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), sardine in Cantabrian Sea and Atlantic Iberian waters (pil.27.8c9a) and jack mackerel in Subdivision 10.a.2 (Azores grounds) (jaa.27.10a2) was assessed in the November meeting.

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 2022 has been estimated as the third highest of the historical series. Recruitment (age 1 biomass at the beginning of the year) in 2023 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. For the western component, the index ratio (1-over-2 rule) based on the PELACUS and PELAGO surveys shows an 83% increase of the stock in 2022 compared with the mean of the two previous years, and the 80% uncertainty cap is applied. For the southern component, the relative SSB from an analytical assessment conducted with GADGET is used as the index of stock size development. The index ratio (1-over-2 rule) indicates that the relative SSB in 2022 is 71% lower than in the two previous years. Given that in 2022 the stock component size is below B_{lim}, a biomass safeguard has been considered.

In the last years **sardine in the Bay of Biscay** (pil.27.8abd) shows a decreasing trend in SSB. In 2022 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. Due to technical reasons, this year the coverage of the survey was incomplete and an estimate of the biomass in the total area was obtained by raising the estimate from the area covered in 2022 to the total area based on historical proportions. The index ratio indicates an increase of 20% in 2022 compared with the two previous years.

The biomass (age 1+) of **sardine in Atlantic Iberian waters** (pil.27.8c9a) in 2022 is estimated to be above MSY $B_{trigger}$, B_{pa} and B_{lim} for the third consecutive year. Fishing mortality in 2021 is slightly above F_{MSY} but is among the lowest of the time-series. ICES advice is based on the ICES MSY advice rule. However, the catch options explored for 2023 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 2022. In 2022 SSB is estimated at 1 155 488 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. Since 2018, recruitment is considered very uncertain due to the lack of the survey index in 2019 and 2020.

The **jack mackerel in Subdivision 10.a.2 (Azores grounds)** (jaa.10.a2) is classified in category 5 and advice is provided biannually. The stock and exploitation status relative to MSY and precautionary approach (PA) reference points cannot be assessed. Given that there is no ancillary

information clearly indicating that the current level of exploitation is appropriate for the stock, the 20% precautionary buffer was applied to provide advice for 2023 and 2024.

ii Expert group information

Expert group name	Working Group on Southern Horse Mackerel Anchovy and Sardine (WGHANSA)
Expert group cycle	Annual
Year cycle started	2022
Reporting year in cycle	1/1
Chair	Leire Ibaibarriaga, Spain
Meeting venues and dates	23–27 May 2022, Online meeting (14 participants)
	21–25 November 2022, Lisbon (19 participants)

1 Introduction

1.1 Terms of reference

2021/2/FRSG14 The Working Group on Southern Horse Mackerel Anchovy and Sardine (WGHANSA), chaired by Leire Ibaibarriaga, Spain, will meet by correspondence **23–27 May 2022** (WGHANSA1) and in Lisbon (if COVID-19 allows, otherwise online), on 21–25 November 2022 (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, ane.27.8 and jaa.27.10a2 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 to the meeting must be available to the group on the dates specified in the 2022 ICES data call.

WGHANSA1 will report by 30 May 2022 and WGHANSA2 will report by 2 December 2022 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 where available;

b) For the aim of providing input for the Fisheries Overviews, consider and comment on the following for the fisheries relevant to the working group:

   i) descriptions of ecosystem impacts on fisheries

   ii) descriptions of developments and recent changes to the fisheries

   iii) mixed fisheries considerations, and

   iv) emerging issues of relevance for management of the fisheries;

c) Conduct an assessment on the stock(s) to be addressed in 2022 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 COVID-19 pandemic disruption 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 2021.

iv) For category 3 and 4 stocks requiring new advice in 2022, 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

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, consider whether it is possible and feasible to resolve the issue through an interbenchmark. If this is not possible, consider providing advice using an appropriate Category 2 to 5 approach.;

vi) The state of the stocks against relevant reference points;

Consistent with ACOM's 2020 decision, the basis for Fpa should be Fp.05.

1) 1. Where Fp.05 for the current set of reference points is reported in the relevant benchmark report, replace the value and basis of Fpa with the information relevant to Fp.05

2) 2. Where Fp.05 for the current set of reference points is not reported in the relevant benchmark report, compute the Fp.05 that is consistent with the current set of reference points and use as Fpa. A review/audit of the computations will be organized.

3) 3. Where Fp.05 for the current set of reference points is not reported and cannot be computed, retain the existing basis for Fpa.

vii) 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;

viii) 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.

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

i. In the section 'Basis for the assessment' under input data match the survey names with the relevant "SurveyCode" listed ICES survey naming convention *(restricted access)* and add the "SurveyCode" to the advice sheet.

e) 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 2023 for conclusion in 2024;
   iii) determine the prioritization score for benchmarks proposed for 2023–2024;
   iv) as necessary, document generic issues to be addressed by the Benchmark Oversight Group (BOG)

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

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

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

i) If not completed in 2020, 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.

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), sardine in divisions 8c and 9a (pil.27.8c9a) and jack mackerel in Subdivision 10.a.2 (jaa.27.10a2) 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 assessments were audited during the meetings (Annex 4). WGHANSA1 and WGHANSA2 reported by 31 May 2022 and 2 December 2022 respectively for the attention of ACOM.

Stock	Stock code	Stock coordinator 1	Stock coordinator 2	Advice to be provided in 2022	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. 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. 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.
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 2022	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	Lionel Pawlowski	Andres Uriarte	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), horse mackerel in Division 9.a (Section 9) and jack mackerel in Subdivision 10.a.2 (Section 10). Ongoing work to improve the management advice for anchovy in Division 9.a is summarised in section 1.10.

The list of participants, the working documents presented, the stock annexes, the audits and a summary of the joint WGACEGG-WGHANSA session conducted on 23rd and 25th May are provided as annexes.

1.3 Conduct of the meeting

WGHANSA1 took place by correspondence from 23 to 27 May 2022. WGHANSA2 took place in Lisbon (Portugal) from 21 to 25 November 2022.

1.3.1 List of participants

The full lists 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 the June meeting could be shorten. However, this year, the five days duration of WGHANSA1 allowed to cope with a delay in the acoustic survey results that are used as input for the assessment of anchovy in 9.a. 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 and third days 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). According to the workplan, in 2023 the RDBES and InterCatch will be used in parallel and from 2024 onwards only RDBES will be used. Therefore, all stock coordinators were encouraged to participate in the workshops about RDBES that will be carried out along the year.

Based on past interactions with WKCOLIAS (Workshop on Atlantic chub mackerel (*Scomber colias*), this year WGHANSA was contacted by the Horizon 2020 EuroSea project (https://eurosea.eu/) to present the work on Atlantic chub mackerel they are conducting within the task "Connecting CMEMS and fishery communities to increase uptake, and inform development of products for fishery management". The work entitled "Assessing the impact of external environmental drivers on Atlantic Chub Mackerel (*Scomber colias*) population dynamics" was presented on the first day of WGHANSA1 (Annex 2).

Stock identity and sub-stock structure of anchovy in division 9.a continues to be one of the major concerns of WGHANSA. This year WGHANSA compiled all the available information about the stock identity of anchovy in division 9.a (surveys, catches, life-traits, morphometrics, genetics, etc.). The summary of the available genetic studies was conducted by the Working Group on Application of Genetics in Fisheries and Aquaculture (WGAGFA). The resulting working document was presented and discussed in WGHANSA (see Annex 2) and was submitted to the Stock Identification Methods Working Group (SIMWG) for consideration. SIMWG2022 concluded that genetic studies up to now provide conflicting results due to the confounding between two ecotypes and two mitochondrial lineages and suggested these differences should be considered in future sampling programs and analyses. However, no further consideration was given to the rest information provided.

1.4 Quality of the fisheries data

The differences between the WG estimates and official data in 2021 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 2021 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	**8120**	100%	19	**2259**	**5699**
Portugal	9638	100%	28	2331	2331
Total	17758	100%	47	4590	8030

Horse Mackerel 9a

Country	Official Catch	% of catch sampled	No. samples	No. measured	No. Aged
Portugal	14627	100%	215	2228	386
Spain	10094	94%	178	12474	868
Total	24721	97%	393	14702	1254

Anchovy 8

Country	Official Catch	% of catch sampled	No. samples	No. measured	No. Aged
Spain	27918	100%	215	24354	2233
France	64	0%	0	0	1886
Total	72982	100%	215	24354	2233

Sardine 8abd

Country	Official Catch	% of catch sampled	No. samples	No. measured	No. Aged
France	20370	100%	31	1869	1794
Spain	5828	100%	202	25328	992
Total	26198	100%	233	27197	2786

Sardine 8c9a

Country	Official Catch	% of catch sampled	No. samples	No. measured	No. Aged
Portugal	26851	100%	119	11417	1720
Spain	13834	100%	112	11678	3828
Total	40685	100%	231	23095	5548

Blue jack mackerel in 10.a2

Country	Official Catch[1]	% of catch sampled[2]	No. samples[3]	No. measured[4]	No. Aged[5]
Portugal	889	8%	419	20747	23
Total					

[1] In Tonnes. 889 = 754 from artisanal Purse-seiners (includes landings for human consumption [609], and excedent landings [withdrawn] used for bait [145];

[2] % of catch sampled was calculated just for the PS fleet (85% of the total landings - weight) in terms of the number of trips. In this case, we have 246 fishing trips sampled (219 at market and 27 at sea) of 3075 fishing trips - 8 %. As LL+HL is a multispecific fishery, I don't have a way to do it quickly, and it represents only 15% of the official landings (weight). I know I'm mixing things here, but I don't see another way to find this percentage – In DCF, we use the number of fishing trips!

[3] Market and onboard samples: 419 samples (330 market: 214 PS + 116 HOK; 89 onboard: 27 PS + 62 HOK)

[4] Length - Market and onboard samples: 20747 individuals measured (16123 market: 12515 PS + 3608 HOK; 4624 onboard: 2935 PS + 1689 HOK);

[5] Age/Length/Weight/Sex ratio/Sexual maturity - Commercial samples: 23 individuals measured / 1 sample

Comment for undersampling in Azores: One laboratory facility was requested and transformed into nucleic acid detection (PCR amplification) of SARS-CoV 2, reduction of staff technicians and scarce landings at the port with laboratory, and bad weather conditions led to a decrease in the number of individuals available for commercial samples.

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 WG proposed to initiate a benchmark in 2023 for anchovy in division 9.a and for horse-mackerel in division 9.a. For both stocks the scoring sheet was completed for consideration of the Benchmark Oversight Group (BOG). The benchmark proposed for anchovy in Subarea 8 for 2022-2023 was accepted by BOG but has not been settled on yet. Therefore, WG notes that the benchmarks for the two anchovy stocks could be considered together.

Table 1.6.1 History of benchmarks and proposals by WGHANSA.

Stock	Stock code	History of Benchmarks	WGHANSA 2022 Proposal 2023-2024
Anchovy (*Engraulis encrasicolus*) in Division 9.a (Atlantic Iberian waters)	ane.27.9a	Full Benchmark 2018	Benchmark proposed for 2023-2024
Horse mackerel (*Trachurus trachurus*) in Division 9.a (Atlantic Iberian waters)	hom.27.9a	Full benchmark 2011 Full benchmark 2017	Benchmark proposed for 2023-2024
Anchovy (*Engraulis encrasicolus*) in Subarea 8 (Bay of Biscay)	ane.27.8	Full benchmark 2013	Benchmark proposed for 2022-2023 and accepted by BOG. It has not been settled on yet, so delayed 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	Benchmark to be proposed for 2024-2025
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	2021	5	0.153	No	**0.062**	No	**-0.079**
Anchovy (*Engraulis encrasicolus*) in Subarea 8 (Bay of Biscay)	ane.27.8	2022	5	-0.146*	Yes	0.177	Yes	-0.295
Sardine (*Sardina pilchardus*) in divisions 8.a–b and 8.d (Bay of Biscay)	pil.27.8abd	2021	5	-0.301	No	0.42	No	0.08
Sardine (*Sardina pilchardus*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)	pil.27.8c9a	2021	5	0.350	Yes	-0.333	Yes	-0.139

*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.

In 2022, WGHANSA continued making progress towards implementing the assessments into TAF, but the work is not finished yet. For anchovy in division 9.a different repositories were created for each of the stock components (western and southern). The western component was 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 was uploaded into TAF. The stocks of anchovy in Subarea 8, sardine in Subarea 7 and sardine in divisions 8.c and 9.a were fully implemented in TAF. Furthermore, some of the sections for anchovy in Subarea 8 was semi-automatically generated using markdown and some progress was 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, sardine in divisions 8.a-b and 8.d and jack mackerel in Subdivision 10.a.2.

1.9 Ecosystem and Fisheries overviews

The audit spread sheet 'Monitor and alert for changes in ecosystem/fisheries productivity' has been completed for all the stocks.

No additional progress has been made on these ToRs.

1.10 Workplan for anchovy in division 9.a

In the last months special efforts are being devoted to improving the assessment and management advice of anchovy in division 9.a. Most recent advances were presented and discussed in WGHANSA1 (Annex 2):

- "Stock structure anchovy 27.9.a" by S. Garrido, N. Rodriguez-Ezpeleta, F. Ramos, M. Rincón, D. Feijó, A. Moreno, R. Castilho, N. Díaz, R.R. Da Fonseca, S.M. Francisco, A. Manuzzi, G. Silva, et al.
- "Current work towards the improvement of scientific advice" by S. Garrido, L. Wise and A. Silva.
- "Life history parameters on anchovy 9.a western component" by L. Wise, A. Silva, A. Uriarte and S. Garrido.
- "Reproductive characteristics of western component of anchovy in 9.a" by S. Garrido, A.M. Costa, C. Nunes, P. Pechirra, H. Mendes, D.S.R. Milhazes, A.V. Silva, C. Silva, L. Wise, A. Silva, et al.
- "Exploratory aassessment of anchovy 9.a-west using a surplus production model" by A. Silva, L. Wise, F. Ramos, M. Rincón, S. Garrido, A. Uriarte and T. Mildenberger.

The working group acknowledged all the work done and considered the results made so far very encouraging. To support further progress, WGHANSA agreed on the following two actions. On the one hand, WGHANSA will submit the working document on stock structure with the most updated information to SIMWG for their consideration (see also section 1.3.3). On the other hand, WGHANSA proposes 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. The proposed draft Terms of Reference for such workshop are the following:

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).

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.
- Continue exploring methods to provide management advice for short-lived stocks in Category 3. In particular, explore alternative methods for the initial catch for the first year of the 1-over-2 and test them within a management strategy evaluation (MSE) framework.
- 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.
- The exact boundaries of some of the stocks assessed by WGHANSA are unclear and further studies are needed.
- 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.
- For stocks like anchovy in division 9.a for which advice is provided separately by components, compare the impact of management measures taken for the whole stock or by components.
- 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 in northern areas

This section has not been updated, as there is no new information.

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 Southwest 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 2022 the Council established a provisional TAC of 24 000 tonnes for the Bay of Biscay anchovy stock for the period from 1 January to 30 June 2022 (Council Regulation No 2022/109). The final TAC was set in March at 33 000 tonnes (Council Regulation No 2022/515) from which 90% corresponded to Spain and 10% to France. However, these percentages might be modified due to bilateral agreements between countries.

According to the European Commission Regulation No. 185/2013, the deductions from the anchovy fishing quota allocated to Spain because of overfishing of mackerel quota in 2009 shall be applied from 2016 to 2023. This supposes a reduction of 3696 tonnes in the 2022 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 2021 and 2022

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 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 2021, there were very low catches by the French fisheries. Only 64 tons were caught by the French fleet in 2021, 83% by purse-seiners and 17% 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 2021 were 27 982 tonnes, from which 27 918 corresponded to Spain and 64 to France. In 2021, 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 anchovy. From the Spanish catches, 1 tonne 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 2021, most of the catches occurred between March and May, where the bulk of the Spanish fishery occur. Although catches were recorded in all the months.

The quarterly catches by division in 2021 are given in Table 3.2.2.3. Most of the catches took place in the second quarter (58.0%), followed by the first quarter (26.4%) and with lower catches in third and fourth quarters (15.5% and 0.2% respectively). The major fishing activity of the Spanish fleet occurred in the second quarter (58.1%) followed by the first quarter (26.5%), whereas the French fleet operated mainly in the third and fourth quarters (51.6 and 41.9% respectively). Regarding fishing areas, most of the Spanish catches in the first and second semesters corresponded to ICES division 8.c East, whereas in the third 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 originated 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 2021 only 6.6 tons 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	VIIIab	VIIIbc	Live Bait Catches			VIII
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 (Up to end of Octo	264	24 619				24 883
AVERAGE (1960-2004)	6 394	26 337				32 824
AVERAGE (2010-2021)	2 973	18 622				21 698

** : Experimental fishery

Table 3.2.2.2: Bay of Biscay anchovy: Monthly catches by country (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

Table 3.2.2.3: Bay of Biscay anchovy: Catches in the Bay of Biscay by country and divisions in 2021 (without live bait catches).

		QUARTERS				CATCH (t)	
COUNTRIES	DIVISIONS	1	2	3	4	ANNUAL	%
SPAIN	8abd	70	0	5	18	93	0.3%
	8cE	6690	15620	2362	0	24672	88.4%
	8cW	626	596	1930	0	3152	11.3%
	TOTAL	7386	16216	4297	18	27917	100.0%
	%	26.5%	58.1%	15.4%	0.1%	100.0%	
FRANCE	8abd	0	4	33	27	64	100.0%
	8cE					0	0.0%
	8cW					0	0.0%
	TOTAL	0	4	33	27	64	100.0%
	%	0.0%	6.5%	51.6%	41.9%	100.0%	
INTERNATIONAL	8abd	70	4	38	45	158	0.6%
	8cE	6690	15620	2362	0	24672	88.2%
	8cW	626	596	1930	0	3152	11.3%
	TOTAL	7386	16220	4330	45	27981	100.0%
	%	26.4%	58.0%	15.5%	0.2%	100.0%	

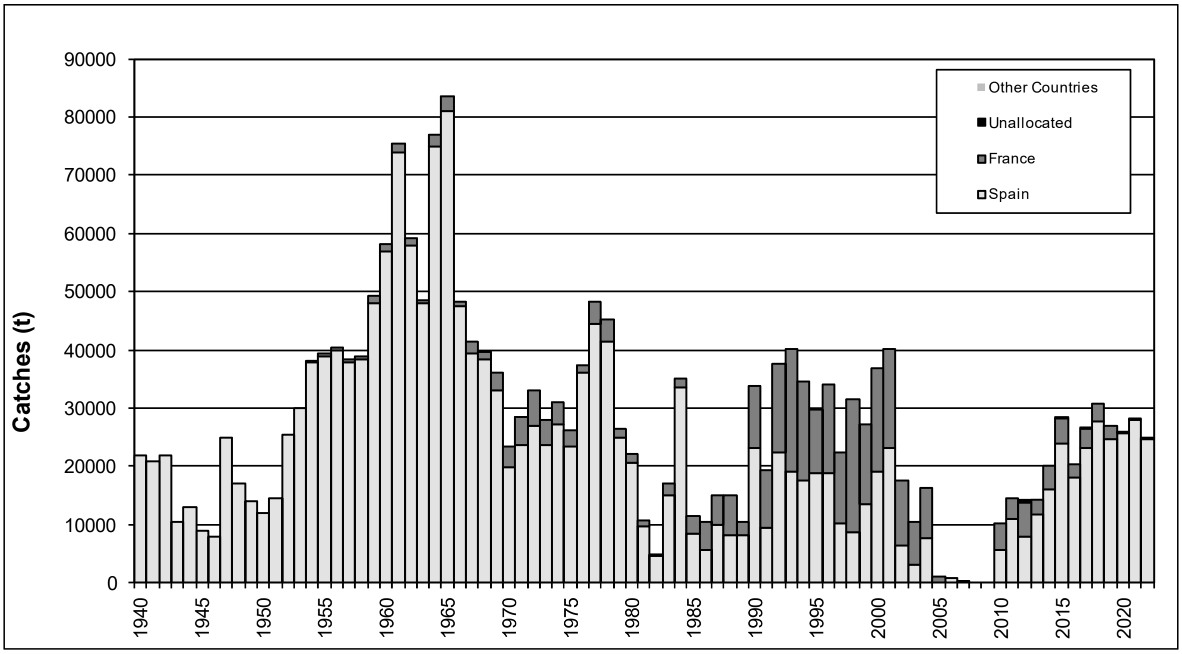


Figure 3.2.2.1: Bay of Biscay anchovy: Historical evolution of catches in Subarea 8 by countries. 2022 data are preliminary.

3.2.3 Catch numbers-at-age and length

In 2021 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 2021 for Spain and France are given in Table 3.2.3.1. Age 1 individuals were predominant in the second and third quarters representing the 51.6% and 70.5% of total catches each quarter respectively while age 2 individuals were predominant in the first quarter with a 48.5% of total catches in that quarter. Age 0 individuals appeared in third and fourth quarters, representing the 0.4% and 88.2% 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 2021, the one-year-old anchovies dominated in the catches in both semesters, representing the 51.1% in the first semester and the 69.6% in the second semester.

See the stock annex for methodological issues.

Table 3.2.3.1: Bay of Biscay anchovy: Catch-at-age in thousands for 2021 by quarter (without the catches from the live bait tuna fishing boats).

	QUARTERS	1	2	3	4	Annual total
	AGE	VIIIabc	VIIIabc	VIIIabc	VIIIabc	VIIIabc
TOTAL Sub-area 8	0	0	0	1 001	2 743	3 744
	1	173 121	383 130	148 122	250	704 623
	2	178 205	336 469	60 662	117	575 453
	3	15 723	21 690	167	0	37 580
	4	311	551	0	0	862
	5	0	0	0	0	0
	TOTAL(n)	367 360	741 839	209 951	3 111	1 322 261
	W MED.	20.10	21.86	20.62	14.45	21.16
	CATCH. (t)	7386	16220	4330	45	27981
	SOP	7385	16219	4330	45	27979
	VAR. %	99.99%	99.99%	100.01%	100.02%	99.99%

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	
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
0	0	37 068	0	443	0	74 571	0	23 725	0	1 770	0	373	0	62 514	0	3 744
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
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
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
4	4 271	0	173	0	231	0	2 339	0	292	0	440	0	171	3	862	0
5	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

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 2021, 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.

INTERNATIONAL

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			
Sources:	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		
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		
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		
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		
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		
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	0.0		
5	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		

3.2.5 Preliminary fishery data in 2022

The provisional catches during the first semester of 2022 were 21 163 t, from which 21 149 t corresponded to Spain and 14 t to France. 23% of the catches (in mass) during the first semester were age 1. During the second semester provisional catches until the end of October were 3721 t, from which 3470 t corresponded to Spain and 250 t to France. Overall, the total catches in 2022 from France were very low (264 t).

It must be emphasised that 2022 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 June, when most of the French catches of the first semester take place. For the assessment, 2022 November and December catches were assumed to be 612 t (2.4% of the total annual catch which is the average percentage of the total catches in November and December in 2010–2021, after the reopening of the fishery). Therefore, the total catch in November and December was estimated at 612 t, resulting in 4333 tonnes for the second semester 2022.

3.3 Fishery-independent data

3.3.1 BIOMAN DEPM survey 2022

All the methodology for the survey and the estimates performance are described in detail in the stock annex. A detailed report of the 2022 survey and the corresponding results is attached as a working document in ICES WGACEGG 2022 in annex 3 (Santos Mokoroa. M et al. BIOMAN 2022).

3.3.1.1 Survey description

The 2022 anchovy DEPM survey was carried out in the Bay of Biscay from the 5th to the 27th of May, covering the whole spawning area of the species, following the procedures described in the stock annex. Two research vessels were used at the same time and place: the RV Vizconde de Eza to collect the plankton samples and the RV Emma Bardán to collect the 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 757. From those, 596 had anchovy eggs (79%) with an average of 310 eggs m-2 per station in the positive stations, and a maximum of 3,380 eggs m-2 in a station. A total of 23,523 anchovy eggs were encountered and classified in the PairoVET stations. The number of CUFES samples (horizontal sampling) obtained was 1,700. Frome those 1,302 (77%) stations had anchovy eggs with an average of 41 eggs m-3 per station and a maximum of 677 eggs m-3 in a station.

This year 17% of the anchovy eggs were found in the Cantabrian Sea, where the western spawning limit was found at 6º20'W. There were eggs all over the platform up to the northern limit of ICES Subarea 8. The eggs passed the 200 m depth isoline almost in all the area except from 47 º 30' to 48ºN that arrived until 180m approximately (Figure 3.3.1.1.1). The total area covered was 115,118Km2 and the spawning area for anchovy was 92,290Km2, representing 80% of the total.

