered for the purpose of the acoustic assessment.

Individual biological sampling (length, weight, sex, maturity stage, stomach fullness, and mesenteric fat content) was performed in each haul for anchovy, sardine, mackerel (2 spp.) and horse-mackerel species (3 spp.), and bogue. Otoliths were extracted from anchovy, sardine and chub mackerel sampled specimens.

Table 2 shows the TS/length relationships used for the acoustic estimation of the assessed species (recent IEO standards after ICES, 1998 and recommendations by ICES, 2006a,b; see Doray *et al.*, 2021).

The *PESMA* software (J. Miquel, IEO, unpublished) has got implemented the needed procedures and routines for the acoustic assessment following the above approach and it has been the software package used for the acoustic estimation.

A *Sea-bird Electronics™ SBE 21 SEACAT* thermosalinograph and a *Turner™ 10 AU 005 CE Field* fluorometer were used during the acoustic tracking to continuously collect some hydrographical variables (sub-surface sea temperature, salinity, and *in vivo* fluorescence). Vertical profiles of hydrographical variables were also recorded by night from 168 $CTDO_2$-LADCP casts over 22 transects (from the 23-transect planned grid) using a *Sea-bird Electronics™ SBE 911+ SEACAT* (with coupled *Teledyne Benthos* altimeter, *SBE 43* oximeter and *WetLabs ECO-FL-NTU* fluoro-turbidimeter sensors) profiler and a *LADCP T-RDI WH Sentinnel* 300 kHz current profiler (**Figure 2**). *VMADCP RDI 150 kHz* records were also continuously recorded by night between CTD stations. The GD hydrography transect (in front of the Guadalquivir river mouth) included this year the conduction of 3 stations of mesozooplankton sampling with Bongo 40 and neuston sledge hauls. Six stations in this same transect also included the water column sampling at different depths with a carousel water sampler.

Census of top predators was recorded for the first time in the series during this survey by one onboard observer using the Distance Sampling method (Buckland *et al.*, 1993). For cetaceans sightings a picture with maximum zoom including the animals and the horizon was taken for the further estimation of distances with photogrammetry (Leaper & Gordon., 2001; Leaper *et al.*, 2010).

RESULTS

Acoustic sampling

The acoustic sampling was accomplished during the period comprised between the 14^{th} and 26^{th} October. The complete grid (21 transects) was acoustically sampled (**Table 4**, **Figure 1**). The first eight acoustic transects were covered before the acoustic sampling was partially interrupted the 15^{th} October due to an engine failure that forced to navigate to the nearest port and fix it. The acoustic sampling was again partially interrupted on 18^{th}-19^{th} October, in order to satisfy the R/V's refueling and provisioning needs. In order to perform the acoustic sampling with daylight, the acoustic sampling started at 06:40-06:45 UTC, although this time might vary depending on the duration of the works related with the hydrographic sampling the previous night.

Groundtruthing hauls

A total of eighteen (21) fishing operations for echo-trace ground-truthing, of which 18 were valid, were performed during the survey (**Table 5**, **Figure 3**). Because of many echo-traces usually occurred close to the bottom, all the pelagic hauls were carried out like a bottom-trawl haul, with the ground rope working over or very close to the bottom. Four hauls were performed over a determined isobath instead of being conducted over the acoustic transect. According to the above, the sampled depth range in the valid hauls oscillated between 27 and 124 m.

During the survey were captured 6 Chondrichthyan, 44 Osteichthyes, 7 Cephalopod, 3 Echinoderm, and several Cnidarian and Ascidian species. The percentage of occurrence of the fish species (sharks excluded) in the hauls is shown **Table 1** (see also **Figure 4**). The pelagic ichthyofauna was both the most frequently captured species set and the one composing the bulk of the overall yields of the catches. Within this pelagic fish species set sardine (94% presence index) and chub mackerel (78%) were the most frequent small pelagic species in the valid hauls, followed by horse mackerel (67%), anchovy (61%), Mediterranean horse mackerel (56%) and bogue (56%). No individuals of round sardinella and blue whiting were observed. Longspine snipefish (11%) and pearlside (6%) showed an incidental occurrence in the hauls performed in the surveyed area.

For the purposes of the acoustic assessment, anchovy, sardine, mackerel species, horse & jack mackerel species, bogue, boarfish, longspine snipefish and pearlside were initially considered as the survey target species. All the invertebrates, skates, rays and benthic fish species were excluded from the computation of the total catches in weight and in number from those fishing stations where they occurred. Catches of the remaining non-target fish species were included in an operational category termed as "Others".

According to the above premises, during the survey were captured a total of 3 533 kg and 106 thousand fish (**Table 6**). Sixty-six per cent (66%) of this "total" of fished biomass corresponded to sardine, 12% to chub mackerel, 7% to anchovy, 5% to Mediterranean horse mackerel, 2% to bogue and contributions lower than 1% for the remaining species. The most abundant species in ground-truthing trawl hauls was anchovy (48%), followed by sardine (43%), chub mackerel (6%), and Mediterranean horse mackerel (1%), with each of the remaining species accounting for equal to or less than 1%.

The species composition of these fishing hauls (as expressed in terms of percentages in number) is shown in **Figure 4**.

Back-scattering energy attributed to the "pelagic assemblage" and individual species

A total of 307 nmi (ESDU) from 21 transects were acoustically sampled by echo-integration for assessment purposes. **Table 3** provides the nautical area-scattering coefficients, NASC, attributed to each of the selected target species and for the whole "pelagic fish assemblage".

For this "pelagic fish assemblage" we estimated a total of 107 026 m^2 nmi^{-2}, 53% lower than the maximum value recorded throughout the time-series, estimated in 2020 (229 241 m^2 nmi^{-2}), and 12% below the historical mean (122 671 m^2 nmi^{-2}). The highest NASC value (7 090 m^2 nmi^{-2}) was observed in the inner-shelf waters (50 m) in front of the Bay of Cádiz (transect R04, **Figure 5**), with relatively high values being also recorded in the inner- and mid-shelf waters (20-123 m depth) of transects R02, R04, R18 and R21. By species, chub mackerel and Mediterranean horse mackerel accounted for 20% of this total back-scattered energy, followed by anchovy, sardine (both 18%), and bogue (11%), with the remaining species showing relative contributions of acoustic energies lower than 6%.

According to the resulting values of integrated acoustic energy and the availability and representativeness of the length frequency distributions in fishing hauls, the species acoustically assessed in the present survey finally were anchovy, sardine, mackerel, chub mackerel, blue jack mackerel, horse mackerel, Mediterranean horse mackerel, bogue, and pearlside.

Spatial distribution and abundance/biomass estimates

Anchovy *Engraulis encrasicolus*

Parameters of the survey's length-weight relationship for anchovy are given in **Table 7**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 7**. The mapping of the backscattering energy (nautical area scattering coefficient, NASC, in m^2nmi^{-2}) attributed to the species and the coherent strata considered for the acoustic estimation are shown in **Figure 8**. The estimated abundance and biomass by size class are given in **Table 8** and **Figure 9**. **Figure 10** shows the acoustic estimates by age group. **Table 9** shows the time-series of estimates for the whole population and Age-0 fish.

Gulf of Cádiz anchovy (18% of the total NASC attributed to fish) was widely distributed in the surveyed area, although it showed very low acoustic detections in the westernmost waters. Higher densities were mainly recorded in two areas: between Doñana and Bay of Cadiz and between El Rompido and Isla Cristina (**Figure 8**). The whole size class range for the pooled catches varied between the 5.0 and 16.5 cm size classes, with 2 modal classes, the main mode at 9.0 cm and a secondary one at 13.5 cm.

Nine (9) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 7**). Overall anchovy acoustic estimates in autumn 2022 were of 1837 million fish and 11 912 tonnes (**Table 8**; **Figure 9**), accounting for 5% and 31% decreases in abundance and biomass, respectively, as compared to last year's estimates (1973 million, 17 512 t). Current overall estimates are also lower than the time-series average (*i.e.* 2851 million; 21 399 t), (see **Table 9** and **Figure 37**). By geographical strata, the Spanish waters yielded 99% (1825 million) and 98% (11 719 t) of the total estimated abundance and biomass in the Gulf, highlighting the importance of these waters in the species' distribution. The estimates for the Portuguese waters were 11 million and 193 t (**Table 8; Figure 9**).

The size class range of the assessed anchovy population in autumn 2022 varied between the 5.0 and 16.0 cm size classes. The size distribution showed a mixed composition, with one main mode at 10.5 cm, a secondary mode at 9.0 cm, and with a small proportion of individuals being observed at 5.0 cm. It is noticeable the occurrence of this last modal size, as a consequence of the record of very tiny juveniles in the coastal waters located between Guadalquivir river mouth and Rota. The size composition of anchovy throughout the surveyed area confirms the usual pattern exhibited by the species during the survey season, with the largest (and oldest) fish being distributed in the westernmost waters and the smallest (and youngest) ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters (**Figures 8** and **9**).

The population was composed by fishes not older than 2 years. Age 0 fish accounted for 93% (1705 million) and 91% (10 797 t) of the total estimated abundance and biomass, respectively (**Table 9**; **Figure 10**). Spanish waters concentrated the bulk (99.8%) of this juvenile fraction. The estimates of age-0 fish experienced a similar trend than the one showed by the whole population in relation to the historical peak recorded in 2019 and the values recorded in 2020. Age-0 fish have shown 5% increase in number and 11% decrease in weight in relation to the estimates recorded in the previous year. The recent strong decreasing trends for the whole population and juveniles seem to have slowed down in 2022, with the 2022 estimates being well below their time-series averages (**Table 9**).

Age 1 fish represented 7% and 9% of the total abundance and biomass, while Age 2 fish accounted for <1% of the total abundance and biomass (**Figure 10**).

The 2022 autumn estimates of mean size and weight of the whole population (10.3 cm, 6.5 g) were somewhat lower than their respective time-series averages (11.3 cm, 9.5 g).

Sardine *Sardina pilchardus*

Size-weight relationship parameters for sardine derived from the survey's biological sampling are detailed in **Table 7**. Spatially explicit size distribution and mean length (±SD) are shown in **Figure 11**. The mapping of the backscattering energy (NASC, in m^2nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 12**. Estimated abundance and biomass by size class are given in **Table 10** and **Figure 13**. **Figure 14** shows the acoustic estimates by age group. **Table 11** shows time-series of estimates for the whole population and Age-0 fish.

GoC sardine showed a relatively high acoustic echo-integration in autumn 2022 (19% of the total NASC attributed to pelagic fish species assemblage). High sardine densities were observed from dense mid-water schools in the Algarve coastal and inner shelf waters (40-57 m), and between the Mazagón and the Bay of Cádiz (20-70 m; **Figure 12**). Sardine was widely distributed all over the surveyed area and, as a consequence of the abovementioned occurrence of dense schools in coastal waters, with very high densities in the inner-middle shelf waters.

The size distribution observed for the pooled catches from hauls ranged between 10.0 and 22.0 cm size classes. Two modal size classes were observed, the main mode at 18.0 cm and a secondary mode at 13.0 cm. The size composition of sardine pooled catches throughout the surveyed area differed from the usual pattern observed by the species during the survey season and area. In autumn 2022, smaller (younger) fish were observed throughout the surveyed area, whereas in previous years the largest (and oldest) fish were distributed in the Portuguese waters and the smallest (and youngest) fish often concentrated in the coastal waters between Chipiona and El Rompido (**Figure 12**).

Ten (10) coherent post-strata were differentiated according to the S_A value distribution and the size distribution sampled in the fishing hauls (**Figure 11**). GoC sardine abundance and biomass in autumn 2022 were estimated at 1085 million fish and 20 909 t, one of the lowest records within its respective series. This year's values were 63% and 86% lower than last year estimates (2985 million and 151 320 t, one of the highest records in the series; **Table 11**, **Figure 37**). Spanish waters comprised the 59% and 64% of the total estimated abundance and biomass, respectively (648 million and 13 255 t). The estimates for Portuguese waters were 437 million and 7 654 t.

Sizes of the assessed sardine population in autumn 2022 ranged between 10.0 and 22.0 cm size classes, showing a clearly bimodal length frequency distribution, with one main mode at 12.5 cm size class and a secondary one at 18.5 cm (**Table 7**; **Figure 10**).

Age-5 group was the oldest age group occurring in the population, although the occurrence of fishes older than Age-0 juveniles was very low. Thus, the population was mainly composed by these juvenile fishes, accounting for 91% (992 million) and 77% (16 177 t) of the total abundance and biomass, respectively. The abundance and biomass of this juvenile fraction was quite similar for both in Spanish (57% of both abundance and biomass) and Portuguese waters (43% of both abundance and biomass) (**Table 10**; **Figures 11** and **14**).

The 2022 autumn estimates of mean length and weight of the whole population (15.6 cm, 37.4 g), are lower than last year's estimates and similar to the time-series averages (*i.e.* 15.9 cm, 39.3 g).

Mackerel *Scomber scombrus*

Parameters of the survey's length-weight relationship are shown in **Table 7**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 15**. The mapping of the backscattering energy (NASC, in m^2nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 16**. Estimated abundance and biomass by size class are given in **Table 12** and **Figure 17**.

Atlantic mackerel (<0.01% of the total NASC) showed two main density core areas, one in the westernmost Algarve and another between Punta Umbría and Matalascañas, near the central zone of the surveyed area (**Figure 16**).

Four (4) coherent post-strata were differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 16**). Mackerel abundance and biomass in autumn 2022 in the GoC shelf waters were estimated at only *c.a.* 1 million fish and 309 t (**Table 12**; **Figure 17**). Almost the whole estimated population (65.0% of the total abundance) was located in Portuguese waters (0.8 million, 194 t). The estimates for the Spanish waters were *c.a.* 0.4 million and 115 t.

The size composition of the mackerel estimated population in autumn 2022 ranged between 27.0 and 36.5 cm size classes; no dominant mode was observed given the size distribution was patchy (**Table 12**; **Figure 17**). No clear spatial pattern in mean size was observed; perhaps the smallest fish were more common in Portuguese waters.

Chub mackerel *Scomber colias*

Parameters of the survey's length-weight relationship are shown in **Table 7**. Size distribution and mean (±SD) size in the fishing hauls are spatially explicit represented in **Figure 18**. The NASC mapping (in m^2nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 19**. Estimated abundance and biomass by size class are given in **Table 13** and **Figure 20**. **Figure 21** shows the acoustic estimates by age group. **Table 14** shows the time-series of estimates for the whole population and Age-0 fish.

Chub mackerel (21% of the total NASC) was mainly distributed over the Portuguese waters, recording higher acoustic densities between the Cape San Vicente and Cape Santa Maria area, with only small densities recorded between Punta Umbría and Rota, in Spanish waters (**Figure 19**). The largest fish have been commonly captured in Spanish waters, with smaller fish occurring in Portuguese waters, although the species' positive hauls did not show a clear spatial pattern in (mean) size (**Table 13**; **Figures 18** and **19**).

Nine (9) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing stations (**Figure 18**). Chub mackerel abundance and biomass in the surveyed area were estimated in 247 million fish and 15 499 t, which were

132% and 18% higher than last year estimates (106 million, 13 115 t; **Table 14**, **Figure 37**). Portuguese waters accounted for 99% of both the total abundance (246 million) and biomass (15 438 t), respectively. Spanish waters yielded a population of 0.6 million and 61 t.

The size distribution of the assessed population of chub mackerel ranged between 17.5 and 29.5 cm size classes, with a dominant modal class at 19.0 cm and a small, secondary mode at 25.0 cm. Given that most of chub mackerel was found in Portuguese waters, no regional size pattern could be detected, although larger (older) fish were observed in Spanish waters while smaller (younger) were observed in Portuguese waters.

The population was composed by fishes not older than 2 years, with the age-0 group being the dominant one (66%, 163 million, and 53%, 8 198 t, of the total abundance and biomass estimated in the surveyed area, respectively; **Figure 21**). Age-1 fish was the second most important age group in the estimated population (31%, 77 million fish, and 40%, 6 272 t, of the total abundance and biomass estimates). Age-0 fish were almost exclusively recorded in the Portuguese waters (99.9% in numbers and weight; 162 million fish, 8191 t).

Horse mackerel *Trachurus trachurus*

Length-weight relationship parameters estimated for this species are shown in **Table 7**. Size composition and mean (±SD) size in the fishing hauls are mapped in **Figure 22**. The NASC mapping (in m^2nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 23**. Estimated abundance and biomass by size class are given in **Table 15** and **Figure 24**.

Horse mackerel (4% of the total NASC) showed a relatively wide distribution, with areas of higher acoustic densities located mainly in the western Algarve and between Guadiana and Tinto-Odiel river mouths (**Figure 23**).

The size distribution observed in positive hauls was comprised between 6.0 and 26.0 cm size classes, with two dominant modal size classes at 12.5 and 20.5 cm, and a smaller, secondary mode at 23.0 cm. Small fish were recorded in the Spanish waters (**Figure 24**).

Seven (7) coherent post-strata were differentiated according to the S_A value distribution and the size distribution observed in the fishing hauls (**Figure 23**). Horse mackerel abundance and biomass in the surveyed area were 39 million fish and 3393 t (**Table 15**, **Figure 24**). Portuguese waters accounted for 80% (31 million) and 87% (2962 t) of the total abundance and biomass, respectively. Spanish waters yielded a population of 8 million and 432 t.

The size range recorded for the estimated population was comprised between 13.0 and 26.0 cm size classes, with two dominant modes, one at 21.5 cm and at 23.0 cm size class (both in Portuguese waters; **Table 15**, **Figure 24**).

Mediterranean horse-mackerel *Trachurus mediterraneus*

The survey's length-weight relationship for this species is shown in **Table 7**. Size composition and mean size in the fishing hauls are mapped in **Figure 25**. The mapping of NASC (in m^2nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 26**. Estimated abundance and biomass by size class are given in **Table 16** and **Figure 27**.

Mediterranean horse mackerel (20% of the total NASC) was observed from Cape Trafalgar to the west of Cape Santa Maria in autumn 2022. The species was mainly distributed all over the Spanish waters, even reaching Portuguese waters, mainly over the inner-mid shelf (**Figure 26**). The size class range for the pooled catches varied between the 11.5 and 36.5 cm size classes, with one modal class at 28.0 cm. No clear spatial pattern in mean size was observed, although the largest fish occurred in the easternmost Spanish waters (**Figure 25**).

Five (5) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 26**). The estimated abundance and biomass estimated for Mediterranean horse mackerel was 103 million fish and 23 648 t, with the bulk of the population (94% of abundance and biomass; 97 million, 22 454 t) located in Spanish waters, as commonly observed in previous surveys (**Table 16**, **Figure 26**).

The size distribution of the estimated population of Mediterranean horse mackerel inhabiting the GoC ranged between 23.0 and 36.5 cm size classes, with at least one clearly distinct mode at 30.5 cm size class. No clear spatial pattern regarding fish size was observed (**Table 16**, **Figure 25**).

Blue jack mackerel *Trachurus picturatus*

The survey's length-weight relationship for this species is shown in **Table 7**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 28**. The mapping of the backscattering energy (NASC, in m^2nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 29**. Estimated abundance and biomass by size class are given in **Table 17** and **Figure 30**.

Blue jack mackerel (0.5% of the total NASC) was restricted exclusively to the Portuguese waters, showing the highest acoustic densities in the western Algarve shelf waters (**Figure 29**). The size class range for the pooled catches varied between the 12.5 and 26.5 cm size classes. Larger fish were observed close to Cape San Vicente, whereas smaller fish were observed east of Cape Santa Maria (**Figure 28**).

Three (3) coherent post-strata have been differentiated according to the S_A value distribution and the size distribution observed in the fishing hauls (**Figure 29**). Blue Jack mackerel abundance and biomass in the surveyed area were estimated at 6 million fish and 406 t, with all the estimated population located in Portuguese waters (**Table 17, Figure 30**).

The size range recorded for the estimated population was comprised between 12.5 and 26.5 cm size classes, with two well distinct modes, the dominant one at 22.0 cm size class and the secondary one at 14.5 cm size class. Larger fish were recorded in the westernmost Algarve (**Table 17**, **Figure 30**).

Bogue *Boops boops*

Length-weight relationship parameters estimated from survey data for this species is shown in **Table 7**. Size composition and mean (SD) size in the fishing hauls are represented in the spatial context in **Figure 31**. The mapping of NASC (in m^2nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 32**. Estimated abundance and biomass by size class are given in **Table 18** and **Figure 33**.

Bogue (11% of the total NASC) was widely distributed throughout the GoC although with low acoustic densities. The highest densities were recorded in the westernmost Algarve shelf waters and all over the Spanish shelf waters (**Figure 32**).

The size distribution for the pooled catches varied between the 11.5 and 35.5 cm size classes, with two modal classes at 19.0 and 25.5 cm. No clear spatial pattern in mean size was observed, although the largest fish occurred in the easternmost Spanish waters (**Figure 31**).

Seven (7) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 32**). Bogue abundance and biomass in the surveyed area were estimated at 56 million fish and 8 829 t (**Table 18**, **Figure 33**). Spanish waters accounted for 71% (40 million) and 79% (6934 t) of both total abundance and biomass, respectively. Portuguese waters yielded a population of 16 million and 1895 t.

The size range recorded for the estimated population was comprised between 11.5 and 31.0 cm size classes, showing a very mixed composition and notably outstanding the mode at 25.5 cm size class (**Table 18**, **Figure 33**).

Pearlside *Maurolicus muelleri*

Length-weight relationship parameters derived from the survey hauls are presented in **Table 7**. However, given the small number of individuals sampled during this year's survey, it was considered more appropriate to use length-weight relationship parameters derived from *ECOCADIZ-RECLUTAS-2020* for biomass estimation. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 34**. The mapping of the backscattering energy (NASC, in m^2nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 35**. Estimated abundance and biomass by size class are given in **Table 19** and **Figure 36**.

Pearlside (7% of total NASC) was commonly observed over the shelf break, especially in the western Algarve waters (**Figure 35**). No positive hauls was available for this species. Instead, the size distribution applied for computing abundance and biomass estimates was the observed in autumn 2020.

Three (3) coherent post-strata were differentiated according to the S_A value distribution and the size distribution observed in the representative fishing hauls (**Figure 35**). Pearlside abundance and biomass in the surveyed area were 2863 million fish and 2844 t. Portuguese waters accounted for 75% (2159 million, 2145 t) of the total abundance and biomass, respectively. Spanish waters yielded a population of 704 million and 699 t. (**Table 19**, **Figure 34**). The size composition recorded for the estimated population was comprised between 3.5 and 5.5 cm size classes, with a dominant mode at 4.5 cm size class (**Table 19**, **Figure 36**).

<u>Census of top predators</u>

During the survey a total of 72 legs were carried out, accounting for a total of 857 km during 43 h and 03 minutes of observation. Almost the whole of planned transects was sampled (**Figure 38**).

Sightings of cetacean species

A total of 18 sightings of cetaceans belonging to two different species were recorded: 12 sightings of common dolphin (*Delphinus delphis*) and 6 of bottlenose dolphin (*Tursiops truncatus*) (**Figure 38**).

Sightings of sea bird species

A total of 291 sightings of sea bird species of 11 different species were recorded during the survey.

Northern gannet (*Morus bassanus*)

Sightings (182) of northern gannet were quite homogeneously distributed all over the study area (**Figure 38**).

Scopoli's shearwater (*Calonectris diomedea*)

Sightings (19) of Scopoli's shearwater were concentrated in the eastern third of the study area, between Punta Umbría and Cape of Trafalgar, with the sightings being more abundant as we approach to the Strait of Gibraltar (**Figure 38**).

Great shearwater (*Puffinus gravis*)

Conversely, great shearwater sightings (18) were just recorded in the zone where the Scopoli's shearwater was not detected, between Punta Umbría and Cape San Vicente (**Figure 39**).

Balearic shearwater (*Puffinus mauritanicus*)

Balearic shearwater sightings (16) did not show a clear pattern of spatial distribution.

Yellow-legged gull (*Larus michahelis*)

Sightings of yellow-legged gull (15) were mainly distributed in the Gulf of Cádiz Spanish waters, between Ayamonte and Cape of Trafalgar (**Figure 39**).

European storm petrel (*Hydrobates pelagicus*)

Sightings of European storm petrel (15) were distributed over the central and western zones of the study area, between Punta Umbría and Cape San Vicente (**Figure 40**).

Great skua (*Stercorarius skua*)

Great skua (12 sightings) was distributed almost all over the study area (**Figure 40**).

Other sea bird species

Lesser black-backed gull (*Larus fuscus*; 10 sightings), parasitic jaeger (*Stercorarius parasiticus*; 2 sightings), Audouin's gull (*Larus audouinii*; 1 sighting) and black-headed gull (*Chroicocephalus ridibundus*; 1 sighting) were also observed during the survey. Additionally, 11 sightings of unidentified sea bird species, 7 sightings of unidentified seagulls and 4 sightings of unidentified shearwaters were also recorded.

(SHORT) DISCUSSION

Trends of anchovy, sardine and chub mackerel time series abundance and biomass estimates from this survey series are described in **Tables 9**, **11**, and **14** and **Figure 37**.

The anchovy population inhabiting the GoC during autumn 2022 showed a slight decrease (5%) in abundance and a more significant decrease in biomass (47%) when compared to last year's estimates **(Table 9**; **Figure 37**). Most, if not all, of the population was concentrated in the Spanish waters, highlighting the importance of this geographical area in the species distribution. The current estimates are lower than the time-series average (*i.e.* 3258 million; 25 627 t). The proportion of age 0 fish accounted for 93% (1705 million fish) and 91% (10 797 t) of the total estimated abundance and biomass, which was 11% lower and 5% higher than last year in terms of biomass and abundance, respectively. The bulk (99.8%) of age 0 fish was concentrated almost exclusively in Spanish waters. The estimates of age-0 fish experienced a similar trend to the one shown by the whole population concerning the historical peak recorded in 2019 and the values recorded in 2020, and with values still well below to the time-series average (**Table 6**). The recent strong decreasing trends for the whole population and juveniles seem to have slowed down in 2022, although such recent fluctuations should be conveniently monitored.

The abundance and biomass of the sardine population inhabiting the GoC in autumn 2022 were 1085 million fish and 20 909 t. These abundance and biomass estimates were 63% and 87% lower than last year's estimates. The 2022 estimates were the second lowest ones of the whole time series (without considering those years when the survey was restricted to Spanish waters; **Table 11**, **Figure 37**). Sardine was observed in Spanish and Portuguese waters, which was similar from last year's distribution pattern; however, this year a higher percentage of the population was concentrated in Spanish waters. The age structure of sardines in the GoC was mainly composed of age-0 fish, accounting for more than 90% of the abundance (992 million fish) and 80% of the biomass (16 177 t) of the total population. In contrast, the abundance and biomass of the rest of the cohorts were residual. Larger (older) fish seemed more frequent in Spanish waters, while smaller (younger) fish were present in all the GoC (**Table 8**; **Figures 10** and **13**). Sardine population inhabiting the Gulf of Cádiz seems to follow the same pattern as anchovy and attention should also be paid to this negative trend.

Chub mackerel abundance (247 million fish) and biomass (15 499 t) in autumn 2022 increased by 15% and 58% compared to the estimates in the previous year (106 million, 13 115 t; **Table 10**, **Figure 20**), but remained below their respective time-series averages (*i.e.* 193 million, 14 743 t), (**Table 14**, **Figure 37**). Portuguese waters concentrated the bulk of the total population abundance and biomass. The population was composed by fishes not older than 2 years, with the age-0 group being the dominant one (66%, 163 million, and 53%, 8 198 t, of the total abundance and biomass estimated in the surveyed area, respectively; **Figure 21**). Age-1 fish was the second most important age group in the estimated population (77 million fish, 6 272 t). This year was recorded the highest age-0 fish abundance and biomass from all the time series and was ~7-fold higher than last year estimates, for both abundance and biomass.

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REFERENCES

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L. 1993. *Distance sampling: Estimating abundance of biological populations*. Chapman and Hall, London.

Demer, D.A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., *et al*. 2015. Calibration of acoustic instruments. *ICES Coop. Res. Rep.*, 326, 133 pp.

Doray, M., Boyra, G., and van der Kooij, J. (Eds.). 2021. ICES Survey Protocols – Manual for acoustic surveys coordinated under the ICES Working Group on Acoustic and Egg Surveys for Small Pelagic Fish (WGACEGG). 1st Edition. *ICES Techniques in Marine Environmental Sciences* Vol. 64. 100 pp. https://doi.org/10.17895/ices.pub.7462.

Fässler, S. M.M., O'Donnell, C., Jech, J.M. 2013. Boarfish (*Capros aper*) target strength modelled from magnetic resonance imaging (MRI) scans of its swimbladder. *ICES Journal of Marine Science*, 70: 1451–1459.

Foote, K.G., Knudsen, H.P., Vestnes, G., MacLennan, D.N., Simmonds, E.J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. *ICES Coop. Res. Rep.*, 144, 57 pp.

ICES, 1998. Report of the Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX. A Coruña, 30- 31 January 1998. ICES CM 1998/G:2.

ICES, 2006a. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas VIII and IX (WGACEGG), 24-28 October 2005, Vigo, Spain. ICES, C.M. 2006/LRC: 01. 126 pp.

ICES, 2006b. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 27 November-1 December 2006, Lisbon, Portugal. ICES C.M. 2006/LRC:18. 169 pp.

Leaper, R., Gordon, J. 2001. Application of photogrammetric methods for locating and tracking cetacean movements at sea. *Journal of Cetacean Research and Management* 3: 131-141.

Leaper, R., Burt, L., Gillespie, D., Macleod, K. 2010. Comparisons of measured and estimated distances and angles from sighting surveys. *Journal of Cetacean Research and Management* 11: 229-237.

Nakken, O., Dommasnes, A. 1975. The application for an echo integration system in investigations on the stock strength of the Barents Sea capelin (*Mallotus villosus*, Müller) 1971-74. ICES CM 1975/B:25.

Ramos, F., Iglesias, M., Miquel, J., Oñate, D., Tornero, J., Ventero, A., Peña, M.A. 2010. Acoustic assessment and distribution of anchovy and sardine juveniles in the ICES Subdivision IXa South during the *ECOCADIZ-RECLUTAS 1009* Spanish survey (October-November 2009). Working document presented in the ICES Working Group on Southern Horse Mackerel, Anchovy and Sardine in ICES Area VIII and IX (WGACEGG), Palma de Mallorca, Spain, 22-26 November 2010. 31 pp.

Ramos, F., Iglesias, M., Miquel, J., Oñate, D., Tornero, J., Ventero, A., Díaz, N. 2013. Acoustic assessment and distribution of the main pelagic fish species in the ICES Subdivision IXa South during the *ECOCADIZ-RECLUTAS 1112* Spanish survey (November 2012). Working document presented in the ICES Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA), Bilbao (Basque Country), Spain, 21-26 June 2013 and in the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG). Lisbon, Portugal, 25-29 November 2013

Table 1. *ECOCADIZ-RECLUTAS 2022-10* survey. Percentage of occurrence, total weight (in kg) and total number of individuals of the fish species (sharks excluded) in the fishing hauls.

Species	OCCURRENCE (Number of valid hauls)	OCCURENCE (% over Total valid hauls)	Total weight (kg)	Total number
Sardina pilchardus	17	94.44 %	2337.815	45866
Scomber colias	14	77.78 %	421.864	6313
Merluccius merluccius	14	77.78 %	8.597	57
Trachurus trachurus	12	66.67 %	86.373	939
Engraulis encrasicolus	11	61.11 %	261.867	50298
Trachurus mediterraneus	10	55.56 %	188.846	1104
Boops boops	10	55.56 %	58.815	382
Sarda sarda	10	55.56 %	11.295	24
Spondyliosoma cantharus	10	55.56 %	8.360	72
Diplodus vulgaris	7	38.89 %	17.517	108
Pagellus erythrinus	7	38.89 %	12.620	76
Spicara flexuosa	7	38.89 %	8.228	125
Pagellus bellottii bellottii	7	38.89 %	7.430	65
Alosa fallax	6	33.33 %	2.100	9
Diplodus bellottii	5	27.78 %	7.430	139
Scomber scombrus	5	27.78 %	5.725	25
Trachurus picturatus	4	22.22 %	10.110	128
Pagellus acarne	4	22.22 %	2.825	9
Pomatomus saltatrix	3	16.67 %	2.125	7
Trachinus draco	3	16.67 %	0.285	3
Serranus hepatus	3	16.67 %	0.155	6
Mola mola	2	11.11 %	8.990	3
Stromateus fiatola	2	11.11 %	5.780	8
Pomadasys incisus	2	11.11 %	1.180	11
Diplodus annularis	2	11.11 %	0.735	14
Mullus barbatus	2	11.11 %	0.405	4
Macroramphosus scolopax	2	11.11 %	0.240	10
Zeus faber	1	5.56 %	0.570	2
Dentex gibbosus	1	5.56 %	0.285	1
Chelidonichthys lucerna	1	5.56 %	0.095	1
Lepidotrigla dieuzeidei	1	5.56 %	0.035	1
Lepidotrigla cavillone	1	5.56 %	0.035	1
Scorpaena notata	1	5.56 %	0.025	1
Maurolicus muelleri	1	5.56 %	0.004	5
Myctophum punctatum	1	5.56 %	0.001	2

Table 2. *ECOCADIZ-RECLUTAS 2022-10* survey. TS/length relationships used for acoustic estimation of assessed species. Boarfish b20 estimate following to Fässler *et al*. (2013). Between parentheses the usual IEO value considered in previous surveys.

Species	b20
Sardine (*Sardina pilchardus*)	-72.6
Round sardinella (*Sardinella aurita*)	-72.6
Anchovy (*Engraulis encrasicolus*)	-72.6
Chub mackerel (*Scomber japonicus*)	-68.7
Mackerel (*S. scombrus*)	-84.9
Horse mackerel (*Trachurus trachurus*)	-68.7
Mediterranean horse-mackerel (*T. mediterraneus*)	-68.7
Blue jack mackerel (*T. picturatus*)	-68.7
Bogue (*Boops boops*)	-67.0
Transparent goby (*Aphia minuta*)	-67.5
Atlantic pomfret (*Brama brama*)	-67.5
Blue whiting (*Micromesistius poutassou*)	-67.5
Silvery lightfish/pearlside (*Maurolicus muelleri*)	-72.2
Longspine snipefish (*Macroramphosus scolopax*)	-80.0
Boarfish (*Capros aper*)	-66.2* (-72.6)

Table 3. *ECOCADIZ-RECLUTAS 2022-10* survey. Total and regional NASC values by species. FAO codes for the species: ANE: *Engraulis encrasicolus*; PIL: *Sardina pilchardus*; VAM: *Scomber colias*; MAC: *S. scombrus*; JAA: *Trachurus picturatus*; HOM: *T. trachurus*; HMM: *T. mediterraneus*; BOG: *Boops boops*; SNS: *Macroramphosus scolopax*; MAV: *Maurolicus muelleri*.

$S_{A(m^2\,nmi^{-2})}$	TOTAL	PIL	ANE	MAC	VAM	HOM	HMM	JAA	BOG	MAV
TOTAL AREA	107026	20186	19631	8	22062	4233	21372	497	12122	6915
%	100	18.9	18.3	0.01	20.6	4.0	20.0	0.5	11.3	6.5
Portugal	41384	6804	198	4.1	21964	3377	1066	496	2649	4824
%	38	66.3	1.0	51.9	99.6	79.8	5.0	100	78.1	69.8
Spain	65641	13381	19433	4	97	856	20305	0	9472	2090
%	62	33.7	99.0	48.1	0.4	20.2	95.0	0	21.9	30.2

Table 4. *ECOCADIZ-RECLUTAS 2022-10* survey. Descriptive characteristics of the acoustic tracks.

Acoustic Track	Location	Date	Start				End			
			Latitude	Longitude	UTC time	Mean depth (m)	Latitude	Longitude	UTC time	Mean depth (m)
1	**Trafalgar**	15/10/22	36º 13.960' N	06º 06.980' W	06:44	18	36º 01.770' N	06º 29.550' W	08:52	277
2	**Sancti-Petri**	15/10/22	36º 08.970' N	06º 34.200' W	09:43	192	36º 19.266' N	06º 15.062' W	11:30	22
3	**Cádiz**	14/10/22	36º 16.954' N	06º 37.050' W	11:16	203	36º 26.950' N	06º 18.570' W	14:51	17
4	**Rota**	14/10/22	36º 33.870' N	06º 23.670' W	06:50	23	36º 23.920' N	06º 41.868' W	10:24	235
5	**Chipiona**	16/10/22	36º 40.870' N	06º 28.520' W	06:59	20	36º 31.172' N	06º 46.444' W	10:33	203
6	**Doñana**	16/10/22	36º 37.956' N	06º 51.619' W	11:27	200	36º 46.700' N	06º 35.570' W	14:52	20
7	**Matalascañas**	17/10/22	36º 53.880' N	06º 40.180' W	06:42	21	36º 43.970' N	06º 58.400' W	10:01	203
8	**Mazagón**	17/10/22	36º 49.426' N	07º 06.101' W	11:10	200	37º 01.420' N	06º 44.010' W	15:11	20
9	**Punta Umbría**	20/10/22	37º 04.530' N	06º 55.920' W	07:01	22	36º 49.681' N	07º 06.605' W	10:25	92
10	**El Rompido**	20/10/22	36º 49.549' N	07º 07.214' W	11:11	223	37º 07.643' N	07º 07.184' W	14:51	19
11	**Isla Cristina**	21/10/22	37º 07.269' N	07º 17.180' W	07:08	21	36º 53.451' N	07º 17.165' W	10:15	207
12	**Vila Real do Santo Antonio**	21/10/22	36º 56.304' N	07º 27.126' W	11:14	200	37º 06.615' N	07º 27.174' W	14:50	20
13	**Tavira**	22/10/22	37º 04.572' N	07º 37.141' W	07:02	19	36º 56.955' N	07º 37.127' W	09:33	205
14	**Fuzeta**	22/10/22	36º 55.473' N	07º 47.105' W	10:21	197	36º 58.698' N	07º 44.397' W	11:42	85
15	**Cabo de Santa María**	23/10/22	36º 56.944' N	07º 57.012' W	06:58	21	36º 52.042' N	07º 56.966' W	07:28	212
16	**Cuarteira**	23/10/22	37º 01.449' N	08º 07.411' W	10:21	23	36º 49.596' N	08º 06.975' W	13:46	47
17	**Albufeira**	24/10/22	37º 02.374' N	08º 17.033' W	07:03	19	36º 49.311' N	08º 16.818' W	10:17	202
18	**Alfanzina**	24/10/22	36º 50.274' N	08º 26.765' W	11:11	202	37º 04.474' N	08º 27.001' W	12:34	25
19	**Portimao**	25/10/22	37º 05.958' N	08º 37.035' W	07:03	24	36º 51.259' N	08º 36.728' W	08:31	199
20	**Burgau**	25/10/22	36º 52.009' N	08º 46.632' W	10:37	195	37º 03.468' N	08º 46.939' W	11:52	24
21	**Ponta de Sagres**	26/10/22	36º 59.386' N	08º 56.812' W	07:01	22	36º 50.433' N	08º 56.656' W	07:56	219

Table 5. *ECOCADIZ-RECLUTAS 2022-10* survey. Descriptive characteristics of the fishing hauls. Fishing hauls 15, 18 and 21 were null.

Fishing station	Date	Position						Timing				Trawled distance (Nmi)	Acoustic transect	Zone/Landmark
		Start			End									
		Latitude	Longitude	Depth	Latitude	Longitude	Depth	Start	End	Effective trawling	Total maneouvre			
1	14-10-2022	36º 30.7184 N	6º 29.4778 W	47.74	36º 32.1772 N	6º 26.3738 W	35.85	07:50	08:33	00:43	01:12	2.895	R04	Rota
2	14-10-2022	36º 22.1505 N	6º 27.5332 W	60.08	36º 20.8541 N	6º 29.9085 W	77.04	12:43	13:18	00:34	01:05	2.314	R03	Cádiz
3	16-10-2022	36º 35.8549 N	6º 37.7670 W	66.37	36º 37.4770 N	6º 34.6877 W	45.15	08:17	09:00	00:43	01:12	2.962	R05	Chipiona
4	16-10-2022	36º 41.8522 N	6º 44.4491 W	72.60	36º 40.3291 N	6º 47.2711 W	99.00	12:40	13:20	00:40	01:13	2.732	R06	Doñana
5	17-10-2022	36º 50.8070 N	6º 45.8063 W	39.58	36º 52.3083 N	6º 43.4536 W	26.86	07:41	08:17	00:35	00:58	2.411	R07	Matalascañas
6	17-10-2022	36º 55.9421 N	6º 54.1853 W	52.93	36º 54.4291 N	6º 56.9311 W	73.43	12:53	13:32	00:38	01:10	2.670	R08	Mazagón
7	20-10-2022	37º 02.2031 N	6º 57.7197 W	35.09	37º 04.1667 N	6º 56.2159 W	26.88	08:08	08:41	00:33	00:53	2.301	R09	Punta Umbría
8	20-10-2022	36º 56.9551 N	7º 07.0149 W	91.09	36º 59.1043 N	7º 06.9266 W	69.65	13:09	13:42	00:33	01:04	2.148	R10	El Rompido
9	21-10-2022	37º 02.8403 N	7º 17.2464 W	46.51	37º 05.4772 N	7º 17.4028 W	28.93	07:59	08:38	00:38	01:05	2.637	R11	Isla Cristina
10	21-10-2022	37º 03.5191 N	7º 27.1111 W	63.23	36º 59.5950 N	7º 27.1593 W	98.96	12:43	13:42	00:58	01:30	3.919	R12	Vila Real do Santo Antonio
11	22-10-2022	37º 03.0787 N	7º 37.1730 W	36.46	37º 01.3312 N	7º 37.0480 W	87.50	08:19	08:45	00:26	00:59	1.748	R13	Tavira
12	22-10-2022	36º 58.1545 N	7º 45.8267 W	82.29	36º 57.7716 N	7º 46.5611 W	81.68	12:04	12:16	00:11	00:55	0.702	R14	Fuzeta
13	22-10-2022	36º 58.2639 N	7º 45.4725 W	83.19	36º 57.7907 N	7º 46.5591 W	80.95	13:40	13:55	00:14	00:45	0.991	R14	Fuzeta
14	23-10-2022	36º 53.3571 N	7º 56.9600 W	99.40	36º 55.8217 N	7º 56.6979 W	60.02	08:00	08:39	00:38	01:22	2.470	R15	Cabo de Santa Maria
15	23-10-2022	na	na		36º 59.7226 N	8º 04.5681 W	31.97	na	12:07	na	na	na	R16	Cuarteira
16	23-10-2022	36º 59.6546 N	8º 04.3526 W	32.07	37º 00.3434 N	8º 06.6290 W	32.98	12:42	13:11	00:28	00:50	1.949	R16	Cuarteira
17	24-10-2022	36º 54.5176 N	8º 16.8568 W	93.59	36º 57.1550 N	8º 16.9677 W	64.95	08:25	09:05	00:39	01:12	2.635	R17	Albufeira
18	24-10-2022	na	na	na	na	na	na	na	na	na	na	na	R18	Alfanzina
19	24-10-2022	37º 00.0169 N	8º 27.0273 W	48.50	37º 01.5025 N	8º 26.9901 W	43.01	14:11	14:34	00:22	00:52	1.484	R18	Alfanzina
20	25-10-2022	36º 53.5025 N	8º 36.7122 W	107.00	36º 54.9246 N	8º 36.6952 W	97.10	08:58	09:19	00:21	00:53	1.420	R19	Portimao
21	26-10-2022	36º 52.7368 N	8º 56.6896 W	123.60	36º 53.6400 N	8º 56.7748 W	114.90	08:23	08:38	00:15	00:52	0.905	R21	Ponta de Sagres

Table 6. *ECOCADIZ-RECLUTAS 2022-10* survey. Catches by species in number (upper panel) and weight (in kg, lower panel) from valid fishing hauls.

Fishing haul	CATCH IN NUMBERS											
	Anchovy	*Bogue*	*Medit. Horse-mack.*	*Horse-mack.*	*Blue jack mack.*	*Mackerel*	*Chub mack.*	*Pearlside*	*Sardine*	*Snipefish*	OTHERS	TOTAL
1	10214	5	11	2	0	0	0	0	803	0	25	**11060**
2	0	15	47	0	0	0	0	0	7	0	11	**80**
3	24420	22	8	0	0	4	2	0	413	0	17	**24886**
4	12894	0	0	0	0	0	1	0	3918	0	3	**16816**
5	0	3	49	2	0	0	2	0	1173	0	138	**1367**
6	141	0	0	0	0	6	2	0	888	0	10	**1047**
7	14	6	21	47	0	0	0	0	59	0	134	**281**
8	2477	0	0	0	0	0	0	0	101	0	4	**2582**
9	0	148	753	288	0	0	2	0	1151	0	151	**2493**
10	95	0	0	24	28	1	2	0	113	0	20	**283**
11	0	26	160	1	0	0	1	0	3	0	41	**232**
12	0	0	2	24	0	0	2	0	1054	6	43	**1131**
13	0	0	0	0	0	0	29	0	31151	4	2	**31186**
14	26	0	1	14	6	0	1	5	14	0	28	**95**
16	1	40	52	2	1	0	8	0	1224	0	91	**1419**
17	14	38	0	34	0	2	96	0	26	0	8	**218**
19	0	79	0	116	0	0	40	0	3768	0	2	**4005**
20	2	0	0	385	93	12	6125	0	0	0	5	**6622**
TOTAL	**50298**	**382**	**1104**	**939**	**128**	**25**	**6313**	**5**	**45866**	**10**	**733**	**105803**

Table 6. *ECOCADIZ-RECLUTAS 2022-10* survey. Cont'd.

Fishing haul	CATCH IN WEIGHT (kg)											
	Anchovy	*Bogue*	*Medit. Horse-mack.*	*Horse-mack.*	*Blue jack mack.*	*Mackerel*	*Chub mack.*	*Pearlside*	*Sardine*	*Snipefish*	OTHERS	TOTAL
1	72,405	1,080	2,471	0,174	0	0	0	0	11,810	0	39,657	**127,597**
2	0	5,205	11,485	0	0	0	0	0	0,110	0	6,980	**23,780**
3	100,060	2,930	1,915	0	0	1,000	0,335	0	6,320	0	6,310	**118,870**
4	65,540	0	0	0	0	0	0,065	0	162,060	0	10,775	**238,440**
5	0	0,805	10,045	0,165	0	0	0,345	0	20,740	0	13,805	**45,905**
6	1,585	0	0	0	0	1,900	0,104	0	16,880	0	12,145	**32,614**
7	0,150	1,240	3,735	2,300	0	0	0	0	1,040	0	8,505	**16,970**
8	20,200	0	0	0	0	0	0	0	1,780	0	0,220	**22,200**
9	0	25,505	113,415	21,185	0	0	0,33	0	15,565	0	22,635	**198,635**
10	1,115	0	0	0,335	0,600	0,225	0,085	0	1,655	0	2,745	**6,760**
11	0	4,860	34,830	0,065	0	0	0,245	0	0,040	0	5,750	**45,790**
12	0	0	0,380	0,695	0	0	0,12	0	50,785	0,140	9,055	**61,175**
13	0	0	0	0	0	0	1,56	0	1965,910	0,100	0,175	**1967,745**
14	0,440	0	0,010	0,400	0,135	0	0,06	0,004	0,220	0	4,291	**5,560**
16	0,016	6,900	10,560	0,069	0,025	0	1,78	0	17,390	0	10,585	**47,325**
17	0,301	4,655	0	3,460	0	0,690	13,04	0	0,480	0	4,990	**27,616**
19	0	5,635	0	8,275	0	0	4,165	0	65,030	0	0,545	**83,650**
20	0,055	0	0	49,25	9,350	1,910	399,63	0	0	0	1,900	**462,095**
TOTAL	**261,867**	**58,815**	**188,846**	**86,373**	**10,110**	**5,725**	**421,864**	**0,004**	**2337,815**	**0,240**	**161,068**	**3532,727**

Table 7. *ECOCADIZ-RECLUTAS 2022-10* survey. Parameters of the size-weight relationships for the survey's target species susceptible of being assessed. FAO codes for the species: ANE: *Engraulis encrasicolus*; PIL: *Sardina pilchardus*; VAM: *Scomber colias*; MAC: *S. scombrus*; JAA: *Trachurus picturatus*; HOM: *T. trachurus*; HMM: *T. mediterraneus*; BOG: *Boops boops*; MAV: *Maurolicus muelleri* (*).

Parameter	ANE	PIL	VAM	MAC	HOM	HMM	JAA	BOG	MAV(*)
Size range (mm)	87 - 166	107 - 221	183 - 318	274 - 367	68 - 263	115 - 364	125 - 268	175 - 358	44 - 63
n	353	739	192	25	298	282	85	249	6
a	0.0041	0.0022	0.0014	0.0004	0.0067	0.0095	0.0031	0.0069	0.0152
b	3.1352	3.4510	3.5477	3.8348	3.0675	2.9474	3.3138	3.1093	2.6500
r^2	0.9904	0.9851	0.9813	0.9608	0.9921	0.9765	0.9973	0.9779	0.9201

(*) For the acoustic assessment, size-weight relationships parameters for MAV were derived from *ECOCADIZ-RECLUTAS-2020* (a=0.0108.; b=2.8308; n=43; size range=32-63 mm; r^{2-}=0.9081).

Tabla 8. *ECOCADIZ-RECLUTAS 2022-10* survey. Anchovy (*E. encrasicolus*). Estimated abundance (absolute numbers and millions of fish) and biomass (t) by size class (in cm). Polygons (i.e., coherent or homogeneous post-strata) numbered as in **Figure 8.**

ECOCADIZ-RECLUTAS 2022-10. Engraulis encrasicolus. ABUNDANCE (in numbers and million fish)														
SIZE CLASS (cm)	POL01	POL02	POL03	Portugal	POL04	POL05	POL06	POL07	POL08	POL09	Spain	TOTAL	Millions		
													Portugal	Spain	Total
5	0	0	0	0	0	0	1996360	0	0	0	1996360	1996360	0	1.99636	1.99636
5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	9998578	0	0	0	9998578	9998578	0	9.998578	9.998578
8.5	0	0	0	0	477788	9169758	115906336	0	0	0	125553882	125553882	0	125.553882	125.553882
9	0	0	0	0	1911152	121112923	223810454	0	0	0	346834529	346834529	0	346.834529	346.834529
9.5	0	0	13331	13331	4982497	104602208	45966618	10226729	381326	71150	166230528	166243859	0.013331	166.230528	166.243859
10	0	0	0	0	21221293	53215504	11994939	209436640	7809305	1457101	305134782	305134782	0	305.134782	305.134782
10.5	0	0	13331	13331	44938656	22022873	0	326917241	12189827	2274442	408343039	408356370	0.013331	408.343039	408.35637
11	0	0	26662	26662	42695685	12853115	0	260485764	9712783	1812262	327559609	327586271	0.026662	327.559609	327.586271
11.5	0	0	173302	173302	27061879	3657600	0	40906914	1525304	284599	73436296	73609598	0.173302	73.436296	73.609598
12	0	297146	333273	630419	22232389	3657600	0	10226729	381326	71150	36569194	37199613	0.630419	36.569194	37.199613
12.5	0	297146	373266	670412	11129097	0	0	5071105	189087	35281	16424570	17094982	0.670412	16.42457	17.094982
13	0	1782877	199964	1982841	2079016	0	0	0	0	0	2079016	4061857	1.982841	2.079016	4.061857
13.5	0	1188585	79986	1268571	1911152	1828800	0	0	0	0	3739952	5008523	1.268571	3.739952	5.008523
14	313449	1782877	39993	2136319	1433364	0	0	0	0	0	1433364	3569683	2.136319	1.433364	3.569683
14.5	156725	1188585	13331	1358641	0	0	0	0	0	0	0	1358641	1.358641	0	1.358641
15	626898	594292	0	1221190	0	0	0	0	0	0	0	1221190	1.22119	0	1.22119
15.5	783623	297146	0	1080769	0	0	0	0	0	0	0	1080769	1.080769	0	1.080769
16	313449	297146	0	610595	0	0	0	0	0	0	0	610595	0.610595	0	0.610595
TOTAL n	2194144	7725800	1266439	11186383	182073968	332120381	409673285	863271122	32188958	6005985	1825333699	1836520082	11	1825	1837
Millions	**2**	**8**	**1**	**11**	**182**	**332**	**410**	**863**	**32**	**6**	**1825**	**1837**			

Table 8. *ECOCADIZ-RECLUTAS 2022-10* survey. Anchovy (*E. encrasicolus*). Cont'd

ECOCADIZ-RECLUTAS 2022-10. Engraulis encrasicolus. **BIOMASS (t)**												
SIZE CLASS (cm)	**POL01**	**POL02**	**POL03**	**Portugal**	**POL04**	**POL05**	**POL06**	**POL07**	**POL08**	**POL09**	**Spain**	**TOTAL**
5	0	0	0	0	0	0	1.495	0	0	0	1.495	1.495
5.5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
7.5	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	30.896	0	0	0	30.896	30.896
8.5	0	0	0	0	1.775	34.075	430.710	0	0	0	466.560	466.560
9	0	0	0	0	8.453	535.712	989.968	0	0	0	1534.133	1534.133
9.5	0	0	0.070	0.070	25.994	545.708	239.807	53.353	1.989	0.371	867.222	867.292
10	0	0	0	0	129.505	324.752	73.200	1278.103	47.657	8.892	1862.109	1862.109
10.5	0	0	0.094	0.094	318.407	156.040	0	2316.331	86.369	16.115	2893.262	2893.356
11	0	0	0.218	0.218	348.857	105.020	0	2128.372	79.361	14.808	2676.418	2676.636
11.5	0	0	1.623	1.623	253.414	34.251	0	383.062	14.283	2.665	687.675	689.298
12	0	3.171	3.556	6.727	237.246	39.031	0	109.131	4.069	0.759	390.236	396.963
12.5	0	3.595	4.515	8.110	134.631	0	0	61.346	2.287	0.427	198.691	206.801
13	0	24.332	2.729	27.061	28.374	0	0	0	0	0	28.374	55.435
13.5	0	18.219	1.226	19.445	29.295	28.032	0	0	0	0	57.327	76.772
14	5.374	30.567	0.686	36.627	24.574	0	0	0	0	0	24.574	61.201
14.5	2.994	22.705	0.255	25.954	0	0	0	0	0	0	0	25.954
15	13.294	12.603	0	25.897	0	0	0	0	0	0	0	25.897
15.5	18.387	6.972	0	25.359	0	0	0	0	0	0	0	25.359
16	8.112	7.690	0	15.802	0	0	0	0	0	0	0	15.802
TOTAL	**48.161**	**129.854**	**14.972**	**192.987**	**1540.525**	**1802.621**	**1766.076**	**6329.698**	**236.015**	**44.037**	**11718.972**	**11911.959**

Tabla 9. *ECOCADIZ-RECLUTAS* surveys series. Anchovy (*E. encrasicolus*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cádiz anchovy population and for the juvenile fraction (*i.e.* age 0 fish, between parentheses). Note that the 2012 survey only surveyed the Spanish waters. The 2017 estimates correspond to an incomplete coverage (only the seven easternmost transects) of the standard surveyed area due to a research vessels' breakdown.

Estimate/Year	**Total Population (Recruits at age 0)**									
	2012	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Biomass (t)	13680 (13354)	8113 (5131)	30827 (29219)	19861 (15969)	7642 (7290)	10493 (3834)	48357 (36405)	36070 (21060)	17512 (12063)	11912 (10797)
Abundance (millions)	2469 (2619)	986 (814)	5227 (5117)	3667 (3445)	1492 (1433)	953 (543)	5505 (4845)	3197 (2385)	1973 (1629)	1837 (1705)

Table 10. *ECOCADIZ-RECLUTAS 2022-10* survey. Sardine (*Sardina pilchardus*). Estimated abundance (absolute numbers and million fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 12**.

ECOCADIZ-RECLUTAS 2022-10. Sardina pilchardus. ABUNDANCE (in numbers and million fish)														Millions		
SIZE CLASS (cm)	POL01	POL02	POL03	POL04	Portugal	POL05	POL06	POL07	POL08	POL09	POL10	Spain	TOTAL	Portugal	Spain	TOTAL
10	0	0	0	0	0	0	0	0	681009	7204	1	688214	688214	0	1	1
10.5	0	0	0	14331	14331	37036	0	250485	681009	7204	1	975735	990066	0	1	1
11	3705037	601690	0	11675	4318402	30171	3826277	250485	4640702	49093	9	8796737	13115139	4	9	13
11.5	6201909	2607323	294	236029	9045555	609976	10903908	250485	18037422	190816	34	29992641	39038196	9	30	39
12	19894436	46129562	0	698215	66722213	1804411	18671404	3395467	65525322	693184	122	90089910	156812123	67	90	157
12.5	78369579	48736885	588	534483	127641535	1381276	44101509	10464719	96025726	1015844	179	152989253	280630788	128	153	281
13	100841432	18150980	1176	222222	119215810	574294	69151765	16532030	55698602	589229	104	142546024	261761834	119	143	262
13.5	41480301	5214646	2647	102355	46799949	264519	56484930	7291906	14311376	151398	27	78504156	125304105	47	79	125
14	23116207	1303662	2058	62328	24484255	161076	20275698	4369577	20966271	221800	39	45994461	70478716	24	46	70
14.5	9101503	0	882	5837	9108222	15085	9386867	2922329	1576159	16674	3	13917117	23025339	9	14	23
15	7571162	0	588	5837	7577587	15085	5113525	2365695	1556654	16468	3	9067430	16645017	8	9	17
15.5	5477011	0	36170	0	5513181	0	2450010	250485	681009	7204	1	3388709	8901890	6	3	9
16	4510479	0	144093	0	4654572	0	911202	306149	0	0	0	1217351	5871923	5	1	6
16.5	1852518	0	108217	0	1960735	0	0	1502912	0	0	0	1502912	3463647	2	2	3
17	241633	0	612544	0	854177	0	2555755	4480904	875644	9263	2	7921568	8775745	1	8	9
17.5	80544	0	1801461	8494	1890499	21951	2390273	4480904	0	0	0	6893128	8783627	2	7	9
18	322177	0	2990672	0	3312849	0	1512887	10464719	0	0	0	11977606	15290455	3	12	15
18.5	161089	0	1693538	17822	1872449	46057	1232517	14055009	0	0	0	15333583	17206032	2	15	17
19	161089	0	1008947	0	1170036	0	0	11077017	0	0	0	11077017	12247053	1	11	12
19.5	161089	0	468450	0	629539	0	0	9880254	0	0	0	9880254	10509793	1	10	11
20	80544	0	144093	0	224637	0	0	2699675	0	0	0	2699675	2924312	0.2	3	3
20.5	80544	0	72047	0	152591	0	0	584466	0	0	0	584466	737057	0.2	1	1
21	0	0	72047	0	72047	0	0	584466	0	0	0	584466	656513	0.1	1	1
21.5	0	0	0	0	0	0	0	584466	0	0	0	584466	584466	0	1	1
22	80544	0	0	0	80544	0	0	0	0	0	0	0	80544	0.1	0	0.1
TOTAL n	303490827	122744748	9160512	1919628	437315715	4960937	248968527	109044604	281256905	2975381	525	647206879	1084522594	**437**	**647**	**1085**
Millions	**303**	**123**	**9**	**2**	**437**	**5**	**249**	**109**	**281**	**3**	**0.001**	**647**	**1085**			

Table 10. *ECOCADIZ-RECLUTAS 2022-10* survey. Sardine (*Sardina pilchardus*). Cont'd.

ECOCADIZ-RECLUTAS 2022-10. Sardina pilchardus. BIOMASS (t)													
SIZE CLASS (cm)	POL01	POL02	POL03	POL04	Portugal	POL05	POL06	POL07	POL08	POL09	POL10	Spain	TOTAL
10	0	0	0	0	0	0	0	0	4.702	0.050	0	4.752	4.752
10.5	0	0	0	0.117	0.117	0.301	0	2.038	5.542	0.059	0	7.940	8.057
11	35.272	5.728	0	0.111	41.111	0.287	36.427	2.385	44.18	0.467	0	83.746	124.857
11.5	68.603	28.841	0.003	2.611	100.058	6.747	120.615	2.771	199.522	2.111	0	331.766	431.824
12	254.101	589.188	0	8.918	852.207	23.047	238.48	43.368	836.920	8.854	0.002	1150.671	2002.878
12.5	1149.161	714.646	0.009	7.837	1871.653	20.254	646.676	153.448	1408.059	14.896	0.003	2243.336	4114.989
13	1688.589	303.938	0.020	3.721	1996.268	9.617	1157.946	276.829	932.673	9.867	0.002	2386.934	4383.202
13.5	789.302	99.226	0.050	1.948	890.526	5.033	1074.815	138.753	272.322	2.881	0.001	1493.805	2384.331
14	497.566	28.061	0.044	1.342	527.013	3.467	436.425	94.053	451.289	4.774	0.001	990.009	1517.022
14.5	220.665	0	0.021	0.142	220.828	0.366	227.584	70.852	38.214	0.404	0	337.420	558.248
15	205.943	0	0.016	0.159	206.118	0.410	139.093	64.349	42.342	0.448	0	246.642	452.760
15.5	166.525	0	1.100	0	167.625	0	74.491	7.616	20.706	0.219	0	103.032	270.657
16	152.756	0	4.880	0	157.636	0	30.860	10.368	0	0	0	41.228	198.864
16.5	69.656	0	4.069	0	73.725	0	0	56.511	0	0	0	56.511	130.236
17	10.056	0	25.493	0	35.549	0	106.365	186.486	36.442	0.386	0	329.679	365.228
17.5	3.699	0	82.743	0.390	86.832	1.008	109.787	205.812	0	0	0	316.607	403.439
18	16.287	0	151.185	0	167.472	0	76.480	529.014	0	0	0	605.494	772.966
18.5	8.940	0	93.982	0.989	103.911	2.556	68.398	779.975	0	0	0	850.929	954.840
19	9.789	0	61.314	0	71.103	0	0	673.156	0	0	0	673.156	744.259
19.5	10.695	0	31.102	0	41.797	0	0	655.983	0	0	0	655.983	697.780
20	5.829	0	10.429	0	16.258	0	0	195.392	0	0	0	195.392	211.650
20.5	6.341	0	5.672	0	12.013	0	0	46.016	0	0	0	46.016	58.029
21	0	0	6.158	0	6.158	0	0	49.957	0	0	0	49.957	56.115
21.5	0	0	0	0	0	0	0	54.132	0	0	0	54.132	54.132
22	8.069	0	0	0	8.069	0	0	0	0	0	0	0	8.069
TOTAL	**5377.844**	**1769.628**	**478.290**	**28.285**	**7654.047**	**73.093**	**4544.442**	**4299.264**	**4292.913**	**45.416**	**0.009**	**13255.137**	**20909.184**

Table 11. *ECOCADIZ-RECLUTAS* surveys series. Sardine (*Sardina pilchardus*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cádiz anchovy population and for the juvenile fraction (*i.e.* age 0 fish, between parentheses). Note that the 2012 survey only surveyed the Spanish waters. The 2017 estimates correspond to an incomplete coverage (only the seven easternmost transects) of the standard surveyed area due to a research vessels' breakdown.

Estimate/Year	Total Population (Recruits at age 0)									
	2012	2014	2015	2016	2017	2018	2019	2020	2021	2022
Biomass (t)	22119 (9182)	36571 (705)	30992 (8645)	35173 (21899)	12119 (8778)	20679 (15224)	36465 (7858)	208400 (49259)	151320 (12854)	20909 (16177)
Abundance (millions)	603 (359)	507 (26)	861 (509)	2379 (1940)	591 (483)	1134 (1036)	937 (384)	5451 (2454)	2986 (638)	1085 (992)

Tabla 12. *ECOCADIZ-RECLUTAS 2022-10* survey. Atlantic mackerel (*Scomber scombrus*). Estimated abundance (absolute numbers and millions of fish) and biomass (t) by size class (in cm). Polygons (i.e., coherent or homogeneous post-strata) numbered as in **Figure 15**.

ECOCADIZ-RECLUTAS 2022-10. Scomber scombrus. ABUNDANCE (in numbers and million fish)										
SIZE CLASS (cm)	POL01	POL02	Portugal	POL03	POL04	Spain	TOTAL	Millions		
								Portugal	Spain	TOTAL
27	32581	0	32581	0	0	0	32581	0.0	0.0	0.0
27.5	130325	0	130325	0	0	0	130325	0.1	0.0	0.1
28	32581	0	32581	0	0	0	32581	0.0	0.0	0.0
28.5	65163	1458	66621	51862	7710	59572	126193	0.1	0.1	0.1
29	32581	0	32581	0	0	0	32581	0.0	0.0	0.0
29.5	32581	0	32581	0	0	0	32581	0.0	0.0	0.0
30	0	875	875	31117	4626	35743	36618	0.0	0.0	0.0
30.5	65163	0	65163	0	0	0	65163	0.1	0.0	0.1
31	0	3498	3498	124468	18503	142971	146469	0.0	0.1	0.1
31.5	0	0	0	0	0	0	0	0.0	0.0	0.0
32	0	583	583	20745	3084	23829	24412	0.0	0.0	0.0
32.5	0	875	875	31117	4626	35743	36618	0.0	0.0	0.0
33	195488	0	195488	0	0	0	195488	0.2	0.0	0.2
33.5	0	0	0	0	0	0	0	0.0	0.0	0.0
34	0	0	0	0	0	0	0	0.0	0.0	0.0
34.5	0	583	583	20745	3084	23829	24412	0.0	0.0	0.0
35	195488	583	196071	20745	3084	23829	219900	0.2	0.0	0.2
35.5	0	875	875	31117	4626	35743	36618	0.0	0.0	0.0
36	0	583	583	20745	3084	23829	24412	0.0	0.0	0.0
36.5	0	583	583	20745	3084	23829	24412	0.0	0.0	0.0
TOTAL n	781951	10496	792447	373406	55511	428917	1221364	1	0.4	1
Millions	1	0.01	1	0.4	0.1	0.4	1			

Table 12. *ECOCADIZ-RECLUTAS 2022-10* survey. Atlantic mackerel (*Scomber scombrus*). Cont'd.

***ECOCADIZ-RECLUTAS 2022-10. Scomber scombrus.* BIOMASS (t)**							
SIZE CLASS (cm)	**POL01**	**POL02**	**Portugal**	**POL03**	**POL04**	**Spain**	**TOTAL**
27	4.369	0	4.369	0	0	0	4.369
27.5	18.736	0	18.736	0	0	0	18.736
28	5.016	0	5.016	0	0	0	5.016
28.5	10.730	0.240	10.970	8.540	1.270	9.810	20.780
29	5.732	0	5.732	0	0	0	5.732
29.5	6.117	0	6.117	0	0	0	6.117
30	0	0.175	0.175	6.227	0.926	7.153	7.328
30.5	13.887	0	13.887	0	0	0	13.887
31	0	0.793	0.793	28.219	4.195	32.414	33.207
31.5	0	0	0	0	0	0	0
32	0	0.149	0.149	5.307	0.789	6.096	6.245
32.5	0	0.237	0.237	8.444	1.255	9.699	9.936
33	56.223	0	56.223	0	0	0	56.223
33.5	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0
34.5	0	0.199	0.199	7.066	1.050	8.116	8.315
35	70.338	0.210	70.548	7.464	1.110	8.574	79.122
35.5	0	0.332	0.332	11.817	1.757	13.574	13.906
36	0	0.234	0.234	8.309	1.235	9.544	9.778
36.5	0	0.246	0.246	8.758	1.302	10.06	10.306
TOTAL	**191.148**	**2.815**	**193.963**	**100.151**	**14.889**	**115.04**	**309.003**

Table 13. *ECOCADIZ-RECLUTAS 2022-10* survey. Chub mackerel (*Scomber colias*). Estimated abundance (absolute numbers and million fish) and biomass (t) by size class (in cm). Polygons (i.e., coherent or homogeneous post-strata) numbered as in **Figure 19.**

***ECOCADIZ-RECLUTAS 2022-10. Scomber colias*. ABUNDANCE (in numbers and million fish)**															
SIZE CLASS (cm)	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	**Portugal**	**POL07**	**POL08**	**POL09**	**Spain**	**TOTAL**	**Millions**		
													Portugal	**Spain**	**TOTAL**
17.5	1516546	0	0	0	138	0	1516684	0	1125	0	1125	1517809	2	0	2
18	18790371	0	0	0	1710	0	18792081	0	13941	0	13941	18806022	19	0	19
18.5	47937641	0	0	912	4363	0	47942916	0	35566	0	35566	47978482	48	0	48
19	59811084	0	0	1216	5444	0	59817744	0	44376	0	44376	59862120	60	0	60
19.5	26853956	0	0	2737	2444	0	26859137	0	19924	0	19924	26879061	27	0	27
20	24523654	0	0	2432	2232	0	24528318	0	18195	0	18195	24546513	25	0	25
20.5	11503554	76533	0	608	1047	0	11581742	0	8535	0	8535	11590277	12	0	12
21	6510050	76533	170775	912	593	54	6758917	105	4830	4037	8972	6767889	7	0	7
21.5	4993504	153066	0	0	455	0	5147025	0	3705	0	3705	5150730	5	0	5
22	6140161	382666	0	0	559	0	6523386	0	4556	0	4556	6527942	7	0	7
22.5	2293313	382666	170775	0	209	54	2847017	105	1701	4037	5843	2852860	3	0	3
23	1146657	535733	512325	0	104	161	2194980	315	851	12112	13278	2208258	2	0	2
23.5	2293313	382666	1366201	0	209	429	4042818	841	1701	32299	34841	4077659	4	0	4
24	3070080	688799	1707751	0	279	536	5467445	1051	2278	40374	43703	5511148	5	0	6
24.5	3070080	0	3415502	0	279	1073	6486934	2102	2278	80747	85127	6572061	6	0.1	7
25	3070080	153066	3415502	0	279	1073	6640000	2102	2278	80747	85127	6725127	7	0.1	7
25.5	1146657	153066	1707751	0	104	536	3008114	1051	851	40374	42276	3050390	3	0	3
26	1146657	0	1536976	0	104	483	2684220	946	851	36336	38133	2722353	3	0	3
26.5	369889	0	1024651	0	34	322	1394896	630	274	24224	25128	1420024	1	0	1
27	369889	0	683100	0	34	215	1053238	420	274	16149	16843	1070081	1	0	1
27.5	0	0	512325	0	0	161	512486	315	0	12112	12427	524913	1	0	1
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	170775	0	0	54	170829	105	0	4037	4142	174971	0	0	0
29.5	0	76533	0	0	0	0	76533	0	0	0	0	76533	0	0	0
TOTAL n	226557136	3061327	16394409	8817	20620	5151	246047460	10088	168090	387585	565763	246613223	**246**	**0.6**	**246.6**
Millions	**227**	**3**	**16**	**0.01**	**0.02**	**0.01**	**246**	**0.01**	**0.2**	**0.4**	**0.6**	**246.6**			

Tabla 13. *ECOCADIZ-RECLUTAS 2022-10* survey. Chub mackerel (*Scomber colias*). Cont'd.

***ECOCADIZ-RECLUTAS 2022-10. Scomber colias.* BIOMASS (t)**												
SIZE CLASS (cm)	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	**Portugal**	**POL07**	**POL08**	**POL09**	**Spain**	**TOTAL**
17.5	55.974	0	0	0	0.005	0	55.979	0	0.042	0	0.042	56.021
18	765.366	0	0	0	0.070	0	765.436	0	0.568	0	0.568	766.004
18.5	2149.093	0	0	0.041	0.196	0	2149.330	0	1.594	0	1.594	2150.924
19	2943.804	0	0	0.060	0.268	0	2944.132	0	2.184	0	2.184	2946.316
19.5	1447.586	0	0	0.148	0.132	0	1447.866	0	1.074	0	1.074	1448.94
20	1444.583	0	0	0.143	0.131	0	1444.857	0	1.072	0	1.072	1445.929
20.5	738.875	4.916	0	0.039	0.067	0	743.897	0	0.548	0	0.548	744.445
21	454.998	5.349	11.936	0.064	0.041	0.004	472.392	0.007	0.338	0.282	0.627	473.019
21.5	379.022	11.618	0	0	0.035	0	390.675	0	0.281	0	0.281	390.956
22	505.193	31.485	0	0	0.046	0	536.724	0	0.375	0	0.375	537.099
22.5	204.165	34.067	15.203	0	0.019	0.005	253.459	0.009	0.151	0.359	0.519	253.978
23	110.268	51.518	49.267	0	0.010	0.015	211.078	0.030	0.082	1.165	1.277	212.355
23.5	237.827	39.684	141.681	0	0.022	0.044	419.258	0.087	0.176	3.350	3.613	422.871
24	342.806	76.911	190.688	0	0.031	0.060	610.496	0.117	0.254	4.508	4.879	615.375
24.5	368.547	0	410.014	0	0.033	0.129	778.723	0.252	0.273	9.693	10.218	788.941
25	395.649	19.726	440.164	0	0.036	0.138	855.713	0.271	0.294	10.406	10.971	866.684
25.5	158.418	21.147	235.937	0	0.014	0.074	415.590	0.145	0.118	5.578	5.841	421.431
26	169.604	0	227.337	0	0.015	0.071	397.027	0.140	0.126	5.375	5.641	402.668
26.5	58.499	0	162.051	0	0.005	0.051	220.606	0.100	0.043	3.831	3.974	224.580
27	62.471	0	115.37	0	0.006	0.036	177.883	0.071	0.046	2.727	2.844	180.727
27.5	0	0	92.293	0	0	0.029	92.322	0.057	0	2.182	2.239	94.561
28	0	0	0	0	0	0	0	0	0	0	0	0
28.5	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	37.082	0	0	0.012	37.094	0.023	0	0.877	0.9	37.994
29.5	0	17.648	0	0	0	0	17.648	0	0	0	0	17.648
TOTAL	**12992.748**	**314.069**	**2129.023**	**0.495**	**1.182**	**0.668**	**15438.185**	**1.309**	**9.639**	**50.333**	**61.281**	**15499.466**

Table 14. *ECOCADIZ-RECLUTAS* surveys series. Chub mackerel (*Scomber colias*) Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cádiz anchovy population and for the juvenile fraction (i.e. age 0 fish, between parentheses). Note that the 2012 survey only surveyed the Spanish waters. The 2017 estimates correspond to an incomplete coverage (only the seven easternmost transects) of the standard surveyed area due to a research vessels' breakdown.

Estimate/Year	Total Population (Recruits at age 0)									
	2012	2014	2015	2016	2017	2018	2019	2020	2021	2022
Biomass (t)	11155 (n.a.)	17471 (n.a.)	5683 (n.a.)	13689 (n.a.)	11726 (n.a.)	6950 (n.a.)	26212 (5265)	22918 (2759)	13115 (1689)	15500 (8198)
Abundance (millions)	157 (n.a.)	148 (n.a.)	65 (n.a.)	297 (n.a.)	86 (n.a.)	108 (n.a.)	367 (88)	295 (51)	106 (26)	246 (163)

Table 15. *ECOCADIZ-RECLUTAS 2022-10* survey. Horse mackerel (*Trachurus trachurus*). Estimated abundance (absolute numbers and millions of fish) and biomass (t) by size class (in cm). Polygons (i.e., coherent or homogeneous post-strata) numbered as in **Figure 23**.

ECOCADIZ-RECLUTAS 2022-10. Trachurus trachurus. ABUNDANCE (in numbers and million fish)													
SIZE CLASS (cm)	POL01	POL02	POL03	Portugal	POL04	POL05	POL06	POL07	Spain	TOTAL	Millions		
											Portugal	Spain	TOTAL
13	0	0	0	0	0	133728	0	0	133728	133728	0	0.1	0.1
13.5	0	0	0	0	0	133728	0	0	133728	133728	0	0.1	0.1
14	0	73149	0	73149	0	133728	0	0	133728	206877	0.1	0.1	0.2
14.5	0	146297	0	146297	0	267456	0	0	267456	413753	0.1	0.3	0.4
15	0	0	0	0	0	401184	0	0	401184	401184	0	0.4	0.4
15.5	0	146297	0	146297	0	133728	0	0	133728	280025	0.1	0.1	0.3
16	0	365743	0	365743	0	133728	0	0	133728	499471	0.4	0.1	0.5
16.5	0	292594	0	292594	0	802368	0	0	802368	1094962	0.3	1	1
17	0	146297	0	146297	0	401184	0	0	401184	547481	0.1	0	1
17.5	0	146297	0	146297	0	534912	0	0	534912	681209	0.1	1	1
18	57825	73149	0	130974	0	802368	0	0	802368	933342	0.1	1	1
18.5	0	0	11619	11619	104126	802368	37522	579	944595	956214	0.0	1	1
19	0	292594	14650	307244	131289	802368	47311	730	981698	1288942	0.3	1.0	1
19.5	327389	438891	11619	777899	104126	133728	37522	579	275955	1053854	1	0.3	1
20	0	1024080	20207	1044287	181089	133728	65256	1007	381080	1425367	1	0.4	1
20.5	327389	1536120	40919	1904428	366705	133728	132144	2038	634615	2539043	2	1	3
21	1752596	1682417	6062	3441075	54327	133728	19577	302	207934	3649009	3	0.2	4
21.5	2667586	877783	8588	3553957	76963	0	27734	428	105125	3659082	4	0.1	4
22	1146288	365743	20207	1532238	181089	0	65256	1007	247352	1779590	2	0.2	2
22.5	1590177	365743	11619	1967539	104126	133728	37522	579	275955	2243494	2	0.3	2
23	4210143	146297	0	4356440	0	133728	0	0	133728	4490168	4	0.1	4
23.5	3593630	292594	0	3886224	0	0	0	0	0	3886224	4	0	4
24	2514521	0	0	2514521	0	0	0	0	0	2514521	3	0	3
24.5	2023011	73149	0	2096160	0	0	0	0	0	2096160	2	0	2
25	703249	0	0	703249	0	0	0	0	0	703249	1	0	1
25.5	645425	0	0	645425	0	0	0	0	0	645425	1	0	1
26	703249	0	0	703249	0	0	0	0	0	703249	1	0	1
TOTAL n	22262478	8485234	145490	30893202	1303840	6285216	469844	7249	8066149	38959351	31	8	39
Millions	22	8	0.1	31	1	6	0.5	0.01	8	39			

Tabla 15. *ECOCADIZ-RECLUTAS 2022-10* survey. Horse mackerel (*Trachurus trachurus*). Cont'd.

ECOCADIZ-RECLUTAS 2022-10. Trachurus trachurus . BIOMASS (t)										
SIZE CLASS (cm)	**POL01**	**POL02**	**POL03**	**Portugal**	**POL04**	**POL05**	**POL06**	**POL07**	**Spain**	**TOTAL**
13	0	0	0	0	0	2.469	0	0	2.469	2.469
13.5	0	0	0	0	0	2.766	0	0	2.766	2.766
14	0	1.688	0	1.688	0	3.086	0	0	3.086	4.774
14.5	0	3.753	0	3.753	0	6.860	0	0	6.860	10.613
15	0	0	0	0	0	11.399	0	0	11.399	11.399
15.5	0	4.589	0	4.589	0	4.195	0	0	4.195	8.784
16	0	12.627	0	12.627	0	4.617	0	0	4.617	17.244
16.5	0	11.086	0	11.086	0	30.399	0	0	30.399	41.485
17	0	6.066	0	6.066	0	16.635	0	0	16.635	22.701
17.5	0	6.622	0	6.622	0	24.212	0	0	24.212	30.834
18	2.850	3.605	0	6.455	0	39.548	0	0	39.548	46.003
18.5	0	0	0.622	0.622	5.576	42.967	2.009	0.031	50.583	51.205
19	0	16.986	0.850	17.836	7.622	46.579	2.746	0.042	56.989	74.825
19.5	20.561	27.563	0.730	48.854	6.539	8.398	2.356	0.036	17.329	66.183
20	0	69.441	1.370	70.811	12.279	9.068	4.425	0.068	25.840	96.651
20.5	23.924	112.254	2.990	139.168	26.798	9.772	9.657	0.149	46.376	185.544
21	137.778	132.261	0.477	270.516	4.271	10.513	1.539	0.024	16.347	286.863
21.5	225.216	74.109	0.725	300.050	6.498	0	2.341	0.036	8.875	308.925
22	103.766	33.108	1.829	138.703	16.393	0	5.907	0.091	22.391	161.094
22.5	154.103	35.444	1.126	190.673	10.091	12.959	3.636	0.056	26.742	217.415
23	436.138	15.155	0	451.293	0	13.853	0	0	13.853	465.146
23.5	397.380	32.355	0	429.735	0	0	0	0	0	429.735
24	296.404	0	0	296.404	0	0	0	0	0	296.404
24.5	253.872	9.180	0	263.052	0	0	0	0	0	263.052
25	93.836	0	0	93.836	0	0	0	0	0	93.836
25.5	91.460	0	0	91.460	0	0	0	0	0	91.460
26	105.709	0	0	105.709	0	0	0	0	0	105.709
TOTAL	**2342.997**	**607.892**	**10.719**	**2961.608**	**96.067**	**300.295**	**34.616**	**0.533**	**431.511**	**3393.119**

Tabla 16. *ECOCADIZ-RECLUTAS 2022-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Estimated abundance (absolute numbers and millions of fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 26**.

ECOCADIZ-RECLUTAS 2022-10. Trachurus mediterraneus. ABUNDANCE (in numbers and million fish)											
SIZE CLASS (cm)	POL01	POL02	Portugal	POL03	POL04	POL05	Spain	TOTAL	Millions		
									Portugal	Spain	TOTAL
23	0	0	0	26647	0	0	26647	26647	0	0	0
23.5	0	0	0	136497	0	0	136497	136497	0	0.1	0.1
24	0	0	0	0	0	0	0	0	0	0	0
24.5	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0
25.5	0	0	0	0	0	0	0	0	0	0	0
26	0	3918	3918	62176	0	0	62176	66094	0	0.1	0.1
26.5	0	7835	7835	198673	0	0	198673	206508	0	0.2	0.2
27	205677	15671	221348	337526	0	0	337526	558874	0.2	0.3	1
27.5	411354	43094	454448	1881591	0	0	1881591	2336039	0	2	2
28	1439738	101859	1541597	1745094	0	0	1745094	3286691	2	2	3
28.5	1131223	97941	1229164	2712717	0	0	2712717	3941881	1	3	4
29	1028384	50930	1079314	1372039	5350237	199	6722475	7801789	1	7	8
29.5	205677	62682	268359	1192037	3566825	133	4758995	5027354	0.3	5	5
30	411354	58765	470119	960191	17834124	664	18794979	19265098	0.5	19	19
30.5	102838	35259	138097	871369	24967774	929	25840072	25978169	0.1	26	26
31	102838	47012	149850	759162	10700474	398	11460034	11609884	0.1	11	12
31.5	0	35259	35259	198673	8917062	332	9116067	9151326	0	9	9
32	102838	31341	134179	533842	10700474	398	11234714	11368893	0.1	11	11
32.5	0	7835	7835	163144	0	0	163144	170979	0	0.2	0.2
33	102838	15671	118509	0	1783412	66	1783478	1901987	0.1	2	2
33.5	0	3918	3918	62176	0	0	62176	66094	0	0.1	0.1
34	0	0	0	136497	0	0	136497	136497	0	0.1	0.1
34.5	0	0	0	0	0	0	0	0	0	0	0
35	0	3918	3918	26647	0	0	26647	30565	0	0	0
35.5	0	0	0	0	0	0	0	0	0	0	0
36	102838	0	102838	0	0	0	0	102838	0.1	0	0.1
36.5	0	3918	3918	0	0	0	0	3918	0	0	0
TOTAL n	5347597	626826	5974423	13376698	83820382	3119	97200199	103174622	**6**	**97**	**103**
Millions	**5**	**1**	**6**	**13**	**84**	**0.003**	**97**	**103**			

Tabla 16. *ECOCADIZ-RECLUTAS 2022-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Cont'd.