Regarding the adult samples, 47 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 were anchovy, sardine, mackerel and horse mackerel. Anchovy adults were found in the same places where the anchovy eggs were found. This year the biggest anchovies were found at the West of the Cantabrian Sea as well as in the Northwest of the French platform. The smallest anchovies were found around the mouth of the Gironde River and at the East of the Cantabrian Sea and Southeast of the French platform. 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(16.7°C) was higher than last year (14.0 °C), the minimum was 12.97°C and the maximum 19.3°C. The mean sea surface salinity (34.8) was lower than last year (35.4) with a minimum of 30.5 and a maximum of 36.8. Figure 3.3.1.1.4 shows the maps of sea surface salinity and temperature found during the survey. There were atypical weather conditions this year during May, it was the warmest of this century and the second driest in the historical series. in addition, from the surface buoys results, a NE-SW drifting trend was observed, which is contrary to the typical NW-SE drift. The buoys reflected the anticyclonic conditions that prevailed in March-April-May.

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 2022 was estimated at 1.61 E+13 with a CV of 0.0824, higher than last year and the second highest of the historical series since 1987. 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 these parameters. The results of all these parameters for 2022 are showed in table (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 198,741t with a CV of 0.1057, lower than the last two years and the third highest of the historical series.

3.3.1.4 Population at age

In order to estimate the numbers-at-age, the age readings based on 3,002 otoliths from 47 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: West Cantabrian (WC), Central Cantabrian (CC), East Cantabrian (EC), East (E), Garonne (G) and North (N; Figure 3.3.1.4.1). 56% of the anchovy in numbers were estimated as individuals of age 1 (42% in mass), 39% of the individuals in numbers were of age 2 (50% in mass) and 4% of the individuals in numbers were of age 3 (8% in mass; Table 3.3.1.4.1). This was a medium year recruitment in relation to the historical series. The anchovy age composition by haul 2022 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 are showed in Figure 3.3.1.4.4.

Table 3.3.1.1.1: Bay of Biscay anchovy: Details of the DEPM survey BIOMAN 2022.

Parameters	Anchovy DEPM survey
Surveyed area	(43º19' to 47º53'N and 6º 20' to 1º14' W)
RV	*Vizconde de Eza* and *Emma Bardán*
Date	05-27/05/2022
Eggs	RV VIZCONDE DE EZA
PairoVET stations (plankton)	757
% st with anchovy eggs	79%
Anchovy egg average by st	310 eggs/m^2
Max. anchovy eggs in a St	3,380 eggs/m^2
Total ANE egg collected&staged	23,523 eggs
North spawning limit	47º'52'N
West spawning limit (Cantabrian)	6º20'W
Total area surveyed	115,118 Km^2
Spawning area for anchovy	92,290 Km^2
CUFES stations (plankton)	1,700
Adults	RV EMMA BARDAN& Purse-seines
Pelagic trawls Emma Bardán	42+4 from RV Thalassa
Pelagic trawls with anchovy	46
Selected for analysis	46
Hauls from purse-seines	1
Total adult samples for analysis	47

Table 3.3.1.2.1: Bay of Biscay anchovy: 2022 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	174.37	14.38	0.0824
z	0.32	0.051	0.1615
Ptot	1.61E+13	1.3E+12	0.0824

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 (P_{tot})(eggs) estimate is showed as well.

Parameter	estimate	S.e.	CV
P_{tot} (eggs)	1.61E+13	1.33E+12	0.0824
R'(% of females)	0.53	0.0048	0.0090
S (% fem. spawning/day)	0.34	0.0143	0.0424
F (eggs/batch/mature fem.)	7,340	591	0.0805
W_f(g)	16.18	0.92	0.0569
DF (eggs/g/day)	81.36	5.38	0.0661
B (tons)	198,741	21,008	0.1057

Table: 3.3.1.4.1: Bay of Biscay anchovy: Anchovy total biomass (B), percentage at age, numbers-at-age, mean weight at age, mean length-at-age, total biomass at age in mass and percentage at age in mass with the corresponding standard error (S.e.) and coefficient of variation (CV) from BIOMAN 2022. As well as the biological features mean weight at age (g) and mean length-at-age (mm).

Parameter	estimate	S.e.	CV
BIOMASS (tons)	198,741	21,008	0.1057
total mean Weight (g)	13.4	0.71	0.0528
Population (millions)	14,835	1903	0.1283
Percentage at age 1	0.56	0.047	0.0838
Percentage at age 2	0.39	0.040	0.1025
Percentage at age 3+	0.04	0.010	0.2189
Numbers-at-age 1	8,396	1,497.2	0.1783
Numbers-at-age 2	5,780	758.6	0.1313
Numbers-at-age 3+	660	139.6	0.2117
Percent. at age 1 in mass	0.42	0.048	0.1144
Percent. at age 2 in mass	0.50	0.038	0.0760

Parameter	estimate	S.e.	CV
Percent. at age 3+ in mass	0.08	0.015	0.1886
Biomass at age 1 (tons)	84,315	14,440	0.1713
Biomass at age 2 (tons)	98,389	11,558	0.1175
Biomass at age 3+ (tons)	16,037	3,193	0.1991

Biological Features	estimate	S.e.	CV
Weight at age 1 (g)	10.03	0.32	0.0314
Weight at age 2 (g)	17.04	0.69	0.0407
Weight at age 3 (g)	24.15	0.89	0.0369
Length-at-age 1 (mm)	122.1	1.13	0.0092
Length-at-age 2 (mm)	141.7	1.52	0.0107
Length-at-age 3 (mm)	157.3	1.81	0.0115

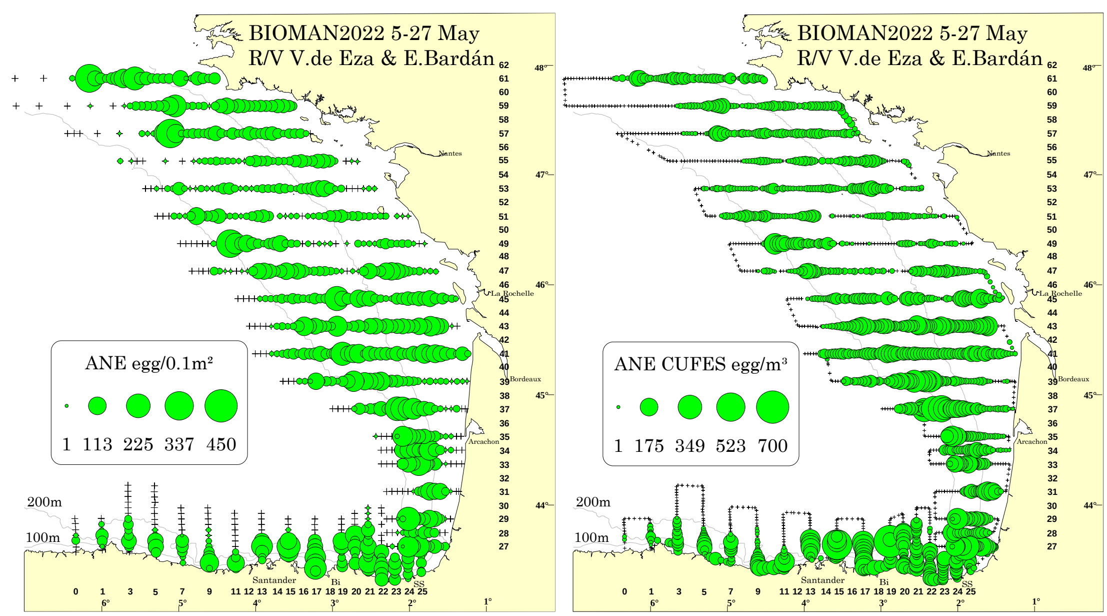


Figure 3.3.1.1.1: Bay of Biscay anchovy: Spatial distribution and abundance of anchovy egg obtained with PairoVET (vertical sampling net) (eggs per 0.1 m2) on the left and CUFES (horizontal sampling net; egg/m³) on the right obtained during the DEPM survey BIOMAN2022.

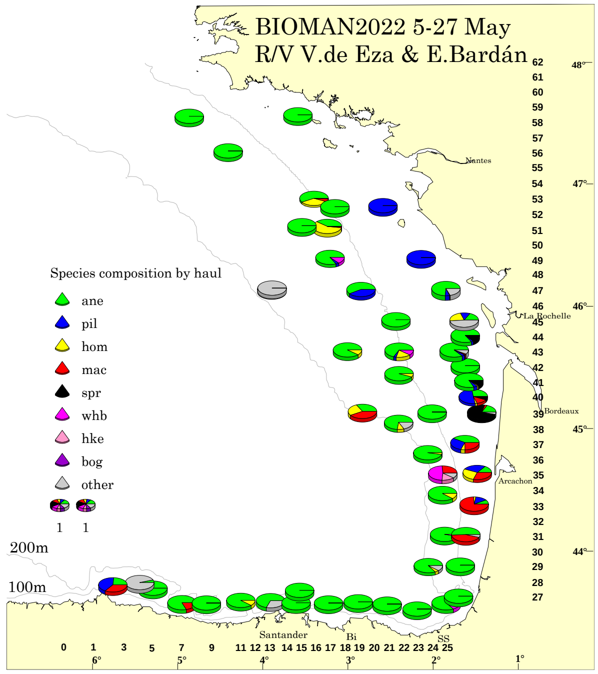
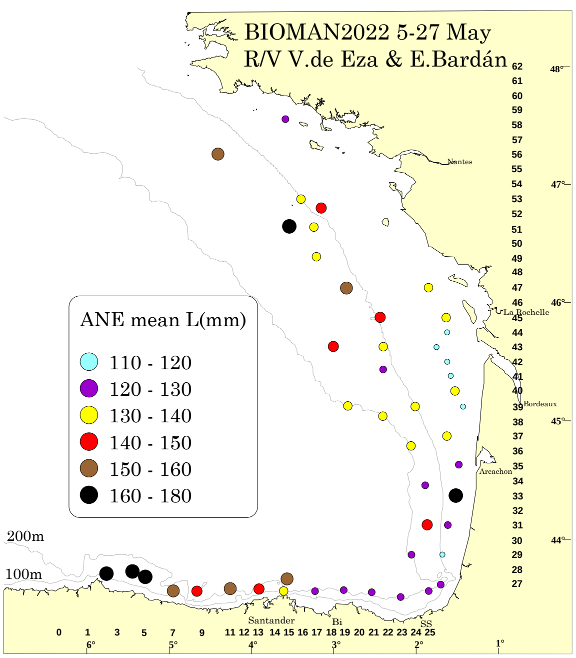


Figure 3.3.1.1.2: Bay of Biscay anchovy: Species composition of the 47 hauls obtained for the anchovy adult parameters analysis for the application of the DEPM.



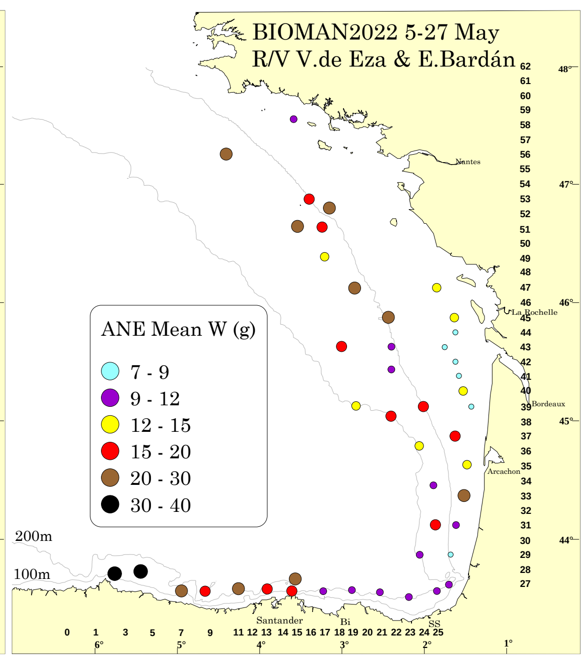


Figure 3.3.1.1.3: Bay of Biscay anchovy: Spatial distribution of anchovy mean length (left) and mean weight (right) (males and females) by haul during BIOMAN2022.

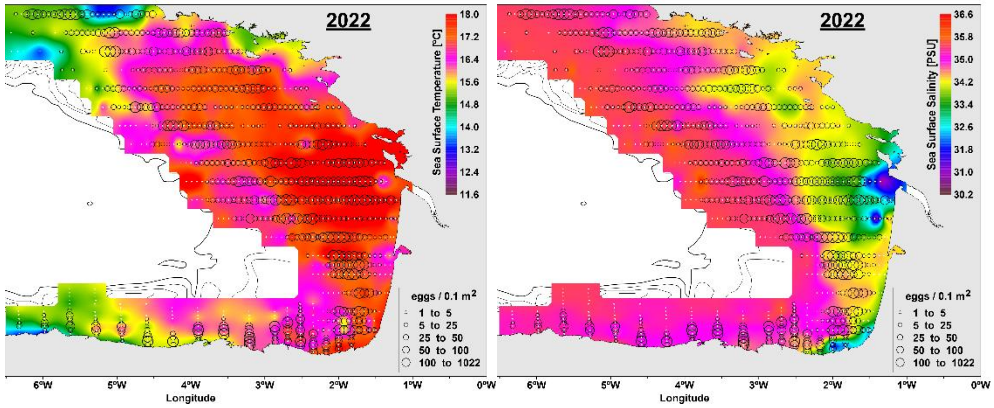


Figure 3.3.1.1.4: Bay of Biscay anchovy: Spatial distribution of sea surface temperature (left) and sea surface salinity (right) during BIOMAN 2022 with the anchovy egg abundances spatial distribution.

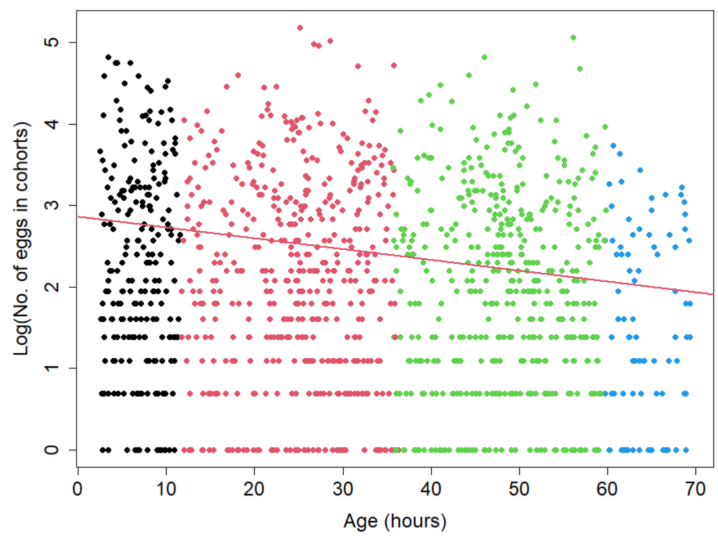


Figure 3.3.1.2.1: Bay of Biscay anchovy: Exponential mortality model in log scale adjusted applying a GLM to the data obtained in the Bayesian egg ageing (spawning peak at 23:00h GMT). The red line is the adjusted line. The coloured dots represent the different cohorts.

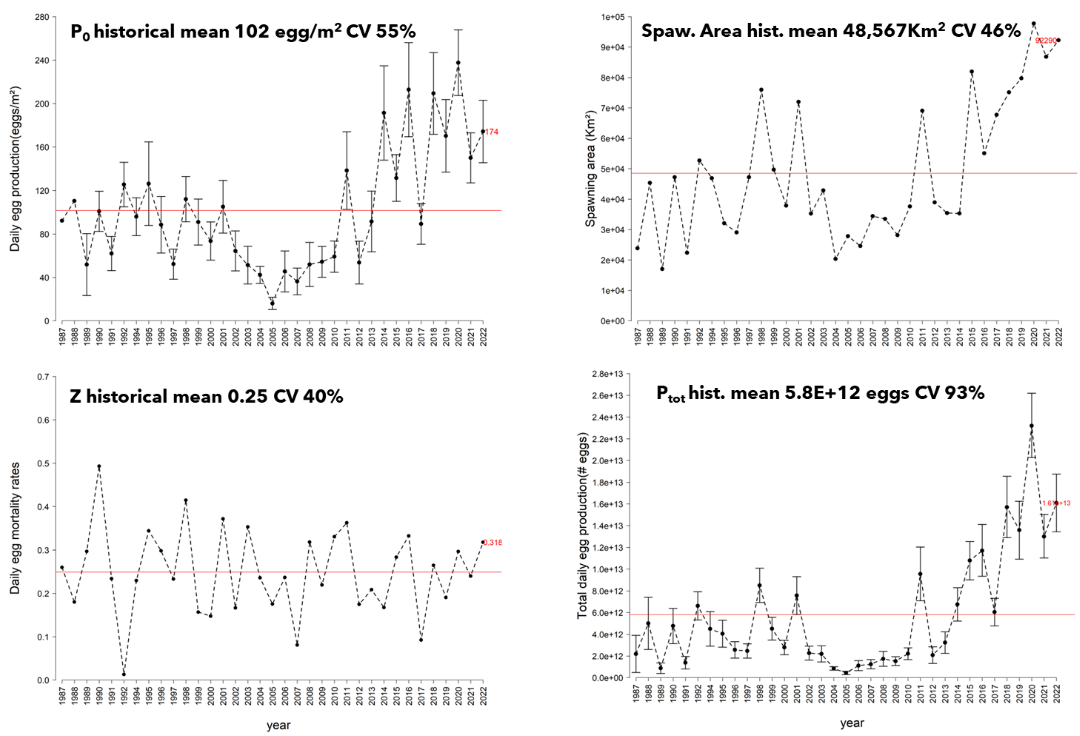


Figure 3.3.1.2.2: Bay of Biscay anchovy: historical series including 2022 estimates for daily egg production (P0) (egg/m2/day), spawning area (Km2), daily mortality rates (z) and total daily egg production (Ptot)(eggs/day) for anchovy in the Bay of Biscay. The red line is the historical mean, the values showed in bold are the historical mean and the CV (coefficient of variation) over time for each parameter.

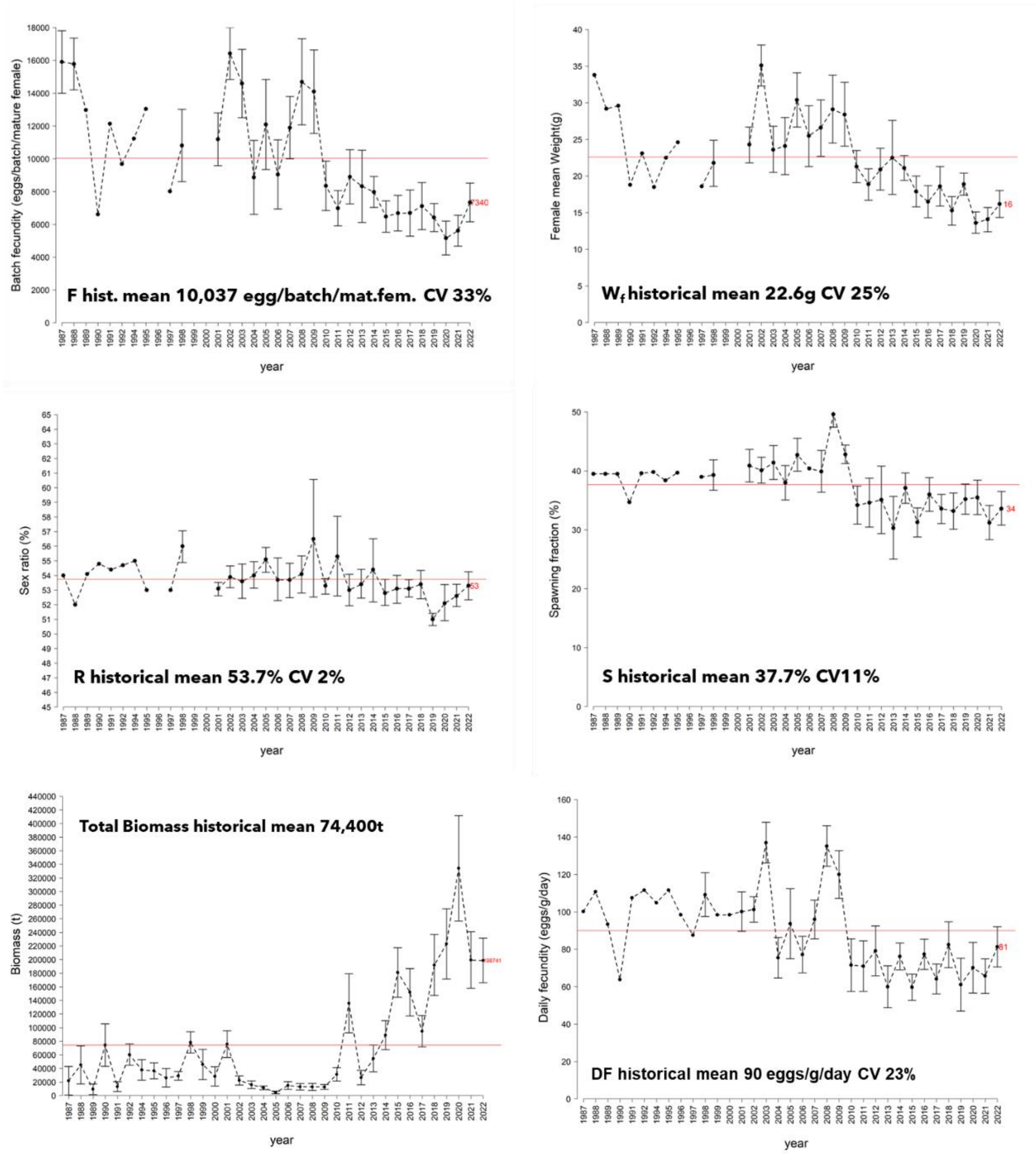


Figure 3.3.1.3.1: Bay of Biscay anchovy: historical series including 2022 estimates of the adult parameters for anchovy in the Bay of Biscay: batch fecundity (F) (eggs/batch/mature female), female mean weight (Wf)(g), sex ratio (R) (% of females), spawning fraction (S) (% of females spawning per day), 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 values showed in bold are the historical mean and the CV (coefficient of variation) over time for each parameter.

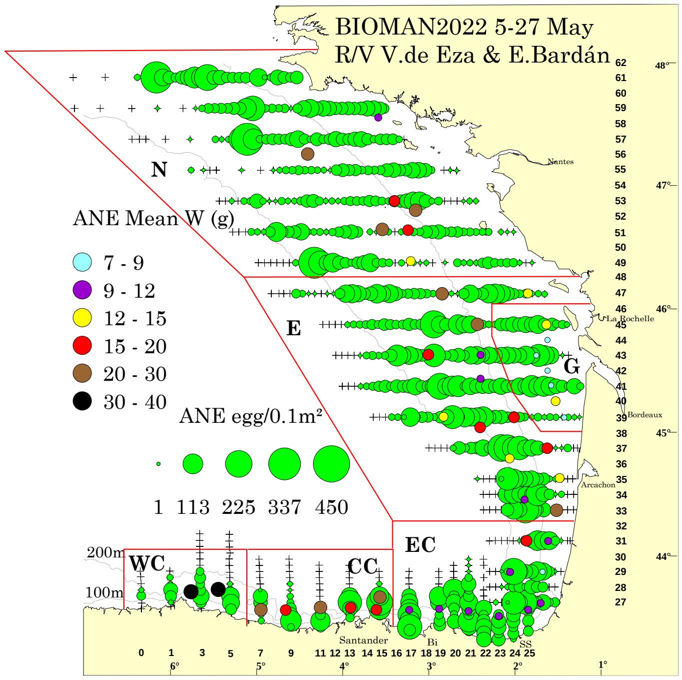


Figure 3.3.1.4.1: Bay of Biscay anchovy: Six regions were defined to weight the adult samples to estimate anchovy numbers-at-age in 2022: West Cantabrian (WC), Central Cantabrian (CC), East Cantabrian (EC), East (E), Garonne (G) and North (N). The red lines represent the border of the regions, the green 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.

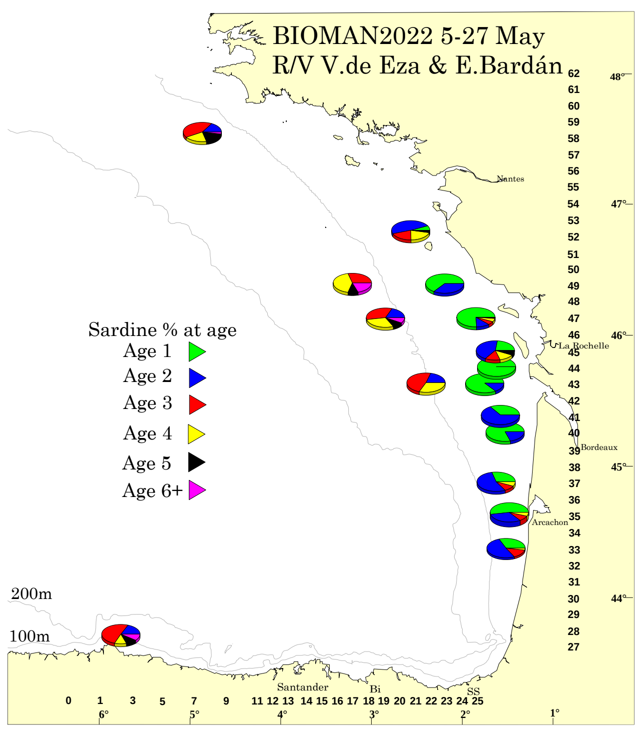


Figure 3.3.1.4.2: Bay of Biscay anchovy: Anchovy age composition by haul during BIOMAN2022.

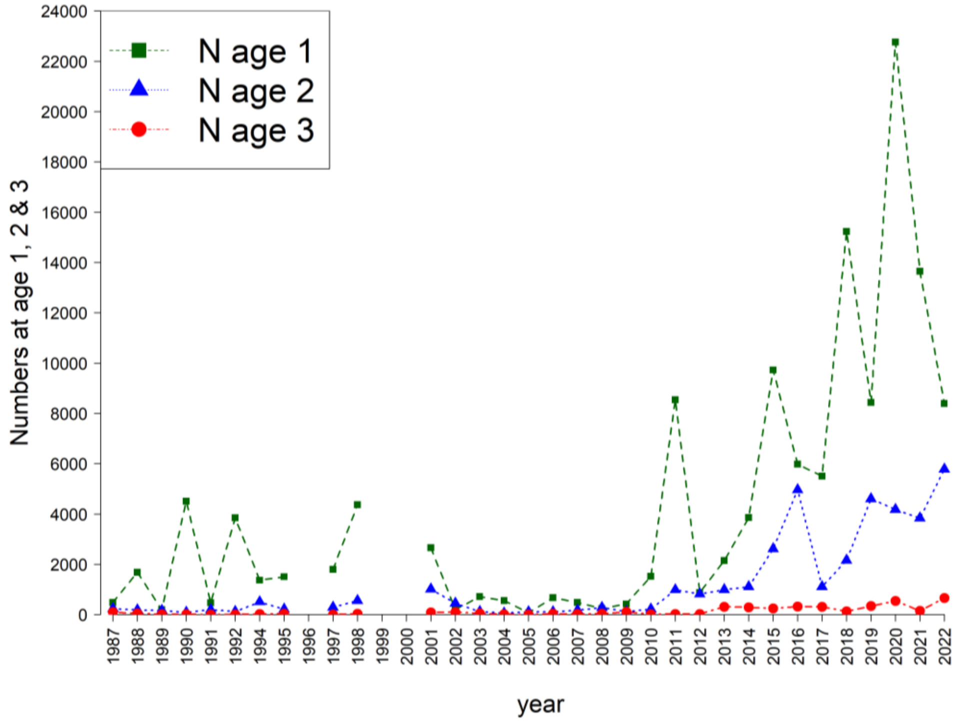


Figure 3.3.1.4.3: Bay of Biscay anchovy: Anchovy historical series of numbers-at-age from 1987 to 2022 from BIOMAN surveys.

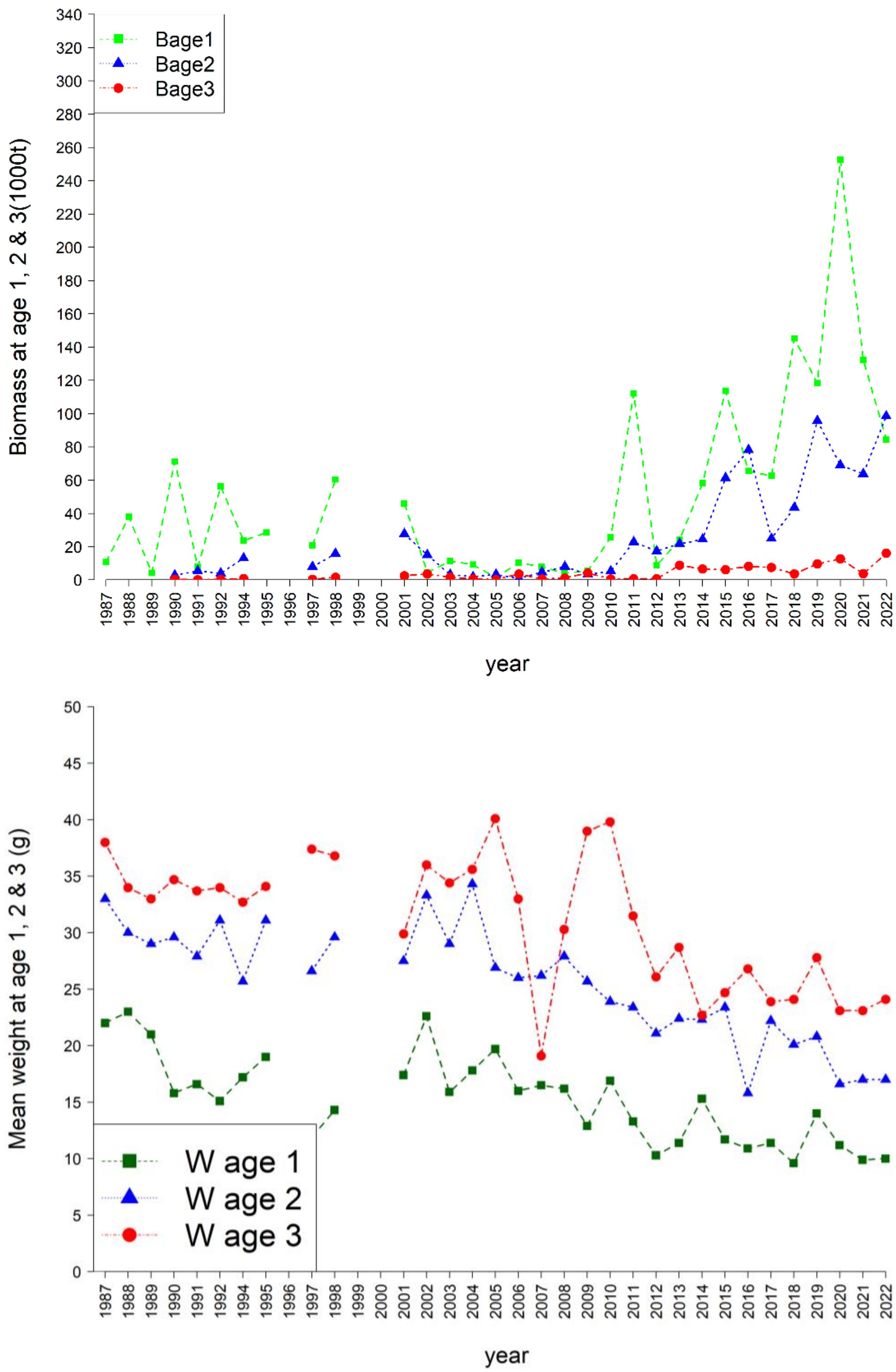


Figure 3.3.1.4.4: Bay of Biscay anchovy: Anchovy historical series (1987-2022) of total biomass at age and mean weight at age in the BIOMAN surveys.

3.3.2 PELGAS spring acoustic survey 2022

An acoustic survey (PELGAS) is carried out every year in the Bay of Biscay in spring onboard the French research vessel Thalassa. All the methodology is described in detail in the stock annex and a detailed report with the 2022 results is presented as a working document to ICES WGACEGG 2022. 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 multispecific context and within an ecosystemic approach as they are located in the centre of the pelagic ecosystem.

A consort survey is routinely organized since 2007 with French commercial vessels during 18 days. This approach is identical with previous year's surveys, using the commercial vessel's hauls for echoes identification and biological parameters to complement the hauls made by the RV Thalassa. Four commercial vessels (two pairs of pelagic trawlers) participated to PELGAS22 survey: A total of 110 hauls (including not valid) were carried out during the consort survey including 53 hauls by the RV Thalassa and 46 hauls by commercial vessels.

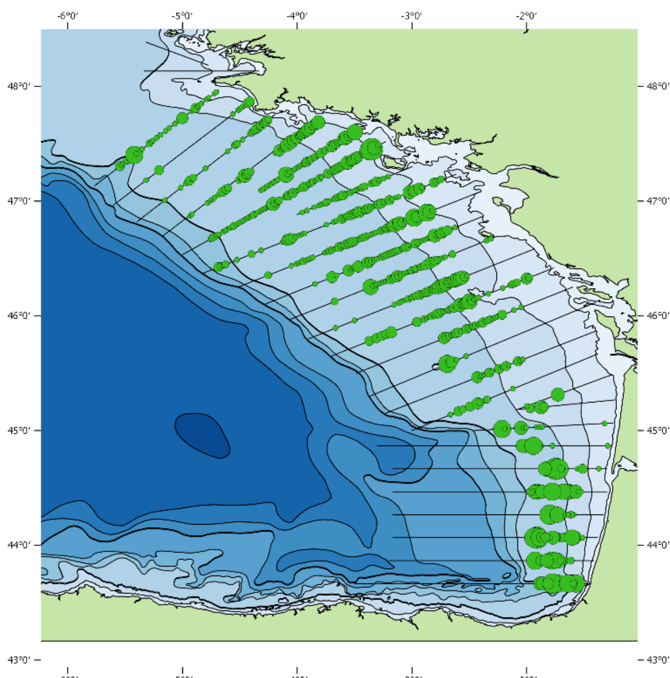


Figure 3.3.2.1: Bay of Biscay anchovy: Total abundance of anchovy per ESDU in 2022.

The biomass estimate of anchovy observed during PELGAS2022 is 180 750 tons, which is above the average of the series, but far away the strong maximum 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 (Figure 3.3.2.1). 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 (two years really differed from the average: 2012 and particularly 2015 where fishes were much smaller) 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 2022 is the massive schools in subsurface in the South, sometimes longer than one nautical mile.

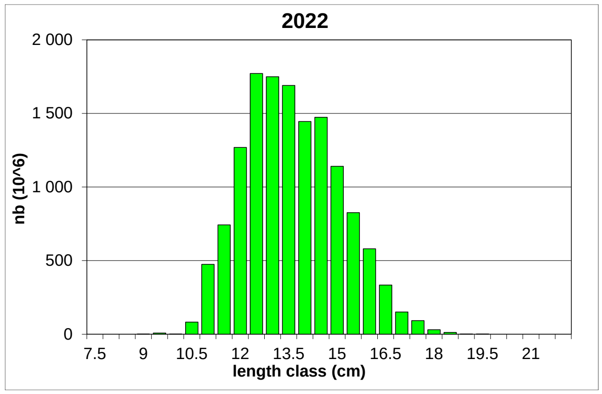


Figure 3.3.2.2: Bay of Biscay anchovy: Length distribution of global anchovy as observed during PELGAS22 survey.

Globally we observe that length structure shows a classic distribution, with fish from 10 to 18 centimetres (Figure 3.3.2.2). 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. 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.

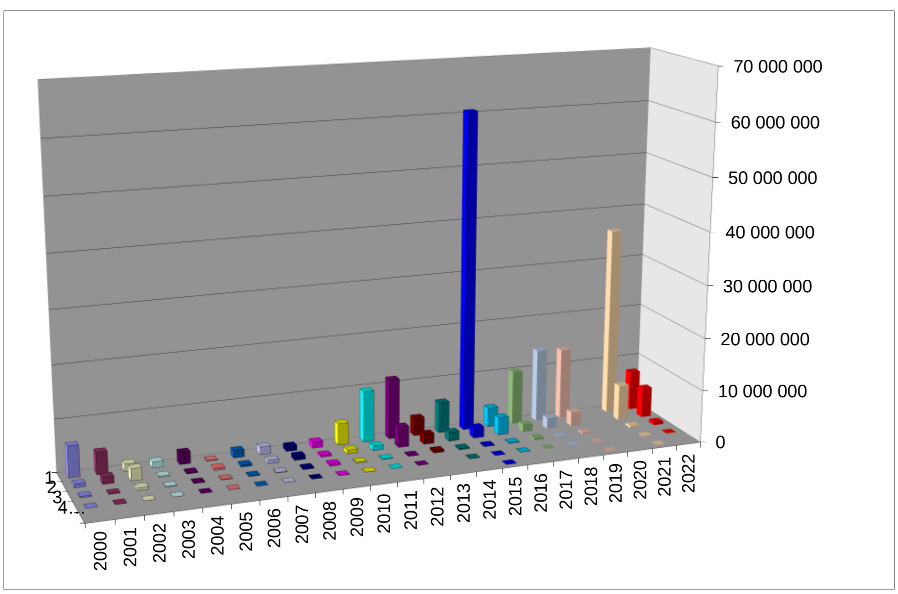


Figure 3.3.2.3: Bay of Biscay anchovy: Anchovy numbers-at-age as observed during PELGAS surveys since 2000.

Looking at the numbers-at-age since 2000, the proportion of 1 year old anchovies (54%) is lower than the exceptional recruitment observed last year (Figure 3.3.2.3). This 2020 cohort (1 year old in 2021) seems to be not tracked this year.

The huge 2015 age-class is not followed in 2016 and in 2017 as well. 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.

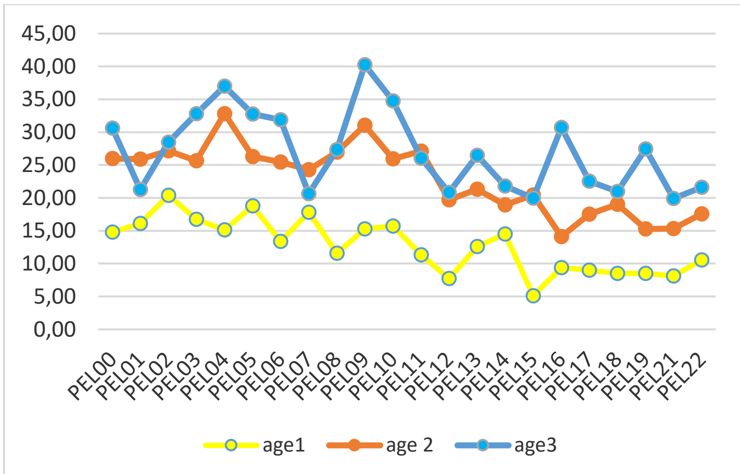


Figure 3.3.2.4: Bay of Biscay anchovy: Evolution of mean weight at age (g) of anchovy along PELGAS series.

As previous years, we observe that globally the trend of the mean weight at age is decreasing (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 investigations should be done to test some initial hypothesis (maybe an effect of density-dependence or a change in planktonic composition), but there is no real explanation for the time being.

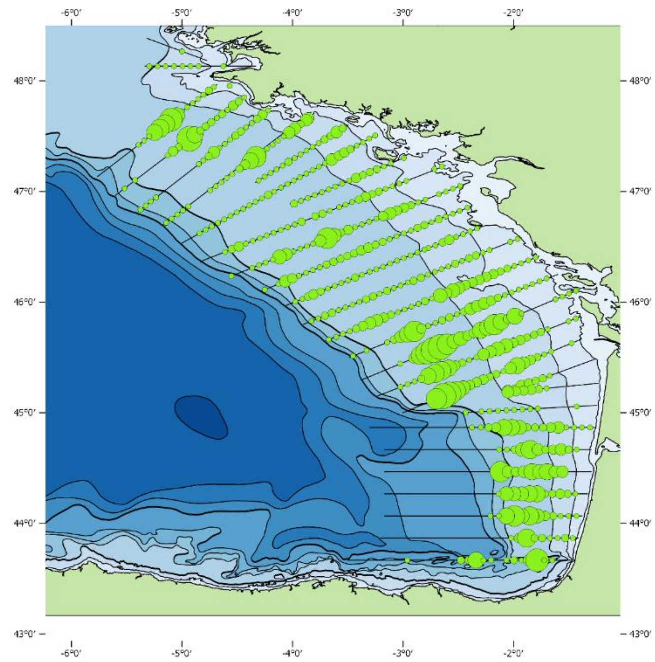


Figure 3.3.2.5: Bay of Biscay anchovy: Distribution of anchovy eggs observed with CUFES during PELGAS22.

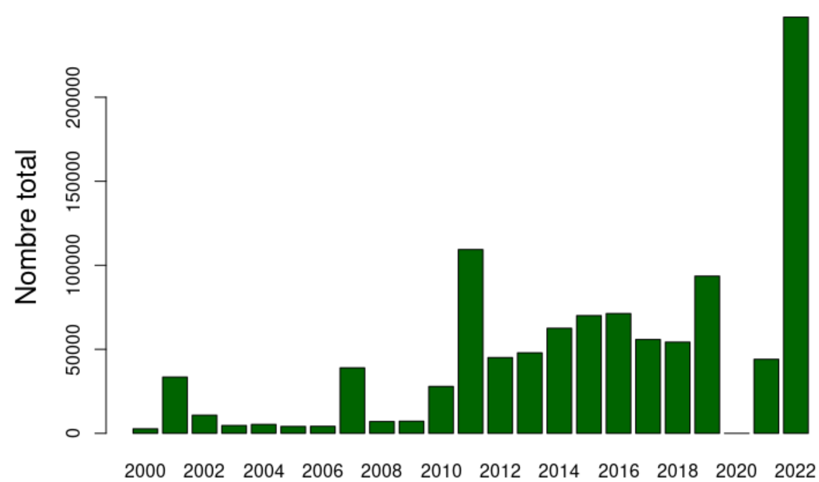


Figure 3.3.2.6: Bay of Biscay anchovy: Number of eggs observed during PELGAS surveys from 2000 to 2022.

During this survey, in addition of acoustic transects and pelagic trawl hauls, 748 CUFES samples were collected and counted, 69 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 was marked by a large quantity of collected and counted anchovy eggs (Figure 3.3.2.6), with the same magnitude over the values, reaching the maximum in 2011.The strong maximum appears this year. Their spatial pattern of distribution was quite usual, with major part of the abundance South of 46°N. However, eggs are present almost everywhere in the Bay of Biscay, according to the high level of adults biomass. Eggs are particularly abundant on the platform and were not present in front of the Gironde. Spawning occurred over the mid-shelf in the North, an area where eggs are observed rarely.

Globally, the total number of eggs seems to be the strong maximum of the series, about two times of the previous higher level in 2019. According to the high level of biomass, the huge number of eggs suggests this year an exceptional fecundity of anchovy in the Bay of Biscay at the period of the PEL-GAS survey.

3.3.3 Autumn juvenile acoustic survey 2022 (JUVENA 2022)

The methodology of the autumn juvenile acoustic survey JUVENA is described in detail in the stock annex. The results of the last survey in autumn 2022 were reported and discussed in ICES WGACEGG 2022 (Boyra et al., 2022, WD WGACEGG2022, ICES, 2022). 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 summer in the Bay of Biscay. In 2022, 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 2022 took place between the 17th of August and 3rd of October on board the chartered RV Ramón Margalef and the RV Emma Bardán, both equipped with scientific echosounders (Boyra et al., 2022; WD to WGACEGG). This year, the sampling strategy was modified by increasing the inter-transect distance from 15 to 18 nm. This was done to reduce the risk of underestimation bias due to coverage issues because of bad weather, allowing also to increase the time devoted to fishing. With this change, the sampling design is intended to be more systematic, returning to the design that was acquired during the first three years of the JUVENA campaign. It assumes ~4% uncertainty (Boyra et al., 2013) in exchange for avoiding a potential underestimate of biomass. Geostatistical simulations are currently underway to estimate the uncertainty in the acoustic interpolation using the entire time-series. The survey covered from 7º22′ W in the Cantabrian area to 47º65′ N in the French coast, with a total of 98 hauls to identify the species detected by the acoustic equipment, 69 of which were positive of anchovy (Figure 3.3.3.1). As usual, most of the biomass of juveniles was located off-the-shelf or in the outer part of the shelf in the first layers of the water column (Figure 3.3.3.2). The area of distribution of juvenile anchovy this year was among the highest in the temporal series, which represents a high estimation (Figure 3.3.3.3). The mean size of anchovy was 8.6 cm long, above the average of the time-series.

The biomass of juveniles estimated for this year was around 481 000 tonnes (Table 3.3.3.1). This value represents a high estimation in 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

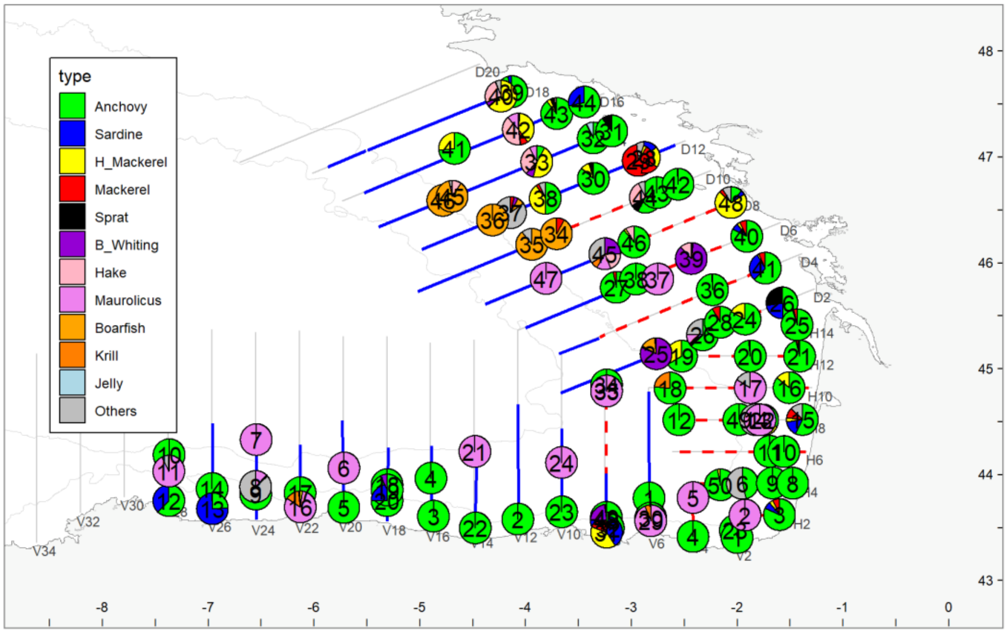


Figure 3.3.3.1: Bay of Biscay anchovy: Survey transects and species composition of the pelagic hauls in JUVENA 2022.

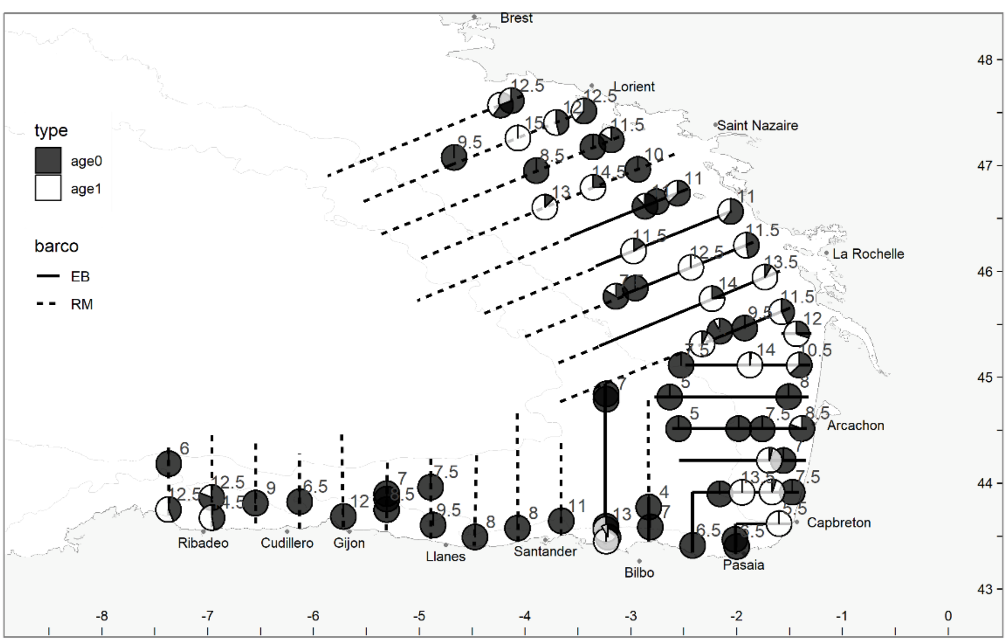
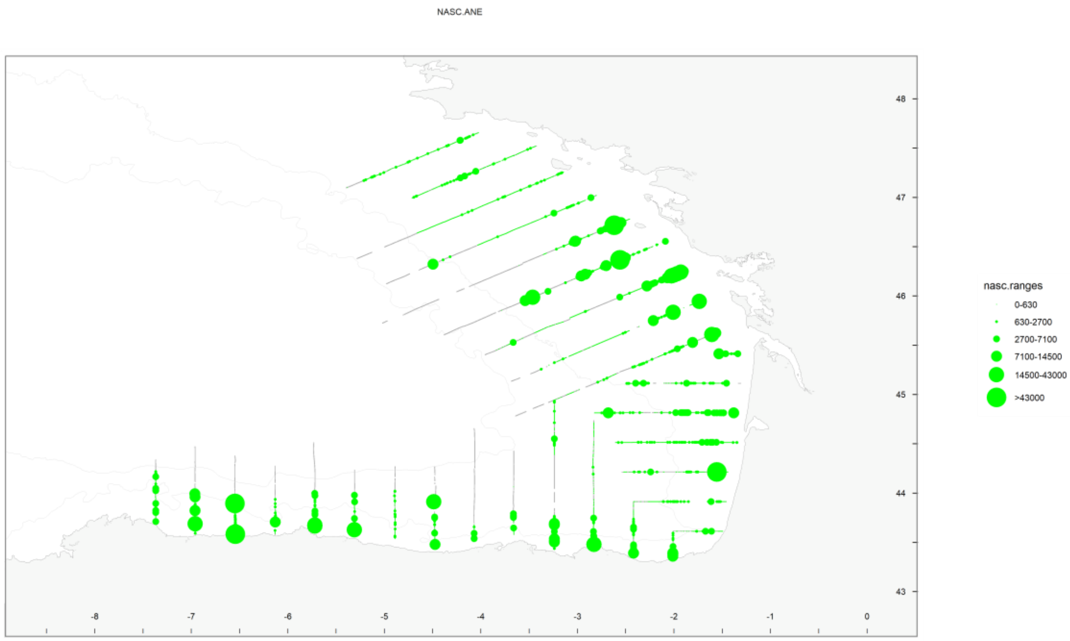


Figure 3.3.3.2: Bay of Biscay anchovy: Positive area of anchovy in JUVENA 2022. The pie charts show the percentage of juveniles (white) and adults (black) in the fishing hauls.