***ECOCADIZ-RECLUTAS 2022-10. Trachurus mediterraneus*. BIOMASS (t)**								
SIZE CLASS (cm)	**POL01**	**POL02**	**Portugal**	**POL03**	**POL04**	**POL05**	**Spain**	**TOTAL**
23	0	0	0	2.705	0	0	2.705	2.705
23.5	0	0	0	14.751	0	0	14.751	14.751
24	0	0	0	0	0	0	0	0
24.5	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
25.5	0	0	0	0	0	0	0	0
26	0	0.569	0.569	9.025	0	0	9.025	9.594
26.5	0	1.202	1.202	30.486	0	0	30.486	31.688
27	33.331	2.540	35.871	54.699	0	0	54.699	90.570
27.5	70.333	7.368	77.701	321.712	0	0	321.712	399.413
28	259.468	18.357	277.825	314.499	0	0	314.499	592.324
28.5	214.687	18.588	233.275	514.829	0	0	514.829	748.104
29	205.345	10.170	215.515	273.965	1068.320	0.040	1342.325	1557.840
29.5	43.173	13.157	56.330	250.216	748.698	0.028	998.942	1055.272
30	90.693	12.956	103.649	211.698	3931.976	0.146	4143.82	4247.469
30.5	23.796	8.159	31.955	201.626	5777.284	0.215	5979.125	6011.080
31	24.954	11.408	36.362	184.215	2596.529	0.097	2780.841	2817.203
31.5	0	8.966	8.966	50.518	2267.412	0.084	2318.014	2326.98
32	27.382	8.345	35.727	142.142	2849.133	0.106	2991.381	3027.108
32.5	0	2.183	2.183	45.454	0	0	45.454	47.637
33	29.961	4.566	34.527	0	519.577	0.019	519.596	554.123
33.5	0	1.193	1.193	18.929	0	0	18.929	20.122
34	0	0	0	43.396	0	0	43.396	43.396
34.5	0	0	0	0	0	0	0	0
35	0	1.356	1.356	9.222	0	0	9.222	10.578
35.5	0	0	0	0	0	0	0	0
36	38.648	0	38.648	0	0	0	0	38.648
36.5	0	1.533	1.533	0	0	0	0	1.533
TOTAL	**1061.771**	**132.616**	**1194.387**	**2694.087**	**19758.929**	**0.735**	**22453.751**	**23648.138**

Table 17 *ECOCADIZ-RECLUTAS 2022-10* survey. Blue Jack mackerel (*Trachurus picturatus*). Estimated abundance (absolute numbers and million fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 29**.

***ECOCADIZ-RECLUTAS 2022-10. Trachurus picturatus*. ABUNDANCE (in numbers and million fish)**							
SIZE CLASS (cm)	**POL01**	**POL02**	**POL03**	**Portugal**	**TOTAL**	**Millions**	
						Portugal	**TOTAL**
12.5	0	63504	10414	73918	73918	0.1	0.1
13	0	179928	29506	209434	209434	0.2	0.2
13.5	0	285768	46863	332631	332631	0.3	0.3
14	0	306936	50334	357270	357270	0.4	0.4
14.5	0	370440	60748	431188	431188	0.4	0.4
15	0	328104	53806	381910	381910	0.4	0.4
15.5	38107	211680	34713	284500	284500	0.3	0.3
16	0	31752	5207	36959	36959	0.0	0
16.5	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
17.5	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
18.5	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
19.5	0	0	0	0	0	0	0
20	76215	0	0	76215	76215	0.1	0.1
20.5	0	0	0	0	0	0	0
21	38107	0	0	38107	38107	0	0
21.5	609717	0	0	609717	609717	1	1
22	685931	0	0	685931	685931	1	1
22.5	457287	0	0	457287	457287	0.5	0.5
23	381073	0	0	381073	381073	0.4	0.4
23.5	342966	0	0	342966	342966	0.3	0.3
24	266751	0	0	266751	266751	0.3	0.3
24.5	457287	0	0	457287	457287	0.5	0.5
25	152429	0	0	152429	152429	0.2	0.2
25.5	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0
26.5	38107	0	0	38107	38107	0	0
TOTAL n	3543977	1778112	291591	5613680	5613680	**6**	**6**
Millions	**4**	**2**	**0.3**	**6**	**6**		

Table 17. *ECOCADIZ-RECLUTAS 2022-10* survey. Blue Jack mackerel (*Trachurus picturatus*). Cont'd.

ECOCADIZ-RECLUTAS 2022-10. Trachurus picturatus. BIOMASS (t)					
SIZE CLASS (cm)	POL01	POL02	POL03	Portugal	TOTAL
12.5	0	0.901	0.148	1.049	1.049
13	0	2.899	0.475	3.374	3.374
13.5	0	5.205	0.854	6.059	6.059
14	0	6.293	1.032	7.325	7.325
14.5	0	8.515	1.396	9.911	9.911
15	0	8.423	1.381	9.804	9.804
15.5	1.089	6.047	0.992	8.128	8.128
16	0	1.006	0.165	1.171	1.171
16.5	0	0	0	0	0
17	0	0	0	0	0
17.5	0	0	0	0	0
18	0	0	0	0	0
18.5	0	0	0	0	0
19	0	0	0	0	0
19.5	0	0	0	0	0
20	5.007	0	0	5.007	5.007
20.5	0	0	0	0	0
21	2.937	0	0	2.937	2.937
21.5	50.759	0	0	50.759	50.759
22	61.571	0	0	61.571	61.571
22.5	44.184	0	0	44.184	44.184
23	39.571	0	0	39.571	39.571
23.5	38.215	0	0	38.215	38.215
24	31.848	0	0	31.848	31.848
24.5	58.416	0	0	58.416	58.416
25	20.806	0	0	20.806	20.806
25.5	0	0	0	0	0
26	0	0	0	0	0
26.5	6.298	0	0	6.298	6.298
TOTAL	**360.701**	**39.289**	**6.443**	**406.433**	**406.433**

Table 18. *ECOCADIZ-RECLUTAS 2022-10* survey. Bogue (*Boops boops*). Estimated abundance (absolute numbers and millions of fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 32.**

ECOCADIZ-RECLUTAS 2022-10. Boops boops. ABUNDANCE (in numbers and million fish)													
SIZE CLASS (cm)	POL01	POL02	POL03	POL04	POL05	Portugal	POL06	POL07	Spain	TOTAL	Millions		
											Portugal	Spain	TOTAL
11.5	867	72811	0	0	0	73678	0	0	0	73678	0.1	0	0.1
12	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0
13.5	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0
14.5	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
15.5	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0
16.5	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0
17.5	3467	291244	0	0	0	294711	0	0	0	294711	0.3	0	0.3
18	9536	800922	0	0	0	810458	0	0	0	810458	1	0	1
18.5	13870	1164978	0	0	0	1178848	0	0	0	1178848	1	0	1
19	17337	1456222	0	0	0	1473559	0	0	0	1473559	1	0	1
19.5	8669	728111	0	0	0	736780	0	0	0	736780	1	0	1
20	7802	655300	0	100462	0	763564	0	0	0	763564	1	0	1
20.5	1734	145622	0	0	2591	149947	815426	37	815463	965410	0.1	1	1
21	0	0	157550	0	1727	159277	543617	25	543642	702919	0.2	1	1
21.5	867	72811	787750	301386	6909	1169723	2174470	98	2174568	3344291	1	2	3
22	1734	145622	0	100462	6045	253863	1902661	86	1902747	2156610	0.3	2	2
22.5	0	0	0	301386	3455	304841	1087235	49	1087284	1392125	0.3	1	1
23	0	0	1102850	401848	6045	1510743	1902661	86	1902747	3413490	2	2	3
23.5	867	72811	945300	200924	7773	1227675	2446279	111	2446390	3674065	1	2	4
24	867	72811	1417950	100462	6909	1598999	2174470	98	2174568	3773567	2	2	4
24.5	0	0	1102850	301386	3455	1407691	1087235	49	1087284	2494975	1	1	2
25	0	0	315100	0	8636	323736	2718087	123	2718210	3041946	0.3	3	3
25.5	0	0	157550	100462	18136	276148	5707984	258	5708242	5984390	0.3	6	6
26	867	72811	0	401848	9500	485026	2989896	135	2990031	3475057	0.5	3	3
26.5	0	0	0	502310	8636	510946	2718087	123	2718210	3229156	0.5	3	3
27	0	0	0	401848	6909	408757	2174470	98	2174568	2583325	0.4	2	3
27.5	0	0	0	200924	6045	206969	1902661	86	1902747	2109716	0.2	2	2
28	0	0	0	301386	7773	309159	2446279	111	2446390	2755549	0.3	2	3
28.5	0	0	0	200924	6045	206969	1902661	86	1902747	2109716	0.2	2	2
29	0	0	0	0	4318	4318	1359044	61	1359105	1363423	0	1	1
29.5	0	0	0	100462	1727	102189	543617	25	543642	645831	0.1	1	1
30	0	0	0	0	1727	1727	543617	25	543642	545369	0	1	1
30.5	0	0	0	0	1727	1727	543617	25	543642	545369	0	1	1
31	0	0	0	0	1727	1727	543617	25	543642	545369	0	1	1
TOTAL n	69484	5752076	5986900	4018480	127815	15953755	40227691	1820	40229511	56183266	16	40	56
Millions	0.1	6	6	4	0.1	16	40	0.002	40	56			

Table 18. *ECOCADIZ-RECLUTAS 2022-10* survey. Bogue (*Boops boops*). Cont'd.

ECOCADIZ-RECLUTAS 2022-10. Boops boops. BIOMASS (t)										
SIZE CLASS (cm)	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**Portugal**	**POL06**	**POL07**	**Spain**	**TOTAL**
11.5	0.013	1.07	0	0	0	1.083	0	0	0	1.083
12	0	0	0	0	0	0	0	0	0	0
12.5	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
13.5	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
14.5	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
15.5	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
16.5	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
17.5	0.184	15.435	0	0	0	15.619	0	0	0	15.619
18	0.551	46.275	0	0	0	46.826	0	0	0	46.826
18.5	0.872	73.211	0	0	0	74.083	0	0	0	74.083
19	1.182	99.317	0	0	0	100.499	0	0	0	100.499
19.5	0.640	53.780	0	0	0	54.420	0	0	0	54.420
20	0.623	52.314	0	8.020	0	60.957	0	0	0	60.957
20.5	0.149	12.541	0	0	0.223	12.913	70.227	0.003	70.230	83.143
21	0	0	14.611	0	0.160	14.771	50.415	0.002	50.417	65.188
21.5	0.086	7.259	78.535	30.047	0.689	116.616	216.784	0.010	216.794	333.410
22	0.186	15.581	0	10.749	0.647	27.163	203.576	0.009	203.585	230.748
22.5	0	0	0	34.554	0.396	34.950	124.651	0.006	124.657	159.607
23	0	0	135.284	49.294	0.742	185.320	233.395	0.011	233.406	418.726
23.5	0.114	9.542	123.888	26.333	1.019	160.896	320.603	0.015	320.618	481.514
24	0.121	10.181	198.269	14.047	0.966	223.584	304.052	0.014	304.066	527.650
24.5	0	0	164.312	44.903	0.515	209.73	161.985	0.007	161.992	371.722
25	0	0	49.958	0	1.369	51.327	430.947	0.020	430.967	482.294
25.5	0	0	26.55	16.929	3.056	46.535	961.88	0.043	961.923	1008.458
26	0.155	13.026	0	71.89	1.700	86.771	534.888	0.024	534.912	621.683
26.5	0	0	0	95.292	1.638	96.930	515.643	0.023	515.666	612.596
27	0	0	0	80.752	1.388	82.140	436.964	0.020	436.984	519.124
27.5	0	0	0	42.724	1.285	44.009	404.581	0.018	404.599	448.608
28	0	0	0	67.746	1.747	69.493	549.875	0.025	549.900	619.393
28.5	0	0	0	47.696	1.435	49.131	451.658	0.020	451.678	500.809
29	0	0	0	0	1.081	1.081	340.380	0.015	340.395	341.476
29.5	0	0	0	26.523	0.456	26.979	143.520	0.007	143.527	170.506
30	0	0	0	0	0.480	0.480	151.153	0.007	151.160	151.640
30.5	0	0	0	0	0.505	0.505	159.058	0.007	159.065	159.570
31	0	0	0	0	0.531	0.531	167.238	0.008	167.246	167.777
TOTAL	**4.876**	**409.532**	**791.407**	**667.499**	**22.028**	**1895.342**	**6933.473**	**0.314**	**6933.787**	**8829.129**

Table 19. *ECOCADIZ-RECLUTAS 2022-10* survey Pearlside (*Maurolicus muelleri*). Estimated abundance (absolute numbers and million fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 35**.

ECOCADIZ-RECLUTAS 2022-10. Maurolicus muelleri . ABUNDANCE (in numbers and million fish)									
SIZE CLASS (cm)	POL01	Portugal	POL02	POL03	Spain	TOTAL	Millions		
							Portugal	Spain	TOTAL
3.5	41028114	41028114	13324148	45277	13369425	54397539	41	13	54
4	305146595	305146595	99098352	336745	99435097	404581692	305	99	405
4.5	941082357	941082357	305622648	1038533	306661181	1247743538	941	307	1248
5	678246004	678246004	220264824	748479	221013303	899259307	678	221	899
5.5	193601411	193601411	62873324	213649	63086973	256688384	194	63	257
TOTAL n	2159104481	2159104481	701183296	2382683	703565979	2862670460	2159	704	2863
Millions	2159	2159	701	2	704	2863			

ECOCADIZ-RECLUTAS 2022-10. Maurolicus muelleri . BIOMASS (t)						
SIZE CLASS (cm)	POL01	Portugal	POL02	POL03	Spain	TOTAL
3.5	18.642	18.642	6.054	0.021	6.075	24.717
4	197.607	197.607	64.174	0.218	64.392	261.999
4.5	834.952	834.952	271.156	0.921	272.077	1107.029
5	798.846	798.846	259.430	0.882	260.312	1059.158
5.5	295.001	295.001	95.804	0.326	96.130	391.131
TOTAL	2145.048	2145.048	696.618	2.368	698.986	2844.034

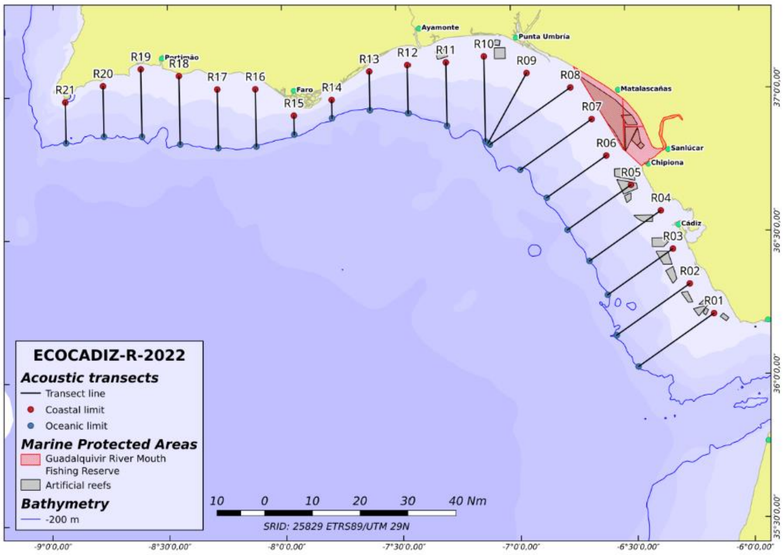


Figure 1. *ECOCADIZ-RECLUTAS 2022-10* survey. Location of the acoustic transects sampled during the survey. The different protected areas inside the Guadalquivir river mouth Fishing Reserve and artificial reef polygons are also shown.

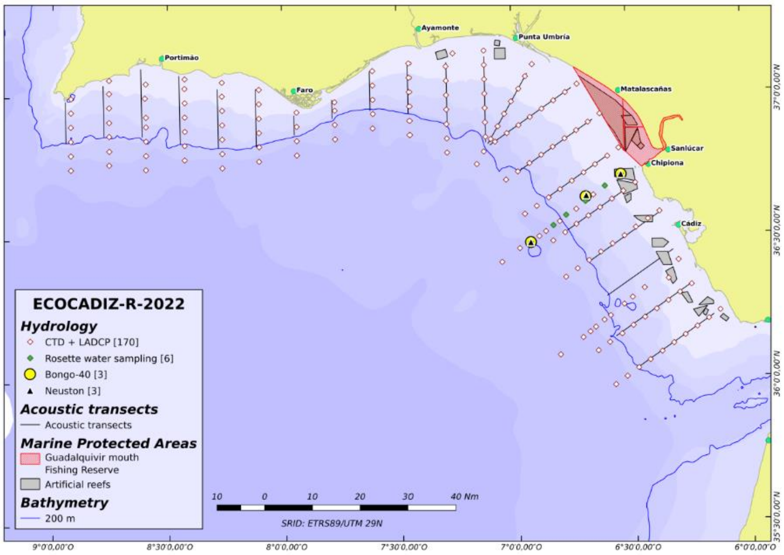


Figure 2. *ECOCADIZ-RECLUTAS 2022-10* survey. Location of CTD-LADCP, Bongo 40, Neuston sledge and water sampling stations.

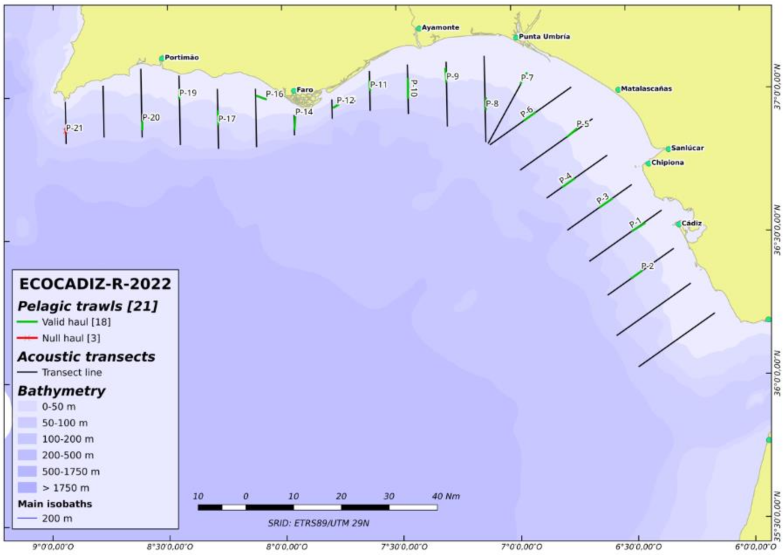


Figure 3. *ECOCADIZ-RECLUTAS 2022-10* survey. Location of ground-truthing fishing hauls.

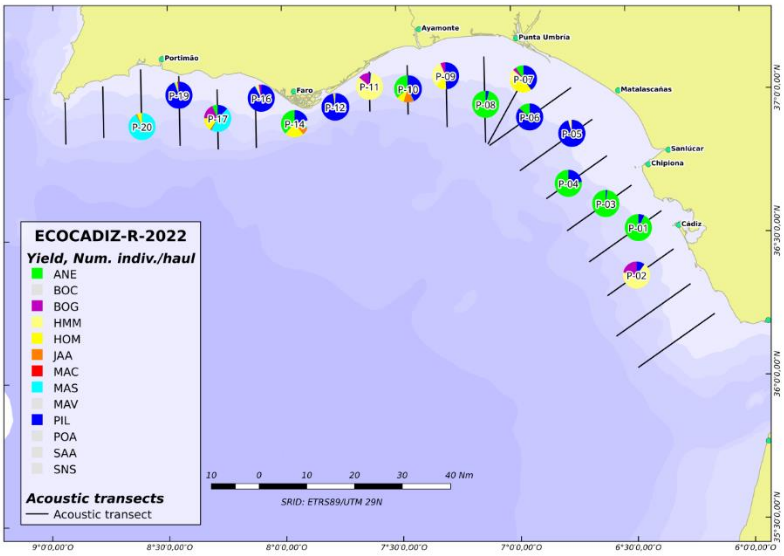


Figure 4. *ECOCADIZ-RECLUTAS 2022-10* survey. Species composition (percentages in number) in valid hauls.

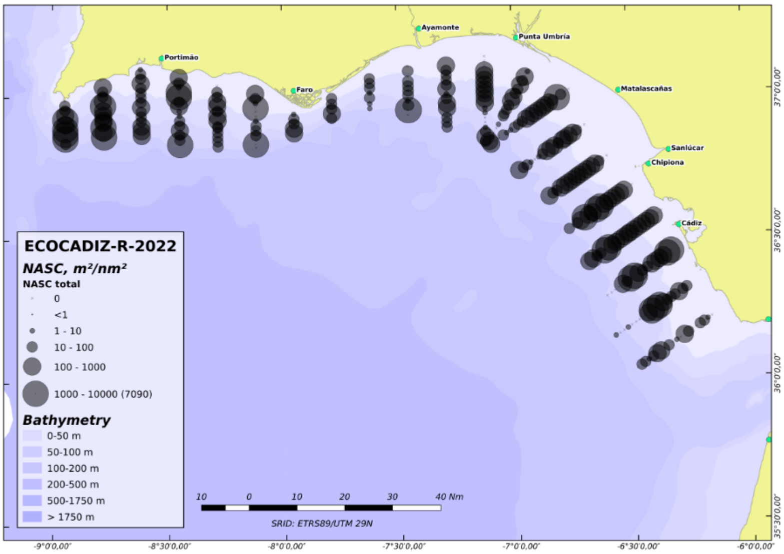


Figure 5. *ECOCADIZ-RECLUTAS 2022-10* survey. Distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in m^2nmi^{-2}) attributed to the pelagic fish species assemblage.

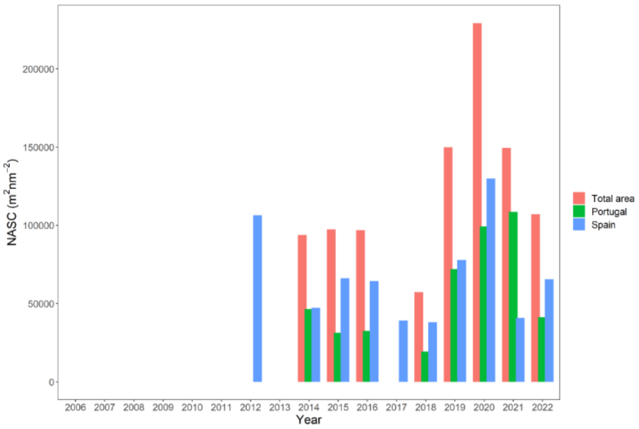


Figure 6. *ECOCADIZ-RECLUTAS 2022-10* survey. Time-series of NASC by total area, Spain and Portugal.

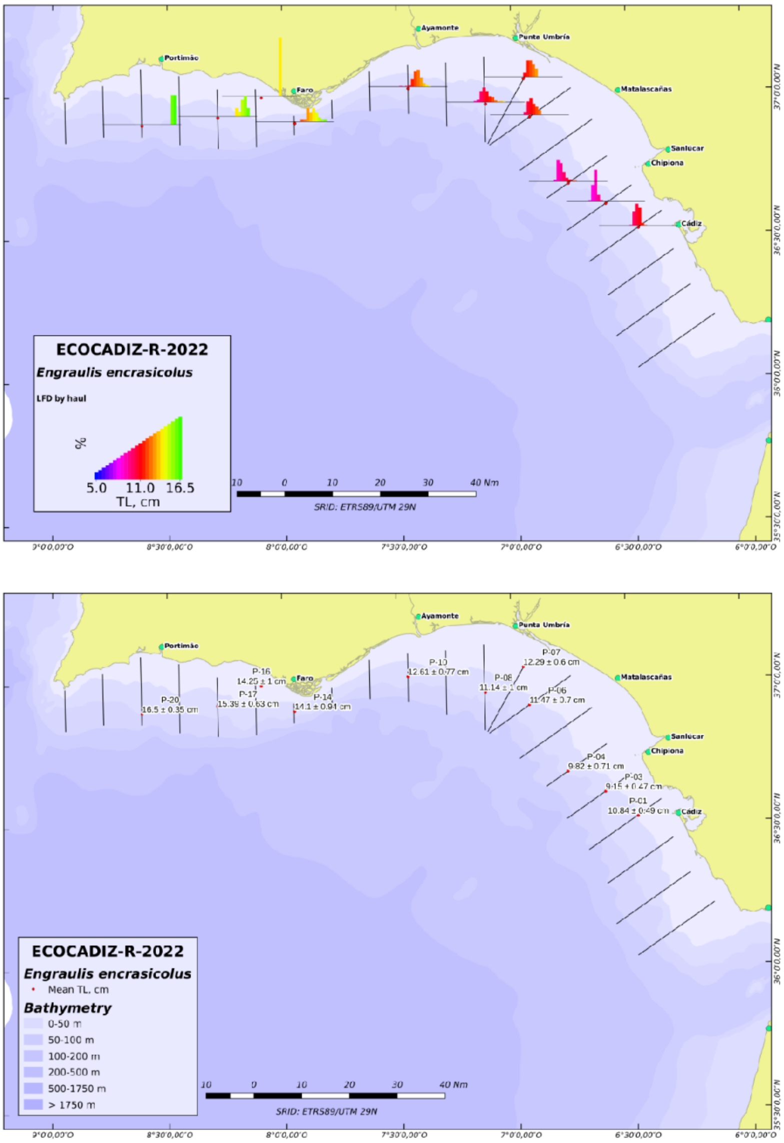


Figure 7. *ECOCADIZ-RECLUTAS 2022-10* survey. Anchovy (*Engraulis encrasicolus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

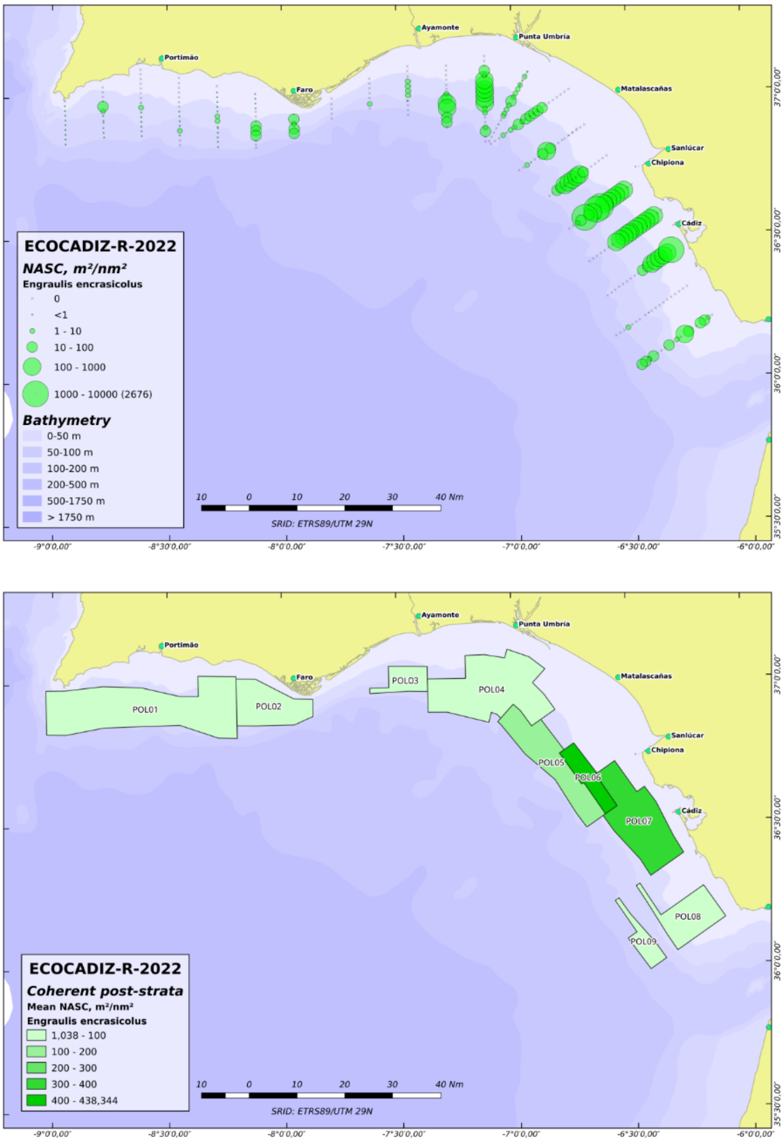


Figure 8. *ECOCADIZ-RECLUTAS 2022-10* survey. Anchovy (*Engraulis encrasicolus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in $m^2 nmi^{-2}$) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

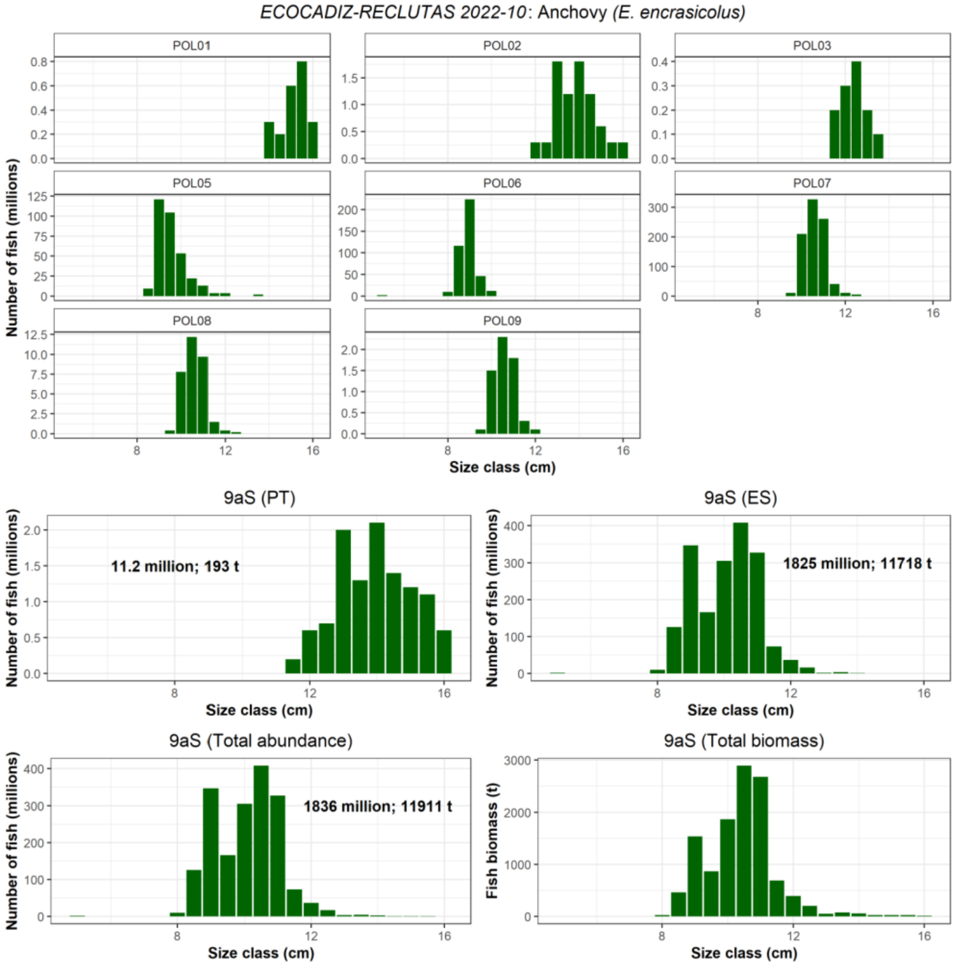


Figure 9 *ECOCADIZ-RECLUTAS 2022-10* survey. Anchovy *(Engraulis encrasicolus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 8**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the *y* axis.

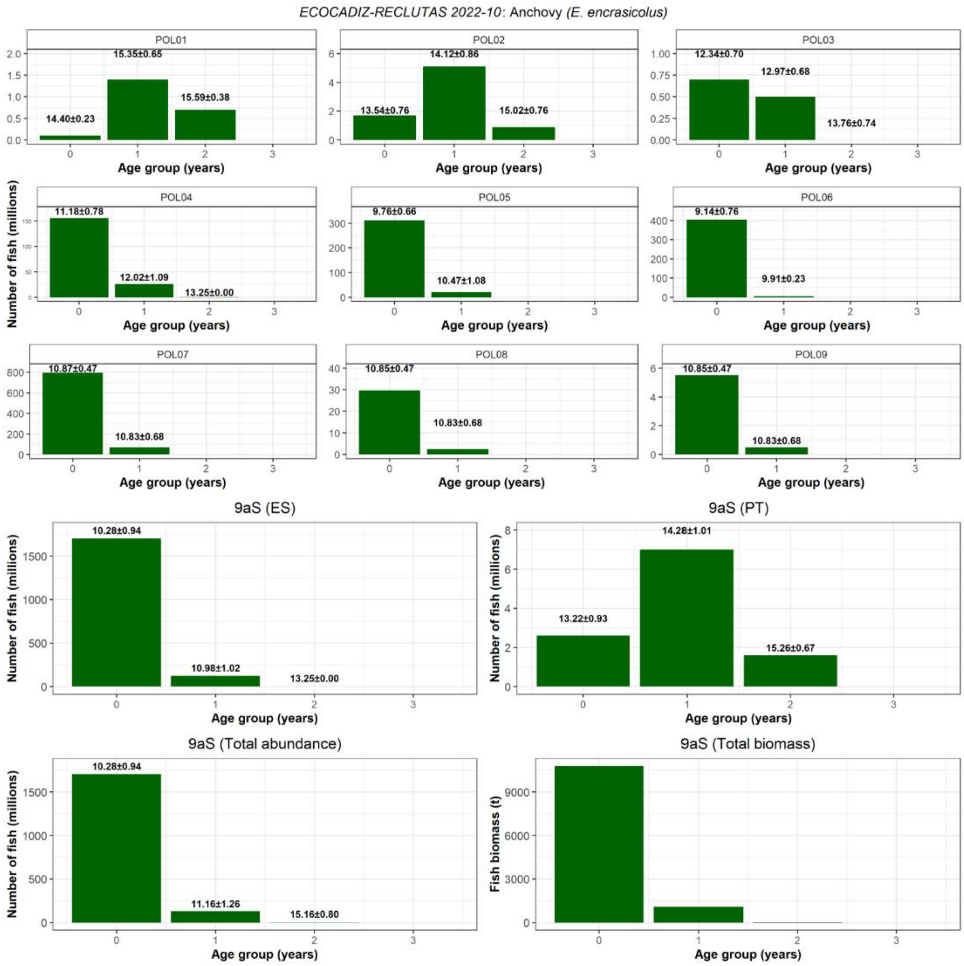


Figure 10. *ECOCADIZ-RECLUTAS 2022-10* survey. Anchovy (*Engraulis encrasicolus*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 7**) and total sampled area. Post-strata ordered in the W-E direction. Mean (±SD) sizes of age groups are also shown. The estimated biomass (t) by age group for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

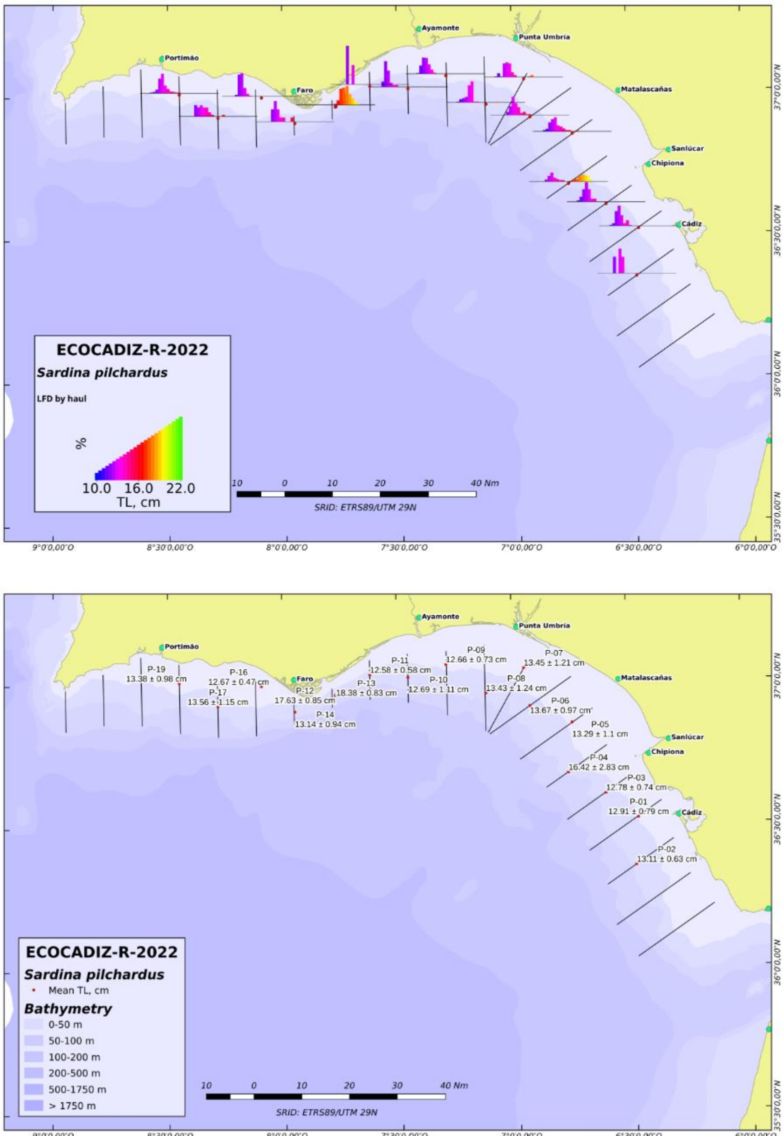


Figure 11. *ECOCADIZ-RECLUTAS 2022-10* survey. Sardine (*Sardina pilchardus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

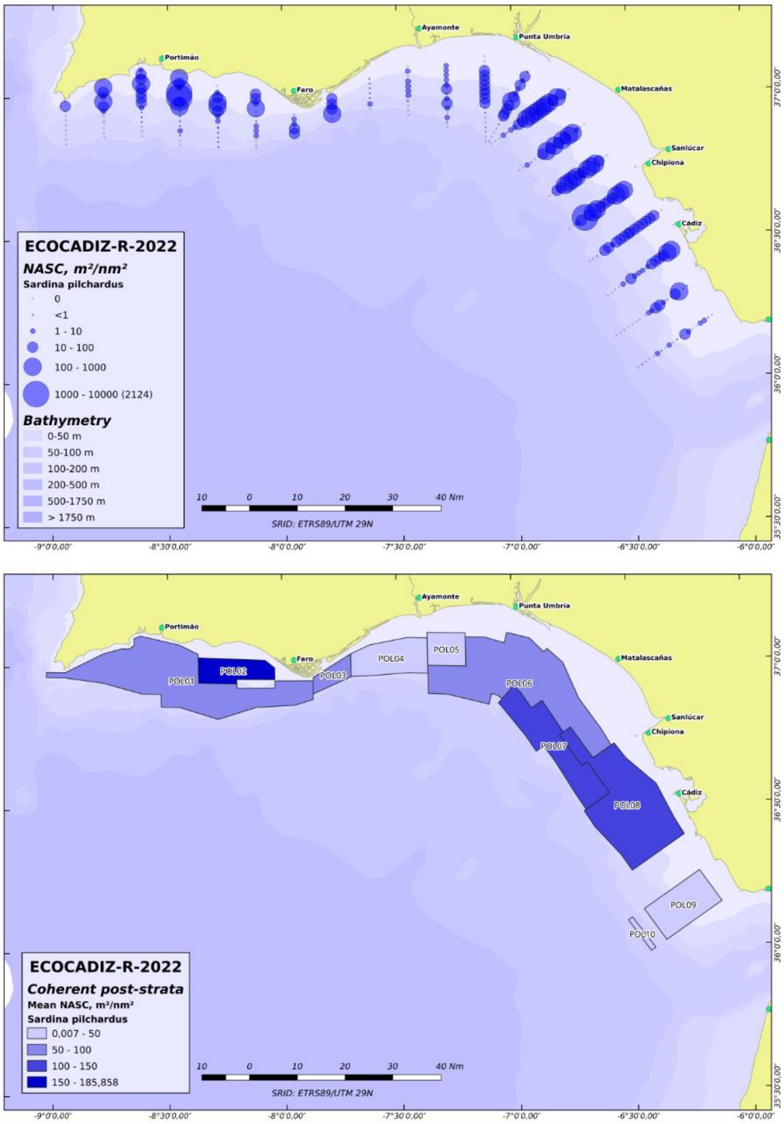


Figure 12. *ECOCADIZ-RECLUTAS 2022-10* survey. Sardine (*Sardina pilchardus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in m^2nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

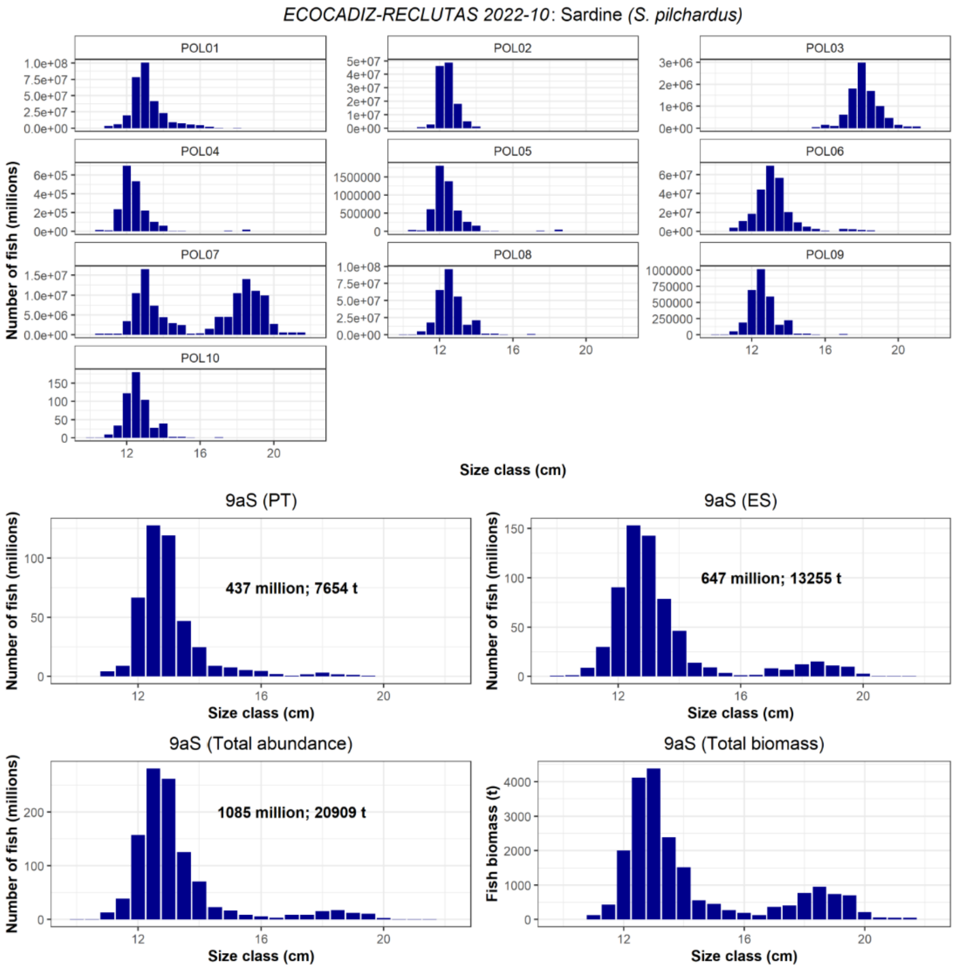


Figure 13. *ECOCADIZ-RECLUTAS 2022-10* survey. Sardine *(Sardina pilchardus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 12** and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the *y* axis.

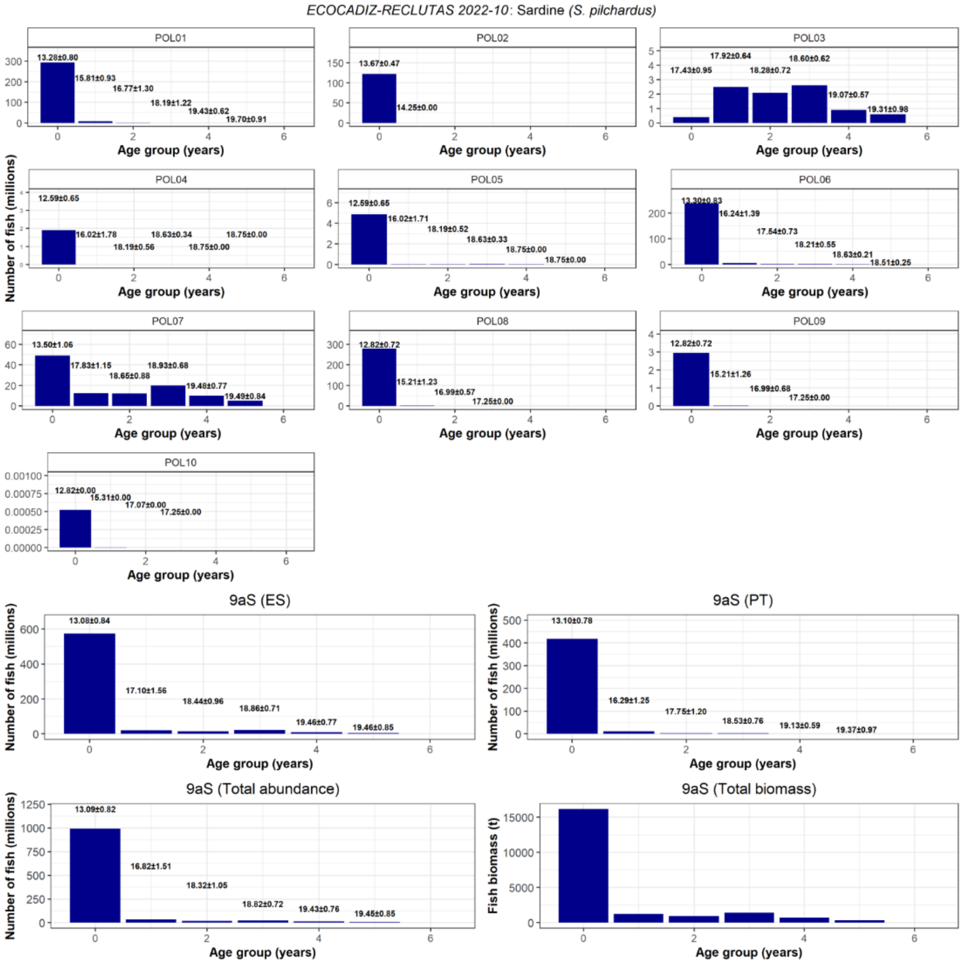


Figure 14. *ECOCADIZ-RECLUTAS 2022-10* survey. Sardine (*Sardina pilchardus*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 12**) and total sampled area. Post-strata ordered in the W-E direction. Mean (±SD) sizes of age groups are also shown. The estimated biomass (t) by age group for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

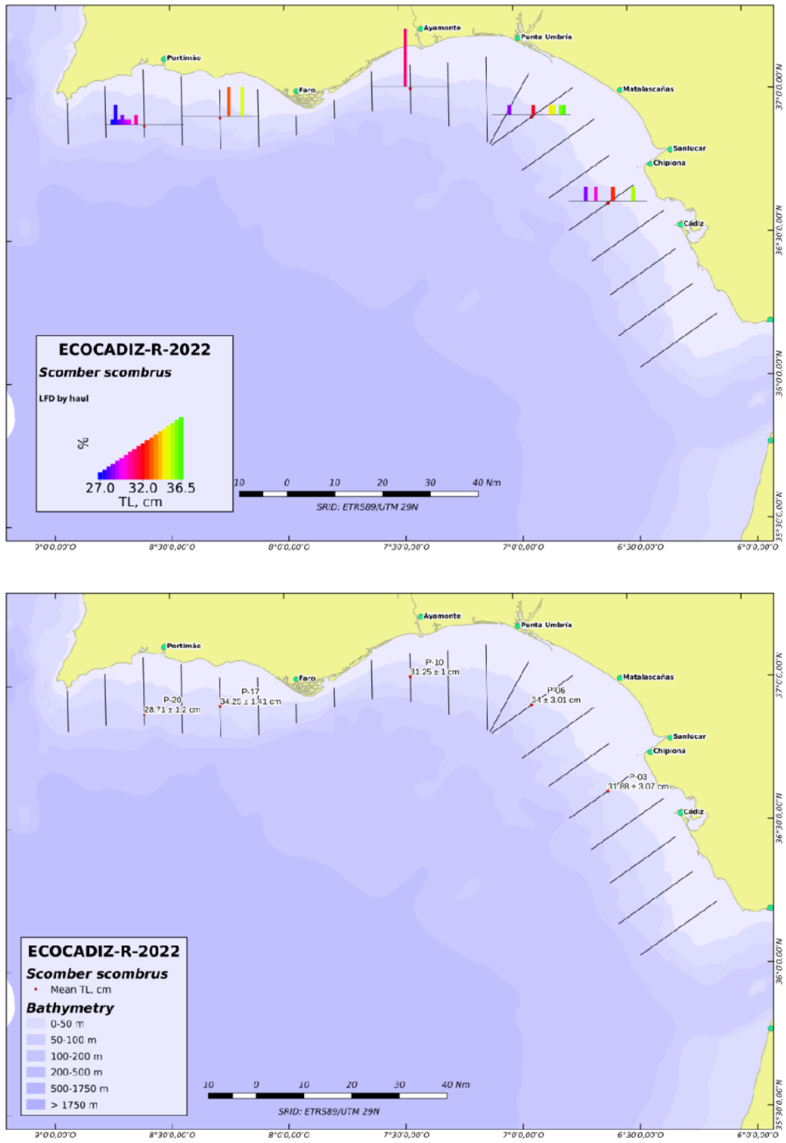


Figure 15. *ECOCADIZ-RECLUTAS 2022-10* survey. Atlantic mackerel (*Scomber scombrus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

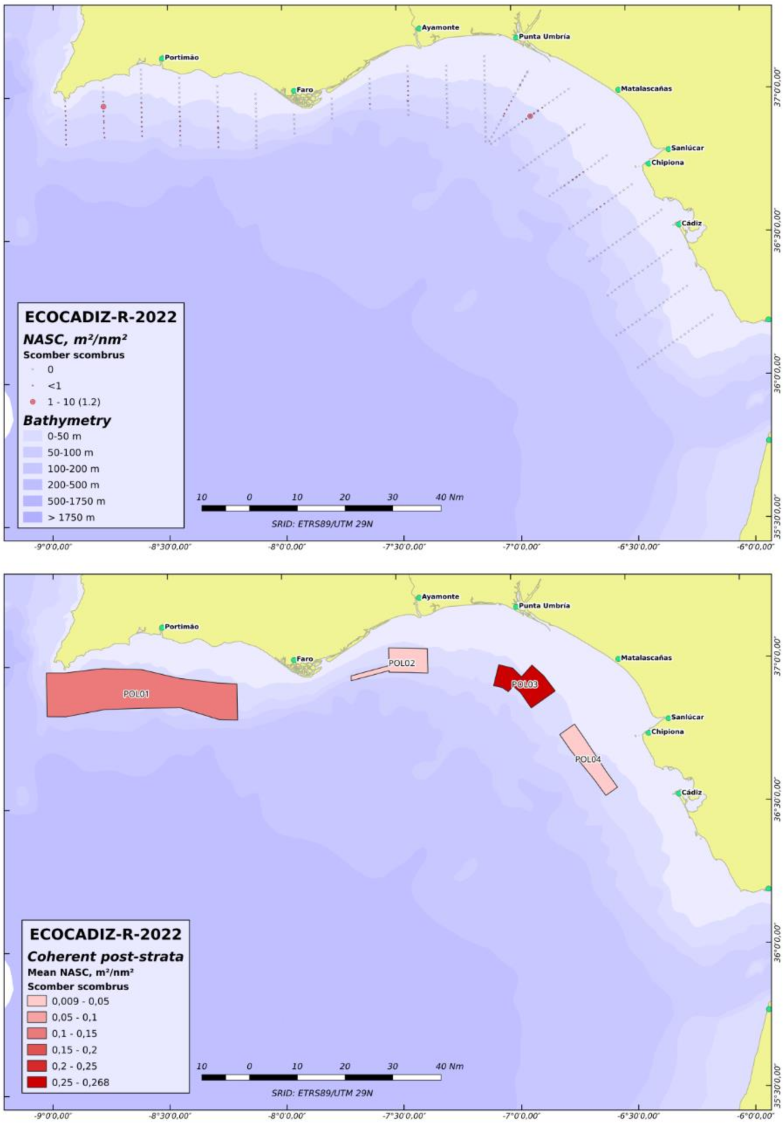


Figure 16. *ECOCADIZ-RECLUTAS 2022-10* survey. Atlantic mackerel (*Scomber scombrus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in m^2nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Color scale according to the mean value of the backscattering energy attributed to the species in each stratum.

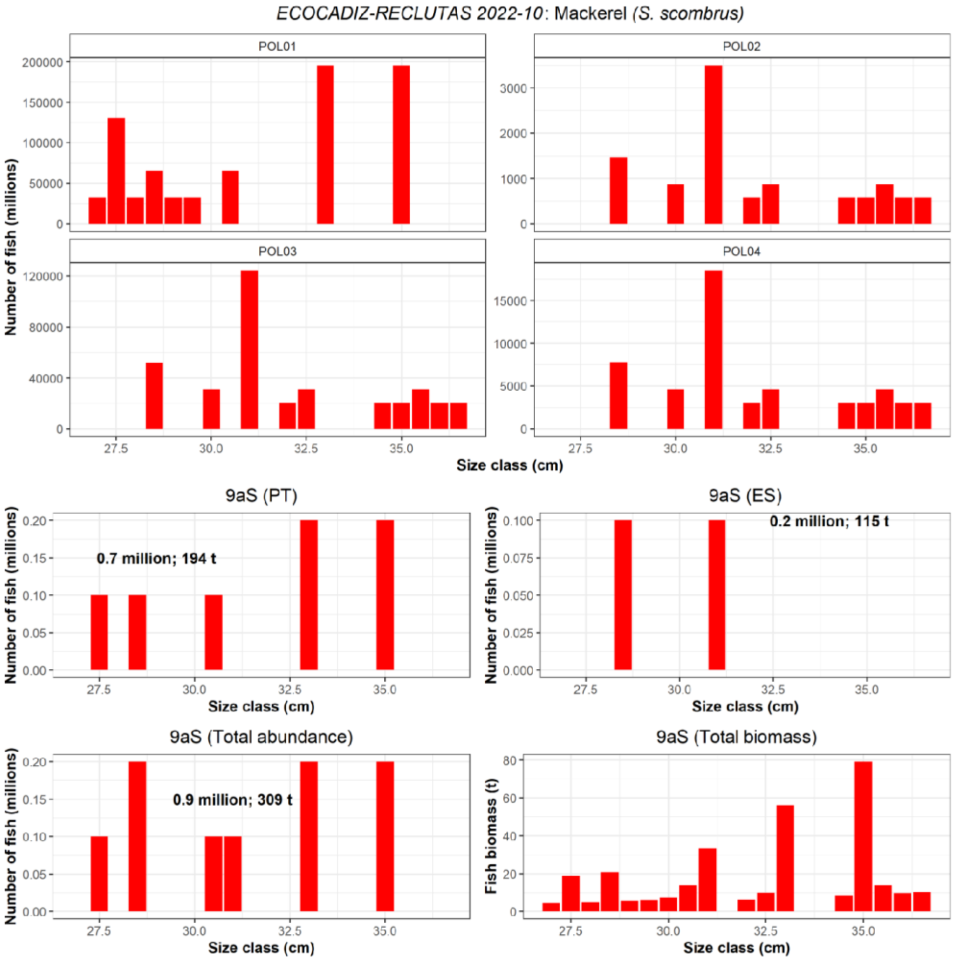


Figure 17. *ECOCADIZ-RECLUTAS 2022-10* survey. Atlantic mackerel (*Scomber scombrus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 15**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the *y* axis

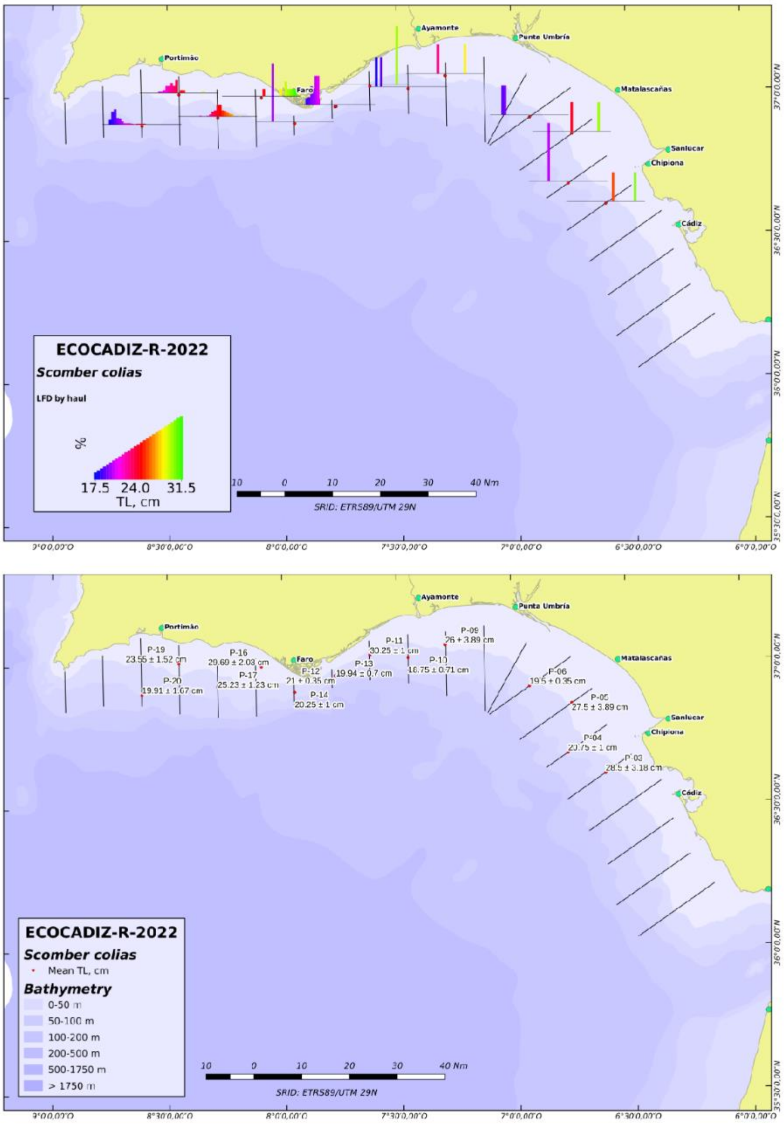


Figure 18. *ECOCADIZ-RECLUTAS 2022-10* survey. Chub mackerel (*Scomber colias*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

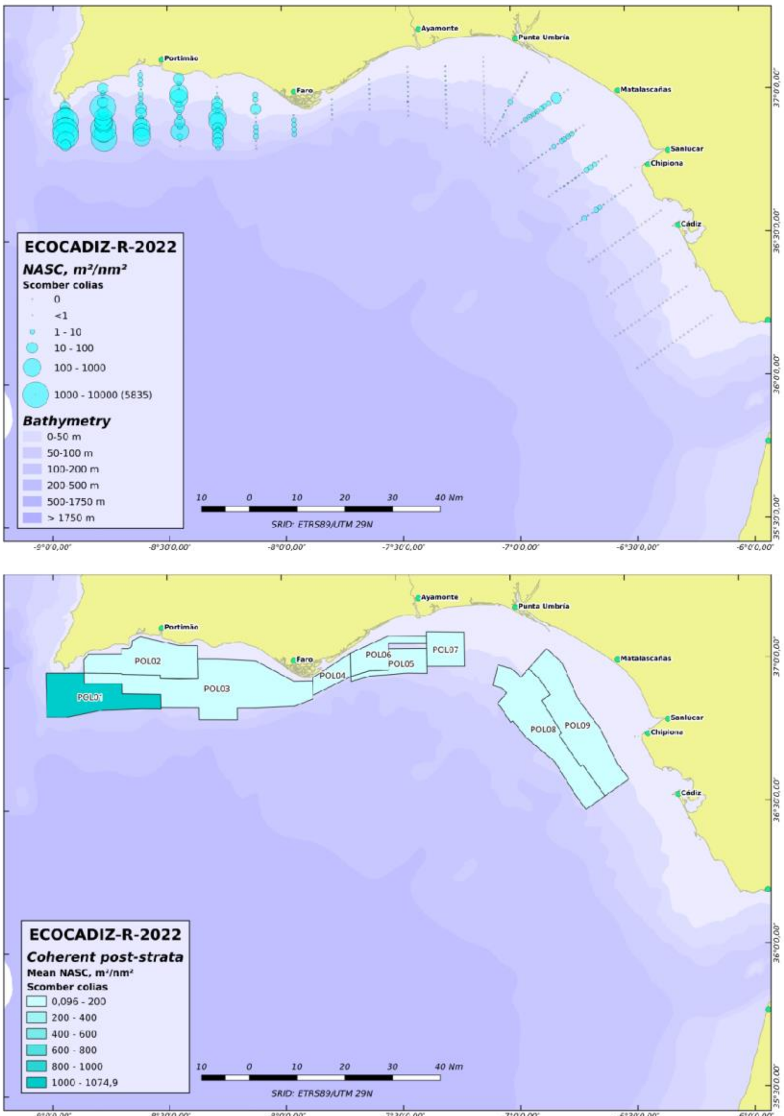


Figure 19. *ECOCADIZ-RECLUTAS 2022-10* survey. Chub mackerel (*Scomber colias*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in m^2nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

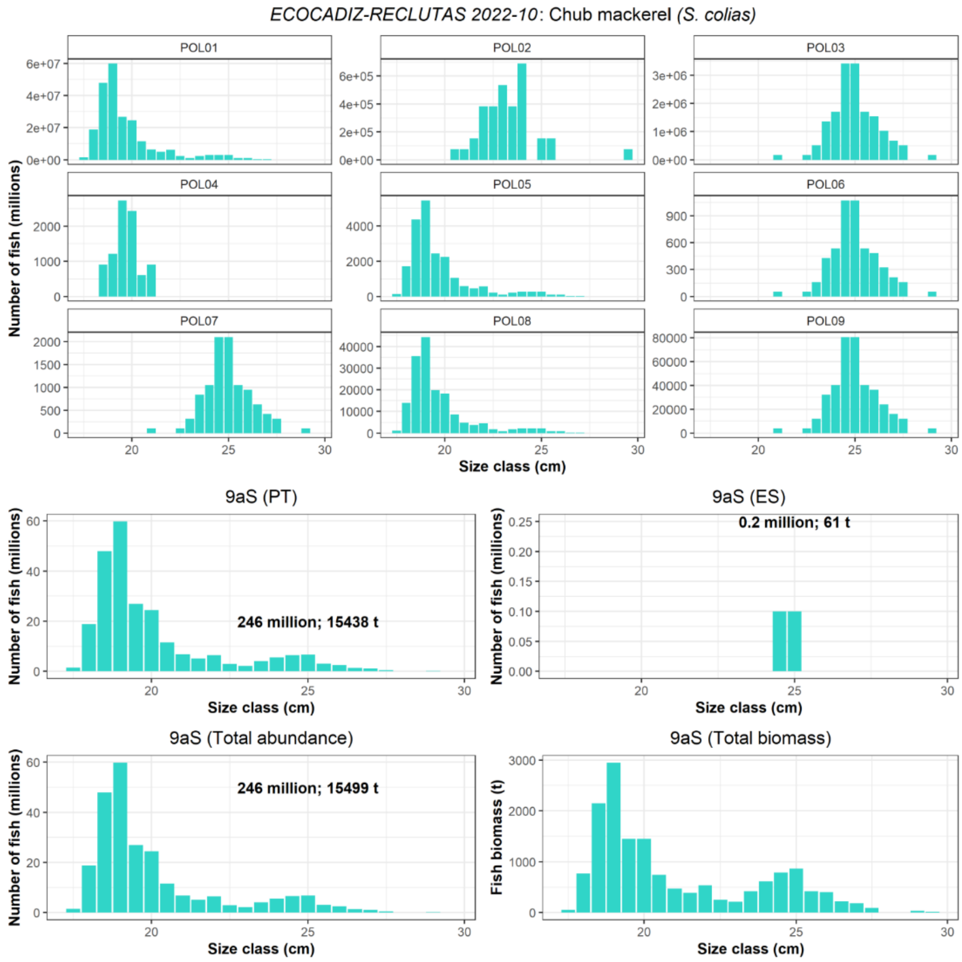


Figure 20. *ECOCADIZ-RECLUTAS 2022-10* survey. Chub mackerel (*Scomber colias*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 19**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the *y*-axis.

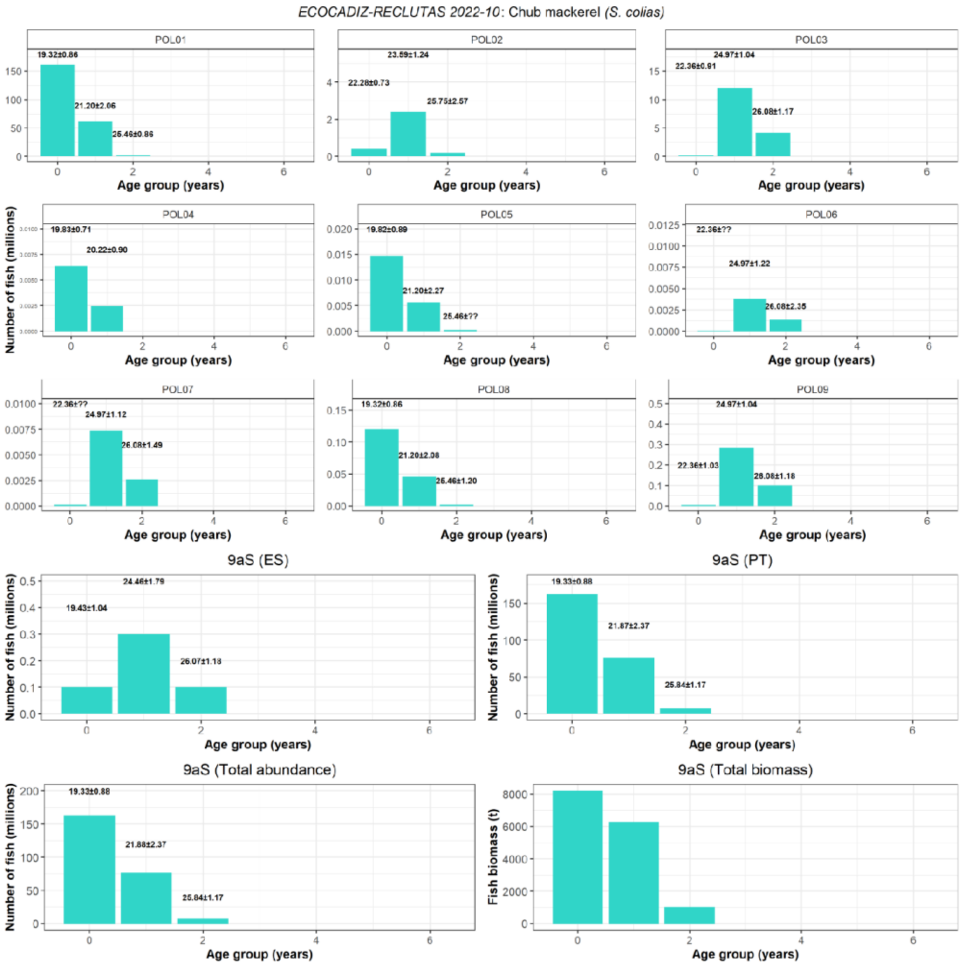


Figure 21. *ECOCADIZ-RECLUTAS 2022-10* survey. Chub mackerel (*Scomber colias*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 18**) and total sampled area. Post-strata ordered in the W-E direction. Mean (±SD) sizes of age groups are also shown. The estimated biomass (t) by age group for the whole sampled area is also shown for comparison. Note the different scales in the *y*-axis.

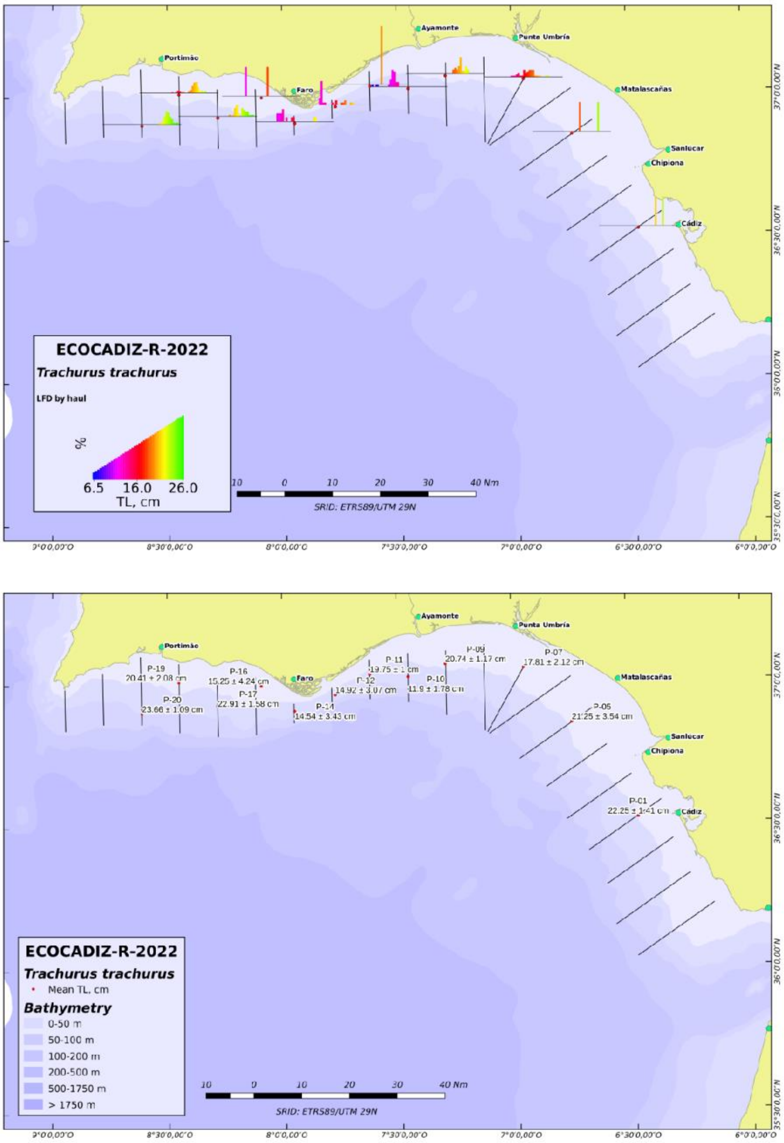


Figure 22. *ECOCADIZ-RECLUTAS 2022-10* survey. Horse mackerel (*Trachurus trachurus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

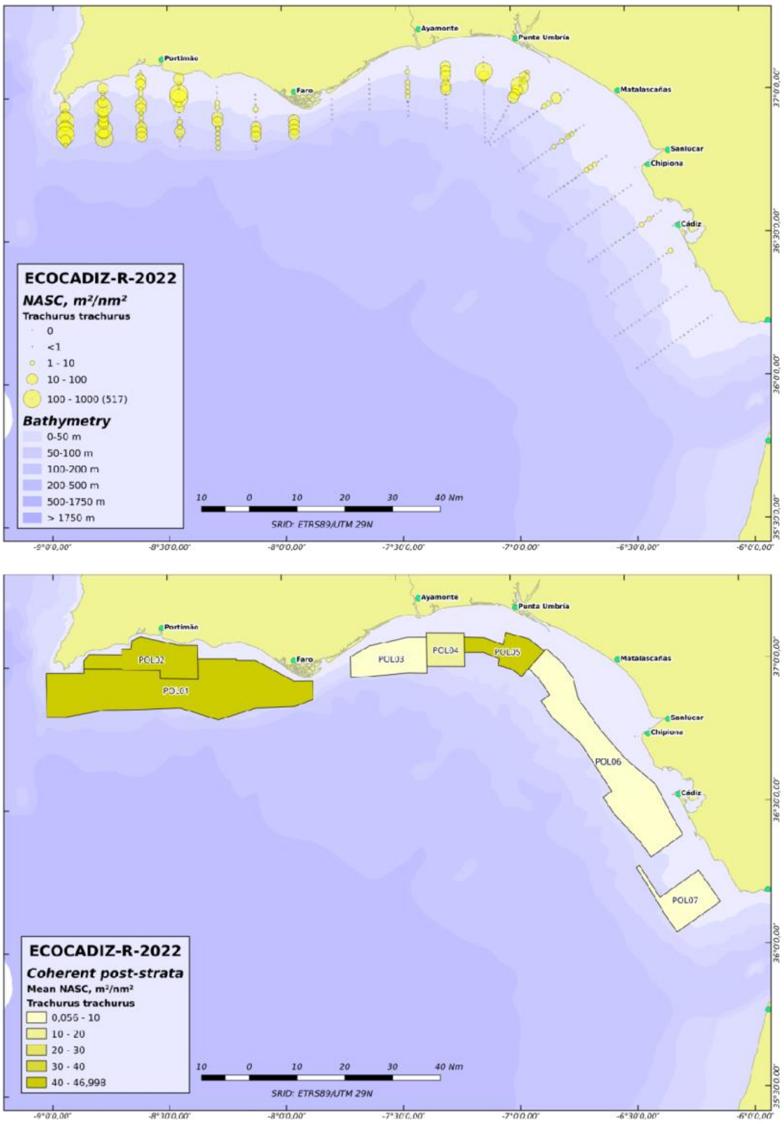


Figure 23. *ECOCADIZ-RECLUTAS 2022-10* survey. Horse mackerel (*Trachurus trachurus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in $m^2 nmi^{-2}$) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

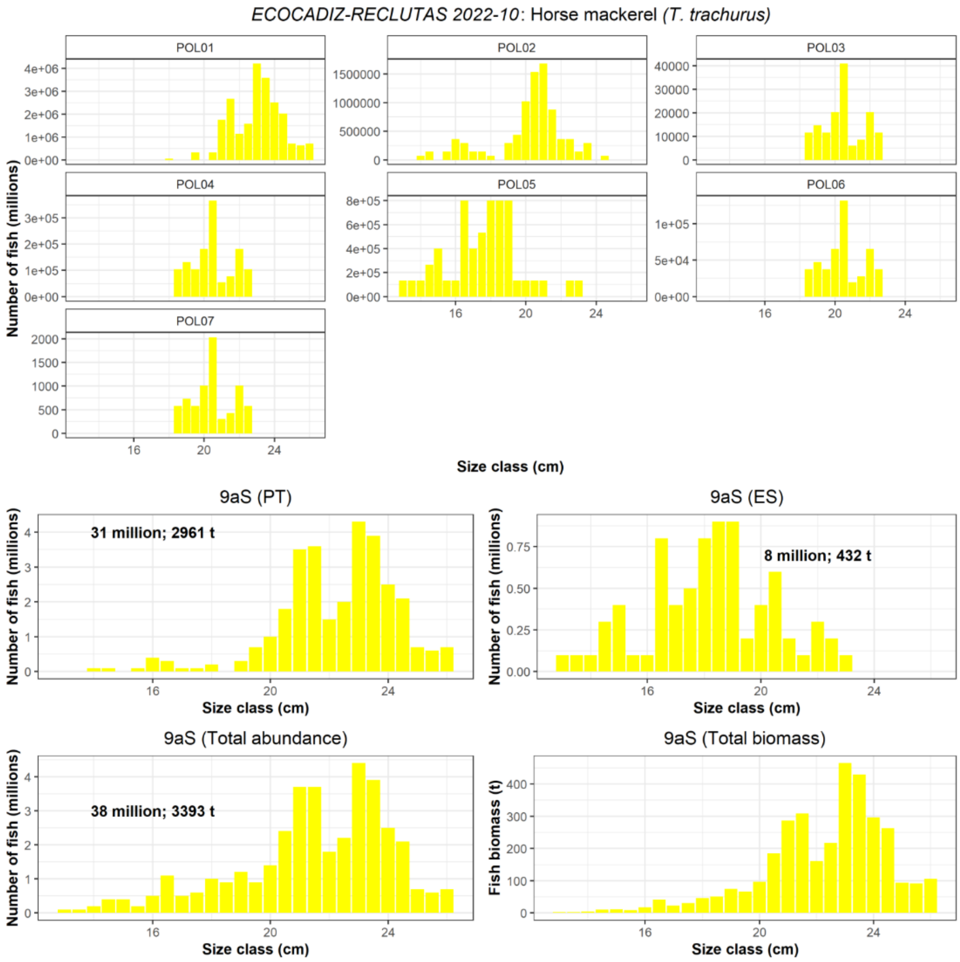


Figure 24. *ECOCADIZ-RECLUTAS 2022-10* survey. Horse mackerel (*Trachurus trachurus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 23**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the *y*-axis.

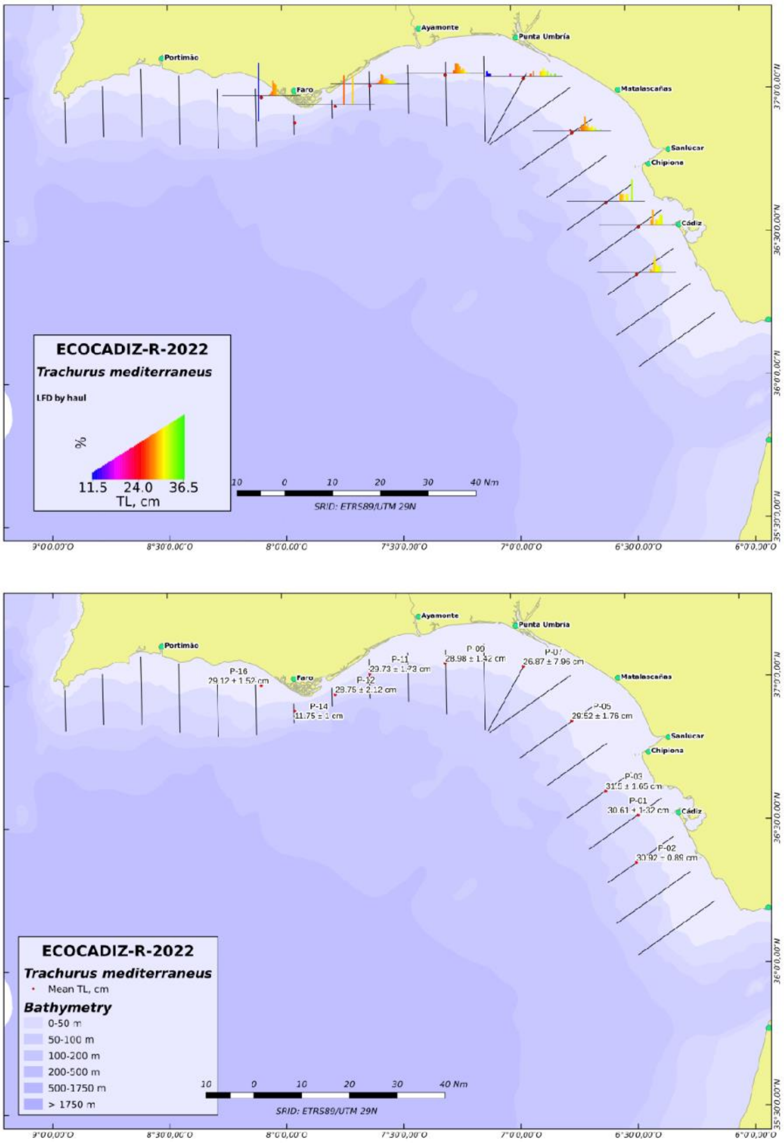


Figure 25. *ECOCADIZ-RECLUTAS 2022-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

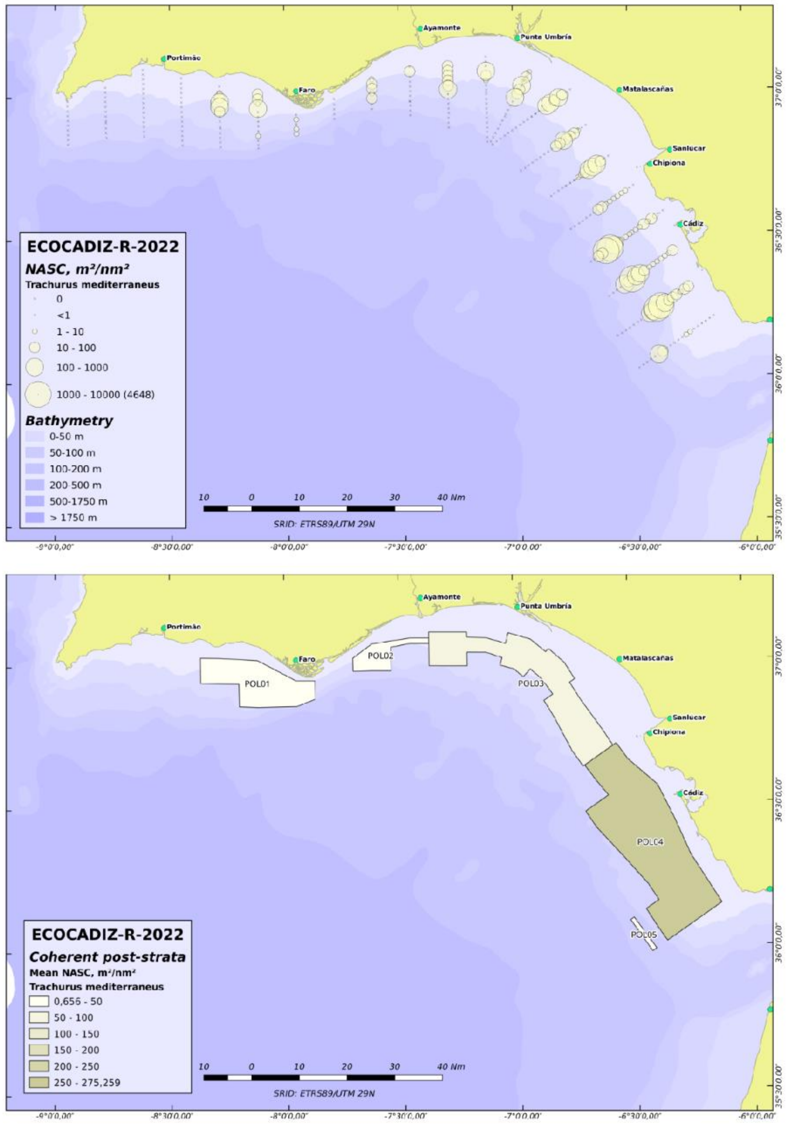


Figure 26. *ECOCADIZ-RECLUTAS 2022-10* survey. Mediterranean horse mackerel *(Trachurus mediterraneus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in m^2nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

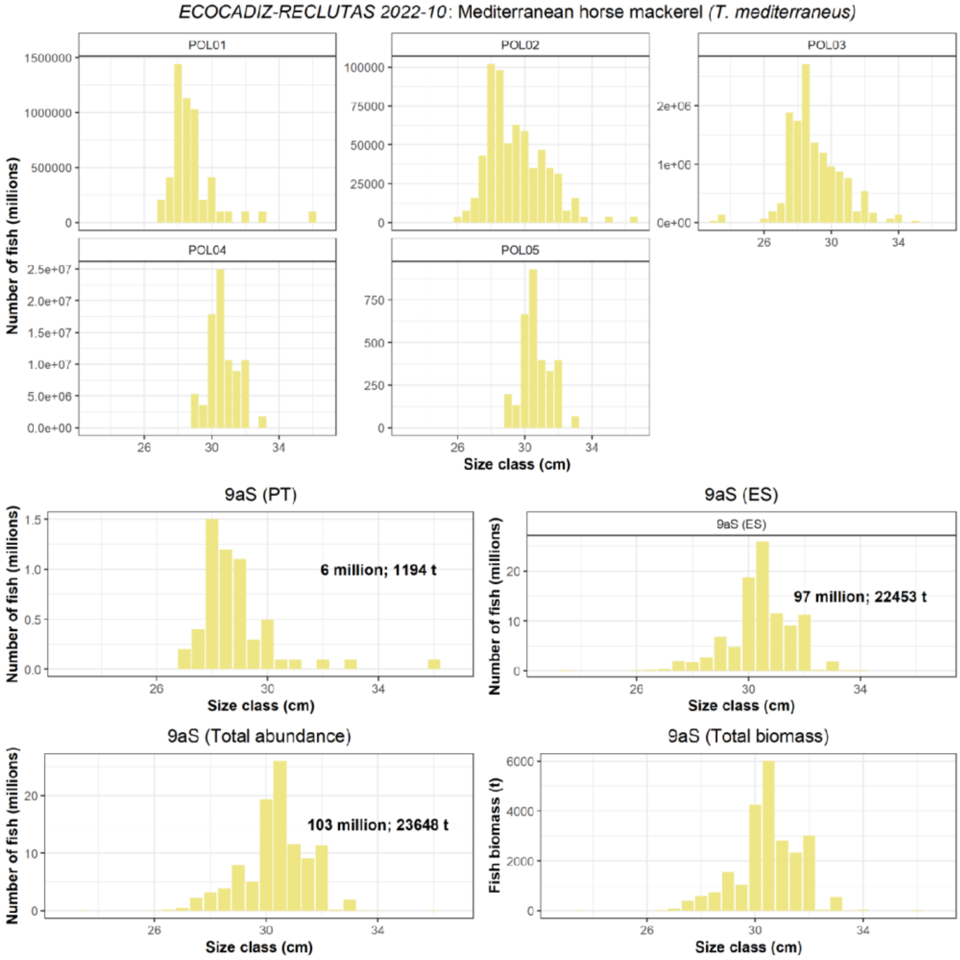


Figure 27. *ECOCADIZ-RECLUTAS 2022-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 26**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the *y*-axis.