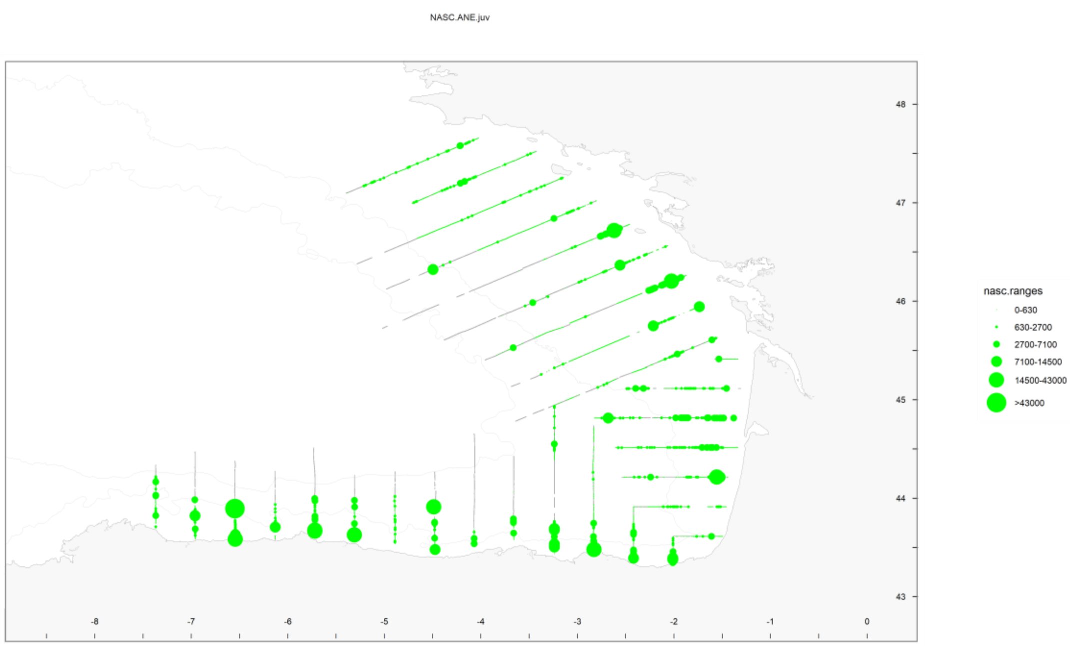


Figure 3.3.3.3: Bay of Biscay anchovy: Bubble maps representing acoustic backscattering by ESDU of 0.1 nm for total anchovy (top) and age 0 anchovy (bottom) in JUVENA 2022.

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 2022 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 2022 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 2022 both the DEPM and the acoustic surveys provided similar SSB estimates

(198 741 and 180 749 t respectively). The largest discrepancy between the SSB estimates from the DEPM and acoustic surveys occurred in 1991, 2000, 2002, 2012, 2015 and 2021.

The agreement between both surveys is usually higher when estimating the relative age composition of the population. In 2022 the DEPM survey age 1 biomass proportion was around 0.42 and the acoustic age 1 biomass proportion was around 0.41 (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 2022 survey index is well above the average value of the temporal time-series, 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 2021 (64 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 2022, the preliminary total catch was around 21 163 t in the first half of the year and 4333 t in the second half. The latter was under the assumption that the November and December catches were 612t (2.4% of the total catch which is the average % of November and December French catches in 2010–2021). Definitive 2022 catch estimates will be provided in WGHANSA 2023. Regarding the age structure of the catches, age 1 proportion in the catches in the first semester in 2022 was 0.23, which is below 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 spawning 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 2022 is approximately 137 278t, which is among the three highest in the time-series, and the 90% probability interval is around 94 268t and 194 166t. This probability interval is among the widest in the time-series, accounting for the lack of PELGAS 2020 and the discrepancies observed in the surveys of the last years. The posterior median of recruitment in 2022 is around 82 388t and the 90% probability interval is between 30 964t and 206 732t. The posterior distribution of recruitment in 2022 is wide because only the JUVENA 2022 survey provides direct information about that recruitment (age 1 biomass) level. Assuming no fishing takes place in 2022, the SSB in 2022 is estimated around 135 608t with a 90% probability interval around 82 692t and 254 490t (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 (i.e. 2020 and 2021) large negative residuals are observed for JUVENA recruitment index, which should be further investigated in next years.

The final estimates are compared with last year's November assessment (ICES, WGHANSA 2021) in Figure 3.5.1.11. In general, the results from both assessments are similar except to small changes in the perception of the last three years. Recruitment in 2022 has been revised upwards, while recruitment in 2020 and 2021 slightly downwards. Fishing mortalities in the first semester of 2020 and 2021 are slightly larger than in last year's assessment. As a result, biomasses in 2020 and 2021 are smaller than in last year's assessment.

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	
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
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

	BIOMAN			PELGAS			JUVENA	CATCH				GROWTH	
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	4,794	21,163	NA	4,333	NA	NA
2,023	NA	NA	NA	NA	NA	NA	481,893	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	0.684	0.831	1.007	Catchability of the DEPM B index
qac	1.223	1.452	1.722	Catchability of the Acoustic B index
qrobs	0.027	0.480	8.440	Parameter of the observation equation for the juvenile index
krobs	0.919	1.185	1.453	Parameter of the observation equation for the juvenile index
psidepm	2.325	4.013	6.836	Precision (inverse of variance) of the observation equation of DEPM B index
psiac	4.582	7.985	13.310	Precision (inverse of variance) of the observation equation of Acoustic B index
psirobs	0.962	1.801	3.139	Precision (inverse of variance) of the observation equation of juvenile index
xidepm	3.407	4.075	4.791	Variance-related parameter for the observation equation of DEPM age 1 proportion
xiac	2.816	3.393	3.945	Variance-related parameter for the observation equation of Acoustic age 1 proportion
xicatch	2.354	2.693	3.015	Variance-related parameter for the observation equation of age 1 proportion in the catch
B0	16,046	20,858	26,452	Initial biomass
mur	10.329	10.613	10.884	Median (in log scale) of the recruitment process
psir	0.759	1.155	1.679	Precision (in log scale) of the recruitment process
sage1sem1	0.393	0.462	0.540	Age 1 selectivity during the 1st semester
sage1sem2	0.852	1.027	1.239	Age 1 selectivity during the second semester
G1	0.487	0.541	0.599	Intrinsic growth at age 1
G2	0.175	0.227	0.285	Intrinsic growth at age 2+
psig	20.434	28.282	38.333	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	11,942	15,676	20,599	15,706	20,468	26,455	0.978	1.267	1.641	0.275	0.380	0.543	0.544	0.703	0.916
1,988	25,736	30,749	37,612	23,346	28,281	35,121	0.836	1.068	1.337	0.308	0.415	0.552	0.410	0.509	0.617
1,989	6,406	8,929	12,363	10,556	14,917	20,746	0.733	1.004	1.364	0.141	0.208	0.313	0.397	0.552	0.780
1,990	58,961	67,249	77,841	45,566	52,683	62,267	1.025	1.268	1.542	0.584	0.773	1.012	0.542	0.640	0.740
1,991	17,576	23,016	30,221	21,943	29,241	38,440	0.902	1.184	1.536	0.211	0.300	0.432	0.471	0.619	0.825
1,992	67,709	86,090	108,999	52,822	70,402	91,931	0.928	1.241	1.658	0.281	0.407	0.598	0.405	0.529	0.704
1,993	51,772	65,183	80,184	60,386	72,428	86,753	0.710	0.890	1.120	0.463	0.603	0.784	0.453	0.543	0.651
1,994	33,205	41,119	50,723	38,354	47,111	58,246	0.957	1.196	1.491	0.493	0.665	0.906	0.577	0.714	0.877
1,995	34,129	44,812	58,304	28,453	39,486	53,966	1.185	1.605	2.171	0.266	0.398	0.619	0.539	0.737	1.023
1,996	40,583	50,333	62,070	38,354	46,426	57,136	0.995	1.281	1.631	0.554	0.757	1.030	0.576	0.708	0.857
1,997	30,542	39,429	50,969	33,931	44,010	57,461	0.513	0.676	0.884	0.442	0.627	0.914	0.356	0.465	0.603
1,998	70,165	90,601	116,758	69,088	89,497	115,198	0.362	0.479	0.638	0.376	0.541	0.795	0.273	0.351	0.454
1,999	30,158	44,550	63,205	50,539	66,799	87,168	0.419	0.553	0.744	0.318	0.446	0.636	0.298	0.389	0.514
2,000	74,036	90,611	109,498	75,924	91,838	109,575	0.590	0.738	0.926	0.315	0.410	0.544	0.337	0.402	0.486
2,001	62,514	73,370	86,889	77,598	89,242	103,113	0.565	0.680	0.822	0.425	0.531	0.662	0.389	0.450	0.517
2,002	9,190	12,763	17,723	31,278	37,719	45,892	0.464	0.567	0.690	0.413	0.533	0.680	0.381	0.464	0.559

	R (tonnes)			SSB (tonnes)			fsem1			fsem2			Harvest rate		
2,003	15,397	19,580	24,294	22,059	26,910	32,871	0.314	0.396	0.494	0.521	0.682	0.910	0.319	0.389	0.475
2,004	24,548	29,988	37,350	24,186	29,990	37,974	0.693	0.891	1.136	0.474	0.660	0.904	0.426	0.540	0.669
2,005	2,699	4,152	6,156	10,159	14,022	19,334	0.118	0.163	0.228	0.000	0.000	0.000	0.058	0.080	0.111
2,006	11,409	15,691	21,235	14,105	19,130	25,388	0.187	0.253	0.345	0.008	0.012	0.017	0.069	0.092	0.124
2,007	15,154	20,809	28,124	21,872	28,812	37,510	0.011	0.014	0.019	0.000	0.000	0.000	0.004	0.005	0.006
2,008	6,036	8,754	12,694	17,641	22,959	29,614	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2,009	6,768	9,625	13,674	14,806	19,163	24,750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2,010	35,771	46,659	61,153	36,619	47,259	61,102	0.322	0.423	0.543	0.145	0.204	0.286	0.165	0.213	0.275
2,011	87,995	110,485	140,126	92,737	116,009	145,188	0.239	0.307	0.391	0.054	0.072	0.097	0.100	0.125	0.156
2,012	34,158	44,839	58,040	77,500	95,732	118,687	0.161	0.202	0.254	0.124	0.160	0.206	0.121	0.150	0.185
2,013	28,597	37,721	49,476	53,566	67,375	84,313	0.296	0.375	0.475	0.094	0.123	0.162	0.167	0.209	0.263
2,014	55,374	71,460	92,058	66,318	84,623	106,780	0.373	0.475	0.607	0.116	0.155	0.211	0.183	0.231	0.295
2,015	87,748	109,804	140,167	102,765	126,223	157,264	0.351	0.446	0.558	0.131	0.173	0.229	0.180	0.224	0.275
2,016	39,156	51,350	69,062	76,434	96,296	122,448	0.283	0.365	0.460	0.083	0.109	0.143	0.158	0.201	0.253
2,017	51,814	66,575	86,259	67,758	86,851	112,038	0.515	0.667	0.857	0.071	0.096	0.130	0.232	0.299	0.384
2,018	86,140	109,836	142,234	95,440	122,060	158,569	0.459	0.602	0.779	0.077	0.106	0.145	0.194	0.252	0.322
2,019	51,488	69,984	94,918	80,052	107,430	142,885	0.381	0.511	0.685	0.071	0.099	0.138	0.188	0.250	0.335
2,020	94,602	128,389	175,558	115,953	155,351	206,898	0.208	0.281	0.379	0.117	0.164	0.230	0.122	0.162	0.218
2,021	103,540	141,682	192,774	135,599	187,017	253,399	0.252	0.343	0.479	0.040	0.057	0.081	0.110	0.149	0.206

	R (tonnes)			SSB (tonnes)			fsem1			fsem2			Harvest rate		
2,022	43,476	65,158	98,865	94,268	137,278	194,166	0.243	0.342	0.491	0.057	0.084	0.126	0.131	0.186	0.270
2,023	30,964	82,389	206,732	82,692	135,608	254,490	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

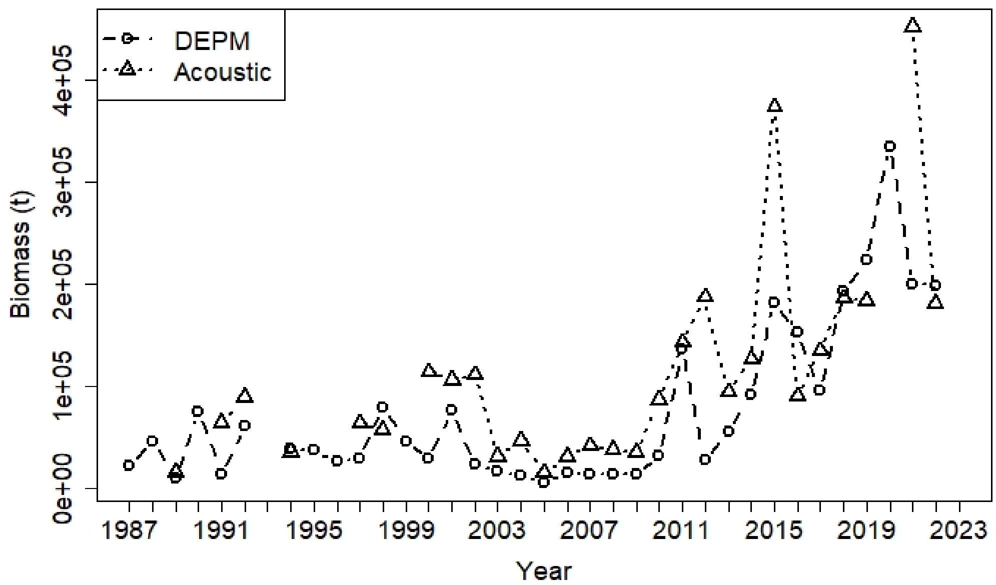


Figure 3.5.1.1: Bay of Biscay anchovy: Historical series of spawning–stock biomass estimates and the corresponding confidence intervals from DEPM (solid line and circles) and acoustics (dashed line and triangles).

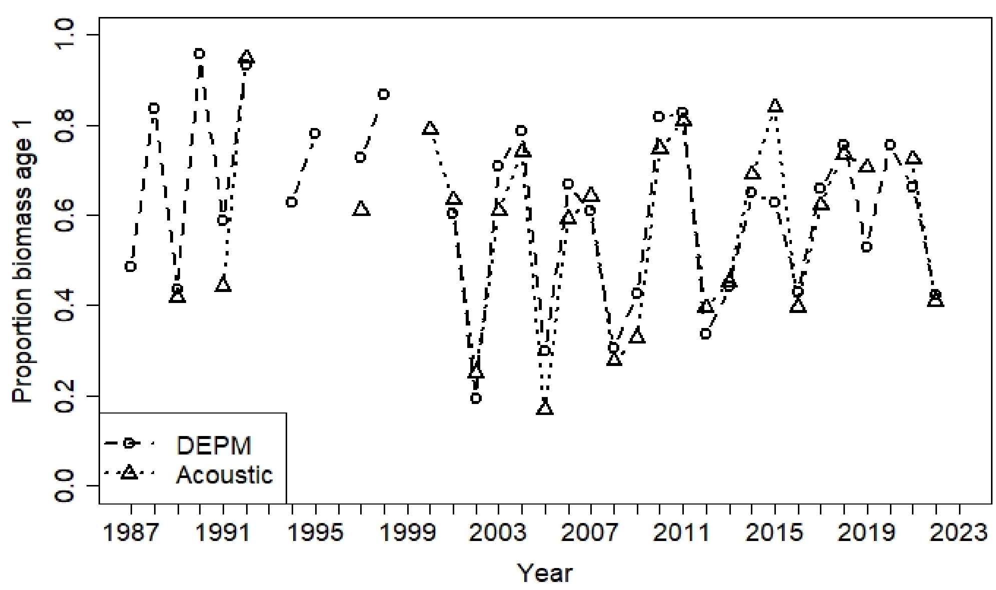


Figure 3.5.1.2: Bay of Biscay anchovy: Historical series of age 1 biomass proportion estimates from DEPM (dashed line and circles) and acoustics (dotted line and triangles).

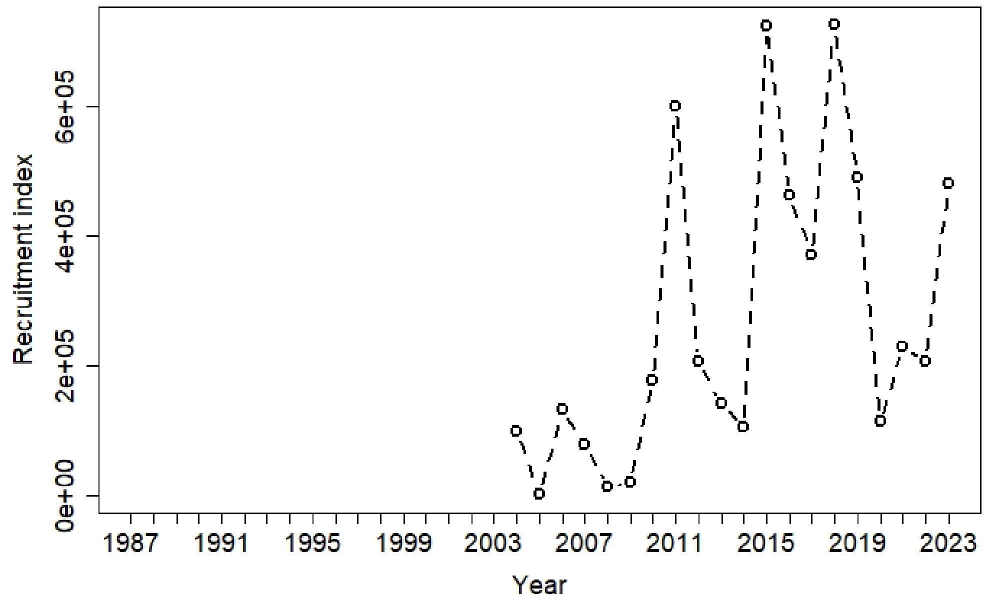


Figure 3.5.1.3: Bay of Biscay anchovy: Historical series of the juvenile abundance index from the autumn acoustic survey JUVENA that is related to recruitment (age 1) next year.

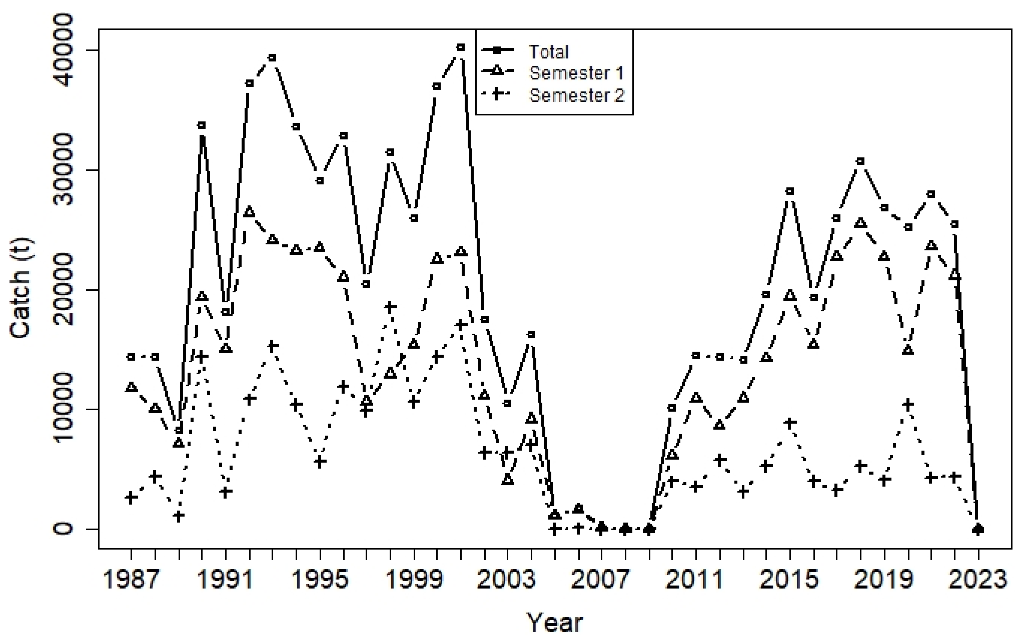


Figure 3.5.1.4: Bay of Biscay anchovy: Historical series of total catch (solid line) and catch by semesters (dashed and dotted lines for the first and second semester respectively). Note that the catch in 2022 is provisional and the catch in 2023 is set at zero.

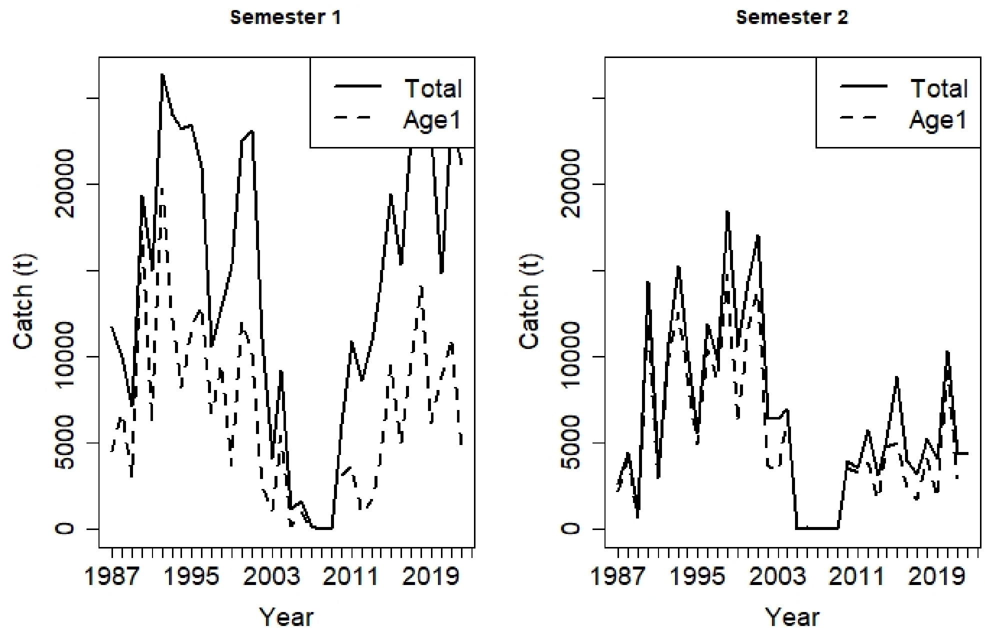


Figure 3.5.1.5: Bay of Biscay anchovy: Historical series of total (solid line) and age 1 (dashed line) catch (in tonnes). The left panel corresponds to the first semester and the right panel to the second semester. Note that the catch in 2022 is provisional.

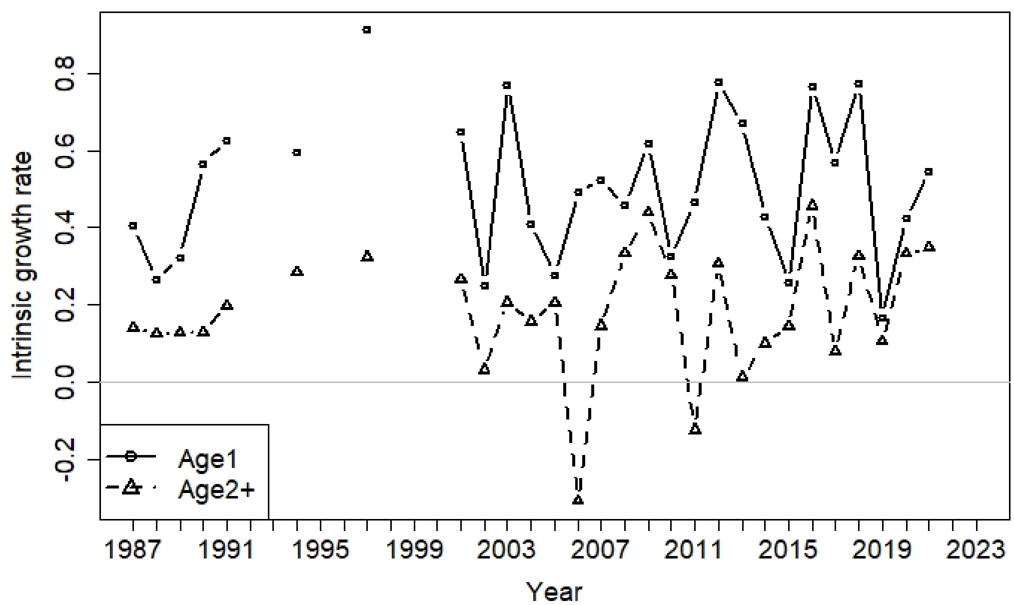


Figure 3.5.1.6: Bay of Biscay anchovy: Historical series of intrinsic growth rates by age as estimated from the mean weights-at-age of the stock.

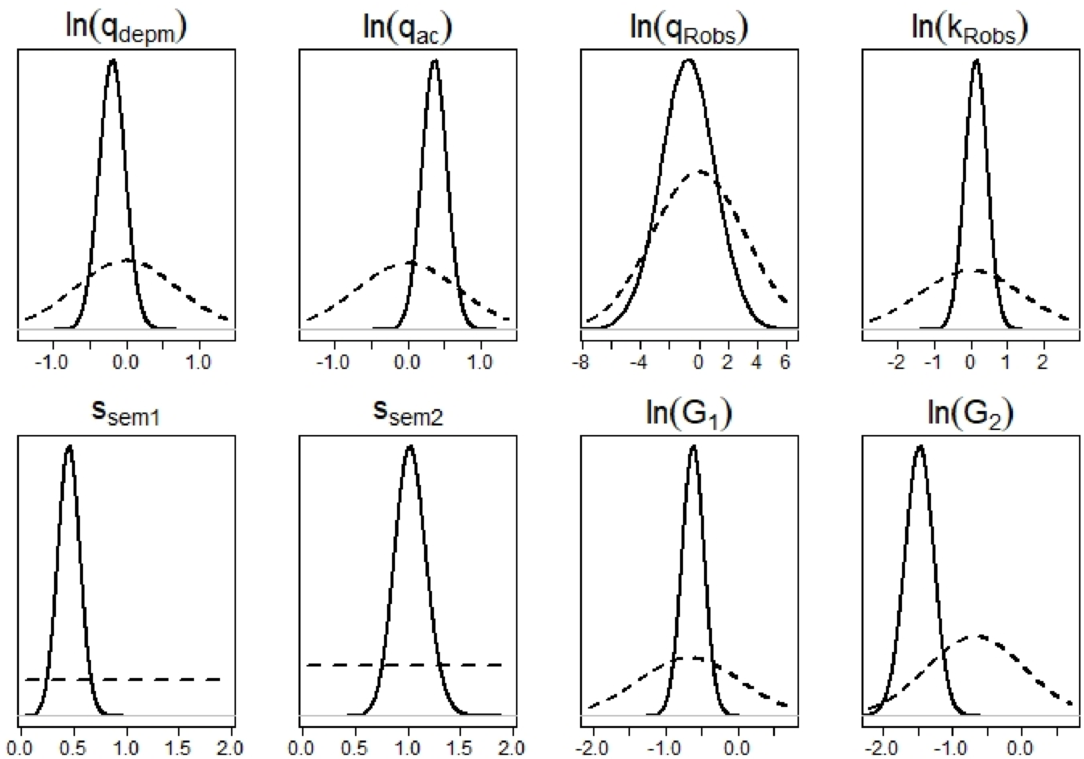
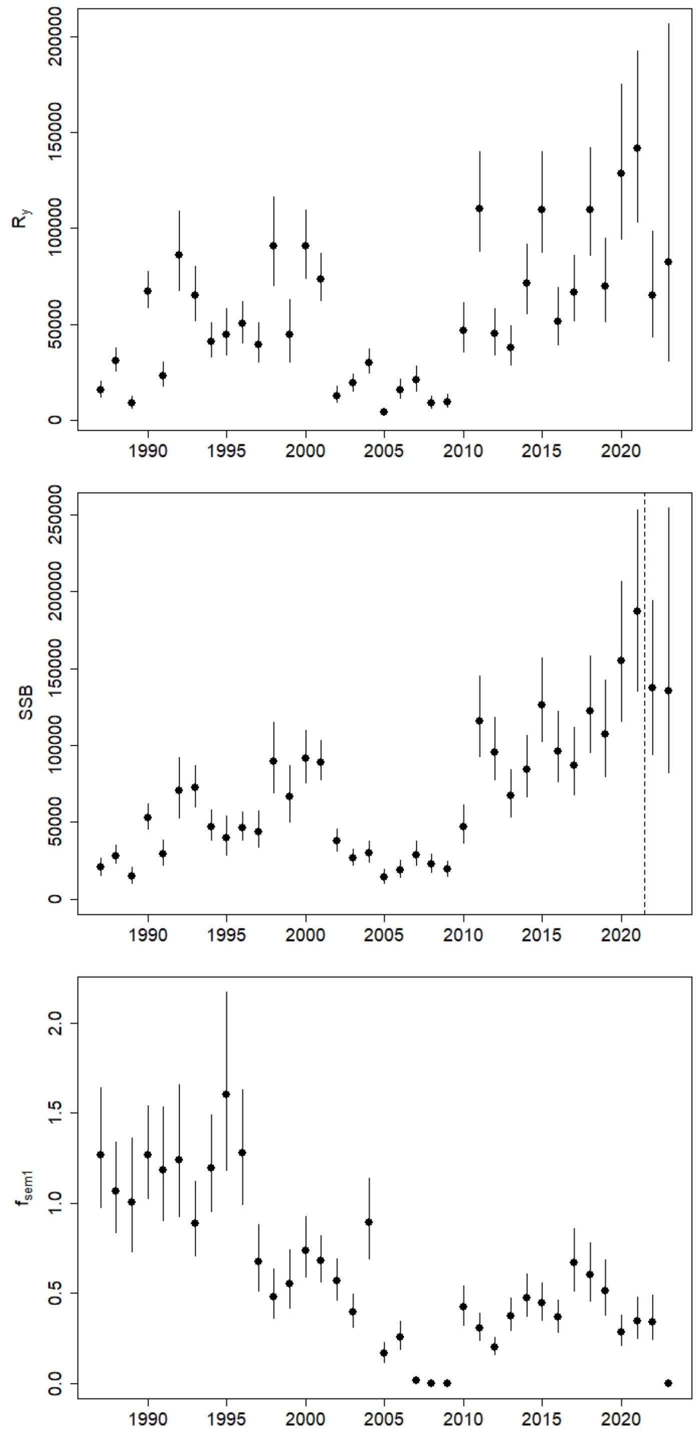


Figure 3.5.1.7: Bay of Biscay anchovy: Comparison between the prior (dotted line) and posterior distribution (solid line) for some of the parameters of CBBM.


R_y
SSB
f_sem1
1990
1995
2000
2005
2010
2015
2020

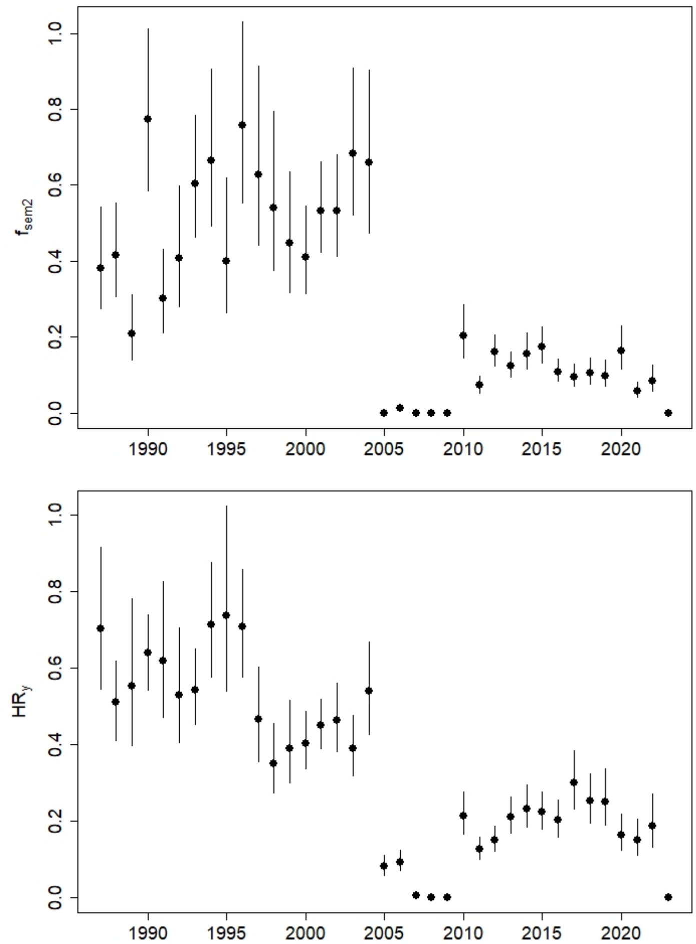


Figure 3.5.1.8: Bay of Biscay anchovy: Posterior median (bullet points) and 90% probability intervals (solid lines) for the recruitment (age 1 in mass in January), the spawning–stock biomass, the fishing mortality for the first and second semesters and the harvest rates (catch/biomass) from the CBBM. It must be taken into account that the fishing mortalities in 2022 are fixed at zero and SSB in 2022 results from no fishing in 2022.

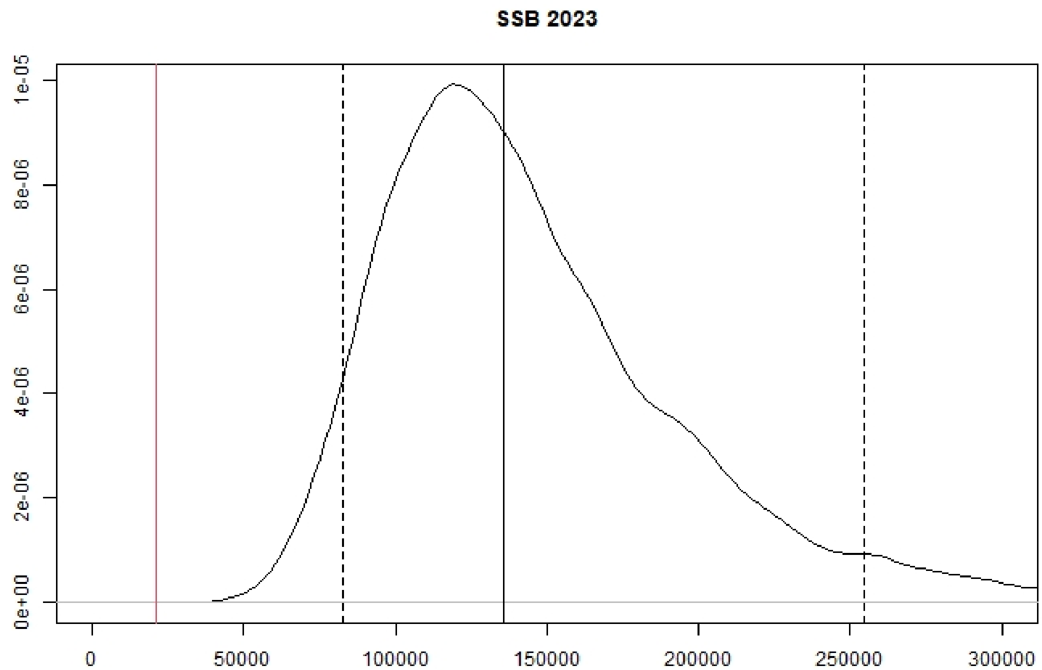


Figure 3.5.1.9: Bay of Biscay anchovy: Posterior distribution of SSB in 2022, under the assumption of no fishing during 2022. The red vertical line represents B_{lim} at 21 000 tonnes.

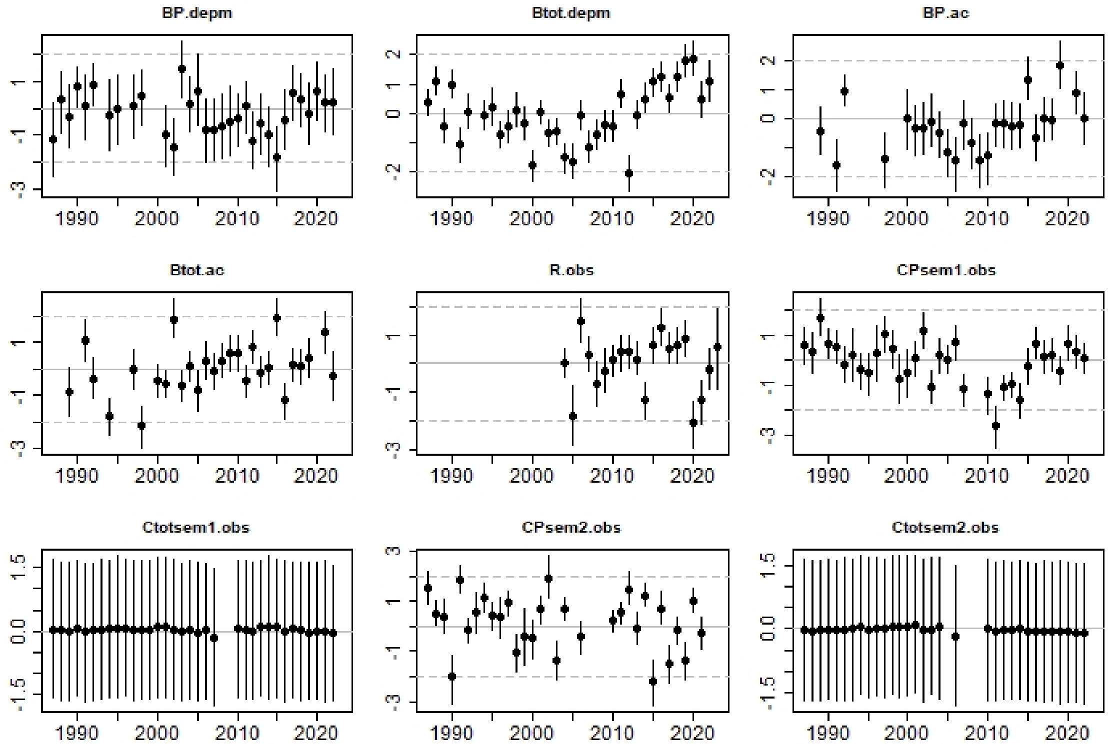
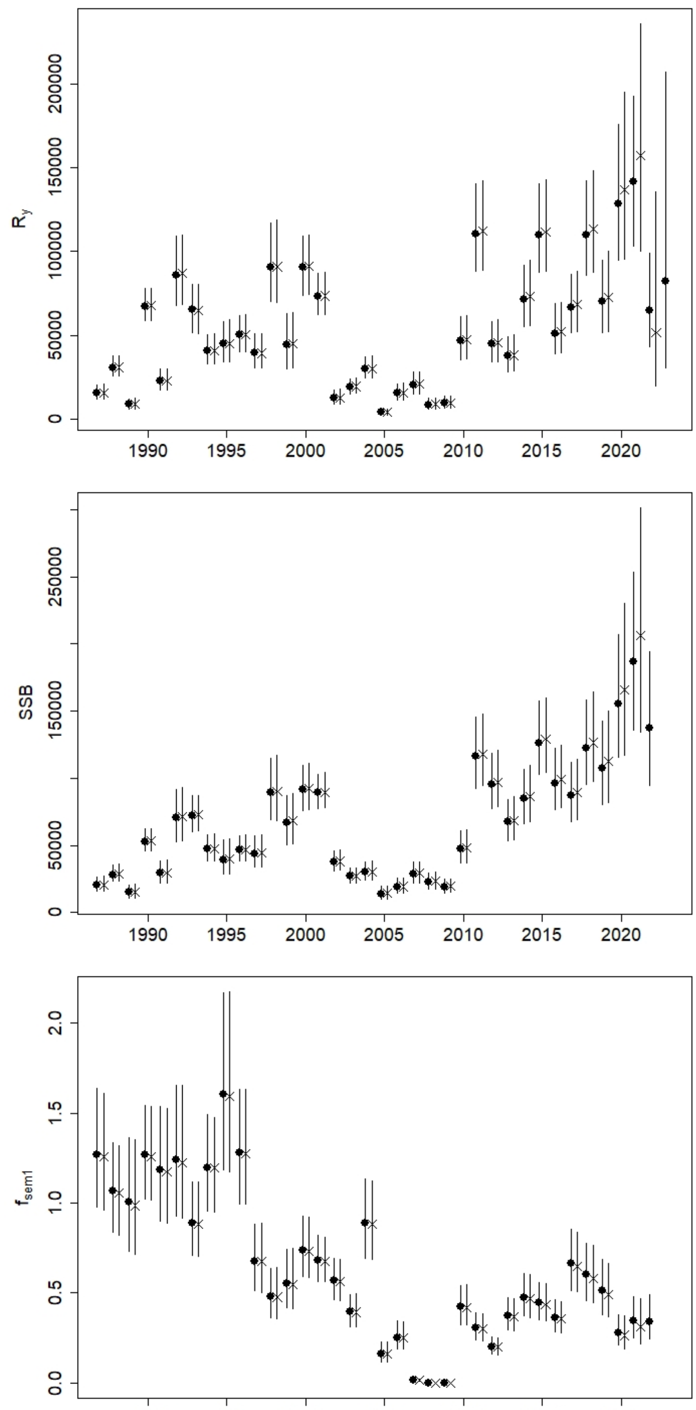


Figure 3.5.1.10: Bay of Biscay anchovy: Pearson residual medians and 90% probability intervals to the survey and catch observations used in the CBBM. From top to bottom and from left to right, residuals of the age 1 biomass proportion from the DEPM, total biomass from the DEPM, age 1 biomass proportion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


Ry
0
50000
100000
150000
200000
SSB
250000
fsem1
0.0
0.5
1.0
1.5
2.0
1990
1995
2000
2005
2010
2015
2020

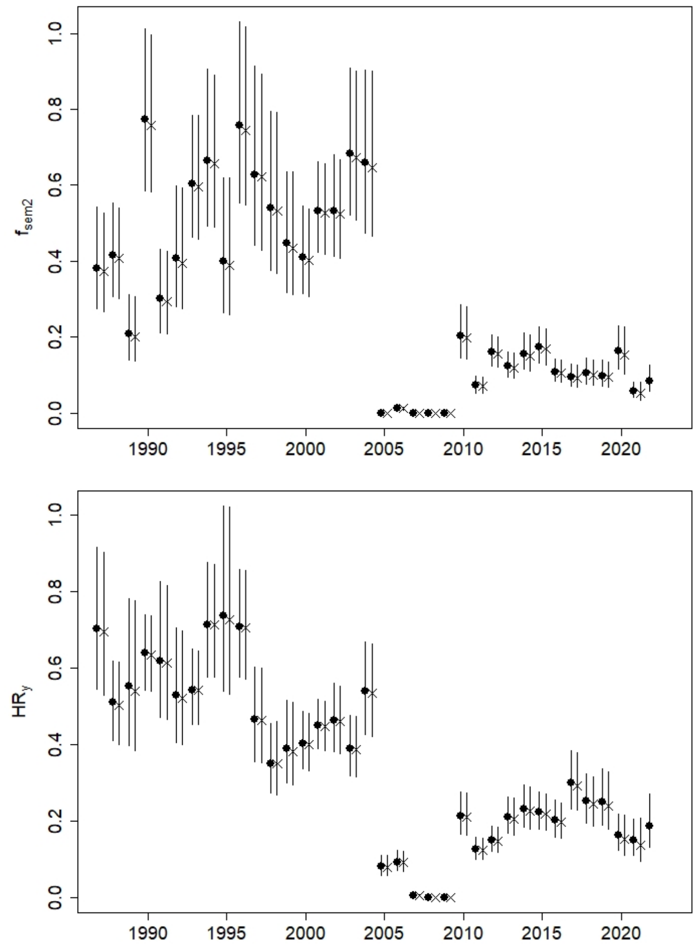


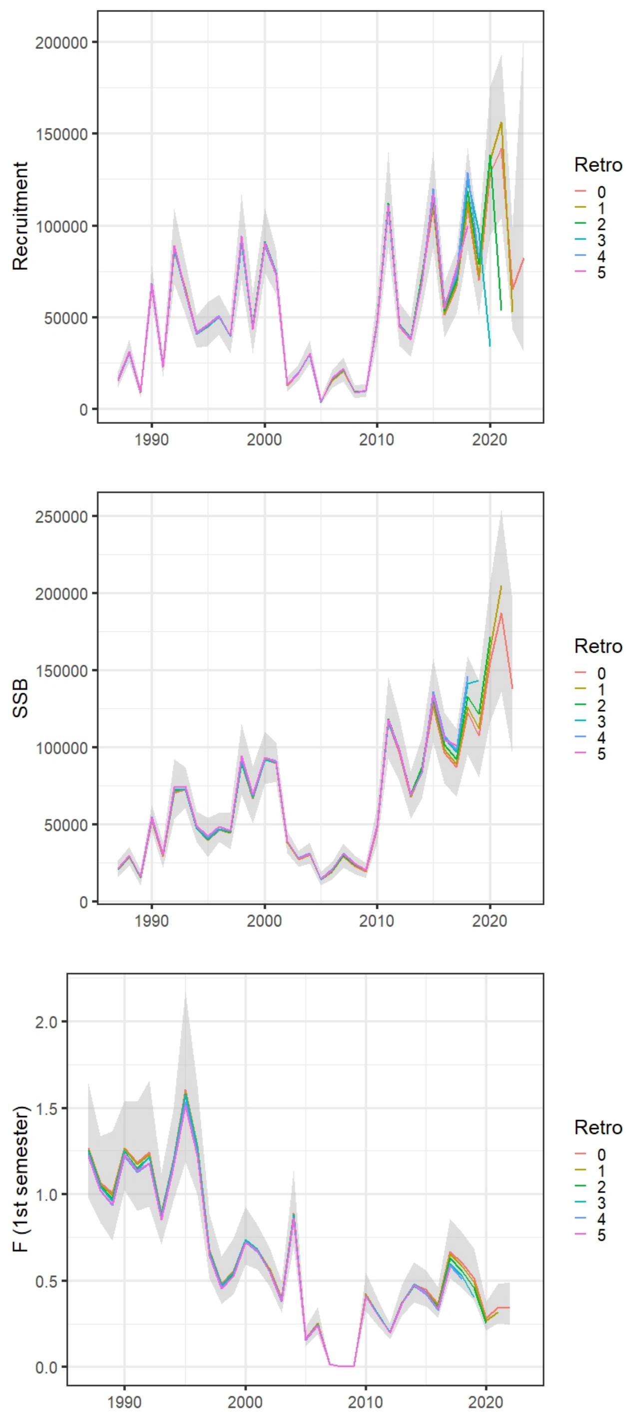
Figure 3.5.1.11: Bay of Biscay anchovy: From top to bottom comparison of the posterior median (points) and 90% probability intervals (solid lines) of the recruitment (age 1 in mass in January), the spawning–stock biomass, the fishing mortality in the first and in the second semester and the harvest rate assessed in WGHANSA 2021 (cross) and in WGHANSA 2022 (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. Furthermore, the estimates from the retrospective analysis are in general within the 90% probability interval of last year's assessment (Figure 3.5.2.1). The only exceptions are recruitments in 2020 and 2021 that have been strongly revised upwards in the following year's assessments.