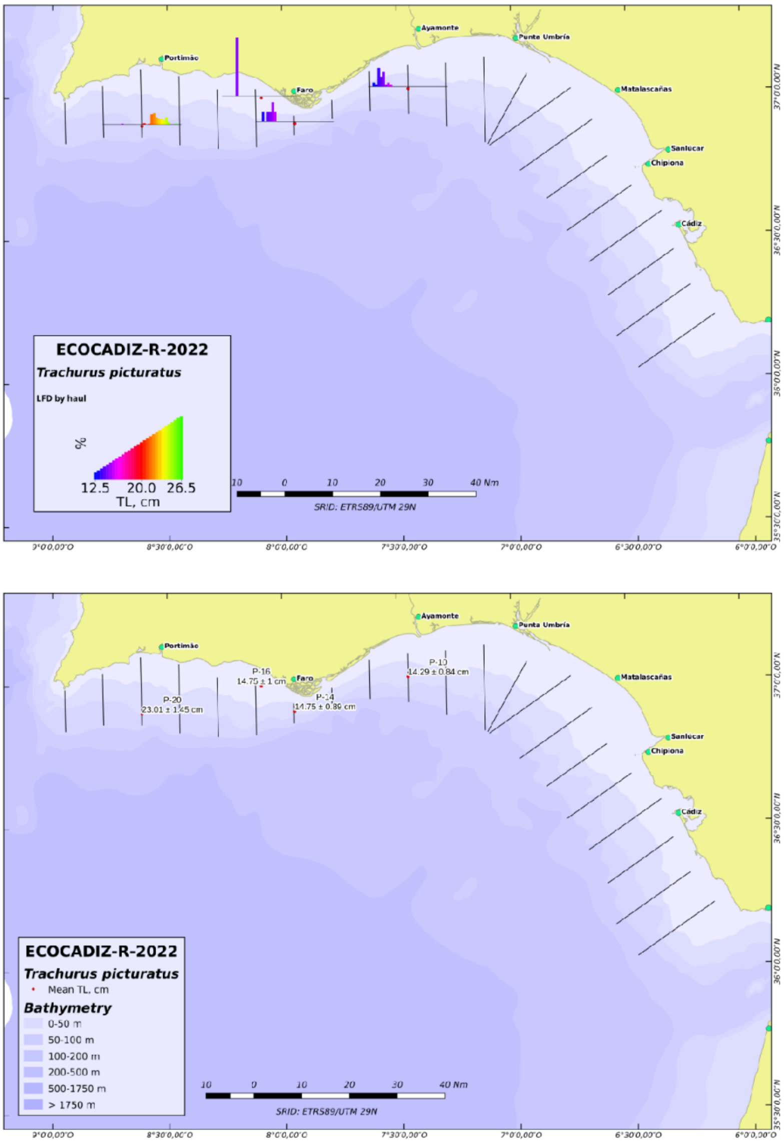


Figure 28. *ECOCADIZ-RECLUTAS 2022-10* survey. Blue jack mackerel (*Trachurus picturatus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

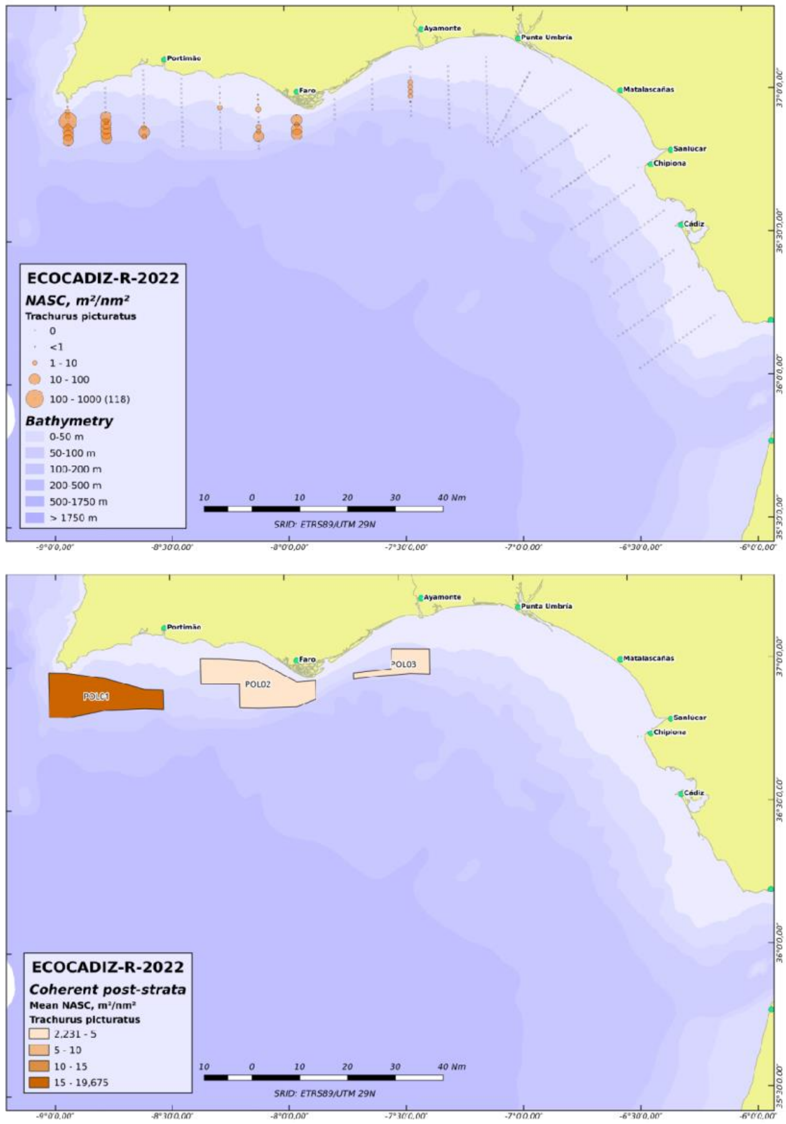


Figure 29. *ECOCADIZ-RECLUTAS 2022-10* survey. Blue jack mackerel (*Trachurus picturatus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in m^2nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

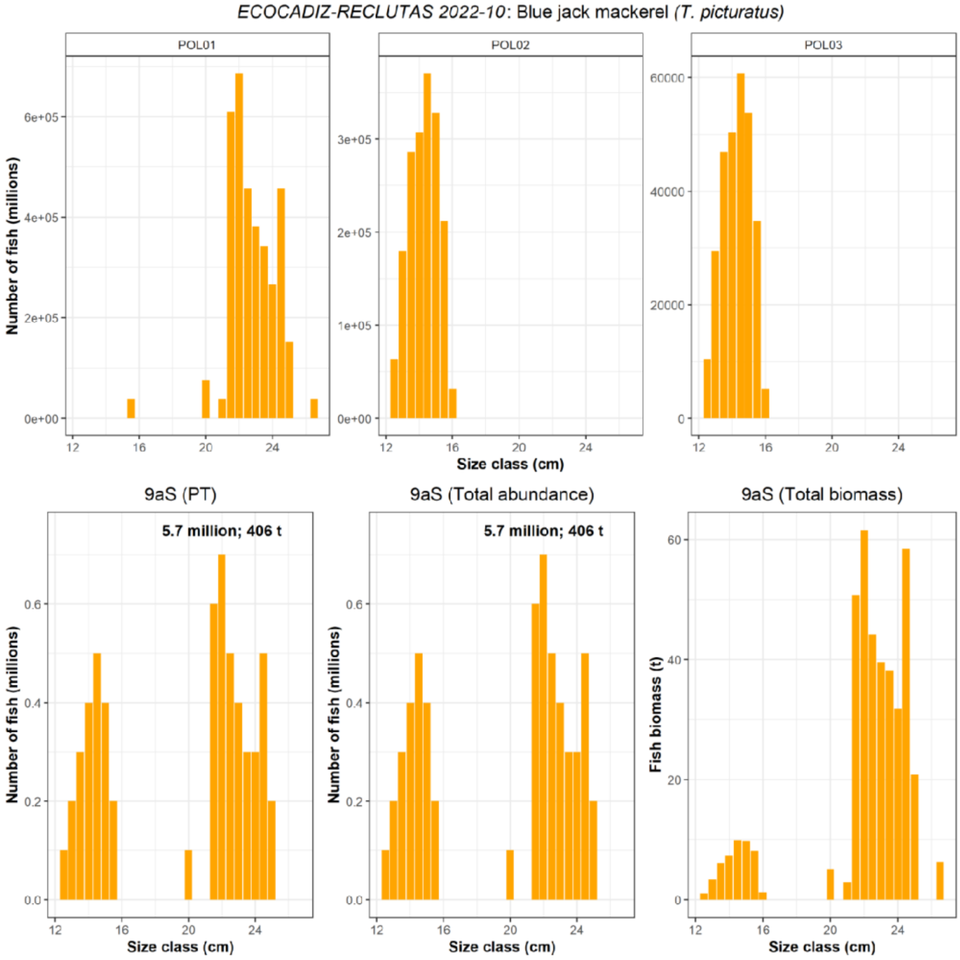


Figure 30. *ECOCADIZ-RECLUTAS 2022-10* survey. Blue jack mackerel (*Trachurus picturatus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 29)** and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the *y*-axis.

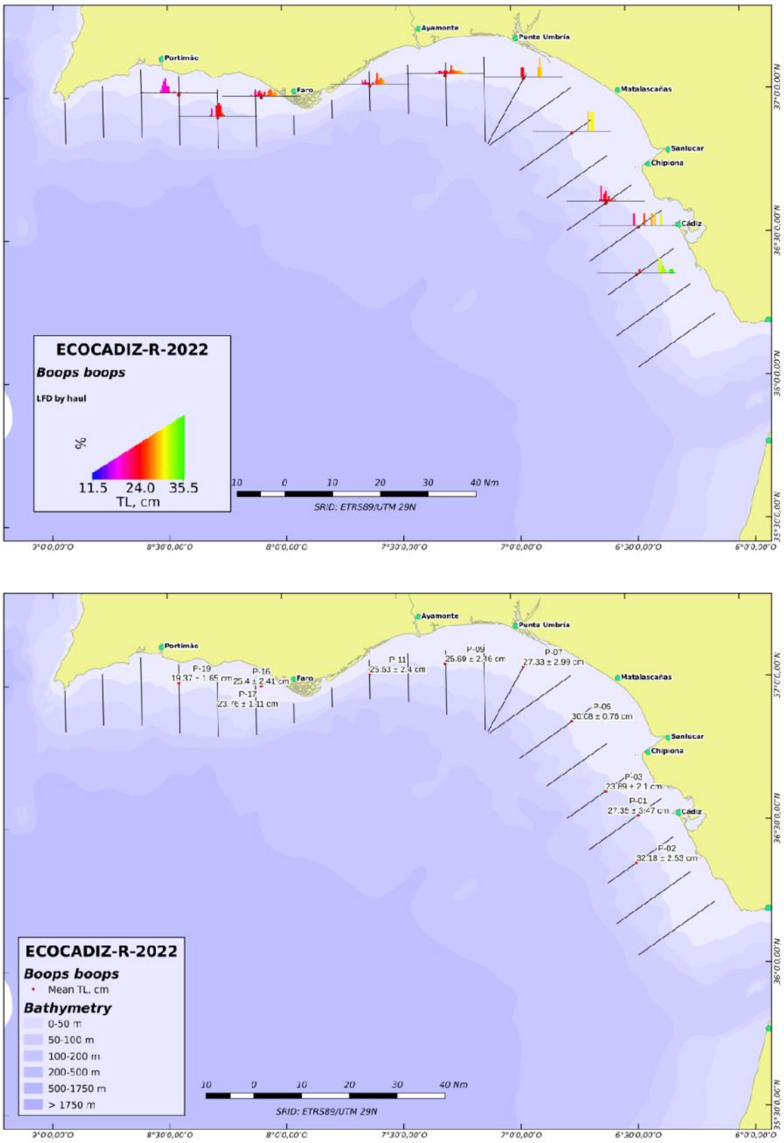


Figure 31. *ECOCADIZ-RECLUTAS 2022-10* survey. Bogue (*Boops boops*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

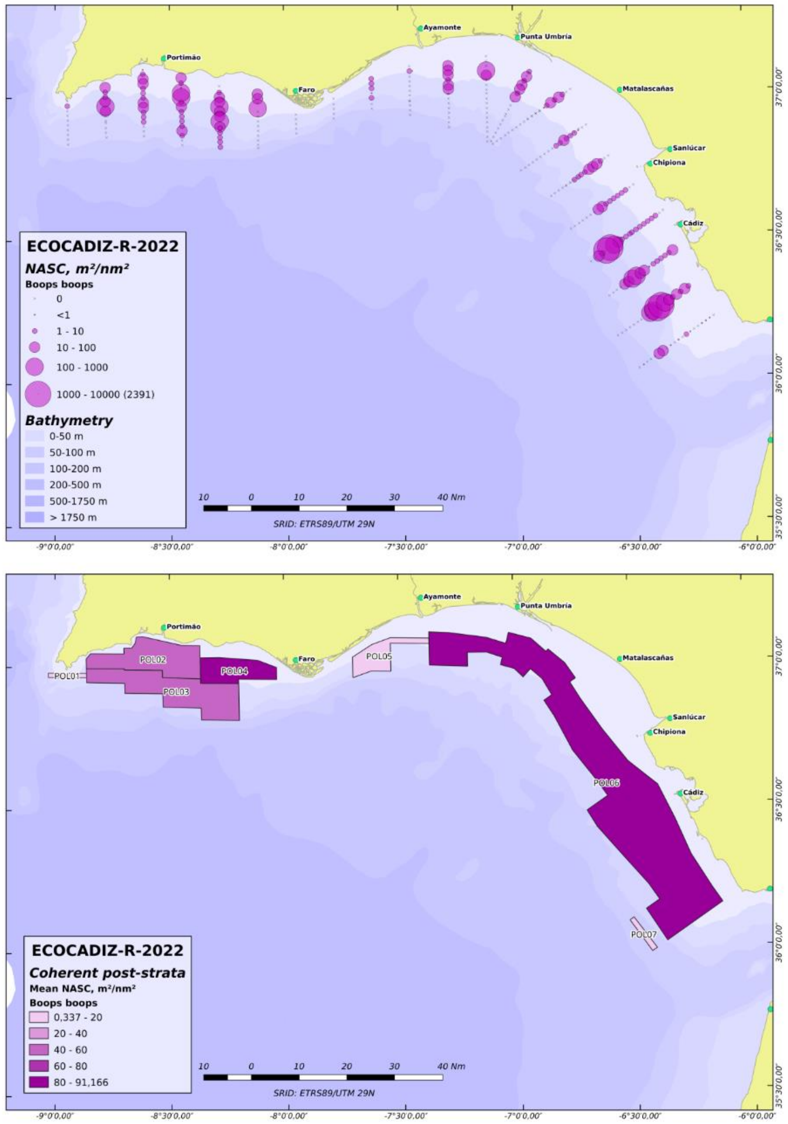


Figure 32. *ECOCADIZ-RECLUTAS 2022-10* survey. Bogue (*Boops boops*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in m^2nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

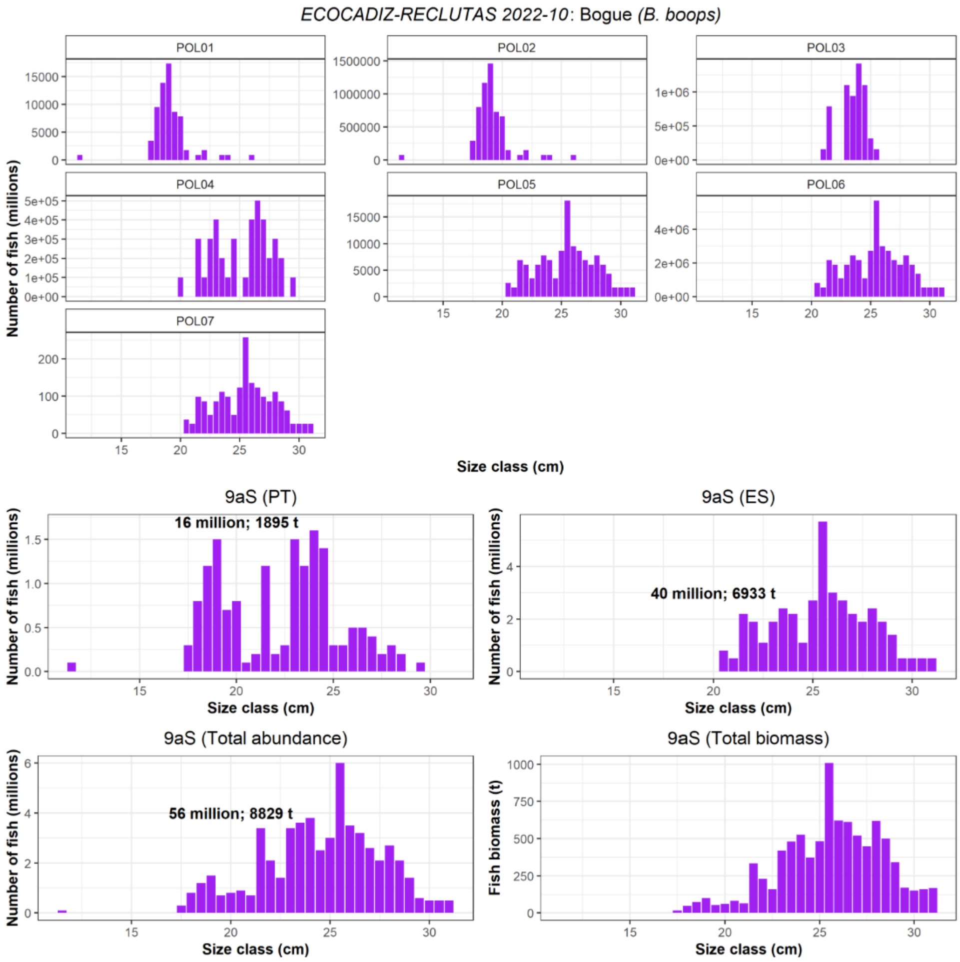
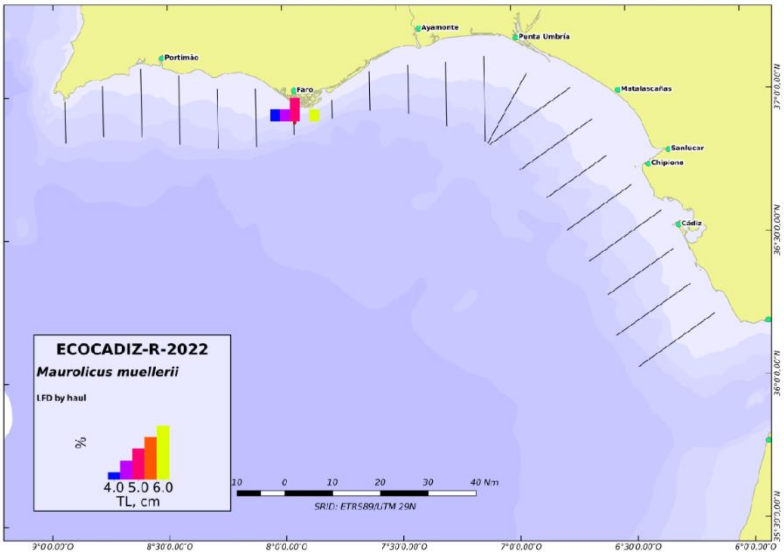


Figure 33. *ECOCADIZ-RECLUTAS 2022-10* survey. Bogue (*Boops boops*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 32**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the *y*-axis.



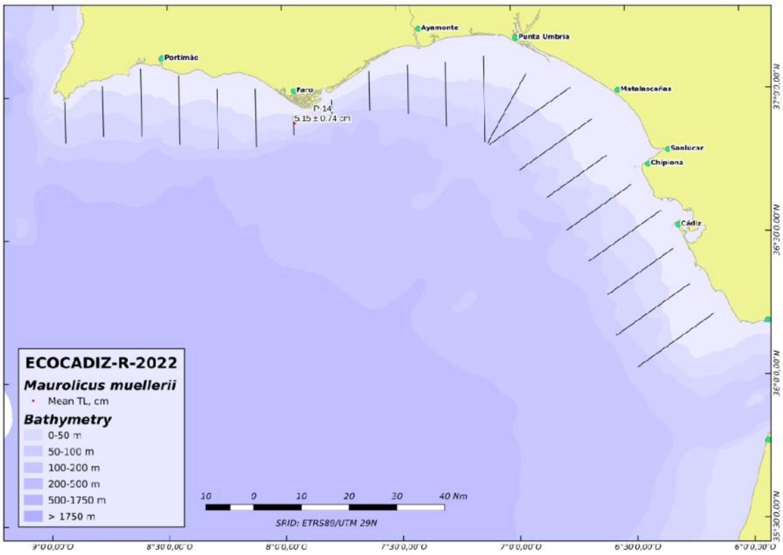
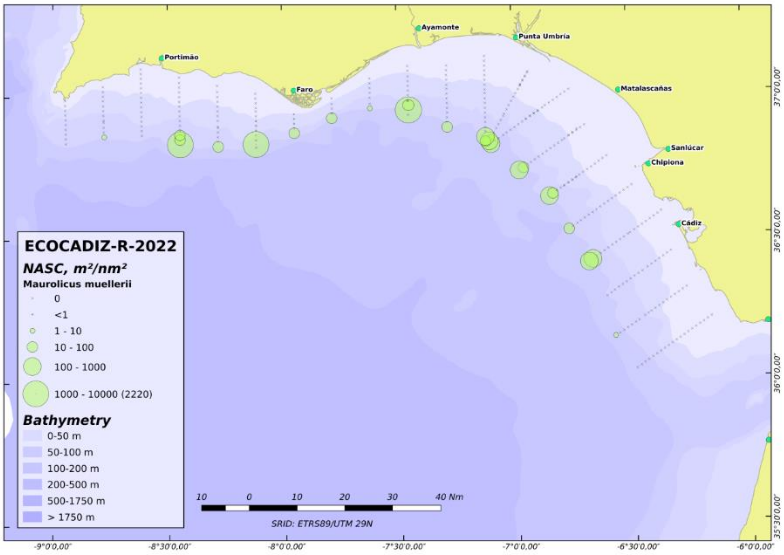


Figure 34. *ECOCADIZ-RECLUTAS 2022-10* survey. Pearlside (*Maurolicus muelleri*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.



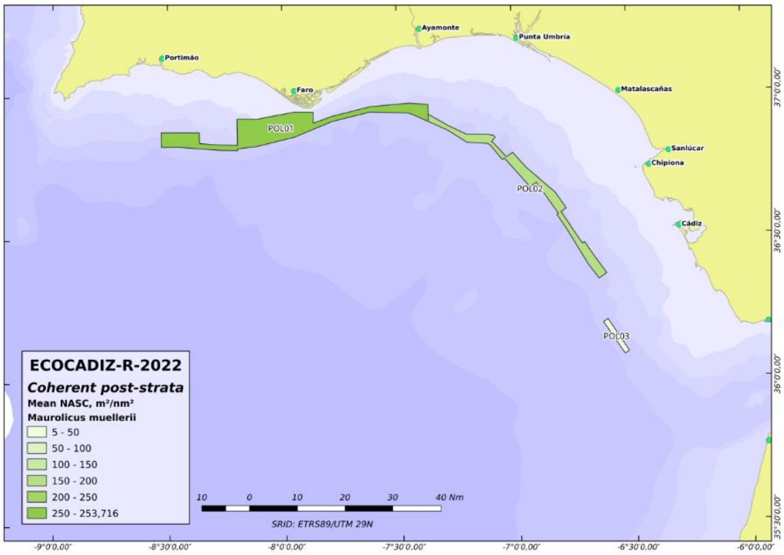


Figure 35. *ECOCADIZ-RECLUTAS 2022-10* survey. Pearlside (*Maurolicus muelleri*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, NASC, in m^2nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

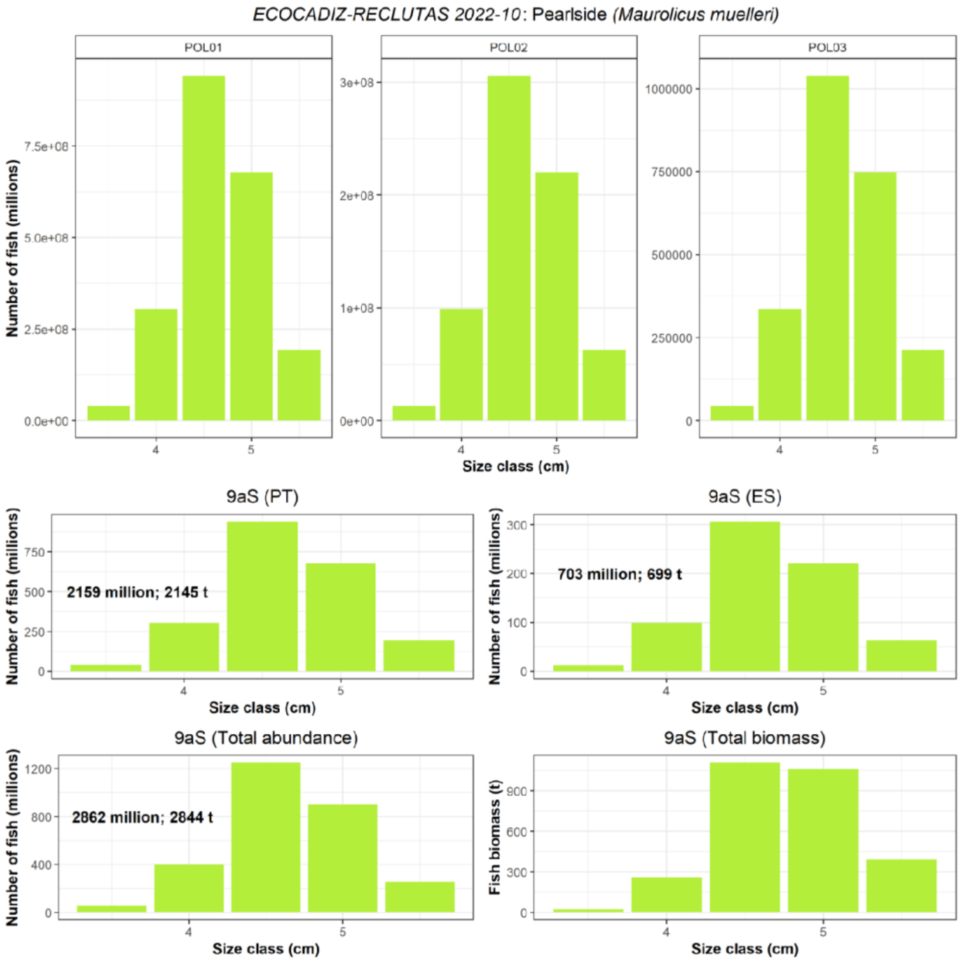


Figure 36. *ECOCADIZ-RECLUTAS 2022-10* survey. Pearlside (*Maurolicus muelleri*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in Figure 40) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the *y*-axis.

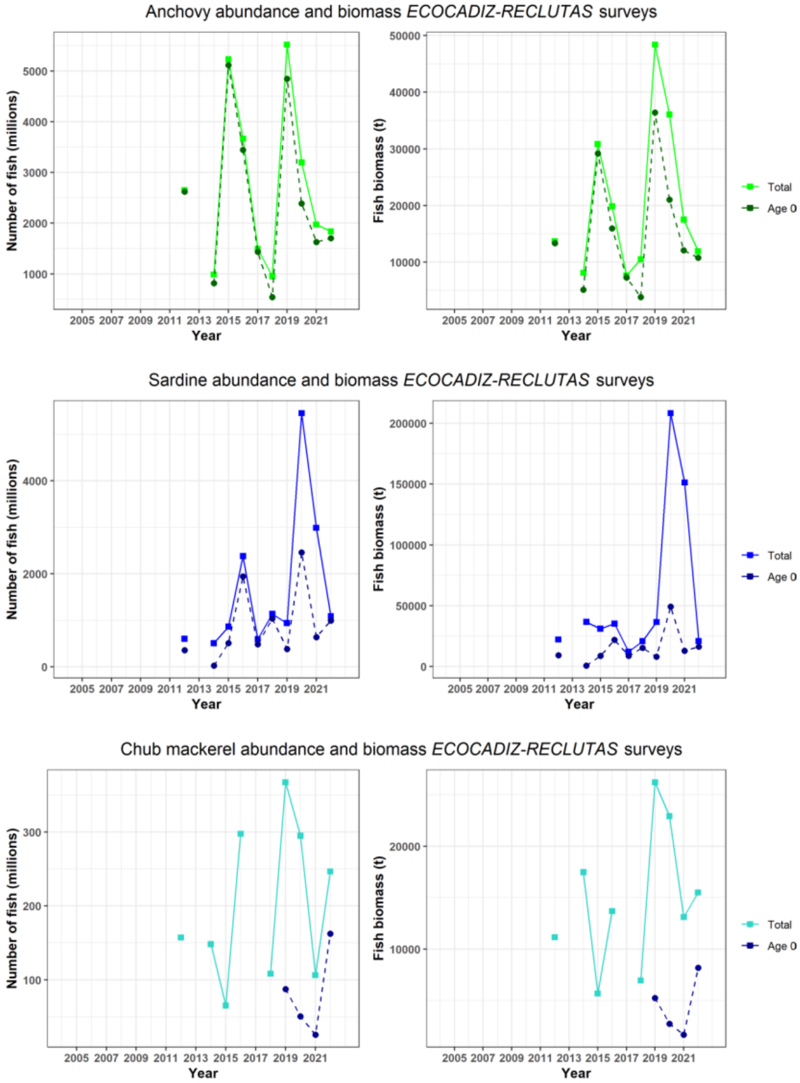


Figure 37. *ECOCADIZ-RECLUTAS* surveys series. Historical series of autumn acoustic estimates of anchovy, sardine and chub mackerel abundance (million) and biomass (t) in Sub-division 9.a South. The estimates correspond to the total population and age 0 fish. The 2012 survey only surveyed the Spanish waters. No survey was conducted in 2013. Although a survey was conducted in 2017, the survey was interrupted for a serious breakdown of the vessel's propulsion system and no estimates were computed. The 2018 estimates should be considered with caution because a possible under-estimation. Age data for chub mackerel started to be available since 2019 on.

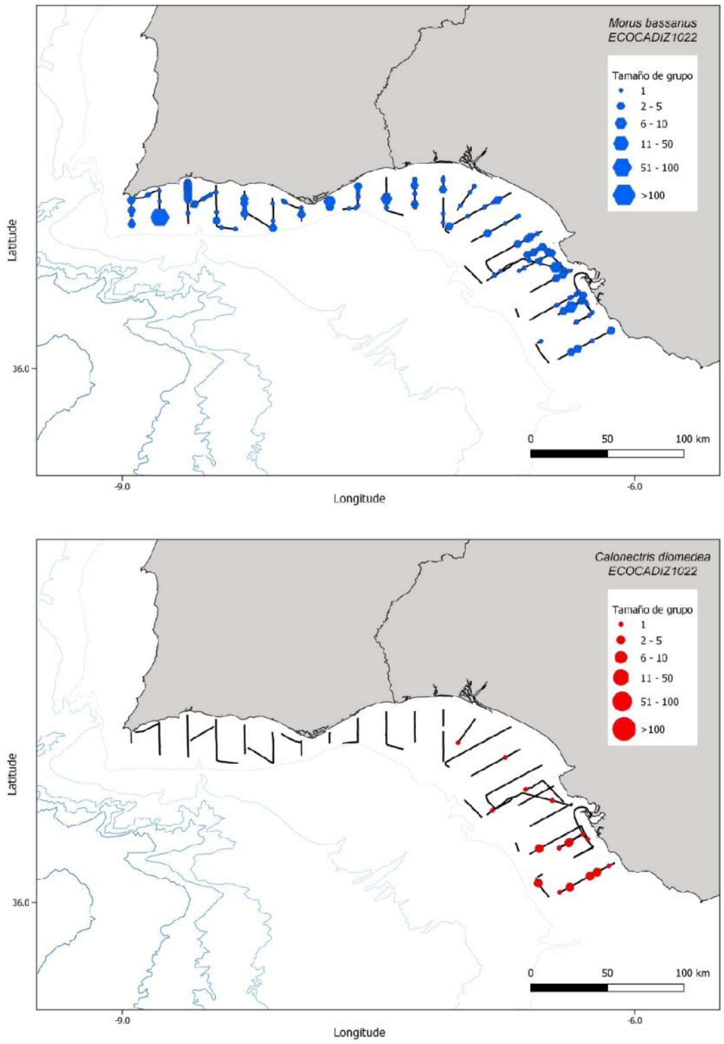
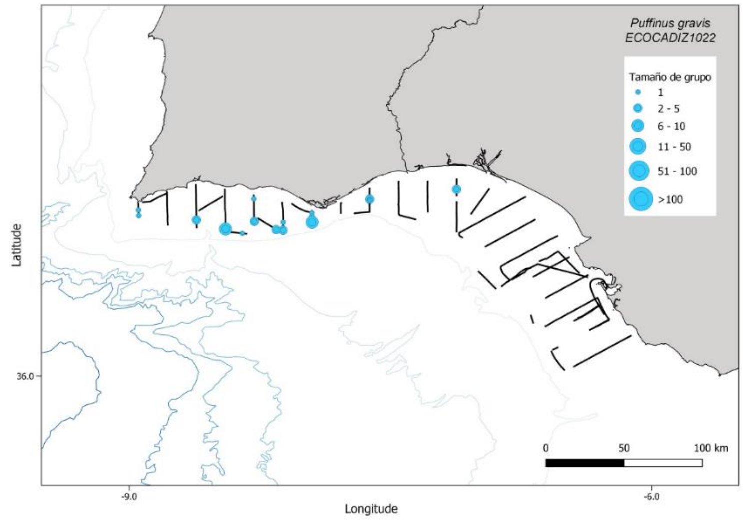


Figure 38. *ECOCADIZ-RECLUTAS 2022-10* survey. Sightings of sea bird species. Top: northern gannet (*Morus bassanus*); bottom: Scopoli's shearwater (*Calonectris diomedea*).



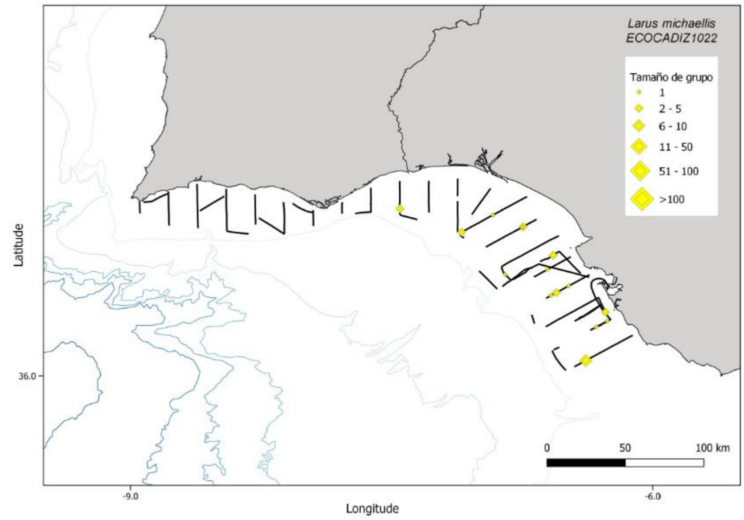


Figure 39. *ECOCADIZ-RECLUTAS 2022-10* survey. Sightings of sea bird species. Top: great shearwater (*Puffinus gravis*); bottom: yellow-legged gull (*Larus michahelis*).

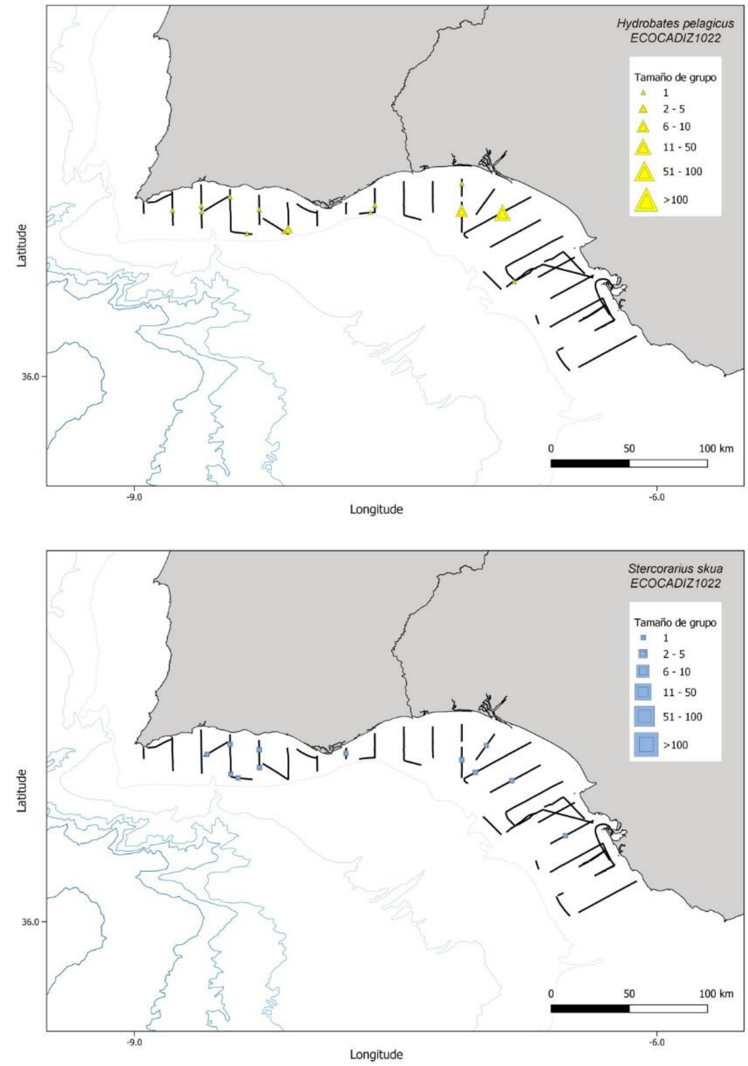


Figure 40. *ECOCADIZ-RECLUTAS 2022-10* survey. Sightings of sea bird species. Top: European storm petrel (*Hydrobates pelagicus*); bottom: great skua (*Stercorarius skua*).

Gadget for anchovy 9a South: Model description and results to provide catch advice and reference points (WGHANSA-1 2023)

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1. Background

The model specifications presented below correspond to those benchmarked in WKPELA 2018. The main difference is that results are presented now for the end of the second quarter of each year instead of be presented at the end of the fourth quarter. This responds to practical modifications in the definition of the assessment year, now it goes from July 1st to June 30th of the next year. Specific model assumptions for this year are presented in section 2.2 and 3, as well as estimated parameters after optimization in Table 2.

2. Model Description

Gadget is an age-length-structured model that integrates different sources of information in order to produce a diagnose of the stock dynamics. It works making forward simulations and minimizing an objective (negative log-likelihood) function that measures the difference between the model and data, the discrepancy is presented as a likelihood score for each time period and model component.

The general Gadget model description and all the options available can be found in Gadget manual (Begley, 2004) and some specific examples can be found in Taylor et al. (2007), Elvarsson et al. (2014) and WKICEMSE assessment for Ling (Elvarsson, 2017). The latest was used as a guide for this document.

The Gadget model implementation consists in three parts, a simulation of biological dynamics of the population (simulation model), a fitting of the model to observed data using a weighted log-likelihood function (observation model) and the optimization of the parameters using different iterative algorithms.

A list of the symbols used and estimated parameters is presented in Table 2 and a graph with the Gadget model structure presented in the last benchmark (WKPELA 2018) is available at Gadget structure graph.

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2.1. Simulation model

The model consists of one stock component of anchovy (*Engraulis encrasicolus*) in the ICES subdivision, 9.a South-Atlantic Iberian waters, Gulf of Cádiz. Gadget works by keeping track of the number of individuals, $N_{a,l,y,t}$, at age $a = 0, \ldots, 3$, at length $l = 3, 3.5, 4, 4.5, \ldots, 22$, at year $y = 1989, \ldots, 2023$, and each year divided into quarters $t = 1, \ldots, 4$.. The last time step of a year involves increasing the age by one year, except for the last age group, which its age remains unchanged and the age group next to is added to it, like a 'plus group' including all ages from the oldest age onwards (Taylor et al., 2007).

Growth

The growth function is a simplified version of the Von Bertalanffy growth equation, defined in Begley (2004) as the LengthVBSimple Growth Function (*lengthvbsimple*). Length increase for each length group of the stock is given by the equation below:

$$\Delta l = (l_\infty - l)(1 - e^{k\Delta t}), \tag{1}$$

where Δt is the length of the timestep, $l_\infty = 19\ cm$ (fixed) is the terminal length and k is the growth rate parameter.

The corresponding increase in weight (in Kg) of the stock is given by:

$$\Delta w = a((l + \Delta l)^b - l^b), \tag{2}$$

with $a = 3.128958e^{-6}$ and $b = 3.277667619$ set as fixed and extracted from all the samples available in third and fourth quarters from 2003 to 2017. The growth functions described above calculate the mean growth for the stock within the model. In a second step the growth is translated into a beta-binomial distribution of actual growths around that mean with parameters β and n. The first is fitted by the model as described in Taylor et al. (2007) and the second represents the number of length classes that an individual is allowed to grow in a quarter and it is fixed and equal to 5.

Initial abundance and recruitment

Stock population in numbers at the starting point of the simulation is defined as:

$$N_{a,l,1,1} = 10000\nu_a q_{a,l}, \quad a = 0, \ldots, 3, l = 3, \ldots, 20$$

Where ν_a is an age factor to be calculated by the model and $q_{a,l}$ is the proportion at lengthgroup l that is determined by a normal density with a specified mean length and standard deviation for each age group. Mean length at age (μ_a) and its standard deviation (σ_a) were extracted from all the data available from 1989 to 2018 including three surveys that are not included in the model: ARSA, ECOCADIZ-RECLUTAS and SAR survey (See table 2). The mean weight at age for this initial population is calculated by multiplying a reference weight corresponding to the length by a relative condition factor assumed as 1. This reference weight at length was calculated using the formula $w = al^b$, with a and b as defined before. In Gadget files this was specified as a normal condition distribution (*Normalcondfile*).

@

Similarly to the process of calculate the initial abundance described above, the recruitment specifies how the stock will be renewed. Recruits enter to the age 0 population at quarters 2, 3, 4 (because of the Gadget order of calculations for each time step this is equivalent to have recruitment one quarter later, i.e. in quarters 3,4 and 1 of the next year) of all years, respectively, as follows:

$$N_{0,l,y,t} = p_{l,t} R_{y,t}, \quad t = 2,3,4, l = 3,\ldots,15,$$

where $R_{y,t}$ represents recruitment at year y and quarter t, and $p_{l,t}$ the proportion in lengthgroup l that is recruited at quarter t which is sampled from a normal density with mean (μ) and standard deviation (σ_t) calculated by the model. The mean weight for these recruits is calculated by multiplying the reference weight corresponding to the length by a relative condition factor assumed as 1. Reference weight at age was the same used to calculate the initial population mean weight at age explained above. In Gadget files this was specified also as a normal condition distribution (*Normalcondfile*).

Fleet operations

In the model the fleets act as predators. There are three fleets inside the model: two for surveys (ECOCADIZ acoustic survey and PELAGO acoustic survey) and one for commercial landings including all fleets: Spanish purse-seine, trawlers, Portuguese purse-seine, and others. The main fleet is Spanish purse-seine representing more than a 90 % of all the catches from 2001 to 2016 and more than a 80 % from 1989 to 2000. It is also the only fleet with a lenght distribution available, then we decide to include all commercial reported data in the same fleet which is mostly the Spanish purse-seine.

Surveys fleets are assumed to remove 1 Kg in each of the quarters when the surveys take place while the commercial fleet is assumed to remove the reported number of individuals each quarter. This total amount of biomass (for the surveys) or numbers (for the commercial fleet) landed is then split between the length groups according to the equations 3 and 4 respectively, as follows:

$$C_{l,y,t} = \frac{E_{y,t} S_{l,T} N_{l,y,t} W_l}{\sum_l S_{l,T} N_{l,y,t} W_l}, \tag{3}$$

and

$$C_{l,y,t} = \frac{E_{y,t} S_{l,T} N_{l,y,t}}{\sum_l S_{l,T} N_{l,y,t}}, \tag{4}$$

where $E_{y,t}$ represents biomass landed (in Kg) at year y and quarter t in equation 3 and numbers landed in equation 4, W_l corresponds to weight at length and $S_{l,T}$ represents the suitability function that determines the proportion of prey of length l that the fleet is willing to consume during period $T, T = 1,2,3$ where $T = 1$ corresponds to the period 1989-2000, $T = 2$ to 2001-**2022** and $T = 3$ to 1989-**2022**.

For this model the suitability function chosen for the fleet and surveys is specified in Gadget manual as an ExponentialL50 function (*expsuitfuncl50*), and it is defined as follows:

$$S_{l,T} = \frac{1}{1 + e^{\alpha_T (l - l_{50,T})}} \tag{5}$$

where $l_{50,T}$ is the length of the prey with a 50% probability of predation during period T and α_T a parameter related to the shape of the function, both parameters are estimated from the data within the Gadget model. The whole model time period (1989-**2022**) has been splited into two different periods for suitability parameters of the commercial fleet because of changes in size regulation for the fishery around 1995 that become effective around 2001.

2.2. Observation model

Data are assimilated by Gadget using a weighted log-likelihood function. The model uses as likelihood components two biomass survey indices: ECOCADIZ acoustic survey and PELAGO acoustic survey; age - length keys from the commercial fleet (Spanish purse-seine), PELAGO survey and the ECOCADIZ survey; and length distributions for the commercial fleet, PELAGO and ECOCADIZ surveys (see Table 2.2 for a detailed description of the likelihood data used in the model).

Biomass Survey indices

The survey indices are defined as the total biomass of fish caught in a survey. The survey index is compared to the modelled abundance using a log linear regression with slope equal to 1 (*fixedslopeloglinearfit*), as follows:

$$\ell = \sum_t (\log(I_{y,t}) - (\alpha + \log(N_{y,t}))^2 \tag{6}$$

where $I_{y,t}$ is the observed survey index at year y and quarter t and $N_{y,t}$ is the corresponding population biomass calculated within the model. Note that the intercept of the log-linear regression, $\alpha = \log(q)$, with q as the catchability of the fleet (i.e $I_{y,t} = qN_{y,t}$).

Catch distribution

Age-length distributions are compared using l lengthgroup at age a and time-step y, t for both, commercial and survey fleets with a sum of squares likelihood function (*sumofsquares*):

$$\ell = \sum_y \sum_t \sum_l (P_{a,l,y,t} - \pi_{a,l,y,t})^2 \tag{7}$$

where $P_{a,l,t,y}$ is the proportion of the data sample for that time/age/length combination, while $\pi_{a,l,t,y}$ is the proportion of the model sample for the same combination, as follows:

$$P_{a,l,t,y} = \frac{O_{a,l,y,t}}{\sum_a \sum_l O_{a,l,y,t}} \tag{8}$$

and

$$\pi_{a,l,t,y} = \frac{N_{a,l,y,t}}{\sum_a \sum_l N_{a,l,y,t}}, \tag{9}$$

where $O_{a,l,y,t}$ corresponds to observed data.

When only length or age distribution is available. It is compared using equation 7 described above but considering all ages or all lengths, respectively.

Understocking

If the total consumption of fish by all the predators (fleets in this case) amounts to more than the biomass of prey available, then the model runs into "understocking". In this case, the consumption by the predators is adjusted so that no more than 95% of the available prey biomass is consumed, and a penalty, given by the equation 10 below, is applied to the likelihood score obtained from the simulation (Stefansson 2005, sec 4.1.)

$$\ell = \sum_t U_t^2 \tag{10}$$

where U_t is the understocking that has occurred in the model for that timestep.

Penalties

The BoundLikelihood likelihood component is used to give a penalty weight to parameters that have moved beyond the bounds in the optimisation process. This component does specify the penalty that is to be applied when these bounds are exceeded.

$$\ell_i = \begin{cases} lw_i(val_i - lb_i)^2 & \text{if } val_i < lb_i \\ uw_i(val_i - ub_i)^2 & \text{if } val_i > ub_i \\ 0 & otherwise \end{cases}$$

Where $lw_i = 10000$ and $uw_i = 10000$ are the weights applied when the parameter exceeds the lower and upper bounds, respectively, val_i is the value of the parameter and, lb_i and ub_i are the lower and upper bounds defined for the parameter.

2.3. Order of calculations

The order of calculations is as follows:

1. **Printing**: model output at the beginning of the time-step
2. **Consumption**: by the fleets
3. **Natural mortality**
4. **Growth**
5. **Recruitment**: new individuals enter to the population
6. **Likelihood comparison**: Comparison of estimated and observed data, a likelihood score is calculated

7. **Printing**: model output at the end of the time-step
8. **Ageing**: if this is the end of year the age is increased

Because of this order of calculations the time step of indexes, age-length keys and length distributions of the surveys are defined in Gadget a quarter before.

2.4. Implementation, weighting procedure

Input data (Likelihood files) were prepared for Gadget format using the *mfdb* R package (Lentin, 2014), running and weighting procedures were implemented in R with the gadget.iterative function from *Rgadget* package. This function follows the approach presented in Taylor et al. (2007) and in the appendix of Elvarsson et al. (2014) based on the iterative reweighting scheme of Stefánsson (1998) and Stefansson (2003), which is summarized as follows:

Let $\mathbf{w_r}$ be a vector of length L with the weights of the likelihood components (excluding understocking and penalties) for the run r, and $SS_{i,r}, i = 1, \ldots, L$, the likelihood score of component i after run r. First, a Gadget optimization run is performed to get a likelihood score ($SS_{i,1}$) for each likelihood component assuming that all components have a weight equal to one, i.e., $\mathbf{w_1} = (1, 1, \ldots, 1)$. Then, a separated optimization run for each of the components (L optimization runs) is performed using the following weight vectors:

$$\mathbf{w_{i+1}} = (1/SS_{1,1}, \ldots, (1/SS_{i,1}) * 10000, 1/SS_{i+1,1}, \ldots, 1/SS_{L,1}), i = 1, \ldots, L.$$

Resulting likelihood scores $SS_{i,i+1}$ are then used to calculate the residual variance, $\hat{\sigma}_i^2 = SS_{i,i+1}/df^*$ for each component, that is used to define the final weight vector as

$$\mathbf{w} = (1/\hat{\sigma}_1^2, \ldots, 1/\hat{\sigma}_L^2).$$

Where degrees of freedom df^* are approximated by the number of non-zero data points in the observed data for each component. Finally, the total objective function is the sum of all likelihoods components multiplied by their respective weights according to the vector $\mathbf{w}$.

In order to assign weights to the individual likelihood components (See table 2.2) in the procedure described above, all the survey indices were grouped together.

2.5. Initial parameters and optimization

Initial parameter values with their boundaries and settings for the optimising algorithms can be found in initial values for parameters file and optimization file. The optimization algorithms converged in individual and weighted runs.

3. Remarkable Model Assumptions (in bold the terms associated to the more recent assumptions)

- Due to lack of information of length distributions and Age-length keys for commercial catches in the first and second quarter of 2020, for this year assessment, the length distribution of those quarters in year 2020 was approximated using the joint distribution of 2018 and 2019. For the Age-length key the one for the PELAGO 2020 survey was used.

- Due to discrepancies on mean lenght and weight at age in PELAGO survey for 2023 a crossvalidation for age composition was required. This crossvalidation reveals some missestimations in the otolith reading suggesting that more analysis is needed to agreed on the definitive age composition. For this reason age distribution of PELAGO survey in 2023 was removed from the model.
- Due to technical problems there are no data available for ECOCADIZ survey in 2021 and 2022.
- The model was implemented quarterly from 1989 to the second quarter of **2023**.
- All commercial fleets where grouped into only one from 1989 to **2023** second quarter: The Spanish purse-seine. The Spanish purse-seine which represents more than a 90 % of all the catches from 2001 to 2016 and more than a 80 % from 1989 to 2000. It is also the only fleet with a lenght distribution available. For the first two quarters of year **2023**, provisional catches estimations of Spanish (until May 18th) purse-seine fleet were used and catches for June were estimated as the **39%** of January to May catches based on historical records from 2009 to **2022**. There were not any catches for Portuguese purse-seine in these two quarters.
- It was decided to include also discards (available from 2014 onwards) in WGHANSA-1-2020. This decision was taken because they were already accounted for some years in the previous assessments to 2020 but we did not notice about that. Since then we include discards in catches data.
- The parameters for weight-length relationship equation ($w = al^b$,) were assumed fixed and defined as $a = 3.128958e^{-6}$ and $b = 3.277667619$. Those values were calculated from all the samples available in third and fourth quarters from 2003 to 2017.
- Natural mortality at age was also considered fixed with $M_0 = 2.21$ and $M_1, M_2, M_3 = 1.3$,.
- There was a minimum landing size restriction from 1995, that were only effective until 2001. As a consequence it was neccesary to define different suitability parameters for two different periods. One from 1989 to 2000, and the other from 2001 to **2022**.
- Age 0 individuals were removed for **all** the data input corresponding to ECOCADIZ survey. It was noticed that age 0 was not removed from the length distribution in the assessments prior to 2021.
- It was noticed that the length distribution for year 2020 in ECOCADIZ survey was not included in the model used for 2021 assessment. We include that missing information in the model described in this document.
- Recruits enter to the age 0 population at quarters 2, 3 and 4 (because of the Gadget order of calculations for each time step this is equivalent to have recruitment one quarter later, i.e. in quarters 3,4 and 1 of the next year) of all years except the last year, because at the end of June there are no recruits (zero age

individuals). Then, biomass and abundance estimates at the end of the second quarter need to be corrected removing age 0 individuals.

4. Natural mortality selection

Natural mortality selection is justified by the following arguments:

- Natural mortality was preferred to be selected from classical indirect formulations based on life history parameters. For it we used the R package *FSA* to obtain empirical estimates of natural mortality.
- For the estimation of the natural mortality rate, the Von Bertalanffy growth parameters and the maximum age that the species can live were used. Growth parameters of the Von Bertalanffy function were taken from Bellido et al. (2000) ($l_\infty = 18.95, k = 0.89, t_0 = -0.02$), and for the maximum observed age, we explored a range from age 3 to 5, but finally age 4 was considered adequate. A total of 13 estimators were produced using the R package *FSA* and the a value of $M = 1.3$ was undertaken (midway between the median and the mean of the available estimates for Agemax=4).
- Currently is generally accepted that Natural mortality may decrease with age, as far as it presumed to be particularly greater at the juvenile phase. It was agreed to adopt for the adult ages of anchovy (ages 1 to 4) the constant natural mortality estimated before (1.3), but for the juveniles (age 0) a greater one in proportion to the ratio of natural mortality at ages 0 and 1 (M_0/M_1) resulting from the application of the Gislason et al. (2010) method for modelling natural mortality as a function of the growth parameters. For it we used four vectors of length-at-age: derived from the Von Bertalanffy growth function in Bellido et al. (2000) for ages 1-5, from the ECOCADIZ-RECLUTAS survey for ages 0-3, the average of the length-at-age in the catches from 1987 to 2016 and the average of the length-at-age in the catches from 2007 to 2016. There was no major basis to select one or the other, we directly choosed the pattern shown by the ECOCADIZ-RECLUTAS data just because it seemed to be smoothest one (particularly for age 1 onwards as presumed here). The ratio M_0/M_1 is 2.722670/ 1.595922 = 1.7. Therefore $M_0 = 1.3 * 1.7 = 2.21$.
- In summary for anchovy 9a South, the adopted natural mortality by ages are $M_0 = 2.21, M_1 = 1.3$ and $M_2^+ = 1.3$ (similar at any older age).

5. Fit to data

A summary of likelihood scores is presented in Figure 1 while a comparison of estimated versus observed data is summarized in the following Figures:

Length distributions

- Figure 2: Length distribution of the commercial fleet.
- Figure 3: Length distribution of the ECOCADIZ acoustic survey.

- Figure 4: Length distribution of the PELAGO acoustic survey.
- Figure 5: Summary of residuals for length distributions.

Age distributions

- Figure 6: Age distribution of the commercial fleet.
- Figure 7: Age distribution of the ECOCADIZ acoustic survey.
- Figure 8: Age distribution of the PELAGO acoustic survey.
- Figure 9: Summary of residuals for age distributions.

Biomass survey indices fit

- Figure 10: Summary of biomass survey indices fit.

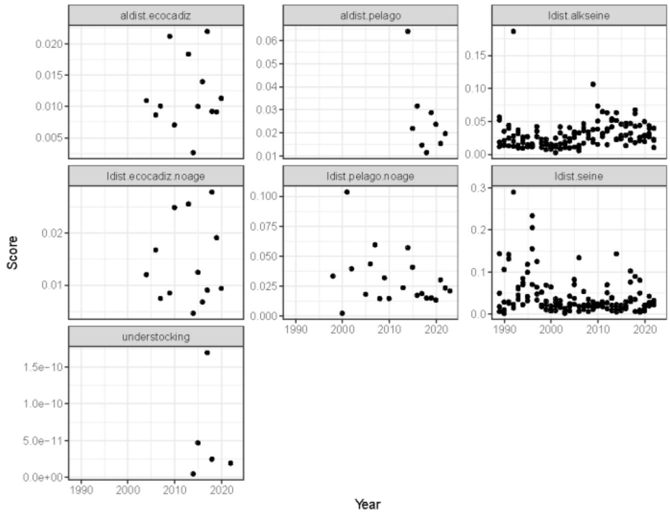


Figure 1: Likelihood scores for age-length key of ECOCADIZ survey, PELAGO survey and commercial landings (Upper panel) and length distribution of ECOCADIZ survey, PELAGO survey and landings. Dots represent the score for each quarter.

Index	
a	Age, $a = 0,\ldots,3$
l	Length, $l = 3,3.5,4,4.5,\ldots,22$
y	Years, $y = 1989,\ldots,2023$
t	Quartely timestep, $t = 1,\ldots,4$
T	$T = 1$ for period 1989-2000, $T = 2$ for period 2001-2022
Parameters	
Fixed	
a	Parameter of weight-length relationship $w = al^b$, $a = 3.128958 \times 10^{-6}$
b	Parameter of weight-length relationship $w = al^b$, $b = 3.277667619$
μ_a	Initial population mean length at age
	$\mu_0 = 9.99, \mu_1 = 12.1, \mu_2 = 15.2, \mu_3 = 16.1$
σ_a	Initial population standard deviation for length at age
	$\sigma_0 = 0.836, \sigma_1 = 0.5, \sigma_2 = 1, \sigma_3 = 1.2$
M_a	Natural mortality, $M_0 = 2.21, M_1 = 1.3, M_2 = 1.3, M_3 = 1.3$
n	Maximum number of length classes that an individual is supposed to grow $n = 5$
Estimated	
l_∞	Asympthotic length, l_∞=29.1744
k	Annual growth rate, $k = 0.0831751$
β	Beta-binomial parameter, $\beta = 5000$
ν_a	Age factor, $\nu_0 = 120000, \nu_1 = 118000,$
	$\nu_2 = 0.0601, \nu_3 = 1.25e-07$
μ	Recruitment mean length, $\mu = 9.86671$
σ_t	Recruitment length standard deviation by quarter, $\sigma_2 = 2.98305$, $\sigma_3 = 1.67904$, $\sigma_4 = 4$
$l_{50,T}$	Length with a 50% probability of predation during period T,
	$l_{50,1}^{seine} = 10.6$, $l_{50,2}^{seine} = 10.9$, $l_{50,3}^{ECO} = 12.8$, $l_{50,3}^{PEL} = 14.3$
α_T	Shape of function, $\alpha_1^{seine} = 0.407$, $\alpha_2^{seine} = 0.865$, $\alpha_3^{ECO} = 1.41$, $\alpha_3^{PEL} = 0.459$
Observed Data	
$E_{y,t}$	Number or biomass landed at year y and quarter t
W_l	Weight at length
$I_{y,t}$	Observed survey index at year y and quarter t
$P_{a,l,y,t}$	Proportion of the data sample over all ages and lengths for timestep/age/length combination
$O_{a,l,y,t}$	Observed data sample for time/age/length combination
$x_{a,y,t}$	Sample mean weight from the data for the timestep/age combination
Others	
Δl	Length increase
Δw	Weight increase
Δt	Length of timestep
$N_{a,l,y,t}$	Number of individuals of age a, length l in the stock at year and quarter y and t, respectively.
$q_{a,l}$	Proportion in lengthgroup l for each age group
$R_{y,t}$	Recruitment at year y and quarter t
$p_{l,t}$	Proportion in lengthgroup l that is recruited at quarter t
$C_{l,y,t}$	Total amount in biomass landed by surveys and in number caught by commercial fleet (discards 2014-2019)
$S_{l,T}$	Proportion of prey of length l that the fleet/predator is willing to consume during period T
$\pi_{a,l,y,t}$	Proportion of the model sample over all ages and lengths for that timestep/age/length combination
$\mu_{a,y,t}$	Mean length at age for the timestep/age combination
U_t	Understocking for timestep t
lw_i and uw_i	Weights applied when the parameter exceeds the lower or upper bound
lb_i and ub_i	Lower and upper bound defined for the parameter
val_i	Value of the parameter

Table 1: List of Symbols used in model specification and parameter estimates after optimization

Data source	type	Timespan	Likelihood function
Commercial catches	Length distribution	All quarters, 1989-**2022**	See eq. 7
(discards from 2014 onwards)	Age-length key	All quarters, 1989-**2022**	See eq. 7
ECOCADIZ acoustic survey	Biomass survey indexes	Second quarter 2004, 2006	see eq. 6
		third quarter 2007, 2009, 2010, 2013-2020	
	Length distribution	Second quarter 2004, 2006	see eq. 7
		third quarter 2007, 2009, 2010, 2013-2020	
	Age-length key	Second quarter 2004, 2006	see eq. 7
		third quarter 2007, 2009, 2010, 2013-2020	
PELAGO acoustic survey	Biomass survey indexes	First quarter 1999, 2001-2003	see eq. 6
		second quarter 2005-2010 and 2013-2023	
	length distribution	First quarter 1999, 2001-2003	see eq. 7
		second quarter 2005-2010, 2013-2023	
	Age-length key	second quarter 2014-2023	see eq. 7

Table 2: Overview of the likelihood data used in the model. Important remark: Due to lack of information of length distributions and Age-length keys for commercial catches in the first and second quarter of 2020, the length distribution was approximated using the joint distribution of 2018 and 2019 and the Age-length key used was the one for the PELAGO 2020 survey.

Figure 2: Comparison between observed and estimated catches length distribution. Black lines represent estimated data while gray lines represent observed data

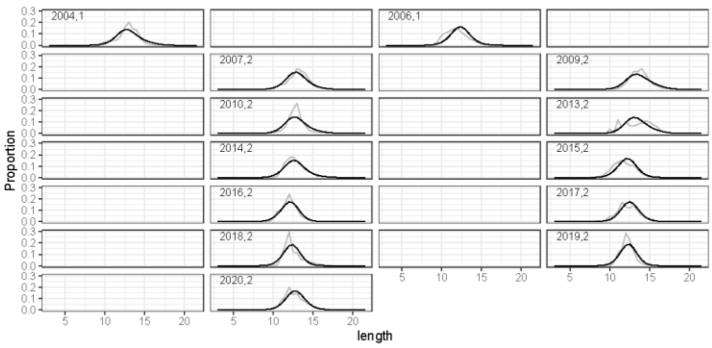


Figure 3: Comparison between observed and estimated catches length distribution for ECOCADIZ survey. Black lines represent estimated data while gray lines represent observed data

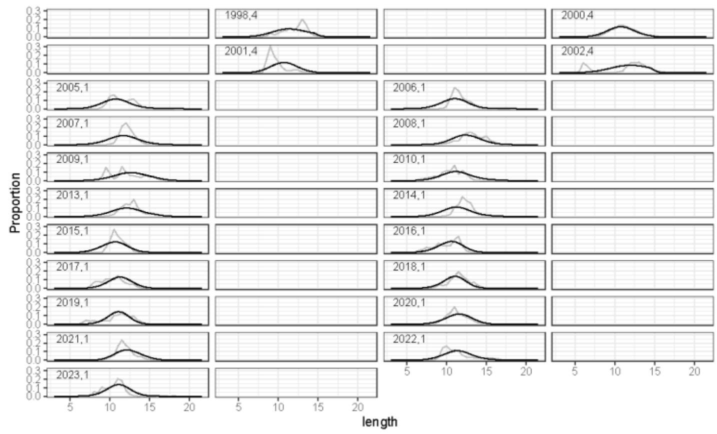


Figure 4: Comparison between observed and estimated catches length distribution for PELAGO survey. Black lines represent estimated data while gray lines represent observed data

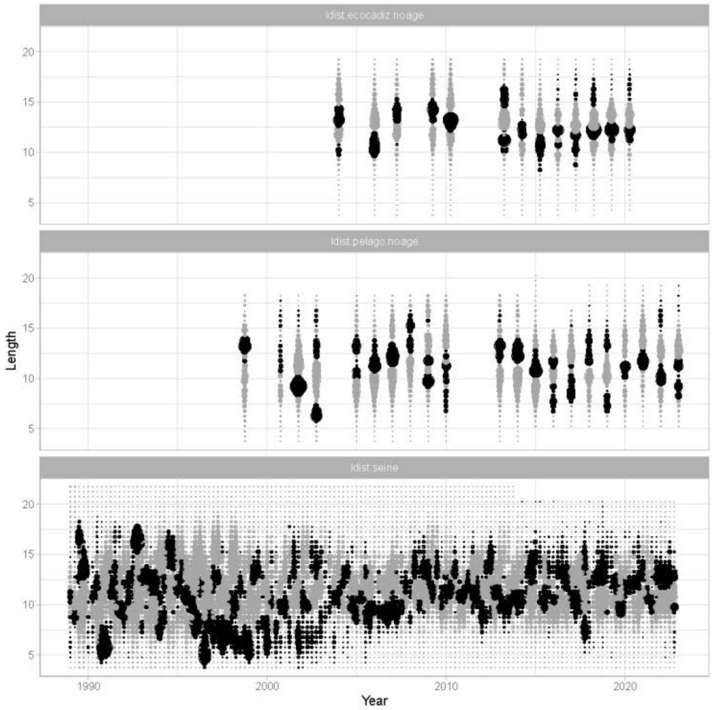


Figure 5: Standardised residual plots for the fitted length distribution from the ECOCADIZ survey, PELAGO survey and commercial landings. Black points denote a model underestimate and gray points an overestimated. The size of the points denote the scale of the standardised residual.

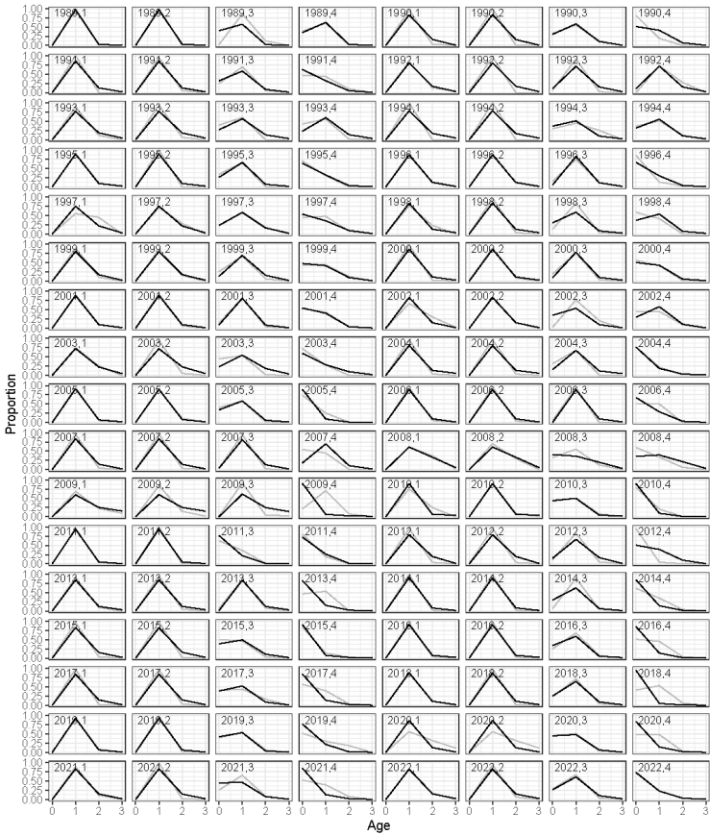


Figure 6: Comparison between observed and estimated catches age distribution. Black lines represent estimated data while gray lines represent observed data.

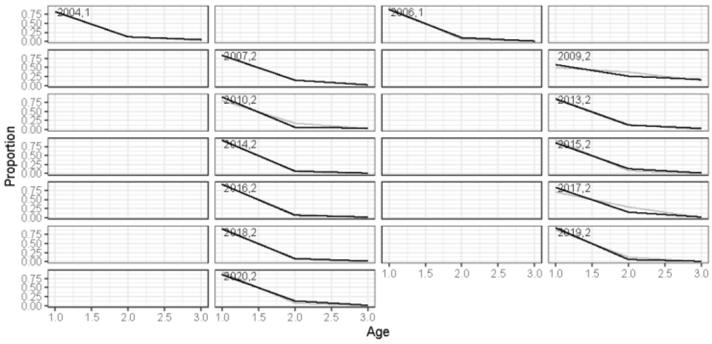


Figure 7: Comparison between observed and estimated ECOCADIZ survey age distribution. Black lines represent estimated data while gray lines represent observed data.

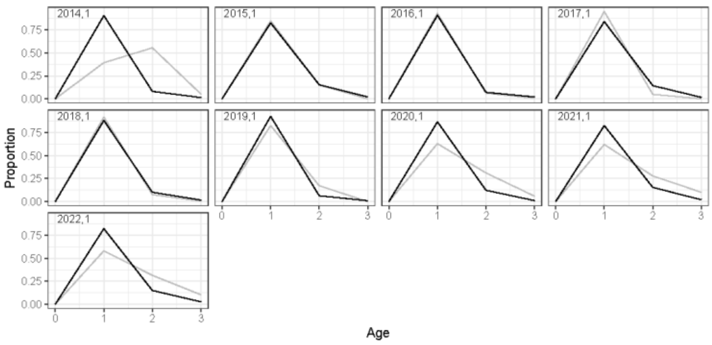


Figure 8: Comparison between observed and estimated PELAGO survey age distribution. Black lines represent estimated data while gray lines represent observed data.

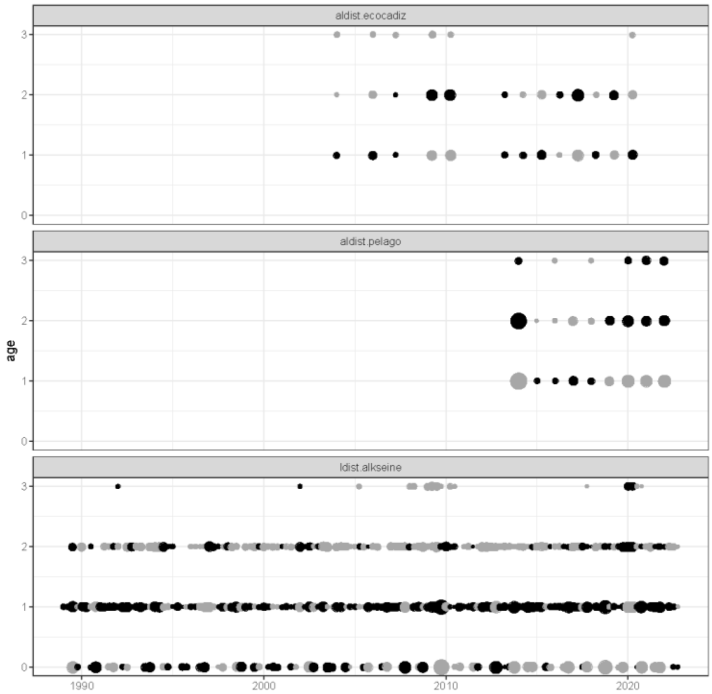


Figure 9: Standardised residual plots for the fitted age distribution from the ECOCADIZ survey, PELAGO survey and commercial fleet. Black points denote a model underestimate and gray points an overestimated. The size of the points denote the scale of the standardised residual.

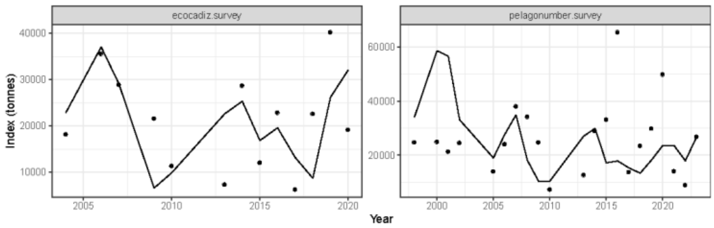


Figure 10: Comparison between observed and estimated survey indices. Black points represent observed data while black line represent estimated data

6. Model estimates

Parameter estimates after optimization are presented in Table 2. Detailed model outputs are available in Results folder on TAF repository, where each file corresponds to the following description:

- sidat: Model fit to the surveyindices
- suitability: Model estimated fleet suitability
- stock.recruitment: Model estimated recruitment
- res.by.year: Results by year
- catchdist.fleets: Data compared with model output for the length and age-length distributions
- stock.full: Modeled abundance and mean weight by year,step, length and stock
- stock.std: Modeled abundance, mean weight, number by age consumed by the fleet, stock and year
- stock.prey: Consumption of the fleet by length, year and step
- fleet.info: Information on catches, harvest rate and harvestable biomass by fleet, year and step
- params: parameter values used for the fit

6.1. Catchability

Figure 11 shows the catchability estimated by the model for the different surveys indices

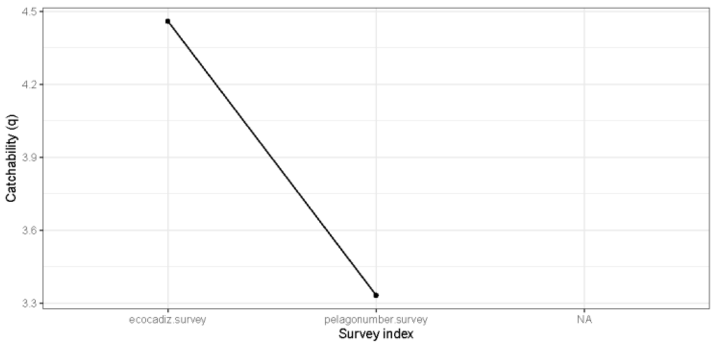


Figure 11: Estimated catchability parameters for the different survey indices

6.2. Estimated age composition

Figure 12 shows the estimated age composition of the population.

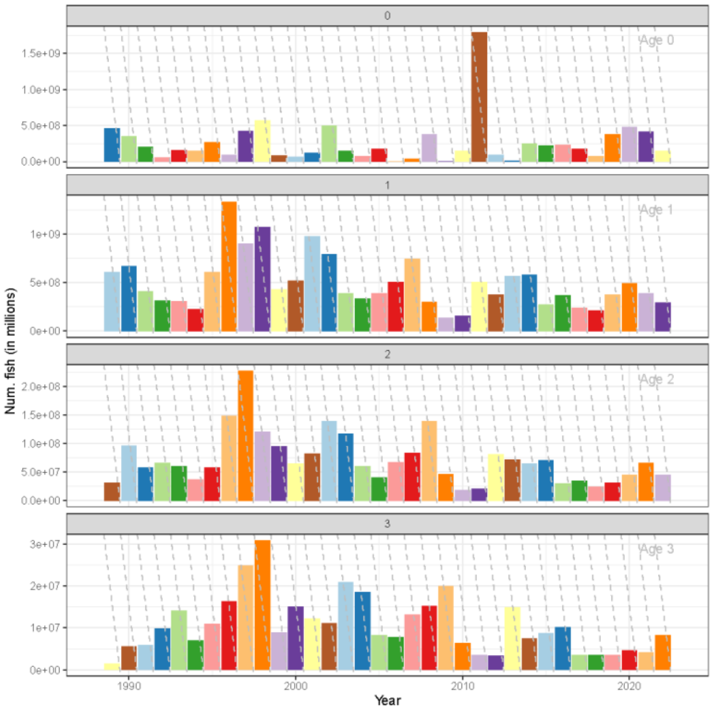


Figure 12: Estimated age composition of the population at the end of the second quarter for each year

6.3. Suitability

Figure 13 shows the fleet suitability functions estimated by the model for the commercial fleet and different surveys

6.4. Abundance, recruitment and Fishing mortality

Figure 14 presents model annual estimates for biomass, abundance (removing age 0 individuals to be accurate with the time of the assessment, see section 3 above for a detailed explanation), recruitment, fishing mortality and catches **at the end of the second quarter of each year**. Figure 15 shows annual estimates for biomass of individuals of age 1+ at the end of the second quarter of each year. Due to some inconsistencies in the maturity ogives not noticed during WKPELA 2018, we assume that all individuals with age 1 or higher (B_1+), are mature i.e. these abundance estimates result equivalent to spawning stock biomass estimates.

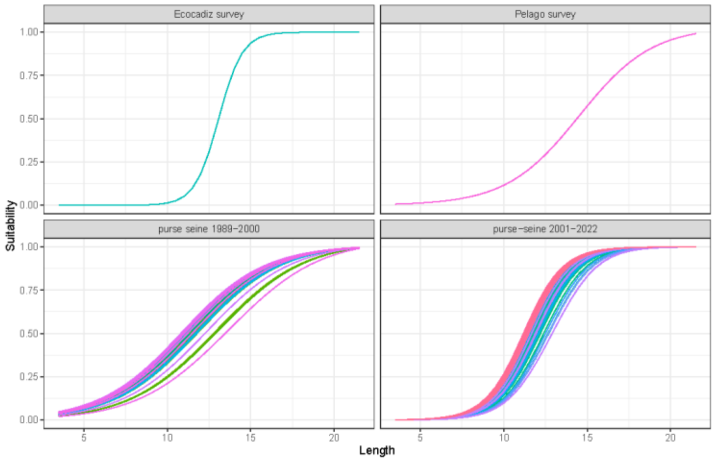


Figure 13: Estimated fleet suitability functions for the commercial fleet and different surveys.

6.5. Comparison with the last two years estimated time series

A comparison with the last two years estimated time series is presented in Figure 16. The pink line represents the current year estimated time series (the one estimated by the model described in this document), the green line, the estimated in 2022 and the blue line, the estimated in 2021. Trends are consistent even considering that each year the model updates the last values with the new information available.

7. Reference points

The methodology applied was the same decided in WKPELA 2018 (page 286 of WKPELA 2018 report (ICES, 2018)) following ICES guidelines for calculation of reference points for category 1 and 2 stocks and the report of the workshop to review the ICES advisory framework for short lived species ICES WKMSYREF5 2017 (ICES, 2017).

According to the above ICES guidelines and the S-R plot characteristics (Figure 17), this stock component can be classified as a "stock type 5" (i.e. stocks showing no evidence of impaired recruitment or with no clear relation between stock and recruitment (no apparent $S-R$ signal)). According to this classification, B_{lim} estimation is possible according to the standard method and it is assumed to be equal to $Bloss$ ($B_{lim} = B_{loss}$). For **2023** the value of B_{loss} for the 9a South anchovy corresponds to the estimated SSB in **2010** (1226.13 t), hence B_{lim} is set at 1226.13 t and the relative B_{lim} (divided by the mean value of B_1+) results equal to 0.286. Note that due to some inconsistencies in the maturity ogives used in WKPELA2018, age 1+ individuals (B_1+) are assumed as mature i.e. B_1+ class is equivalent to Stock Spawning Biomass (SSB) (see subsection 6.4 above).

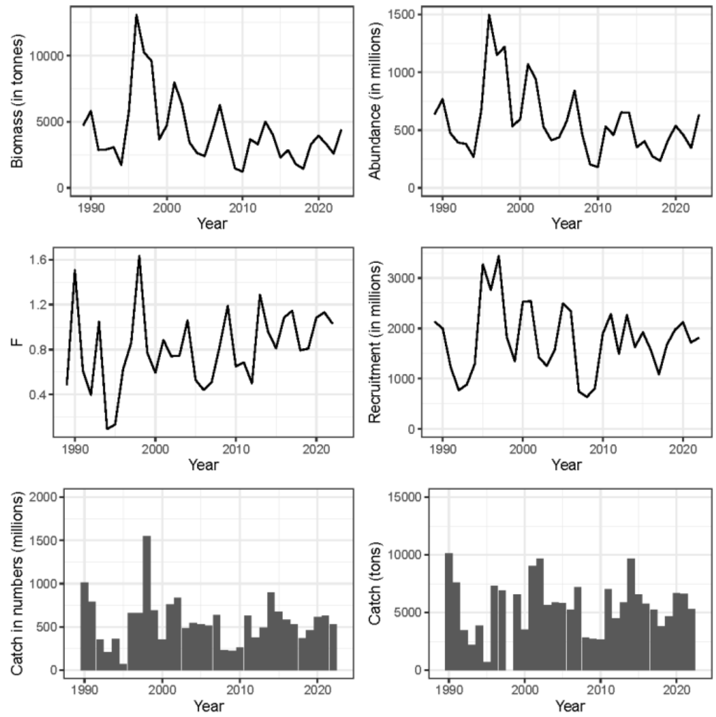


Figure 14: Annual catches time series (in numbers and biomass) compared with annual model estimates for abundance of individuals with more than one year of age(in numbers and biomass) recruitment and fishing mortality. Measures were summarized at the end of June each year, assuming that a year starts in July and ends in June of the next year. Recruitment was calculated including all the recruits of the previous year according to calendar year

ICES recommends to calculate B_{pa} as follows:

$$B_{pa} = e^{(1.645\sigma)} B_{lim},$$

where σ is the estimated standard deviation of $ln(SSB)$ in the last year of the assessment, accounting for the uncertainty in SSB for the terminal year. If σ is unknown and for short living species, as it is in our case, it can be assumed that $\sigma = 0.30$ (see page 34 of ICES WKMSYREF5 2017 report (ICES, 2017)), then $B_{pa} = e^{(1.645\sigma)} B_{lim} = 1.64 B_{lim}$. According to this B_{pa} is set at 2010.8532 t.