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 negative in the other years, with high absolute values for 2020 and 2021 (Figure 3.5.2.2). It ranged between -0.75 and 0.12 and the Mohn's rho was calculated at -0.29. The relative bias for SSB in the terminal year was always positive (Figure 3.5.2.2). The relative bias for SSB ranged between 0.1 and 0.33, and the Mohn's rho was 0.18. Mohn's rho for the fishing mortality by semester and annual harvest rate was -0.14, -0.19 and -0.15 respectively. The relative bias for the three time-series was negative in all the years (Figure 3.5.2.2).



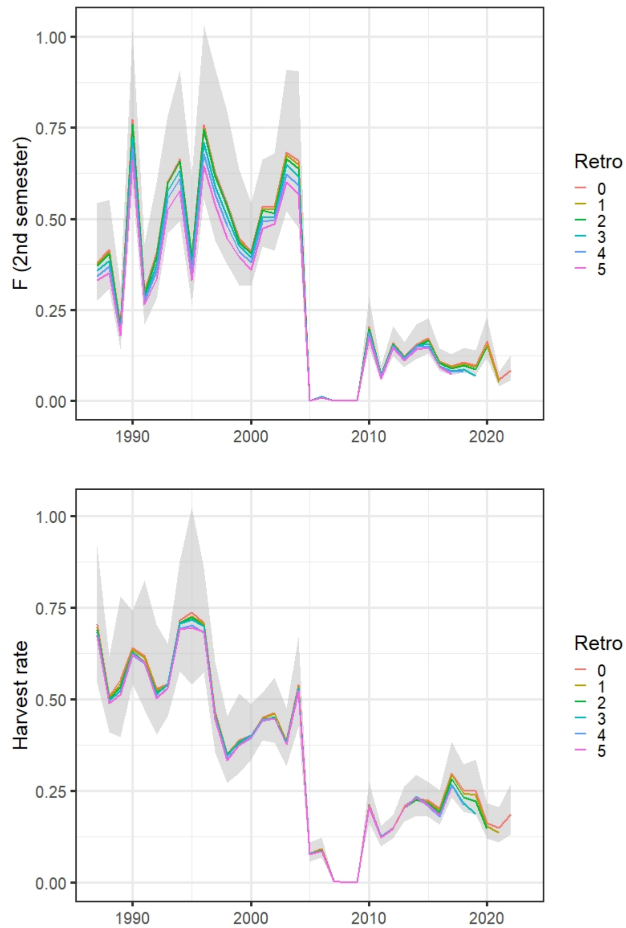


Figure 3.5.2.1: Bay of Biscay anchovy: From top to bottom retrospective pattern of recruitment (age 1 in tonnes on 1st January), SSB, fishing mortality on 1st and second semesters and harvest rate. The shaded are represents the 90% probability intervals from this year's assessment.

Figure 3.5.2.2: Bay of Biscay anchovy: From top to bottom and from left to right relative bias of recruitment (age 1 in tonnes on 1st January), SSB, fishing mortality on 1st and second 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. All these patterns should be further investigated in next years.

The catch data for 2022 are preliminary and the definite data will be available for WGHANSA 2023. As a result, the fishing mortality estimates in 2022 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 2023 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 2023 from the assessment in November. The median recruitment (age 1 biomass on 1st January) in 2023 for the November projections is around 82 389t.

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 2022, biomass at-age 2+ at the beginning of 2022, 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 2023 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 2023 is 120 428 t (Table 3.6.3). When the projection is stochastic, the median SSB in 2022 is around 121 860 t with a 90% probability interval between 69 110t and 240 614t (Figure 3.6.3). The probability of SSB in 2022 being below B_{lim} is below 0.001.

Starting from the posterior distribution of recruitment (age 1 biomass) and biomass at-age 2+ on the 1st January 2023, the population was projected forward for one year. Total allowable catch during 2023 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 2023 were derived for each of the catch options. For all cases, the probability of SSB in 2023 being below B_{lim} is below 0.03 (Table 3.6.1 and Figure 3.6.4) and the corresponding median SSB values in 2023 are above 85 000t (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 2023 being below B_{lim} is lower than 0.05 for total catches up to 138 113 t (Table 3.6.3 and Figure 3.6.5). The harvest rate in 2022 was equal to 0.186. The same harvest rate in 2023 would lead to catches around 23 136 t and SSB around 124 568 t, with probability of SSB being below Blim lower than 0.001.

The final catch options table for 2023 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 reopening 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 2022 of being below Blim under different catch options for 2023 and alternative catch allocation by semesters.

P(SSB < Blim)			% CATCHES IN THE FIRST SEMESTER 2023										
			0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
R estimated	TOTAL CATCH 2023	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	0.0000	0.0000
		30000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		35000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		40000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
		45000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0011
		50000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0011	0.0020
		55000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0020	0.0033
		60000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0015	0.0029	0.0069
		65000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0024	0.0053	0.0131
		70000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0018	0.0036	0.0109	0.0202

Table 3.6.2: Bay of Biscay anchovy: Median SSB in 2022 under different catch options for 2023 and alternative catch allocation by semesters.

P(SSB < Blim)		% CATCHES IN THE FIRST SEMESTER 2023										
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
R estimated	TOTAL CATCH 2023											
	0	135,608	135,608	135,608	135,608	135,608	135,608	135,608	135,608	135,608	135,608	135,608
	5000	135,608	135,268	134,927	134,584	134,241	133,898	133,556	133,212	132,870	132,528	132,185
	10000	135,608	134,927	134,241	133,556	132,870	132,185	131,495	130,801	130,104	129,406	128,717
	15000	135,608	134,584	133,556	132,528	131,495	130,453	129,406	128,373	127,336	126,297	125,251
	20000	135,608	134,241	132,870	131,495	130,104	128,717	127,336	125,950	124,552	123,132	121,718
	25000	135,608	133,898	132,185	130,453	128,717	126,986	125,251	123,488	121,718	119,960	118,206
	30000	135,608	133,556	131,495	129,406	127,336	125,251	123,132	121,012	118,908	116,798	114,663
	35000	135,608	133,212	130,801	128,373	125,950	123,488	121,012	118,557	116,091	113,592	111,084
	40000	135,608	132,870	130,104	127,336	124,552	121,718	118,908	116,091	113,235	110,363	107,456
	45000	135,608	132,528	129,406	126,297	123,132	119,960	116,798	113,592	110,363	107,095	103,839
	50000	135,608	132,185	128,717	125,251	121,718	118,206	114,663	111,084	107,456	103,839	100,131
	55000	135,608	131,841	128,028	124,198	120,311	116,446	112,521	108,551	104,564	100,501	96,387
	60000	135,608	131,495	127,336	123,132	118,908	114,663	110,363	106,011	101,610	97,140	92,623
	65000	135,608	131,148	126,642	122,072	117,503	112,878	108,186	103,471	98,641	93,760	88,793
	70000	135,608	130,801	125,950	121,012	116,091	111,084	106,011	100,871	95,638	90,322	85,025

Table 3.6.3: Bay of Biscay anchovy: Catch options for 2023 under the assumption that 60% of the catches were taken in the first semester.

		STOCHASTIC	DETERMINISTIC	
Basis	Catch 2023	P(SSB 2023<Blim)	SSB 2023	Harvest rate 2023
G3 with hr=0.4	33,000	0.000	120,428	0.274
Zero catches	0	0.000	134,125	0.000
Same deterministic harvest rate as 2022	23,136	0.000	124,568	0.186
P(SSB2023<Blim)=0.05	138,113	0.050	73,291	1.884
Other options	10,000	0.000	130,020	0.077
Other options	20,000	0.000	125,876	0.159
Other options	30,000	0.000	121,692	0.247
Other options	40,000	0.000	117,465	0.341
Other options	50,000	0.000	113,195	0.442

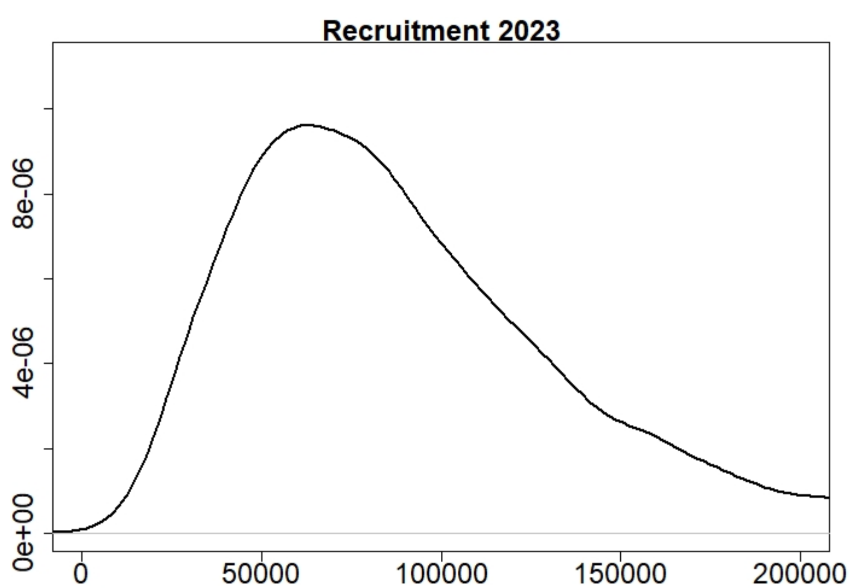


Figure 3.6.1: Bay of Biscay anchovy: Posterior distribution of recruitment (age 1 biomass at the beginning of the year) in 2023.

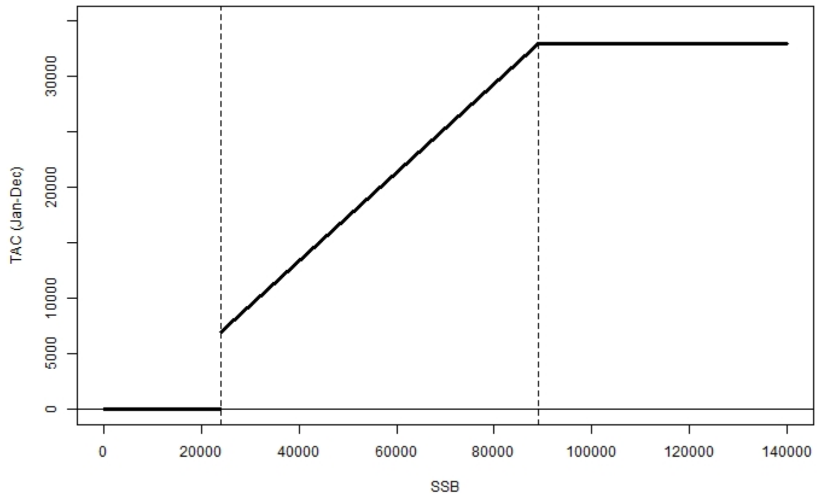


Figure 3.6.2: Bay of Biscay anchovy: Harvest control rule G3 with harvest rate of 0.4 according to which the TAC from January to December is set as a function of the expected spawning–stock biomass (on 15th May) in the management year.

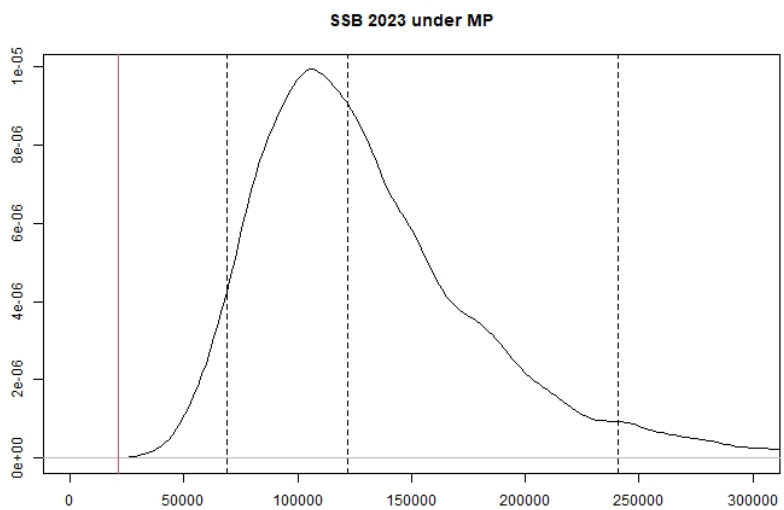


Figure 3.6.3: Bay of Biscay anchovy: Posterior distribution of SSB in 2023 if the annual catch is set according to the LTMP at 33 000 t and 60% of the catch is taken during the first semester. Vertical black dashed lines represent the 5, 50 and 95 posterior quantiles, whereas the red vertical line is Blim (21 000 t).

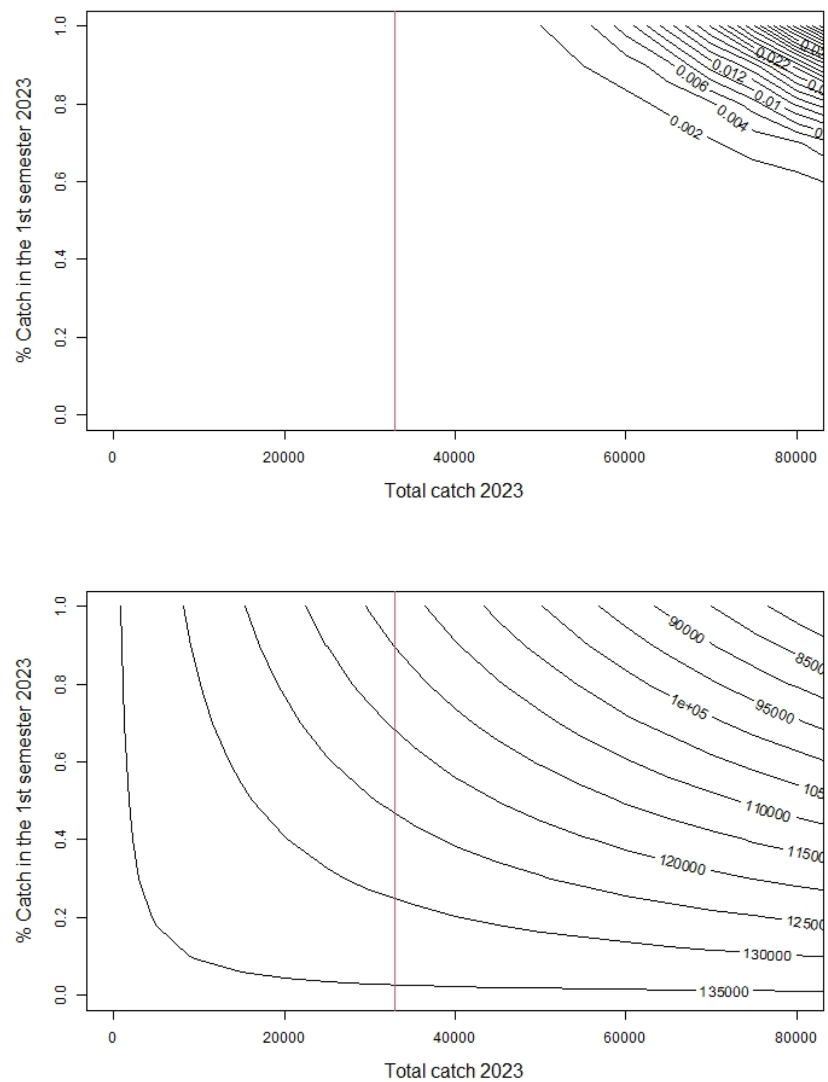


Figure 3.6.4: Bay of Biscay anchovy: Contour plots of probability of SSB in 2023 being below Blim (on the top) and median SSB in 2023 (on the bottom) depending on the total catch in 2023 (x-axis) and the % of the catch in the first semester (y-axis). The vertical red line is set at 33 000 t.

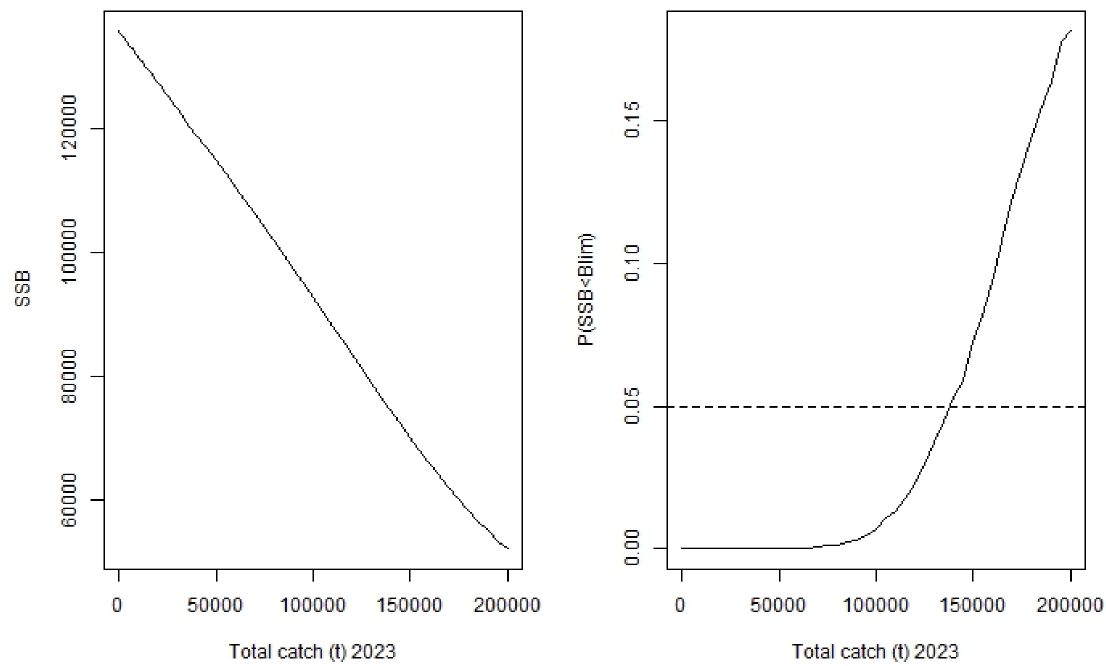


Figure 3.6.5: Bay of Biscay anchovy: SSB in 2023 (on the left) and probability of SSB in 2023 been below Blim (on the right) depending on the total catch taken in 2023 when 60% of the catch is taken during the first semester.

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 $B_{escapement}$, 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 F_{MSY} 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 $B_{escapement}$ 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 uncer-tainty 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 juvenile 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 B_{lim}, 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:

$$TAC_{Jan_y-Dec_y} = \begin{cases} 0 & if \widehat{SSB}_y \leq 24000 \\ -3800 + 0.45\widehat{SSB}_y & if 24000 < \widehat{SSB}_y \leq 64000 \\ 33000 & if \widehat{SSB}_y > 64000 \end{cases}$$

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:

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

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.

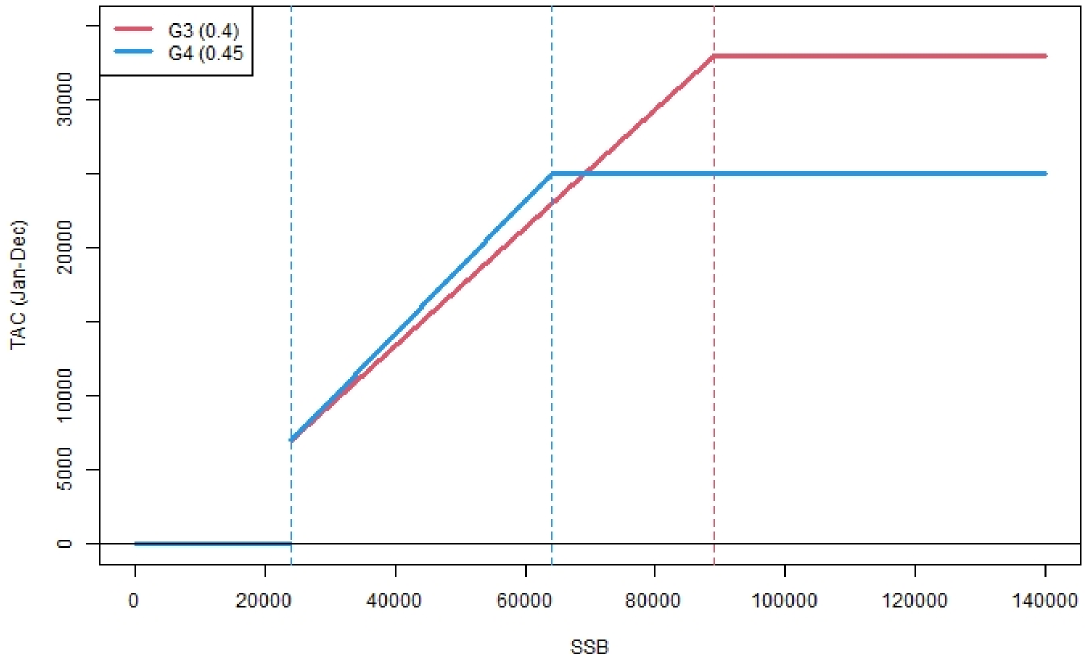


Figure 3.7.3.1: Bay of Biscay anchovy: Harvest control rules G4 with harvest rate of 0.45 (in red) and G3 with harvest rate of 0.4 (in blue) according to which the TAC from January to December is set as a function of the expected spawning–stock biomass (on 15th May) in the management year.

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

Boyra, G., Martínez, U., Cotano, U., Santos, M., Irigoien, X., and Uriarte, A. 2013. Acoustic surveys for juvenile anchovy in the Bay of Biscay: abundance estimate as an indicator of the next year's recruitment and spatial distribution patterns. ICES Journal of Marine Science, 70: 1354–1368.

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.

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.

ICES. 2020. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES Scientific Reports. Report. https://doi.org/10.17895/ices.pub.5977

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

ICES. 2022. Working Group on Acoustic and Egg Surveys for small pelagic fish in Northeast Atlantic (WGACEGG). ICES Scientific Reports.

4 Anchovy in Division 9.a

4.1 ACOM Advice Applicable to the management period July 2021–June 2022

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.

ICES could not give catch advice for 2018 under a management calendar based on calendar years. This is due to the lack of available data on year classes that constitute the bulk of the biomass and catches (no survey indices for such year classes are available at the time of the formulation of the advice). ICES notes, however, that the historical fisheries along the division seem to have been sustainable.

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 interannual 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 2021 to 30th June 2022 that when the precautionary approach is applied, catches from the western component should be no more than 7824 t and catches from the southern component should be no more than 7181 t (no more than 15 005 t for the whole stock). The TAC for this same management period was initially agreed in 15 005 t (Portugal: 7829 t; Spain: 7176 t). After the application of interannual flexibility criteria the national quotas were finally adjusted to 8571 t for Portugal and 8023 t for Spain.

Official anchovy landings in the division in 2021 were of 17 758 t. Estimated total catches were 17 837 t. Provisional estimated catches for the current management calendar are 17 056 t (western component: 11 217 t; southern component: 5839 t).

4.2 Population structure and stock identity

A review of the anchovy substock 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 Golf 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 the working document, WGHANSA supports 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 subdivisions in the western coast (9a North, Central-North and Central-South), and therefore submits it to the ICES Stock Identification Methods Working Group (SIMWG) for consideration.

4.3 The fishery in 2021

4.3.1 Fishing fleets

Anchovy harvesting throughout the Division 9.a was carried out in 2021 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 2021 by a total of 99 vessels (two vessels with unknown technical characteristics are not included in the **Table 4.3.1.1**). From this total, 94 vessels (95%) were purse-seiners (**Table 4.3.1.1**). No information on the number of Portuguese vessels fishing anchovy in 2021 was available to the working group, but it may be assumed that the fleet operating in 2021 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 2021, GoC anchovy fishing was practised by 61 purse-seiners, five vessels less targeting anchovy than in 2020, 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 2021 was estimated at 17 837 t, which represented a 38% increase on the catches landed in the previous year (12 956 t), it becomes in the historical maxima recorded through the time-series (since 1989) and culminates a 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 17 758 t of official landings and 80 t of discards (see **Section 4.3.3**).

As usual, the anchovy fishery in 2021 was almost exclusively harvested by purse-seine fleets (99.6% 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 bycatch) only have targeted anchovy when its abundance was high, as occurred in 2011 and in 2014–2021.

Provisional official landings during the first semester in 2022 amounted to 3502 t (updated until 31st March 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 (mean 2009–2021) were added to account for catches in June 2022 not yet reported. After such computations, the official landings in the Spanish fishery in 9a S during the first semester in 2022 were estimated in 2465 t.

Provisional catches during the current management period (July 2021–June 2022), as the result of summing up total catches from the second semester in 2021 and provisional official (estimated) landings from the first semester in 2022, amounted to 17 056 t for the whole division.