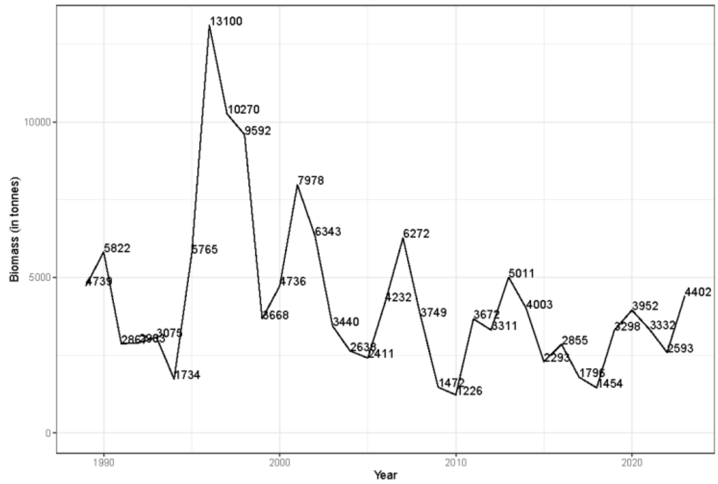


Figure 15: Estimated biomass time series at the end of quarter two (Age 0 removed to be consistent with recruitment at the end of the second quarter of the year). Note that under the assumption that all individuals in $B1+$ class are mature, this biomass is equivalent to SSB

8. Catch advice for July 2023 to June 2024

8.1. One over two harvest control rule

The ratio between the last year biomass estimate and the mean of the two previous years is:

$$\frac{B_y}{B_{y-1} + B_{y-2}} = \frac{4402}{(3332 + 2593)/2} = 1.486$$

for B representing the estimated abundance by the model as shown in Figure 15. According to the report of WKLIFEVX (ICES,2021), if this ratio is above 1.8, the advice would be equal to the latest advice mutiplied by 1.8, if not, the latest advice would be multiplied by this ratio. In case the estimated abundance is below a biomass trigger, which in this case is B_{lim}, it is also multiplied by a biomass safe guard as follows:

$$C_{y+1} = \hat{C}_y * \min\left(1.8, \frac{B_y}{(B_{y-1} + B_{y-2})/2}\right)$$

where $\hat{C}_y$ is the value of adviced catches in the previous year. Then the adviced catches (in tonnes) for the next year (July 2023 to June 2024) would be:

$$C_{y+1} = 1694 * 1.49 = 2517.3.$$

This procedure modification has been implemented since this year and it is not specified in the Stock annex.

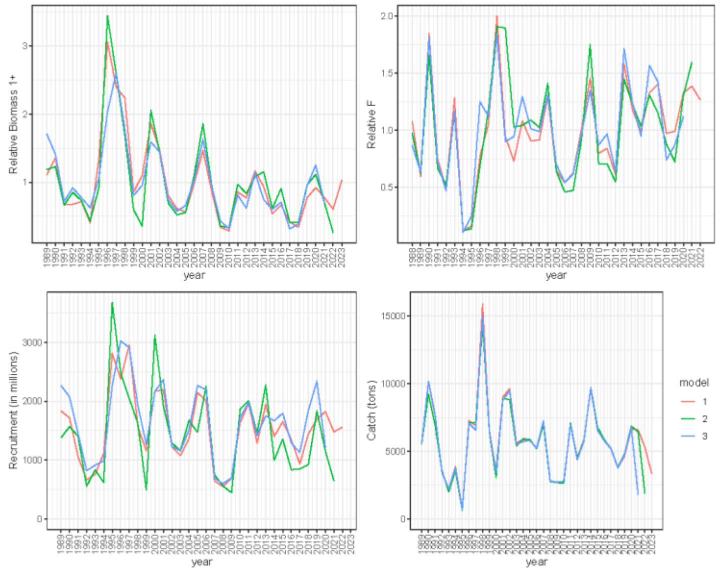


Figure 16: Comparison of estimates from different model implementations. Pink line corresponds to the current year estimated time series (the one estimated by the model described in this document), the green line, to the estimated in 2022 and the blue line, to the estimated in 2021. Measures were summarized at the end of June each year, assuming that a year starts in July and ends in June of the next year.

8.2. Constant harvest rate rule

According to this rule, adviced catches (in tonnes) for the next year (July 2023 to June 2024) would be the product of the last year biomass estimate and a constant harvest rate. In this case a rate of 0.5 was considered like the most suitable rate for this stock, as follows:

$$C_{y+1} = B_y * 0.5 = 4402 * 0.5 = 2201.$$

This procedure modification has been implemented since this year and it is not specified in the Stock annex.

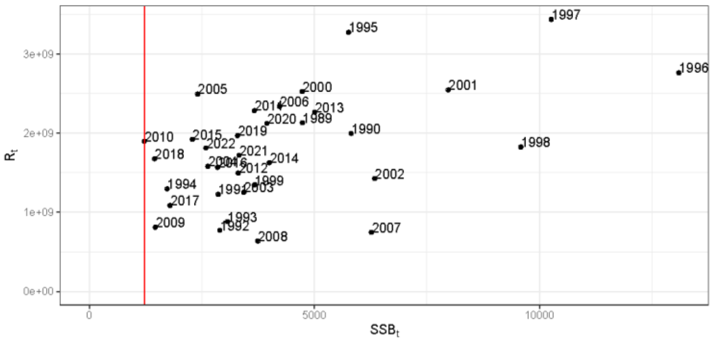


Figure 17: Estimated Stock Spawning biomass (SSB_t) vs. Recruitment (R_t), SSB_t corresponds to the Stock Spawning Biomass at the end of quarter 2 of year t, while R_t corresponds to the sum of the recruitment at the beginning of quarters 3,4 and 1 of years t and $t+1$, respectively.

9. Acknowledgements

We thank Jamie Lentin from Shuttlethread for the automatization of data input, Bjarki Elvarsson for having an open repository with very useful Gadget data processing routines and his valuable help, and to the members of WGHANSA group for their guidance and support.

We gratefully thank CESGA (Galician Supercomputing Center) for computational time at the FTII Supercomputer and technical assistance.

10. References

Begley, J., 2004. Gadget User Guide. URL: `http://www.hafro.is/gadget/files/userguide.pdf`.

Bellido, J.M., Pierce, G.J., Romero, J.L., Millan, M., 2000. Use of frequency analysis methods to estimate growth of anchovy (*Engraulis encrasicolus L.* 1758) in the gulf of cádiz (SW spain). Fisheries Research 48, 107–115.

Elvarsson, B., Taylor, L., Trenkel, V., Kupca, V., Stefansson, G., 2014. A bootstrap method for estimating bias and variance in statistical fisheries modelling frameworks using highly disparate datasets. African Journal of Marine Science 36, 99–110. URL: `http://www.tandfonline.com/doi/abs/10.2989/1814232X.2014.897253`, doi:`10.2989/1814232X.2014.897253`.

Gislason, H., Daan, N., Rice, J.C., Pope, J.G., 2010. Size, growth, temperature and the natural mortality of marine fish. Fish and Fisheries 11, 149–158.

Lentin, J., 2014. mfdb: MareFrame DB Querying Library. R package version 3.2-0.

Stefansson, G., 2003. Issues in Multispecies Models. Natural Resource Modeling 16, 415–437. URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1939-7445.2003.tb00121.x/abstract, doi:10.1111/j.1939-7445.2003.tb00121.x.

Stefánsson, G., 1998. Comparing different information sources in a multispecies context. Fishery stock assessment models. Alaska Sea Grant College Program. AK-SG-98-01 , 741–758URL: http://mdgs.un.org/unsd/envaccounting/ceea/archive/Fish/Iceland.PDF.

Taylor, L., Begley, J., Kupca, V., Stefansson, G., 2007. A simple implementation of the statistical modelling framework Gadget for cod in Icelandic waters. African Journal of Marine Science 29, 223–245. URL: http://www.tandfonline.com/doi/abs/10.2989/AJMS.2007.29.2.7.190, doi:10.2989/AJMS.2007.29.2.7.190.

Annex 3: Stock Annexes

The table below provides an overview of the WGHANSA Stock Annexes. Stock Annexes for other stocks are available on the ICES website library under the publication type "Stock Annexes". Use the search facility to find a particular Stock Annex, refining your search in the left-hand column to include the *year*, *ecoregion*, *species*, and *acronym* of the relevant ICES expert group.

Stock ID	Stock name	Last up-dated	Link
ane.27.8	Anchovy (*Engraulis encrasicolus*) in Subarea 8 (Bay of Biscay)	October 2013	Anchovy 8
ane.27.9a	Anchovy (*Engraulis encrasicolus*) in Division 9.a (Atlantic Iberian waters)	July 2018	Anchovy 9a
hom.27.9a	Horse mackerel (*Trachurus trachurus*) in Division 9.a (Atlantic Iberian waters)	May 2021	Southern horse mackerel 9a
jaa.27.10a2	Blue jack mackerel (*Trachurus picturatus*) in Subdivision 10.a.2 (Azores grounds)	June 2015	Blue jack mackerel 10a2
pil.27.7	Sardine (*Sardina pilchardus*) in Subarea 7 (Bay of Biscay, southern Celtic Seas, and the English Channel)	November 2021	Sardine 7
pil.27.8abd	Sardine (*Sardina pilchardus*) in divisions 8.a–b and 8.d (Bay of Biscay)	December 2022	Sardine 8abd
pil.27.8c9a	Sardine (*Sardina pilchardus*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)	November 2023	Sardine 8c and 9a

Annex 4: Audits

Review of ICES Scientific Report, WGHANSA 2023, 29 May – 2 June

Expert group Chair: Leire Ibaibarriaga

Secretariat representative: David Miller

Audit of Anchovy 9a
Date: 05/06/2023
Auditor: **Andrés Uriarte**

General
The stock of anchovy in 9a is divided in western and southern components following the 2018 benchmark. Each component is assessed separately. Both components are classified as ICES category 3 stocks and Catch advice has been based on the recently approved ICES-guidelines for short lived species category 3 stocks, whereby catch advice is changed from year to year according to the 1-over-2 rule subject to an uncertainty cap of +/- 80% (maximum relative allowable change between years). Nevertheless, an interbenchmark has been carried out before the May WGHANSA meeting to define Constant Harvest rate (CHR) strategies to manage these anchovy populations. Final MSE work have been presented to the WGHANSA meeting covering most of the suggestions made by the external reviewers. The WGHANSA group has proposed risk averse sustainable CHRs which could be applicable to these stocks for provision of advice, and which have been inserted in the table of catch options (instead of the original 1 over 2 rule).

- For both components the stock annex has been followed as much as possible. However for the Southern major weakness has come from the lack of the summer ECOCADIZ acoustic survey in 9aSouth in 2021 and 2022 whose continuity is not guaranteed. In addition the age composition of the PELAGO 2023 survey for this southern region was not taken into account by the group because experts indicated the proportions by age should be further checked and were considered too premature.
- Catch option based on the default 1 over 2 rule and on the constant harves rate CHRs have been both evaluated by the group but only the CHR are included in the draft summary sheet for consideration of ADG and ACOM

There is an increasing amount of auxiliary information which is not yet taken into account for the assessment. In particular for anchovy in 9a South, information from the acoustic survey ECOCADIZ-Reclutas series and from the DEPM (carried out every three years) is not used. ECOCADIZ-Reclutas aims at assessing the strength of anchovy recruitment (juveniles); the series started in 2012 and nowadays there is a total of 10 surveys available to the group. The DEPM assesses the anchovy Spawning Biomass. The series started in 2005 and a total of 6 surveys have already been reported to the group. In 2023 a new DEPM survey will take place.

For the western component the information on recruits coming from IBERAS acoustic survey in autumn is not used, though preliminary analysis of its consistency versus the PELAGO age 1 estimates in the following year, shows it yet to be weak.

Recommendation: The evaluation of the potential utility of these surveys to improve the assessment and provision of advice should be checked at the future benchmark scheduled for 2024.

A. Audit for Anchovy 9a South:

For the southern component of anchovy in 9a (distributed in 9a South) the stock size indicator is the SSB (that equals B1+) at the end of the second quarter, as estimated from the GADGET assessment model. This is the sixth year where advice following the precautionary approach will be provided and the fifth without the use of the 80% uncertainty cap (because in the first year a 20% UC was applied).

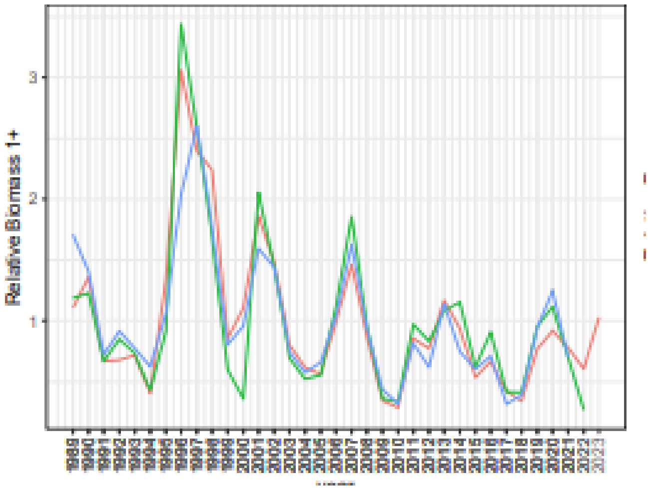
The assessment of Anchovy 9a South:

- It was carried out as expected, i.e. following the stock annex, by incorporating the new information from the acoustic survey PELAGO 2023 (without the age composition), and commercial catch in the last year (2022) with the quarterly ALKs and finally the total catch for the first half of the year 2023 (assuming historical % of catches in June).

For single stock summary sheet advice:

1) **Assessment type:** update (last benchmarked in 2018)
2) **Assessment**: Analytical assessment accepted. Since this is a Category 3 stock, the analytical assessment is only used as a relative indicator of stock trends (not as absolute estimates). Historical Outputs are rather consistent with past year, except for the latest biomass trends affecting advice which have changed markedly (see below comments).
3) **Forecast**: not required; The advice follows the catch advice Rule for category 3 short lived data limited stocks.
4) **Assessment model**: Gadget in quarterly time steps using catches by length and ALKs + 2 acoustic surveys (biomass index, length distribution and ALKs): PELAGO (Spring, 2023 index included without the age composition) and ECOCADIZ just until Summer 2020 (already included in the assessments carried out in 2021 and 2022).
5) **Consistency**: This new assessment was carried out accordingly to the stock annex but the ECOCADIZ survey estimate in 2021 and 2022 were missing and age composition from PELAGO was removed.

Compared to last year assessment, Outputs are rather consistent with past year, except for the latest biomass trends in 2021 and 2022, which in in last year resulted in pronounced reduction trend (dropping to 26% of the historical mean), whilst in 2023 the decline is not so sharp (dropping to 61% of the mean). These changes are somewhat expected with the addition of new data (catch and index information), however have a major impact on the advice would have been provided in last year if current correction would been known. This affects the advice procedure which uses recent biomass ratios to correct the former catch advices (see technical comments at the end of this subsection on anchovy in 9a).



6) **Stock status**: Relative Biomass in 2023 is assessed to be around mean historical Biomass (B2023/Bhistorical = 1.03). Biomass in 2022 was assessed to be below Blim in the assessment carried out last year, but this year there is an upward correction and B2022 is assessed to be about 61% mean historical biomass. Therefore the warning passed last year is not sustained with the current perception of the stock trends. B_{lim} is assumed as B_{loss}, excluding the last year of the assessment. B_{loss} corresponds to the estimated B1+ in 2010.

7) **Management Plan**: There is no management plan for this stock.

8) **Basis of the advice**: Until 2022 a trend based advice, following the "one-over-two" ratio of B1+ series from the Gadget assessment model, with an uncertainty cap of +/- 80%, was applied to the former catch advice of the previous management season (from July previous year to June of the interim year). This was like in-year advice as approved in the stock annex for this category 3 stock. Following the annex in WKLIFE X (ICES 2021) the rule in 2022 was implemented with a biomass safe guard reducing factor, because the B1+ was estimated to be below B_{lim}, which is taken as $B_{trigger}$ for this assessment.

   This year 2023, a constant harvest rate (CHR) applicable to the spawning biomass reported for the current year 2023 (as if it were an absolute estimator) is used to provide the advice for the period July 2023 to June 2024. A CHR of 0.5 was selected through MSE as the maximum CHR proved sustainable and risk averse given the uncertainties in growth and natural mortality and on the actual catchability affecting the surveys used to input the assessment, whereby a maximum presumed catchability was taken to be the one resulting from the assessment (i.e., 3.65 for PELAGO and 4.65 for Ecocadiz). The high values of maximum potential catchability are far above normal catchability values assessed for acoustic surveys on anchovy in other areas, as for instance for Bay of Biscay anchovy (with catchability assessed to be around 1.45 -- ICES 2022); south African anchovy (with catchability assessed to be slightly smaller than 1 -- De Moor 2020). The catchability of the PELAGO survey on sardine as assessed for the Iberian sardine stock (sar 8c9a) was last year estimated to be about 1.34 (lnQ= 0.293). And Acoustic catchability for sardine in the Californian waters is considered to be around 1 (Zwolinski and Demer 2013), although in recent years it is assumed to be around 0.74 in order to include unsurveyed close to coast sardine distribution of abundance (Kuriyama et al. 2020).
   Those high maximum presumed catchability values were allowed just to secure that the chosen CHR is risk averse, and such CHR is considered valid as an interim solution until a new benchmark takes place in 2024.

In order to cope with the eventuality of the current CHR approach to provide advice not being accepted by the ADG, an alternative advice in terms of 1-over-2 ratio (1.49) is provided in the WG report, allowing catches of about 2517 t. This year there is no need of applying a biomass safeguard and actually that was also unnecessary in the last year advice. This imply that the current 1over2 advice is conditioned (and reduced) by the undue reduction of the advice in the previous year.

- **Data issues:** the summer ECOCADIZ acoustic survey in 9a South in 2021 and 2022 were not carried out due to technical problems and because of other priorities and hence couldn't be used as input to the assessment. The continuity of this survey is not guaranteed.
- In addition this year the age composition from PELAGO 2023 was not taken into account. The reason for not including it was that the age reader experts of IPMA and IEO considered that this composition was not reliable yet and required joint discussion from. WGHANSA had prompted a question to the experts on the reliability of this age composition because preliminary look at those results pointed out contradictions with the past year biomass estimates in PELAGO. Preliminary assessments also showed that the age composition input induced a major revision of recent trend in the anchovy assessments. Therefore, corroboration was required before using such input for the standard assessment.
- Some additional surveys (ECOCADIZ-Reclutas and Bocadeva) are available but aren't used in the assessment. This was agreed in the 2018 benchmark because at the time the time series was considered too short (e.g. Bocadeva) or their performance was still in evaluation (e.g. JUVESAR, ECOCADIZ-Reclutas). Its considered that the time has come to test for their reliability as to be used in future assessments.

General comments
The assessment was well documented and the stock annex was followed, except in the basis for the provision of advice.

Technical comments
The group acknowledges that the estimated SSB (= B1+) time series is being updated every year with the addition of new data. This causes some changes in the relative changes of B1+ estimates between the most recent years which affects the consistency of the ratios used for the provision of advice between updated assessments. Such inconsistencies affect the catch advice and actually propagate to the following years in case of using the 1over2 rule.
This derives from the fact that the trend advisory rule (1-over-2) assumes implicitly that past advice is unbiased, but since every new assessment updates the whole time series estimates of the indicator B1+, it is likely that the trend based indicator for providing advice in previous years were partially biased (as far as the biomass series of B1+ estimates have changed). Therefore, the application of the 1 over 2 rule is incorporating a catch advise for the previous year which is known to be inconsistent with what would have been advised in case of perceiving the population as in the current (most recent) assessment. This is probably a general problem which may affect others stock in category 3 with an indicator linked to an analytical assessment. However, this type of situation was not considered when putting forward the guidelines for category 3 short lived species. Certainly the stability/variability of the assessment producing the stock trend indicators is something that has to be incorporated when assessing the performance of these HCRs for category 3 stocks and it requires further investigations.

Using the CHR for provision of advice doe not incur on the same propagation of errors in time as the 1 over 2, thought it will still be sujected to the biass in the most recent biomass estimates of the stock.

On the basis of the advice: ADVICE does not deviate from the standard ICES guidelines for category 3 short lived stocks, as far the CHR is included as Method 3.2 for short lived species (ICES 2022b)

Conclusions

- The assessment has been performed correctly SALY.

- The southern component of the stock is assessed to be about historical mean
- The revision of the estimates of B1+ in recent years, according to the updated assessment, would have induced some changes (upwards) in the advice of previous years
- The basis of the advice deviates from the 1over 2 rule applied in previous years and moves to a risk averse CHR of 0.5 after a full analysis through MSE.

References

ICES. 2022. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 4:51. 518 pp. http://doi.org/10.17895/ices.pub.19982720

ICES 2022b. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11. https://doi.org/10.17895/ices.advice.19801564

de Moor, C. 2020. The South African anchovy assessment with an informative prior distribution on the bias in hydroacoustic survey estimates of abundance. Department of Forestry, Fisheries and the Environment: Branch Fisheries Document FISHERIES/2020/JUN/SWG‐PEL/40.

Peter T. Kuriyama, Juan P. Zwolinski, Kevin T. Hill, and Paul R. Crone. 2020. Assessment of the Pacific sardine resource in 2020 for U.S. management in 2020-2021, U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-628.

Zwolinski, J. P., and Demer, D. A. 2013. Measurements of natural mortality for Pacific sardine (Sardinops sagax). – ICES Journal of Marine Science, 70: 1408–1415.

Stock. Anchovy 9a. Western component

Auditor: Rosana Ourens

General

The stock of anchovy in 9a is divided in western and southern components following the 2018 benchmark and they are assessed separately. Both components are classified as ICES category 3 stocks and the catch advice has been based on the 1-over-2 rule subject to an uncertainty cap of +/- 80% (maximum relative allowable change between years) in recent years. However, before WGHANSA 2023, there was an ICES workshop to evaluate the performance of a constant harvest rate (CHR) simulated with a management strategy evaluation (MSE) for both components independently. The authors of the MSE presented in WGHANSA the newest work to address most of the comments from the external reviewers of the workshop. WGHANSA welcomed the updates and suggests using a CHR (25% for the western component and 50% for the southern component) to provide advice for the period July 2023-June 2024. It must be noted that the stock will be benchmarked again in 2024, and therefore the basis for the advice might change again next year.

Audit for the western component:

Assessment type: update (last benchmark in 2018)

Assessment: accepted

Forecast: not required. The advice follows the catch advice rule for category 3 short-lived stocks

Assessment model: There is no assessment model. The assessment and advice are based on the combined spring acoustic surveys covering subdivisions 9a North + 9a Central North + 9a Central South (PELAGO and PELACUS).

Consistency: The biomass index for 2023 was estimated as stated in the stock annex. The basis for the advice has changed as explained above.

Stock status: The stock status is unknown because reference points are undefined. However, the biomass index 2023 is the second highest value of the time series (2007-2023).

Management plan: There is no management plan for this stock.

General comments

The assessment was well documented, and the stock annex was followed, except for the basis of the advice.

The new information from PELAGO 2023 + PELACUS 2023, and the commercial catch in the second half of year 2022 and the first half of the year 2023 catches (assuming catches in May and June) were presented. Catches in 2022 were lower than in 2021 but similar to the values in 2020. The biomass index also decreased compared to 2022 but it is still the second highest value in the time series.

In order to cope with the eventuality of the current CHR approach to provide advice not being accepted by the ADG, an alternative advice based on the 1-over-2 ratio (0.83) is provided in the WG report, which advise catches up to 11640 t. The MSE work presented in the workshop, the reviewers comments, and the updated work done to address the reviewers' comments are included in the WG report.

Technical comments

The WG report has not been reviewed because it was not available at the moment of this audit.

Conclusions

The assessment has been performed correctly.

The biomass of the western component of the anchovy stock is assessed to be well above historical mean value.

The basis of the advice deviates from the 1over 2 rule applied in previous years and moves to a risk averse CHR of 25% after an analysis through MSE. The basis for the new advice is still in line with the ICES guidelines for short-lived stocks (ICES 2022).

References

ICES 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11. https://doi.org/10.17895/ices.advice.19801564

Southern Horse Mackerel (hom.27.9a)

Date: 09/06/2022
Auditor: Leire Citores

General

The southern horse mackerel stock is analytically assessed every year using annual Spanish and Portuguese catch and survey data, for which some missing data was reported in years 2012, 2019 and 2020 due to technical/legal issues or Covid disruption in 2020. For 2021 and 2022 no missing data was reported, and the assessment model fitting was carried out following the stock annex.

For single-stock summary sheet advice

Stock: hom.27.9a

1) Assessment type: update (SALY)
2) Assessment: accepted
3) Forecast: accepted
4) Assessment model: AMISH (Assessment Method for the Ibero-Atlantic Southern Horse mackerel)– as in stock annex – tuning by time-series of total catch, catch-at-age, biomass index of IBTS survey, abundance-at-age from IBTS survey and mean weight-at-age in the catch and stock.
5) Consistency: The assessment is consistent with last year assessment; Fishing mortality and SSB in 2021 remain basically the same as in the last assessment, no significant upward or downward revisions have been observed.
6) Stock status: SSB >> MSYBtrigger; F << FMSY ; high uncertainty on R and SSB.
7) Management plan: A management plan was proposed and evaluated as precautionary by ICES (ICES, 2018). However, ICES was requested by the EU to base its advice for 2023 on the ICES MSY approach and include the MP as a catch scenario.

General comments

The assessment was well documented, no deviations from the stock annex were needed. Input data for stock assessment and short-term forecast was checked by confronting the report tables and the input and output data files.

Technical comments: none

Conclusions

- The assessment has been performed correctly SALY.
- The update assessment gives a valid basis for advice.
- The perception is consistent with previous years with fishing mortalities below F_{MSY} and SSB above $MSYB_{trigger}$
- There is a concern about the assumptions on selectivity for catch-at-age on the last period of the assessment that may lead to a misestimation of the total biomass of the stock. It is noted that the possible violation of this assumptions needs immediate investigation. Some alternative models were presented during the working group, however, this issue will be addressed during next benchmark in 2024.

Audit of Bay of Biscay anchovy stock (ane.27.8)

Reviewers: Lionel Pawlowski

Expert group Chair: Leire Ibaibarriaga

Secretariat representative: David Miller

General

The stock assessment was conducted using a Bayesian two-stage biomass model (CBBM; Ibaibarriaga et al., 2011). The stock relies on biomass estimates from DEPM (BIOMAN survey) and Acoustic (PELGAS survey). A juvenile abundance index (JUVENA survey) is also used. Catch data are divided into 2 semesters. Input data are catch number- and weight- at age Population dynamics are described in biomass with two age groups: age 1 and age 2+. Model outputs are estimates of biomass and fishing mortality with 95% confidence intervals. The assessment followed the procedure set by the benchmark in 2013 (ICES, 2013) as described in the relevant stock annex. The assessment does not show major issues. Some residuals show some drifts that have there for many years and that will be explored during next benchmark.

This year, the assessment shows a downward revision of SSB in previous years unusually greater but this is likely the consequence of conflicting signals between survey trends and model assumptions. This was not considered as an issue as it has happened occasionally in past assessments.

The advice has been repeatedly a fixed ceiling (33000t) value for several years due to a continuous overall good shape of the stock and the implementation of a long-term management plan for this fishery in place of ICES MSY traditional approach. This assessment will be benchmarked in 2024. This might imply in addition of changes in model settings, revision of reference points and management plan.

For single-stock summary sheet advice

Ane.27.8 Bay of Biscay anchovy.

Short description of the assessment as follows:

8) Assessment type: Update.
9) Assessment: Accepted.
10) Forecast: Accepted.
11) Assessment model: Bayesian two-stage biomass dynamic model. Inputs to the model are the total catch in weight by semester, catch numbers- and weight-at-age.
12) Consistency: Assessment has been continuously accepted since the benchmark in 2013. This year follows the settings of the stock annex. As last year, the age structure for the French catches was missing due to lack of length sampling, therefore the age structure is considered to be the same than the one for the Spanish catches. This is not considered to be an issue considering also the very low amount of French catches.
13) Stock status: B>Blim since 2010. No reference exists for Flim, Fmsy and MSY Btrigger
14) Management plan: A long-term management plan using a harvest control rule was evaluated as precautionary by ICES and agreed in 2016. According to this HCR,

TAC_{y+1}=0 if the estimated $SSB_{y+1} \leq$ 24000 tonnes, TAC_{y+1}=-2600+0.4*SSB_{y+1} if 24000 ≤ $SSB_{y+1} \leq$ 89000 tonnes and TAC_{y+1} = 33000 tonnes if SSB_{y+1} > 89000 tonnes.

General comments

The assessment is well document. No deviations from the stock annex were needed. All informations (input data, rationales, code) were available and checked. Assessment this year stays consistent with last year's one.

Technical comments

- In the advice sheet, a small error has been found regarding the mention of the Pelgas time series in table 5. The survey did not operate in 2020 due to COVID therefore the time period should probably be labelled 1989–2019, 2021-2023.
- In a similar way than for the Bay of Biscay sardine advice and as it is mentioned in the issues relevant to the advice, it would be more consistent across stock advice sheets to have in table 8 the amount of catches in 25E4, 25E5 although it's a small proportion among the small contribution of French catches. But in cases, the proportions of French catches and/in those rectangles increase substantially, it could be interesting to have that information available.

Conclusions

The assessment and short-term forecast have been performed accordingly to stock annex and no major issues have been found in the assessment and data, giving a valid basis for advice.

References

Ibaibarriaga, L., Fernandez, C., and Uriarte, A. 2011. Gaining information from commercial catch for a Bayesian two stage biomass dynamic model: application to Bay of Biscay anchovy. – ICES Journal of Marine Science, 68: 1435 –1446.

ICES. 2013. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA 2013), 4–8 February 2013, Copenhagen, Denmark. ICES CM 2013/ACOM:46. 483 pp

Audit of Sardine (Sardina pilchardus) in Subarea 7 (southern Celtic Seas and the English Channel)

Review of ICES Scientific Report, WGHANSA 2023, 20-24 November 2023

Reviewers: Susana Garrido

Expert group Chair: Leire Ibaibarriaga

Secretariat representative: David Miller

Audience to write for: advice drafting group, ACOM, and next year's expert group

For single-stock summary sheet advice

Stock: Sardine (Sardina pilchardus) in Subarea 7 (southern Celtic Seas and the English Channel)

Short description of the assessment as follows:

1) Assessment type: update
2) Assessment: accepted
3) Forecast: No short-term projections have been carried out for this stock.
4) Assessment model: The stock was benchmarked in 2021 and upgraded from category 5 to category 3. Stock indicator is a time-series of biomass derived from the PELTIC acoustic survey. A surplus production model in continuous time (SPiCT) is used to provide indication of the status of the stock. The catch advice is then provided based on the 1-over-2 rule with a symmetric 80% uncertainty cap and a biomass safeguard.
5) Consistency: Assumptions of the model are met, namely the catch and biomass data have normal distributions, and there is no autocorrelation or bias in the data. Although the time-series is short and therefore the retrospective patterns of the model could not be properly analysed, the retrospective trajectories for the relative biomass and fishing mortality were inside of the confidence intervals and the Mohn's rho values were small. However, there is a tendency to overestimate biomass and underestimate the fishing mortality and parameter estimates are influenced by initial values.
6) Stock status: The survey index was estimated to have increased 62% with respect to 2022. The stock size was estimated to be above Istat (index trigger value for biomass safeguard, a precautionary approach reference point) and the biomass safeguard was not applied. MSY reference points are undefined.
7) Management plan: This stock doesn't have a management plan.

General comments

There was a discussion if the Istat should be updated but it was decided not to do it because Ihist is now 5 years long and updating it would mean including the 2022 PELTIC index that resulted from a survey with limited coverage (30% of the total area) for which the estimate was obtained by raising the historical proportion in the area. It was discussed that there was no intention to update the Istat value in the following years.

Technical comments

The 2023 guidance and checklist for audits in ICES expert groups was followed. The advice sheet, report section, and the TAF repository for the stock were used for this audit.

The assessment follows the methodology described in the stock annex. Minor issues in the advice sheet and in the report were detected during the audit and were amended accordingly.

Conclusions

The assessment has been performed correctly following the stock annex. Everything was well documented and included the necessary generic information needed for an ICES category 3 assessment and producing the advice sheet.

Audit of Sardine (*Sardina pilchardus*) in divisions 8.a–b and 8.d (Bay of Biscay)

Review of ICES Scientific Report, WGHANSA 2023, 20-24 November

Reviewers: Rosana Ourens

Expert group Chair: Leire Ibaibarriaga

Secretariat representative: David Miller

Audience to write for: advice drafting group, ACOM, and next year's expert group

General

The stock is assessed using an age-based model in Stock Synthesis 3. French catches from ICES rectangles 25E5 and 25E4 (in Subarea 7) have been allocated to Division 8a as they occur at the boundary of both sardine stocks. These catches typically represent 25% of the total stock catches, and this percentage increased in the last two years up to 47% of the total stock catches. The boundary between both sardine stocks in Subareas 7 and 8 is uncertain and the origin of the French catches in those rectangles should be revised.

Residuals do not highlight major issues regarding the input data and model fit, although there is a slight tendency to overestimate SSB and underestimate F. This retrospective pattern was less clear this year.

The spawning biomass shows a decreasing trend since 2012. In the last few years, there was also observed a decreasing trend in the weight-at-age and maturity-at-age. The impact of these decreasing trends in the SSB estimations was discussed during the working group. The spawning biomass is below MSY $B_{trigger}$, B_{pa}, and above Blim. Fishing pressure on the stock is above F_{MSY} and below F_{lim}.

As the stock is below MSY $B_{trigger,}$ the advised catch for 2024 is based on the deterministic projection (*fwd* function from FLR) with F = F_{MSY} * SSB(2024)/ MSY $B_{trigger}$ = 0.37. The advice for 2024 (19 811 tonnes) is 7.8% lower than the advice for 2023 due to a decline in weight at age, a low proportion of age-1 fish reaching maturity, and a persistently under average biomass index value.
The stock assessment and short term forecast followed the methodology described in the stock annex.

For single-stock summary sheet advice

Stock: **Sardine in Bay of Biscay (pil.27.8abd)**

1) **Assessment type:** update
2) **Assessment:** accepted
3) **Forecast:** accepted
4) **Assessment model:** The model used is Stock Synthesis 3, version 3.24. The sardine assessment is an age-based assessment assuming a single area, a single fishery, a yearly season and genders combined. Input data included updates from catch (in tonnes), age composition of the catch, total abundance (in numbers) and age composition from the annual acoustic survey (PELGAS), egg abundance from BIOMAN survey and SSB from a triennial DEPM survey.
5) **Consistency:** The retrospective analysis shows that there is a tendency to overestimate biomass and underestimate F, although the 2022 and 2023 assessment outputs were quite consistent. Consequently, the Mohn's rho

values for F and SSB are smaller than last year (-0.14 and 0.24, respectively).

6) **Stock status:** Fishing mortality is above F_{MSY} and F_{pa} and below F_{lim}. SSB shows a decreasing trend since 2012 and it is has been below MSY Btrigger in the last 3 years. Recruitment in 2022 was at average levels.
7) **Management plan:** There is no management plan and no official TAC is set for this stock. ICES advice is based on the MSY approach.

General comments

The 2023 guidance and checklist for audits in ICES expert groups was followed. The presentation in the sharepoint, advice sheet, report section, and the TAF repository for the stock were used for this audit.

The assessment follows the agreed methodology in the 2019 interbenchmark and described in the stock annex. The stock annex was updated in December 2022 to incorporate minor suggestions from the audit last year.

Technical comments

Minor issues in the advice sheet and report were detected during the audit and the stock assessor and EG chair were contacted to amend them.

Conclusions

The assessment and short-term forecast have been performed correctly following the stock annex. Everything was well documented and included the necessary generic information needed for an ICES category 1 assessment and producing the advice sheet.

Audit of Sardine (*Sardina pilchardus*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian Waters)

Review of ICES Scientific Report, WGHANSA 2023, 20-24 November 2023

Reviewers: Leire Ibaibarriaga

Expert group Chair: Leire Ibaibarriaga

Secretariat representative: David Miller

Audience to write for: advice drafting group, ACOM, and next year's expert group

For single-stock summary sheet advice

Stock: Sardine (Sardina pilchardus) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian Waters)

Short description of the assessment as follows:

1) Assessment type: update
2) Assessment: accepted
3) Forecast: accepted
4) Assessment model: Age-structured model implemented in Stock Synthesis (V3.30.22.00) that uses as input single fleet catch-at-age, weight-at-age in the catch, total abundance (numbers) and age-structure indices from a joint acoustic survey and SSB index from triennial joint DEPM survey. Stock maturity-at-age and weight-at-age are taken from the triennial joint DEPM survey. In the intermediate years in which there is no DEPM survey, these values are linearly interpolated. Since the interbenchmark carried out in 2021, a recruitment index from an autumn acoustic survey is included in the assessment. Total catch for 2023 is provisional.
5) Consistency: The model tends to underestimate the stock size (B1+) and to overestimate the fishing mortality (Fbar ages 2-5). This year Mohn's rho values of B1+ is -0.363 and of Fbar is 0.457, which are slightly larger than in previous years.
6) Stock status: Fishing pressure on the stock is below FMSY. After a series of years in which the stock size has been below Blim, since 2017 the stock size is above Blim and since 2020 the stock size is above MSY Btrigger, Bpa. Recruitment is again estimated to be low in 2023.
7) Management plan: This stock doesn't have an EU-TAC and it's managed by the national legislations. In 2021, ICES assessed by simulation the performance of a set of harvest control rules. The harvest control rules (HCRs) HCR30, HCR35, HCR40, HCR45, and HCR50 were assessed to be consistent with ICES precautionary criterion of no more than 5% probability of the spawning stock biomass (B1+) falling below Blim in both the short and the long term and in both low (current) and a low–medium (transition) productivity scenarios (ICES, 2021a). Portugal and Spain agreed a management plan for 2021-2026 that included the tested HCRs. For 2023, Portugal and Spain agreed to implement a total catch of 56 604 tonnes, based on the maximum fishing mortality of 0.12 of the HCRs of the management plan, but without any cap.

General comments

Sardine in divisions 8.c and 9.a is a Category 1 stock that is assessed yearly using an age-structured assessment model implemented in Stock Synthesis. Apart from the information from the fishery, the model uses information on abundance and age structure from acoustic and DEPM surveys and indications of recruitment from an autumn acoustic survey.

The recruitment index corresponds to age-0 abundance in the 9aCN area as estimated from the IBERAS survey. This area is assumed to cover the core recruitment area of the stock. However, in 2023 the age 0 abundance in this area was almost null. The age 0 individuals found outside this area was also low, but showed a spatial distribution different from the previous years. This triggered the discussion on whether the area covered by the recruitment index should be expanded in the near future.

The 2023 catches included in the model are preliminary. Last year these catches were based on the bilateral agreement between Portugal and Spain. This year the agreed catches were 56 604 tonnes based on the HCR without cap. Based on the catches of both countries until the end of October, this number looked unrealistic and the WG decided to use the HCR with the cap of 50 000 tonnes as preliminary catches.

Maturity-at-age and weight-at-age estimates included in the stock assessment correspond to the joint DEPM surveys that are conducted triennially. This year the latest estimates from the 2023 surveys were included. Most of the individuals found in the survey were mature, which resulted in problems for estimating the maturity ogive curve. Therefore, the maturity-at-age was based on raw maturity percentages by age class. The percentage of age 1 individuals was estimated to be very large, and these will be the values used until a next DEPM survey results are available. This does not affect the stock size with respect to the precautionary reference points, as the stock size is evaluated in terms of age 1+ biomass (instead of SSB).

The residuals for some of the survey indices (e.g. acoustic survey) are a bit worse than usual. This may be due to conflicting signals between the survey indices and should be further investigated.

The retrospective analysis shows that the stock size tends to be underestimated while the fishing mortality tends to be overestimated. As a consequence, the Mohn's rho values are slightly worse than in previous years, and should be further investigated.

The stock is assumed to be in a low productivity regime since 2006, but there are indications that the stock may be moving to a higher productivity regime. There are no clear guidelines on the exact conditions needed to corroborate a regime shift. After some improved recruitments in the period 2019-2022, the 2023 recruitment is among the lowest of the time series. This stopped the WG to further discuss the possibility of abandoning the low recruitment scenario. However, the WG will need to continue monitoring the productivity regime in the subsequent years.

Technical comments

The 2023 guidance and checklist for audits in ICES expert groups was followed. The advice sheet, report section, and the TAF repository for the stock were used for this audit.

The assessment follows the methodology described in the stock annex. Minor issues in the advice sheet and in the report were detected during the audit and were amended accordingly.

Conclusions

The assessment and short-term forecast have been performed correctly following the stock annex. Everything was well documented and included the necessary generic information needed for an ICES category 1 assessment and producing the advice sheet.

Annex 5: Joint Session WGACEGG-WGHANSA

On the first day of WGHANSA-1, 29th May 2023, a joint WGACEGG-WGHANSA session took place. The objective was to present and discuss the abundance indices of the PELAGO and PELACUS acoustic surveys before their inclusion in the stock assessment.

The following presentations were carried out:

- "PELAGO 23 Acoustic survey. Preliminary Results"
- "PELACUS 23: Preliminary results"

The main results of these presentations are briefly summarised in the stock assessment input data sections of the WGHANSA report.

The estimates from the surveys were not fully available during the presentations but were made available during the first day of WGHANSA-1. Overall, the estimates were considered sufficiently reliable and the abundance indices from PELAGO and PELACUS 2023 surveys were approved for their inclusion in the stock assessment. The WGs identified some inconsistencies on the PELAGO age structured estimates. Therefore, the age structured estimates were not included in the stock assessment until further verifications are carried out. These surveys will be discussed more extensively within WGACEGG in the meeting that will take place in November 2023 and a detailed description will be available in the corresponding WGACEGG report.

Annex 6: Working Documents of the 27.9.a anchovy MSE

This annex contains the working documents with the methods, results and conclusions of the MSE work for the 27.9.a anchovy stock (separately for components south and west) that were presented during the online meeting of WGHANSA members and the ICES designated external reviewers, hold the 5th of May 2023. It also includes two separate documents with the reviewer´s comments, and two working documents including the extra MSE work conducted to deal with the main reviewer´s concerns.

Working documents online meeting 5th of May 2023:

Pérez-Rodríguez, A; Zúñiga, M.J.; Sánchez, S.; Ramos, F.; Wise, L. and Rincón, M.M. 2023a. Anchovy 9a southern stock-specific management strategy evaluation conducted to determine an alternative to the current advice rule.

Wise, L., Garrido, S. and Silva, A. A, Pérez-Rodríguez, A. 2023a. Anchovy 9a west stock-specific management strategy evaluation conducted to determine an alternative to the current advice rule.

External reviewers documents:

Elvarsson, B. 2023. Review of the 2023 WGHANSA MSE for anchovy in ICES Division 9.a

Fischer, S. 2023. Review of the 2023 WGHANSA MSE for anchovy in ICES Division 9.a

Working documents presented during the WGHANSA-I 2023 meeting:

Pérez-Rodríguez, A; Woods, P.; Zúñiga, M.J.; Sánchez, S.; Ramos, F.; Wise, L. and Rincón, M.M. 2023b. Additional work and reply to reviewers concerning: Anchovy 9a southern stock-specific management strategy evaluation conducted to determine an alternative to the current advice rule

Wise, L., Garrido, S., Silva, A. A., Pérez-Rodríguez, A , Ibaibarriaga, L. and Uriarte, A. 2023b. Additional work and reply to reviewers concerning: Anchovy 9a west stock-specific management strategy evaluation conducted to determine an alternative to the current advice rule.

WORKING DOCUMENT

Anchovy 9a southern stock-specific management strategy evaluation conducted to determine an alternative to the current advice rule

Authors: Pérez-Rodríguez, A; Zúñiga, M. J.; Sánchez, S.; Ramos, F.; Wise, L.; and Rincón, M.M.

1 Introduction

The anchovy stock in the ICES division 27.9.a (Figure 1.1) includes two components of the same stock: west (ICES sub-divisions 9a.N, 9aCN and 9aCS) and south (ICES sub-divisions 9a.S).

Scientific advice for this stock started in 2018 after a Benchmark WKPELA 2018 (ICES 2018). WKPELA 2018 supported the proposal of considering two different components of the stock (western and southern component) due to the different dynamics of their fisheries and populations. However, it advised to add more information regarding the structure along the distribution, namely genetic information, and until then, the provision of advice should be given for the whole stock, but with separate catch advice for each stock component. An in-year monitoring and management was proposed, as for other small pelagic fish, and the management calendar for the application of the advice has been agreed to be the one from 1st July of year *y* to 30th June of year *y+1* since 2018 onwards.

Assessment for this stock is done in the framework of the ICES Working Group of Horse mackerel, anchovy and sardine (ICES-WGHANSA) that meets at the end of May to decide upon the advice for this stock from July of the same year to June of the following year.

Figure 1.1 - ICES Statistical Divisions and Subdivisions in Southern Europe. Western component of anchovy stock distributes in the area identified in blue as 9.a. West (comprising Sub-divisions 9aN, 9aCN, 9aCS). Southern component of anchovy stock distributes in the area identified in blue as 9.a. South (comprising sub-divisions 27.9.a.S -Portugal- and 27.9.a.S - Spain).

1.1 Goals of the MSE for 27.9a_south anchovy component

The MSE exercise of constant harvest rates strategies for the south component of anchovy in Division 27.9a is intended to:

a) Develop a Management Strategy Evaluation framework to test alternative advice rules for anchovy in Division 9a south component (Gulf of Cádiz);
b) Identify constant harvest rate rules that could be appropriate to provide advice for this stock and compare them with respect to the current basis for advice (1-over-2 rule with 80% uncertainty cap and biomass safeguard).

1.2 Current advice rule (Method DLSSL 3 – 1-over-2 rule)

Currently, ICES framework for category 3 short-lived stocks is applied (ICES, 2021) whereby the 1-over-2 rule is constrained by an uncertainty cap of +/- 80% of the former catch advice as follows:

$$A_{y+1} = \left\{ \begin{Bmatrix} 0.2\, A_y & \frac{I_y}{\sum_{y-1}^{y-2} I_y/2} < 0.2 \\ A_y \frac{I_y}{\sum_{y-1}^{y-2} I_y/2} & 0.2 \leq \frac{I_y}{\sum_{y-1}^{y-2} I_y/2} < 1.8 \\ 1.8\, A_y & \frac{I_y}{\sum_{y-1}^{y-2} I_y/2} \geq 1.8 \end{Bmatrix} \right. \cdot \left[min\left(1, \frac{I_{current}}{I_{trig}}\right)\right]$$

where A_y and I_y represent the advised catch and the estimated Spawning Stock Biomass (*SSB*) for year *y* obtained from the Gadget assessment model, respectively. The first and third cases of the formula correspond to the application of an 80% symmetrical uncertainty cap.

The last term in the equation refers to the biomass safeguard based on a trigger index value, below which the advice would be corrected downwards in proportion to the drop of the most recent abundance index over the $I_{trigger}$ value. This is a term, which has been shown to further reduce the risks associated to this management system. The notation of these rules is for in-year advice where the advised catch for the current year is based on last year's advised catch adjusted by the trend in the most recent abundance index, I_y, relative to the average of the index value in the previous two years. An uncertainty cap is applied to limit the change in the index trend, the I_y component of the harvest control rule (*HCR*), to ±80%, which allows the current years advised catch to increase or decrease up to 80% relative to the previous year's advised catch."

For the southern component, the biomass input to this *1over2 HCR* are the estimates of the *SSB* from the approved Gadget assessment (ICES, 2018), which are taken as relative estimates (ICES, 2022).

1.3 Alternative to the current advice rule (Method DLSSL 2 – Constant harvest rate)

The current rule cannot accommodate the huge fluctuations in biomass of both components of the anchovy stock. For this reason, this approach is considered provisional, while a better formulation for providing advice is developed. According to WKLIFE X (ICES, 2021), the best way to adjust catches to the highly fluctuating nature of these stocks may be achieved by removing a constant fraction of the stock every year, corresponding with a sustainable harvest rate ($HR_{msy.proxy}$), applicable to the abundance indicator of the stock ($I_{current}$, the *SSB* estimate from the Gadget assessment model), so that the maximum probability of the *SSB* being below B_{lim} is kept <0.05.

$$A_{y+1} = I_{current} * HR_{MSY.proxy}$$

The constant harvest rate *HCR* (*chr*) can be complemented with a biomass safeguard factor based on a trigger index value, $I_{trigger}$, below which the advice should be corrected downwards in proportion to the drop of the most recent abundance index over the $I_{trigger}$ value.

$$A_{y+1} = I_{current} * HR_{MSY.proxy} * \min(1, \frac{I_{current}}{I_{trigger}})$$

A stock-specific management strategy evaluation (*MSE*) was conducted to determine the *chr* that is the most robust to the operating model (*OM*) and observation system uncertainties. The performance of the candidate *chr* and the 1over2 HCRs was compared

2 Assessment framework

The input data and model specifications presented below correspond to those benchmarked in WKPELA 2018 (ICES, 2018). The main difference is that results are presented now for the end of the second quarter of each year instead of the end of the fourth quarter. This responds to practical modifications in the definition of the assessment year, now it goes from July 1st to June 30th of the next year.

2.1 Data

Data input for optimization routines is summarized in Table 2.1.1. It corresponds to all the information of the fishery available until the end of June 2022, together with data from *ECOCADIZ* and *PELAGO* survey series up to 2020 (no *ECOCADIZ* survey in 2021) and 2022, respectively. Catches (landings +discards, discards from 2014 onwards) from Spain and Portugal are assumed to be removed from the population by only one fleet (purse seine) from 1989 to the second quarter of 2022.

Table 2.1.1.- Overview of the data used in the assessment model optimization. Due to lack of information of length distributions and Age-length keys for commercial catches in the first and second quarter of 2020, the length distribution was approximated using the joint distribution of 2018 and 2019 and the Age-length key used was the one for the PELAGO 2020 survey.

Data source	Type	Time span
Commercial landings	Length distribution	All quarters, 1989–2021
	Age–length key	All quarters, 1989–2021
ECOCADIZ acoustic survey	Biomass survey indexes	Second quarter 2004, 2006 third quarter 2007, 2009, 2010, 2013–
	Length distribution	Second quarter 2004, 2006 third quarter 2007, 2009, 2010, 2013–
	Age–length key	Second quarter 2004, 2006 third quarter 2007, 2009, 2010, 2013–
PELAGO acoustic survey	Biomass survey indexes	First quarter 1999, 2001–2003 second quarter 2005–2010 and 2013–
	Length distribution	First quarter 1999, 2001–2003 second quarter 2005–2010, 2013–2022
	Age–length key	second quarter 2014–2022

2.2 Model configuration

Gadget (Globally applicable Area Dissagregated General Ecosystem Toolbox) is the assessment model used to evaluate the status of the southern component of the Iberian anchovy stock. Gadget is an age-length-structured model that integrates different sources of information in order to produce a diagnosis of the stock dynamics. It works making forward simulations starting at the first year in the historic period, and minimizing an objective (negative log-likelihood) function that measures the difference between the model estimates and observed data.

The general Gadget model description and all the options available can be found in Gadget manual (Begley, 2004) and some specific examples can be found in Taylor et al. (2007) and Elvarsson *et al.* (2014).

The Gadget model implementation consists in three parts, a simulation of biological dynamics of the population (simulation model), a fitting of the model to observed data using a weighted log-likelihood function (observation model) and the optimization of the parameters using different iterative search algorithms.

The 27.9a_south anchovy Gadget model consists of one stock component, and keeps track of the number of individuals at age (age range 0-3), length (range 3-22cm), year (from 1989 to 2022) and quarters (seasons 1 to 4). The last time step of a year involves increasing the age by one year, except for the last age group, for which the age remains unchanged and the age group next to is added to it, like a 'plus group' including all ages from the oldest age onwards.

The initial stock population at age is defined by an age factor parameter to be estimated during the model optimization. Those numbers at age are distributed by length based on a normal density distribution with a specified mean length and standard deviation at age, which are estimated from all the data available from 1989 to 2022.

The growth function within Gadget selected for the 27.9a_south anchovy is a simplified version of the von Bertalanffy growth equation, defined in Begley (2004) as the *LengthVBSimple Growth Function*. Length increase for each length group in a given time-step is given by the length at the end of the previous time-step and the growth equation, with two parameters: L_{inf} (length at infinity) and K (growth rate). The corresponding increase in weight is estimated from a length-weight relationship, with a = 3.123e-6 and b = 3.277, fixed in the model and calculated from all the samples available in third and fourth quarters from 2003 to 2017. Natural mortality is variable by age but fixed over time (M_{age_0} = 2.21, M_{age_1+} = 1.3) and was estimated following Gislason *et al.* (2010) approach. Regarding maturity, in the current version of the model, the maturity process is not modelled internally, but the *SSB* is estimated a posteriori using a sharp-knife maturity ogive, with all individuals older than age 1 are assumed to be mature.

Recruits enter the population at age 0 in quarters 2, 3, 4. The number of annual recruits are estimated during the model optimization. The length distribution of those recruits is defined by a normal distribution with mean and standard deviation estimated as part of the model fitting, and kept constant over time.

In the model the fleets act as predators. There are three fleets inside the model: two for surveys (*ECOCADIZ* acoustic survey and *PELAGO* acoustic survey) and one for commercial landings including all fleets: Spanish purse-seine, trawlers, Portuguese purse-seine, and others. The main fleet is Spanish purse-seine representing more than a 90 % of all the catches from 2001 to 2016. It is also the only fleet with a length distribution available.

Different likelihood functions are used for different components of information. Data are assimilated by Gadget using a weighted log-likelihood function. The model uses as likelihood components two biomass survey indices: *ECOCADIZ* acoustic survey and *PELAGO* acoustic survey; age-length keys from the commercial fleet (Spanish purse-seine), *PELAGO* survey and the *ECOCADIZ* survey; and length distributions for the commercial fleet, *PELAGO* and *ECOCADIZ* surveys.

The working document by Rincón *et al*. (WD 2022) is appended to this report. This document presents a detailed model description and settings for a model run which considers both the assessment and management periods based on calendar years and including all the information available until the year *y-1*.

3 Management calendar

The Total Allowed Catch (*TAC*) of 9a anchovy followed calendar years, known as interim year advice (*int*), until 2017. In this management calendar, the *TAC* from January to December in year (*y+1*) was set at the end of year *y*. At the time there was no assessment of the stock. Since 2018, following a benchmark (WKPELA 2018), the stock started to be assessed as a category 3 stock, and the advice provided as an in-year advice (*iny*), *i.e.*, the management calendar is seasonal, running from July (year *y*) to June (year *y+1*). This means that the *TAC* is set soon after the biomass index on *B1+* is available (Table 3.1).

Table 3.1 - Anchovy in Division 9.a. ICES advice, the agreed TAC, and ICES catches. All weights are in tons. Catches from 1 July to 30 June in the following year to match the advised period.

Management year	Catches corresponding to advice		Agreed TAC	ICES catches	
	West component	South component		West component	South component
Jul 2018 – Jun 2019	13308	3760	17068	10093	3815
Jul 2019 – Jun2020	2662	6290	10240	2624	6472
Jul 2020 – Jun 2021	4347	11322	15669	5461	7904
Jul 2021 – Jun 2022	7824	7181	15005	11217*	5839*
Jul 2022 – Jun 2023	14083**	1694**			

* Catch estimates of the first two quarters of 2022 are provisional.
** Preliminary data resulting from WGHANSA May 2022.

The current management calendar is aligned with WKDLSSLS-1 and 2 conclusions which highlighted the "relevance of the time-lag between the survey, the advice and the management". In both workshops all simulations proved that the shorter the lag between observations, advice, and management the smaller will be risks, usually for higher (or similar) catches. This means that, given the current situation, where the survey indices an assessment model results are produced in the spring, the in-year advice is the best option at the moment.

4 Methods

A stock-specific management strategy evaluation (*MSE*) was conducted to determine the constant harvest rate (*chr*) that is the most robust to the operating model (*OM*) and assessment uncertainties. The performance of the current advice rule (1-over-2 with 80% uncertainty cap) was evaluated against the *chr* that maximized catches while preventing a risk maximum of 5% in the long run.

The *MSE* simulations were carried out using the FLR packages FLCore (version 2.6.18; Kell *et al*., 2007) and FLBEIA (version 1.16.1.6.; García *et al*., 2017) software. The work presented in this report was based on 1000 populations (*iters*). The *MSE* is structured by semesters and by age.

The historic period (1989-2021) in the operating model (*OM*) of FLBEIA was conditioned with the information produced by the 27.9a_south Gadget assessment model, using the relevant data such as numbers at age, weight at age, catch at age, etc (see sections below). The conditioned *OM* provided the starting point as well as basic settings for the projection period (such as commercial fleet catchability at age, mean weight or natural mortality at age). Advice measures where then implemented for a 30-year projection period. The stock assessment with the Gadget assessment model was generated from the "true" population at the beginning of second semester.

The assessment error, the effect in the perception of stock status derived from a potential overestimation of survey catchability by the Gadget assessment model, or the seasonal distribution of catches were considered the key uncertainties; scenarios were considered for each of these uncertainties.

Performance of the advice options were monitored in the *MSE* mainly through two performance statistics:

- **Risk**: The maximum probability of *SSB* being below B_{lim} where the maximum of the annual probabilities is taken across iterations and time. Values < 0.05 are considered precautionary. This is Risk type 3 that ICES currently uses as the basis for defining a multiannual plan as precautionary.
- **Annual yield**: Median of the mean catch over time and across iterations.

Other performance statistics such as the median average biomass of Spawning Stock Biomass (*SSB*), fishing mortality and catch are also presented for some scenarios.

These metrics were estimated for three time periods:

- Short: an initial time period covering the first five years of the projection period;
- Mid: the next five years of the projection period;
- Long: last ten years of projection period.

4.1 Operating model

The operating model (*OM*) is the mathematical representation of the *true* stock and the fleets. All the relevant information required to condition the historic and projection period in the *OM* was based on the ane27.9a_south Gadget stock assessment model used to assess the status of the stock (ICES, 2022).

The population dynamics of the 27.9a anchovy south component was simulated by semester using an age-structured population model (ages 0 to 3+) exploited by a unique fleet (composed by one *métier*). The numbers at age during the historic period was set based on the estimated values by the Gadget assessment model (Figure 4.1.1)

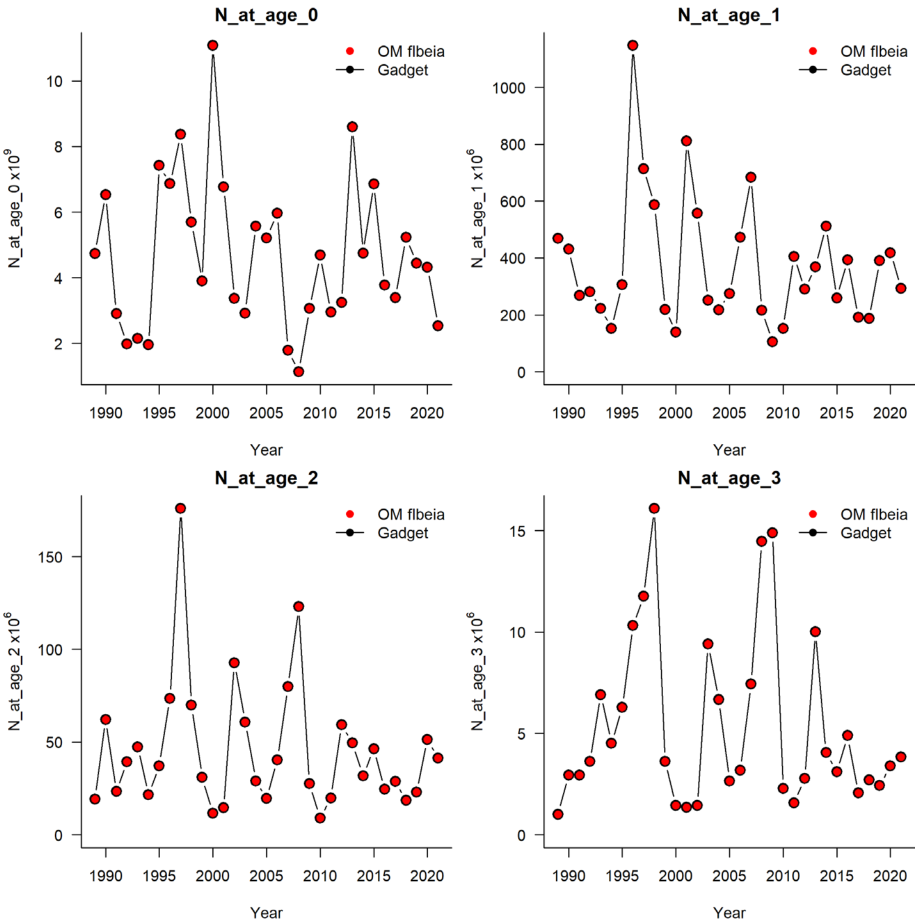


Figure 4.1.1.- Number of individuals at age at the beginning of semester 2.

Mean weight at age (Figure 4.1.2) in the historic period (1989-2021) was taken from the estimates made by the Gadget assessment model. For ages 1 to 3, these values are the result of the mean length at age estimated by Gadget based in a von Bertalanffy growth model, whose parameters are fitted internally during the model optimization (L_{inf}=28.429; *K*= 0.0773). Mean length at age 0 is estimated as a separate parameter. Length at age are converted internally in Gadget to mean weight at age using a length-weight relationship (*a* = 0.00313; *b* = 3.277). Mean weight at age in the projection period (2022-2050) was assumed as the average of the last three years in the historic period (2019-2021). Estimated mean weight at age by Gadget model was used to condition both the mean weight at age in the population and commercial catches.

Natural mortality (*M*) at age in the historic and projection period (Figure 4.1.2) were taken from the ane27.9a_south Gadget assessment model. These values were estimated based on life history parameters using the approach by Gislason *et al.* (2010), resulting in a variant *M* at age, but constant over time.

Proportion of mature individuals at age was modelled as a knife edge, with 0% mature at age 0 and fully mature from age 1 onward for the baseline *OM*.

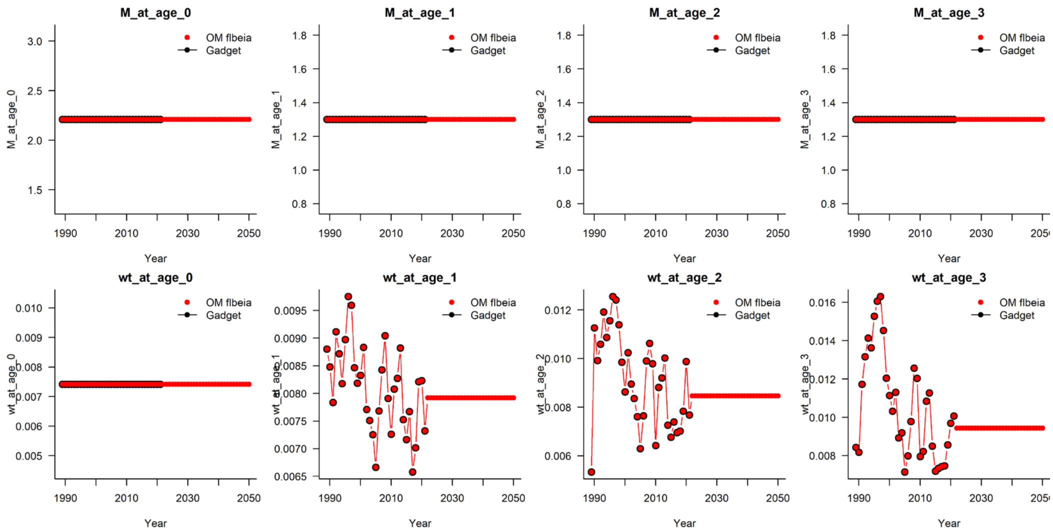


Figure 4.1.2.- Natural mortality and mean weight at age.

Catch by age in the historic period was conditioned based in the official reported catches, which are taken as absolute values during the optimization of the ane27.9a_south Gadget assessment model (Figure 4.1.3). In the assessment of the stock, it is assumed that discards in the commercial fleet are negligible, and the same was done in the conditioning of the *OM*. Fleet effort in the historic period was conditioned based in the values presented in the report of WGHANSA 2022 (ICES, 2022). Fleet catchability by age was estimated during the conditioning of the *OM*, based in the fishing effort, population biomass and catch by age (Figure 4.1.4). The estimated catchability at age for the commercial fleet was maintained constant over the projection period.

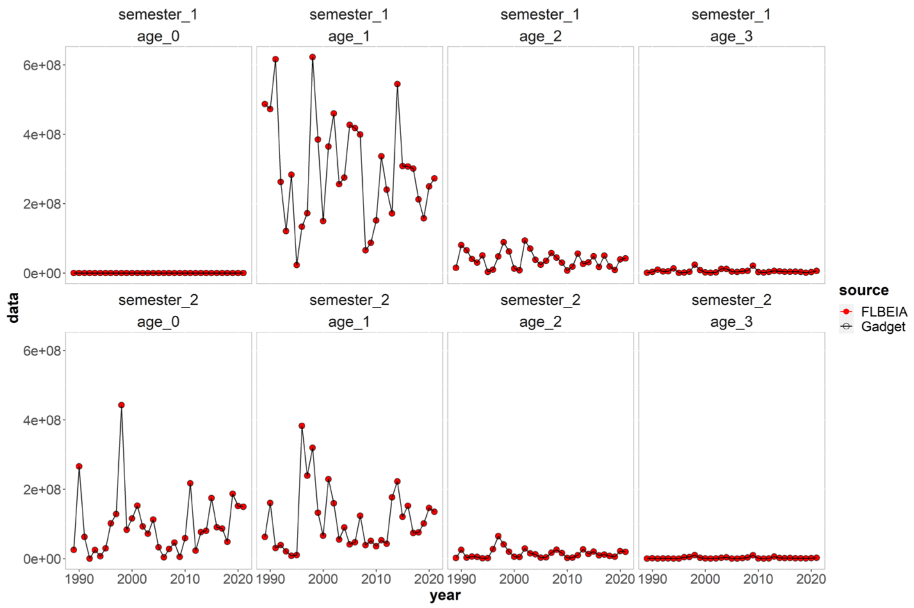


Figure 4.1.3.- Total catch at age by semester.

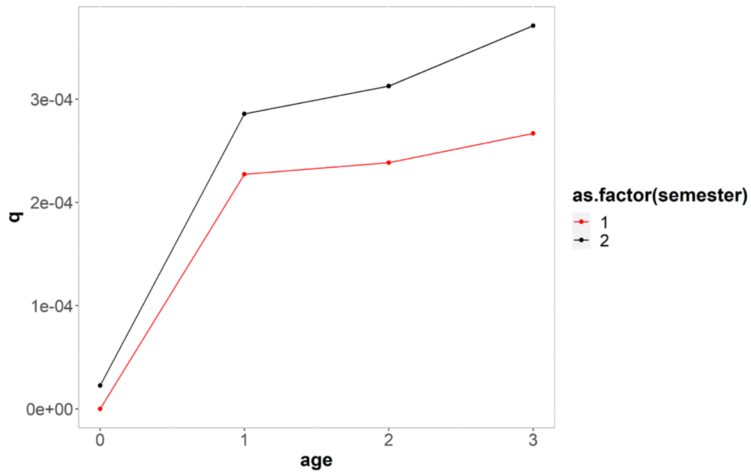


Figure 4.1.4.- Average catchability by age and semester along the historic and projection period in the OM.

A segmented regression *SSB-Recruitment* model was fit to the historic *SSB* and recruitment data (Figure 4.1.5). As indicated in the ICES guidelines, the breakpoint of the segmented regression was fixed as B_{lim}. For the anchovy 27.9a south component, B_{lim}=B_{loss}, 1186.340 tons, as defined during the WGHANSA 2022 meeting (ICES, 2022). This *SSB-Recruitment* model was used in the *OM* to produce recruitment values in the beginning of the second semester every year during the projection period. The natural logarithm of the standard deviation of the residuals was used to simulate variability in the recruitment rendered by a given *SSB* assuming a log-normal distribution. Autocorrelation was low, and hence it was not considered when estimating time series of random residuals (Figure 4.1.6). 1000 populations (*iters*) were run for each of the simulated scenarios. Accordingly, 1000 values of recruitment residuals were simulated for each year in the projection period (a sample of recruitment distribution around the mean recruitment estimated by the segmented regression model and the observed recruitment is presented in Figure 4.1.7).

Figure 4.1.5.- Observed (Gadget estimated values, black points) and predicted recruitment (from segmented-regression model, red line) as a function of the SSB.

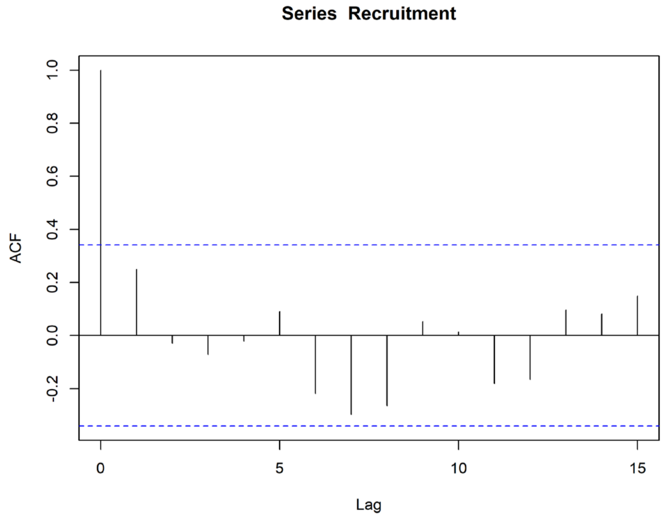


Figure 4.1.6.- Autocorrelation at different time lags for the time series of estimated recruitment at age 0 by the Gadget assessment model over the period 1989-2021.

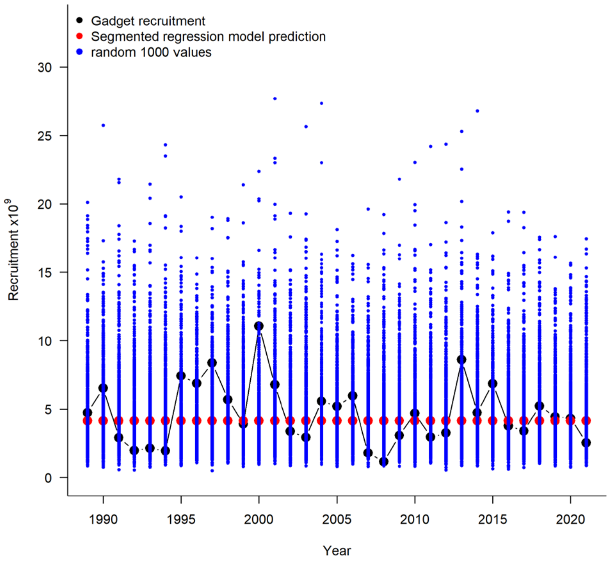


Figure 4.1.7.- Observed (Gadget estimated recruitment, black points), fitted by segmented regression (red points) and randomly simulated recruitment (1000 values assuming a log-normal distribution, blue points) over the historic period.

In the initial base-case *MSE*, the *OM* was conditioned using the outputs from the Gadget assessment model presented in the WGHANSA 2022 meeting (ICES, 2022). However, with the intention of testing the effect that a biased perception of the stock status due to a potential overestimation of the survey catchability (for *PELAGO* and *ECOCADIZ* surveys) might have regarding the precautionarity of a management strategy (*HCR*), as a sensitivity analysis, the *OM* was conditioned using 3 alternative Gadget assessment models. This is explained in detail in the *Sensitivity Analysis* section.

4.2 Observation model

The Harvest Control Rules (*HCR*) tested in this study take as input the estimated *SSB* result of the assessment conducted with the ane27.9a_south Gadget assessment model. In this *MSE*, a shortcut approach has been implemented to simulate the assessment, producing each year in the simulation an estimate of the *SSB* at the beginning of the second semester. Therefore, there is not an observation model in this *MSE*, but the observation error is integrated with the assessment error (including assessment bias and dispersion) in the Management Procedure. For this reason, a perfect observation approach is taken, and the *SSB* from the *OM* in the beginning of the second semester is passed to the Management Procedure (*MP*) without any modification. This unbiased observation is a subject in the sensitivity analysis through the simulation of assessment bias and assessment error implemented in the *MP* module. This is explained more in detail in the *Sensitivity Analysis* and *Management Procedure* sections below.

4.3 Management procedure

The management procedure (*MP*) includes the stock assessment ('perceived' stock) and the scientific advice for fisheries management following the application of the management strategy (Harvest Control Rules, *HCR*s). The assessment model emulator was applied every year in the simulation in the beginning of the second semester.

The stock assessment is simulated within the *MP* module without error in first place. However, this is only a basic step to be used for comparison of the performance indicators when more realism is set in the assessment by simulating the assessment error.

The time series of estimated *SSB* from the 2018 to 2022 assessments (Figure 4.3.1; taken from WGHANSA reports; ICES 2018, 2019, 2020, 2021 and 2022) were used as a historic retrospective pattern to estimate the assessment error. For the estimation of the assessment error, it was assumed that the last assessment (2022 assessment) was the closest to real stock status. The use of the retrospective analysis to estimate the assessment error has been used before (e.g. WKNSMSE; ICES, 2019), and has been proposed as an appropriate way to estimate the assessment error when implementing a shortcut approach on an *MSE* (WKGMSE3, ICES 2020). Due to the shortage of 'retrospective peels', the approach followed in this study has differed from the one in the North Sea cod *MSE* (WKNSMSE; ICES, 2019), and instead of using the terminal *SSB* estimates of the retro peels, the entire time series were used to quantify the assessment error. The error in each year of the 2018-2021 assessments in relation to the 2022 assessment was quantified as the ratio SSB_{y_X}/SSB_{y_2022}, where SSB_{y_X} is the *SSB* in a year *y* in the assessment conducted in year *X* (from 2018 to 2022) and SSB_{y_2022} is the *SSB* in year *y* in the 2022 assessment. The result of these calculations is presented in Figure 4.3.2.

The analysis of auto-correlation showed that correlation of the ratio over the historic period was lower than 0.2 for time lags of 1, 2 and 3 years (Figure 4.3.3)

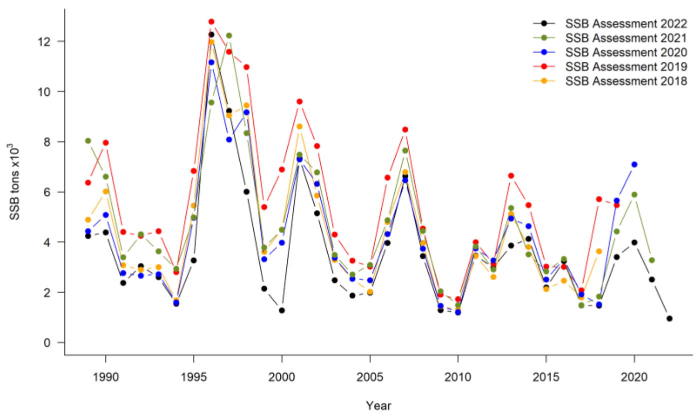


Figure 4.3.1.- SSB (in thousand tons) time series estimated in the stock assessments from 2018 to 2022.

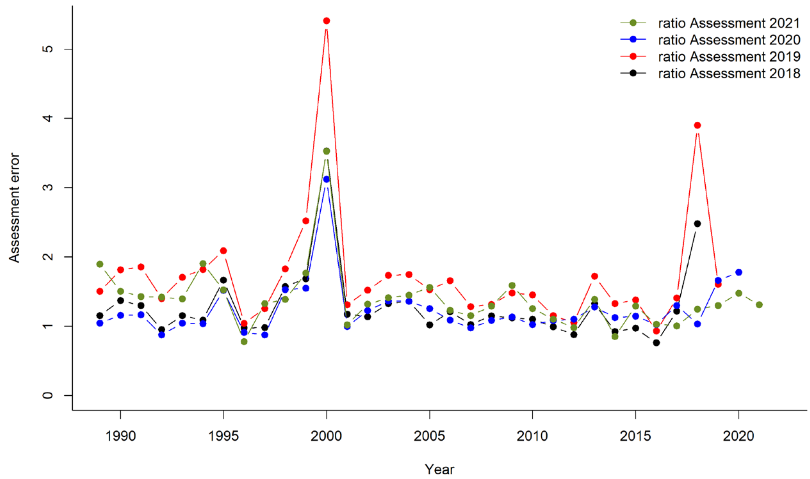


Figure 4.3.2.- Assessment error estimated as ratio SSB_{y_x}/SSB_{y_2022}, where SSB_{y_x} is the SSB in a year y for the year of assessment X (from 1989 to 2022) and SSB_{y_2022} is the SSB in year y for the assessment conducted in 2022.

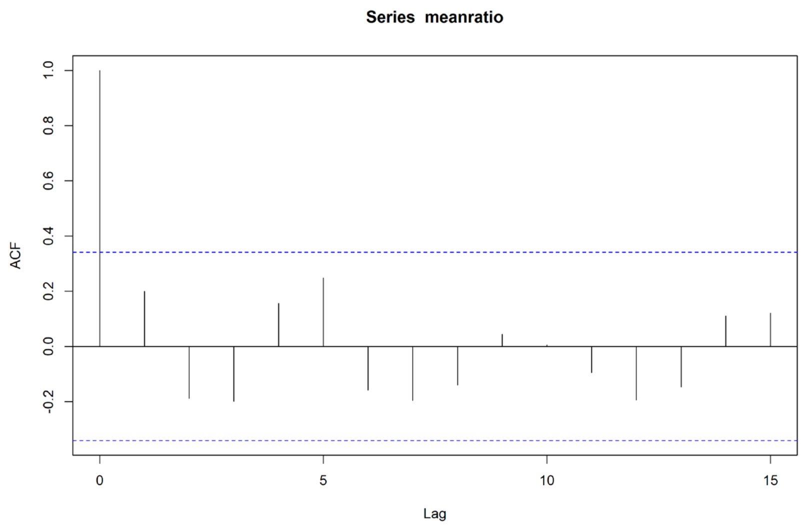


Figure 4.3.3.- Time correlation in the time series of assessment error.

The ratios time series showed in Figure 4.3.2 suggest a high degree of covariance in the error for a given year in successive assessments (mean correlation between the 4 time series of assessment error is 0.61). While covariance in the assessment error is not important when the *chr HCR* is applied, it must be taken into account to simulate time series of assessment error when the *1over2 HCR* is to be implemented. The approach followed to simulate time series of assessment error that takes into account the covariance was:

1.- Estimate the natural logarithm of ratios SSB_{y_x}/SSB_{y_2022} (those in Figure 4.3.2) and calculate the overall mean value *(meanlog)* of the log-ratio of the 4 time series of log-ratios over the period 1989-2021.

2.- Estimate the variance-covariance matrix of the 4 time series of log-ratios (2018-2021).

3.- Estimate the mean value of the variance (*meanvarlog*) of the time series of log-ratios in assessments of 2018-2021 (diagonal of the variance-covariance matrix).

4.- Estimate the mean value of the covariance (*meancovlog*) of the time series of log-ratios in assessments of years 2018-2021 (mean value of the off-diagonal in the variance-covariance matrix).

5.- Define a custom-made variance-covariance matrix, with as many columns and rows as number of years in the projection period (30 years), and where the diagonal is populated with the estimated *meanvarlog* and the off-diagonal with the *meancovlog*.

6. Draw samples from a normal multivariate distribution with mean and variance equal to the mean log-ratio and variance log-ratio, respectively, repeated as long as the number of years in the projection period (30 years). And with a covariance matrix equal to the one derived in the previous step. Draw 30000 samples from this distribution (30 years*1000 iterations) for each scenario (1000 iterations).

These samples were produced by using the eigenvalue decomposition method of the covariance matrix which implementation in R is provided by the function *mvrnorm* of the R library MASS.

The resulting time series were assumed as assessment error samples (ratios) to be used in the projection period (after exponential transformation of the log-ratios). It wasn't necessary to modify mean, variance and covariance due to log-transform because the difference was negligible (<0.009).

The values of the ratio obtained in years 2000 and 2018 where higher than the values in the other years (see Figures 4.3.2 and 4.3.4). If they were considered to estimate the variance covariance matrix, the simulated assessment error would be higher than the observed assessment error most of the years (see Figure 4.3.4 as an example). For this reason, in the base-case *MSE* framework, the error estimates in years 2000 and 2018 were removed to simulate the assessment error. Values of 2000 and 2018 are considered in an alternative approach to simulate what is called "spasmodic assessment error". This approach is presented in the *Sensitivity Analysis* section.

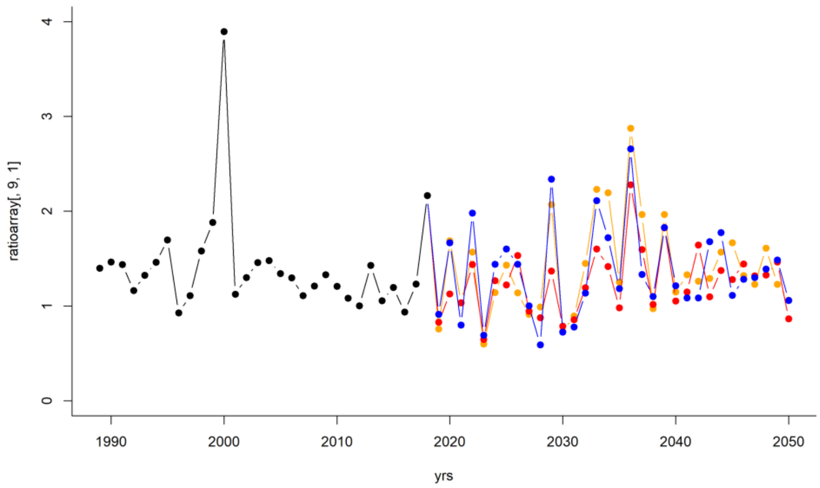


Figure 4.3.4.- As an example, the figure depicts three time series of simulated assessment error over the projection period if the values of 2000 and 2018 where included to estimate the mean ratio and the variance-covariance matrix of the ratio. From 1989-2018, the line in the figure represents the mean annual value of the ratio obtained in the 4 assessments (2018-2022).

The approach to implement the assessment error in the simulations was using the ratio-error time series described above to multiply the *SSB* time series (perfect observations) passed from the *OM* to the *MP*. Figure 4.3.5 shows some samples of these assessment error time series. These series were simulated without considering error estimates in years 2000 and 2018 to calculate the mean and covariance of the multivariate normal distribution (steps 1-6 above).

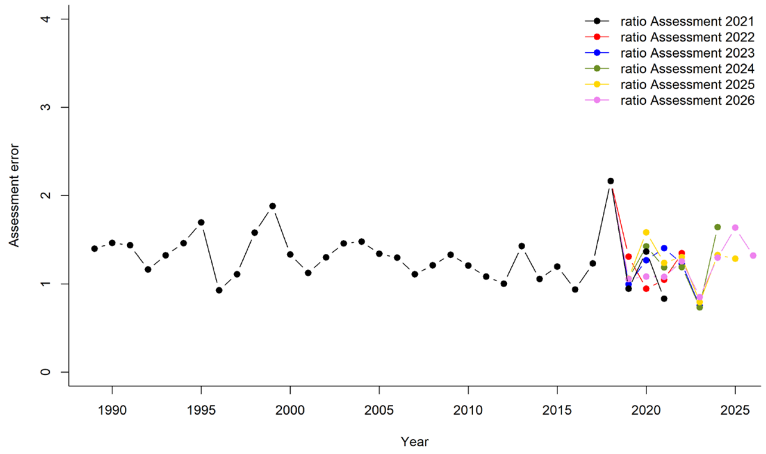


Figure 4.3.5.- Samples of simulated error time series for years 2022-2026.

Within the *MP*, the Harvest Control Rules (*HCR*) tested are applied directly to the *SSB* estimated in the simulated assessment (after the assessment error is applied). The *HCR* tested were:

i) The "*1-over-2*" rule, i.e., the ratio of the last *SSB* estimate and the average of the two previous years; this rule was applied with an 80% uncertainty cap. In the first year of application of the rule, the rule depended on a reference *TAC* value, which was taken as the catch in the last year of the historic period. This is the advice rule in place at the moment, defined as follows:

$$A_{y+1} = \left\{ \begin{cases} 0.2\,A_y & \frac{I_y}{\sum_{y-1}^{y-2} I_y/2} < 0.2 \\ A_y \frac{I_y}{\sum_{y-1}^{y-2} I_y/2} & 0.2 \le \frac{I_y}{\sum_{y-1}^{y-2} I_y/2} < 1.8 \\ 1.8\,A_y & \frac{I_y}{\sum_{y-1}^{y-2} I_y/2} \ge 1.8 \end{cases} \right\} \cdot \left[min\left(1, \frac{I_{current}}{I_{trig}}\right)\right],$$

where A_y and I_y represent the advised catch and the estimated Spawning Stock Biomass (*SSB*) for year *y* obtained from the *SSB* estimated in the simulated assessment (after the assessment error is applied), respectively. I_{current} is equal to I_y, and I_{trig} is defined as $exp(mean(log(I_y))-1.645*sd(log(I_y))$. The first and third cases of the formula correspond to the application of an 80% symmetrical uncertainty cap.

ii) A constant harvest rate (*chr*), *i.e.*, to remove a constant fraction of the stock every year applicable to the *SSB* estimated in the assessment (I_{current}); the approach is to find the maximum *chr* that keeps the biological risk at or below 5% (HR_{MSYproxy}), according to the ICES precautionary criteria as follows:

$$A_{y+1} = I_{current} * HR_{MSY.proxy}$$

Where A_y is the advised catch and $I_{\text{current}} = I_y$ as in the *1over2* rule above.

As recommended in the ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3 (ICES, 2022), a Biomass safeguard (B_{safe}) factor should be included in the HCRs formula when $I_{\text{current}} < I_{\text{trig}}$. For the *1over2* HCR above, $B_{safe} = I_{\text{current}}/I_{trig}$, and analogously for the *chr* rules, the rules including a B_{safe} factor will be as follows:

$$A_{y+1} = A_{y+1} * min(1, I_{current}/I_{trig}),$$

where I_{trig} is defined as before in the *1over2* rule.

4.4 Implementation model

The present *MSE* was run without implementation error, *i.e.*, assuming perfect implementation of the advised catch.

The analysis of distribution of commercial catches between semesters shows that in the last two years (2020 and 2021), nearly 50% of catches were taken each semester (Figure 4.4.1). Accordingly, as a first approach, the commercial catches were distributed homogeneously between semesters 1 and 2 in the simulations. An alternative approach considering the average percentage of catches on each semester in the last 10 years was also implemented (see the *Sensitivity Analysis* section).

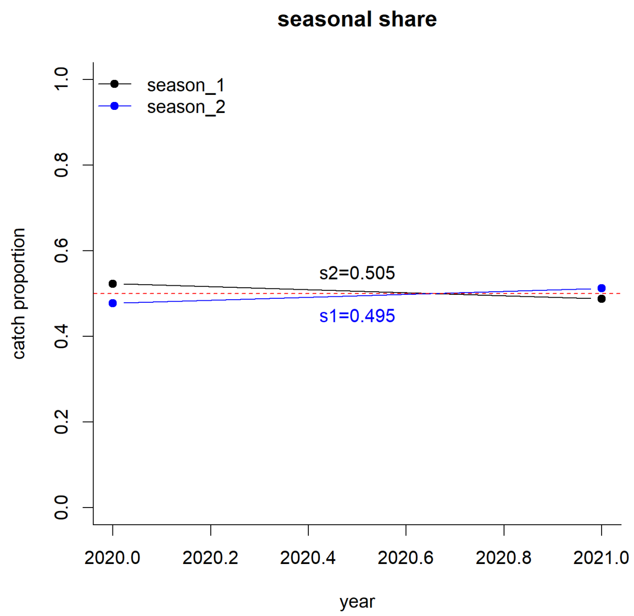


Figure 4.4.1.- Seasonal distribution of commercial catches in 2020 and 2021. The red dotted line represents the 0.5 proportion.

4.5 Base Case

The base-case *MSE* framework was defined as:

- Operating Model:
  - Conditioning of the *OM* using the 27.9a_south Gadget assessment model presented in WGHANSA 2022 (ICES, 2022).
  - Based in the historic data, an *SSB-Recruitment* model is fitted and used to simulated random recruitment from a lognormal distribution (no upper limit to maximum recruitment).
- Observation Model:
  - Provides a perfect observation.
- Management Procedure:
  - Implementation of assessment error. Years 2000 and 2018 were not considered to estimate and simulate the error.
  - HCR: Constant Harvest Rate (*chr*) with different Harvest Rates (*HR*) values.
- Implementation model:
  - Commercial catches distributed homogeneously between seasons (50% seasonal share).
  - Catch threshold set to the 90% of total stock biomass.

The *MSE* was run for the base-case scenario with the Constant Harvest Rate (*chr*) advice rule with a wide range of harvest rate (between 0.05 and 1). Performance statistics were calculated for all the runs.

4.6 Sensitivity Analysis

Sensitivity of the *chr* (with a broad range of *HRs*) to a number of key elements affecting the *OM*, the *MP* and the implementation model was tested (see Table 4.6.1 for a brief overview of the sensitivity analysis conducted). If one of the elements tested showed an important effect in the performance statistics, the MSE configuration taken as 'base case' was updated to include that element before to continue with another sensitivity analysis.

Taking the original base case as a starting point, the first sensitivity analysis included a modification in the *MP* and was focused on the effect of including or not the Biomass Safeguard in the *HCR*s.

A second sensitivity analysis assessed the robustness to an increase in the maximum proportion of the stock that can be caught by the commercial fishery to reach the advised catch (called *catch threshold* in this document). In this sensitivity analysis the catch threshold was increased from 90% to 100% in the implementation model.

It is a matter of discussion if the maximum recruitment allowed in the simulation period shouldn´t exceed the maximum observed recruitment in the historic period. The sensitivity to the limitation in the maximum recruitment during the projection period was explored by truncating the lognormal distribution used to simulate annual recruitment to the maximum observed recruitment in the historic period.

Another sensitivity analysis explored the effect of spasmodic assessment errors. In this case, the values of assessment error estimated in years 2000 and 2018 (not used in the simulation of the assessment error in the base-case *MSE* framework), were randomly included in the simulated time series of error following a binomial distribution, where the probability of success (introduction of a higher than usual assessment error) was 0.06 (proportion of 2 years (2000 and 2018) in relation to the number of years in the historic period (33 years)). In those years where a spasmodic recruitment was 'successful', the value of the assessment error to be implemented (either the assessment error in 2000 or 2018) was selected randomly with equal probability for both years.

The sensitivity to the seasonal distribution of the commercial catches was tested by exploring a scenario where the seasonal share in the implementation model was set as the average percentage of catches by season in the last 10 years of the historic period. As shown in Figure 4.6.1, the alternative seasonal share values were 0.436 in semester 2 and 0.564 in semester 1.

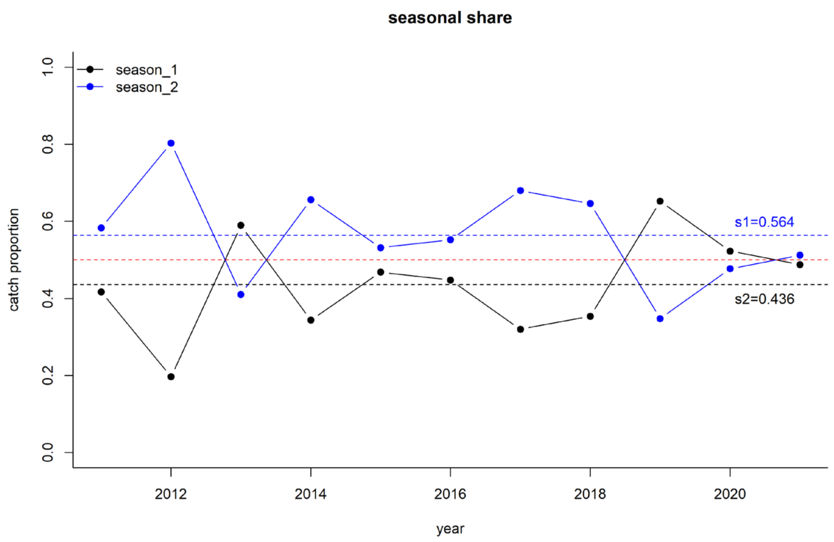


Figure 4.6.1.- Seasonal distribution of commercial catches in the last 10 years of the historic period. The continuous black line depicts the proportion of annual catch in season 1, while the continuous blue line represents the annual proportion in season 2. The blue and black dotted lines represent the average proportion of catch in season 1 and 2 respectively, and the red dotted line represents the 0.5 proportion.

Finally, a major sensitivity analysis in this *MSE* exercise was focused on the effect of the survey catchability (Q) in the ane27.9a_south Gadget assessment model. The values of Q for the *PELAGO* and the *ECOCADIZ* surveys (the two scientific surveys providing abundance and biomass indices to the assessment model) estimated in the optimization of the Gadget assessment model are 3.64 and 4.65 respectively (ICES-WGHANSA, 2022). These values are higher than the catchability usually assumed or estimated for similar type of acoustic surveys, which are often between 1 and 1.5. In order to assess the sensitivity of the candidate *HCR*s to the uncertainty in the survey catchability in the assessment model, three alternative Gadget assessment models were fit to the same input data used in the 2022 assessment (ICES-WGHANSA, 2022), but in these models the catchability parameters were fixed as:

1- 0.75 for *PELAGO* survey and 0.959 for *ECOCADIZ* survey (PelagoQ_0.75_EcocadizQ_0.96).
2- 1.0 for *PELAGO* and 1.278 for *ECOCADIZ* survey (PelagoQ_1_EcocadizQ_1.28).
3- 1.5 for *PELAGO* survey and 1.9175 for *ECOCADIZ* survey (PelagoQ_1.5_EcocadizQ_1.92).

The difference in the Q values for *PELAGO* and *ECOCADIZ* surveys within each of the three new model configurations was intended to keep the proportion between the Qs estimated for each survey in the original Gadget assessment model.

The optimized models where then used to condition three alternative *OM*s following the same approach described in the section *Operating and Observation models*. The *SSB-Recruitment* model was re-fitted, and 1000 time series of random recruitment residuals were re-estimated. The reference point B_{lim} was also re-estimated for each alternative *OM*, assuming that B_{lim}=B_{loss}, as it was done with the accepted assessment (WGHANSA, ICES, 2022).

The fitted Gadget models showed that despite the relation between Q and the mean estimated *SSB* over the historic period was not linear (Figure 4.6.2), the estimated *SSB* in the three alternative models followed nearly parallel trajectories with the *SSB* time series estimated by the original Gadget assessment model (Figure 4.6.3). The lower the catchability parameters in the *PELAGO* and *ECOCADIZ* surveys, the higher the estimated *SSB* by the Gadget assessment model.

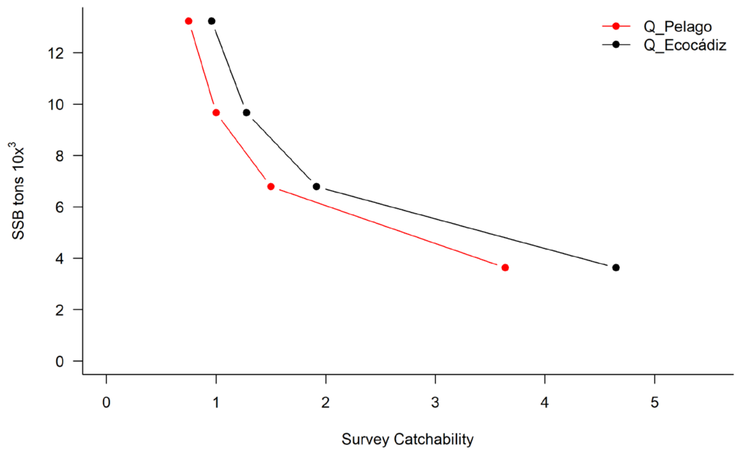


Figure 4.6.2.- Estimated SSB by Q for the PELAGO and ECOCADIZ surveys in the 4 Gadget assessment models fitted with different survey catchability parameters.

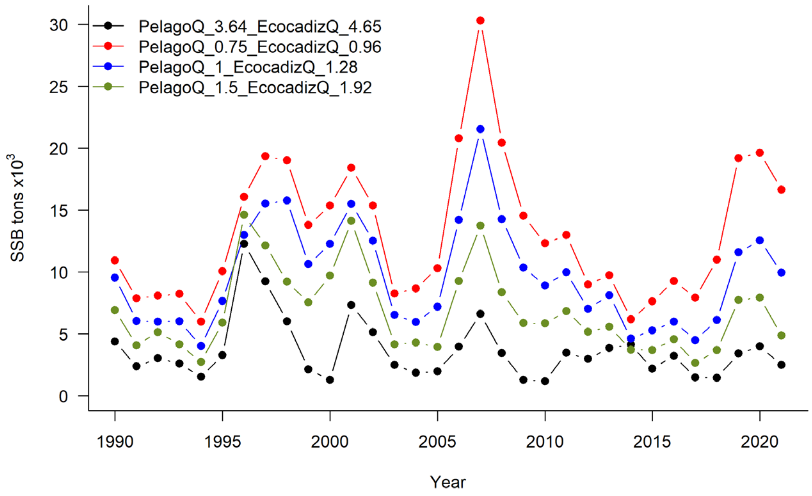


Figure 4.6.3.- Estimated SSB by year at the beginning of second semester in the 4 Gadget assessment models fitted with different survey catchability parameters.

The aim of re-fitting alternative Gadget models for which the survey Q was fixed around the usual Q in acoustic surveys was assessing the sensitivity of the performance of candidate *HCRs* to a potential biased perception of the status of the stock produced by an over-estimation of the survey catchability in the Gadget assessment models presented in WGHANSA (ICES 2018, 2019, 2020, 2021 and 2022). For this reason, it is not only necessary conditioning different *OMs* with the input from these alternative Gadget assessment models, but also introducing the necessary changes in the *MPs* to simulate a biased perception (biased assessment) of the real status of the stock in the *OM*. As showed in Figure 4.6.3, the higher the Q in the Gadget model used to condition the *OM* the lower the *SSB* in that *OM* will be. The biased perception of the status of the stock (biased assessment) was simulated by keeping that perception as similar as possible in all the 4 different *MPs* (base case and 3 Catchability scenarios), while the real status of the stock in the *OM* changed by conditioning it with the output of each of the 4 different gadget models. The equal perception of the status of the stock (in terms of *SSB*) in the four *MPs* requires the introduction of an extra *assessment bias parameter due to potential Q over-estimation*. These bias parameters were calculated as the ratio between the percentile 90 of the *SSB* in the historic period estimated by the base case Gadget assessment model and the percentile 90 of the *SSB* estimated by the 3 alternative Gadget models with lower Q. The 90 percentile was chosen to account for most of the *SSB* estimates, but disregarding the more extreme values. The bias parameters estimated were:

1- PelagoQ_0.75_EcocadizQ_0.96 bias parameter: 0.335
2- PelagoQ_1_EcocadizQ_1.28 bias parameter: 0.423
3- PelagoQ_1.5_EcocadizQ_1.92 bias parameter: 0.552

Each of these *assessment bias parameters due to Q over-estimation* was then used in the *MP*s of the alternative *MSE* frameworks where the *OM* was conditioned with the corresponding Gadget assessment model. The *assessment bias parameter* was used to multiply the perfect observation of *SSB* passed from the three *OM*s, forcing a biased perception of the real status of the biomass within the *MP*. Based in the *SSB*/Q relation presented in Figure 4.6.2, the lower the Q assumed in the Gadget assessment model conditioning the *OM* the higher the bias in the perception of the *SSB* will be. In addition, as it was done in the other sensitivity analysis, the assessment error was implemented to this biased perception of the *SSB* within the *MP*.

Table 4.1. - List of alternative scenarios simulated for the different components.

Variable	Description	Scenario description
Catch threshold	Limit to the maximum proportion of the stock caught by the commercial fleet	0.9
		1
Assessment error	Approach to simulate the assessment error	No assessment error
		Assessment error without outliers
		Spasmodic assessment error
Recruitment residuals	Limit to the maximum residuals in the recruitment	Limited by the lognormal distribution
		Limited by the historic maximum residual
Seasonal share	Seasonal distribution of catches	50%
		56.4% season 1/43.6% season 2
Estimated Gadget survey catchability	Explore the sensitivity of HCR to a biased perception of the stock status related with the uncertainty in survey catchabiity	PelagoQ_0.75_EcocadizQ_0.959
		PelagoQ_1_EcocadizQ_1.278
		PelagoQ_1.5_EcocadizQ_1.9175

4.7 Reference points

There are two sets of reference points estimated in this study:

1) Those corresponding to the 'real' stock in the *OM*.

2) Those estimated for the 'perceived' stock in the *MP*.

The reference point in the first group is B_{lim}. As described above, B_{lim} is set using the *SSB-Recruitment* pairs of values estimated by Gadget. As it was presented in WGHANSA 2022 (ICES, 2022), anchovy is assigned to a stock type 5 regarding the *SSB-Recruitment* relation (ICES, 2021). For type 5 stocks, B_{lim} is set as B_{loss} (*i.e.* the lowest estimated *SSB* in the assessment of the historic period). B_{lim} is used to assess the performance of each *HCR* in the short, medium and long term from a precautionary approach (here the ICES risk type 3 was used, annual maximum risk of *SSB* falling below B_{lim}). Given the type of *HCR*s being tested in this study (category 3 short-living stocks), B_{lim} is the only parameter required to assess *HCR*s from a precautionary approach. Given the different stock productivity estimated by the four Gadget assessment models described in previous sections, B_{lim} was estimated separately for each of the four conditioned OMs as B_{lim}=B_{loss}.

The reference point in the second group is I_{trig}, which is estimated from the perceived *SSB* in the historic period. The perceived *SSB* is the *SSB* multiplied by the *assessment bias parameter* described in previous section for each of the four *MSE* frameworks set using the four different Gadget assessment models. Another reference point used in the *chr HCR*s is the *HR*.

5 Results

5.1 Base case

Despite the scenario "not having error in the assessment" is unrealistic, it was still simulated with the intention of assessing the impact in the performance statistics when the assessment error is indeed included. The results of simulations with both options (with and without assessment error) shows that the assessment error increased the median catch for any given harvest rate (*HR*), at the cost of increasing remarkably the risk of being below B_{lim} (Figure 5.1.1). The range of *HR* where the risk in the long term was below 5% was narrower when the assessment error was simulated in the *MP*, with *HR*=0.6 as the upper limit to precautionary *HR*.

These results are in line with the expected effect of the estimated assessment error, which tend to over-estimate the *SSB* (mean estimated error as ratio *SSB_estimated/SSB_real* in the historic period was 1.313).

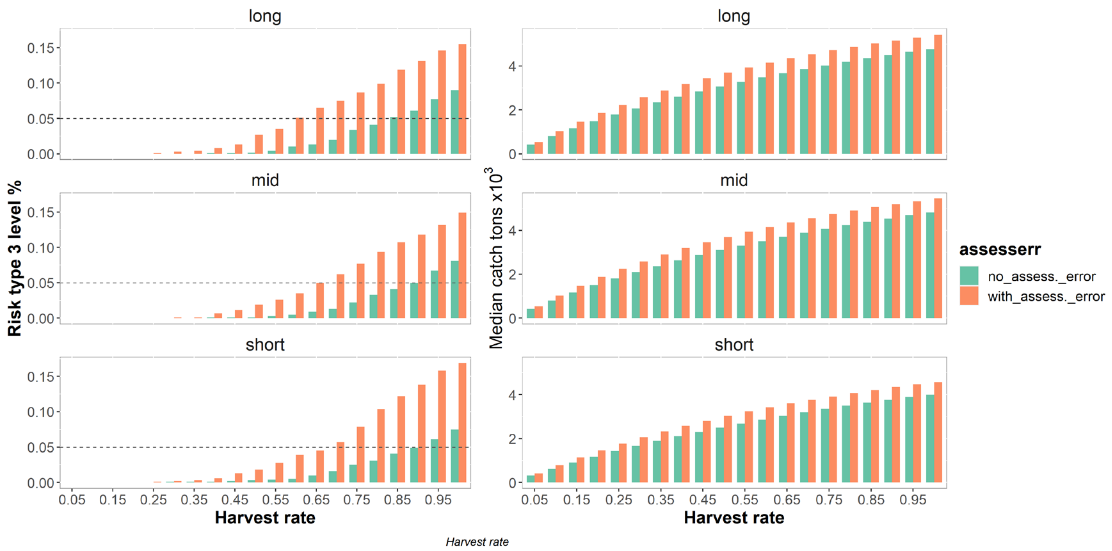


Figure 5.1.1.- Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations with (orange bars) and without assessment error (green bars).

5.2 The effect of a Biomass safeguard in the HCR

Taken the base case *MSE* framework with assessment error, the next analysis was focused on testing the effect of including a biomass safeguard (defined as described in the *Methods* section) in the *chr HCR*. The results indicate that the biomass safeguard had only minor effects in the performance statistics, as shown in Figure 5.2.1 for the risk of being below B_{lim} and commercial catches.

Despite the small differences, the *MSE* framework including assessment error and biomass safeguard in the *MP* was taken as the base case for the next analysis.

The I_{trig} (defined in the *Methods* section) for the base-case *MSE* was 1180 tons. This low *SSB* value is likely the reason to not finding significant differences in terms of risk and median annual catch when the Biomass safeguard is considered in the *HCR*.

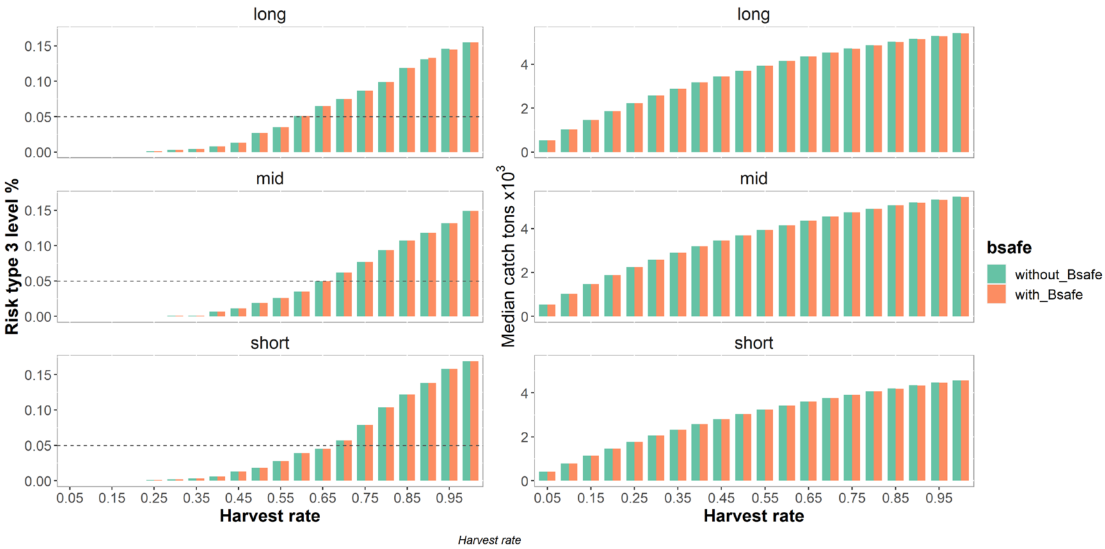


Figure 5.2.1.- Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations with (orange bars) and without (green bars) Biomass safeguard in the chr HCR. All the simulations in this panel included assessment error.

5.3 Sensitivity to catch threshold

A sensitivity analysis tested the effect of increasing the catch threshold (maximum percentage of the stock that could be taken by the commercial fleet) from 90% that is set in the base case, to 100% percent if necessary to reach the advised catch. Despite this is likely an unrealistic scenario, the goal of this sensitivity exercise was estimating the importance that fishing the entire stock might have in the dynamic of the population. The median of commercial catches didn´t show appreciable differences for any *HR* simulated. However, although small, the risk of being below B_{lim} slightly increased when the catch threshold was increased to 100%, especially in the highest *HR*s.

However, the differences were small, probably due to the fact that, within the *MSE*, the fleet didn´t need to fish the 100% of the stock biomass to reach the advised catch in almost none of the 1000 populations (*iters*) simulated. In addition, as shown in the *Methods* section regarding the *SSB-Recruitment* relation, once the stock is above B_{lim}= 1186.34 tons (the lowest *SSB* in the historic period), mean recruitment is stabilized. Hence, the simulated recruitment capacity of the stock is the same for almost all the range of *SSB*. It is hence a very resilient stock.

Since it is more realistic that part of the stock survives to fishing than the total exhaustion of the available fishable biomass, it was decided that despite the slight change in the risk of being below B_{lim}, the catch threshold would be maintained at 90% in the base-case *MSE* framework to be used in further comparisons.

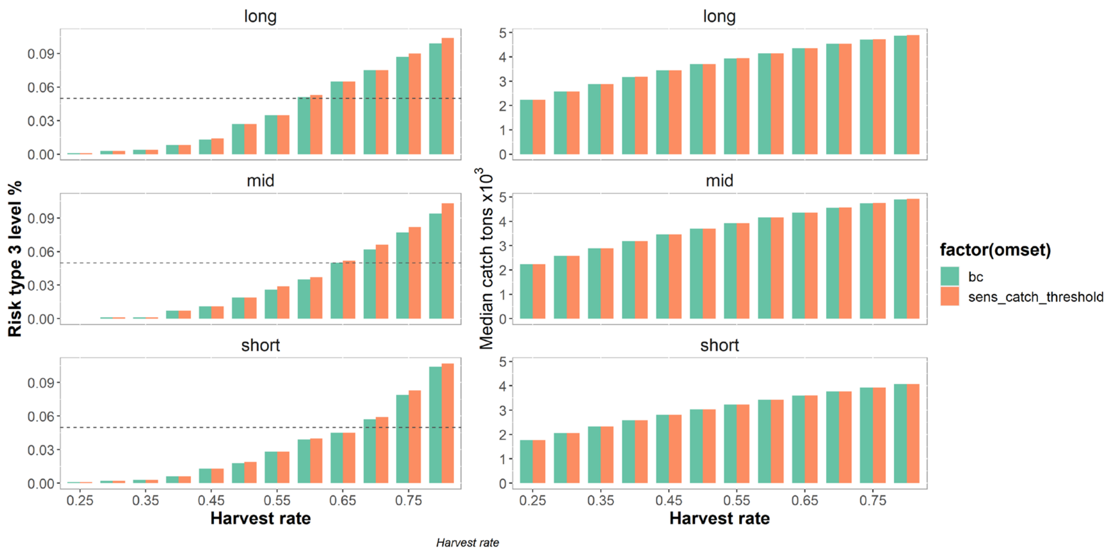


Figure 5.3.1.- Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations. Colour bars refer to simulations where the catch threshold is set as 0.9 (green bars) and 1.0 (orange bars).

5.4 Sensitivity to limitation of maximum recruitment

The analysis of sensitivity to the limitation in the maximum recruitment showed no relevant differences neither in the commercial catches nor the risk of being below *B_{lim}*. Accordingly, a recruitment limitation will not be included in the base case *MSE* framework for further analysis.

The low number of iterations (only a 2.5-3% of the 1000 simulated) with at least one recruitment value higher than the maximum observed recruitment in the historic period is probably the reason for the very minor effect of allowing recruitment being higher than the maximum historic value.

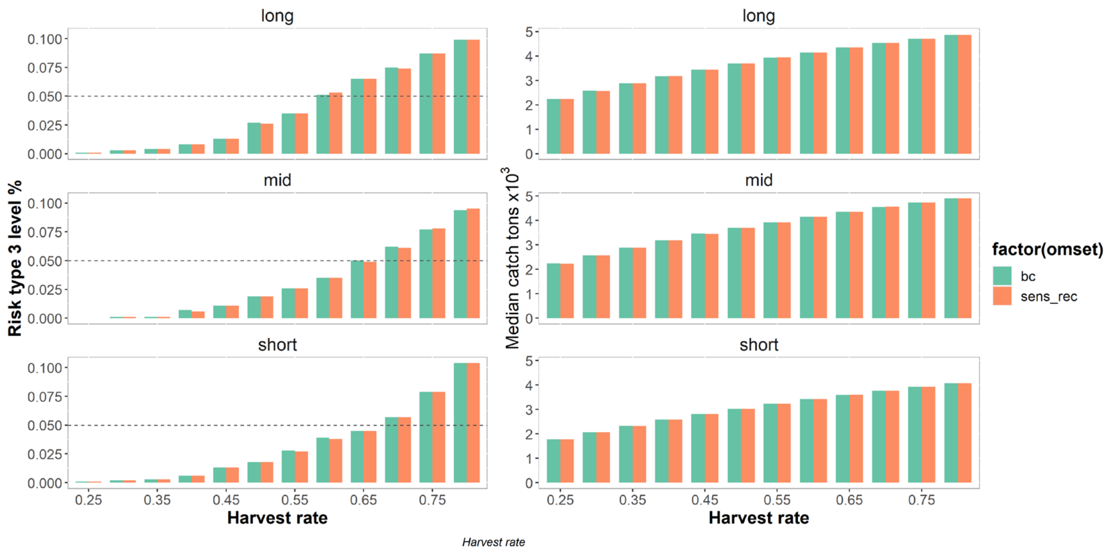


Figure 5.4.1.- Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations where the maximum recruitment is limited to the highest value in the historic period (orange bars), compared to simulations where recruitment is not limited (green bars).

5.5 Sensitivity to sporadic extreme assessment error

As indicated above, another sensitivity analysis explored the effect of spasmodic assessment errors (random introduction of the assessment error from years 2000 and 2018 following the indications in section 4.5). The results of these simulations indicate slightly higher median catch for all *HR*s and time intervals at the cost of substantially higher risk of being below B_{lim} (Figure 5.5.1). The *HR*=0.5 was the higher *HR* for which the risk of being under B_{lim} was lower than 0.05. Based on these results, and since high assessment error values were observed in the past, it was considered that it is precautionary including the spasmodic assessment error within the management procedure in the *MSE* framework to be used in further simulations.

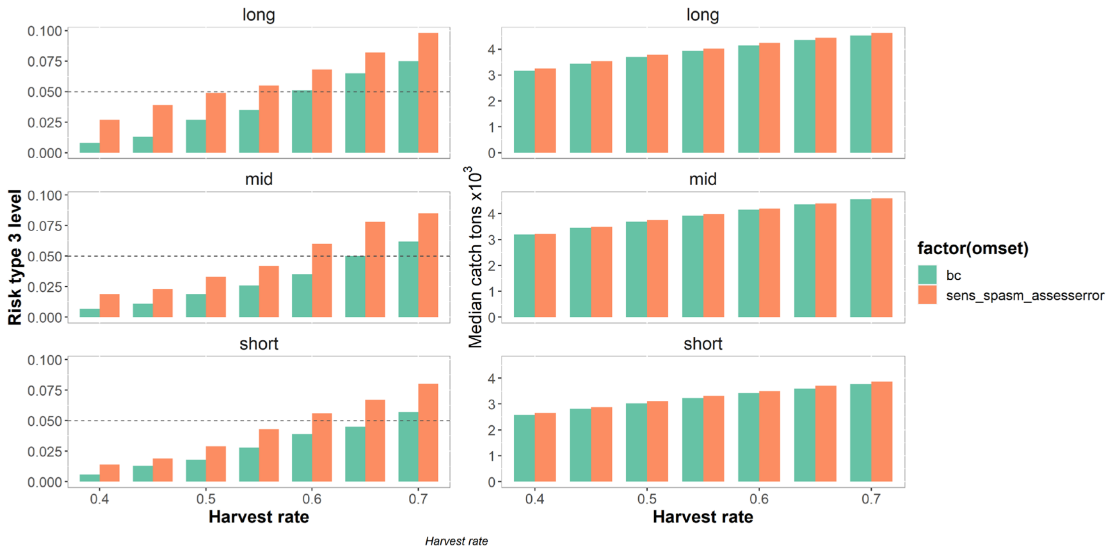


Figure 5.5.1.- Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations where the assessment error does not include sporadic extreme values (green bars) compared to simulations were the extreme errors observed in 2000 and 2018 were introduced randomly (orange bars).

5.6 Sensitivity to seasonal distribution of catches

When the seasonal distribution of catches (seasonal share) was set as the average proportions observed in the last ten years of the historic period (43.6% catch in season 2 and 56.4% in season 1), the median annual catch showed a slight decline in all the three time intervals and *HR*s simulated (Figure 5.6.1). Although relatively small, a consistent increase in the risk of falling below B_{lim} was estimated for all *HR*s and time intervals. For this reason, and given that excepting the last two years in the historic period commercial catches were always higher in the first semester, it was considered that this setting should be included in the implementation model of the *MSE* framework used in the next simulations.

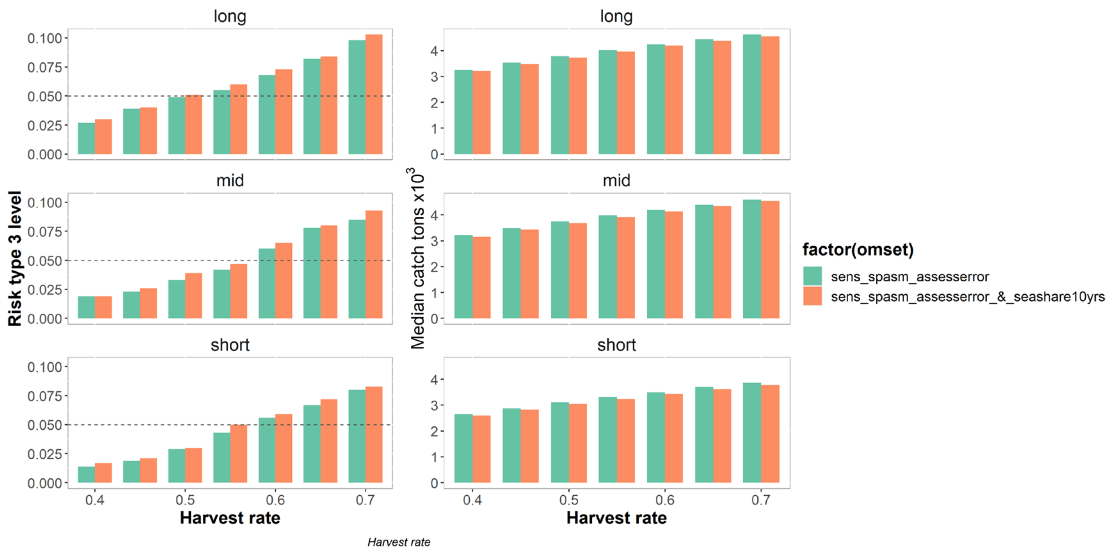


Figure 5.6.1.- Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations where the assessment error does not include sporadic extreme values (green bars) compared to simulations were the extreme errors observed in 2000 and 2018 were introduced randomly (orange bars).

5.7 Sensitivity to uncertainty in survey catchability in the stock assessment

The simulations run with the four different *MSE* frameworks, with *OM*s conditioned using the output of the four Gadget models fitted with different catchability values for the *PELAGO* and *ECOCADIZ* surveys, showed that the median annual commercial catch stayed very similar in all scenarios for a given *HR*. This was due to the implementation of the assessment bias perception parameter. However, since the actual *SSB* in the alternative *OM*s was higher than perceived by the *MP*, the risk of falling below B_{lim} was substantially lower for all the three cases where the catchability of *PELAGO* and *ECOCADIZ* was lower than in the original Gadget assessment model. These results support that, if the current settings of the 27.9a_south Gadget assessment model (with *Pelago_Q*=3.64 and *Ecocadiz_Q*=4.65) produces an infra-estimation of the *SSB* (as shown in Figures 4.6.2 and 4.6.3), the *HCR* selected as precautionary using the *MSE* framework with the *OM* conditioned with the outputs of the currently approved Gadget assessment model would be precautionary.

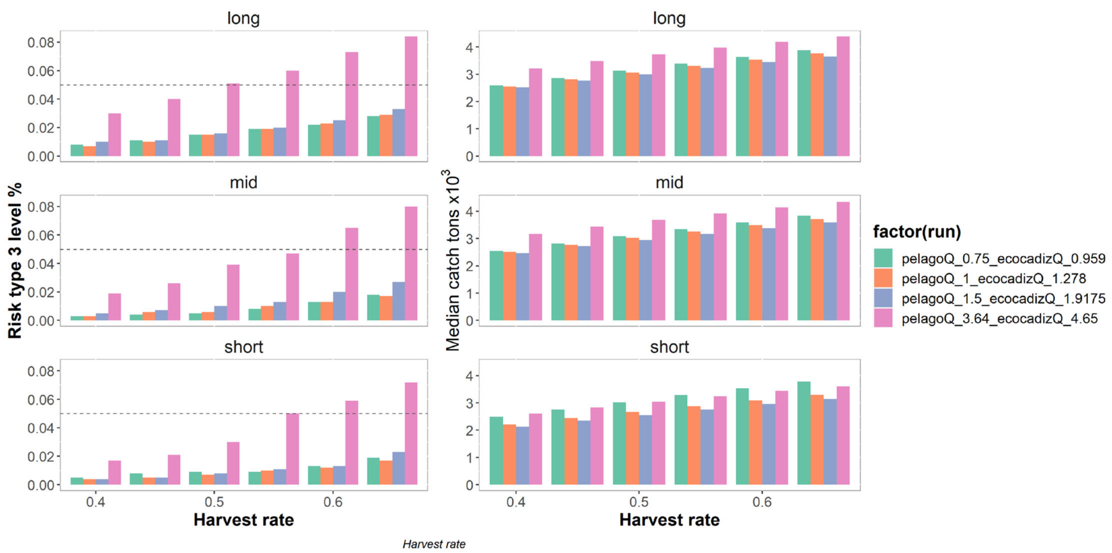


Figure 5.7.1.- Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations conducted with MSE frameworks where the OM was conditioned with information from Gadget assessment models were the catchability was fixed as 0.75 for PELAGO survey and 0.959 for ECOCADIZ (PelagoQ_0.75_EcocadizQ_0.96, green bars); 1.0 for PELAGO and 1.278 for ECOCADIZ survey (PelagoQ_1_EcocadizQ_1.28, orange bars); 1.5 for PELAGO survey and 1.9175 for ECOCADIZ survey (PelagoQ_1.5_EcocadizQ_1.92, blue bars); and as estimated by the Gadget assessment model in 2022 assessment: 3.64 for PELAGO survey and 4.65 for ECOCADIZ survey (PelagoQ_3.64_EcocadizQ_4.65, pink bars).

5.8 Rules comparison

Based in the results from the sensitivity analysis conducted in the previous sections (summarized in Figure 5.8.1), the *MSE* framework used for further comparisons include:

- Biomass safeguard in the *1over2* and *chr HCR*s
- Assessment error with sporadic high error values.
- Recruitment defined by a lognormal distribution without limitation to the maximum recruitment.
- Distribution of catches over the year as the mean values in the last 10 years of the historic period.
- *OM* conditioned with input data from Gadget assessment model with survey catchability as presented in the ane27.9a_south component 2022 assessment (ICES, WGHANSA 2022).

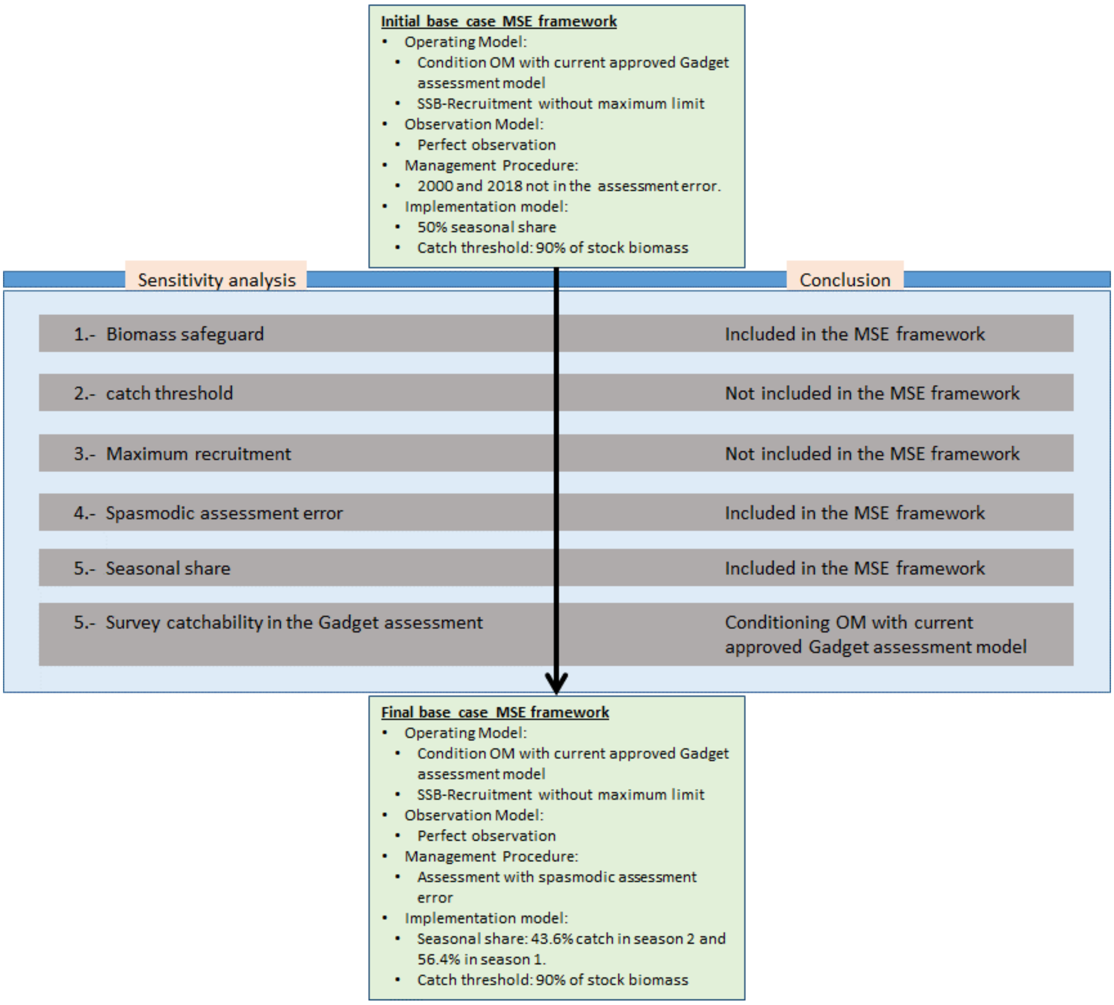


Figure 5.8.1.- Flowchart summarizing the initial configuration of the MSE framework as base case, the sensitivity analysis conducted and conclusions for each analysis, and the configuration for the MSE framework used for HCRs comparisons.

Based in the results from previous sections it was considered that running simulations for scenarios with a range of *HR*s in the *chr* between 0.4 and 0.7 should be enough to compare the performance of the *1over2* and *chr* HCRs in terms of annual median catch and risk of falling below B_{lim}.

The results of those simulations show that the *1over2* HCR produced lower median annual catch than any of the *chr* tested in the short, mid and long term time periods (Figure 5.8.2; Table 5.8.1), while the risk of falling below B_{lim} was below 0.05 in the mid and long term, but not in the short term. Regarding the *chr*, a wide range of *HR*s produced higher catch than the *1over2* rule in all the three time intervals, while being always below B_{lim}. The maximum value of *HR* that stayed below the 0.05 probability of falling below B_{lim} was *HR*=0.5 (in the long term scenario the probability was only slightly above 0.05 (prob=0.051)). The *chr* with *HR*=0.5 was selected for further comparisons with the *1over2* rule.

The analysis of the performance statistics for the *1over2* rule over the period 1989-2050 shows a decreasing trend over the projection period in commercial catches, which, given a stable median recruitment, resulted in an increasing trend in the *SSB* over time (Figure 5.8.3). By contrast, the *chr* with *HR*=0.5 showed a stable pattern in all the performance statistics, with little variation over time in the median values. The median annual commercial catch in the *chr* was always above the values for the *1over2* rule (Figure 5.8.3), and the differences became more clear from short to mid and long term periods (see also Table 5.8.1). According to these results, the *1over2* rule seems to infra-utilize the fishing opportunities in comparison to the *chr HR*=0.5. This conclusion is in agreement with results obtained in previous studies for the Bay of Biscay anchovy (Sanchez-Maroño, 2019).

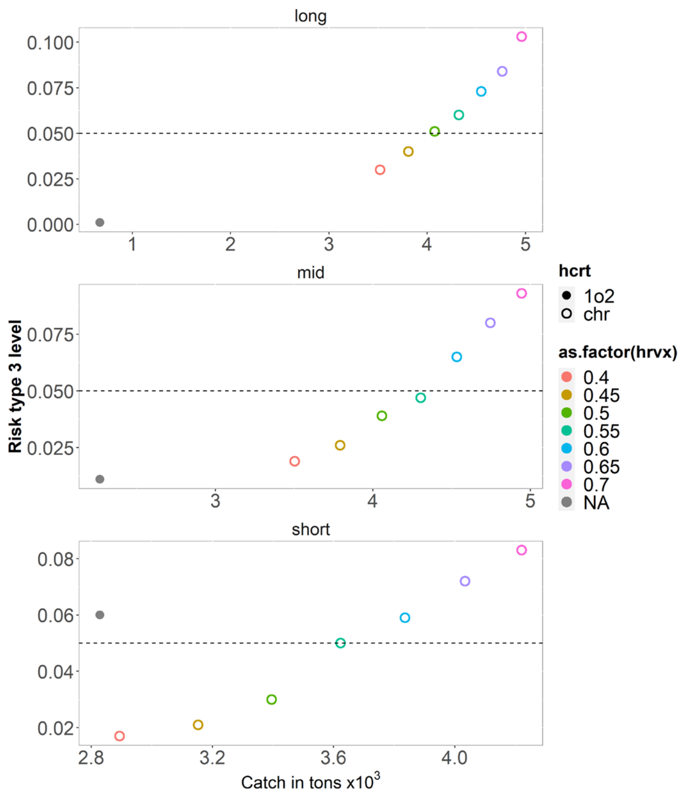


Figure 5.8.2.- Biological risk as Risk3.B_{lim}: (maximum probability of falling below B_{lim}, y-axis) versus yield (catches in tonnes, x-axis) for the 1-over-2 advice rule (full circle) and the constant harvest rate rule (open circle) with different harvest rates (colours). The columns correspond to the simulations where the OM has been conditioned with data from Gadget assessment models fitted using different values of catchability for the PELAGO and ECOCADIZ surveys. The rows correspond to the temporal scales: the short-term (first 5 projection years), medium-term (next 5 projection years) and the long-term (last 10 years of the projection years). Dashed line corresponds to the 0.05 risk.

Table 5.8.1.- Summary of performance statistics for the two advice rule types tested in the short (first five years), medium (next five years) and long (last ten years) period. Reported statistics: SSB and Catch in thousand tonnes, Risk3.B_{lim}: maximum probability of falling below B_{lim} in percentage.

Variable	Time interval	*1-over-2*	*chr* HR=0.5
Risk type 3	Short	6	3
	Mid	1.1	3.9
	long	0.1	5.1
SSB	Short	4.67	4.26
	Mid	6.47	5.17
	long	7.83	5.13
Catches	Short	2.5	3.04
	Mid	1.89	3.69
	long	0.407	3.73
F	Short	0.43	0.486
	Mid	0.267	0.528
	long	0.066	0.54

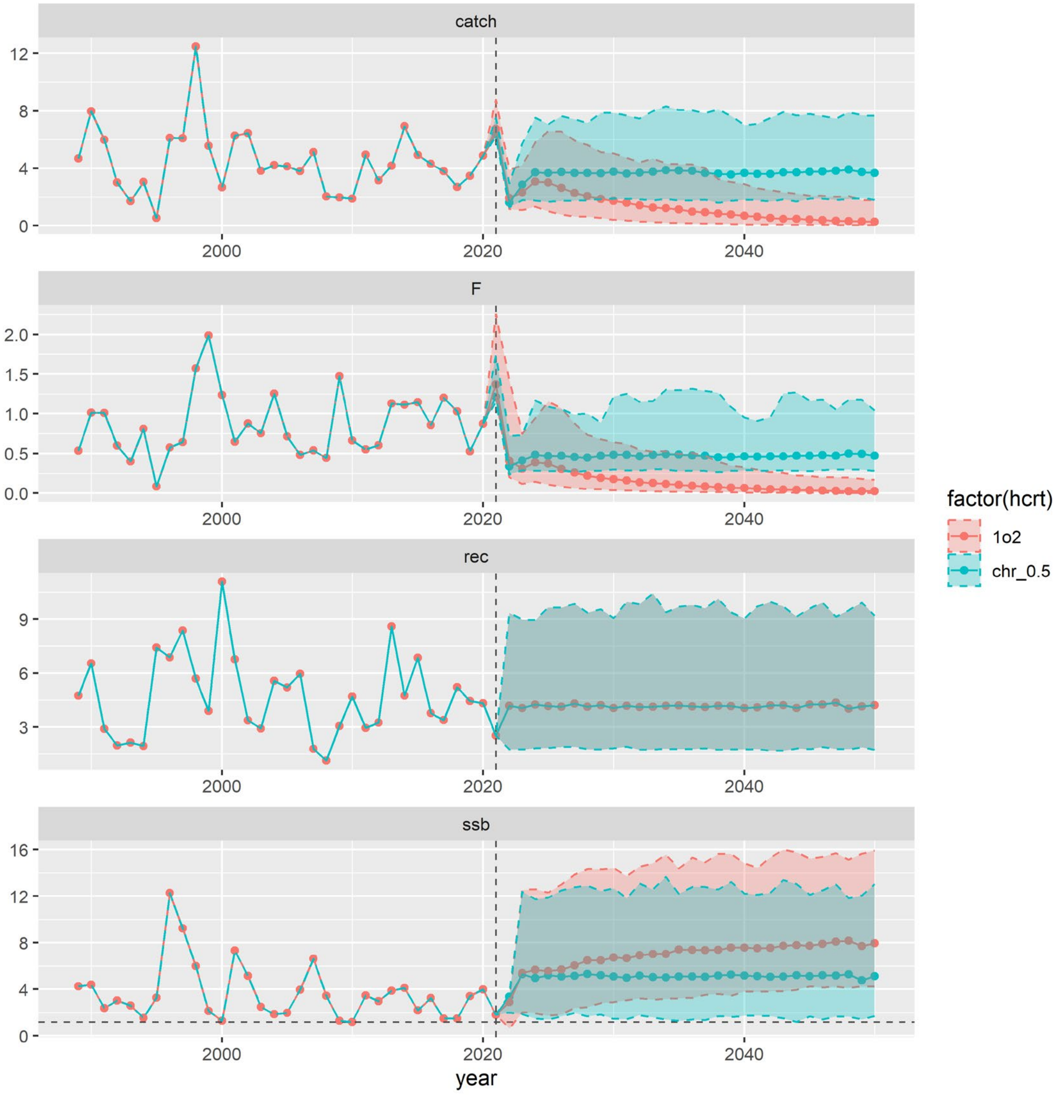


Figure 5.8.3.- Comparison of performance statistic for advice rules 1-over-2 and chr HR=0.5. Recruitment (rec x10⁹ individuals), biomass of fish age 1 and older (ssb, thousand tonnes), fishing mortality (F, year-1) and catch (thousand tonnes) for the historical period and the projected period. Shaded area represents 90% confidence intervals. Horizontal dashed line in SSB show B_{lim}. Vertical long dashed lines separate the historical from the projected period.

6 Conclusions

- The sensitivity analysis showed that in order to account for uncertainty in the most relevant factors affecting the perception of stock status and behaviour of the commercial fleet, the final settings for the *MSE* framework should include:
    - Biomass safeguard in the *1over2* and *chr HCR*s
    - Assessment error with sporadic high error values.
    - Limitation to recruitment to the maximum observed in the historic period
    - Distribution of catches over the year as observed in the last 10 years of the historic period.
    - *OM* conditioned with input data from Gadget assessment model with survey catchability as approved in the ane27.9a_south component 2022 assessment (ICES, WGHANSA 2022). This is the most precautionary scenario regarding the uncertainty in survey catchability in the assessment model.
- With this configuration of the *MSE* framework, the maximum precautionary *HR* in a *chr* was 0.5. Accordingly, HR=0.5 applied to the estimated SSB (by the Gadget assessment model) could be proposed as the $HR_{MSYproxy}$ for the 27.9a_south anchovy. In addition, a biomass safeguard with $I_{trigger}$ = 1194.132 tones should be applied.
- When compared to the *1-over-2* rule, the *chr* with a HR=0.5 produces higher yield while being precautionary.

7 References

Begley, J., and Howell, D. 2004. An overview of Gadget, the Globally applicable Area-Disaggregated General Ecosystem Toolbox. ICES CM 2004/FF:13.

Elvarsson, B., Taylor, L., Trenkel, V., Kupca, V., and Stefansson, G. 2014. A bootstrap method for estimating bias and variance in statistical fisheries modelling frameworks using highly disparate datasets. African Journal of Marine Science 36(1): 99-110.

García D., Sánchez S., Prellezo R., Urtizberea A. and Andrés M. 2017. FLBEIA: A simulation model to conduct Bio-Economic evaluation of fisheries management strategies, SoftwareX, Volume 6, Pages 141–147. https://doi.org/10.1016/j.softx.2017.06.001.

Gislason, H., Daan, N., Rice, J. C., and Pope, J. G. (2010). Size, growth, temperature and the natural mortality of marine fish. Fish Fish. 11, 149–158. doi: 10.1111/j.1467-2979.2009.00350.x.

ICES. 2018. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA 2018), 12–16 February 2018, ICES HQ, Copenhagen, Denmark. ICES CM 2018/ACOM:32. 313 pp.

ICES. 2018. Report of the Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA), 26–30 June 2018, Lisbon, Portugal. ICES CM 2018/ACOM:17. 605 pp.

ICES. 2019. Workshop on Data-limited Stocks of Short-Lived Species (WKDLSSLS). ICES Scientific Reports, 1: 73. 166 pp. http://doi.org/10.17895/ices.pub.5549.

ICES. 2019. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 1:34. 653 pp. http://doi.org/10.17895/ices.pub.4983

ICES. 2019b. Workshop on North Sea stocks management strategy evaluation (WKNSMSE). ICES Scientific Reports. 1:12. 378 pp. http://doi.org/10.17895/ices.pub.5090

ICES. 2020. Workshop on Data-limited Stocks of Short-Lived Species (WKDLSSLS2). ICES Scientific Reports. 2:99. 119 pp. http://doi.org/10.17895/ices.pub.5984

ICES. 2020. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 2:41. 655 pp. http://doi.org/10.17895/ices.pub.5977

ICES. 2020. The third Workshop on Guidelines for Management Strategy Evaluations (WKGMSE3). ICES Scientific Reports. 2:116. 112 pp. http://doi.org/10.17895/ices.pub.7627

ICES. 2021. Tenth Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE X). ICES Scientific Reports. https://doi.org/10.17895/ices.pub.5985

ICES. 2021. Working Group on Southern Horse Mackerel Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 3:55. 689 pp. https://doi.org/10.17895/ices.pub.8138

ICES (2021): ICES fisheries management reference points for category 1 and 2 stocks (2021). ICES Technical Guidelines. Report. https://doi.org/10.17895/ices.advice.7891

ICES. 2022. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 4:51. 518 pp. http://doi.org/10.17895/ices.pub.19982720

ICES (2022): ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. ICES Technical Guidelines. Report. https://doi.org/10.17895/ices.advice.19801564.v1

Kell, L.T., Mosqueira, I., Grosjean, P., Fromentin, J.-M., Garcia, D., Hillary, R., Jardim, E., Mardle, S., Pastoors, M., and Poos, J. 2007. FLR: an open-source framework for the evaluation and development of management strategies. ICES Journal of Marine Science 64(4): 640-646

Rincón, M, Ramos, F., Tornero, J., Garrido, S., Elvarsson, B, Lentin, J. 2022. Gadget for anchovy 9a South: Model description and results to provide catch advice and reference points (WGHANSA-1 2022).

Sánchez-Maroño, S, Uriarte, A., Ibaibarraga, L., Citores, L. 2021. Adapting Simple Index-Based Catch Rules for Data-Limited Stocks to Short-Lived Fish Stocks' Characteristics. Front. Mar. Sci., Volume 8. https://doi.org/10.3389/fmars.2021.662942

Taylor, L., Begley, J., Kupca, V., and Stefansson, G. 2007. A simple implementation of the statistical modelling framework Gadget for cod in Icelandic waters. African Journal of Marine Science 990 29(2): 223-245.

8 Acknowledgments

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WORKING DOCUMENT

Anchovy 9a west stock-specific management strategy evaluation conducted to determine an alternative to the current advice rule

Authors:
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1 Introduction

The anchovy stock in the ICES division 27.9.a (Figure 1.1) is a category 3 stock that includes two components: the western (ICES sub-divisions 9a.N, 9aCN and 9aCS) and the southern (ICES sub-divisions 9a.S).

Figure 1-1 - ICES Statistical Divisions and Subdivisions in Southern Europe. Western component of anchovy stock distributes in the area identified in blue as 9.a. West (comprising Sub-divisions 9aN, 9aCN, 9aCS). Southern component of anchovy stock distributes in the area identified in blue as 9.a. South (comprising sub-divisions 27.9.a.S -Portugal- and 27.9.a.S - Spain).

Scientific advice for this stock started in 2018 after a Benchmark WKPELA2018 (ICES 2018). WKPELA 2018 supported the proposal of considering two different components of the stock (western and southern component) due to the different dynamics of their fisheries and populations. However, it advised to add more information regarding the structure along the distribution, namely genetic information, and until then, the provision of advice should be given for the whole stock, but with separate catch advice for each stock component. An in-year monitoring and management was proposed, as for other small pelagic fish, and the management calendar for the application of the advice has been agreed to be the one from 1st July of year y to 30th June of year y+1 since 2018 onwards.

Assessment for this stock is done in the framework of the ICES Working Group of Horse mackerel, anchovy and sardine (WGHANSA) that meets at the end of May to decide upon the advice for this stock from July of the same year to June of the following year.

The western component of the stock is a data limited component, given that data availability to the present was insufficient to provide advice using an analytical model. The absence of data in the past is related to very low catches in accordance to very low abundance registered by the acoustic surveys in the area. For that early period there is no continuous quarterly information of length and age of catches in Portugal, where most of the component distributes.

Figure 1-2 shows the time series of the harvest rate (catch divided by the acoustic index) since 2007. The average harvest rate from 2007 to 2021 is 0.324.

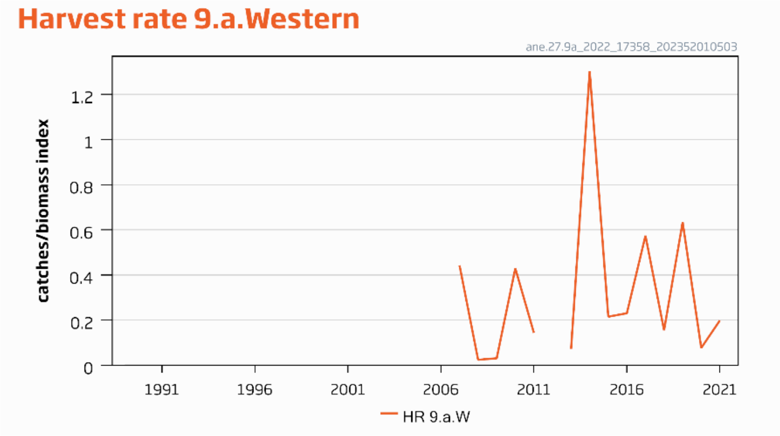

Figure 1-2 – Time series of the harvest rate (catch divided by the acoustic index) of the anchovy 9a in the western component (source: ICES, 2022).

1.1 Current advice rule (Method DLSSL 3 – 1-over-2 rule)

Currently, ICES framework for category 3 short-lived stocks is applied (ICES, 2021) whereby the 1-over-2 rule is constrained by an uncertainty cap of +/- 80% of the former catch advice as follows:

$$C_{y+1} = \left\{ \begin{cases} 0.2C_y & : \frac{I_y}{\sum_{i=y-2}^{y-1} I_i/2} < 0.2 \\ C_y \frac{I_y}{\sum_{i=y-2}^{y-1} I_i/2} & : 0.2 \leq \frac{I_y}{\sum_{i=y-2}^{y-1} I_i/2} < 1.8 \\ 1.8C_y & : \frac{I_y}{\sum_{i-y-2}^{y-1} I_i/2} < 0.2 \geq 1.8 \end{cases} \right\} . [min(1, \frac{I_{current}}{I_{trigger}})]$$

where C_y and I_y represent the advised catch and the biomass indicator for year y, respectively. The first and third cases of the formula correspond to the application of an 80% symmetrical uncertainty cap.

The notation of these rules is for in-year advice where the advised catch for the current year is based on last year's advised catch adjusted by the trend in the most recent abundance index, I_y, relative to the average of the index value in the previous two years. An uncertainty cap is applied to limit the change in the index trend, the I_y component of the harvest control rule, to ±80%, which allows the current years advised catch to increase or decrease up to 80% relative to the previous years advised catch. The last term in the equation refers to the biomass safeguard based on a trigger index value, below which the advice would be corrected downwards in proportion to the drop of the most recent abundance index over the $I_{trigger}$ value. This is a term, which has been shown to further reduce the risks associated to this advice rule.

For the Western component, the biomass indicator input has been taken from the results of two acoustic spring surveys covering this area, by adding the biomass estimated in the acoustic survey PELAGO (conducted in western Portugal, sub-divisions 9aCN and 9aCS) and PELACUS (conducted in western Portugal, sub-divisions 9aN).

1.2 Alternative to the current advice rule (Method DLSSL 2 – Constant harvest rate)

The current rule cannot accommodate the huge fluctuations in biomass of both components of the anchovy stock. For this reason, this approach is considered provisional, while a better formulation for providing advice is developed. According to WKLIFE X (ICES, 2021a), 'when a SPiCT model cannot be fitted to a short-lived data-limited stock (SLDLS), and the stock has an accepted survey, the best way to adjust catches to the highly fluctuating nature of these stocks may be achieved by removing a constant fraction of the stock every year, corresponding with a sustainable harvest rate ($HR_{msy.proxy}$), applicable to the abundance indicator of the stock ($I_{current}$), so that the maximum probability of the spawning stock biomass (SSB) being below B_{lim} is kept <0.05.

$$C_{y+1} = I_{current} * HR_{MSY.proxy}$$

The constant harvest rate (CHR) can be complemented with a biomass safeguard factor based on a trigger index value, $I_{trigger}$, below which the advice should be corrected downwards in proportion to the drop of the most recent abundance index over the $I_{trigger}$ value.'

To implement this method, WKLIFE X (ICES, 2021) recommended to conduct a stock-specific management strategy evaluation (MSE) process to fine-tune the parameters of the advice rule. The MSE should: (1) determine the constant harvest rate that is most robust to the OM and observation system uncertainties; (2) consider the time-lag between the index availability and management implementation; and, (3) determine the $I_{trigger}$ value, aiming at assuring allowable risk levels.

1.3 Approach

This working document presents a stock-specific management strategy evaluation conducted to determine the CHR that is the most robust to the operating model (OM) and observation system uncertainties. First, available fisheries independent and dependent data and biological information such as growth parameters are reviewed (sections 2, 3 and 4). Then, the MSE framework is described (section 6). The time-lag between the index availability and management implementation (management calendar) and the inclusion of a biomass safeguard were considered. In section 7 we present the main results of the study including the comparison of the current applied advice rule with the CHR advice rule for a fixed value of harvest rate, followed by a sensitivity analysis. Finally, some general conclusions are drawn in section 8.

2 Survey and indices

There are 3 spring acoustic surveys, coordinated by WGACEGG since 2002, that cover the Atlantic Iberian waters: PELGAS in the Bay of Biscay, PELACUS in western Galician waters and the Cantabrian Sea, and PELAGO, covering the area from western and southern Portugal and the Gulf of Cadiz (Massé *et al*., 2018). In all 3 surveys, transects are perpendicular to the coast and cover the entire shelf, which is wider in the Bay of Biscay than along the Portuguese and Spanish coasts. According to the estimates provided by the spring acoustic surveys carried out in the Atlantic Iberian waters from 2013 to 2021, adult anchovy core distribution areas in springtime are, by decreasing order of importance: coastal areas in Southern Bay of Biscay (Gironde and Landes coast, ~46°N), the Gulf of Cadiz (~37°N), and in the northwestern Portuguese coast, North of Cape Mondego (~40°N) (**Figure 2-1**). There is a gap in the distribution of adult anchovy in the western side of the Cantabrian Sea and in the southwestern Portuguese coast.

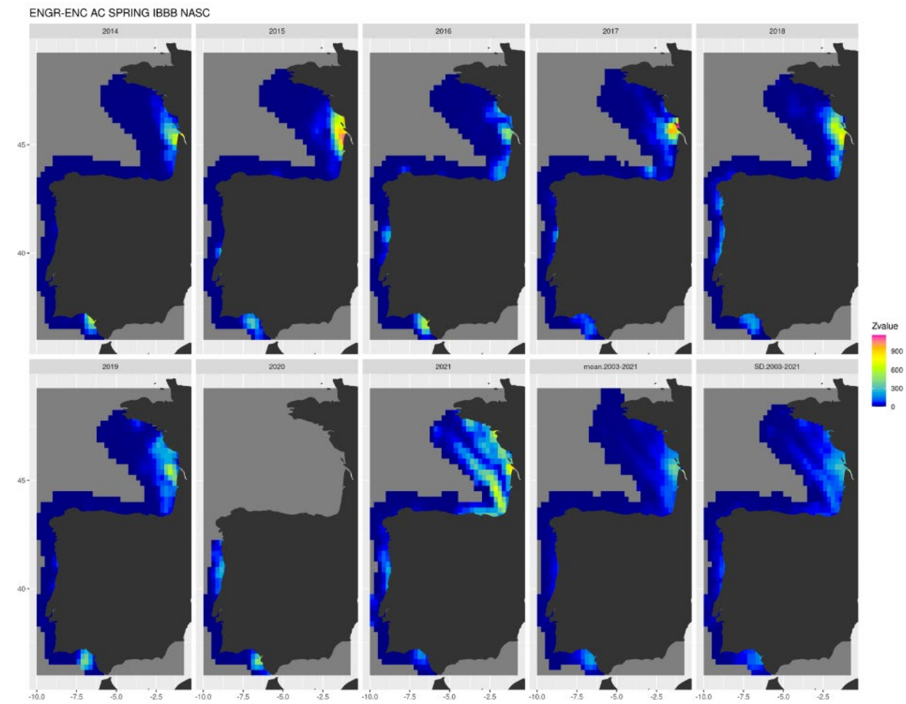

Figure 2-1 - Mean acoustic density (NASC, $m^2.NM^{-2}$) of anchovy in surveys PELGAS, PELACUS and PELAGO from 2014 to 2021. Last two maps: mean and standard deviation from 2003 to 2021. Source: ICES WGACEGG 2021 Report.

Anchovy egg distribution estimated during the spring acoustic surveys from 2018 to 2021 is similar to that of the adults, being higher in the Bay of Biscay, followed by the Gulf of Cadiz and the northwestern coast of Portugal (Figure 2-2). However, it should be noted that peak spawning for anchovies in Division 9a generally occurs two months after these surveys.

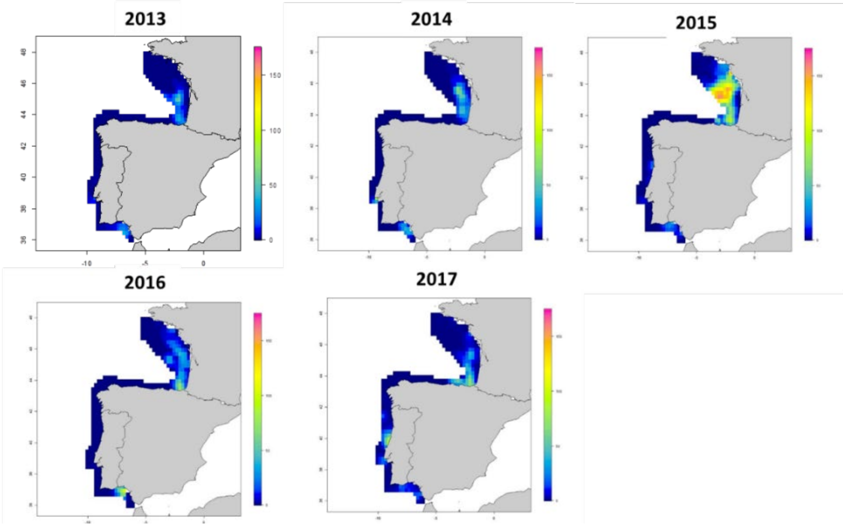

Figure 2-2 - Anchovy egg density (eggs m^{-3}) distribution derived from CUFES sampling during the spring acoustic surveys, PELGAS (IFREMER), PELACUS (IEO) and PELAGO (IPMA) for the period 2013-2017. Source: ICES WGACEGG 2017 Report.

There are 2 spring acoustic surveys that cover the distribution area of this component: PELACUS in western Galician waters and PELAGO covering the western Portuguese area.

The PELAGO survey covers most of 9a Division, from sub-areas 9aCN to the Gulf of Cadiz, only excluding the 9aN Sub-division, that accounts, on average, 5.4 ± 6.24% of anchovy abundance in Division 9a and 3.3 ± 4.91% of anchovy in the western component (data from 2007 to 2021) and is covered by complementary survey PELACUS. Acoustic surveying is undertaken along 71 transects perpendicular to the coast, covering the whole platform, and separated approximately 6 (south) or 8 nautical miles (west). Fishing hauls are carried out for species ground-truthing and fish size composition. Zooplankton samples are collected underway every 3 nautical miles, with the CUFES system (water pumped from 3 m from the surface, system fitted with a 335 µm mesh size net), concurrently to the acoustic surveying along the trajectory of the acoustic transects.

The PELACUS survey covers the subdivision 9aN and subarea 8c since 1984. The survey design consists of a grid of parallel transects, eight nautical miles apart and perpendicular to the coastline, and covering the continental shelf up to a depth of 200 m. The starting point of each transect is located close to the coast although the exact location can be modified due to adverse weather conditions or the presence of shallows. The end point of each transect can be also extended if shoals are detected in deeper waters. Acoustic records were obtained during daylight together with egg samples from a CUFES, with an internal water intake located at 5 m depth. In addition, pelagic trawl hauls were performed opportunistically to verify the acoustic data. This series provides the size composition (LFD) of the estimated population of anchovy in numbers and biomass. Age composition is available since 2008.

There are also autumn acoustic surveys to estimate sardine and anchovy recruitment strength. Until 2017, the acoustic survey series was limited to the north western Portuguese coast (JUVESAR survey series). From 2018 onwards, the surveyed area was extended to the whole Iberian western coast, including Sub-divisions 9aN, 9aCN and 9aCS (IBERAS survey series).

During the IBERAS survey series, anchovy was found to be particularly high in the 9aCN area during peak abundance years (2018 and 2021), accounting for >99.9% of total anchovy abundance and 70% in a low abundance year (2019), while showed low abundance during 2020 when most anchovy was found in the 9aN area (94%). For the remaining years, abundance in the 9a.N area was residual. In the 9a.CS subdivision, anchovy abundance was very low (<0.2%

of western abundance) in 2018, 2020 and 2021 and was 29% in the low abundance year (2019) when it occurred in the northern part of the southwestern Iberian coast, near Lisbon.

To convert acoustic biomass to abundance, a Target Strength (TS) equation is used. No dedicated anchovy specific TS equation is available for the area and the estimated value for herring of b20 = -72.6 dB is used (Degnbol *et al.*, 1985). This is the same value used for sardine that is also estimated by the same surveys in the same area (Massé *et al.*, 2018).

Advice for anchovy 27.9.a western component is provided by ICES on an annual basis and has been based on the analysis of biomass trends from adding the PELAGO and PELACUS survey estimates (Table 2.1, Figure 2-3).

Table 2.1 – Combined survey index for the anchovy 9a western component (source: ICES,2022).

Year	Survey index 9.a.W
	t
2007	1945
2008	5810.507
2009	2114.915
2010	1230.396
2011	28558.451
2012	
2013	4284.294
2014	1947
2015	8237
2016	38507.4
2017	19047
2018	65096.873
2019	4129
2020	56525.9
2021	65683
2022	111963.414
Average	27672.01

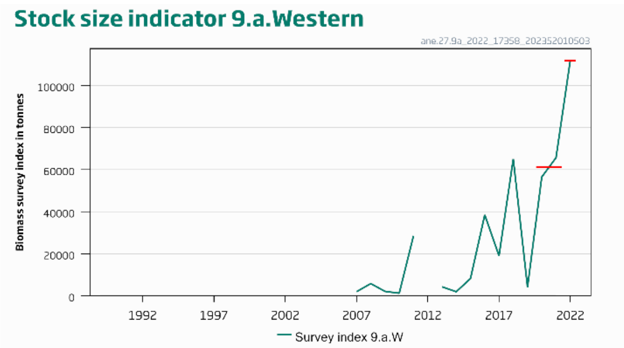

Figure 2-3 – Combined survey index for the anchovy 9a in the western component. The horizontal orange lines indicate the average values of the respective years (source: ICES, 2022).

3 Fishery dependent data

Anchovy in Division 9a is mostly harvested by purse-seine fleets (generally 99% of total catches). For Portugal, statistics of annual landings date back to 1943 while Spanish annual landings are available since 1989 (before those reported catches included catches from Spanish and Moroccan fishing grounds). Large populations in Galicia and Portugal have historically supported large harvests until the early 1960s, when these populations declined (Junquera, 1986; Pestana, 1989). For the period with complete data for the whole Division (from 1989 to present), landings have ranged from 1984 t (1993) to 13775 t (2018) (Figure 3-1). Landings have been dominated by those done in the Gulf of Cadiz (Subdivision 9a South – Cadiz) for most of the time series, representing >80% of catches during most years. In contrast, in the western Iberia, anchovy was only harvested during years of high abundance. As of 2016, the majority of catches were taken in the western Iberia, of which >90% concentrated in the 9a Central North Subdivision that coincides with an increase of biomass in this area (Figure 3-1).

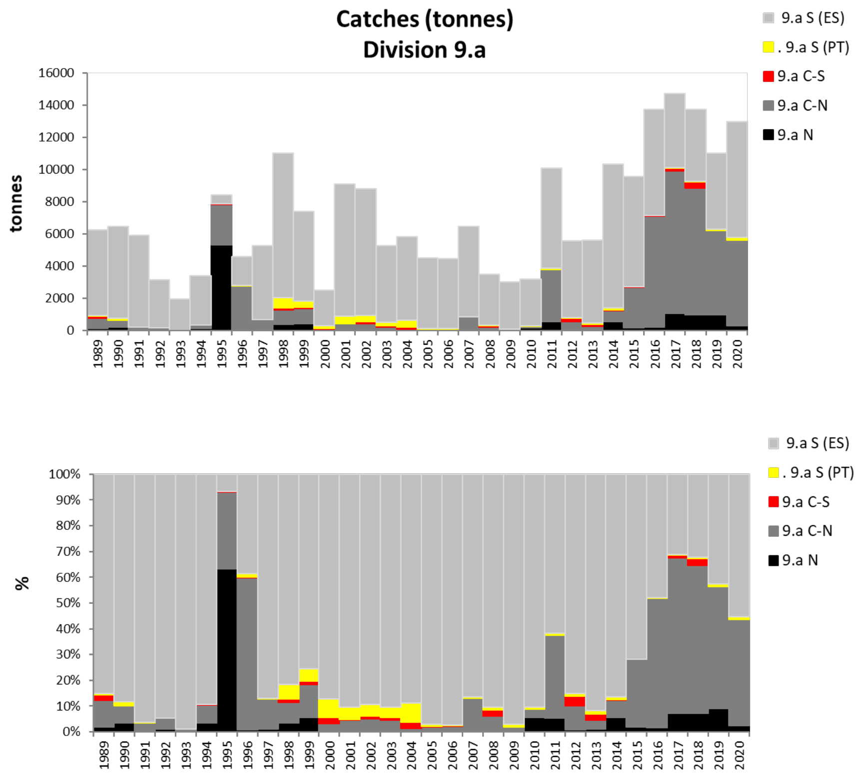

Figure 3-1 - Time series of anchovy landings in Division 9a (1989-2020) in ICES Subdivisions 9a North, Central-North and Central-South (western component) and Subdivisions 9a South-Alg and 9a South-Cad (Southern Component).

The distribution of catches by main fishing ports in Portugal reveals that the great majority of catches take place in the northern part of the northwestern Iberia (north of 9aCN area), followed by the area around Lisbon (port of Sesimbra). Catches in the southwestern coast and in the south are significantly lower (Figure 3-2).

Although the actual magnitude of discarding practices for the past anchovy fishery in the Division 9a is unknown, the respective Data Collection Framework national sampling programs have revealed that for the recent fishery (since the early 2000s), in general terms, anchovy discards may be considered as negligible or even null.

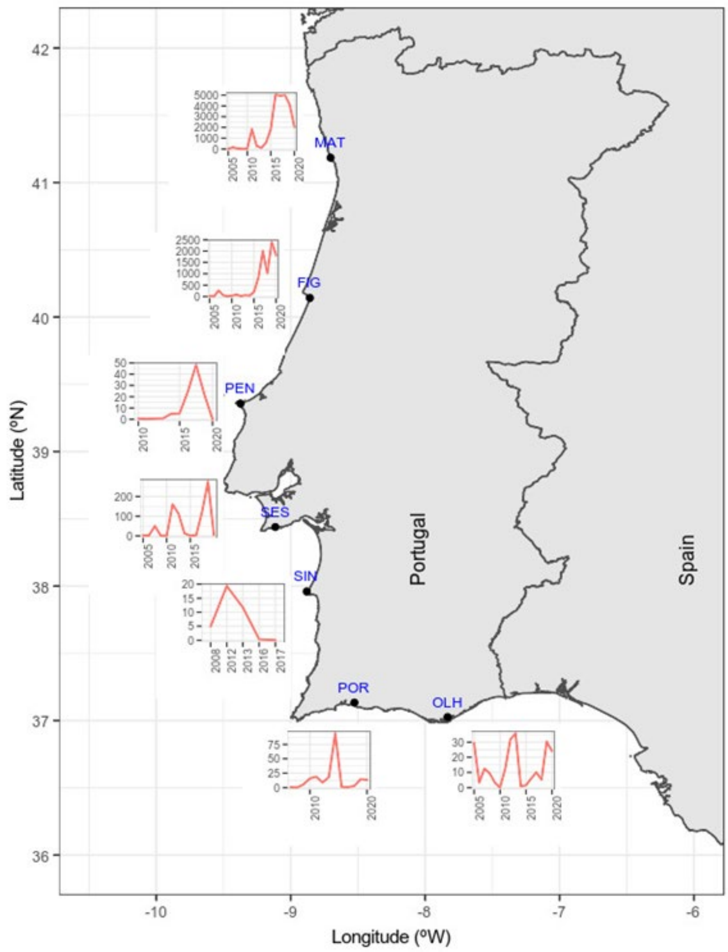

Figure 3-2 - Distribution of catches (tons) in the main fishing ports (Matosinhos - MAT, Figueira da Foz – FIG, Peniche – PEN, Sesimbra – SES, Sines – SIN, Portimão – POR, Olhão – OLH) of Portugal from 2005 to 2020.

Regarding the age structure of the population in the catches, there is limited data from the Spanish (9aN) and Portuguese (9aCN) fisheries. Age distribution of anchovy in the catches from both areas are dominated by fish of 1 and 2 years old. Fish with 3 years old and Age 0 are rare (Figure 3-3).

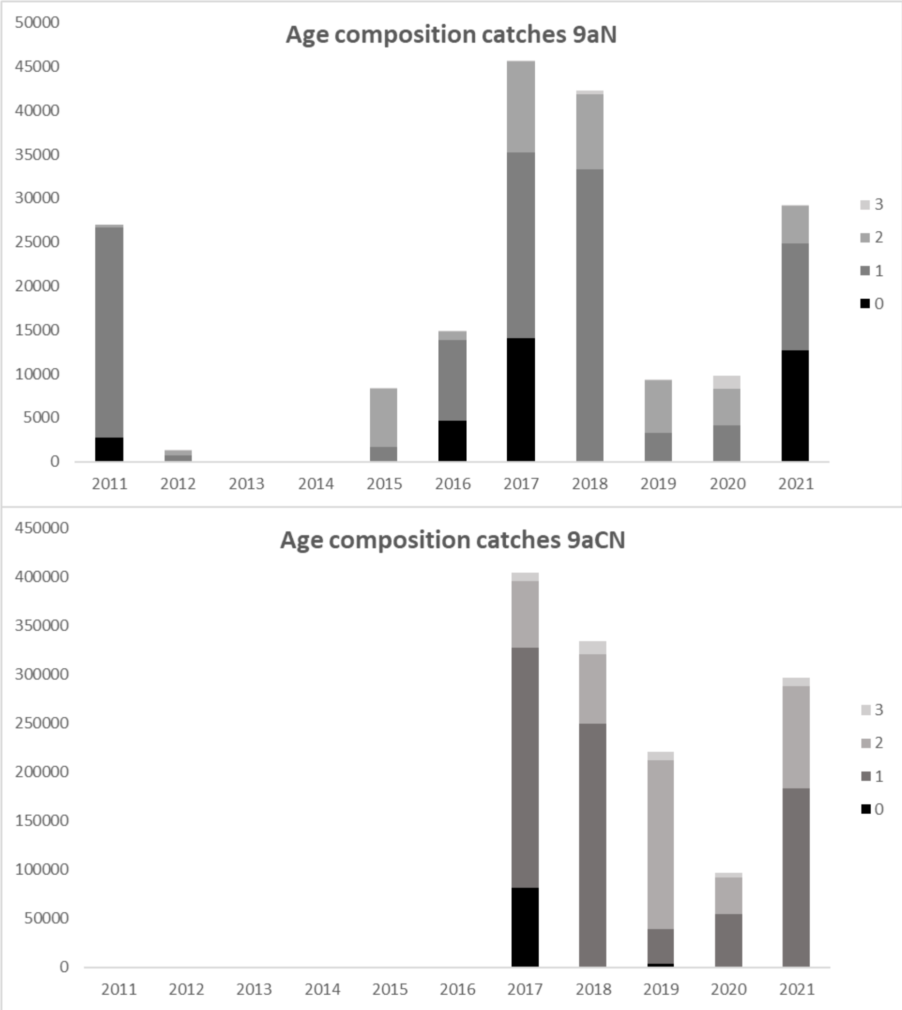

Figure 3-3 - Age composition of catches for the 9aN (upper panel) and 9aCN (lower panel) areas. No information available for the 9aCS sub-division.

4 Growth parameters

Using data from both the Autumn (JUVESAR and IBERAS) and Spring (PELACUS and PELAGO) acoustic surveys that cover the area of the western component of the Iberian anchovy stock, a von Bertalanffy growth function expressed as $L_t = L_{inf} * (1 - \exp(-K * (age - t_0)))$ was estimated. Two different approaches were explored, length frequency analysis (ELEFAN method with new optimisation techniques by Taylor & Mildenberger (2017)) and length-at-age analysis. Only the latter is presented in this working document because it had the best fit.

The von Bertalanffy growth model (VBGM) was estimated using the R package FSA: Fisheries Stock Analysis (Ogle *et al*., 2021). Mean length at age data from the Spring and Autumn acoustic surveys were used. Starting values for k, t0 and L_{inf} were estimated using the function vbStarts().

Different data subsets were used to estimate the VBGM. Data from age group 5 was omitted since it only appears in 1 survey (2008). First, we tried to fit a VBGM to the subset data of the Spring surveys (subset ss). Then, we removed individuals equal or bigger than 22 cm (subset ss22) since they only appeared in one survey and area (PELACUS 2010) and then we also fitted the model using decimal ages (ss22D), i.e., we adjusted the age to account for the survey timing. We assume that age zero only enters the population at the middle of the year (beginning of July). A fitting of the model was also done to the recruitment survey data (subset rs) since these include mean length at age for age zero. Finally, we combined both surveys, removed individuals equal or bigger than 22 cm and used decimal ages (subset all).

The starting values estimated from the different data sets using vbStarts() are shown in Table 4.1 while the point estimate, standard error and respective t-value and p-value for the VBGM parameters are shown in Table 4.2.

Table 4.1 - Initial parameters of the VBGM used for the different subsets.

Parameters	L_{inf}	k	t_0
all	15.36	0.38	-2.43
ss	19.53	0.38	-1.86
ss22	16.57	0.96	-0.56
ss22D	16.13	1.00	-0.80
Rs	18.40	0.47	-2.20

Table 4.2 - Fitted parameters of the VBGM for the different subsets.