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 2021 catches by subdivision is shown in **Table 4.3.2.2.2**.

Western component

The total catch in 2021 for this stock component was estimated at 10 276 t, which accounted for 82% increase on the 2020 catch (5639 t) and accounted for 58% of the total catch in the division. This 2021 estimate is the historical maximum within its time-series. The fractions composing this total catch in 2021 were: 10 276 t of official landings and 0 t of discards.

Provisional official landings during the first semester in 2022 amounted to 1037 t.

Provisional catches during the current management period (July 2021–June 2022) amounted to 11 217 t.

The distribution of these catches by subdivision is as follows:

Subdivision 9a North

In this Spanish subdivision a total of 747 t was caught in 2021, which accounted for 12% increase in relation to the 2020 catches (309 t), 55% of the total catch estimated for the Western component and 4% for the whole division. Purse seiners were the main responsible for the fishery (99.9% of the total catch in the subdivision). The fishery was concentrated in the third and fourth quarters.

Provisional official landings during the first semester in 2022 amounted to 12 t (up to 17th May 2021). Those ones corresponding to the current management calendar amounted to 705 t.

Subdivision 9a Central-North

This subdivision concentrated a great part of the anchovy fishery in 2021, both in relation to the whole division (53%) and to the Western component (94%): a total catch of 9521 t was estimated (with all of these catches corresponding to official landings; neither unallocated nor discarded catches were reported). These catches represented a 79% increase on the catches estimated the previous year (5327 t), and they become in the historical maximum within its recent time-series. Purse-seiners practically harvested the whole fishery, mainly during the third and fourth quarters in the year.

Provisional official landings during the first semester in 2022 amounted to 1024 t (up to end of April). Official landings for the current management calendar were 10 505 t.

Subdivision 9a Central-South

Anchovy catches from this subdivision were only 8 t (all of them official landings), accounting for a 213% increase in relation to the catches in 2020 (2 t) but still staying this value close to its historical minima. Such catches accounted only for 0.04% both of the total catch in the Western component and on the total catch in the division. The fishery was mainly harvested by purse-seiners, mostly during the third quarter.

No provisional official landings were recorded during the first semester in 2022 (up to end of April) in this subdivision. Official landings during 2021 for the current management calendar were ca. 7 t.

Southern component

Subdivision 9a South

The total catch in 2021 of this stock component was estimated at 7562 t, which accounted for a 3% increase with respect to the 2020 catch (7317 t) and represented 42% of the total catch in the division. The fractions composing this total catch in 2021 were: 7482 t of official landings (Portugal: 109 t, Spain: 7373 t) and 80 t of (Spanish) discards.

Almost the whole of the total catch (99%) was captured by the purse-seine fleet.

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

Provisional official landings during the first semester in 2022 amounted to 2465 t, all of them fished by the Spanish fishery. Preliminary; 692 t, corresponding to 39% of the Spanish official landings in January–May (mean 2009–2021), were added to the Spanish data to account for landings in June 2022 not yet reported. Official landings and total catches during 2021 in the subdivision for the current management calendar were 3311 t and 3374 t, respectively. Preliminary estimates for catches for the current management calendar (July 2021–June 2022) amounted to 5839 t (official landings: 5775 t; discards: 64 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 programmes 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 programmes performed as planned in 2021.

Average discard estimates (in t) in subdivision 9a N for the available time-series (2014–2021) 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 2021 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 2021 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 (14 t) and the bottom-trawl fishery (66 t) mainly during the third quarter. The estimated discards (80 t) represented an annual discard ratio of 0.01 (1.1%) 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 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 (1988–2021) 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 2018–2021 period, which was coupled with steeply increasing catches which resulted 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 three 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 and ALKs in 2021 have been provided for the Spanish fishery in Subdivision 9.a N. No LFD was available for the second quarter landings; hence these landings were raised to the first quarter LFD. Quarterly ALKs were based on half-yearly ALKs made by combining March commercial and *PELACUS* survey samples (for the first and second quarters), and *IBERAS* survey samples/ALK (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 good coverage.

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 0.1% and 1% of the Portuguese catches occurred in the 9.a Central-South and 9.a South (Algarve) subdivisions, respectively. Data were only available for the 3rd and 4th Quarters.

Catch-at-age data in 2021 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 2021 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 2021 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 (mode at 13.5 cm size class), with an annual mean size and weight in catches being estimated at 15.1 cm and 25.6 g, respectively.

Subdivision 9.a Central-North

The size composition of 2021 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 second semester and incidental bottom-trawl catches in the fourth quarter, 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 >95% of all catches. Anchovy size composition in catches from the whole fishery in the second semester 2021 ranged between 12.5 and 19.5 cm size classes (mode at 15.5 cm size class), with a mean size and weight in catches from that semester being estimated at 16.2 cm and 30.4 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 2021 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 5.5 and 17.5 cm size classes, with the modal class located at the 10.5 cm size class. Anchovy mean length and weight in the Spanish 2021 annual catch (11.5 cm and 12.1 g) were quite similar to those values recorded in previous years 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 2021 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 2021 was of 29.2 million fish, composed by ages 0, 1, 2 and 3 anchovies, with ages 0 and 1 accounting for 43% and 42% of the total catch, respectively.

Subdivision 9.a Central-North

Estimates from the fishery in this subdivision in 2021 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 2021 second semester was of 297 million fish, composed by 1, 2 and 3 year old anchovies, which accounted for 58%, 39%, and 3% of the total catch in that semester, respectively.

Subdivision 9.a Central-South

No estimate from this subdivision in 2021 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 2021. Total catches in the Spanish fishery in 2021 were estimated at 618 million fish, which accounted for a 3% increase in relation to the 599 million caught during the previous year. Such a small increase was mainly caused by 19% and 2% increases of ages 1 and 2, respectively, but also by a 26% decrease in Age 0 anchovies. Age 1 group is the dominant age group (72% 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 2021 are shown in **Tables 4.3.6.1** and **4.3.6.2**. Anchovy mean length and weight in the catches were 15.1 cm and 25.6 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 2021, all the age groups experienced a small increase in the mean length and weight in catches, a trend which was not coupled to the exhibited one by the overall mean estimates for the whole exploited population because the relative importance of the Age-0 anchovies.

Subdivision 9.a Central-North

The available estimates for the fishery in 2021 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 of the second semester 2021 from north-western Portugal were 16.2 cm and 30.4 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 2021 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 2021 annual catches were estimated at 11.5 cm and 12.1 g respectively, a slightly lower mean size and higher mean weight than those ones recorded in the previous year. Age-0 and Age-2 anchovies showed lower mean size and weight than in 2020, whereas the reverse trend was recorded in Age-1 anchovies.

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 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 2021 and 2022 WGHANSA meetings.

***PELACUS* series**

PELACUS 0322

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 subsurface 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 intercalibration 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 0422 was conducted between 1st and 26th April 2022 on board the R/V *Vizconde de Eza* instead of on board the vessel routinely used, the R/V *Miguel Oliver*, because the occurrence of electric issues affecting the echosounder in the latter. The start of the survey suffered a one-week delay. Covid-19 issues also occurred at the end of the first leg (13rd April) entailing an interruption of the survey until the 24th April. All these contingencies resulted on a reduction of the available ship time for surveying the Cantabrian Sea to only 5.5 days and a reduced number of fishing stations (27 fishing hauls). Rough weather conditions occurred during the first leg of the survey. 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. Anchovy schools were almost exclusively recorded in the inner part of the Bay of Biscay (zone 8cEe), accounting for

99.9% of the total abundance and biomass estimated for the whole surveyed area. The occurrence of the species in the Subdivision 9a N was incidental. **Figure 4.4.2.1** shows the species contribution (% in number) in each of the valid hauls performed during the survey. A total of 0.3 t anchovies were caught in the whole surveyed area, corresponding to 24 505 specimens, 104 of those were measured (2 kg of fish). Sardine, with a presence in 61% of the fishing hauls accounted for the 38% of the total catch in number (**Table 4.4.2.1**). Anchovy was caught in 19% of the trawl hauls, and represented 9.2% of total catch number. Overall mean length in the catch was 13.59 cm. **Figure 4.4.2.2** shows the distribution area and density derived from the NASC values attributed to this fish species in the surveyed area.

A total of only 2 t, corresponding to 0.1 million fish were estimated in the Subdivision 9.a N, corresponding to one the lowest values of the *PELACUS* time-series (**Table 4.4.2.2**). The population was structured by the age groups 1, 2 and 3, with the bulk of the biomass belonging to age group 1 (75% in biomass, 82% in number). **Figure 4.4.2.3** shows the estimated abundance and biomass by length class, while in **Figure 4.4.2.4** the estimates are shown by age group. **Figure 4.4.2.5** shows the time-series (1996–2022) of anchovy biomass estimates from *PELACUS* in area 9.a N.

PELAGO series

PELAGO 21

The *PELAGO 22* survey was conducted this year in two legs making use of two different research vessels (first leg: between 1st and 9th March on board R/V *Miguel Oliver* (MO); second leg: between 16th and 30th March on board R/V *Vizconde de Eza* (VE)), after the breakdown suffered by the former because electric issues. Seventy-one (71) transects were acoustically sampled between Caminha and Cape Trafalgar (30–200 m depth). Five (5) transects in 9a. S (ALG) surveyed with MO were repeated with VE at the beginning of leg 2. A total of 39 pelagic trawl hauls were carried out by the research vessel, 28 additional hauls were done by one purse-seiner. The distribution and species composition of all of these hauls are shown in **Figure 4.4.2.6**.

Regarding the mapping of acoustic energy, anchovy was mainly concentrated in 9.a CN and, showing lower densities, in the 9.a S (CAD). A large increase in the distribution along the 9.a CN extended further south, in the northern 9.a CS area. The distribution extended further south on the west coast than in previous years (**Figure 4.4.2.7)**.

Anchovy acoustic estimates for the whole surveyed area were 5637 million fish and 120 934 t.

In 9.a Central-North were estimated a total of 4589 million fish and 108 571 t, estimates which represent the second highest peak of abundance and the first of biomass of the time-series (50% and 103% increases in abundance and biomass in relation to the 2021 estimates). The estimated population in this subdivision ranged between 11.5 and 19.0 cm size classes, with a mode at 16.0 cm size class (**Figure 4.4.2.8**). The assessed population abundance from this subdivision was structured by Age-1, Age-2, Age-3 and Age-4 fish, with the Age-2 being the dominant age (46%), followed by Age-1 fish (27%), Age-3 (26%) and Age-4 (0.7%) fish (**Figure 4.4.2.9**).

Anchovy population in 9a Central-South was supported by 198 million fish and 3391 t, entailing 62% and 44% decreases of abundance and biomass in relation to the 2021 estimates. The population showed a size range between 11.5 and 18.5 size classes, with a 13.0 cm modal size, and with a predominance of Age 2 individuals (62%), followed by Age 1 (36%) and Age 3 (1%) (**Figures 4.4.2.8** and **4.4.2.9**).

In the Subdivision 9.a South, with values of 849 million fish and 8972 t (**Table 4.4.2.3**), the Spanish waters concentrated most of the population (77% and 61% of abundance and biomass, respectively). The above 2022 estimates accounted for 43% and 36% decreases in relation to those estimated in the 2021 survey. In 9a South-Algarve a total of 196 million fish and 3535 t were estimated, representing very increased population levels in relation to the last years (**Figure 4.4.2.8**). The estimated population in Subdivision 9.a South-Algarve ranged between 10.0 and 17.5 cm size classes, with two clearly differentiated modes at 11.5 cm (the dominant one) and 15.5 cm size class, and a dominance of Age 1 (52.8%) followed by Age 2 (25.1%) and lastly Age 3 (22.1%) individuals (**Figure 4.4.2.9**).

In 9a South-Cadiz a total of 654 million fish and 5438 t were estimated, entailing strong 56% and 61% decreases in abundance and biomass in relation to the previous year's estimates, respectively (**Figure 4.4.2.8**). The estimated population in this Subdivision 9.a South-Cadiz ranged between 8.5 and 14.5 cm size classes, with a main mode at 10.0 cm size class. The population was dominated by Age 1 individuals (80.0%), followed by Age 2 (15.0%) and Age 3 (0.6%) (**Figure 4.4.2.9**).

Table 4.4.2.3 and **Figure 4.4.2.10** 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 the last two years down to levels well below the historical average (**Figure 4.4.2.10**).

Figure 4.4.2.11 shows the age structure of the population estimates in the western component. Age 2 anchovies constitute the bulk of the population in spring 2022 (47%), followed by age 1 (28%) and 3 (25%). Age 4 was present in very low numbers in spring 2022. Strong incoming recruitments seem to be inferred in the period 2019–2021, 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 4.4.2.5** and **Figure 4.4.2.12** we revisit the trends observed in the age structure of the population as estimated by the *PELAGO* and *ECOCADIZ* survey series. As described in previous reports, Portuguese acoustic estimates for anchovy until 2013 did not provide age-structured data 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.

Regarding the last years in the series, the Southern component population age structure in 2010, as estimated by the Portuguese survey, evidenced a strong decrease in 1-year-old anchovies, but especially in two-year-old fish, suggesting a weak population structure sustaining a very low biomass level.

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 2021-07

The *ECOCADIZ 2021-07* survey was planned to be conducted by IEO between 31st July and 13rd August 2021 in the Portuguese and Spanish shelf waters (20–200 m isobaths) off the Gulf of Cadiz on board the Spanish R/V *Miguel Oliver*. However, a malfunctioning of the echo-sounder, probably caused by RV's electric problems, during the previous acoustic survey (*MEDIAS*) caused the interruption of that survey. Failed attempts of solving such problems also led to the definitive suspension of the *ECOCADIZ* survey.

The R/V Miguel Oliver's EK60 echo-sounder was replaced by the EK80 this winter, including the corresponding further checks (calibration, self-noises, acoustic recording, etc.).

Time-series of available estimates so far are shown in **Table 4.4.2.4** and **Figure 4.4.2.13**.

Table 4.4.2.5 shows the time-series of population estimates at age in the southern component estimated by *PELAGO* and *ECOCADIZ* surveys (see also **Figure 4.4.2.12**).

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 0921

The monitoring of the *Cumbre Vieja* volcano eruption caused drastic changes in the planning of the *IBERAS 0921* survey on board R/V *Ramón Margalef.* The survey was finally conducted during two legs: 18th - 20th September (subdivision 9a N) and 9th - 18th October (subdivisions 9a CN and 9a CS). The survey area (from 20 to 100 m isobath) was planned to be covered using an adaptive grid with 73 tracks with random start and evenly distributed each 8 nmi on those areas out of the main expected recruitment areas and each 4 nmi on the main ones. However, the acoustic sampling of the survey area was incomplete (67 transects from the 73 initially planned ones) and restricted to the waters to the north of Sines, the northern area of the 9.a CS. Additionally, zig-zag transects were also conducted inside the Rías (**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 23 pelagic hauls and 9 purse-seine shots were done as shown in **Figure 4.4.3.1**. Sardine accounted 61% of the total catch in weight, and was present in 74% of the hauls. Anchovy occurred in 35% of the hauls, with a 25% contribution in the total catch.

Anchovy was absent in 9a N (**Figure 4.4.3.2**), while in 2020 it was found in the outer part of the surveyed area (e.g. close to the slope), occurring in rather dense epi-pelagic schools. Given the short duration of the 2021 survey, the outer shelf waters deeper than 100 m depth were not sampled and no information is available on if this same pattern was repeated in 2021. The bulk of the estimated population was concentrated in the subdivision 9a CN, with the centre of gravity of its distribution being located in the coastal waters (c.a. 20 m depth), as it was also recorded in previous years (except 2020).

The estimated biomass in 2019 and 2020 ($4*10^3$ t and $5*10^3$ t, respectively) showed an important decrease in relation to 2018 ($182*10^3$ t). Anchovy biomass in autumn 2021 experienced a relative increase up to 31.2 10^3 t (1431 million fish). Anchovy recruits accounted for 47% 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 2021-10

ECOCADIZ-RECLUTAS 2021-10 survey was conducted by IEO between 25th October and 6th November 2021 in the Portuguese and Spanish shelf waters (20–200 m isobaths) off the Gulf of Cadiz on board the R/V *Ramón Margalef*. Subsurface sea temperature, salinity and *in vivo* fluorescence were continuously collected with a thermosalinograph-fluorometer. Vertical profiles of hydrographical variables were also recorded by night from 168 $CTDO_2$ casts. Neither CUFES sampling nor census of top predators were carried out during the survey. Results from this survey have been reported to this WG by Ramos *et al*. (WD 2022).

The 21 foreseen acoustic transects were sampled. A total of 18 valid fishing hauls were carried out for echotrace ground-truthing purposes. From the pelagic fish species set, chub mackerel, anchovy and sardine were the most frequent captured species in the fishing hauls, followed by horse mackerel, bogue, Atlantic mackerel, Mediterranean horse mackerel and blue jack mackerel. Boarfish, 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 (**Figure 4.4.3.5**).

Total and Spanish estimates of total NASC allocated to the "pelagic fish species assemblage" in this survey showed lower values than those recorded last year, whereas the Portuguese estimates showed an increasing trend. By species, sardine accounted for 55% of the total back-scattered energy, followed by anchovy (16%) and chub mackerel (9%), and the remaining species with relative contributions of acoustic energies lower than 6%.

GoC anchovy was widely distributed in the surveyed area, although avoided the easternmost waters. Higher densities were mainly recorded in two areas: between Alfanzina and west of Cape Santa Maria, in the Algarve, and between Isla Cristina and Bay of Cadiz, in Spanish waters (**Figure 4.4.3.5**)

GoC anchovy acoustic estimates in autumn 2021 were of 1973 million fish and 17 512 tones (**Table 4.4.3.3**; **Figure 4.4.3.6**), entailing 38% and 51% decreases in abundance and biomass, respectively, in relation to the last year's estimates (3197 million, 36 070 t). The current overall estimates are lower than the time-series average (i.e. 3258 million; 25 627 t). By geographical strata, the Spanish waters yielded 89% (1763 million) and 76% (13 370 t) of the total estimated abundance and biomass in the Gulf, confirming the importance of these waters in the species' distribution. The estimates for the Portuguese waters were 211 million and 4143 t (**Table 4.4.3.3**; **Figure 4.4.3.6**).

The size class range of the assessed anchovy population in autumn 2021 varied between the 2.0 and 18.5 cm size classes. The size distribution showed a mixed composition, with several modal classes, the main mode at 10.0 cm, a secondary mode at 14.0 cm, and less important modes at 8.0 and 3.0 cm size class. It is noticeable the occurrence of this last modal size, as a consequence of the record of very tiny juveniles (size class range: 2.0 – 4.5 cm) in the coastal waters located between Mazagón and Punta Umbría. 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 83% (1629 million) and 69% (12 063 t) of the total estimated abundance and biomass, respectively (**Table 4.4.3.3**; **Figure 4.4.3.7**). Spanish waters concentrated the bulk (97%) of this juvenile fraction. The estimates of age-0 fish experienced a similar decreasing trend than the one showed by the whole population in relation to the historical peak recorded in 2019 and the values recorded in 2020, but with values close to the time-series average (**Table 4.4.3.3**). Age 1 fish represented 16% and 28% of the total abundance and biomass (**Figure 4.4.3.7**).

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

First estimates of mean weight-at-age for this stock component from *PELACUS* and *PELAGO* spring acoustic surveys were presented to WKPELA 2018. Given the assessment and provision of advice for this stock component is survey trend-based, no weight-at-age estimates have been provided to the present WG, although the collections of otoliths of the Portuguese surveys are being analysed by IPMA to be able to reconstruct a time-series of weights-at-age for this stock component to present.

Southern component

Weight-at-age in the stock are shown in **Table 4.5.1.1**. 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.

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 using an interim trend-based procedure according to ICES data-limited stock approaches (by analogy with the current method 3.2, DLS: ICES CM 2012/ACOM 68) and following the guidelines presented on ICES (2021), as follows:

$$C_y = \begin{cases} 0.2C_{y-1} & if\ \dfrac{I_y}{(I_{y-1}+I_{y-2})/2} < 0.2 \\ C_{y-1}\dfrac{I_y}{(I_{y-1}+I_{y-2})/2} & if\ \ 0.2 \le \dfrac{I_y}{(I_{y-1}+I_{y-2})/2} \le 1.8 \\ 1.8C_{y-1} & if\ \dfrac{I_y}{(I_{y-1}+I_{y-2})/2} > 1.8 \end{cases},$$

where C_y and C_{y-1} represent the catch advice corresponding to the current (y) and previous (y-1) years, respectively, and I_y, I_{y-1} and I_{y-2} represent the biomass indicators corresponding to the current (y) and two previous years (y-1 and y-2), respectively. Note that the first and third cases correspond to the application of an uncertainty cap of 0.2 and 1.8, respectively. For the Western component the biomass indicator input has been taken from the results of the acoustic spring surveys covering this area (by adding *PELAGO* and *PELACUS* estimates), while for the Southern component the biomass indicator input has been obtained from the results of SSB estimates from the Gadget assessment model, using those as a relative index. The basis of this procedure for both components was approved in the last benchmark for this stock (WKPELA 2018; ICES, 2018a), when it was also decided that instead of providing advice for calendar years, advice would be given in-year for the period from 1st July to 30th June next year, after obtaining the results of the spring acoustic surveys. The uncertainty cap for this year is different to the one used in 2018 as a consequence of the conclusions obtained in ICES WKLIFE 10 (ICES, 2021b).

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 2021 are described in Rincón *et al*. (WD 2022).

A model issue for this year regarding last year implementation was found. It was noticed that the length distribution data for *ECOCADIZ* in year 2020 was not included. It was included in the model of this year. A comparison between both models was performed and no significant differences were found.

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 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 from 1989 to the second quarter of 2022. For the first two quarters of year 2022, 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 2021.

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 estimates used for 2022 advice are those corresponding to years 2020, 2021 and 2022, with values of 3987, 2502 and 953 t, respectively (**Figure 4.6.2.1.3.2**). Detailed model outputs are available at https://github.com/ices-taf/2022_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 1186.34 t (corresponding to a relative B_{lim} equal to 0.325) and a B_{pa} of 1946 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) was obtained this year.

4.8.2 Southern component

The SSB has been fluctuating without a trend over the time-series showing a decrease in the last two years which is consistent with the trend on recruitment and survey biomass estimates, and with an increase 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 scenarios

4.9.1 Western component

The ICES framework for category 3 stocks was applied (ICES, 2012). The advice is based on the ratio between the last index value corresponding to 2022 (111 963 t) and the average of the two preceding values of 2020 and 2021 (61 104 327 t), and the Advised Catch (July 2020 to June 2021, 4 347 t). The index is estimated to have increased by 83% and thus the 80% uncertainty cap was applied.

4.9.2 Southern component

The ICES framework for category 3 stocks was applied (ICES, 2021b). The SSB estimated by the assessment model relative to the average of the time-series (1989-2021) was used as the index of stock size development. The advice is based on the ratio between the last index value (0.261) and the average of the two preceding values (0.89), multiplied by the recent advised catches for 2021 (July 2021 to June 2022, 7181 t). The index ratio is estimated to have decreased 71%, i.e. less than 80% and thus the 80% uncertainty cap was not applied. Given that the estimated abundance is below a biomass trigger, which in this case is B_{lim}, the ratio is also multiplied by a biomass safe guard defined as the quotient between the last index value and the biomass trigger. The advice rule with an 80% uncertainty cap and a biomass safe guard is considered precautionary and as such the precautionary buffer was not considered (ICES 2021b). Fishing mortality was not used to consider the application of this buffer because fishing mortality reference points are not considered relevant for short lived species.

4.10 Short-term projections

Short-term projections were not calculated in the two components.

4.11 Quality of the assessment

4.11.1 Western Component

In the last benchmark it was decided that this stock component would be assessed using a biomass survey trend as the basis of the advice. This decision was made taking into account that there is no time-series of regular information of the composition by length and age of the catches available. This data gap corresponds to a very low abundance index and low catches in the first half of the time-series.

Advised catches were calculated according to the Guidance on the applications of the advisory rules for category 3 short lived stocks drafted by WKLIFE 10 (ICES, 2021b), whereby the 1-over-2 rules is constrained by an uncertainty cap of +/- 80% of the former catch advice.

The expert group considers that the current advice procedure for short-lived species category 3 stocks, based on the 1-over-2 ratio with uncertainty cap of 80%, is still not flexible enough to adapt to the highly fluctuating nature of this stock. For this reason, work is being carried out in the framework of WKDLSSLS/WKLIFE guidelines to evaluate a new method to provide advice for this stock.

4.11.2 Southern Component

The biomass estimates provided by the Gadget model are assumed as relative because during the last benchmark it was observed that although the model provided a good model fit, it presented some instability (as shown by the occurrence of a certain retrospective pattern) and also the estimated catchability for both surveys was very high. These issues need to be further investigated.