Parameter	Estimate	Std Error	t-value	Pr(>|t|)
rs				
Linf	17.7977737	3.64	4.88	0.00
K	0.4999318	0.53	0.93	0.36
t0	-2.1964082	1.64	−1.34	0.20
ss22D				
Linf	17.2024044	1.06	16.23	0.00
K	0.7327237	0.38	1.92	0.06
t0	-0.8811932	0.78	−1.13	0.27
ss22				
Linf	17.2024044	1.06	16.23	0.00
K	0.7327237	0.38	1.92	0.06
t0	-0.8811932	0.78	−1.13	0.27
ss				
Linf	19.6908019	3.73	5.28	0.00
K	0.3679001	0.31	1.18	0.24
t0	-1.8904173	1.56	−1.21	0.23
all				
Linf	17.4554402	0.98	17.74	0.00
K	0.6242448	0.23	2.77	0.01
t0	-1.1760832	0.53	−2.24	0.03

Figure 4-1 shows the fit of the different estimated VBGM with confidence intervals estimated with bootstrap. We propose the model fitted to all data (red line and text) as the candidate model for the base operating model of the MSE since: (i) takes advantage of using age zeros from the autumn acoustic surveys, (ii) has the highest *quasi* r^2 value (0.651); (iii) although the fit (measured by the estimation of the residual mean square error) to ages 1 and 2 (the most important fraction of the explored population) is very similar, or identical, between models (with the exception of the model fitted only to the recruitment survey), the fit to the other ages are in general better.

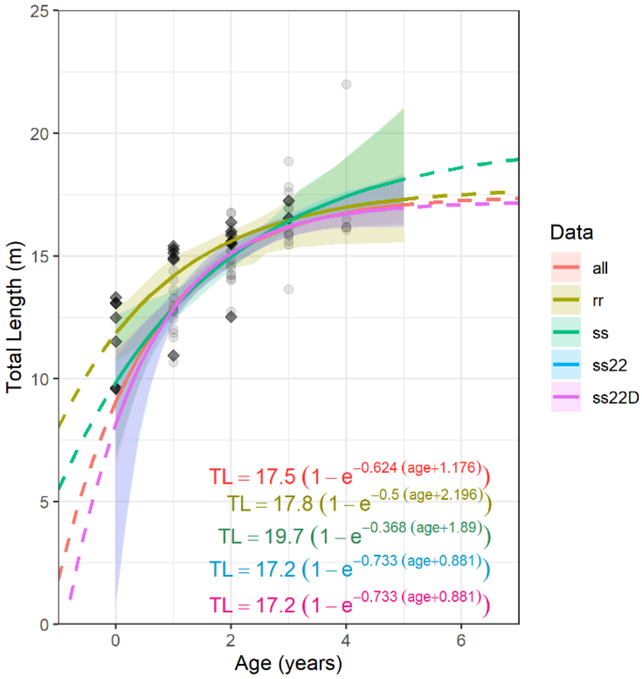

Figure 4-1 – Fitted VBGM to the weighted mean of total length observed by age and survey. Grey circles represent data from the spring surveys while diamond black shapes represent data from the autumn surveys. If data are overlapped the colour gets darker.

5 Management calendar

The Total Allowed Catch (TAC) of 9a anchovy followed calendar years, known as interim year advice (int), until 2017. In this management calendar, the TAC from January to December in year (y+1) was set at the end of year y. At the time there was no assessment of the stock. Since 2018, following a benchmark (WKPELA 2018), the stock started to be assessed as a category 3 stock, and the advice provided as an in-year advice (iny), i.e., the management calendar is seasonal, running from July (year y) to June (year y+1). This means that the TAC is set soon after the biomass index on B1+ is available (Table 3.1).

Table 5.1 - Anchovy in Division 9.a. ICES advice, the agreed TAC, and ICES catches. All weights are in tonnes. Catches from 1 July to 30 June in the following year to match the advised period.

Management year	Catches corresponding to advice		Agreed TAC	ICES catches	
	West component	South component		West component	South component
Jul 2018 – Jun 2019	13308	3760	17068	10093	3815
Jul 2019 – Jun2020	2662	6290	10240	2624	6472
Jul 2020 – Jun 2021	4347	11322	15669	5461	7904
Jul 2021 – Jun 2022	7824	7181	15005	11217*	5839*
Jul 2022 – Jun 2023	14083**	1694**			

* Catch estimates of the first two quarters of 2022 are provisional.
** Preliminary data resulting from WGHANSA May 2022.

The current management calendar is aligned with WKDLSSLS-1 and 2 conclusions which highlighted the "relevance of the time-lag between the survey, the advice and the management. In both workshops all simulations proved that the shorter the lag between observations, advice, and management the smaller will be risks, usually for higher (or similar) catches. This means that the in-year advice should always be preferred over the normal calendar year advice (with one interim year lag). Results were very consistent across different operating models".

6 Methods

A stock-specific management strategy evaluation (MSE) was conducted to determine the constant harvest rate (CHR) that is the most robust to the operating model (OM) and observation system uncertainties. The time-lag between the index availability and management implementation (management calendar) and the inclusion of a biomass safeguard were considered. The performance of the current advice rule (1-over-2 with 80% uncertainty cap) was evaluated against the CHR that maximized catches while preventing a risk maximum of 5% in the long run for the base case scenario.

The MSE simulations were carried out using the FLR packages FLCore (version 2.6.18; Kell *et al*., 2007) and FLBEIA (version 1.16.1.6.; García *et al*., 2017) software. The methodology followed was the one used in Sánchez-Maroño *et al*. (2021), but the dynamics of the stock and the fishery were adapted for the western component of the anchovy stock in ICES division 9a. The work presented in this report was based on 1000 populations (*iters*). The MSE is structured by semesters and by age.

Each stock started from a virgin population (B_0) equal to 100 000 tonnes. Three fishing histories were created for all stocks over a 30-year spin-up period. We assumed that fishing effort was increasing over time for the first 10 years up to a constant level of fishing mortality (F): (i) underexploited, $F = 0.5 \cdot F_{MSYproxy}$; (ii) fully exploited, $F = F_{MSYproxy}$; and (iii) overexploited, $F = 2 \cdot F_{MSYproxy}$). These levels of fishing effort established different starting points (depletion levels) at the beginning of the simulation period. Variability in the historical fishing mortality (F) was included through a log-normal distribution with a coefficient of variation (CV) of 10%. Advice measures where then implemented for a 30-year projection period. The abundance index of biomass at age was generated from the "true" population on individuals age 1 or older and is assumed to take place between March and April (0.30 fraction of the year).

Stock status, productivity level, survey catchability and survey coefficient of variation were considered the key uncertainties; scenarios were considered for each of these uncertainties.

Performance of the advice options were monitored in the MSE mainly through two performance statistics (Table 6.1):

- **Risk**: The maximum probability of SSB being below B_{lim} where the maximum of the annual probabilities is taken across iterations and time. Values < 0.05 are considered precautionary. This is Risk type 3 that ICES currently uses as the basis for defining a multiannual plan as precautionary.
- **Relative yield**: Median of the catch divided by MSY.

Other performance statistics such as the median average biomass of fish age 1 and older (B1+), fishing mortality and catch are also presented for some scenarios.

These metrics were estimated for three time periods:

- Short: an initial time period covering the first five years of the projection period;
- Mid: the next five years of the projection period;
- Long: last ten years of projection period.

Table 6.1. Statistics used to summarize the performance of the proposed HCRs.

Indicator

Relative Yield	Median of the mean catch over time and across iterations divided by MSY
Fishing Mortality	Median F_{bar}, 5th and 95th percentiles
SSB	Median SSB, 5th and 95th percentiles
Precautionary considerations	$Risk3 = \max(prob\ of\ SSB\ being\ below\ Blim)$

6.1 Operating and observation models

The operating model (OM) is the mathematical representation of the *true* stock and the fleets. The OMs were based on a limited number of life history parameters estimated for the western component of the 9a anchovy stock. The population dynamics of the component was simulated using an age-structured population model (ages 0 to 3+) exploited by a unique fleet (composed by one métier).

Growth was based on the von Bertalanffy growth model (L_{inf} = 17.4554; k = 0.6242; t_0 = -1.1761) estimated using data from acoustic survey samples (see Section 4). To account for uncertainty in the growth model alternative operating models were defined (Table 6.2) and a reduced number of scenarios were run for the no fishing scenario, the current advice rule and the CHR rule.

Table 6.2 – von Bertalanffy growth models considered to account for uncertainty in life-history parameters.

Parameters	Values		
Growth	VB1	VB2	VB3
L_{inf}	17.4554	17.4554	15.70986
k	0.6242	0.56178	0.6242
t_0	-1.1761	-1.1761	-1.1761

Lengths were converted to weight-at-age using a length-weight model (a = 0.0021; b = 3.216) also estimated with data from the acoustic survey samples. These constitute the best approximation to the stock component. Assumptions about future mean weight-at-age of anchovy were based on the length-weight relationship derived from the biological data collected in both the autumn and spring acoustic surveys (Figure 6-1). No variability was considered as there is no indication of significant trends in historical weight-at-age.

Natural mortality and proportion of mature individuals at-age were considered time-invariant during the projection period. Natural mortality is age-dependent (Figure 6-1) and was derived from the von Bertalanffy growth parameters according to life-history theory (FLife R package, version 3.4.0; Kell, 2018) following Gislason *et al*. (2010). Maturity is modelled as a knife edge, with 0% mature at age 0 and fully mature from age 1 onward for the baseline OM (Figure 6-1).

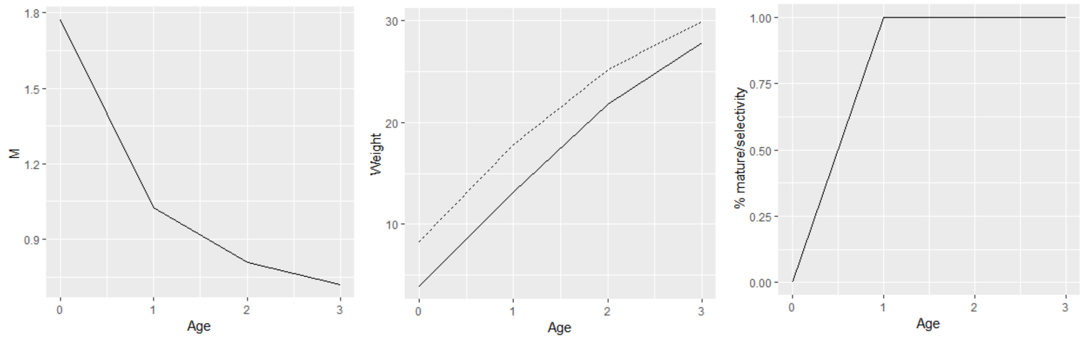

Figure 6-1.Natural mortality, mean weight-at-age, proportion of mature individuals and selectivity for ages 0–3+, used in the simulations. In the middle panel, the dotted line corresponds to weights in the second semester and the full line corresponds to weights in the first semester.

Fleet selectivity was modelled as maturity for the base case. To allow for some age zero catches, some scenarios were run considering a 20% catch of age zero individuals. This represents the maximum percentage observed in the whole available catch time series.

Recruitment was based on the Beverton-Holt stock recruitment relationship parametrised with the steepness parameter h = 0.75 (default scenario) that represents a medium productivity (Jardim *et al*., 2015; Fischer *et al.*, 2020), virgin biomass (B0) equal to 100 000 tonnes and a standard deviation (σ_{REC}) at 0.75 since large fluctuations in recruitment are observed from one year to the next. However, other values of steepness such as h = 0.5 (low productivity) and h = 0.9 (high productivity) and recruitment standard deviation (lower and higher than 0.75) were also tested.

The biomass indicator (that corresponds to the spawning stock biomass) is assumed to take place between March and April (0.30), during the first semester, and was generated from the "true" population: it was derived by estimating the spawning biomass of the stock at the moment that the survey takes places and multiplying it by the assumed catchability of the survey. It already takes into account the fishing mortality that might have occurred before the survey takes places. Survey catchability for the combined index of PELAGO and PELACUS is not known, therefore several values were tested ranging from 0.5 to 2 (extreme case). The default case is assumed to be 1, similarly to what has been estimated for other pelagic species caught by the same surveys. Catchability at age is the same for all ages. Coefficient of variation for the survey is also not known. The Iberian sardine stock assessment considers that the CV of the survey is 0.25. Scenarios of a CV of 0.5 and 1 were also tested.

6.2 Management procedure

The management procedure (MP) includes the stock assessment ('perceived' stock) and advice for fisheries management following the application of the management strategy (Harvest Control Rules), and the management process to implement the scientific advice. The assessment model emulator was applied yearly in the simulation.

The assessment is based on empirical estimates from the spring acoustic survey carried out in the stock component area. Hence, the assessment emulator draws a 'perceived' stock (biomass) from the true population and the observation error.

The Harvest Control Rules (HCR) tested are applied directly to the simulated biomass index. The HCR tested are:

i) the "1-over-2" rule, i.e., the ratio of the last biomass estimates and the average of the two previous years of the fisheries independent index; this rule was applied with an

80% uncertainty cap; This is the advice rule in place at the moment. In the first year of application of the rule, the rule depended on a reference TAC value, which was calculated as an average of the catch in the most recent 2 years.

ii) a constant harvest rate (CHR), i.e., to remove a constant fraction of the stock every year applicable to the abundance indicator of the stock; the approach is to find the maximum CHR that keeps the biological risk at or below 5% (following the ICES precautionary criteria this is the acceptable risk).

6.3 Implementation model

The present MSE was run without implementation error, i.e., assuming perfect implementation of the Total Allowable Catch (TAC) advice.

Most anchovy west catches occur during the second semester (Table 6.3). From 1998 until 2017, catches in the second semester were on average 71% of the total yearly catches and ranged from 28 to 98%.

Table 6.3 - Distribution of anchovy 9a western component catches in biomass and percentage biomass per semester. Colours represent semesters corresponding to the same management year.

	Biomass		Percentage Biomass	
year	Semester 1	Semester 2	Semester 1	Semester 2
1998	243	128	65	35
1999	122	699	15	85
2011	13	535	2	98
2012	24	10	72	28
2013	14	55	21	79
2014	17	564	3	97
2015	432	550	44	56
2016	112	587	16	84
2017	2149	7939	21	79
2018	2735	6194	31	69
2019	3850	2349	62	38
2020	503	7658	6	94
2021	350	9089	4	96

Regarding the most recent years, following the benchmark, catches have consistently been higher in the second semester of the year corresponding to the first semester after provision of advice (Table 6.4). From July to December catches were on average 80% of the total allowed catches of the management year.

Table 6.4 - Distribution of anchovy 9a western component catches per semester for the most recent years when assessment took place.

	Biomass (tonnes)		Biomass (%)	
management year	**jul-dec**	**jan-jun**	**jul-dec**	**jan-jun**
2018/2019	6194	3850	62	38
2019/2020	2349	503	82	18
2020/2021	7658	350	96	4

The time series of available catch data includes years of very high and very low abundance, with very high and very low allowed catches and consistently most of the catches are concentrated in the second semester of the year. Therefore, it is reasonable to assume that catches in the future will follow the same tendency and a distribution of 70% of catches for the second semester of the calendar year and 30% in the first semester of calendar years can be assumed (mean of catches from 1998 to 2017 following calendar years and 2018 to 2021 following advice years are of 73% and 27%).

6.4 Base Case

The base case that best describes the western component of the anchovy and was used to determine the CHR that maximized catches while preventing a risk maximum of 5% in the long run was defined as:

- The OM assumes a stock with a medium productivity (h = 0.75; LHSC = 'bc') with a standard deviation for recruitment of 0.75 (SIGR = 0.75); The selectivity of the fishery is considered to be zero for age zero and one for all other ages (STKN = 'ane9w');
- The observation model considers that the biomass index has no bias (QIDX = 1) and has a low coefficient of variation of 25% (CVID = 'low');
- The calendar year is the one in place, i.e., an in-year advice (ADVT = 'iny'). where advice and management of the stock takes place soon after the biomass index is available;
- It also considers that no biomass safeguard is in place (BSAFE = 'none').

To search for the maximum sustainable CHR, the MSE was run for the base case scenario with the CHR advice rule (ADVT = 'chr') with different values for the harvest rate (HRVX between 0.1 and 0.6). Performance statistics were calculated for all the runs. The scenario with the highest relative yield and risks below 0.05 in the long term in all the historical fishing patterns was selected. This scenario was then compared to the base case scenario but where the current 1-over-2 advice rule is applied in the projection period.

6.5 Sensitivity Analysis

For each historical fishing pattern, we also evaluated the performance of the two advice rules under 2 management calendars: in-year (iny) and interim year advice (int). In the interim year advice, the TAC from January to December in year (y+1) is based on the indices on B1+ in the interim year y (in the middle of first semester). The in-year advice shortens the time lag between the biomass index and the management advice: the management calendar is moved to July-June and the TAC is set at the beginning of the second semester, shortly after the biomass index on B1+ is available.

We then tested the sensitivity of the rules' performance to the coefficient of the variation (CVID) and the catchability (QIDX) of the survey index (

Table). As alternatives to the assumed value of 0.25 that was considered a low CV, we considered a high CV equal to 0.5 and CV equal to 1. As alternatives to the assumed value of 1 that was considered the standard catchability value, we considered a lower value of 0.5 and three higher values of 1.25, 1.5 and 2.

The implementation of a Biomass safeguard was also evaluated. This consists in a multiplicative factor that reduced the TAC advice when the observed index was below a threshold value ($I_{trigger}$): $TAC_{y+1} = TAC_{y+1} * \min(1, \frac{Icurrent}{Itrigger})$. $I_{current}$ is the last available index and the biomass safeguard $I_{trigger}$ can adopt three alternative values listed in

Table

Finally, another option for the fishing selectivity was evaluated to allow for some age zero catches. This scenario was only run for some scenarios with the constant harvest rate advice rule.

Table 6.5. - List of alternative scenarios simulated for the different components.

Variable	Description	Scenario	Scenario description
LHSC	Life-history scenario (productivity)	BC	h = 0.75
		Low	h = 0.5
		High	h = 0.9
SIGR	Standard deviation for the recruitment log-normal error	0.75	Default value to account for the high variability
		0.5	
		1	
FHIST	F target in the historical period	fopt	$F_{target} = F_{40\%}B_0$
		flow	$F_{target} = 0.5 * F_{40\%}B_0$
		fhigh	$F_{target} = 2 * F_{40\%}B_0$
CVFH	CV for FHIST error	0.10	
IDTX	Index type	b1p	Biomass index on individuals age 1 or older
CVID	Coefficient of variation of the error term for the B1+ index	low	CV = 0.25
		medium	CV = 0.5
		high	CV = 1
QIDX	Catchability for the B1+ index	1	Neutral
		0.5	Low
		1.25	Medium
		1.5	High
		2	Extreme
ADVT	Advice type	iny	in year advice
		int	interim year advice
HCRT	HCR type	1o2, chr	1-over-2 and constant harvest rate advice rule
UC	Uncertainty cap	0.8	Maximum increase/decrease in TAC of 80% from previous year
BSAFE	Biomass safeguard	I_{min}	$I_{trigger} = \min(I_{hist})$
		I_{minpa}	$I_{trigger} = 1.64 * \min(I_{hist})$
		I_{norm}	$I_{trigger} = e^{mean(log(Ihist) – 1.645 sd(log(Ihist))}$
HCRI	HCR initialisation (i.e., reference TAC in the 1st simulation year)	nin	Mean of the last two years catch

6.6 Reference points

At present there are no reference points defined for this component. Reference points were estimated based on the above dynamics and assuming that 70% of the catches occurred in the second semester. The limit biomass (B_{lim}) was set as 20% of the virgin biomass B0 (Smith et al., 2009). A proxy for F_{MSY} ($F_{MSYproxy}$) was based on $F_{40\%\ B0}$ (Punt et al., 2014), i.e., the fishing mortality rate associated with a biomass of 40% B0 at equilibrium.

7 Results

7.1 Life History Characteristics

The initial population status for the stock is different given the historical fishing patterns considered and the fishing selectivity considered (Table 7.1 – Biological risks for the different operating model conditioning (initial depletion level – FHIST) for the base case productivity and recruitment standard deviation at 0.75. Initial risks correspond to the probability of falling below B_{lim} in the last historical year. Short-term and long-term risks (F = 0) correspond to the maximum expected risks in the absence of catches, in the first 5 and last 10 projection years, respectively. Initial risks are higher with increasing exploitation level and if the selectivity of the fishery allows for some age zero catches. For the optimum level of exploitation (F_{proxy} leading to 40%B_0) the stock component had an initial risk of being below B_{lim} of 0.159 or 0-209 if 20% of zero catches are allowed. The initial risk decreases to 0.015 and 0.014 if the stock component is under exploited and increases to 0.43 and 0.653 if the stock component is overexploited. If the stock was not exploited during the projection period (no fishing scenario), short-term risks were above 0.05 for both the fully and the overexploited historical fishing trajectories. These risk levels, in the absence of fishery, would drop to zero in the long-term for all cases.

Table 7.1 – Biological risks for the different operating model conditioning (initial depletion level – FHIST) for the base case productivity and recruitment standard deviation at 0.75. Initial risks correspond to the probability of falling below B_{lim} in the last historical year. Short-term and long-term risks (F = 0) correspond to the maximum expected risks in the absence of catches, in the first 5 and last 10 projection years, respectively.

Selectivity	FHIST	Initial risks	Short-term risks (F = 0)	Long-term risks (F = 0)
0% age zero catches	flow	0.015	0.004	0
	fopt	0.159	0.061	0
	fhigh	0.43	0.19	0
20% age zero catches	flow	0.014	0.003	0
	fopt	0.209	0.061	0
	fhigh	0.653	0.394	0

The inter-annual variation of the catches (IAV) is a function of the initial depletion level (FHIST), the recruitment variability (SIGR) and of the stock productivity (LHSC) (Figure 7-1). The IAV tends to increase as exploitation level, recruitment variability or stock productivity increases. On the other hand, the IAV tends to decrease if some catches of age zero are allowed (Figure 7-1)

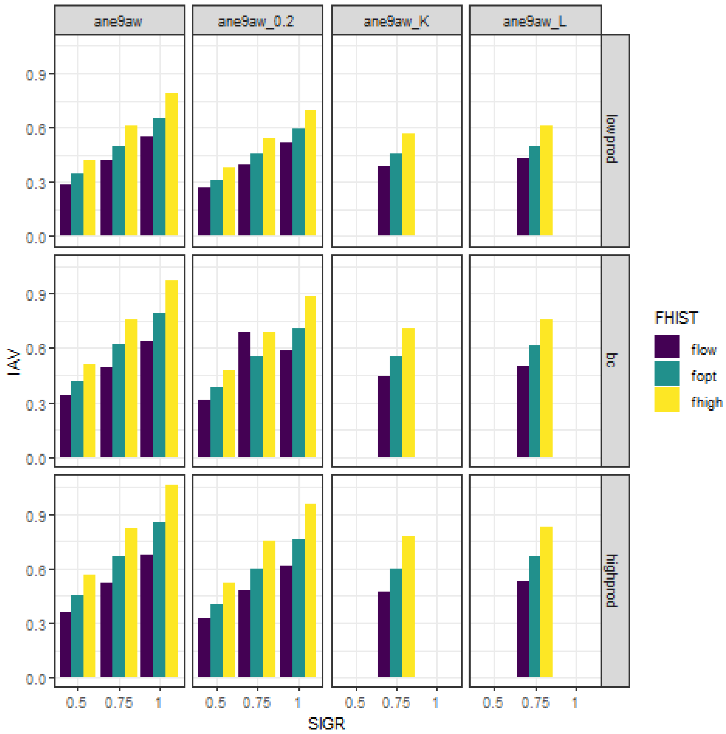

Figure 7-1. – Inter-annual variation in the historical period of the simulations (year 0 to year 30) by standard deviation for the recruitment log-normal error (SIGR, x-axis) as a function of the operating model considered (columns), stock productivity: low (lowprod), medium (bc) and high (highprod) and the exploitation level: under exploitation (flow), fully exploited (fopt) and overexploitation (fhigh).

7.2 Base case

Figure 7-2 shows the biological risk for the base case scenario with the constant harvest rate advice rule tested for different levels of harvest rate (from 0.1 to 0.7) in two different periods of the projection period (short and long). Risks increase with the increase of the harvest rate and, in general, with the historical fishing pattern and the increase in age zero catches. In some cases, and for the long run, stocks that are fully exploited have higher risks that the under and the over exploited stocks.

In the long term, scenarios with a harvest rate up until 0.5 have biological risks below the threshold of 0.05. Therefore, the scenario with a harvest rate of 0.5 was chosen to evaluate against the implementation of the 1-over-2 advice rule and for the sensitivity analysis.

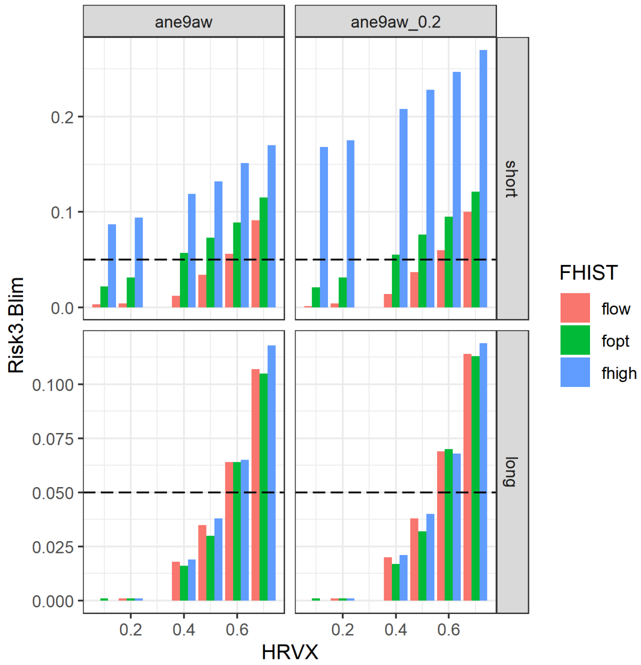

Figure 7-2 - Biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) with the constant harvest rate rule with different harvest rates (x-axis). The columns correspond to the different fishing selectivity pattern evaluated (left panel knife-edge selectivity, right panel allowing for 20% of age zero catches) and the rows correspond to the temporal scales: the short-term (first 5 projection years) and the long-term (last 10 years of the projection years). Colours refer to the different historical fishing pattern. Dashed line corresponds to the 0.05 risk.

Figure 7-3 shows the yield for the base case scenario with the constant harvest rate advice rule tested for different levels of harvest rate (from 0.1 to 0.7) in two different periods of the projection period (short and long). Catches increase when the harvest rates increase in both the short and the long-term. However, in the short-term they decrease with the historical fishing pattern. In the long-term, catches are very similar between historical fishing patterns but generally increase with the exploitation level.

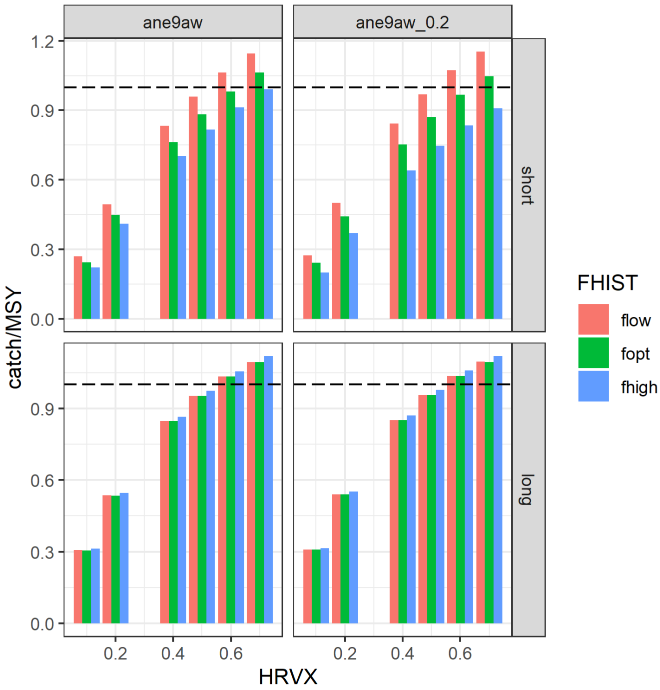

Figure 7-3. — Relative yield with the constant harvest rate rule with different harvest rates (x-axis). The columns correspond to the different fishing selectivity pattern evaluated (left panel knife-edge selectivity, right panel allowing for 20% of age zero catches) and the rows correspond to the temporal scales: the short-term (first 5 projection years) and the long-term (last 10 years of the projection years). Colours refer to the different historical fishing pattern. Dashed line corresponds to the 0.05 risk.

In Figure 7-4 we can see the biological risks versus the relative yields for the 1-over-2 rule with uncertainty cap of 80% without a biomass safeguard in the base case scenario and the constant harvest rate rule with different harvest rates values when the fishing selectivity is simulated as a knife-edge (colours). In the short and the medium-term the 1-over-2 rule stands out from the constant harvest rate both in terms of catches and risks, i.e., for a given relative yield level the CHR provides lower risks when compared with the 1-over-2 rule. In the long term, the 1-over-2 rule has very low risk for a given relative yield. However, the CHR can provide similar yields for the same risk. The difference is that, depending on the harvest rate value, the CHR can provide risks below the threshold for relative yields higher than the 1-over-2 rule.

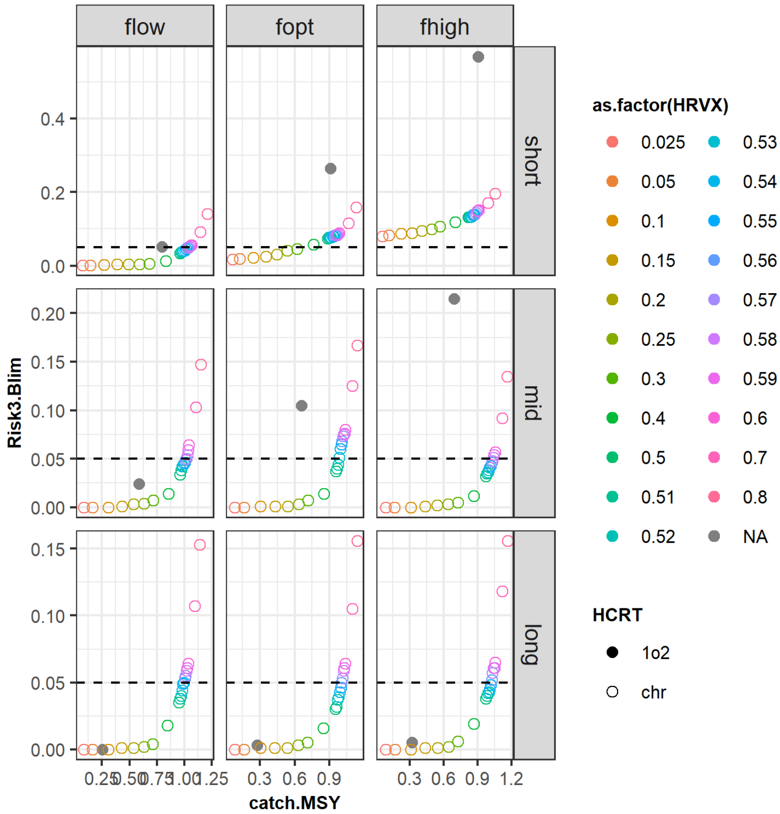

Figure 7-4 - Biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) versus the relative yields (catches/MSY) (x-axis) for the 1-over-2 advice rule (full circle) and the constant harvest rate rule (open circle) with different harvest rates (colours). The columns correspond to the different historical exploitation and the rows to the temporal scales: the short-term (first 5 projection years), medium-term (next 5 projection years) and the long-term (last 10 years of the projection years). Dashed line corresponds to the 0.05 risk.

7.3 Rules comparison under the base case

For the 1-over-2 rule, the shorter the time lag between observation and management, the bigger were the expected relative yields and the smaller the risks for both the short and the long term (Figure 7-5). The exception was for the scenario with the under exploited stock in the short term where relative yields are slightly lower for a larger time lag. For the constant harvest rate, all the populations would crash in the first year if the advice was set to be as type interim-year.

Generally, risks are higher for the over exploited stock, followed by the fully exploited and under exploited stocks. Risks decrease with time and are below the threshold of 0.05 in the long-term for all scenarios. Risks with the 1-over-2 rule are very high in the short-term while for the CHR these risks are smaller.

The inclusion of a biomass safeguard affects the relative yields which then translate into corresponding risks. The use of a biomass safeguard decreases relative yields with the 1-over-2 rule but has very small impact when the constant harvest rate rule is implemented (Figure 7-5). From the different options tested, the I_{minpa} biomass safeguard type is the one that is able to reduce risks the most both in the short and long terms (Table 7.2).

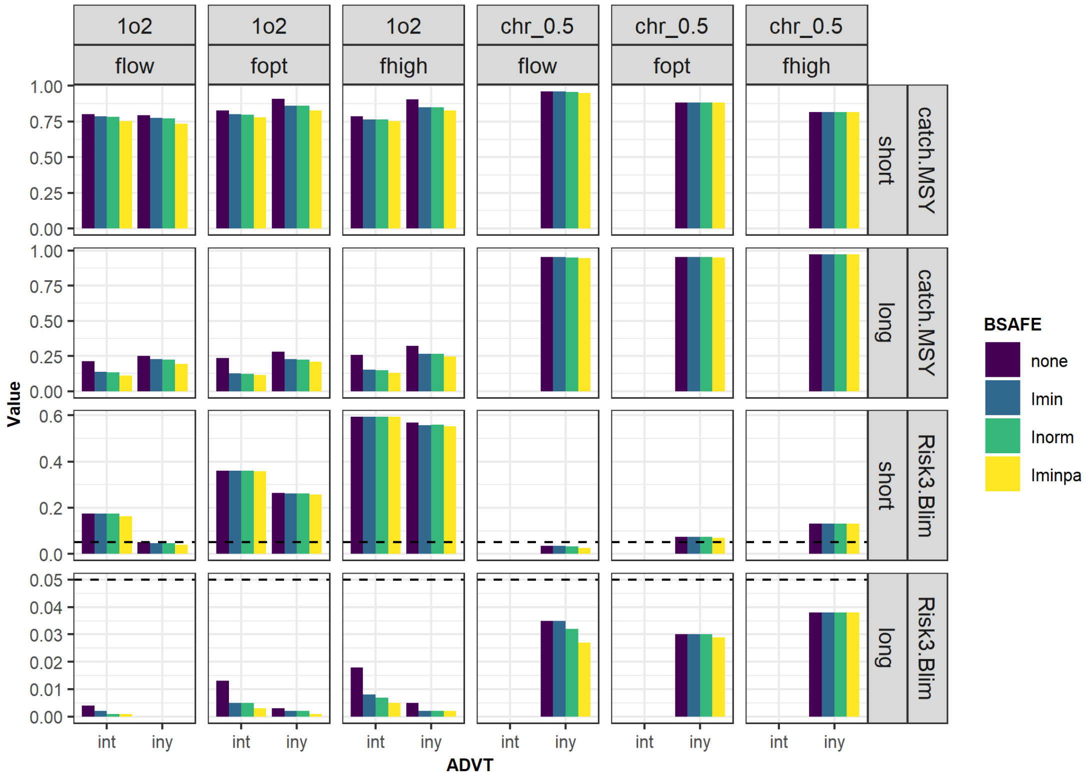

Figure 7-5. Relative yields (catch/MSY) and biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) in the short and long terms (rows) by calendar type (ADVT, x-axis), biomass safeguard (colour) and operating models for the two different advice rules tested (columns). The horizontal dashed line corresponds the 0.05 risk in the Risk3.Blim plot.

Table 7.2 – Biological risk decrease (percentage) in the short and long terms for the calendar type 'iny' dependent of fishing history (FHIST), the advice rule tested (HCR) when a biomass safeguard is introduced. Risks were compared to equivalent scenarios without any biomass safeguard.

Term	FHIST	HCR	Inorm	Iminpa	Imin
short	flow	chr_0.5	-3	-24	NA
	fopt		0	-4	0
	fhigh		0	NA	0
long	flow		-9	-23	NA
	fopt		0	-3	0
	fhigh		0	NA	0
short	flow	1o2	-8	-24	-10
	fopt		-1	-3	-1
	fhigh		-2	-3	-2
long	flow		0	0	0
	fopt		-33	-67	-33
	fhigh		-60	-60	-60

Figure 7-6 and Figure 7-7 show the trajectories of the key parameters yield, fishing mortality (f) recruitment (rec) and SSB (B1+) for the two advice rules tested under three different fishing histories (under, fully and over exploited) under the base case scenario.

For the 1-over-2 advice rule with an 80% uncertainty cap, independently of the historical exploitation level, there is a decreasing trend in the catch (and fishing mortality) while B1+ tends to increase towards an equilibrium value (Figure 7-6). Productivity is the same across all fishing history trajectories and therefore are very similar between scenarios of fishing history.

Figure 7-6. 1-over-2 advice rule without biomass safeguard. Catch (tonnes), fishing mortality (F, year-1), recruitment (rec, million individuals) and biomass of fish age 1 and older (ssb, thousand tonnes) for the historical period (0–30) and during the projected period (31–60) for the base case scenario under different historical exploitation levels (fhigh = over exploitation, flow = under exploitation, fopt = fully exploitation). Shaded area represents 90% confidence intervals. Horizontal dashed lines in SSB show B_{lim} (20% B0, grey) and $B_{collapse}$ (10% B0, black) and in catch represents MSY. Vertical long dashed lines separate the historical from the projected period.

For the constant harvest rate advice rule, independently of the historical exploitation level, there is a sharp decrease in the catch at the beginning of the projection period but then they increase until a stable value (Figure 7-7). B1+ tends to increase towards an equilibrium value. Productivity is the same across all fishing history trajectories and therefore are very similar between scenarios of fishing history.

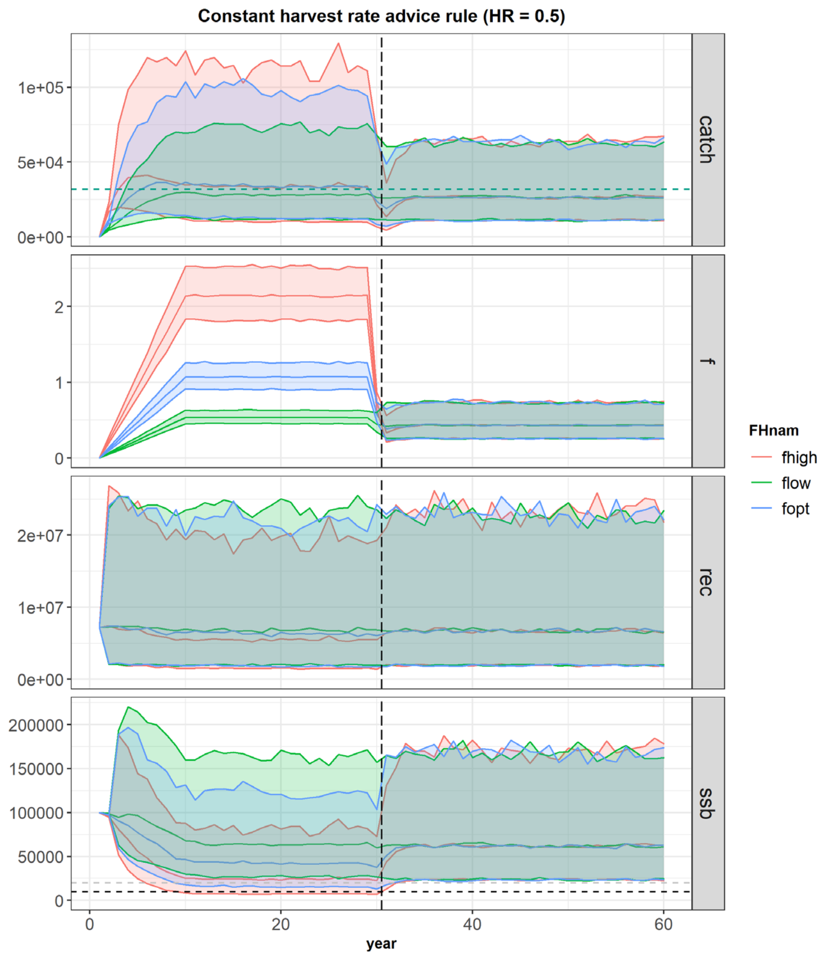

Figure 7-7. Constant harvest rate advice rule (HR = 0.5) without biomass safeguard. Catch (tonnes), fishing mortality (F, year-1), recruitment (rec, million individuals) and biomass of fish age 1 and older (ssb, thousand tonnes) for the historical period (0–30) and during the projected period (31–60) for the base case scenario under different historical exploitation levels (fhigh = over exploitation, flow = under exploitation, fopt = fully exploitation). Shaded area represents 90% confidence intervals. Horizontal dashed lines in SSB show B_{lim} (20% B0, grey) and $B_{collapse}$ (10% B0, black) and in catch represents MSY. Vertical long dashed lines separate the historical from the projected period.

In all cases, variability of the SSB and recruitment trajectories are very high leading to large biological risks in the short-term (between 0.05 and 0.57 for the 1-over-2 advice rule and between 0.03 and 0.17 for the constant harvest rate advice rule, depending on the initial exploitation status) (Figure 7-8). In both cases, risks are reduced in the long-term to under a 5% probability of being below B_{lim} (Table 7.3).

Risks at the beginning of the simulation period depend on the historical fishing pattern, increasing with the level of exploitation. With the 1-over-2 rule, risks increase in the first years of the simulation period and only after a couple of years start to decrease. Risks for the constant harvest rate advice rule are lower and start to decrease from the first year of the projection period. In the long term both advice type rules have no risks but catches are higher for the constant harvest rule advice rule. This is independent of the exploitation level at the beginning of the simulation period.

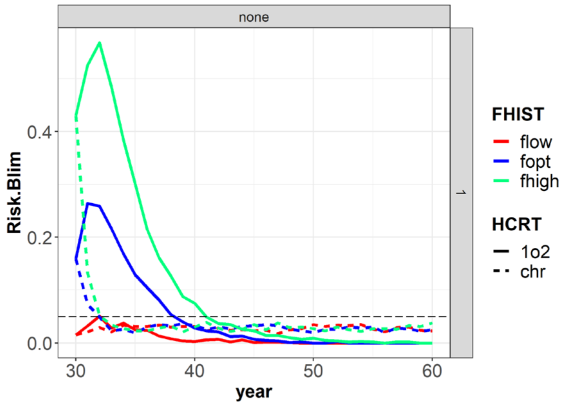

Figure 7-8. Trajectories of biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) along years (x-axis) under an in-year advice for the base case scenario. The colours correspond to the historical exploitation level and the line type to the harvest control rule type (1-over-2 rule and CHR with HR = 0.5, both without biomass safeguard). The horizontal dashed line corresponds to the 0.05 risk.

Table 7.3. Summary of performance statistics for the base case scenario and the two advice rule types tested (1-over-2 rule and CHR with HR = 0.5, both without biomass safeguard). Reported statistics (SSB and Catch in thousand tonnes, Risk3.Blim: maximum probability of falling below B_{lim} – 20%B0- in percentage, Risk3.Collapse: maximum probability of falling below 10%B0 in percentage) were calculated in the short (first five years) and long (last ten years) period.

		Exploitation level		
HCRT	term	fopt	flow	fhigh
ssb				
1o2	short	58.4	79.7	38.7
1o2	long	115.3	117.2	115.1
chr	short	72.5	75.6	70.0
chr	long	74.7	74.6	76.3
catch				
1o2	short	29.0	25.4	28.9
1o2	long	8.9	8.0	10.3
chr	short	28.2	30.6	26.1
chr	long	30.4	30.4	31.1
f				
1o2	short	0.840	0.404	1.57
1o2	long	0.0902	0.0760	0.106
chr	short	0.440	0.456	0.422
chr	long	0.456	0.457	0.459
Risk3.Blim				
1o2	short	26	5	57
1o2	long	0	0	0
chr	short	7	3	13
chr	long	3	4	4
Risk3.Collapse				
1o2	short	12	1	38
1o2	long	0	0	0
chr	short	0	0	2
chr	long	0	0	0

7.4 Sensitivity to coefficient of variation and catchability of the Survey Index

The two types of advice rule tested have different behaviours to the change of the coefficient of variation and catchability of the survey index (Figure 7-9). The impact of the CV of the survey on the relative catch is higher for the 1-over-2 rule while the impact of the catchability of the survey is higher for the CHR.

For the 1-over-2 rule, the relative catch increases when the CV of the survey index decreases from 1 (high) to 0.5 (medium) and then to 0.25 (low). However, for the constant harvest rate relative catches slightly increase when the CV of the survey also increases. For both advice rules, the behaviour is the same in the short and the long term.

In terms of risks, we see that they decrease from the short to the long term for the 1-over-2 advice rule while they may increase for the constant harvest rate advice rule. With the 1-over-2 rule and in the short-term risks may increase or decrease with the CV of the survey index depending on the exploitation state of the stock. For the constant harvest rate, risks always increase with the CV of the survey index.

For the 1-over-2 rule, the relative catch and risks is more or less the same when the catchability (QIDX) of the survey index varies between 0.5 and 2. The reduction of risk in the long term occurred at the expense of a significant reduction in the catches in the case of the 1-over-2 rule. For the constant harvest rate relative catches increase when the catchability of the survey index increases, increasing risks (Figure 7-9). In the short-term, risks are always above or at the threshold of 0.05 with the exception of some combination of CV, QIDX and FHIST options with the CHR advice rule. In the long term all cases have risks below the threshold of 0.05 with the 1-over-2 advice rule while for the CHR advice rule only some scenarios are below that threshold.

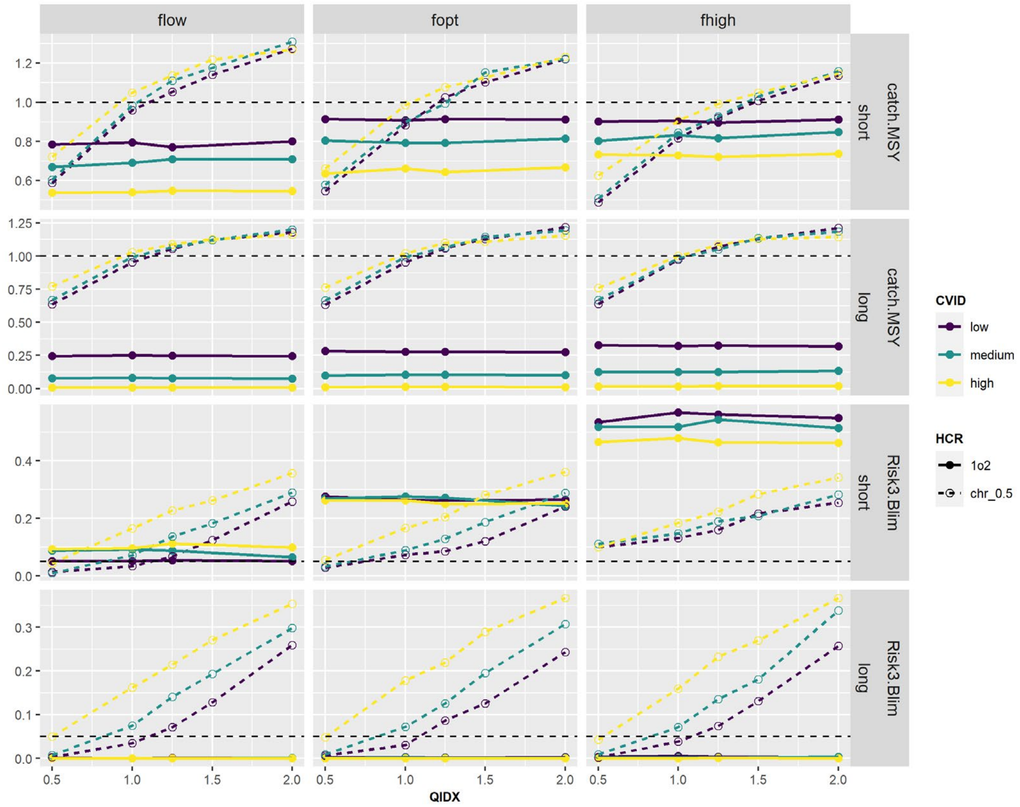

Figure 7-9. – Relative yields (catch/MSY) and biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) in the short and long terms (columns) under an in-year advice without any biomass safeguard for the different catchability (x-axis) and CV (line colour) values of the survey index. The columns correspond to the operating model (historical exploitation level). The harvest control rules type are represented by the line and point types (solid line and full circle: 80% uncertainty cap 1-over-2 advice rule; dashed line and open circle: constant harvest rate rule with a harvest rate of 0.2). The horizontal dashed line corresponds to the 0.05 risk in the Risk3.Blim plot.

7.5 Sensitivity to the Operating Model assumptions

For the 1-over-2 rule with 80% uncertainty cap, when the standard deviation of the recruitment increased, risks in the short term increased for the under and fully exploited stocks while for the over exploited stocks risks decreased. In the long term, risks may increase or decrease with the increase of the standard deviation of the recruitment. This seems to be related to the life-history scenario considered (Figure 7-10).

For the constant harvest rate advice rule, when the standard deviation of the recruitment increased, risks both in the short and long term increased for all the exploitation levels simulated. These risks decrease with the increase in the productivity of the stock (Figure 7-10).

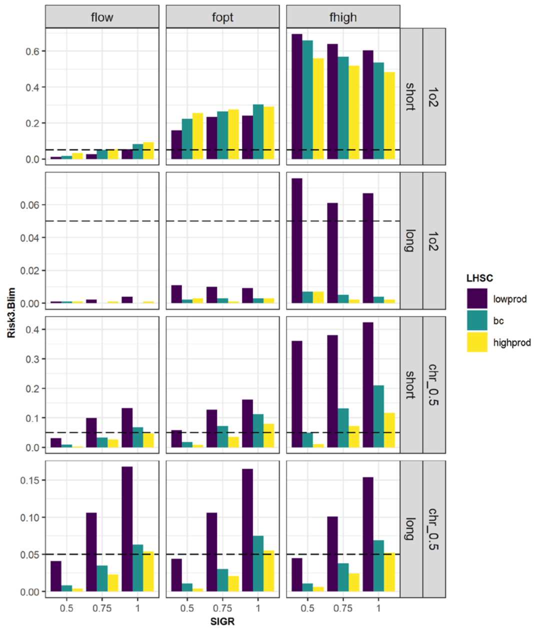

Figure 7-10. Biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) by advice rule in the short and long terms (rows) under an in-year advice without any biomass safeguard for the different standard deviation of recruitment (x-axis) and stock productivity (colours). The columns correspond to the operating model (historical exploitation level). The horizontal dashed line corresponds to the 0.05 risk.

Regarding catches and the 1-over-2 advice rule, relative yields tend to decrease in the long term with the increase of the standard deviation of recruitment and the increase of productivity (Figure 7-11). For the constant harvest rate advice rule and in both the short- and the long-term, relative yields decrease with the increase of productivity of the stock and increase when the standard deviation of recruitment increases (Figure 7-11).

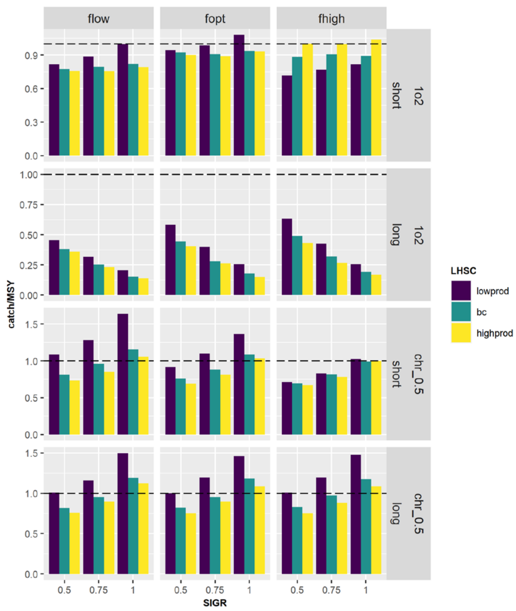

Figure 7-11. Relative yields (catches/MSY) by advice rule in the short and long terms (rows) under an in-year advice without any biomass safeguard for the different standard deviation of recruitment (x-axis) and stock productivity (colours). The columns correspond to the operating model (historical exploitation level). The horizontal dashed line corresponds to catch = MSY.

7.6 Additional scenarios

To account for the high sensitivity of the CHR advice rule to the catchability of the survey index, additional scenarios were run to estimate the maximum sustainable harvest rate as a function of the catchability of the survey index and other uncertainties such as coefficient of variation of the survey index and the productivity of the stock (Figure 7-12).

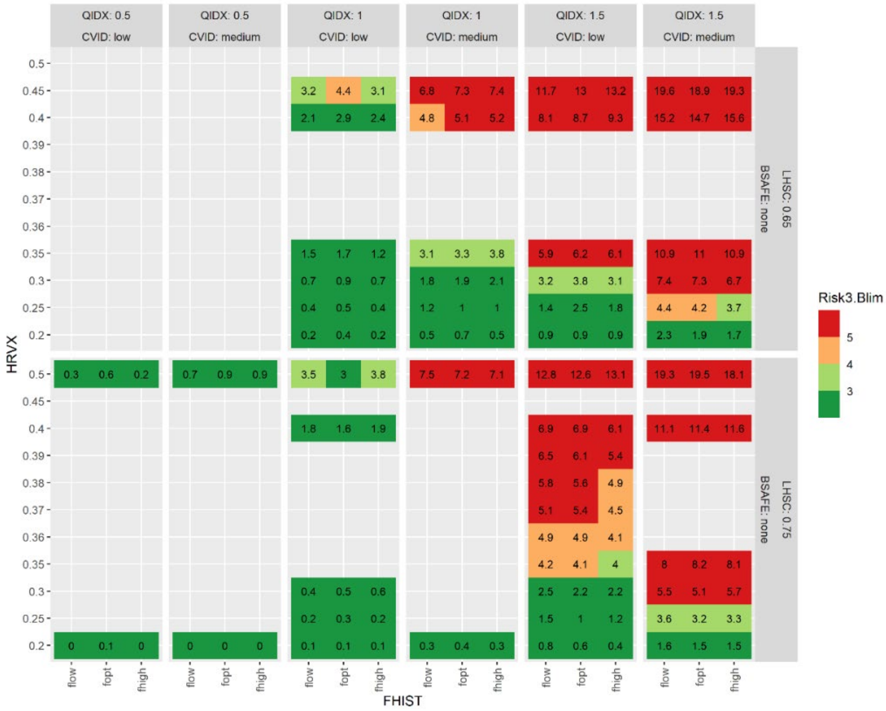

Figure 7-12 - Percentual biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) in the long term for the three fishing trajectories: flow, fopt and fhigh (xx-axis) dependent of the harvest rate value (HRVX, yy-axis), the catchability (QIDX) and coefficient of variation (CVID) of the abundance index (columns) and the productivity of the stock (LHSC, rows). Results are presented for the in-year advice, assuming that SIGR is 0.75 and no biomass safeguard was implemented.

If we would take as the base case the catchability estimates resulting from the assessment of the Bay of Biscay anchovy stock, with an acoustic survey catchability of 1.452, or the catchability base case scenario (= 1.5) considered precautionary in the MSE of the sprat stock in 7.de (ICES, 2021b), we would have to consider a CHR advice rule with a harvest rate of 0.36. In Figure 7-13 one can compare the performance of this CHR with the 1-over-2 advice rule.

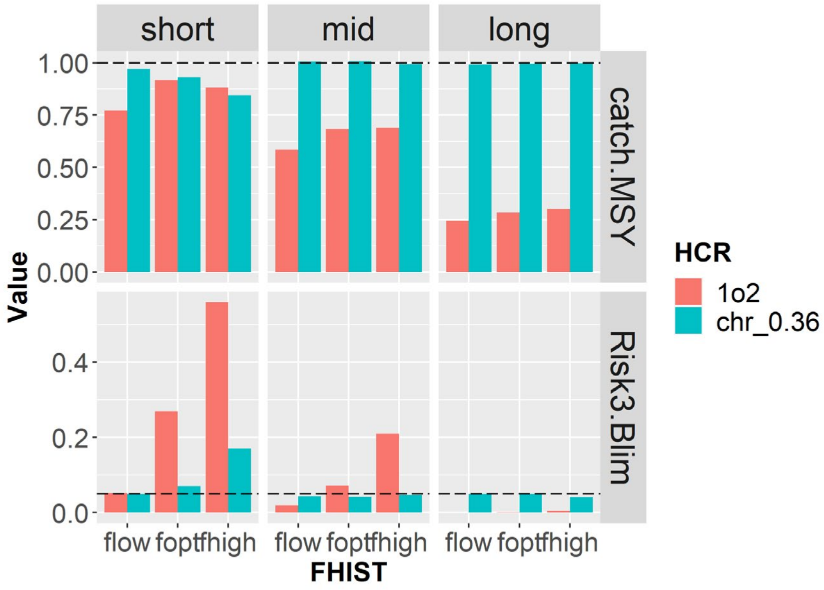

Figure 7-13 - Relative yields (catches/MSY) and biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) by advice rule (colour) in the short, mid and long terms (columns) under an in-year advice without any biomass safe-guard for the different fishing history (x-axis). The columns correspond to the operating model (historical exploitation level). The horizontal dashed line corresponds to catch = MSY.

8 Conclusions

The main conclusions from this stock-specific management strategy evaluation conducted to determine a robust CHR were the following:

- For the considered base case (see section 6.4) the CHR advice rule with a harvest rate of 0.5 is still precautionary according to ICES standards (i.e., the maximum probability of SSB being below B_{lim} in the long term is less than 0.05) for any of the historical fishing trajectory.
- In the long-term, when compared to the 1-over-2 rule, the CHR advice rule with a harvest rate of 0.5 has higher risks but leads to 200% higher relative yields.
- In general, the change in selectivity pattern (allowing for 20% of age zero catches) increases risks. Mean risk increase (across the HRVX values tested) vary from 5% to 75% in the short-term and from 5% to 9% in the long term.
- The CHR advice rule is sensitive mainly to the management calendar (populations crash with the interim year advice) and the catchability of the survey index (risks increase sharply).
- The preferred management calendar is the one currently in place (the in-year advice).
- To account for the high sensitivity of the CHR advice rule to the catchability of the survey index, additional scenarios were run to determine the maximum sustainable harvest rate in the long-term. It's estimated that the sustainable harvest rate should be between 0.36 for a catchability of 1.5.
- The CHR advice rule is also sensitive to the initial depletion level of the stock: in the short-term risks increase from 0.034, to 0.073 and to 0.132 with increasing exploitation level. In the long-term risks tend to be similar, decreasing from 0.035 to 0.03 and increasing again to 0.038.
- The CHR advice rule is also sensitive to the standard deviation of the mean recruitment assumed. Risks almost double when the standard deviation increases from 0.5, to 0.75 and to 0.1.
- From the different options tested, the I_{minpa} biomass safeguard type is the one that is able to reduce risks the most both in the short and long terms.

Following the stock-specific MSE work and considering the high sensitivity of the CHR advice rule to the value of the catchability of the survey index (which is very uncertain), it is recommended that **advice for Anchovy 9a west should be based on a CHR with a $HR_{msy.proxy}$ = 0.36 applied to the most recent survey-based biomass index derived by the combination of the PELACUS and PELAGO survey in sub-divisions 9aN, 9aCN and 9aCS.** Advice should be applied in the current seasonal management calendar (July to June). In addition, a biomass safeguard factor based on $I_{trigger} = I_{minpa} = 1.64 * \min(I_{hist}) = 2017$ tonnes should be considered. This is considered a precautionary option when compared to the $HR_{msy.proxy}$ = 0.50 estimated for the base case considered.

9 References

Degnbol, P., Lassen, H., and Stæhr, K-J. 1985. In-situ determinations of target strength of herring and sprat at 38 and 120 kHz. Dana, 5: 45–54.

ICES. 2018. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA 2018), 12–16 February 2018, ICES HQ, Copenhagen, Denmark. ICES CM 2018/ACOM:32. 313 pp.

ICES. 2019. Workshop on Data-limited Stocks of Short-Lived Species (WKDLSSLS). ICES Scientific Reports, 1: 73. 166 pp. http://doi.org/10.17895/ices.pub.5549.

ICES. 2020. Workshop on Data-limited Stocks of Short-Lived Species (WKDLSSLS2). ICES Scientific Reports. 2:99. 119 pp. http://doi.org/10.17895/ices.pub.5984

ICES. 2021a. Tenth Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE X). ICES Scientific Reports. https://doi.org/10.17895/ices.pub.5985

ICES. 2021b. Inter-benchmark to revise the advice framework for the Sprat stock in 7.de based on the most recent changes to data-limited short-lived species assessments (IBPSprat). ICES Scientific Reports. 3:23. 42 pp. https://doi.org/10.17895/ices.pub.7918

ICES. 2022. Anchovy (Engraulis encrasicolus) in Division 9.a (Atlantic Iberian waters). In Report of the ICES Advisory Committee, 2022. ICES Advice 2022, ane.27.9a. https://doi.org/10.17895/ices.advice.19447751

Massé, J., Uriarte, A., Angélico, M. M., and Carrera, P. (Eds.) 2018. Pelagic survey series for sardine and anchovy in ICES subareas 8 and 9 – Towards an ecosystem approach. ICES Cooperative Research Report No. 332. 268 pp. https://doi.org/10.17895/ices.pub.4599

Junquera, S.1986. Pêche de l'anchois (*Engraulis encrasicholus*) dans le golfe de Gascogne et sur le littoral atlantique de Galice depuis 1920. Variations quantitatives. Rev Trav Inst Pêches Marit 48: 133–142.

Pestana, G. 1989. Manancial Ibero Atlântico de Sardinha (*Sardina pilchardus*, Walbaum) sua avaliação e medidas de gestão. Ph.D. thesis. Univ. Lisboa.

Ogle, D.H., J.C. Doll, P. Wheeler, and A. Dinno. 2021. FSA: Fisheries Stock Analysis. R package version 0.9.1, https://github.com/droglenc/FSA.

Taylor M. H., Mildenberger T. K. Extending electronic length frequency analysis in R. Fish Manag. Ecol. 2017; 24:330–338. https://doi.org/10.1111/fme.12232

Fischer, S. H., De Oliveira, J. A. A., and Kell, L. T. 2020. Linking the performance of a data-limited empirical catch rule to life-history traits. ICES Journal of Marine Science, 77: 1914–1926. https://doi.org/10.1093/icesjms/fsaa054.

García D., Sánchez S., Prellezo R., Urtizberea A. and Andrés M. 2017. FLBEIA: A simulation model to conduct Bio-Economic evaluation of fisheries management strategies, SoftwareX, Volume 6, Pages 141–147. https://doi.org/10.1016/j.softx.2017.06.001.

Gislason, H., Daan, N., Rice, J. C., and Pope, J. G. (2010). Size, growth, temperature and the natural mortality of marine fish. Fish Fish. 11, 149–158. doi: 10.1111/j.1467-2979.2009.00350.x.

Jardim, E., Azevedo, M., and Brites, N. M. (2015). Harvest control rules for data limited stocks using length-based reference points and survey biomass indices. Fish. Res. 171, 12–19. doi: 10.1016/j.fishres.2014.11.013

Kell, L. (2018). FLife: Methods for Modelling Life History Traits. R package version 3.4.0.

Kell, L.T., Mosqueira, I., Grosjean, P., Fromentin, J-M., Garcia, D., Hillary, R., Jardim, E., Mardle, S., Pastoors, M.A., Poos, J.J., Scott, F., Scott, R.D. 2007. FLR: an open-source framework for the evaluation and development of management strategies. ICES Journal of Marine Science, 64: 640-646.

Punt, A. E., Smith, A. D. M., Smith, D. C., Tuck, G. N., and Klaer, N. L. (2014). Selecting relative abundance proxies for BMSY and BMEY. ICES J. Mar. Sci. 71, 469–483. doi: 10.1093/icesjms/fst162.

Sánchez-Maroño S, Uriarte A, Ibaibarriaga L and Citores L (2021). Adapting Simple Index-Based Catch Rules for Data-Limited Stocks to Short-Lived Fish Stocks' Characteristics. Front. Mar. Sci. 8: 662-942. doi: 10.3389/fmars.2021.662942.

Smith, D., Punt, A., Dowling, N., Smith, A., Tuck, G., and Knuckey, I. (2009). Reconciling approaches to the assessment and management of data-poor species and fisheries with Australia's harvest strategy policy. Mar. Coast. Fish. 1, 244–254. doi: 10.1577/c08-041.1

1 Review of the 2023 WGHANSA MSE for anchovy in ICES Division 9.a

Bjarki Elvarsson - 28/05/2023

1.1 General comments

The following are a few notes the evaluation of alternative HCR for the anchovy stock in ICES subarea 9a. The review reflects the work in progress presented on the 5th of May 2023,

and has not considered progress that has been made since.

The ICES advice for anchovy in the 9a is split into two components, the Southern and the Western part. The advice for these two components is currently based on ICES DLS rules adapted

for short lived species. The advice for the next calendar year is based the ratio between the current index and the average of the two preceding indices (1 over 2 rule). This rule is

considered appropriate due to high variability in stock size, and the 20 % limit on advice variation is not seen as appropriate. Therefore the aim of the work presented was develop HCR

that better reflected the dynamics of the stock, and in both components the aim was to develop a advice rule of the form:

$$C_{y+1} = HR \times I_y \times f(I_y)$$

where the index is either the combined PELAGO/PELAGUS survey (Western component) or the output from an assessment model (Gadget).

The simulations presented were fairly comprehensive and attempted to capture the key features of the population dynamics. However key uncertainties were not included in the HCR evalations. For instance no uncertainty is considered for growth parameters. This may lead to inappropriate estimates of total risk. Additional work to address the stock specific uncertainties is therefore required before the proposed HCR are implemented.

1.2 Specific comments

1.2.1 Western component

The HCR simulations for the western stock component should include uncertainty estimates for key life-history parameters in the base set of simulations. This means that new set of life history parameters should be simulated prior to a new iteration of the simulation experiment. Also, given the dramatic shift in the catch levels observed in after 2010, shifts in productivity should be considered in alternate scenarios

.

1.2.2 Southern component

The advice for the southern component is currently based on the output from an assessment model (Gadget), which is used as basis for the HCR evaluation. This approach therefore assumes that assessment model is an appropriate representation of the stock dynamics. However, issues in the model fit need to be considered in the HCR simulations. The model is fit to two main indices, the ECOCADIZ and PELAGO accoustic surveys that the assessment model is not able to fit simultaneously. Although alternate data weighting scenarios are considered in the simulations, this does point to inconsistency between the two surveys that should be a prominent feature of the simulations as it may affect the performance of the HCR.

As with the western component, uncertainty on key life history parameters is not fully included in the simulations. This could be accommodated in the simulations by refitting the assessment model to simulated input data, via a bootstrap or other means. This would results in a set of fitted models that would each form a basis for a new set of simulations.

On the surface the suggested form of the advice is similar between the two components, however as the input value for the advice rule in the southern component is the modelled biomass from the assessment. This will have different statistical properties than a simple survey index, which may be represented using a full feedback simulation. This raises the question, is this intermediate assessment necessary or could a purely index based rule be used for the advice of this stock.

2 Review of the 2023 WGHANSA MSE for anchovy in ICES Division 9.a

Simon Fischer – 22/05/2023

2.1 Introduction

This report is a review of the simulations conducted for anchovy in ICES Division 9.a as presented in two working documents and an online meeting on 05/05/2023.

The working documents describe a simulation exercise (management strategy evaluation, MSE, in the sense of a closed-loop simulation) for the Western and Southern components of anchovy in ICES Division 9.a. The aim of the work is to parameterise a constant harvest rate rule (CHR rule) to replace the currently used "1 over 2" rule. This approach follows the ICES technical guidelines for category 2 and 3 stocks (ICES, 2022), which recommend using a case-specific MSE to define the target harvest rate. The operating model is modelled on life-history parameters for the western component of the stock and a Gadget stock assessment model for the southern component. While the approach of using MSE to tune the CHR rule is greatly appreciated, the simulation work so far does not appear to be ready to be used by ICES to provide advice. The main reasons for this conclusion are that (1) the simulations are generic and not specific to the anchovy stock, and (2) the simulations lack sufficient uncertainty considerations to ensure the robustness of the management strategy. The review focuses mainly on the operating models and the MSE framework. The results of the simulations were not reviewed in detail because the simulation framework requires more work. The following sections provide more details.

2.2 Western component

Due to the lack of a stock assessment model for the western component of anchovy in 9.a, the operating model for MSE is modelled on life-history parameters. For most processes in this operating model, the basis is a von Bertalanffy growth model, and other processes are derived from this growth model (e.g. natural mortality, maturity, selectivity, etc.). However, the von Bertalanffy growth parameters are assumed to be known perfectly without any uncertainty, i.e. growth is deterministic, and there is no difference between the different simulation replicates (iterations). For data-limited stocks, growth is unlikely to be known precisely and assuming growth is deterministic is a strong simplification of reality and ignores a crucial source of uncertainty.

For the historical part of the operating models, three historical fishing histories (0.5/1/2F_{MSY} + noise) were included, and assume that fishing was constant (on average) for the last twenty historical years. These scenarios could be considered unlikely in reality. Such scenarios can be useful for generic testing of management strategies but are insufficient to provide stock-specific recommendations. Another issue is that F_{MSY} is defined as the F that leads to a stock biomass corresponding to 40% of the unfished biomass. This is a generic assumption that might not hold for this anchovy stock. Instead, F_{MSY} could be derived from the MSE framework (including uncertainty) to ensure the reference point is consistent with the dynamics of the operating model. For a stock-specific MSE, the operating models should be conditioned on the history of the actual stock. There are acoustic surveys and some length/weight/age data. The survey data could give some idea of the stock trend (and variability) over time. The other data could be used to have a rough idea about the stock status (fishing pressure, depletion), e.g. by using length-based indicators or some other length-based model, and this should be used for the operating model conditioning.

Recruitment is modelled with a von Bertalanffy stock-recruit model with a generic steepness of 0.75, but alternative steepness values (0.5, 0.9) are considered. Different recruitment scenarios are considered, but only by changing the recruitment uncertainty or steepness. More interesting would be the impact of different recruitment levels (higher/lower R_0, recruitment failure) on the performance of the management strategies in the projection. The biomass reference point B_{lim} is defined as the biomass corresponding to 20% of the unfished biomass. This means that the condition of the stock is different depending on the recruitment steepness. In scenarios with higher steepness, the stock is in a more productive state (higher R/R_0) at B_{lim} compared to scenarios with lower steepness. This means the risk values (the probability of a stock being below B_{lim}) are not comparable between different recruitment scenarios. This is an important shortcoming because the target harvest rate is selected by finding the harvest rate where B_{lim} risk meets 5%.

So far, the simulations are generic but based on life-history considerations. However, for such simulations to be useful in ICES, they must also be stock-specific. To achieve this, more stock-specific fishing histories should be considered, uncertainty should be considered more broadly (e.g. in life-history parameters/growth, alternative operating models), and uncertainty estimates (observation error, recruitment uncertainty) should be more stock/fishery-specific.

2.3 Southern component

There is a Gadget stock assessment for the southern component of the anchovy stock. However, this model is only accepted for trends to inform the currently used “1 over 2” rule, and the model fit appears mediocre with conflicting information from the two acoustic surveys. Nevertheless, the output from this model is used as the underlying truth to condition the operating model in the MSE.

The operating model is conditioned on the absolute and deterministic estimates of the Gadget model. This means that the historical part of the operating model does not include uncertainty for any metric (stock numbers at age, weight at age, etc.) and all simulation replicates (iterations) are identical. It also means that there is only a single deterministic starting point of the stock for the MSE (the stock status in the last historical year). This situation is likely an oversimplification of reality, and crucial uncertainty considerations are missing in the MSE, both in the historical part of the operating model as well as in the projection.

The management strategies tested for the southern component of the anchovy stock rely on the stock size estimates of the Gadget model. However, the stock assessment is not included in the feedback loop of the simulation and is only approximated by adding uncertainty to the values from the operating model, i.e. it is a shortcut MSE. Shortcut MSEs can be controversial because they do not test the management strategy as it is applied in reality. The main disadvantage is that the effect of alternative operating models cannot be evaluated properly, and therefore the robustness of the management strategy to uncertainty and plausible alternative scenarios is unknown. Shortcuts can be useful to narrow down the parameter space when optimising a management strategy, but the optimised parameterisation should be checked with a full MSE, including the stock assessment model. The working document justifies the use of a retrospective analysis to estimate the assessment error of the shortcut by citing WKNSME (ICES, 2019); however, WKNSMSE did not use a shortcut. Furthermore, WKGMSE3 (ICES, 2020) is cited to suggest that this approach is appropriate. There was no consensus at WKGMSE3 that this approach is appropriate, and it was shown that using this approach can lead to biased results in a shortcut simulation.

Using the Gadget model for this stock seems to have little benefit. The CHR rule could well be applied to the estimates from the acoustic survey. This would avoid concerns about the appropriateness of the model for this stock and is easier to test in a simulation.

The simulation period (30 years) is very long for a stock-specific simulation, corresponding to several generation times. Typical MSE simulations consider 1-2 generation times.

There could be an issue with the operating model dynamics and its productivity. In Figure 5.1.1 of the working document, the catch continuously increases with the harvest rate without a peak at harvest rates up to 1. At a harvest rate of 1 (i.e. the entire stock is fished), the highest catch is observed while the risk is still below 10%. This indicates that the stock is most productive (i.e. MSY without the ICES consideration of risk) when the entire biomass is fished every year, which seems illogical.

Due to the limited considerations of uncertainty and the approach of using a shortcut, the simulations for the southern component of the anchovy stock are rather a simulation exercise but not (yet) an MSE.

2.4 Comments for both components

The simulations for both components aim to define a target harvest rate by finding a harvest rate where the risk (probability of the stock falling below B_{lim}) does not exceed 5%, as suggested by the ICES MSY and precautionary approach. However, the risk level in a simulation crucially depends on the included uncertainty, where more uncertainty will result in a higher risk. For both components, there are only very limited uncertainty considerations and this likely means that the recommended harvest rates are not precautionary if more realistic (higher) uncertainty is considered.

Internationally accepted best practices for MSEs exist (e.g. Punt et al., 2016) and should be followed. Furthermore, the WKLIFE XI report section 2.2.6 (ICES, 2023, p. 26) includes some minimum considerations for data-limited stock-specific MSE simulations. This section is aimed at longer-lived species, but the principle is the same for shorter-live species such as anchovy.

In general, both working documents require more explanations of the simulation model, including equations (e.g. the catch equation, observation error model), to help understand the work. It would also be helpful to provide some time series figures of both the historical part as well as the period where the management strategies are applied. Ideally, figures of the important stock metrics (SSB, F, recruitment, natural mortality, etc.) are presented, including confidence intervals and worm plots (individual simulation replicates/iterations) for all operating models/scenarios.

It would also be useful to have some additional scenarios for the projected period, such as zero fishing, fishing at F_{MSY}, etc., to see that the models are working as expected and MSY is well defined.

For both stocks, specific constant harvest rates are suggested, but it is difficult to put these values into context. What could help would be plotting the harvest rate's time series (catch divided by the stock size/acoustic index) for the historical period. This could allow an interpretation of the recommended harvest rate levels and ensure these are not outside the range of observed values.

2.5 Conclusion

The work and effort in developing simulations to parameterise a constant harvest rate rule for the anchovy stock iss much appreciated. However, the simulations presented so far are not yet ready to be considered by ICES.

The most important shortcoming is the deterministic nature and lack of uncertainty in the simulations. The minimum change would be to include more realistic uncertainty (e.g. by including uncertainty in growth, which then propagates to other growth-related processes), and results should then be re-evaluated. Ideally, all points mentioned in this review are addressed before ICES considers the work.

2.6 References

ICES. 2019. Workshop on North Sea stocks management strategy evaluation (WKNSMSE). ICES Scientific Reports. 1:12. 378 pp. http://doi.org/10.17895/ices.pub.5090

ICES. 2020. The third Workshop on Guidelines for Management Strategy Evaluations (WKGMSE3). ICES Scientific Reports. 2:116. 112 pp. http://doi.org/10.17895/ices.pub.7627

ICES. 2022. ICES technical guidance for harvest control rules and stock assessments for stocks in categories 2 and 3. In Report of ICES Advisory Committee, 2022. ICES Advice 2022, Section 16.4.11, 20 pp. https://doi.org/10.17895/ices.advice.19801564

ICES. 2023. Eleventh Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE XI). ICES Scientific reports, 5: 74 pp. https://doi.org/10.17895/ices.pub.22140260

Punt, A. E., Butterworth, D. S., de Moor, C. L., De Oliveira, J. A. A. and Haddon, M. 2016. Management strategy evaluation: best practices. Fish and Fisheries, 17: 303-334. https://doi.org/10.1111/faf.12104

WORKING DOCUMENT

ADDITIONAL WORK AND REPLY TO REVIEWERS concerning:

Anchovy 9a west stock-specific management strategy evaluation conducted to determine an alternative to the current advice rule

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1 Introduction

A working document "Anchovy 9a west stock-specific management strategy evaluation conducted to determine an alternative to the current advice rule" (see Wise *et al.*, 2023a in annex 6) was elaborated and shared to present a stock-specific management strategy evaluation conducted to determine the Constant Harvest Rate (CHR) that is the most robust to the operating model (OM) and observation system uncertainties.

On the 5th of May 2023 a meeting took place between the ICES designated external reviewers of this work, several members of WHGANSA including those involved in the MSE work and stock assessors and coordinators, to further elaborate on the work carried out for both the western and the southern components of the anchovy stock. On this meeting reviewers explained their general views and concerns on the work that was conducted.

Based on these preliminary comments a workplan was defined during the meeting and it was possible to extend the work done prior and during the WGHANSA meeting that took place from the 29th of May to the 2nd of June 2023 to best accommodate these comments.

This document serves both as a description of the work that was done between the meeting on the 5th of May 2023 and the WGHANSA meeting (section 2) and a point-to-point reply to the reviewers' comments (section 3 and 4), meanwhile shared with the group as a written document (see reviewers documents in annex 6).

Despite the decrease in risk of being below B_{lim} as result of the re-estimation of the reference points for the then assumed base case, we support that the advice for Anchovy 9a west should be based on a CHR with a $HR_{msy.proxy}$ = 0.25 applied to the most recent survey-based biomass index derived by the combination of the PELACUS and PELAGO survey in sub-divisions 9aN, 9aCN and 9aCS.

This recommendation is based on the assumption that instead of a base case productivity (steepness = 0.75) we adopt a risk averse option of assuming the productivity to be intermediate (steepness = 0.65).

The results show that the CHR advice rule with HR=0.25 overcomes the performance of the 1-over-2 rule, reducing the risk of falling below B_{lim} in the short and medium terms, with higher relative yields in the medium and long term.

2 Additional work

The stock-specific management strategy evaluation (MSE) conducted to determine the constant harvest rate (CHR) for the western component of the 9a anchovy stock was updated to accommodate the reviewers' comments. The work focused mainly on the inclusion of uncertainty in the operating model and the re-estimation of references points. New runs of the base case scenario with the CHR and the 1 over 2 advice rules were made.

We assume that the base case that best describes the western component of the anchovy is now defined as:

- The OM assumes a stock with a base case productivity (h = 0.75; LHSC = 'bc') with a standard deviation for recruitment of 0.75 (SIGR = 0.75); The selectivity of the fishery is considered to be zero for age zero and one for all other ages;
- The observation model considers that the biomass index has bias (QIDX = 1.5) and has a low coefficient of variation of 25% (CVID = 'low');
- The calendar year is the one in place, i.e., an in-year advice (ADVT = 'iny'). where advice and management of the stock takes place soon after the biomass index is available;
- It also considers that no biomass safeguard is in place (BSAFE = 'none').

To search for the maximum sustainable CHR, the MSE was run for the base case scenario with the CHR advice rule (ADVT = 'chr') with different values for the harvest rate (HRVX between 0.1 and 0.5) and for an optimal historical fishing history.

Limited runs with other productivity scenarios (low and intermediate) and higher coefficient of variation for the abundance index (medium) were also made. The performance statistics estimated were the same as in the previous work.

2.1 Uncertainty in the operating model

Growth was based on the von Bertalanffy growth model (L_{inf} = 17.4554; k = 0.6242; t_0 = -1.1761) estimated using data from acoustic survey samples. To account for uncertainty in the growth model in each simulation replicate the von Bertalanffy growth model (VBGM) parameters were sampled from the correlation matrix of the model fit. To avoid unreasonable large values only the sets of values that have L_{inf} within the interval [0.9L_{inf}, 1.1L_{inf}] and k > 0 and within the interval [0.5*k*, 1.5*k*] were kept (Figure 3.1 - Paired scatterplots of the parameters for the typical VBGM used in the new simulations of the western anchovy component.Figure 3.1).

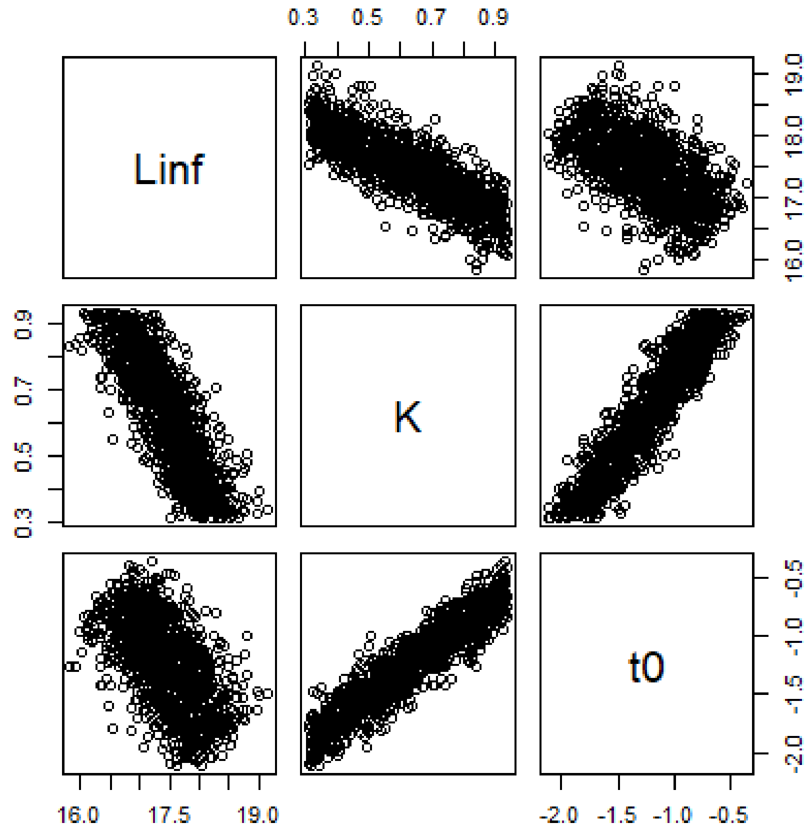

Figure 2.1 - Paired scatterplots of the parameters for the typical VBGM used in the new simulations of the western anchovy component.

Lengths were converted to weight-at-age using a length-weight model (a = 0.0021; b = 3.216) estimated with data from the acoustic survey samples. Uncertainty from the length-weight model was introduced by sampling parameters a and b from the correlation matrix of the model fit as was done with the VBGM parameters (Figure 3.2).

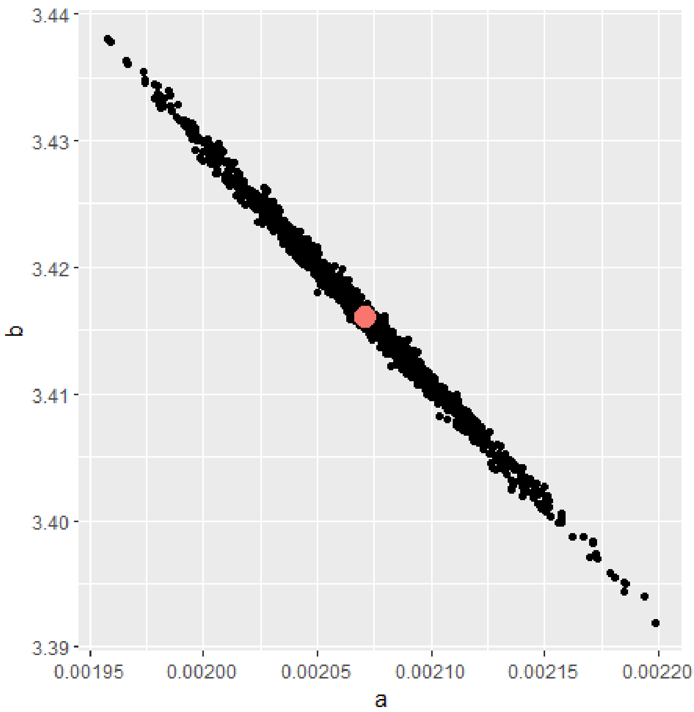

Figure 2.2 – Pairs of the length-weight model parameters a (xx-axis) and b (yy-axis) used in the new simulations of the western anchovy component. The red point shows the previous pair used in the simulations.

This implies that the weight-at-age and the natural mortality at age are derived at each simulation replicate. Initial population values were updated for each set (simulation replicate) of biological parameters.

Growth, weights (Figure 6-1), natural mortality and proportion of mature individuals at-age were considered time-invariant during the projection period. Natural mortality is age-dependent (Figure 2.4) and was derived from the von Bertalanffy growth parameters according to life-history theory following Gislason *et al*. (2010). Maturity is modelled as a knife edge, with 0% mature at age 0 and fully mature from age 1 onward. Fleet selectivity was modelled as maturity.

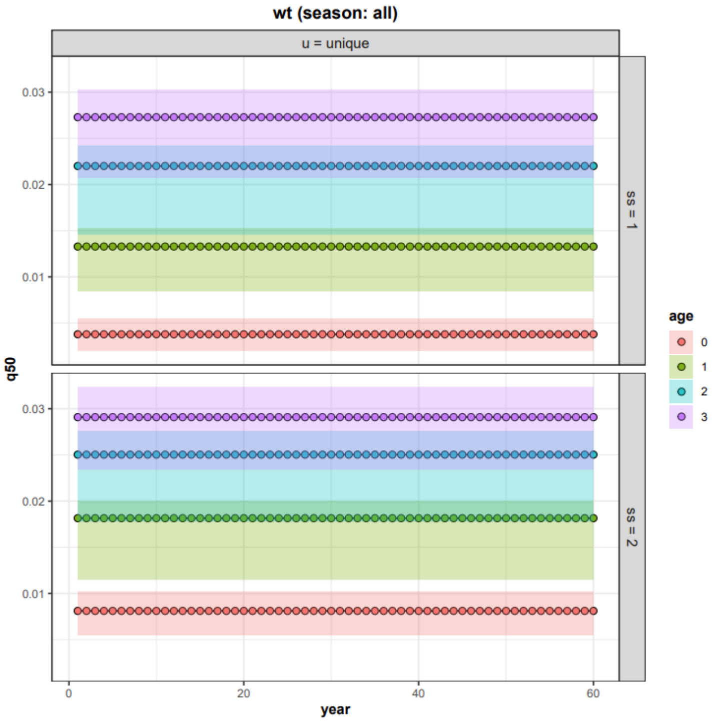

Figure 2.3. Weight-at-age for ages 0–3+ by season (ss) used in the new simulations. The dots correspond to the mean values and the horizontal bars represent the 90% interval of the 1000 simulation replicates.

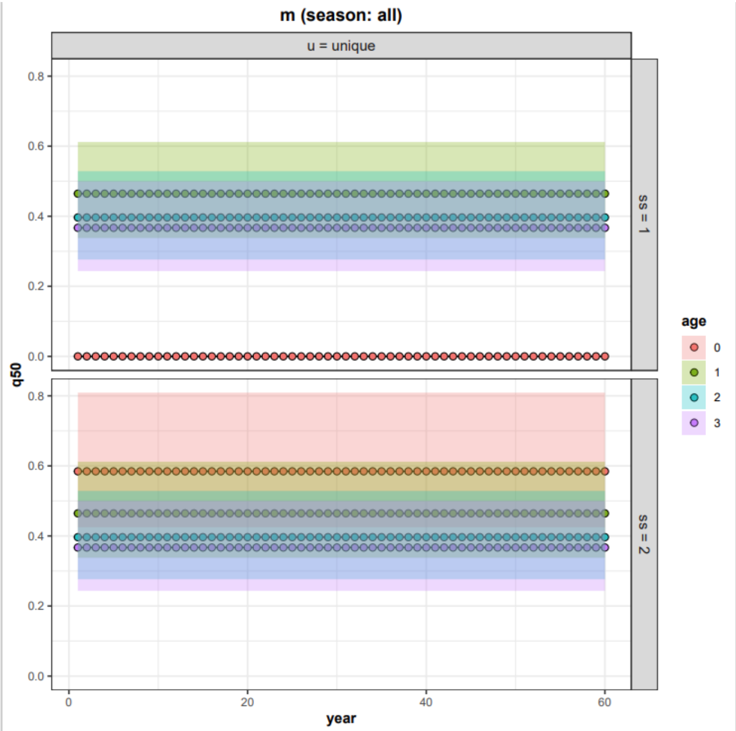

Figure 2.4 - Mortality-at-age for ages 0–3+ by season (ss) used in the new simulations. The dots correspond to the mean values and the horizontal bars represent the 90% interval of the 1000 simulation replicates.

Recruitment was based on the Beverton-Holt stock recruitment relationship classic parametrization:

$$R = \frac{a * SSB}{b + SSB}$$

The default scenario assumes a steepness parameter h = 0.75 to represents a medium productivity (Jardim *et al.*, 2015; Fischer *et al.*, 2020) and a standard deviation (σ_{REC}) at 0.75 since large fluctuations in recruitment are observed from one year to the next. However, other values of steepness such as h = 0.5 (low productivity) and h = 0.65 (intermediate productivity) were also tested.

The 'abPars' function in FLCore was used to estimate the parameters of the recruitment model. This function takes the steepness parameter (*h*, dependent on the productivity simulated), the virgin biomass parameter (B_0 = 100 000 tonnes) and the virgin spawners per recruit (spr_0). Table 3.2 shows the parameters estimated for the stock recruitment models of the 1000 simulation replicates.

Table 2.1 – Parameters of the Beverton-Holt stock recruitment models used in the new simulations for the western component of the anchovy stock. For parameter a we present mean values and standard deviation, parameter b is aways the same value since steepness (*h*) and B_0 are fixed.

Parameter	BC (h = 0.75)	Intermediate (h = 0.65)	Low (h = 0.5)
a	8519959 ± 2838136	9024846 ± 3006322	10413283 ± 3468833
b	9090.909	15555.56	33333.33

Survey catchability for the combined index of PELAGO and PELACUS is not known. The default case is assumed to be 1.5. Catchability at age is the same for all ages. Coefficient of variation for the survey is also not known. The Iberian sardine stock assessment considers that the CV of the survey is 0.25 (low). Scenarios of a CV of 0.5 (medium) were also tested.

2.2 Reference points

At present there are no reference points defined for this component. Reference points were estimated based on the above dynamics and assuming that 70% of the catches occurred in the second semester.

Reference points (B_{lim}, F_{MSY}, F_{lim}) were calculated for each simulation replicate within each productivity scenario. B_{lim} is now defined as the stock level where recruitment is 70% of the recruitment achieved at virgin stock spawning biomass (R_0). For each productivity scenario, B_{lim} is the same for all the simulation replicates but changes according to the productivity scenario (Table 3.1). F_{MSY} is defined as the fishing mortality that provides the maximum sustainable yield and F_{lim} is defined as the fishing mortality that will lead the stock to levels equal to B_{lim}.

For the low productivity scenario (h = 0.5) the reference point F_{MSY} is always (with the exception of two iterations) above F_{lim} (Figure 3.3). This means that it is expected that the risk during the last 20 years of the historical period and at the beginning of the projection period is very high and so the population starts from a very depleted state, in particular in the fishing history trajectory 'fopt' and 'fhigh', i.e., fishing history with a target of F_{MSY} and 2 F_{MSY} (+ noise).

Table 2.2 – Reference points assumed for the different productivity scenarios. Since F_{MSY} and F_{lim} are different for each simulation replicate we present mean values and corresponding standard deviation.

Reference point	BC (h = 0.75)	Intermediate (h = 0.65)	Low (h = 0.5)
B_{lim}	16279.07	23902.44	36842.11
F_{MSY}	1.59 ± 0.434	1.16 ± 0.325	0.695 ± 0.196
F_{lim}	2.35 ± 0.558	1.43 ± 0.380	0.669 ± 0.183

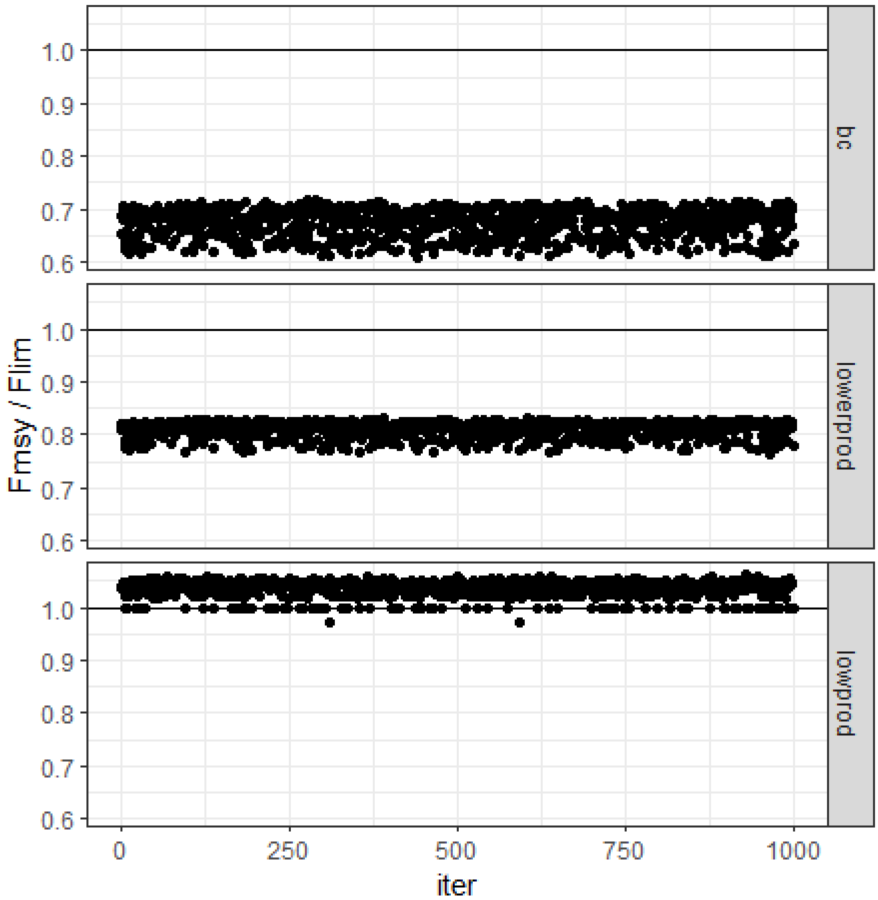

Figure 2.5 – Ratio between F_{MSY} and F_{lim} for each iteration and productivity considered.

2.3 Risks

The maximum probability of being below B_{lim}, being below B_{50} and of collapse P (SSB < 0.1 B_0) were calculated. B_{50} was defined as the stock level that produces 50%R_0. In this report we only present the risks of being below B_{lim} since this is the precautionary criteria adopted by ICES to evaluate long-term management plans.

2.4 Results

In Figure 2.6 we can see the biological risks versus the relative yields for the 1-over-2 rule with uncertainty cap of 80% and the constant harvest rate rule with different harvest rates values (colours) in the long-term for a catchability scenario value of 1.5. In the long term, the 1-over-2 rule has very low risk for a given relative yield. However, the CHR can provide similar yields for the same risk. The difference is that, depending on the harvest rate value, the CHR can provide risks below the threshold for relative yields higher than the 1-over-2 rule. This behaviour had already been shown in the previous work.

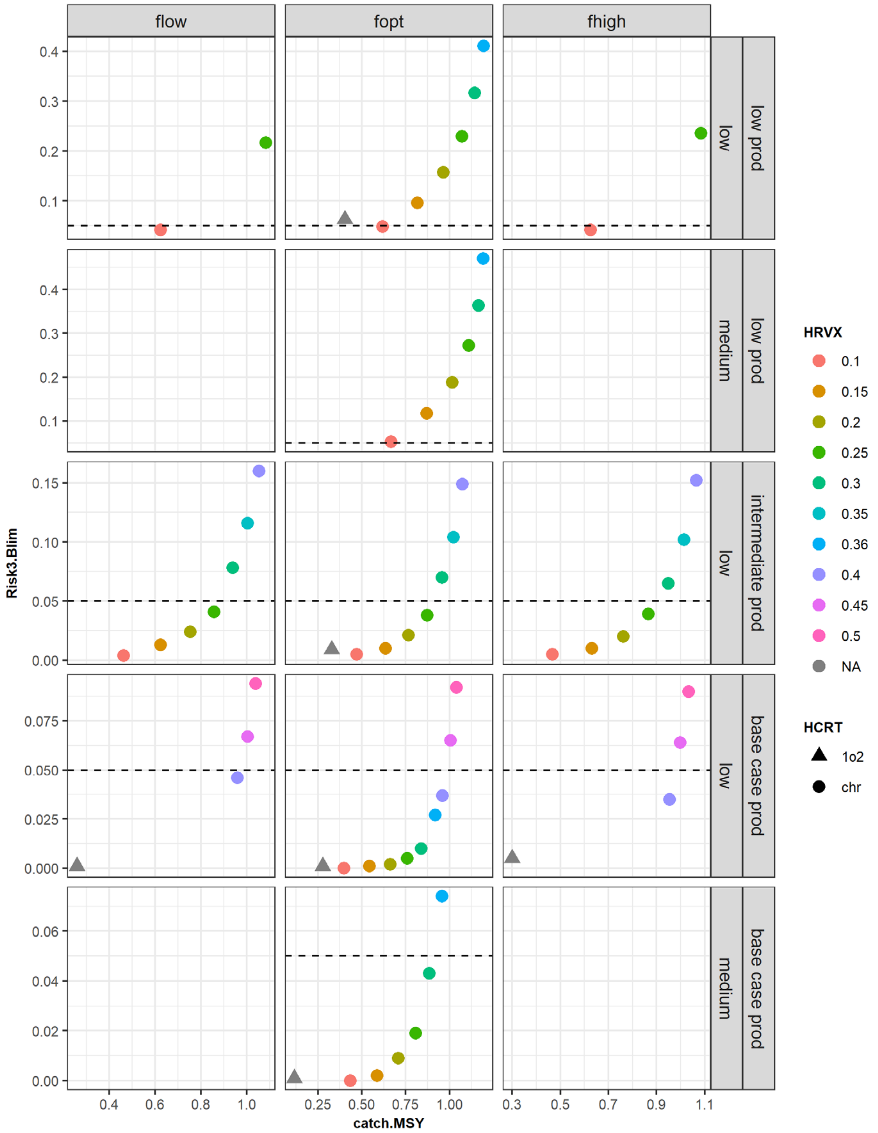

Figure 2.6 - Biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) versus the relative yields (catches/MSY) (x-axis) for the 1-over-2 advice rule (triangle) and the constant harvest rate rule (circle) with different harvest rates (colours). The columns correspond to the different historical exploitation and the rows to the combination of the productivity scenario (low prod = steepness 0.5, intermediate prod = steepness 0.65 and base case prod = steepness 0.75) and the coefficient of variation of the abundance index (low = 25% and medium = 50%). These scenarios correspond to values of 1.5. Dashed horizontal line corresponds to the 0.05 risk.

It was also shown that for the base case scenario the CHR can provide higher relative yields for lower risks in the short and medium term when compared with the 1-over-2 rule (Figure 2.7).

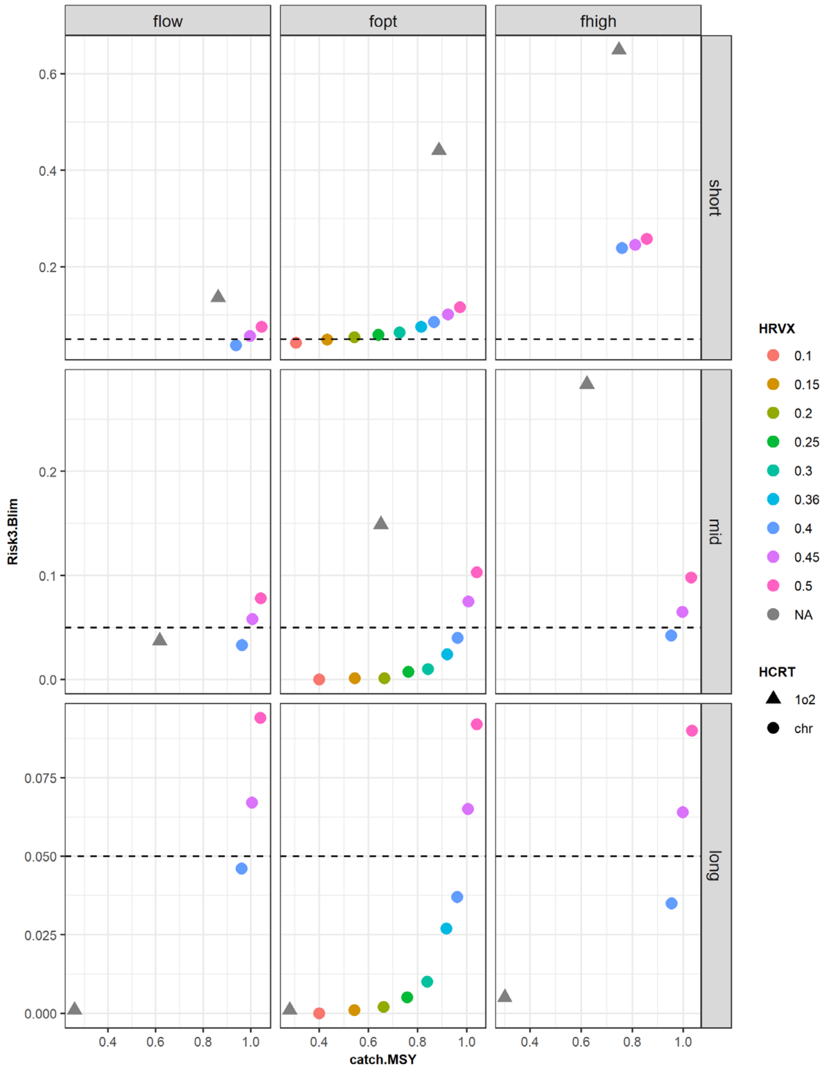

Figure 2.7 - Biological risks (Risk3.Blim: maximum probability of falling below Blim) versus the relative yields (catches/MSY) (x-axis) for the 1-over-2 advice rule (triangle) and the constant harvest rate rule (circle) with different harvest rates (colours) for the base case. The columns correspond to the different historical exploitation and the rows to the temporal scales: the short-term (first 5 projection years), medium-term (next 5 projection years) and the long-term (last 10 years of the projection years). Dashed line corresponds to the 0.05 risk.

Figure 2.8 and Figure 2.9 show the trajectories of the key parameters yield, fishing mortality (f) recruitment (rec) and SSB (B1+) for the two advice rules tested under three different fishing histories (under, fully and over exploited) under the base case scenario.

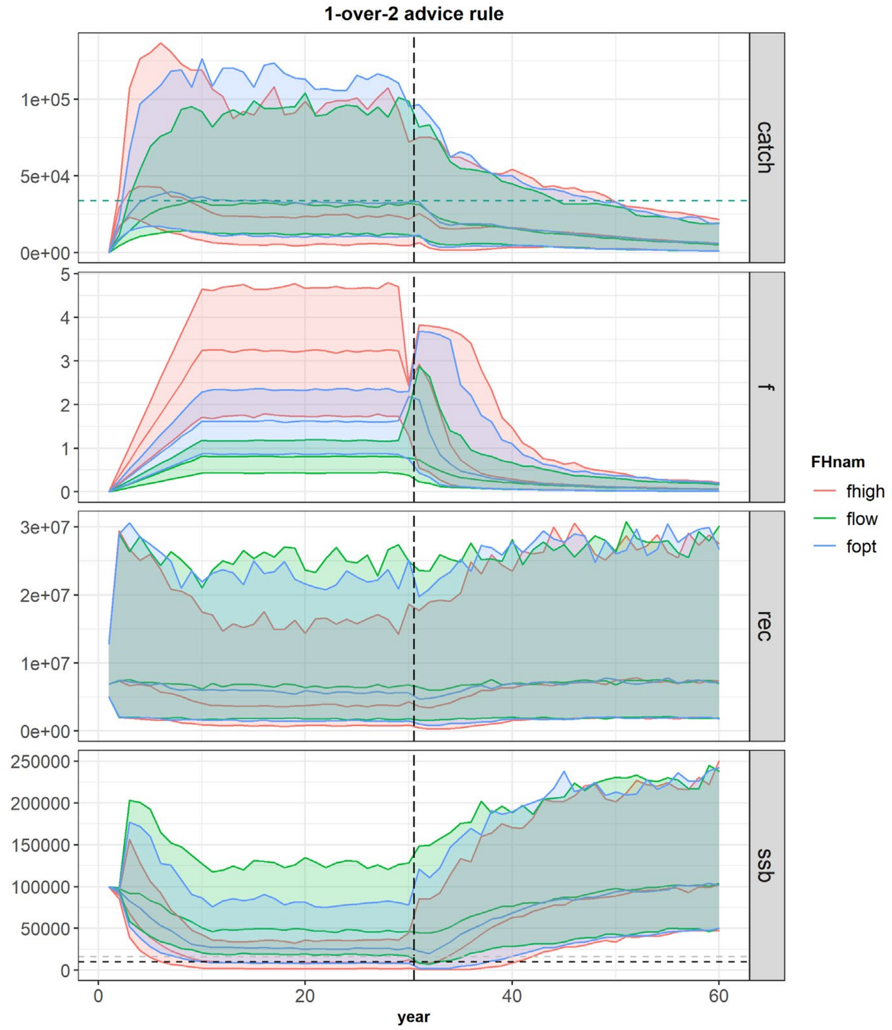

Figure 2.8 - 1-over-2 advice rule. Catch (tonnes), fishing mortality (F, year-1), recruitment (rec, million individuals) and biomass of fish age 1 and older (ssb, thousand tonnes) for the historical period (0–30) and during the projected period (31–60) for the base case scenario under different historical exploitation levels (fhigh = over exploitation, flow = under exploitation, fopt = fully exploitation). Shaded area represents 90% confidence intervals. Horizontal dashed lines in SSB show B_{lim} and $B_{collapse}$ (10% B_0, black) and in catch represents the mean value of MSY. Vertical long dashed lines separate the historical from the projected period.

For the 1-over-2 advice rule with an 80% uncertainty cap, independently of the historical exploitation level, there is a decreasing trend in the catch (and fishing mortality) while B1+ tends to increase towards an equilibrium value (Figure 2.8).

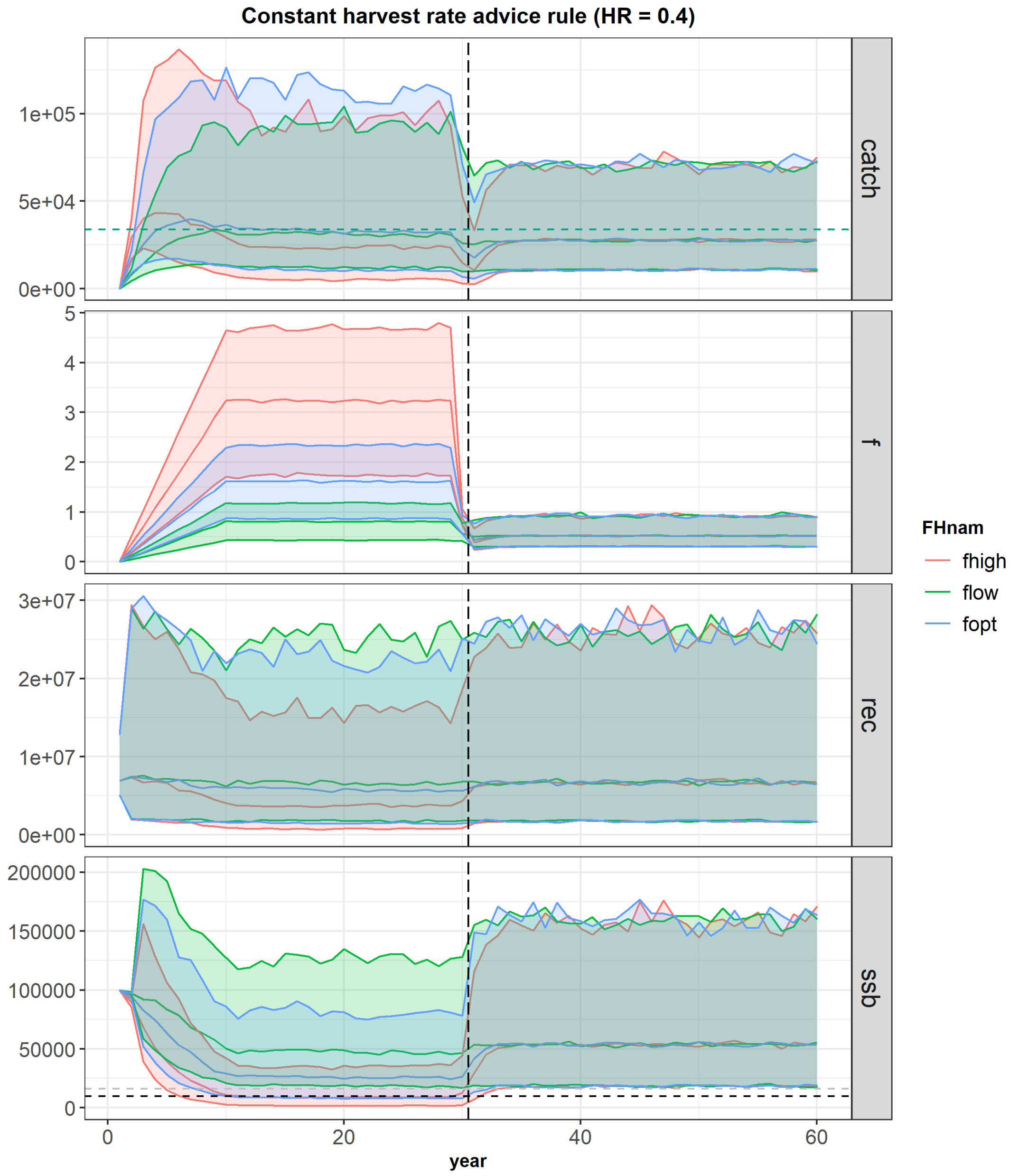

Figure 2.9 - Constant harvest rate advice rule (HR = 0.4). Catch (tonnes), fishing mortality (F, year-1), recruitment (rec, million individuals) and biomass of fish age 1 and older (ssb, thousand tonnes) for the historical period (0–30) and during the projected period (31–60) for the base case scenario under different historical exploitation levels (fhigh = over exploitation, flow = under exploitation, fopt = fully exploitation). Shaded area represents 90% confidence intervals. Horizontal dashed lines in SSB show B_{lim} and $B_{collapse}$ (10% B_0, black) and in catch represents mean value of MSY. Vertical long dashed lines separate the historical from the projected period.

For the constant harvest rate advice rule, independently of the historical exploitation level, there is a slight decrease in the catch at the beginning of the projection period but then they increase until a stable value (Figure 2.9). B1+ tends to increase towards an equilibrium value.

Risks at the beginning of the simulation period depend on the historical fishing pattern, increasing with the level of exploitation. With the 1-over-2 rule, risks increase in the first years of the simulation period and only after a couple of years start to decrease. Risks for the constant harvest rate advice rule start to decrease from the first year of the projection period. In the long term both advice type rules have no risks but catches are higher for the constant harvest rule advice rule.

This is independent of the exploitation level at the beginning of the simulation period (Figure 2.10).

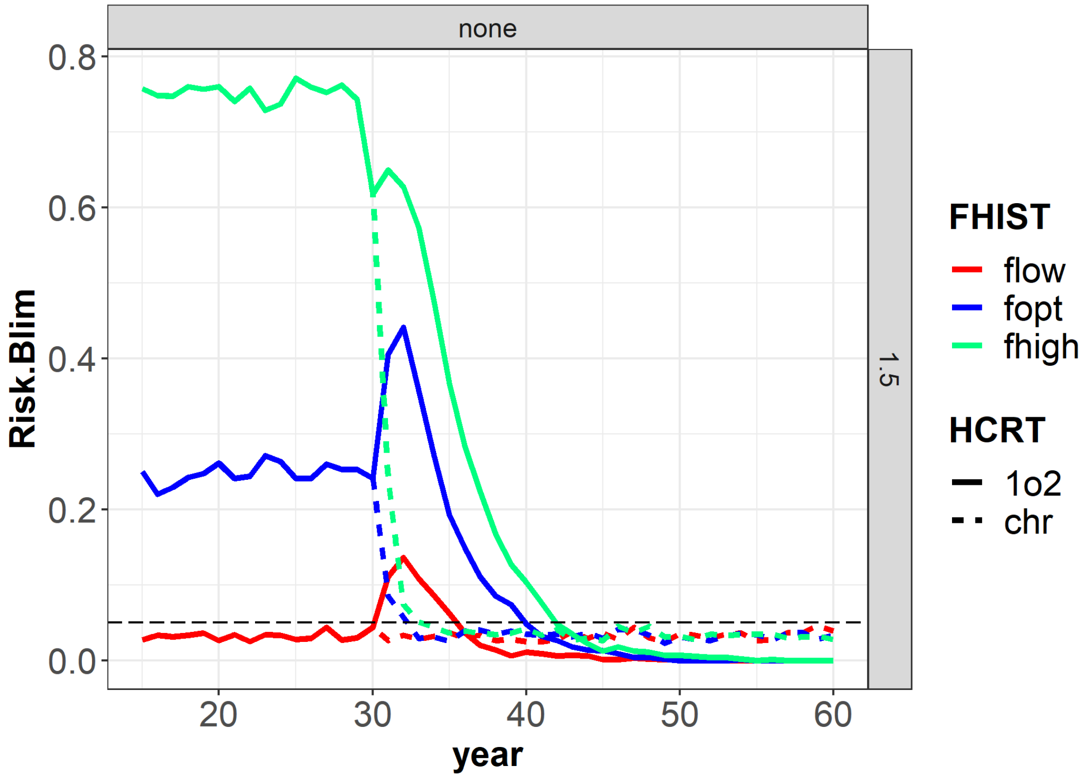

Figure 2.10 - Trajectories of biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) along years (x-axis) under an in-year advice for the base case scenario. The colours correspond to the historical exploitation level and the line type to the harvest control rule type (1-over-2 rule and CHR with HR = 0.4, both without biomass safeguard). The horizontal dashed line corresponds to the 0.05 risk.

The harvest rates simulated in the historical period for the base case scenario depend on the historical fishing trajectory simulated (Figure 2.11). Both the harvest rates simulated for the 'fhigh' and 'fopt' fishing patterns are above the observed harvest rates (calendar years). The 'flow' historical fishing pattern simulated is more in line with the historical observed harvest rates.

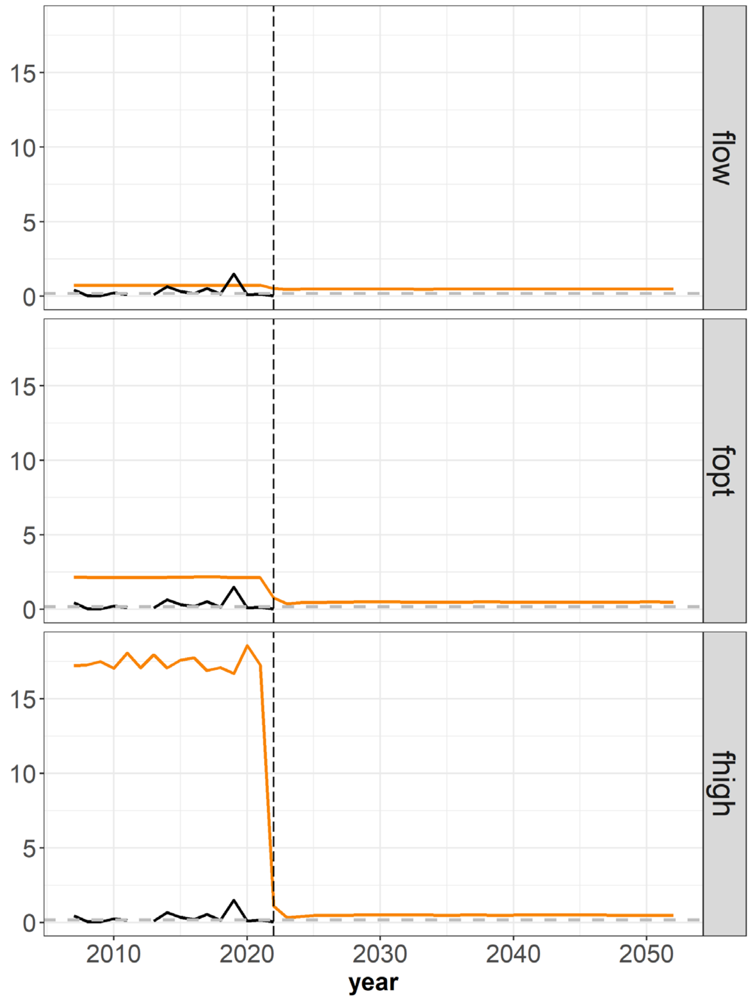

Figure 2.11 - Trajectories of harvest rates (catch divided by the abundance index) along years (x-axis) under an in-year advice for the base case scenario. The black line corresponds to the observed harvest rate while the orange line corresponds to the simulated harvest rate both in the historical period and the projection period. The horizontal dashed line corresponds to the geometric mean of the calendar year harvest rate observed from 2007 to 2022.

For the same catchability value of 1.5, an in-year advice, SIGR of 0.75 and no biomass safeguard it was found that risks change according to the productivity assumed and the value of CVID (Figure 2.12). It was found that for the base case productivity (h = 0.75) a harvest rate of 0.4 is precautionary when the CVID is low (CVID = 25%) but the harvest rate decreases to 30% if the CVID is assumed to be medium (CVID = 50%). Also, it was found that for an intermediate productivity (h = 0.65) a harvest rate of 0.25 is precautionary when the CVID is low (CVID = 25%).

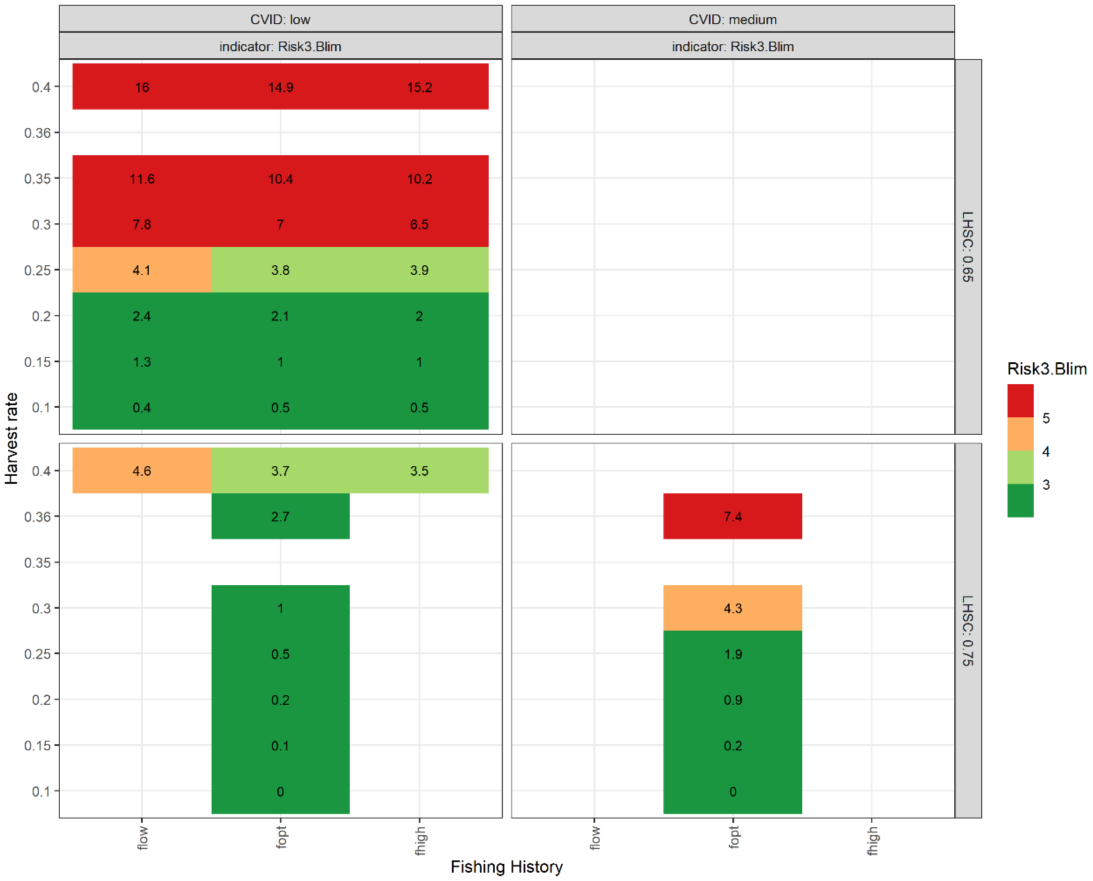

Figure 2.12 - Percentual biological risks (Risk3.Blim: maximum probability of falling below B_{lim}) in the long term for the three fishing trajectories: flow, fopt and fhigh (xx-axis) dependent of the harvest rate value (HRVX, yy-axis), for a catch-ability (QIDX) of 1.5 and coefficient of variation (CVID) of the abundance index (columns) and the productivity of the stock (LHSC, rows). Results are presented for the in-year advice, assuming that SIGR is 0.75 and no biomass safeguard was implemented.

2.5 Summary

Based on the additional work done for this stock-specific MSE conducted to determine a robust CHR for the western component of the 9a anchovy stock we can conclude that:

- The CHR advice rule also outperforms the current 1-over-2 advice rule when additional uncertainty is included in the operating models.
- New values for B_{lim} were adopted according to the re-estimation of the reference points. For the base case productivity (h = 0.75) this means that now B_{lim} = 16 279 t is lower than previously assumed ($0.2B_0$ = 20 000 t) decreasing risks. The opposite behaviour was observed for the other two scenarios of productivity considered in this additional work.
- For the base case considered a harvest rate of 0.4 is considered to be precautionary by ICES standards in the medium and long terms. In this base case we take into account the high sensitivity of the CHR advice rule to the value of the catchability of the survey index (QIDX = 1.5).
- However, to account for possible shifts in productivity (as mentioned by one of the reviewers) we now support the harvest rate HR = 0.25 as the basis of advice for the CHR advice rule to be applied to the Anchovy 9a western.

3 Reply to comments from reviewer Simon Fisher

Comment 1:

"Due to the lack of a stock assessment model for the western component of anchovy in 9.a, the operating model for MSE is modelled on life-history parameters. For most processes in this operating model, the basis is a von Bertalanffy growth model, and other processes are derived from this growth model (e.g. natural mortality, maturity, selectivity, etc.). However, the von Bertalanffy growth parameters are assumed to be known perfectly without any uncertainty, i.e. growth is deterministic, and there is no difference between the different simulation replicates (iterations). For data-limited stocks, growth is unlikely to be known precisely and assuming growth is deterministic is a strong simplification of reality and ignores a crucial source of uncertainty. "

Reply:

The typical parametrization of the von Bertalanffy growth model (VBGM) was used in this work:

$$L_t = L_{inf}\ (1 - e^{-K(t-t_0)})$$

In this parametrization of the model, the parameters L_{inf}, K and t_0 are highly correlated. For that reason, in each simulation replicate the von Bertalanffy growth model (VBGM) parameters were sampled from the correlation matrix of the model fit. To avoid unreasonable large values only the sets of values that have L_{inf} within the interval [0.9L_{inf}, 1.1L_{inf}) and K>0 and within the interval [0.5K, 1.5K) were kept (Figure 3.1 - Paired scatterplots of the parameters for the typical VBGM used in the new simulations of the western anchovy component.Figure 3.1). Therefore, the VBGM parameters are no longer assumed to be known perfectly.

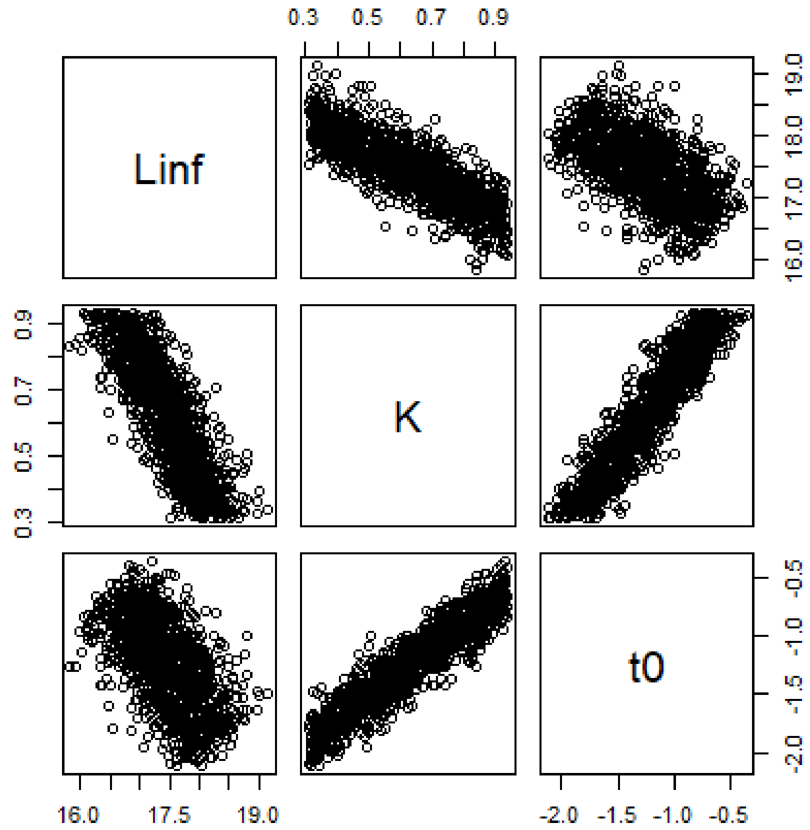

Figure 3.1 - Paired scatterplots of the parameters for the typical VBGM used in the new simulations of the western anchovy component.

In addition, uncertainty from the Length-Weight model was introduced by sampling parameters *a* and *b* from the correlation matrix of the model fit as was done with the VBGM parameters (Figure 3.2).

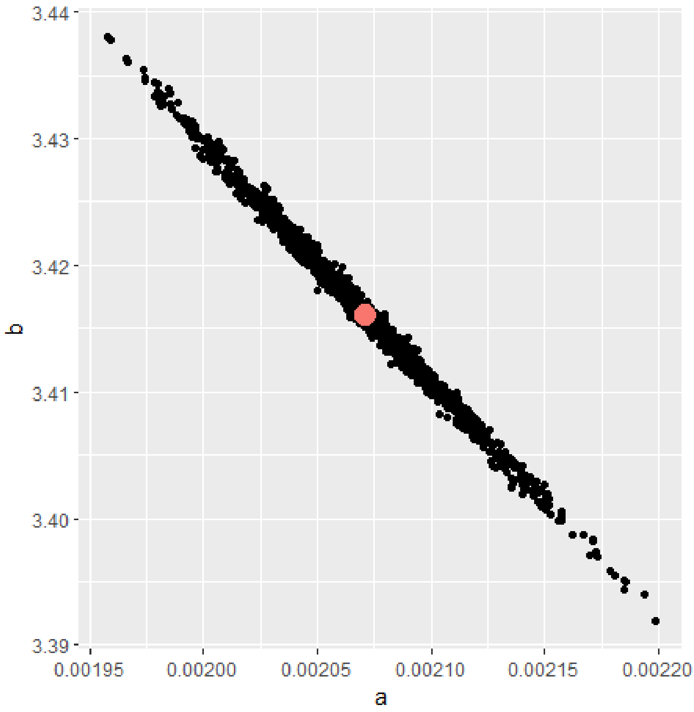

Figure 3.2 – Pairs of the Length-Weight model parameters a (xx-axis) and b (yy-axis) used in the new simulations of the western anchovy component. The red point shows the previous only pair used in the simulations.

This implies that the weight-at-age and the natural mortality at age are derived at each simulation replicate. Initial population values were updated for each set (simulation replicate) of biological parameters.

Comment 2:

"For the historical part of the operating models, three historical fishing histories (0.5/1/2F_{MSY} + noise) were included, and assume that fishing was constant (on average) for the last twenty historical years. These scenarios could be considered unlikely in reality. Such scenarios can be useful for generic testing of management strategies but are insufficient to provide stock-specific recommendations."

Reply:

The case study of English Chanel sprat (Walker *et al*. 2023) shows that for a CHR strategy the final optimal CHR does not depend upon the historical fishing pattern. This seems to be the also the case for this component of the anchovy stock.

Moreover, the harvest rates simulated in the historical period for the 'fhigh' and 'fopt' fishing patterns are above the observed harvest rates (calendar years) and the 'flow' historical fishing pattern simulated is more in line with the historical observed harvest rates. This is considered to be risk averse.

Comment 3:

"Another issue is that F_{MSY} is defined as the F that leads to a stock biomass corresponding to 40% of the unfished biomass. This is a generic assumption that might not hold for this anchovy stock. Instead, F_{MSY} could be derived from the MSE framework (including uncertainty) to ensure the reference point is consistent with the dynamics of the operating model. "

"The biomass reference point B_{lim} is defined as the biomass corresponding to 20% of the unfished biomass. This means that the condition of the stock is different depending on the recruitment steepness. In scenarios with higher steepness, the stock is in a more productive state (higher R/R_0) at B_{lim} compared to scenarios with lower steepness. This means the risk values (the probability of a stock being below B_{lim}) are not comparable between different recruitment scenarios. This is an important shortcoming because the target harvest rate is selected by finding the harvest rate where B_{lim} risk meets 5%."

Reply:

Reference points (B_{lim}, F_{MSY}, F_{lim}) were calculated for each simulation replicate within each productivity scenario. B_{lim} is now defined as the stock level where recruitment is 70% of the recruitment achieved at virgin stock spawning biomass (R_0). For each productivity scenario, B_{lim} is the same for all the simulation replicates but changes according to the productivity scenario (Table 3.1). F_{MSY} is defined as the fishing mortality that provides the maximum sustainable yield and F_{lim} is defined as the fishing mortality that will lead the stock to levels equal to B_{lim}.

Reference points are now consistent with the dynamics of the operating model. For the low productivity scenario (h = 0.5) the reference point F_{MSY} is always (with the exception of two iterations) above F_{lim} (Figure 3.3). This means that it is expected that the risk during the last 20 years of the historical period and at the beginning of the projection period is very high and so the population starts from a very depleted state, in particular in the fishing history trajectory 'fopt' and 'fhigh', i.e., fishing history with a target of F_{MSY} and 2 F_{MSY} (+ noise).

Fishing at F_{MSY} for small-body pelagic species may place recruitment at risk (van Deurs *et al.*, 2021). It has, for example, been shown that F_{MSY} is either above or close to the fishing mortality leading to a 5% risk of impaired recruitment in three out of four clupeids stocks in the North Sea and Baltic Sea (Rindorf *et al.*, 2017).

Table 3.1 – Reference points assumed for the different productivity scenarios. Since F_{MSY} *and* F_{lim} are different for each simulation replicate we present mean values and corresponding standard deviation.

Reference point	BC (h = 0.75)	Intermediate (h = 0.65)	Low (h = 0.5)
B_{lim}	16279.07	23902.44	36842.11
F_{MSY}	1.59 ± 0.434	1.16 ± 0.325	0.695 ± 0.196
F_{lim}	2.35 ± 0.558	1.43 ± 0.380	0.669 ± 0.183

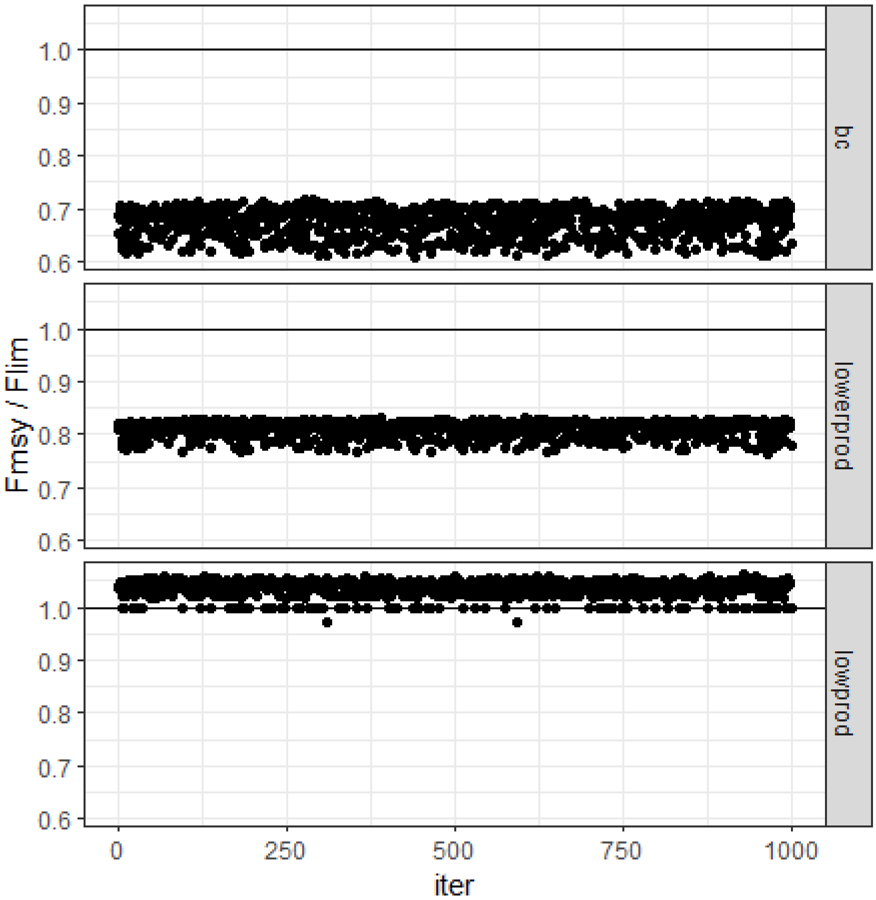

Figure 3.3 – Ratio between F_{MSY} and F_{lim} for each iteration and productivity considered.

In this work the key issue is the impact of a CHR on a population being assessed through a survey monitoring system, therefore the key issue is the catchability of the survey relative to the actual population. For the steepness we think that the assumed variability seems to be sufficiently covered. For the variability in the recruitment a standard deviation sigma was set at 0.75 since large fluctuations in recruitment are observed from one year to the next. This seems a sensible value consistent with literature.

Comment 4:

"For a stock-specific MSE, the operating models should be conditioned on the history of the actual stock. There are acoustic surveys and some length/weight/age data. The survey data could give some idea of the stock trend (and variability) over time. The other data could be used to have a rough idea about the stock status (fishing pressure, depletion), e.g. by using length-based indicators or some other length-based model, and this should be used for the operating model conditioning."

Reply:

Data available from the acoustic surveys (length/weight/age data) were used to fit the von Bertalanffy model and the length-weight model. The maturity ogive was also derived based on the available data.

The authors are not aware of any length-based indicator of fishing mortality applied elsewhere, as for short lived species like anchovy, length follows simply recruitment pulses entering the fishery. Furthermore, length and age structures of catches and of surveys were shown in the report and they point out that selectivity is focussed on the mature fraction of the population (ages 1+). Hence the selectivity profile assumed for the base case is correct for an optimal exploitation of the resource. Moreover, an alternative selectivity pattern was also simulated to account for the possibility of some age zero catches (maximum observed in the time series available is 20% in the catches).

There are no clear trends in the population and there is no clear trend in the harvest rate, except declining after the introduction of the current management system based on the 1over2 rule.

For these reasons this might be not a major issue in the analysis performed.

Comment 5:

"Recruitment is modelled with a von Bertalanffy stock-recruit model with a generic steepness of 0.75, but alternative steepness values (0.5, 0.9) are considered. Different recruitment scenarios are considered, but only by changing the recruitment uncertainty or steepness. More interesting would be the impact of different recruitment levels (higher/lower R_0, recruitment failure) on the performance of the management strategies in the projection. "

Reply:

Recruitment was based on the Beverton-Holt stock recruitment relationship classic parametrization:

$$R = \frac{a * SSB}{b + SSB}$$

The 'abPars' function in FLCore was used to estimate the parameters of the recruitment model. This function takes the steepness parameter (*h*, dependent on the productivity simulated), the virgin biomass parameter (B_0 = 100 000 tonnes) and the virgin spawners per recruit (spr_0). Table 3.2 shows the parameters estimated for the stock recruitment models of the 1000 simulation replicates.

Table 3.2 – Parameters of the Beverton-Holt stock recruitment models used in the new simulations for the western component of the anchovy stock. For parameter a we present mean values and standard deviation, parameter b is aways the same value since steepness (h) and B0 are fixed.

Parameter	BC (h = 0.75)	Intermediate (h = 0.65)	Low (h = 0.5)
a	8519959 ± 2838136	9024846 ± 3006322	10413283 ± 3468833
b	9090.909	15555.56	33333.33

Comment 6:

"So far, the simulations are generic but based on life-history considerations. However, for such simulations to be useful in ICES, they must also be stock-specific. To achieve this, more stock-specific fishing histories

should be considered, uncertainty should be considered more broadly (e.g. in life-history parameters/growth, alternative operating models), and uncertainty estimates (observation error, recruitment uncertainty) should be more stock/fishery-specific. "

Reply:

The work done between the meeting on the 5th of May and the WGHANSA meeting took into considerations the comments from both reviewers. The critical issue of including uncertainty was achieved and the reference points were estimated according to the productivity scenario considered instead of being related to the virgin biomass. The simulation presented in the previous report already included uncertainty in the observation error (catchability and coefficient of variation of the abundance index), the fishing history simulated and in recruitment. Therefore, we consider that the work presented is not generic and includes the necessary uncertainty about the western anchovy component.

4 Reply to comments from reviewer Bjarki Elvarsson

Comment 1:

"The HCR simulations for the western stock component should include uncertainty estimates for key life-history parameters in the base set of simulations. This means that new set of life history parameters should be simulated prior to a new iteration of the simulation experiment."

Reply:

Please check reply to comments 1 to 5 made to reviewer Simon Fisher in the previous section.

Comment 2:

"Also, given the dramatic shift in the catch levels observed in after 2010, shifts in productivity should be considered in alternate scenarios."

Reply:

Considering the limited information about the stock size, trends and what variable exactly may have an impact on them it is very difficult to envision what type of shifts in recruitment, when and how long for these shifts should be implemented for this component.

We believe that this issue is not a priority for the work presented. The current 1-over-2 rule advice rule was also not tested under shifts in productivity and it has been shown that the CHR outperforms the 1-over-2 rule. However, to account for that possibility the final proposal of harvest rate for this component is based on a risk averse scenario of productivity with steepness 0.65.

5 References

Fischer, S. H., De Oliveira, J. A. A., and Kell, L. T. 2020. Linking the performance of a data-limited empirical catch rule to life-history traits. ICES Journal of Marine Science, 77: 1914–1926. https://doi.org/10.1093/icesjms/fsaa054.

Gislason, H., Daan, N., Rice, J. C., and Pope, J. G. (2010). Size, growth, temperature and the natural mortality of marine fish. Fish Fish. 11, 149–158. doi: 10.1111/j.1467-2979.2009.00350.x.

Jardim, E., Azevedo, M., and Brites, N. M. (2015). Harvest control rules for data limited stocks using length-based reference points and survey biomass indices. Fish. Res. 171, 12–19. doi: 10.1016/j.fishres.2014.11.013

Rindorf, A., Cardinale, M., Shephard, S., De Oliveira, J. A. A., Hjorleifsson, E., Kempf, A., Vinther, M. (2017). Fishing for MSY: using "pretty good yield" ranges without impairing recruitment. ICES Journal of Marine Science, 74, 525–534. https://doi.org/10.1093/icesj ms/ fsw111

van Deurs, M., Brooks, M. E., Lindegren, M., Henriksen, O., & Rindorf, A. (2021). Biomass limit reference points are sensitive to estimation method, time-series length and stock development. Fish and Fisheries, 22(1), 18-30

N D Walker, R Ouréns, J E Ball, J van der Kooij, A Uriarte, J White, P Carpi, P Schuchert, R D M Nash (2023). Defining sustainable and precautionary harvest rates for data-limited short-lived stocks: a case study of sprat (Sprattus sprattus) in the English Channel, ICES Journal of Marine Science, 2023; fsad061, https://doi.org/10.1093/icesjms/fsad061

WORKING DOCUMENT

ADDITIONAL WORK AND REPLY TO REVIEWERS concerning:

Anchovy 9a southern stock-specific management strategy evaluation conducted to determine an alternative to the current advice rule

Authors: Pérez-Rodríguez, A; Woods, P.; Zúñiga, M. J.; Sánchez, S.; Ramos, F.; Wise, L.; and Rincón, M.M.

1 Summary

As result of the meeting hold the 5th of May, when the results and conclusions of the first part of the MSE conducted on the southern component was presented to the ICES designated external reviewers, a list of comments and approaches to solve some relevant issues was compiled and it was agreed to carry out those improvements in the simulation framework and scenarios tested. This working document compiles those extra simulations and compile the results that were presented during the WGHANSA meeting from 29th of May to 2nd of June 2023.

Despite the increase in risk of being below Blim as result of higher uncertainty in the biological-fisheries elements simulated, the results of this second part of the MSE continues to support the harvest rate HR=0.5 as candidate reference point to be used on a constant harvest rate *chr* HCR, with a biomass safeguard $B_{trigger}$ = 1194.132 tons. This chr should be applied to the SSB estimated by the gadget assessment model approved by WKPELA 2018.

The simulations conducted during the first part of the MSE exercise proved that, since the likely overestimation of the survey catchability by the gadget model would lead to an underestimation of the stock size, any HR that is proved to be precautionary would in reality be highly precautionary. For this reason, it was concluded that using the absolute estimates of the gadget assessment model with a HR=0.5 is precautionary as far as the catchability estimated by the gadget assessment model does not go much lower than the values estimated in the 2022 assessment.

The results of the first and second MSE exercises proved that the HCR *chr* with HR=0.5 overcome the performance of the 1over2 rule, reducing the risk of falling below Blim in the short term, while producing a higher yield in the short, medium and long term.

2 Introduction

The 5th of May, the results and conclusions of a first group of simulations conducted with FLBEIA were presented to the reviewers (see Pérez-Rodríguez et al, 2023a in annex 6). The conclusions included as part of that first MSE work were:

- The sensitivity analysis showed that in order to account for uncertainty in the most relevant factors affecting the perception of stock status and behaviour of the commercial fleet, the final settings for the *MSE* framework should include:
  - Biomass safeguard in the *1over2* and *chr HCR*s
  - Assessment error with sporadic high error values.
  - Limitation to recruitment to the maximum observed in the historic period
  - Distribution of catches over the year as observed in the last 10 years of the historic period.
  - *OM* conditioned with input data from Gadget assessment model with survey catchability as approved in the ane27.9a_south component 2022 assessment (ICES, WGHANSA 2022). This is the most precautionary scenario regarding the uncertainty in survey catchability in the assessment model.
- With this configuration of the *MSE* framework, the maximum precautionary *HR* in a *chr* was 0.5. Accordingly, HR=0.5 applied to the estimated SSB (by the Gadget assessment model) could be proposed as the $HR_{MSYproxy}$ for the 27.9a_south anchovy.

- When compared to the *1-over-2* rule, the *chr* with a HR=0.5 produces higher yield while being precautionary.

During the online meeting, the reviewers expressed their criticisms, which are presented in the documents Elvarsson, B. 2023 and Fischer, S. 2023. in annex 6. Next, a list with the main reviewer´s concerns followed by a comment clarifying:

1. *The approach followed is a shortcut MSE instead of a full MSE*
   This was a concern that was supported only by one of the reviewers. It was recognized that the full MSE is not the only approach accepted by ICES at this moment.

2. *Use of gadget outputs in absolute terms, when it was actually approved by WKPELA for relative estimates.*
   During WKPELA (2018) it was decided to use gadget estimates in relative terms because it was considered that the survey catchability estimated by gadget was excessively high (around 3 times higher than usual catchability in acoustic surveys). The results of the simulations presented to the reviewers (Pérez-Rodríguez et al, 2023a in annex 6) as part of the MSE proved that, if the concerns raised during WKPELA are correct, the stock size is underestimated by the gadget assessment model presented in ICES-WGHANSA (2022). Accordingly, the HCR that is proved to be precautionary with this model is certainly safe in terms of risk of falling below Blim.

3. *Criticisms about the PELAGO survey model fit*
   The reviewers pointed to the bad fit to the PELAGO survey, and proposed some options to modify the configuration of the current approved gadget assessment model that would result in a different model configuration or even would involve the replacement of the current model with a different assessment method. However, these kind of modification would require the organization of a benchmark, which is indeed planned for 2024. Accordingly, at this moment the available assessment model has been used in the MSE.

4. *The historical part of the operating model does not include uncertainty for any metric*
   The gadget2 model, unlike the gadget3 model, doesn´t produce estimates of parameter uncertainty, and it produce deterministic values for all the variables of interest (SSB, numbers and weight at age, etc). The FLBEIA OM was conditioned with this information and hence, it doesn´t provide uncertainty in the stock size in the year before starting the projection period. This was considered one of the key issues to be addressed.

5. *Explore uncertainty in biological-fisheries related processes*
   Both reviewers considered that there was need to simulate uncertainty and variability in a few more elements of the OM, assessing the impact of that extra uncertainty in the sustainability and productivity of the stock. Among the processes proposed by the reviewers were:
   - Growth (as weight at age)
   - Natural mortality
   - Variability in the SSB-Recruitment relationship (parameterization)
   - Fishing catchability/selectivity

   The reviewers proposed that, as a solution to both, historic population uncertainty and variability in biological-fishery related processes in the projection period, a parametric bootstrap resampling of residuals could be conducted to produce new input data that could be used to refit the gadget assessment model, and hence producing new values of growth, natural mortality, fisheries selectivity, etc. It was considered, that repeating this process 100 times would potentially provide enough variability in both the historic and projection period. It was agreed to take this as the way to move forward. These new simulations could contribute to solve some of the main concerns of the reviewers, which could be taken as prove in support of using the new proposed chr HCR for the next year, but, a more in depth development of an MSE will be required if a long term use HCR is to be proposed.

6. *Excessively long projection period*
   It was mentioned by one of the reviewers that 30 years of simulations might be excessive, and that covering 1-2 generations should be enough. In this MSE exercise the performance statistics are estimated and presented for three different time frames: short (5 years after the historic period), medium (from 5th to 10th year after the end of the historic period), long term (last 10 years of the projection period). In this way, the length of the projection period should not be an issue to assess the performance of a HCR for a reduced number of fish generations. However, in this second part of the MSE exercise it was decided reducing the number of years in the projection period, from 2022-2050 in the first part of the MSE exercise to 2022-2040.

7. *Producing extra figures*
   It was recommended producing plots including historic and projection period in order to compare levels of exploitation and productivity in the past with output in the simulation period. Variables to be presented should include usual variable like SSB, mean annual catch, but also the harvest rate in the historic period compared to the HR proposed as $HR_{MSYproxy}$.

It was agreed during the meeting with the reviewers that a second batch of simulations would be performed to deal with some of the main concerns of the reviewers. The efforts in this second part of the MSE simulations were focused on dealing with: concerns 4 to 7. In the sections below, the methodology employed, the structure of the simulations, results and conclusions are described.

3 Methods

The estimation of uncertainty in stock status was accomplished following the approach by Woods et al (in preparation) to perform an MSE for two inshore stocks of Northern shrimp in the Westfjords region of Iceland. Based on this approach, model uncertainty due the fitting procedure and observation error were simulated by repeating the model-fitting procedure (with the same fixed likelihood score weights obtained for the gadget assessment model presented in ICES-WGHANSA, 2022) on 100 sets of simulated input data. For each set of simulated data, observation error was simulated by performing a parametric bootstrap of the residuals obtained in the original gadget assessment model. In the parametric bootstrap, parametric distributions were fit to residuals, after which the sets of simulated data were created as 100 random draws from the parametric distributions. To prevent generation of negative values in the simulated data, residuals were calculated as the log of predictions from the operating model divided by observations, and therefore error was applied multiplicatively to the original data. A normal distribution was fitted to each set of residuals of survey indices. A multivariate normal distribution was fitted to length distribution proportions using the function *mlest* of the R library *mvmle*. This function finds the maximum likelihood estimate of the mean vector and variance-covariance matrix for multivariate normal data, allowing for missing data. The multivariate normal distribution fitted to the ECOCADIZ survey length distribution residuals was borrowed to generate data for the commercial seine fleet and PELAGO survey data. Because data were too sparse to fit a multivariate normal distribution to each length distribution residuals by age, the variance-covariance matrix obtained from the multivariate normal distribution fitted to ECOCADIZ survey length distribution residuals was borrowed to generate data for all ages in the age-length distribution data. Gadget models were then optimized for each of the 100 simulated data sets, resulting in re-optimized parameter values involved in biological-fisheries processes like the growth model, annual recruitment, or survey and commercial selectivity.

The output of each of the 100 fitted gadget models were used to condition the historic period of 10 iterations of the FLBEIA operating model OM, producing 1000 iterations in total. For each of the two semesters simulated in FLBEIA, the stock numbers at age, catch in numbers at age, stock and catch weight at age, natural mortality at age, proportion of fishing and natural mortality before spawning, and some more information was used to condition the 1000 iterations of the OM. This way, the OM was conditioned simulating the uncertainty in all of these sources of information in the historic period, based in the variability in the input data generated with the parametric bootstrapping and the variable assessment conducted with alternative gadget models.

The projection period on each of the 1000 iterations was conditioned based in the values of the historic period on each iteration:

- Maturity, fecundity, fishing, natural mortality and weight at age: average of the values by age in the last 3 years of the historic period
- Seine fleet catchability at age: average of the catchability at age in the last 3 years of the historic period.
- Annual recruitment at age 0: result of two elements:
    - An SSB-Recruitment relation fitted independently to each of the 100 different historic periods (100 different gadget models SSB and recruitment estimates).
    - Simulation of random variability around the recruitment defined by the fitted SSB-Recruitment model based on the assumption of a normal distribution with mean=0 and standard deviation estimated from the model residuals. The randomization of the residuals lead to 1000 different recruitment time series in the projection period.
- Natural mortality at age was re-estimated as the product of the ratio of weight at age in the gadget model fit to the bootstrapped data and weight at age in the original gadget assessment model times the natural mortality at age in the historic period.

$$M_{age\_projection} = M_{age\_historic}\ x\ (\frac{Weight_{age\_original}}{Weight_{age\_bootstrap}})$$

Different simulations were run to assess the effect of considering a number of options in the SSB-Recruitment relationship:

- Segmented regression where the breakpoint was fixed as Blim=Bloss (Bloss= lowest estimated SSB in the assessment time series) on each of the 100 gadget models
- Segmented regression where the breakpoint was fixed as Blim=1186.34 tons (ICES, 2022)
- Segmented regression where the breakpoint is optimized during the fitting to the SSB-Recruitment data.

The rest of the methodology was as described in the Methods section of the first batch of simulations. In this batch of simulations there was no exploration of the effect that a biased perception in the status of the stock due to a potential overestimation of catchability might have in terms of risk and yield. That analysis was already accomplished in the first group of simulations, and it was shown that conditioning the OM with the output of the original gadget model (with survey catchability 4.65 in ECOCADIZ and 4.2.64 in PELAGO) was the most precautionary option. Here, the original gadget model was used (ICES-WGHANSA, 2022), and the focus was put in one of the main reviewer´s concerns, including extra uncertainty in the simulations in biological and fisheries related processes not explored before in the first MSE simulation exercise, and assessing the impact in the productivity and sustainability of the proposed HCR (chr HR=0.5) and adjacent HR values. As described above, fitting the gadget model with 100 different bootstrap samples of input data allowed including uncertainty in a number of biological and fishery elements that was continued in the projection period. These new elements formed the extension in the uncertainty accounted for in this second MSE simulation exercise. Precisely:

- Weight at age
- Natural mortality at age
- Parameterization of SSB-Recruitment relationship
- Commercial fleet seine catchability at age

The projection period was reduced in comparison to the period simulated in the first round of MSE simulations. Here the projection period covered from 2021 to 2040. The reasons for the reduction in the simulated period was the comments from the reviewers regarding the excessive number of years simulated and the need of reducing the time needed to accomplish the simulations.

4 Results

4.1 Simulation of input data with parametric bootstrap resampling

The 100 simulated input data sources are presented in figures 4.1.1 to 4.1.15. The 100 biomass survey indices time series for ECOCADIZ and PELAGO surveys, obtained by implementing the parametric bootstrap are shown in figures 4.2.1 and 4.2.2. Black lines indicate the original survey index time series used in the gadget assessment model presented in ICES-WGHANSA, 2022. The 100 survey indices generated randomly assuming a normal distribution to generate 100 replicates followed the same pattern over time as it was observed in the original input data. The length distribution data generated as parametric bootstrap replicates for the ECOCADIZ, PELAGO surveys and seine fleet also described the observed distribution patterns (black lines) with some variability around the original length distributions (Figures 4.1.3 to 4.2.8). The length distribution by age for all the three fleets is presented in figures 4.1.9 to 4.1.18.

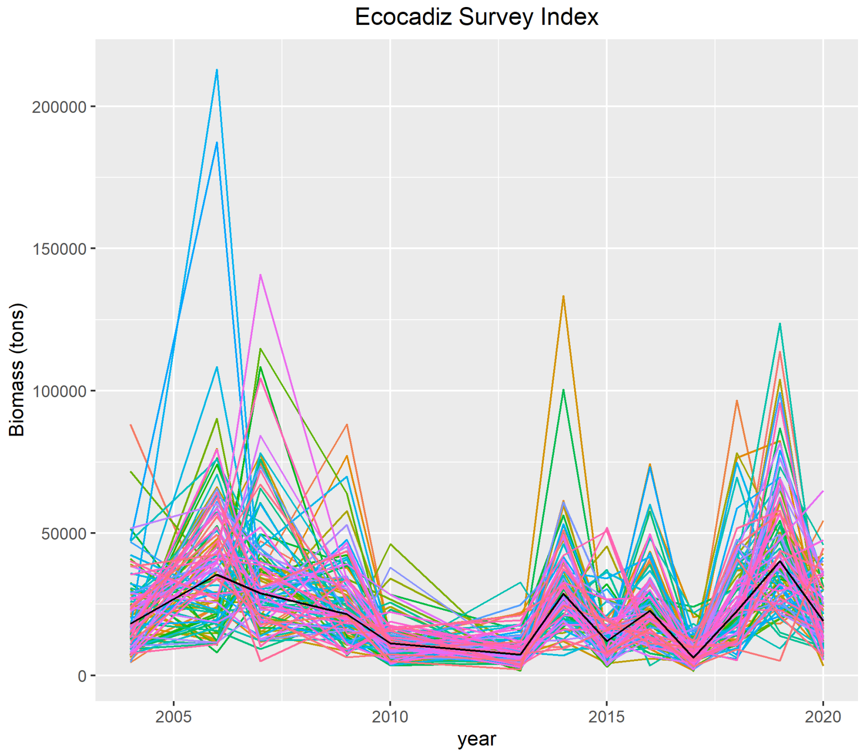

Figure 4.1.1.- One hundred parametric bootstrapped ECOCADIZ survey index time series (colored lines) compared to the original ECOCADIZ survey index (black line).

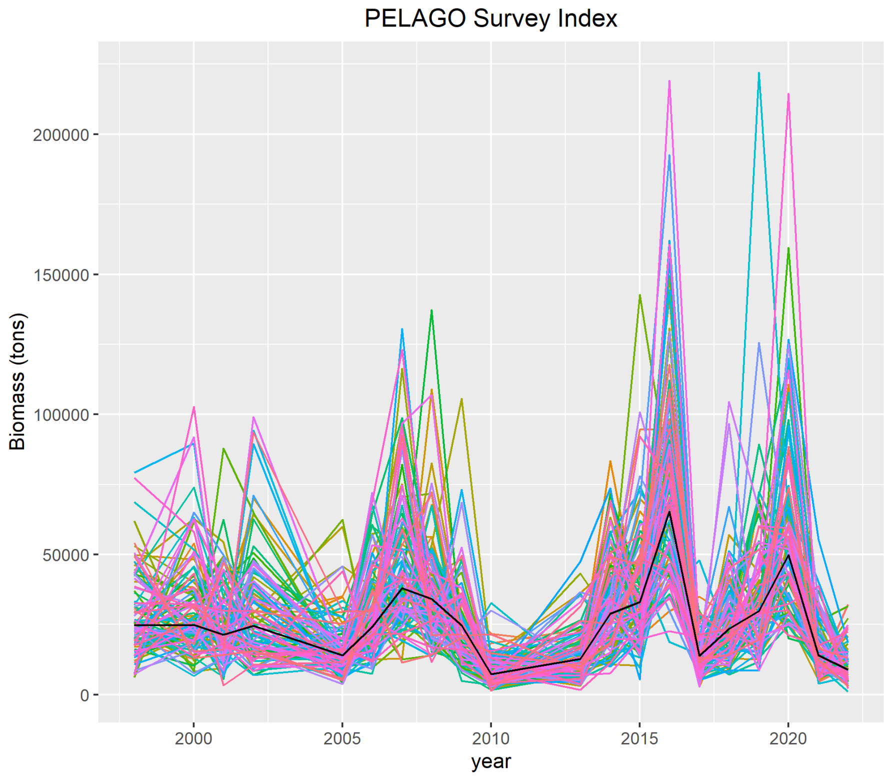

Figure 4.1.2.- One hundred parametric bootstrapped PELAGO survey index time series (colored lines) compared to the original PELAGO survey index (black line).

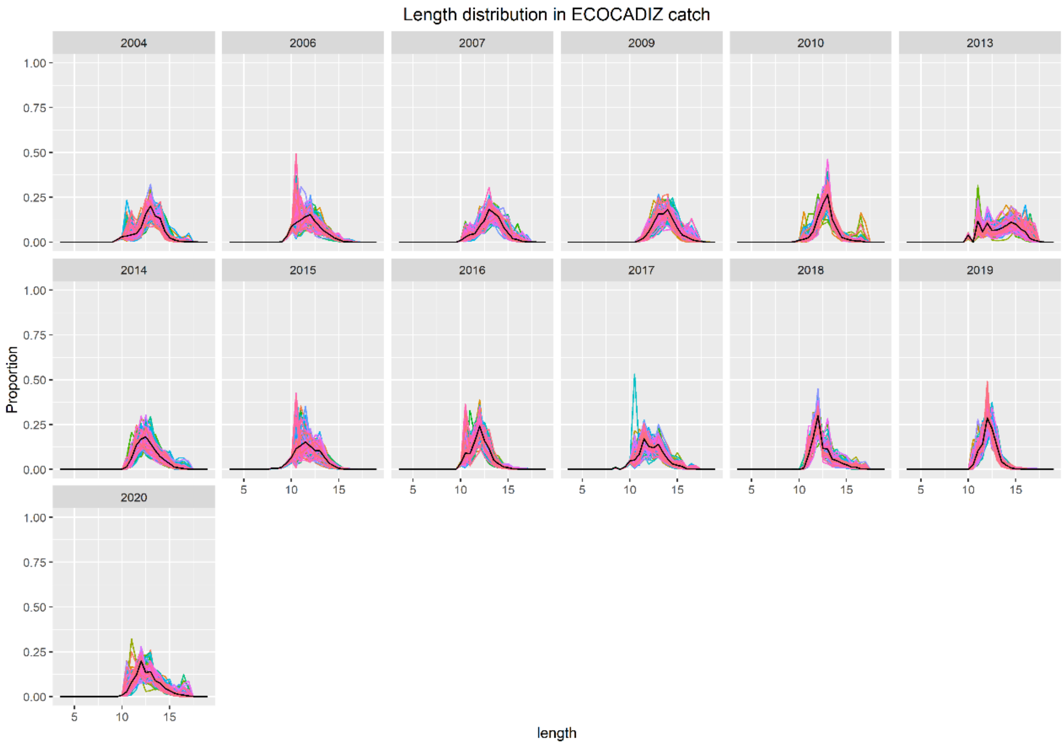

Figure 4.1.4.2.- One hundred parametric bootstrapped length distribution by year in the ECOCADIZ survey index (colored lines) compared to the original ECOCADIZ length distribution (black line).

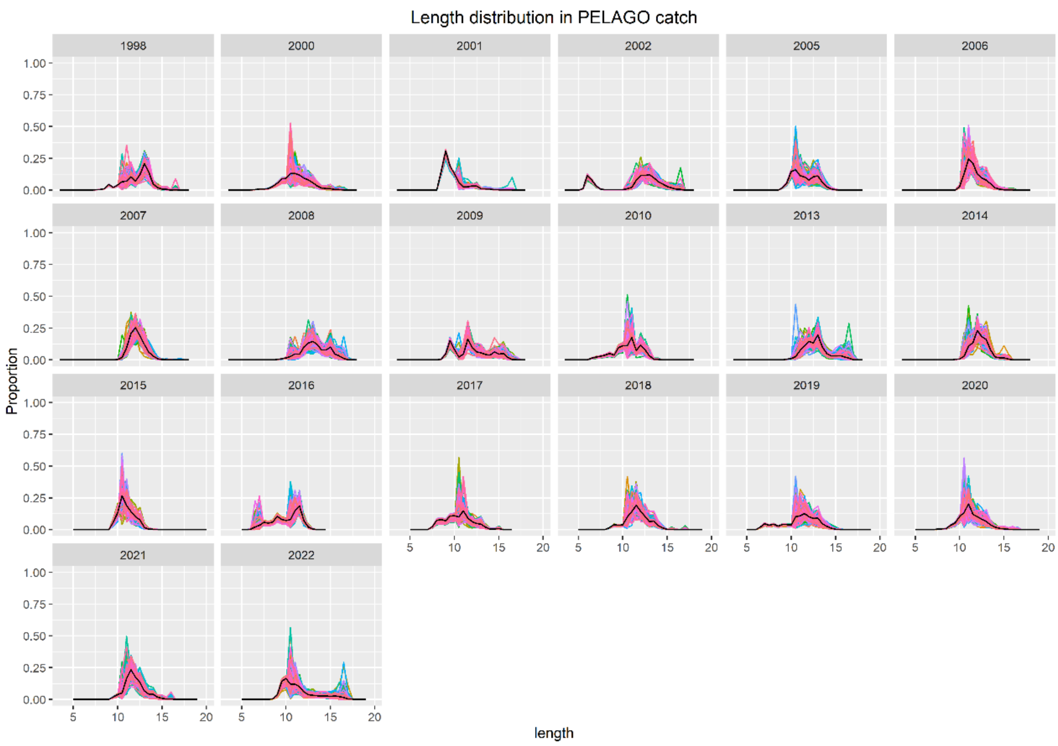

Figure 4.1.4.- One hundred parametric bootstrapped length distribution by year in the PELAGO survey index (colored lines) compared to the original PELAGO length distribution (black line).

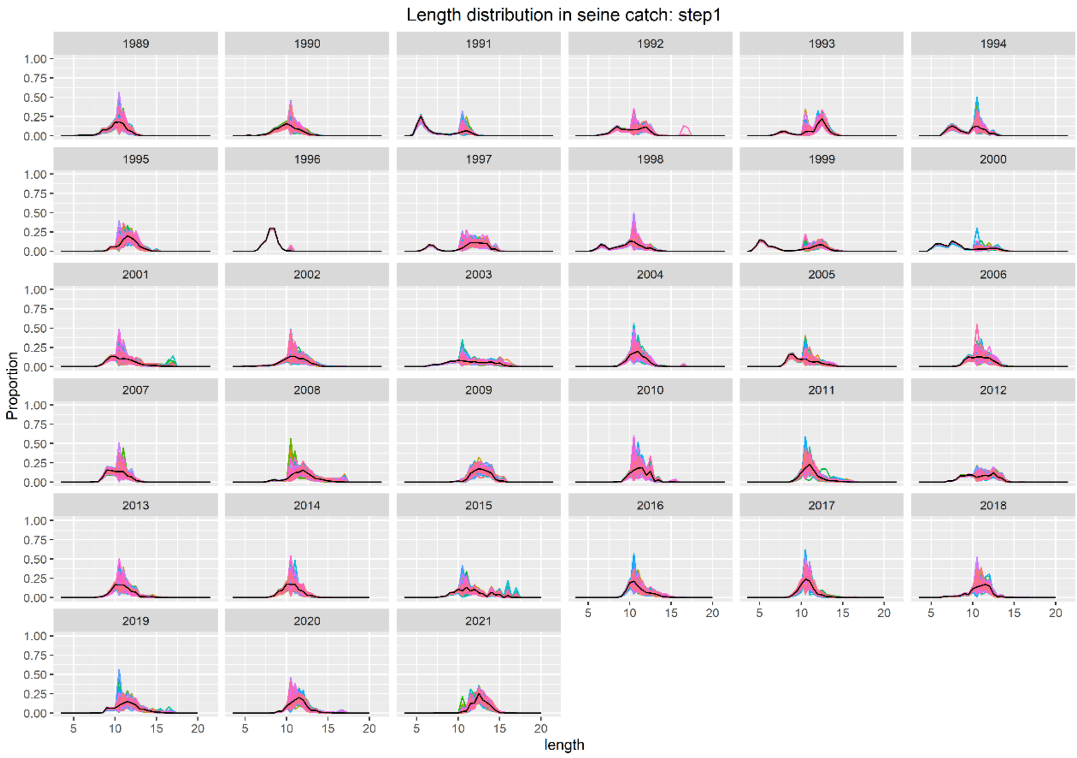

Figure 4.1.5.- One hundred parametric bootstrapped length distribution by year in time step 1 in the seine fleet (colored lines) compared to the original length distribution (black line).

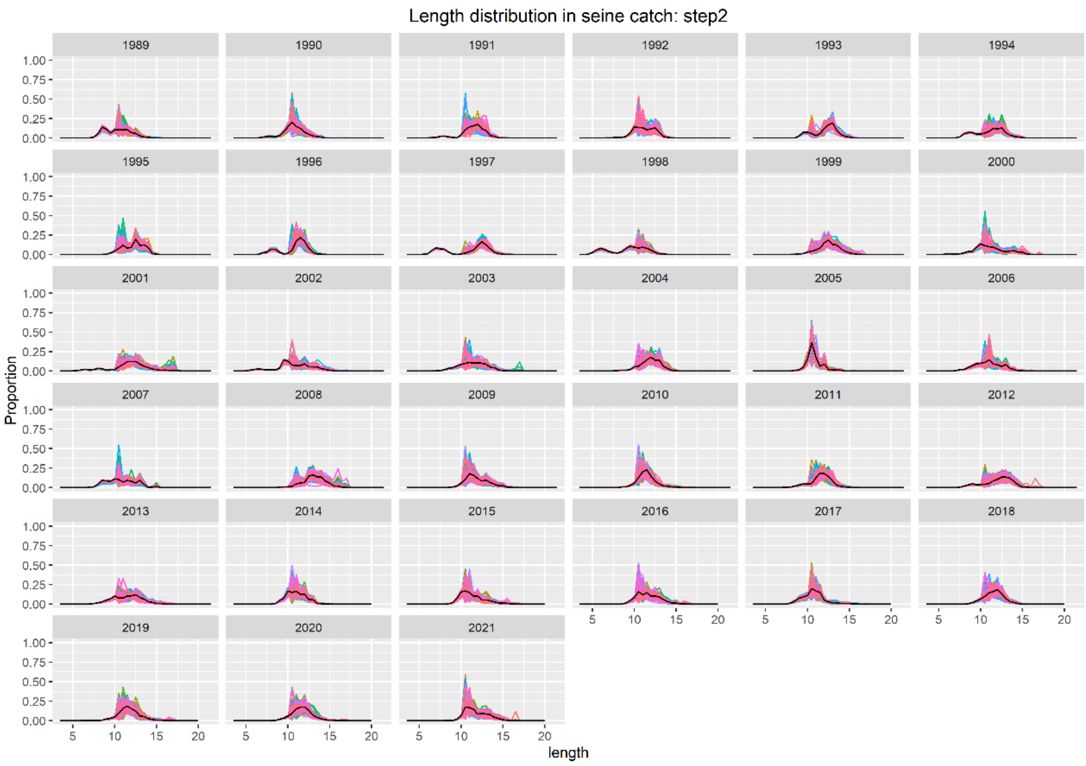

Figure 4.1.6.- One hundred parametric bootstrapped length distribution by year in time step 2 in the seine fleet (colored lines) compared to the original length distribution (black line).

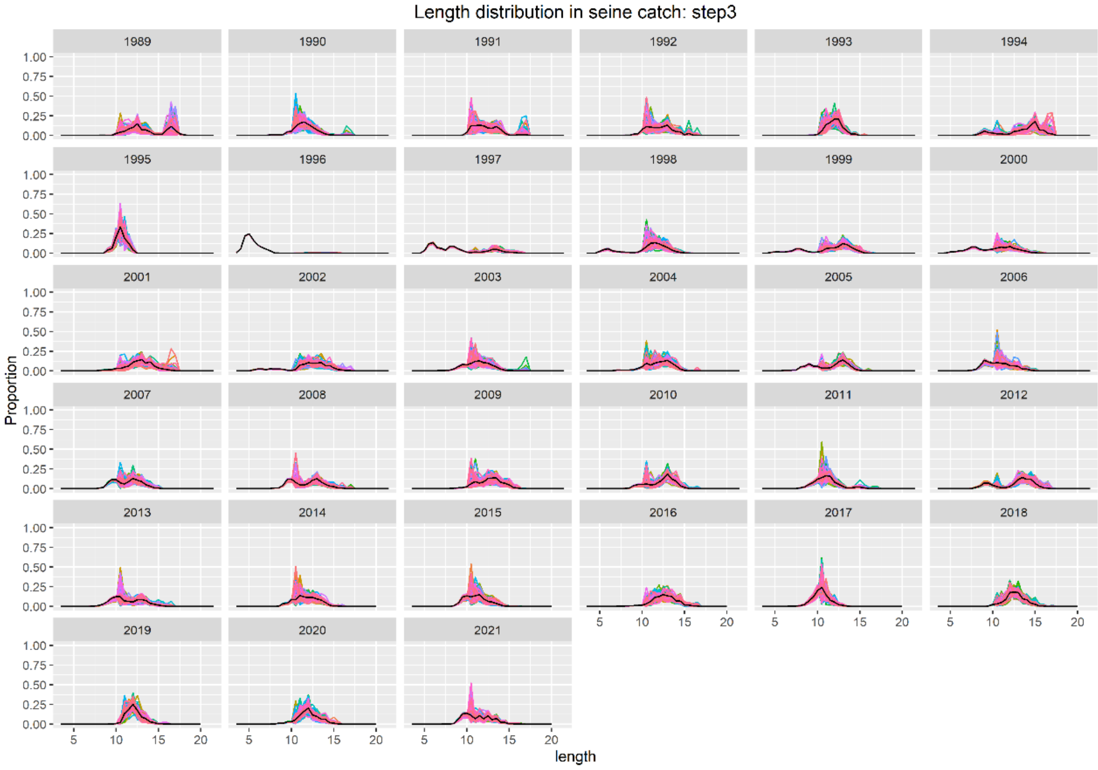

Figure 4.1.7.- One hundred parametric bootstrapped length distribution by year in time step 3 in the seine fleet (colored lines) compared to the original length distribution (black line).

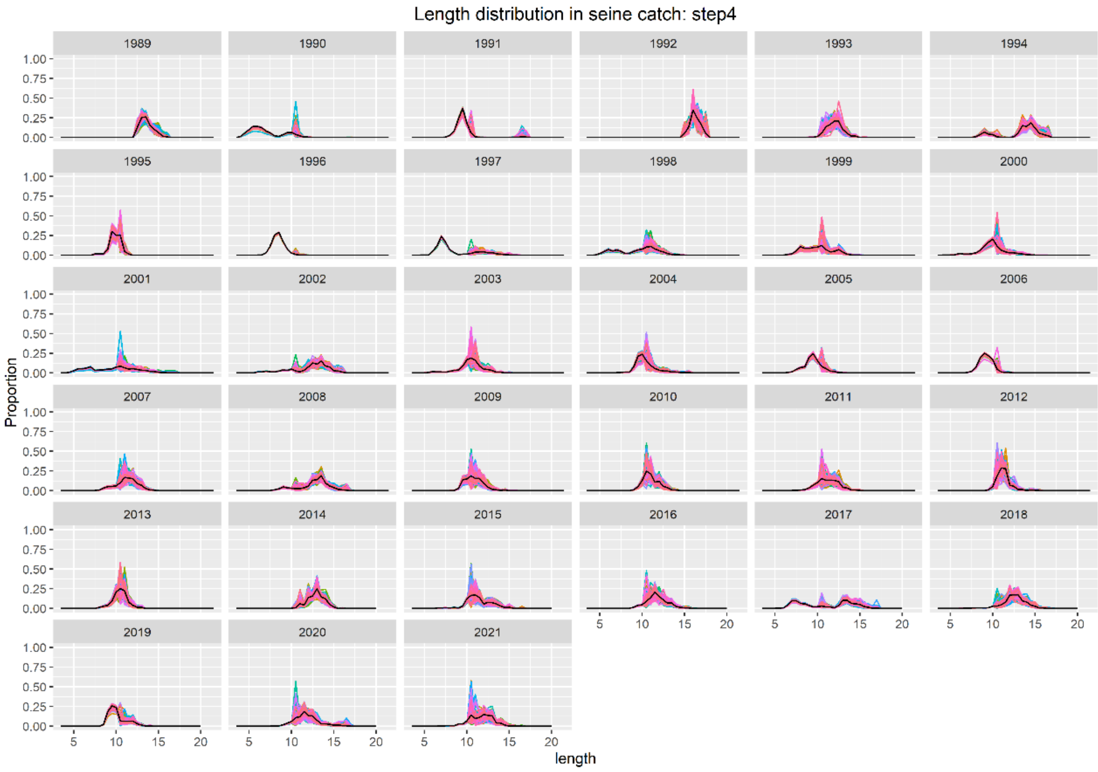

Figure 4.1.8.- One hundred parametric bootstrapped length distribution by year in time step 4 in the seine fleet (colored lines) compared to the original length distribution (black line).

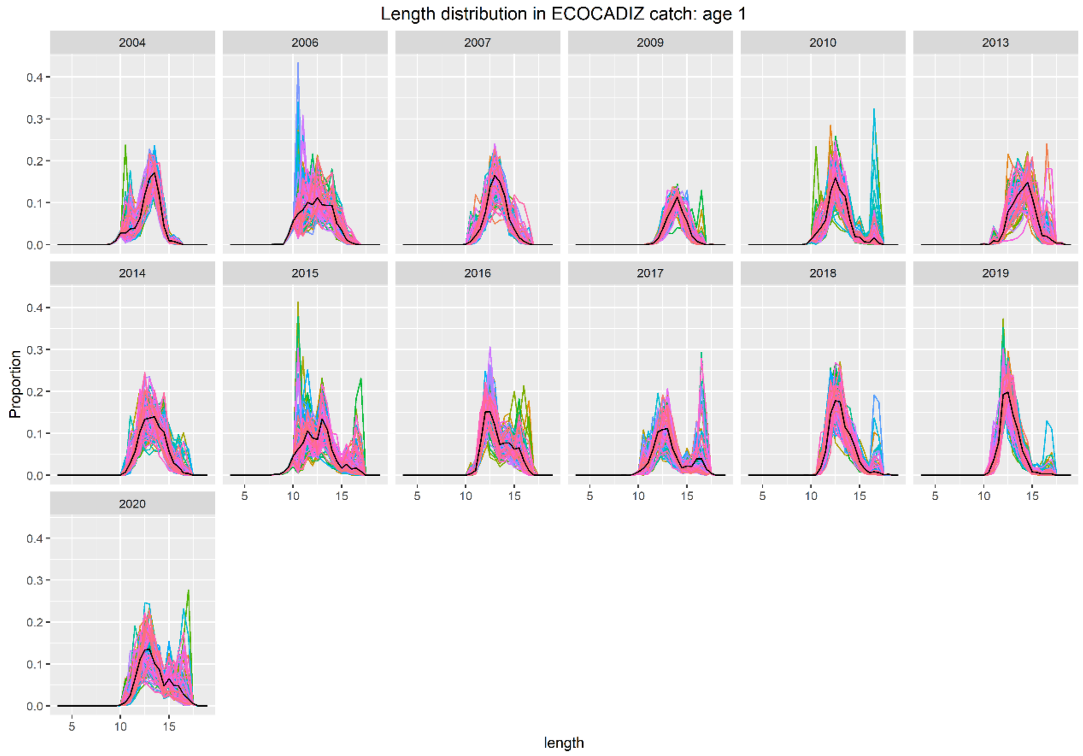

Figure 4.1.9.- One hundred parametric bootstrapped length distribution by year at age 1 in the ECOCADIZ survey (colored lines) compared to the original length distribution (black line).

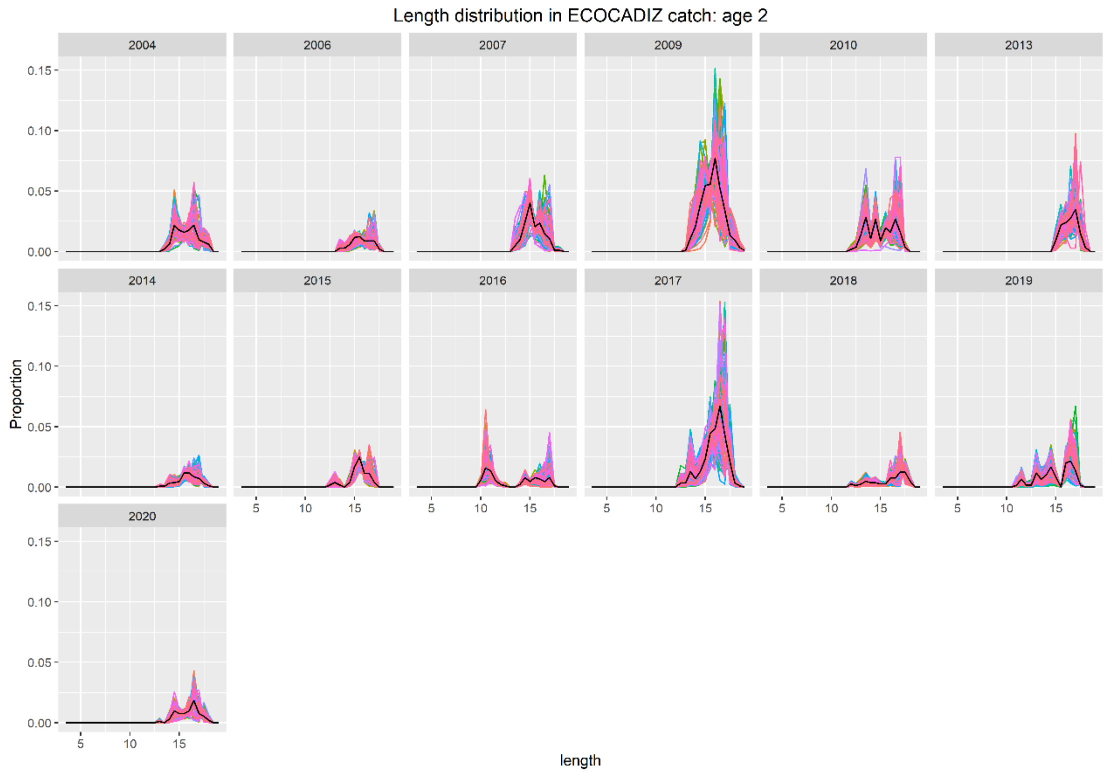

Figure 4.1.10.- One hundred parametric bootstrapped length distribution by year at age 2 in the ECOCADIZ survey (varied colors) compared to the original length distribution.

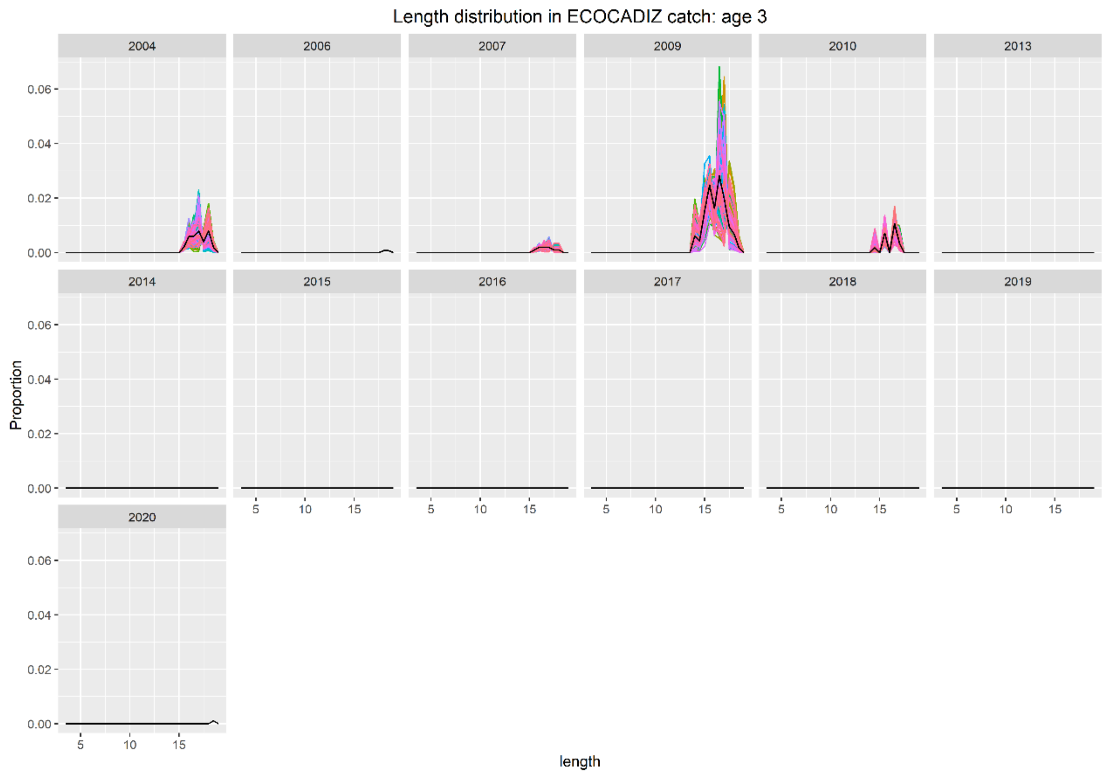

Figure 4.1.11.- One hundred parametric bootstrapped length distribution by year at age 3 in the ECOCADIZ survey (varied colors) compared to the original length distribution.

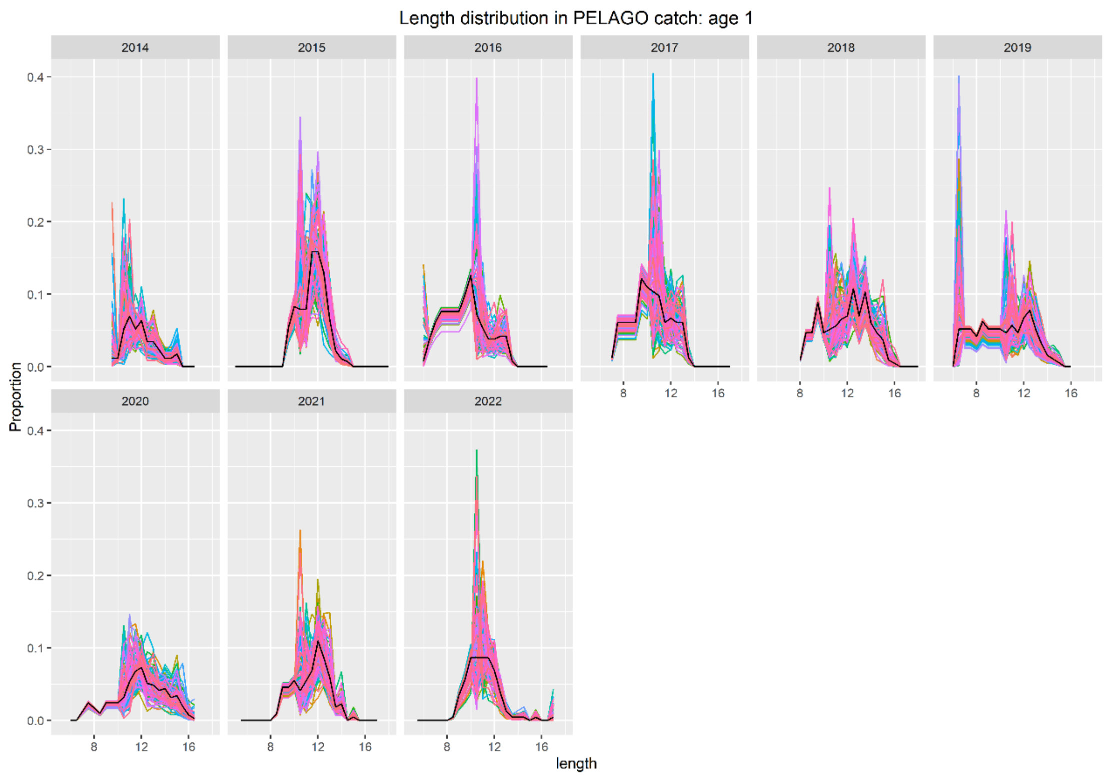

Figure 4.1.12.- One hundred parametric bootstrapped length distribution by year at age 1 in the PELAGO survey (varied colors) compared to the original length distribution.

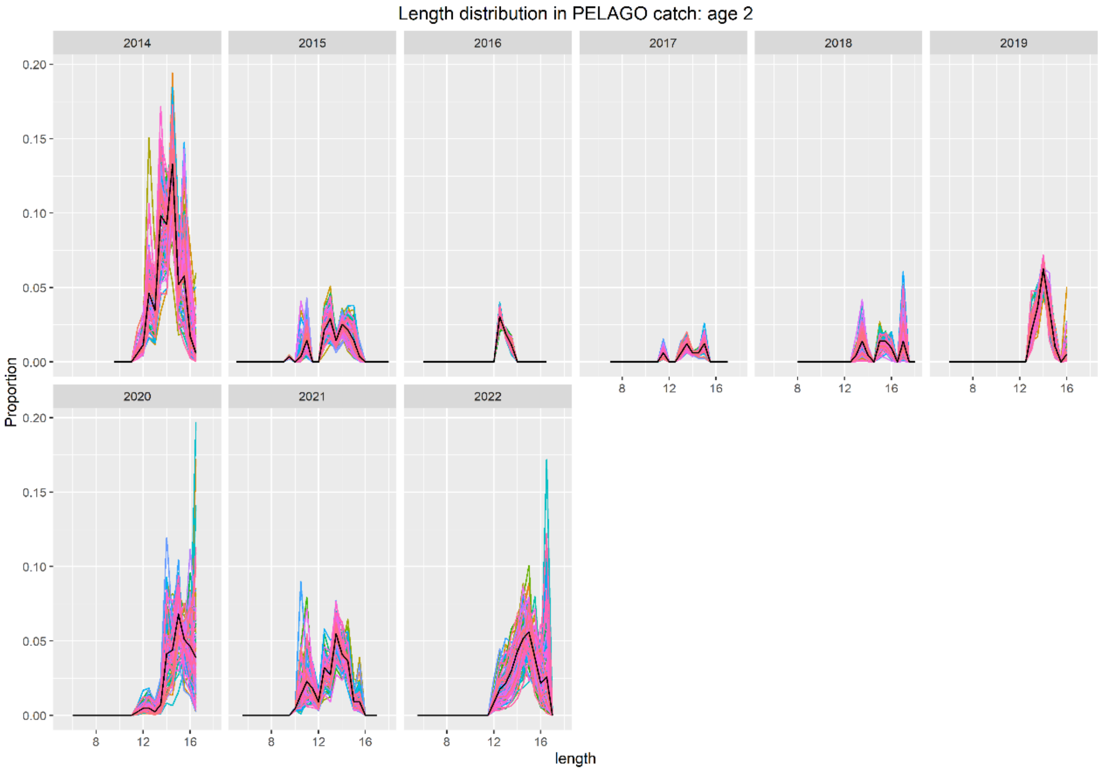

Figure 4.1.14.2.- One hundred parametric bootstrapped length distribution by year at age 2 in the PELAGO survey (varied colors) compared to the original length distribution.

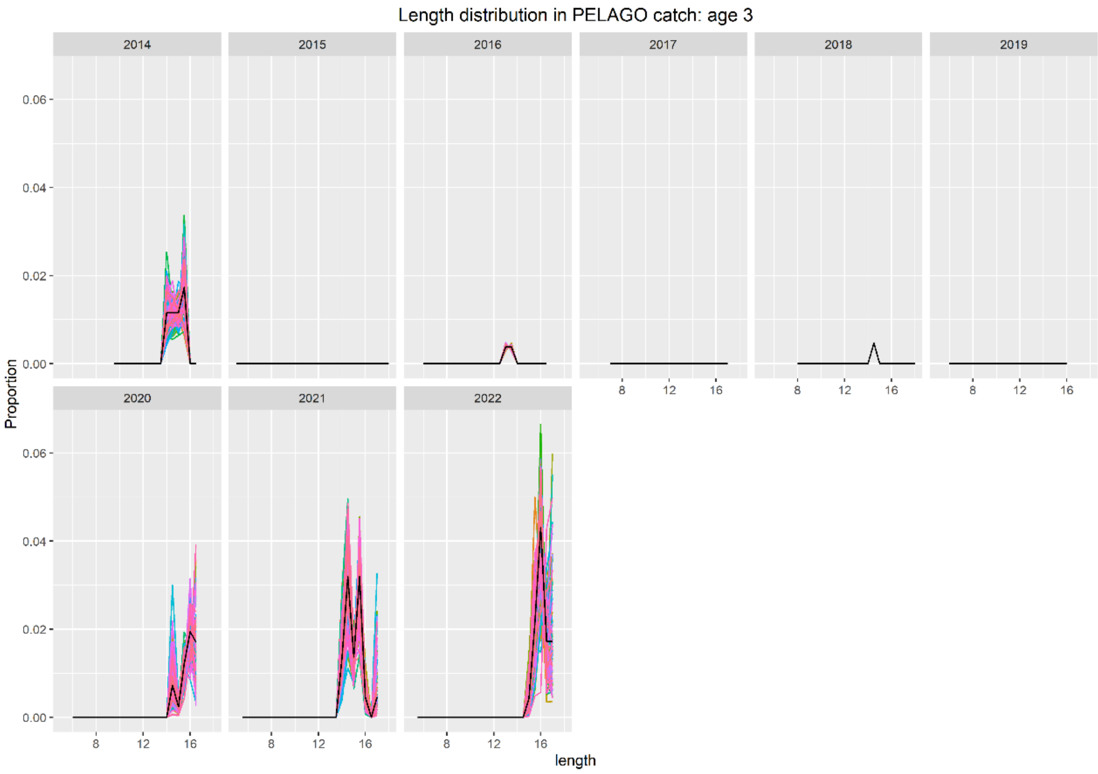

Figure 4.1.14.- One hundred parametric bootstrapped length distribution by year at age 3 in the PELAGO survey (varied colors) compared to the original length distribution.

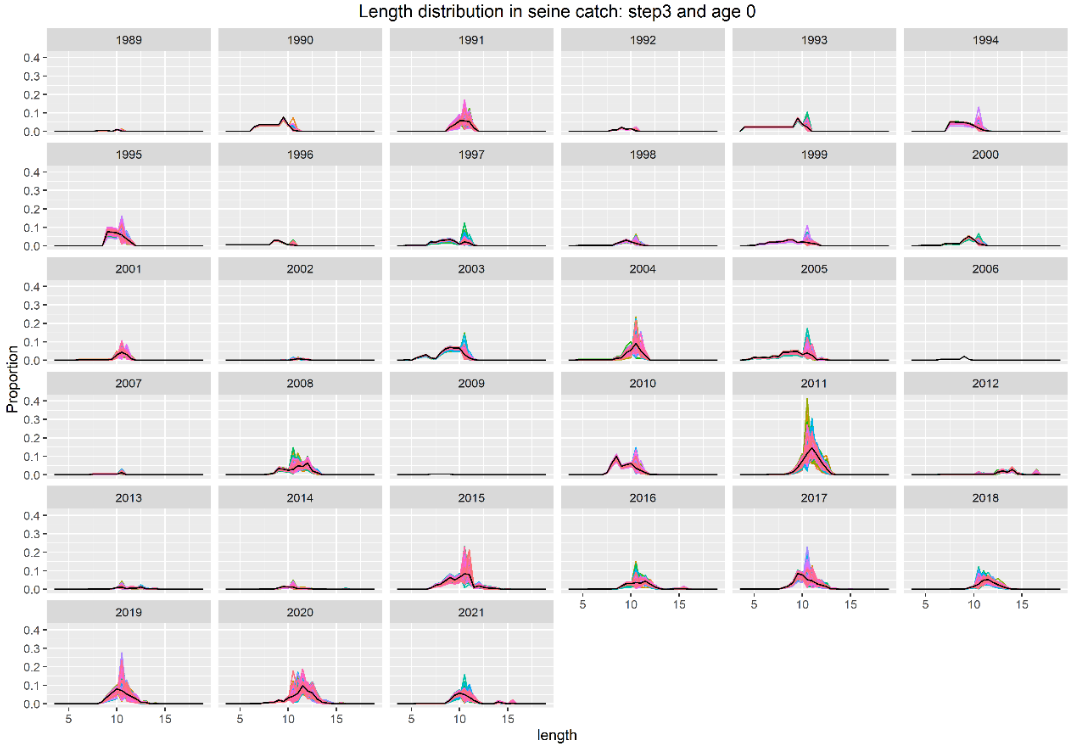

Figure 4.1.15.- One hundred parametric bootstrapped length distribution by year at age 0 and time-step 3 in the seine fleet (varied colors) compared to the original length distribution. In the commercial fleet, age-length distributions were obtained also in time steps 1, 2 and 4. The length distribution at age is presented only in time-step 3 because it has a good coverage for all the ages from 0 to 3 and is representative of what has been resampled in the other time steps.

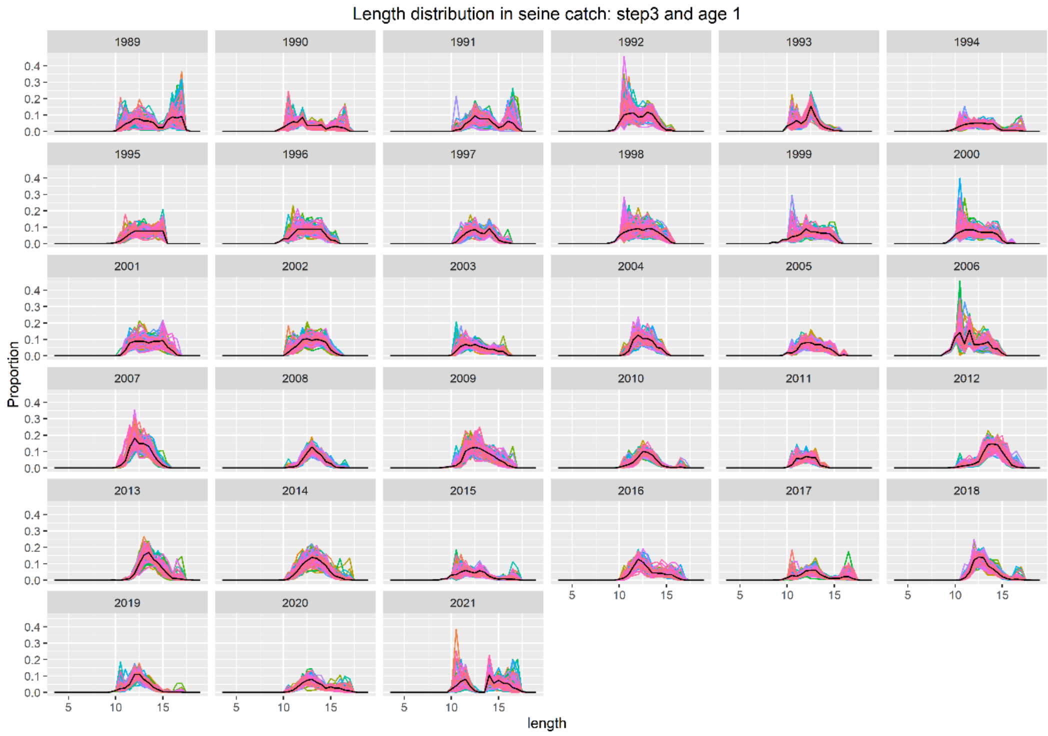

Figure 4.1.16.- One hundred parametric bootstrapped length distribution by year at age 1 and time-step 3 in the seine fleet (varied colors) compared to the original length distribution. In the commercial fleet, age-length distributions were obtained also in time steps 1, 2 and 4. The length distribution at age is presented only in time-step 3 because it has a good coverage for all the ages from 0 to 3 and is representative of what has been resampled in the other time steps.

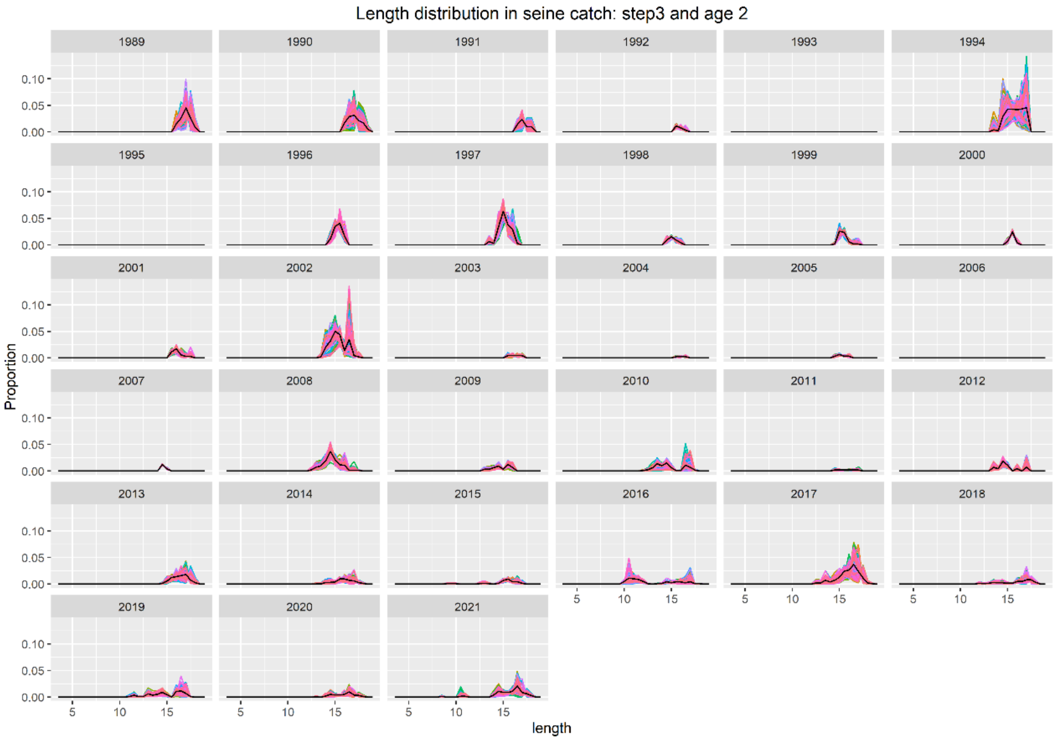

Figure 4.1.17.- One hundred parametric bootstrapped length distribution by year at age 2 and time-step 3 in the seine fleet (varied colors) compared to the original length distribution. In the commercial fleet, age-length distributions were obtained also in time steps 1, 2 and 4. The length distribution at age is presented only in time-step 3 because it has a good coverage for all the ages from 0 to 3 and is representative of what has been resampled in the other time steps.

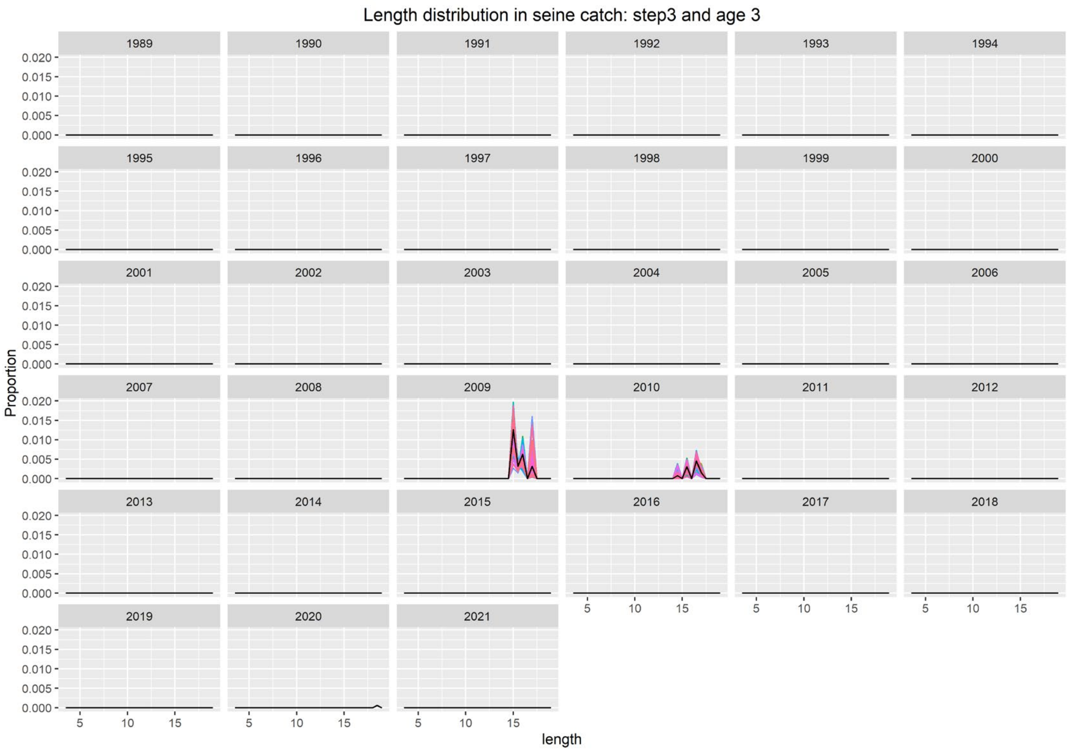

Figure 4.1.18.- One hundred parametric bootstrapped length distribution by year at age 3 and time-step 3 in the seine fleet (varied colors) compared to the original length distribution. In the commercial fleet, age-length distributions were obtained also in time steps 1, 2 and 4. The length distribution at age is presented only in time-step 3 because it has a good coverage for all the ages from 0 to 3 and is representative of what has been resampled in the other time steps.

4.2 Gadget model estimates: bootstrap versus original models

In all the 100 gadget models the optimization stopped when the convergence criteria were met or the accuracy limit for the gradient calculation was reached before the number of function evaluations was reached in any of the three search algorithms used.

The capacity of Gadget to fit the observed data, and simulate with reliability the dynamic of a population, strongly depends on the capacity to model the individual growth in size. For this reason, it is important to release the von Bertalanffy growth parameters, so they are optimized for each of the 100 models fitted to 100 different groups of input data. The variability in length distribution and age-length distribution input data for all the three fleets presented in the previous sections lead to a range of values optimized for L0, K and Linf, which, in combination with the parameters defining the length-weight relationship lead to a wide range of values in the weight at age over time (see figure 4.2.1). Similar to the mean weight at age, the estimated number of individuals by age on the 100 gadget models were also distributed around the numbers at age estimated in the original gadget model (see figure 4.2.2). Likewise, the estimated Spawning Stock Biomass (SSB) in the 100 simulated gadget assessment models followed the trend observed in the original gadget assessment model estimates, with a fairly symmetrical distribution around those SSB values (figure 4.2.3).

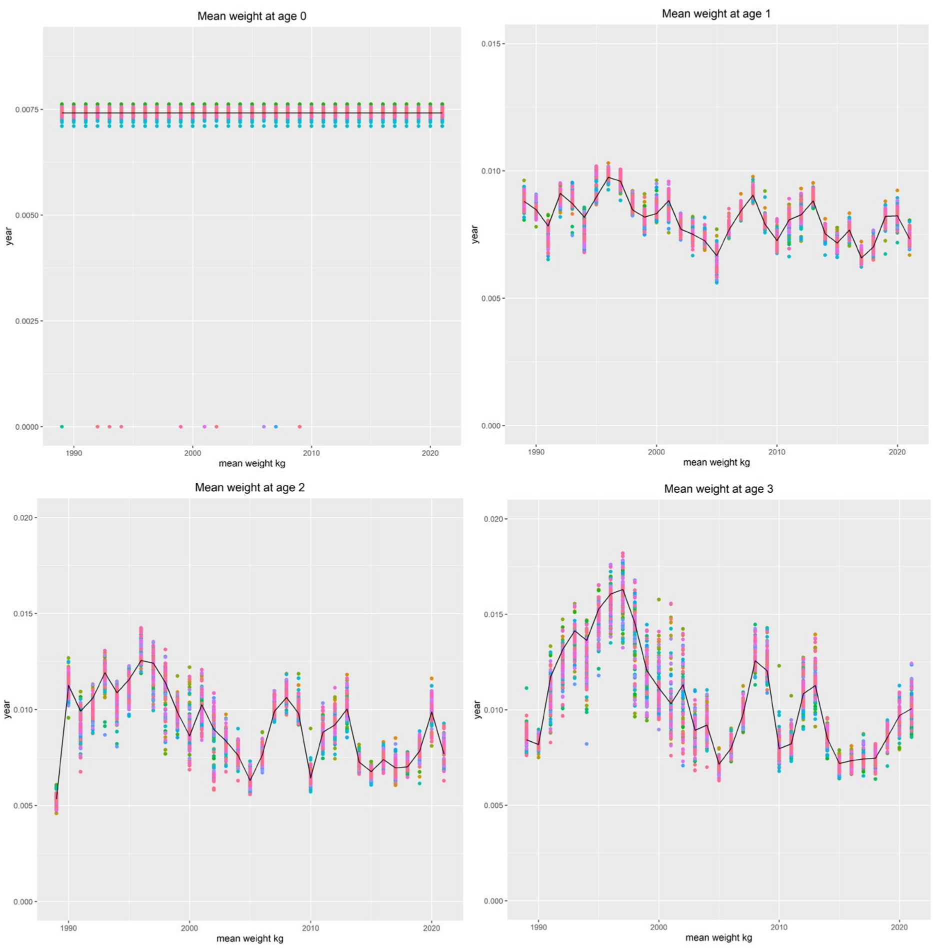

Figure 4.2.1.- Mean weight on each of the 100 gadget models fitted to the parametric bootstrapped data (colored dots) versus mean weight at age in the gadget assessment model presented in ICES-WGHANSA, 2022 (black line).

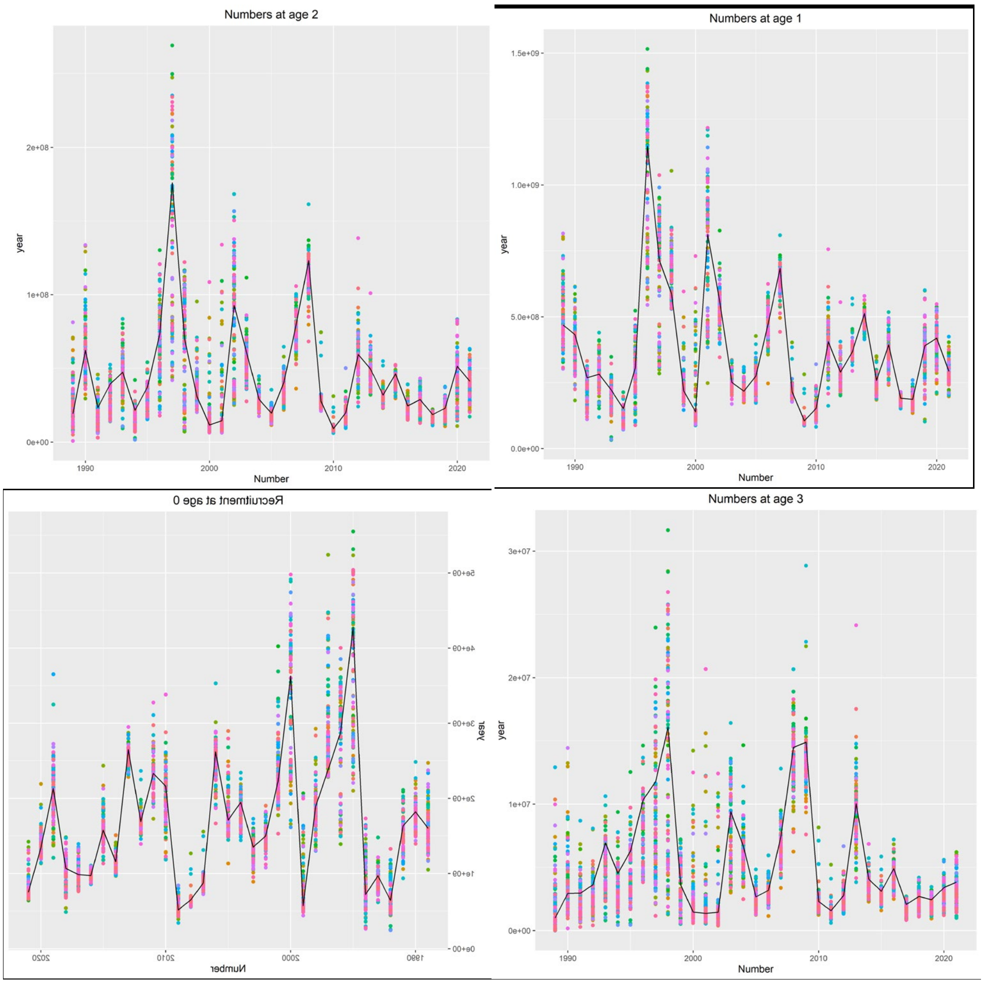

Figure 4.2.2.- Number of individuals by age on each of the 100 gadget models fitted to the parametric bootstrapped data (colored dots) versus the number of individuals at age in the gadget assessment model presented in ICES-WGHANSA, 2022 (black line).

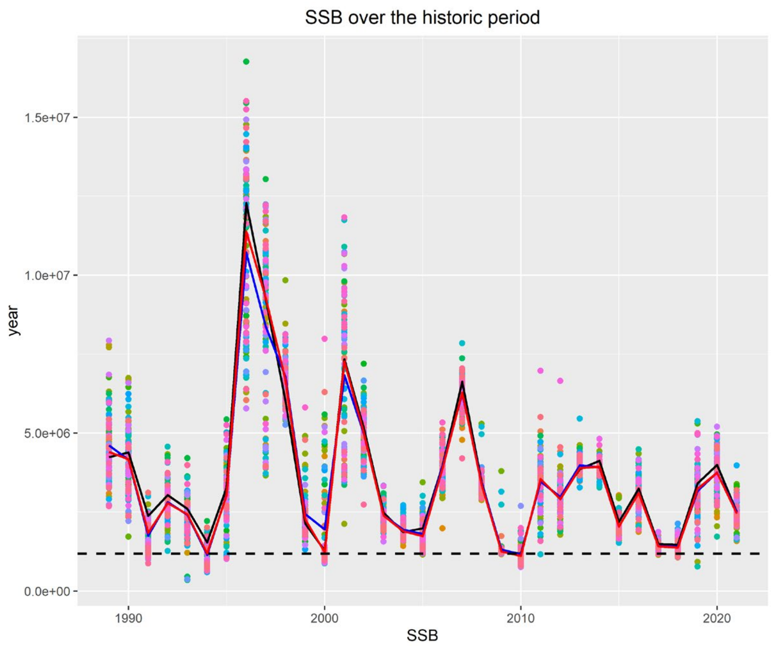

Figure 4.2.3.- Spawning Stock Biomass (SSB) on each of the 100 gadget models fitted to the parametric bootstrapped data (colored dots) versus the SSB estimated in the gadget assessment model presented in ICES-WGHANSA, 2022 (black line). The horizontal dotted black line represents the Blim prosposed during the WGHANSA, 2022 (B_{lim}=B_{loss}=1186.34 tons). The red and blue continued lines represent the median and mean SSB in the 100 gadget models.

4.3 Conditioning the operating model in FLBEIA

The FLBEIA operating model (OM) was formed by 1000 iterations or populations, which will be continued from the start of the historic period to the end of the projection period. The output of each of the 100 fitted gadget models was used to condition the historic period of 10 iterations of the FLBEIA operating model OM. For each of the two semesters simulated in FLBEIA, the information taken from the gadget models was:

- Stock numbers at age
- Catch in numbers at age
- Stock and catch weight at age
- Natural mortality at age
- Proportion of fishing and natural mortality before spawning

In this way, based in the variability obtained with the 100 gadget models, the historic period of the OM was conditioned accounting for the uncertainty on the status of the stock and the biological-fisheries variables affecting its productivity.

The conditioning of the OM in the projection period was conducted following the same approach as in the first group of simulations presented to the reviewers. But, in this second group of simulations, the projection period of each of the 1000 iterations was conditioned based in the historic period of that same iteration.

- The Maturity, fecundity and weight at age: average of the values by age in the last 3 years of the historic period
- Seine fleet catchability at age: average of the catchability at age in the last 5 years of the historic period.

In addition:

- Variability in annual recruitment at age 0 was simulated as result of two elements:

- SSB-Recruitment relation fitted independently on each of the 100 different historic periods (SSB and recruitment at age 0 estimated on each of the 100 gadget models).
- Simulation of random variability around the recruitment defined by the fitted SSB-Recruitment model based on the assumption of a log-normal distribution with mean=0 and standard deviation estimated from the model fit residuals.

The randomization of the residuals led to 1000 different recruitment time series in the projection period.

- The natural mortality at age was re-estimated for each one of the 1000 iterations assuming a linear relation between the change in mean weight at age in the new gadget models ($weight_{age\_bootstrap}$ in the equation below) in relation to the mean weight at age in the original gadget model. ($weight_{age\_original}$ in the equation below) multiplied times the M at age in the historic period.

$$M_{age\_projection} = M_{age\_historic} * (weight_{age\_original}/weight_{age\_bootstrap})$$

4.4 Base case MSE framework

Based in the results from the sensitivity analysis conducted in the first group of simulations, the *MSE* framework used for further comparisons include:

- Biomass safeguard in the *1over2* and *chr HCR*s
- Assessment error with sporadic extreme error values.
- Recruitment defined by a lognormal distribution without limitation to the maximum recruitment.
- Distribution of catches over the year as the mean values in the last 10 years of the historic period.
- *OM* conditioned with input data from the 100 Gadget assessment models fitted to the bootstrapped data, with survey catchability as presented in the ane27.9a_south component 2022 assessment (ICES, WGHANSA 2022).

In addition, three different options have been explored to model the SSB-Recruitment relationship in the OM:

- Segmented regression with breakpoint fixed as Blim=Bloss estimated for each of the 100 gadget models separately.
- Segmented regression with breakpoint fixed as Blim=Bloss estimated in the original gadget assessment model.
- Segmented regression with breakpoint released and optimized separately for each of the 100 gadget models.

The scenarios tested in the management procedure (MP) included the *1over2* and the *chr* HCRs (see table 4.4.1). The range of harvest rates implemented in the chr HCR ranged from 0.2 to 0.6.

Table 4.4.1.- Summary table with the main features of the scenarios tested in the second part of the MSE simulations.

MP	HCR type	Lower unc.cap	Upper unc.cap	Harvest rate
mp0001	ft0	0	0	NA
mp0002	1o2	0.8	0.8	NA
mp0003	chr	0	0	0.2
mp0004	chr	0	0	0.25
mp0005	chr	0	0	0.3
mp0006	chr	0	0	0.35
mp0007	chr	0	0	0.4
mp0008	chr	0	0	0.45
mp0009	chr	0	0	0.5
mp0010	chr	0	0	0.55
mp0011	chr	0	0	0.6

4.5 Sensitivity to uncertainty in biological and fisheries processes in historic and projection periods

The SSB-Recruitment relationship looked different depending on the three options considered to define the breakpoint in the segmented regression models (figure 4.5.1). When Blim was considered as Bloss for each of the 100 gadget models, these values were fixed as the breakpoint in the segmented regressions. In most cases, these breakpoint values were lower than the breakpoint set for the original gadget assessment model (ICES-WGHANSA, 2022; Blim=Bloss=1186.34 tons). When the breakpoint was released and fitted during the optimization of the SSB-Recruitment model, the estimated breakpoints (with the exception of a few models) were around the breakpoint in the segmented regression model fit to the SSB and recruitment data estimated by the original gadget model.

As a first approach, the Blim defined with the original gadget assessment model (ICES-WGHANSA, 2022, Blim=11.86.34 tons) was taken as the reference point to be used in the risk assessment. Despite the differences in the breakpoints, the results were very similar in the three different approaches (figures 4.5.2, 4.5.3 and 4.5.4). In comparison to the base case selected in the first MSE simulation exercise (see Pérez-Rodríguez et al, 2023a in annex 6), orange bars in figures 4.5.2, 4.5.3 and 4.5.4), adding extra uncertainty and variability in biological-fisheries related processes in the historic and projection period led to higher risk for all the harvest rates and temporal frames (short, medium and long). Despite of this, the harvest rate 0.5 was still precautionary in all time frames and scenarios. It is important to note that, following the reviewer's advice, the long term period was shortened from 2041-2050 to 2031-2040. This change resulted in a slightly lower risk of being below Blim in the long term period. Commercial catches were slightly higher in the short term than in the base case selected in the first MSE simulation exercise (see Pérez-Rodríguez et al, 2023a in annex 6), but slightly lower in the medium and long term.

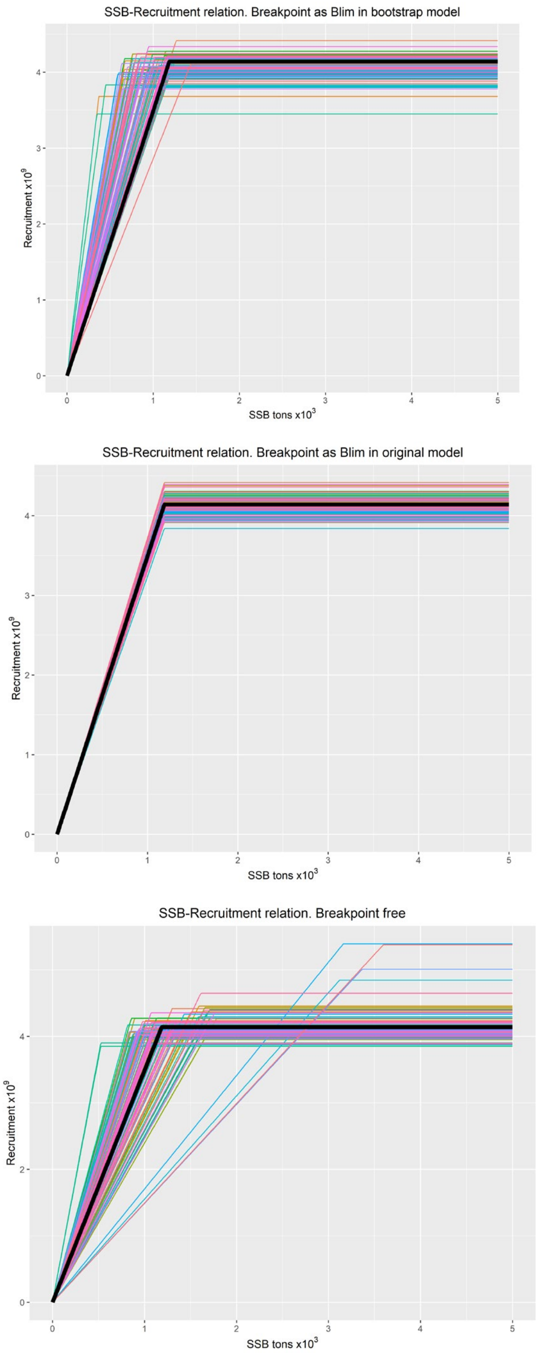

Figure 4.5.1.- Recruitment prediction for a wide range of SSB based on 100 segmented regression models fitted to the SSB-Recruitment estimated by the 100 gadget models. In the upper panel, the breakpoint was assumed equal to the Blim=Bloss separately for each gadget model. In the mid panel, breakpoint=Blim=Bloss in the original gadget model for all the 100 SSB-Recruitment models. In the lower panel, Blim was released and fitted separately for each of the 100 SSB-Recruitment models. In all the three panels, the black line depict the SSB-Recruitment model fitted to the original SSB and recruitment estimates from the gadget assessment model presented in ICES-WGHANSA, 2022.

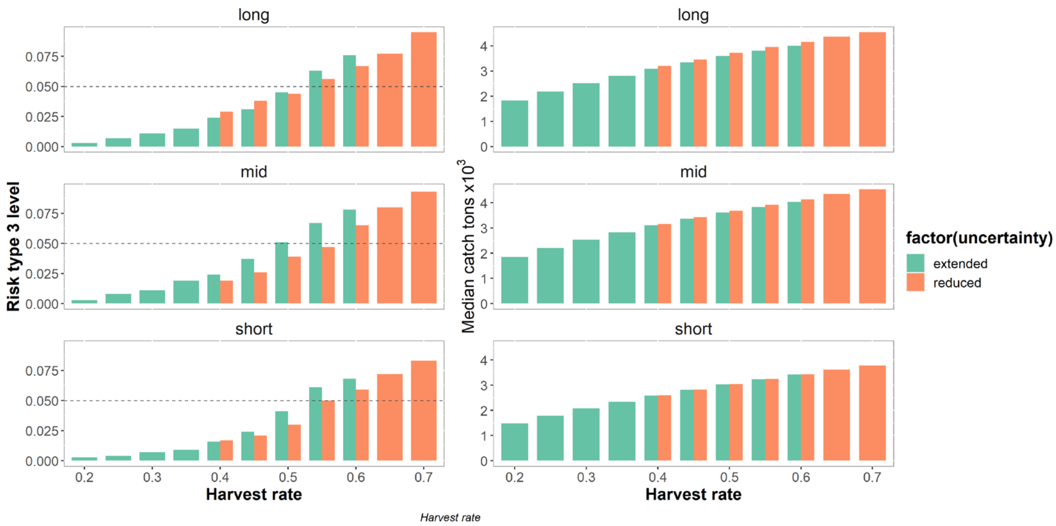

Figure 4.5.2.- Results of the scenario where the breakpoint in the segmented SSB-recruitment regression model is defined as Blim=Bloss separately for each of the 100 gadget models used to condition the OM. Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations presented in the first MSE exercise, where uncertainty was explored exclusively in the recruitment process (called "reduced" in the plot; orange bars) and this second MSE exercise, where uncertainty has been explored in a wide range of biological and fisheries processes affecting the productivity of the stock (called "extended" in the plot; green bars).

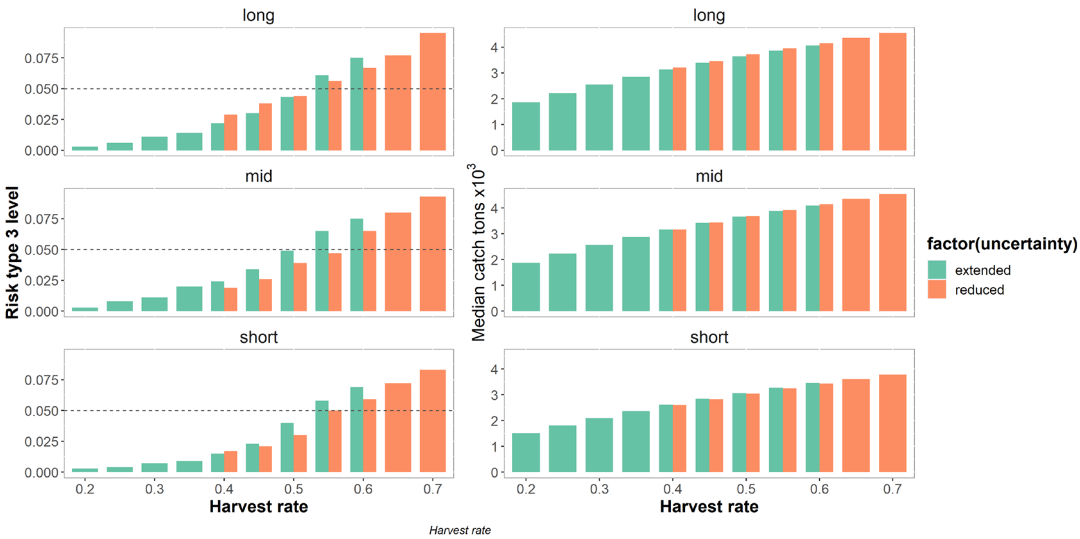

Figure 4.5.3.- Results of the scenario where the breakpoint in the segmented SSB-recruitment regression model is defined as Blim=Bloss in the original gadget assessment model (ICES-WGHANSA, 2022). Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations presented in the first MSE exercise, where uncertainty was explored exclusively in the recruitment process (called "reduced" in the plot; orange bars) and this second MSE exercise, where uncertainty has been explored in a wide range of biological and fisheries processes affecting the productivity of the stock (called "extended" in the plot; green bars).

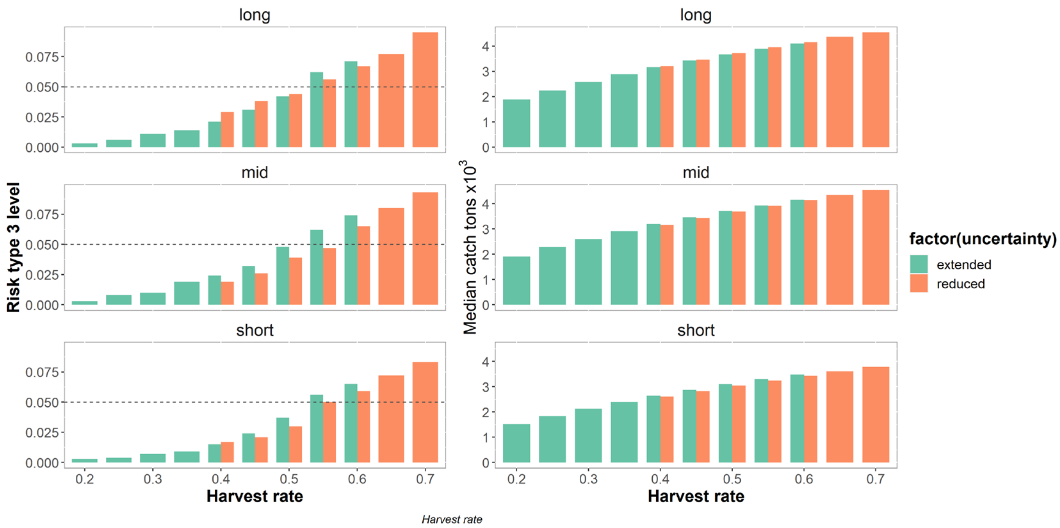

Figure 4.5.4.- Results of the scenario where the breakpoint in the segmented SSB-recruitment regression model is released and optimized separately for each of the 100 gadget models used to condition the OM. Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations presented in the first MSE exercise, where uncertainty was explored exclusively in the recruitment process (called "reduced" in the plot; orange bars) and this second MSE exercise, where uncertainty has been explored in a wide range of biological and fisheries processes affecting the productivity of the stock (called "extended" in the plot; green bars).

If the reference point Blim considered to assess the performance on each of the 1000 iterations was the Bloss on each of those iterations instead of the Blim proposed in ICES-WGHANSA (2022), the risk of falling below Blim was lower. The results were very similar in the three scenarios of SSB-Recruitment relationship tested. For the sake of simplicity results have been presented exclusively in the scenario where the breakpoint in the SSB-Recruitment curve was set as the Blim=Bloss on each of the 1000 iterations (figure 4.2.5.5).

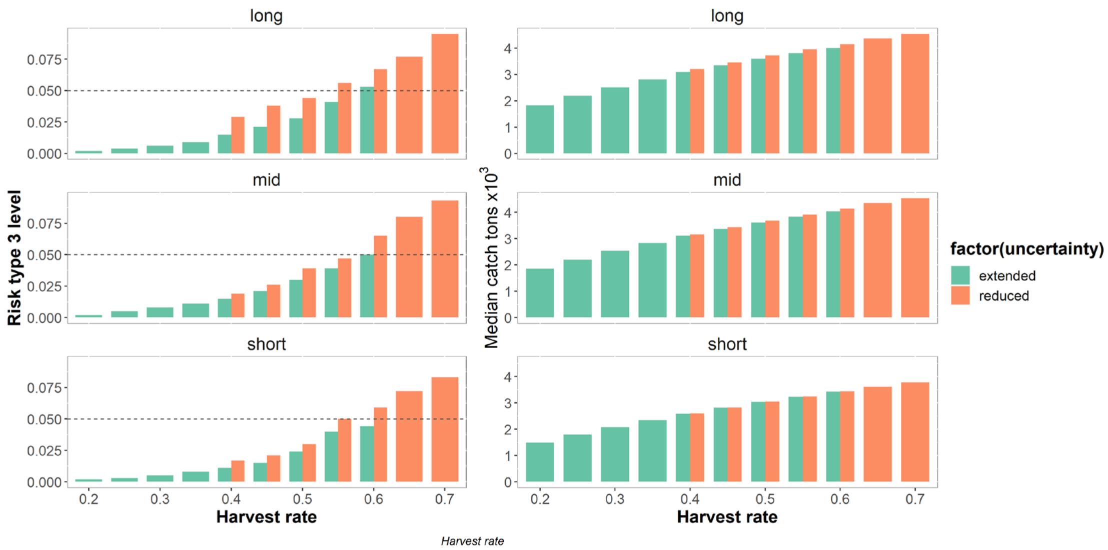

Figure 4.5.5.- Results of the scenario where the breakpoint in the segmented SSB-recruitment regression model is released and optimized separately for each of the 100 gadget models used to condition the OM. Maximum probability of falling below B_{lim} (Risk of type 3, left column) and median commercial catches (in thousand tonnes, right column) when the constant harvest rate (chr) rule is implemented within the MSE with different harvest rates (x-axis). The rows correspond to the temporal scales: the short-term (first 5 projection years), mid-term (from 6th to 10th year in the projection period) and the long-term (last 10 years of the projection period). Colour bars refer to simulations presented in the first MSE exercise, where uncertainty was explored exclusively in the recruitment process (called "reduced" in the plot; orange bars) and this second MSE exercise, where uncertainty has been explored in a wide range of biological and fisheries processes affecting the productivity of the stock (called "extended" in the plot; green bars). In this case, the Blim used as reference point was taken as Bloss separately for each of the 1000 iterations.

Based on these results it was decided to use as reference point the Blim=Bloss=1186.34 tons, presented in the ICES-WGHANSA, 2022, since this approach render results that lead to more precautionary decisions in terms of proposing a candidate $HR_{MSYproxy}$.

4.6 Rules comparison

Based in the results from the sensitivity analysis conducted in the previous sections (summarized in Figure 5.8.1), the *MSE* framework used for further comparisons include:

1. *OM* conditioned in the historic period with input data from 100 Gadget assessment models with survey catchability as presented in the ane27.9a_south component 2022 assessment (ICES, WGHANSA 2022).
2. Recruitment defined by a segmented regression, with breakpoint as Blim=Bloss on each of the SSB time series estimated by the 100 gadget models.
3. Uncertainty in recruitment simulated as a random process assuming a lognormal distribution in the residuals and without limitation to the maximum recruitment.
4. Variability in mean weight at age, natural mortality, catchability at age.
5. Assessment error with sporadic high error values.
6. Distribution of catches over the year as the mean values in the last 10 years of the historic period.
7. Biomass safeguard in the *1over2* and *chr HCRs*

Based in the results from previous sections it was considered that running simulations for scenarios with a range of *HRs* in the *chr* between 0.2 and 0.6 was enough to compare the performance of the *1over2* and *chr* HCRs in terms of annual median catch and risk of falling below B_{lim}.

In the short term, the results show that the *1over2* HCR produced lower median annual catch than the *chr* when the HR was lower than 0.4 (Figure 4.6.1), while the risk of falling below B_{lim} was higher than 0.05 in the *1over2* rule (0.071). In the mid and long term, the Risk type 3 was below 0.05 in the 1over2. Regarding the *chr*, a wide range of *HRs* produced higher catch than the *1over2* rule in all the three time intervals, while being always below B_{lim}. The maximum value of *HR* that stayed below the 0.05 probability of falling below B_{lim} was *HR*=0.5 (in the long term scenario the probability was only slightly above 0.05 (risk=0.051)). The *chr* with *HR*=0.5 was selected for further comparisons with the *1over2* rule.

The analysis of the performance statistics for the *1over2* rule over the period 1989-2040 shows a decreasing trend over the projection period in commercial catches, which, given a stable median recruitment, resulted in an increasing trend in the *SSB* over time (Figure 4.6.2). By contrast, the *chr* with *HR*=0.5 showed a stable pattern in all the performance statistics, with little variation over time in the median values. The median annual commercial catch in the *chr* was always above the values for the *1over2* rule (Figure 4.6.2), and the differences became more clear from short to mid and long term periods (see also Table 4.6.1). According to these results, the *1over2* rule seems to infra-utilize the fishing opportunities in comparison to the *chr* rule with *HR*=0.5. This conclusion is in agreement with results obtained in previous studies for the Bay of Biscay anchovy (Sanchez-Maroño, 2019).

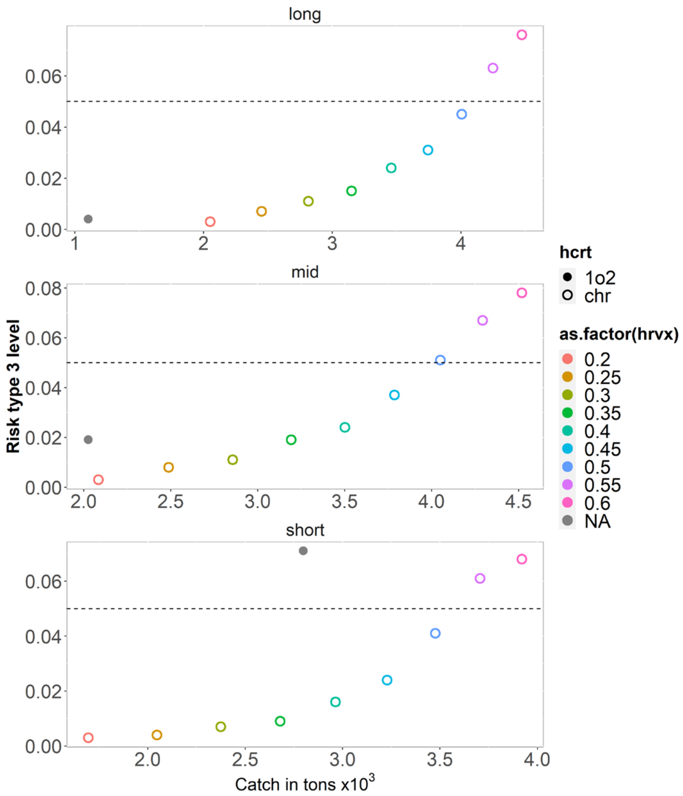

Figure 4.6.1.- Biological risk as Risk4.2.B_{lim}: (maximum probability of falling below B_{lim}, y-axis) versus yield (catches in tonnes, x-axis) for the 1over2 advice rule (full circle) and the constant harvest rate rule (open circle) with different harvest rates (colours). The rows correspond to the temporal scales: the short-term (first 5 projection years), medium-term (next 5 projection years) and the long-term (last 10 years of the projection years). Black dashed line corresponds to the 0.05 risk.

Table 4.6.1.- Summary of performance statistics for the two advice rule types tested in the short (first five years), medium (next five years) and long (last ten years) period. Reported statistics: SSB and Catch in thousand tonnes, Risk.3.B_{lim}: maximum probability of falling below B_{lim} in percentage.

Variable	Time interval	*1-over-2*	*chr* HR=0.5
Risk type 3	Short	7.1	4.1
	Mid	1.9	5.1
	long	0.4	4.5
SSB	Short	4.79	4.37
	Mid	6.46	4.95
	long	7.16	4.87
Catches	Short	2.44	4.2.04
	Mid	1.59	4.2.62
	long	0.75	4.2.59
F	Short	0.44	0.5
	Mid	0.25	0.55
	long	0.12	0.54

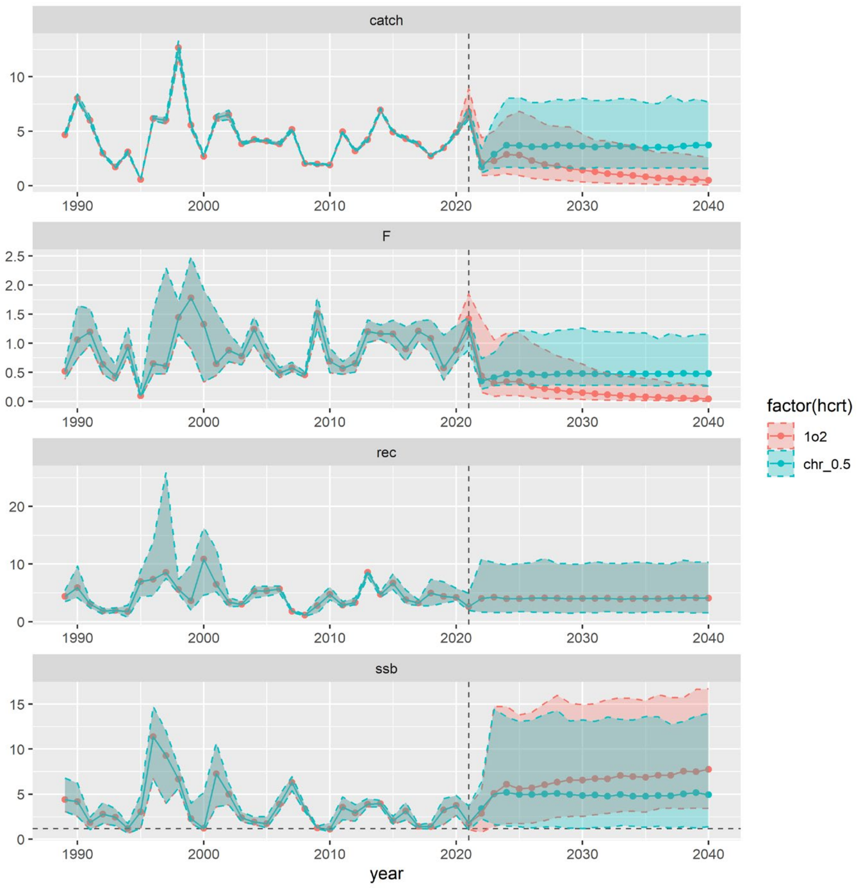

Figure 4. 6.2.- Comparison of performance statistic for advice rules 1-over-2 and chr HR=0.5. Recruitment (rec x10^9 individuals), biomass of fish age 1 and older (ssb, thousand tonnes), fishing mortality (F, year-1) and catch (thousand tonnes) for the historical period and the projected period. Shaded area represents 90% confidence intervals. Horizontal dashed line in SSB show B_{lim}. Vertical long dashed lines separate the historical from the projected period.

5 Performance statistics and biology-fisheries variables along the historic and projection periods

This section covers one of the reviewer´s recommendations, which was producing plots that shows values over time (covering the historic and projection periods) for the most important variables determining the productivity (like weight at age, natural mortality at age, recruitment, catchability, etc), but also the performance indicators (SSB, catch in kg, harvest rate). The outputs of the simulation with HR=0.5 were used to produce the figures that are shown in this section.

As it was explained in the methods section, the mean weight at age in the projection period was taken as the mean value in the last three years of the historic period, which, in turn was very similar to the mean weight at age in the entire historic period (figure 5.1). The natural mortality at age was not variable during the historic period (it was fixed in the gadget assessment model). However, based in the range of values in the weight at age (over 20% change in weight between maximum and minimum weight), the natural mortality was re-estimated as described in the methods section, showing also a wide variation (see figure 5.2).
Despite the wide range of recruitment that was simulated in the 1000 iterations in the projection period (figure 5.3), the average recruitment was the same in the historic and projection periods. The reason is that, with a HR=0.5, the SSB seldom goes below Blim, as showed in the previous section. Since Blim is the breakpoint in the SSB-Recruitment, most of the years in the simulation the average recruitment had the same distribution (the same as long as the SSB is above Blim).

Figure 5.1.- Weight at age in Kg over the historic and projection period (divided by the vertical dotted line). The horizontal dotted line shows the average value over the historic and projection periods. The coloured dots represent annual values in the 1000 iterations of the Operating Model (OM).

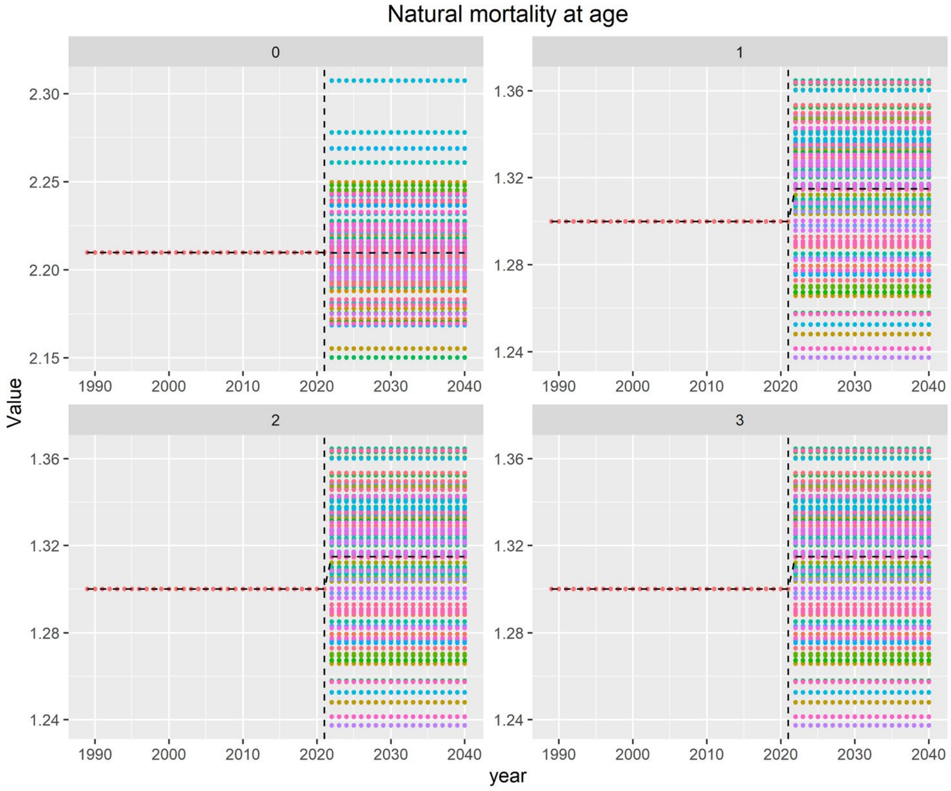

Figure 5.2.- Natural mortality at age over the historic and projection period (divided by the vertical dotted line). The horizontal dotted line shows the average value over the historic and projection periods. The coloured dots represent annual values in the 1000 iterations of the Operating Model (OM).

Figure 5.3.- Recruitment at age 0 over the historic and projection period (divided by the vertical dotted line). The horizontal dotted line shows the average value over the historic and projection periods. The coloured dots represent annual values in the 1000 iterations of the Operating Model (OM).

When a harvest rate of 0.5 was applied, the in-year harvest rate (harvest rate result of catches from June in year *y* to July in year *y+1*), was much higher during the historic period than during the projection period (Figure 5.4). It is important to note that the resulting harvest rate is higher than 0.5 because the average assessment error is 1.313 (i.e. 31.3% overestimation of SSB on average). This assessment error will lead to a higher harvest rate than intended (around 30% higher).

A lower harvest rate in the projection period while recruitment, weight and mortality at age stays similar, results in a higher SSB. The higher SSB partially compensates the lower harvest rate, but still, the average annual catch during the projection period is lower than during the historic period.

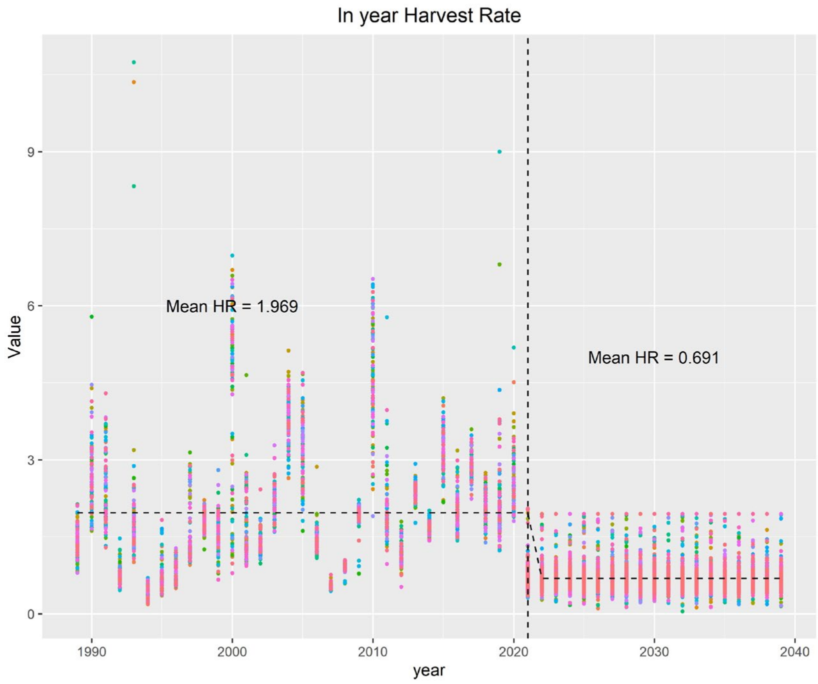

Figure 5.4.- Harvest rate over the historic and projection period (divided by the vertical dotted line). The horizontal dotted line shows the average value over the historic and projection periods. The coloured dots represent annual values in the 1000 iterations of the Operating Model (OM).

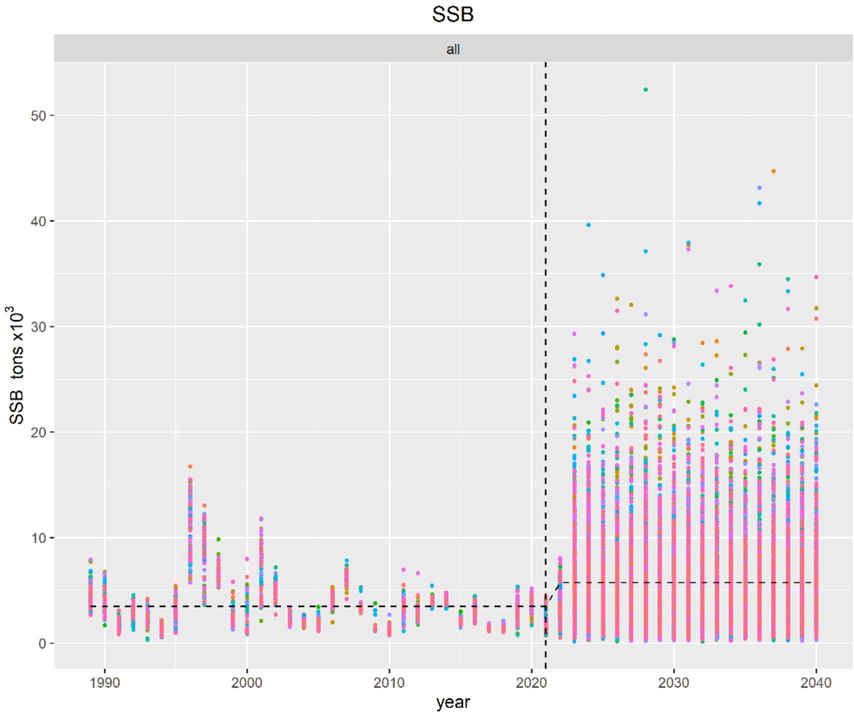

Figure 5.5.- Spawning Stock Biomass (SSB) over the historic and projection period (divided by the vertical dotted line). The horizontal dotted line shows the average value over the historic and projection periods. The coloured dots represent annual values in the 1000 iterations of the Operating Model (OM).

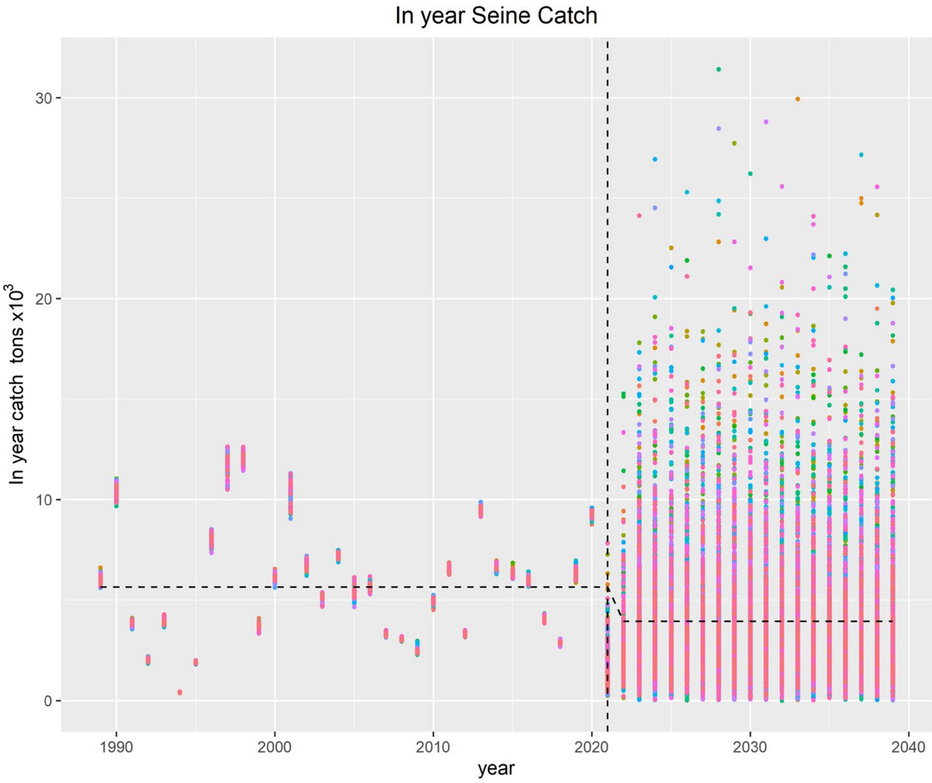

Figure 5.5.- Commercial catches over the historic and projection period (divided by the vertical dotted line). The horizontal dotted line shows the average value over the historic and projection periods. The coloured dots represent annual values in the 1000 iterations of the Operating Model (OM).

6 Conclusions

- Based in the extra sensitivity analysis conducted in the second part of the MSE exercise, the final settings for the MSE framework should include:
    - *OM* conditioned in the historic period with input data from 100 Gadget assessment models with survey catchability as presented in the ane27.9a_south component 2022 assessment (ICES, WGHANSA 2022).
    - Recruitment defined by a segmented regression, with breakpoint as Blim=Bloss on each of the SSB time series estimated by the 100 gadget models.
    - Uncertainty in recruitment simulated as a random process assuming a lognormal distribution in the residuals and without limitation to the maximum recruitment.
    - Variability in mean weight at age, natural mortality, catchability at age.
    - Assessment error with sporadic high error values.
    - Distribution of catches over the year as the mean values in the last 10 years of the historic period.
    - Biomass safeguard in the *1over2* and *chr HCR*s

- The maximum precautionary HR in a chr was 0.5.
- When compared to the 1-over-2 rule, the chr with a HR=0.5 produces higher yield while being precautionary.
- HR=0.5 applied to the estimated SSB (by the Gadget assessment model) could be proposed as the $HR_{MSYproxy}$ for the 27.9a_south anchovy. In addition, a biomass safeguard with Itrigger = 1194.132 tones should be applied

7 References

ICES. 2022. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 4:51. 518 pp. http://doi.org/10.17895/ices.pub.19982720

8 Acknowledgments

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