A comparison with last year estimated time series and also a sensitivity analysis regarding including the 2020 length distribution for the *ECOCADIZ* survey (missing in the last year model) was performed and it 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). The pink line represents last year estimated time series, the green line the estimated by the same model but including the ECOCADIZ length distribution in 2020 and the blue line the estimated by the model used this year. It was observed that the estimated biomass for some of the last years is smaller when including the length distribution missing (green line) but population trend remains very similar. It is also important to remark that the number of iterations for the optimization process in the model corresponding to the pink line was 2 000 000, while in the others was just 1 000 000. In a previous meeting the group acknowledged that the rule assumes the past advice was unbiased, but as far as our new assessment updates the past series estimates of the indicator SSB, it is saying at the same time that the trend-based indicator for providing advice in 2021 was partially biased (as far as those biomass estimates SSB have now been changed). Therefore, the new application of the rule is incorporating a catch advice for the previous year which is now known to be not consistent 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.

This 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 has to be incorporated when assessing the performance of these HCRs for category 3 stocks and it requires further investigation.

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 from Covid-19 disruption (and other reasons)

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 2021-07* 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 survey was planned to be conducted from 31/07 – 13/08/2021. A malfunctioning of the echo-sounder (probably caused by RV's electric problems affecting to the echo-sounder) during the previous acoustic survey (*MEDIAS_ES*) caused the interruption of that survey. Further failed attempts of solving such problems also led to the definitive suspension of the *ECOCADIZ 2021-07* survey.

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 distribution (LFD) and age-length key (ALK) for Spanish commercial catches in the second quarter (Q2) in 2021 in 9a N; missing ALK for Q4 also for the same year and subdivision. Missing LFDs and ALKs in Q1 and Q2 2021 for the Portuguese fishery in 9a CN. No data from the Portuguese fishery in 9a CS in 2021, but catches were very scarce in that subdivision. For the southern component: no missing data for the Spanish fishery. Missing LFDs and ALKs for commercial catches from the Portuguese fishery, but landings are comparatively very scarce (1.4% of total catches from this component in 2021).

6. Brief description of methods explored to remedy the challenge: For the western component: 2021 Q1 LFD from 9a N was propagated to the 2021 Q2 catches in 9a N (without LFD). Quarterly

ALKs for Spanish commercial catches in 9a N were based in a combination of samples from commercial and research (*PELACUS 0321*) samples (the same ALK for Q1 and Q2) and research (*IBERAS 0921*) 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: 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 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.

7. Suggested solution to the challenge, including reason for this selecting this solution: For the western component: 2021 Q1 LFD from 9a N was propagated to the 2021 Q2 catches in 9a N (without LFD). Quarterly ALKs for Spanish commercial catches in 9a N were based in a combination of samples from commercial (one sample in March) and research (*PELACUS 0321*) samples (the same ALK for Q1 and Q2) and research (*IBERAS 0921*) 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: quarterly LFDs and ALKs from the Spanish fishery were propagated to the very low quarterly catches from the Portuguese fishery. The model for this year did not include the missing data corresponding to 2021 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.

8. 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 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

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

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 2021. 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	2					2
11–15	5	15	13			33
16–20		1	11	12		24
>20			6	29	3	38
Total	7	16	30	41	3	97
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	1	4	1	1		7
16–20		6	23	10		39
>20			3	11	1	15
Total	1	10	27	22	1	61

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. (*) Provisional official landings data for the 2022 first semester updated until 31st March (9a.CN, 9a.CS, 9a.S-ALG) –17th May (9a.N, 9a.S-CAD).

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

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
2013	69	192	131	392	67	5172	5240	5632
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*	12	1024	0	1037	0	1425	1425	2462

Table 4.3.2.2.1. Anchovy in Division 9.a. Catches (t) by gear and subdivision in 1989–2021. 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

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

Table 4.3.2.2.2. Anchovy in Division 9.a. Quarterly anchovy catches (t) by subdivision in 2021.

SUBDIVISION/ COMPONENT	QUARTER 1		QUARTER 2		QUARTER 3		QUARTER 4		ANNUAL (2020)	
	C(t)	%	C(t)	%	C(t)	%	C(t)	%	C (t)	%
9.a North	47	6,3	7	0,9	433	57,9	260	34,8	747	4,2
9.a Central North	2	0,02	39	0,4	6688	70,2	2792	29,3	9521	53,4
9.a Central South	0,01	0,1	1	12,7	5	66,8	2	20,4	8	0,04
Western Comp.	49	0,5	47	0,5	7126	69,3	3054	29,7	10276	57,6
9.a South (PT)	2	1,5	1	1,1	106	97,3	0,1	0,1	109	0,6
9.a South (ES)	643	8,6	3542	47,5	2659	35,7	609	8,2	7452	41,8
Southern Comp.	644	8,5	3543	46,9	2765	36,6	609	8,1	7562	42,4
TOTAL	694	3,9	3590	20,1	9890	55,4	3664	20,5	17837	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 2021. Discards were sampled but they were null, hence landings equals to catches.

2021	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	254	0	254
12	1	0	507	144	653
12.5	21	3	888	289	1201
13	63	9	2157	796	3025
13.5	68	10	2537	1432	4047
14	109	15	1269	2287	3680
14.5	143	20	381	2698	3242
15	277	39	127	1592	2034
15.5	334	47	90	1626	2096
16	234	33	362	578	1207
16.5	214	30	1538	0	1783
17	117	16	2443	289	2866
17.5	58	8	1900	0	1967
18	58	8	814	0	881
18.5	0	0	271	0	271

2021	Q1	Q2	Q3	Q4	TOTAL
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	1698	238	15539	11731	29206
Catch (T)	47	7	421	273	747
L avg (cm)	15,7	15,7	15,3	14,7	15,1
W avg (g)	28,1	28,1	27,1	23,2	25,6

Table 4.3.5.1.2. Anchovy in Division 9.a. Western Component. Subdivision 9.a Central North. Portuguese fishery (all fleets). Seasonal and annual length distributions ('000) of anchovy catches in 2021. Discards are null, hence landings correspond to catches. Length frequency distributions were not available for other métiers. They have been estimated by raising total catches to the respective quarterly LFDs from the métier PS_SPF_0_0_0, that represents >95% of catches from all quarters. In this case, TOTAL corresponds to data from the second semester.

2021	Q1	Q2	Q3	Q4	TOTAL
Length (cm)	9.a CN	9.a CN	9.a CN	9.a CN	9.a CN
6	-	-	0	0	0
6.5	-	-	0	0	0
7	-	-	0	0	0
7.5	-	-	0	0	0
8	-	-	0	0	0
8.5	-	-	0	0	0
9	-	-	0	0	0
9.5	-	-	0	0	0
10	-	-	0	0	0
10.5	-	-	0	0	0
11	-	-	0	0	0
11.5	-	-	0	0	0
12	-	-	0	0	0
12.5	-	-	0	2608	2608

2021	Q1	Q2	Q3	Q4	TOTAL
13	-	-	0	2608	2608
13.5	-	-	1251	4334	5584
14	-	-	6157	5317	11474
14.5	-	-	13915	11710	25625
15	-	-	23468	11710	35177
15.5	-	-	26824	12998	39822
16	-	-	26824	10390	37213
16.5	-	-	26824	10390	37213
17	-	-	25573	10390	35963
17.5	-	-	20672	7681	28353
18	-	-	15710	5956	21666
18.5	-	-	7934	1288	9222
19	-	-	3012	0	3012
19.5	-	-	1740	0	1740
20	-	-	0	0	0
20.5	-	-	0	0	0
21	-	-	0	0	0
21.5	-	-	0	0	0
Total N	-	-	0	0	0
Catch (T)	2	39	6688	2792	9480
L avg (cm)	-	-	16.6	15.9	16.2
W avg (g)	-	-	32.8	28.0	30.4

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 2021. Discards were sampled and estimated.

2021	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	0	0	0	0
5	0	0	0	0	0
5,5	0	0	19	0	19
6	0	0	10	0	10
6.5	3	0	12	81	96
7	12	0	106	164	281
7.5	9	9	171	278	467
8	9	38	247	357	651
8.5	20	179	2600	179	2977
9	14	709	16074	1551	18348
9.5	23	4743	31246	1561	37573
10	54	18399	33022	3897	55372
10.5	790	48696	26594	8331	84411
11	1113	46728	16464	5760	70065
11.5	5346	40229	25804	6500	77879
12	5830	22845	16352	8706	53733
12.5	11100	25801	25256	7953	70111
13	7355	23840	13732	7702	52629
13.5	5938	21403	16805	2416	46562
14	3916	11103	5988	2259	23266
14.5	1648	7613	5371	782	15415
15	325	3457	1131	121	5034
15.5	155	1188	759	111	2213
16	7	0	535	9	551

2021	Q1	Q2	Q3	Q4	TOTAL
16.5	7	264	129	9	409
17	16	0	1	0	17
17.5	0	0	5	0	5
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	0	0	0	0	0
20.5	0	0	0	0	0
Total N	43690	277244	238433	58727	618094
Catch (T)	643	3499	2688	623	7452
L avg (cm)	12,9	12,0	11,5	11,9	11,9
W avg (g)	14,7	12,6	11,3	10,6	12,1

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 2021 on a quarterly (Q), half-year (HY) and annual basis.

2021	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	7400	5297	0	12697	12697
	1	782	110	5275	5982	891	11257	12148
	2	890	125	2864	452	1015	3316	4331
	3	26	4	0	0	30	0	30
	Total (n)	1698	238	15539	11731	1936	27270	29206
	Catch (t)	47	7	433	260	54	693	747
	SOP	48	7	420	273	54	693	748
	VAR.%	0,99	0,99	1,03	0,95	0,99	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 2015–2021).

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

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 2021 on a quarterly (Q), half-year (HY) and annual basis.

2021	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	-	-	0	0	-	0	-
	1	-	-	130889	51953	-	171925	-
	2	-	-	62636	42299	-	115535	-
	3	-	-	6376	3127	-	9821	-
	Total (n)	-	-	199901	97379	-	297281	-
	Catch (t)	2	39	6688	2792	41	9480	9521
	SOP	-	-	6544	2729	-	9031	-
	VAR.%	-	-	0,98	0.97	-	0.71	-

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 2021 on a quarterly (Q), half-year (HY) and annual basis.

2021	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	0	0	101943	42984	0	144927	144927
	1	28574	266558	133670	15619	295132	149290	444421
	2	15116	10686	2819	123	25802	2943	28745
	3	0	0	0	0	0	0	0
	Total (n)	43690	277244	238433	58727	320934	297160	618094
	Catch (t)	643	3542	2659	609	4184	3268	7452
	SOP	643	3499	2697	622	4142	3319	7462
	VAR.%	1,00	1,01	0,99	0,98	1,01	0,98	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 (1995–2021).

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
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

Year	Age 0	Age 1	Age 2	Age 3
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

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 2021 on a quarterly (Q), half-year (HY) and annual basis.

2021	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	-	-	13,4	13,9	-	13,6	13,6
	1	15,0	15,0	16,9	15,3	15,0	16,1	16,0
	2	16,3	16,3	17,4	16,1	16,3	17,2	17,0
	3	17,3	17,3	-	-	17,3	-	17,3
	Total	15,7	15,7	15,3	14,7	15,7	15,1	15,1

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 2021 on a quarterly (Q), half-year (HY) and annual basis.

2021	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	-	-	0,018	0,020	-	0,019	0,019
	1	0,025	0,025	0,034	0,026	0,025	0,030	0,029
	2	0,031	0,031	0,037	0,030	0,031	0,036	0,035
	3	0,036	0,036	-	-	0,036	-	0,036
	Total	0,028	0,028	0,027	0,023	0,028	0,025	0,026

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 2021 on a quarterly (Q), half-year (HY) and annual basis.

2021	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	-	-	0	0	-	0	-
	1	-	-	15,0	15,0	-	15,8	-
	2	-	-	16,8	16,8	-	17,0	-
	3	-	-	18,0	18,0	-	15,2	-
	Total	-	-	15,9	15,9	-	16,2	-

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 2021 on a quarterly (Q), half-year (HY) and annual basis.

2021	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	-	-	0	0	-	0	-
	1	-	-	0,030	0,023	-	0,027	-
	2	-	-	0,037	0,033	-	0,034	-
	3	-	-	0,050	0,041	-	0,045	-
	Total	-	-	0,033	0,028	-	0,030	-

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 2021 on a quarterly (Q), half-year (HY) and annual basis.

2021	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	-	-	10,2	11,5	-	10,6	10,6
	1	12,6	11,9	12,4	13,0	12,0	12,5	12,2
	2	13,5	14,6	12,3	15,0	14,0	12,4	13,8
	3	-	-	-	-	-	-	-
	Total	12,9	12,0	11,5	11,9	12,1	11,6	11,9

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 2021 on a quarterly (Q), half-year (HY) and annual basis.

2021	AGE	Q1	Q2	Q3	Q4	HY1	HY2	ANNUAL
	0	-	-	0,007	0,009	-	0,008	0,008
	1	0,014	0,012	0,014	0,014	0,012	0,014	0,013
	2	0,017	0,023	0,015	0,021	0,019	0,016	0,019
	3	-	-	-	-			-
	Total	0,015	0,013	0,011	0,011	0,013	0,011	0,012

Table 4.4.1. Acoustic and DEPM surveys providing direct estimates for anchovy in Division 9.a. (1): *ECOCADIZ-COSTA 0709*, (pilot) Spanish survey surveying shallow waters <20 m depth and complementary to the standard survey; ((Month)): surveys that were carried out but did not provide any anchovy acoustic estimate because of its very low presence and/or for an incomplete geographical coverage (some areas were not covered: either the Spanish or the Portuguese part of the Gulf of Cadiz).

Method	**Acoustics**										**DEPM**	
Survey	PELACUS 04	PELAGO		SAR	JUVESAR	IBERAS		ECOCADIZ		ECO-CADIZ-RE-CLUTAS	BOCADEVA	
Institute (Country)	IEO (ES)	IPMA (PT)		IPMA (PT)	IPMA (PT)	IPMA-IEO (PT-ES)		IEO (ES)		IEO (ES)	IEO (ES)	
Subareas	9.a N	9.a CN-9.a S		9.a CN-9.a S	9.a CN	9.a N-9.a CS		9.a S		9.a S	9.a S	
Year/Quarter	Q2	Q1	Q2	Q4	Q4	Q3	Q4	Q2	Q3	Q4	Q2	Q3
1998				Nov								
1999		Mar										
2000				Nov								
2001		Mar		Nov								
2002		Mar										
2003		Feb		(Nov)								
2004			(Jun)					Jun				
2005			Apr	(Nov)							Jun	
2006			Apr	(Nov)				Jun				
2007			Apr	Nov					Jul			
2008	Apr		Apr	(Nov)							Jun	
2009	Apr		Apr					Jun	(Jul)(1)	(Oct)		
2010	Apr		Apr						(Jul)			
2011	Apr		Apr									Jul
2012	Apr									Nov		
2013	Mar		Apr		(Nov)				Aug			
2014	Mar		Apr		(Nov)				Jul	Oct		Jul
2015	Mar		Apr		Dec				Jul	Oct		
2016	Mar		Apr		Dec				Jul	Oct		

Method	Acoustics								DEPM
2017	Mar		Apr	Dec			Jul	Oct	Jul
2018	Mar		Apr			Nov	Jul	Oct	
2019	Mar		Apr		Sep		Jul	Oct	
2020	No survey (Covid-19 disruption)	Mar			Sep		Aug	Oct	Jul
2021	Apr	Mar			Sep		No survey	Oct	
2022	Apr	Mar							

Table 4.4.1.1. Anchovy in Division 9.a. *BOCADEVA* survey series (summer Spanish anchovy DEPM survey in Subdivision 9.a South). Historical series of eggs, adult and SSB estimates in Subdivision 9.a South. (1): time-series average

Year	2005	2008	2011	2014	2017	2020
P0 (eggs/m^2/day)	50.8 / 224.5	184 / 348	276	314	146	523
Z (day^{-1}) (CV)	-0.039	-1,43	-0.29	-0.33	-0,16	-1.11
Ptotal (eggs/day) (x10^{12})	1,13	2,11	1,87	1,95	0,74	5,26
Surveyed area (km^2)	11982	13029	13107	14595	15556	16223
Positive area (km^2)	6139	6863	6770	6214	5080	10058
Female Weight (g)	25.2 / 16.7	23,7	15,2	18,2	16,2	16,6
Batch Fecundity	13820/ 11160	13778	7486	7502	7507	8212
Sex Ratio	0.53 / 0.54	0,53	0,53	0,54	0,53	0,54
Spawning Fraction	0.26 / 0.21	0,218	0,276	0,276	0,243	0,241 (1)
Spawning Biomass (tons)	14673	31527	32757	31569	12392	81466

Table 4.4.2.1. Anchovy in Division 9.a. *PELACUS* survey series (spring Spanish acoustic survey in Subdivision 9.a North and Subarea 8.c). Summary of the fishing stations performed during *PELACUS 0422*.

	TOTAL CAP (Kg)	No ind.	No Fishing st	Sample weight (kg)	Measured fish	Mean length	%PRES	% Catch_W	% Catch_No
ANE	323	24505	5	2	144	13.59	19.23	1.70	9.19
BOC	52	1243	3	16	371	13.10	11.54	0.27	0.47
BOG	1252	10866	13	159	1355	22.99	50.00	6.60	4.08
HKE	58	673	18	52	595	21.81	69.23	0.31	0.25
HOM	391	4428	9	80	373	24.33	34.62	2.06	1.66
HOM_S	752	31518	9	59	1332	15.61	34.62	3.97	11.82
HMM	1	2	1	1	2	35	3.85	0.00	0.00
JAA	0	2	1	0	2	22.00	3.85	0.00	0.00
MAC	5634	17295	19	266	1003	33.31	73.08	29.72	6.49
PIL	6532	102069	16	116	1958	19.70	61.54	34.46	38.28
SBR	125	336	10	119	284	28.76	38.46	0.66	0.13
VMA	709	6583	11	96	640	25.21	42.31	3.74	2.47
WHB	3451	91625	11	34	821	19.11	42.31	18.21	34.36
Total	**18957**	**266640**	**26**	**998**	**8736**				

Table 4.4.2.2. Anchovy in Division 9.a. *PELACUS* survey series (spring Spanish acoustic survey in Subdivision 9.a North and Subarea 8.c). Historical series of acoustic estimates of anchovy abundance (N, millions) and biomass (B, tonnes) in Subdivision 9.a North.

Survey	Estimate	9.a North
April 2008	N	10
	B	306
April 2009	N	0.7
	B	26
April 2010	N	0.03
	B	90
April 2011	N	73
	B	1650
April 2012	N	1
	B	45
March 2013	N	-
	B	-
March 2014	N	-
	B	-
March 2015	N	-

Survey	Estimate	9.a North
	B	-
March 2016	N	8
	B	205
March 2017	N	124
	B	3566
March 2018	N	771
	B	10660
March 2019	N	7
	B	192
March 2020	N	No survey (Covid-19 disruption)
	B	
April 2021	N	358
	B	6075
April 2022	N	0.1
	B	2

Table 4.4.2.3. Anchovy in Division 9.a. *PELAGO* survey series (spring Portuguese acoustic survey in Subdivisions 9.a Central-North to 9.a South). Historical series of overall and regional acoustic estimates of anchovy abundance (N, millions) and biomass (B, tonnes).

Survey	Estimate	Portugal				Spain	S(Total)	TOTAL
		C-N	C-S	S(A)	Total	S(C)		
Mar. 99	N	22	15	*	37	2079	2079	2116
	B	190	406	*	596	24763	24763	25359
Mar. 00	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Mar. 01	N	25	13	285	324	2415	2700	2738
	B	281	87	2561	2929	22352	24913	25281
Mar. 02	N	22	156	92	270	3731 **	3823 **	4001 **
	B	472	1070	1706	3248	19629 **	21335 **	22877 **
Feb. 03	N	0	14	*	14	2314	2314	2328
	B	0	112	*	112	24565	24565	24677
Mar. 04	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Apr. 05	N	-	59	-	59	1306	1306	1364
	B	-	1062	-	1062	14041	14041	15103
Apr. 06	N	-	-	319	319	1928	2246	2246
	B	-	-	4490	4490	19592	24082	24082
Apr. 07	N	0	103	284	387	2860	3144	3247
	B	0	1945	4607	6552	33413	38020	39965
Apr.08	N	69	252	213	534	1819	2032	2353
	B	3000	2505	4661	10166	29501	34162	39667
Apr.09	N	127	0****	159	286	1910	2069	2196
	B	2089	0****	3759	5848	20986	24745	26834
Apr. 10	N	0	62	0	62	963	963	1026
	B	0	1188	0	1188	7395	7395	8583
Apr. 11	N	1558	0	0	1558	0	0	1558
	B	27050	0	0	27050	0	0	27050

Survey	Estimate	Portugal				Spain	S(Total)	TOTAL
		C-N	C-S	S(A)	Total	S(C)		
Apr. 12	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-

***Due to the distribution observed during the survey, the last transect (near the border with Spain) that normally belongs to the Algarve subarea was included in Cadiz.**

****Corrected estimates after detection of errors in the sA values attributed to the Cadiz area (Marques and Morais, 2003).**

******Possible underestimation: although no echo-traces attributable to the species were detected in this area, however, the loss of pelagic gear samplers prevented from confirming directly this.**

Table 4.4.2.3. Anchovy in Division 9.a. *PELAGO* survey series (spring Portuguese acoustic survey in Subdivisions 9.a Central-North to 9.a South). Cont'd.

Survey	Estimate	Portugal				Spain	S(Total)	TOTAL
		C-N	C-S	S(A)	Total	S(C)		
Apr. 13	N	251	0	263	514	634	897	1148
	B	3955	0	5044	8999	7656	12700	16655
Apr. 14	N	130	0	26	156	2216	2241	2371
	B	1947	0	509	2456	28408	28917	30864
Apr. 15	N	645	0	158	802	3531	3689	4334
	B	8237	0	2156	10393	30944	33100	41337
Apr. 16	N	3198	0	0	3198	9811	9811	13009
	B	38302	0	0	38302	65345	65345	103647
May 17	N	1015	0	137	1152	1718	1855	2870
	B	15481	0	1208	16689	12589	13797	29278
Apr. 18	N	4845	0	300	5145	1857	2157	7001
	B	54437	0	4328	58765	19145	23473	77910
Apr. 19	N	229	7	0	236	3398	3398	3634
	B	3814	123	0	3937	29876	29876	33813
Apr. 20	N	3152	0.3	89	3242	5550	5639	8791
	B	50282	9	1789	52080	47998	49787	100078
Mar. 21	N	3069	519	9	3597	1485	1485	5082
	B	53513	6095	107	59715	13958	13958	73673
Apr. 22	N	4589	198	196	4983	654	849	5637

Survey	Estimate	Portugal				Spain	S(Total)	TOTAL
		C-N	C-S	S(A)	Total	S(C)		
	B	108571	3391	3535	115496	5438	8972	120934

Table 4.4.2.4. Anchovy in Division 9.a. *ECOCADIZ* survey series (summer Spanish acoustic survey in Subdivision 9.a South). Historical series of overall and regional acoustic estimates of anchovy abundance (N, millions) and biomass (B, tonnes).

Survey	Estimate	Portugal S(A)	Spain S(C)	TOTAL S(Total)
Jun. 04***	N	125	1109	1235
	B	2474	15703	18177
Jun. 05	N	-	-	-
	B	-	-	-
Jun. 06	N	363	2801	3163
	B	6477	30043	36521
Jul. 07	N	558	1232	1790
	B	11639	17243	28882
Jul. 08	N	-	-	-
	B	-	-	-
Jul. 09	N	35	1102	1137
	B	1075	20506	21580
Jul. 10	N	?	954+	954 +
	B	?	12339 +	12339 +
Jul. 11	N	-	-	-
	B	-	-	-
Jul. 12	N	-	-	-
	B	-	-	-
Aug. 13	N	50	558	609
	B	1315	7172	8487
Jul. 14	N	184	1778	1962
	B	4440	24779	29219
Jul. 15	N	168	2506	2674
	B	2137	19168	21305
Jul. 16	N	346	3341	3686
	B	5250	29051	34301

Survey	Estimate	Portugal	Spain	TOTAL
		S(A)	S(C)	S(Total)
Jul. 17	N	151	1354	1504
	B	2666	9563	12229
Jul. 18	N	224	2839	3063
	B	4224	30683	34908
Jul. 19	N	80	5405	5485
	B	1561	56139	57670
Aug. 20	N	439	4714	5153
	B	7773	37114	44887
Aug. 21	N	-	-	-
	B	-	-	-

*****Possible underestimation: shallow waters between 20 and 30 m depth were not acoustically sampled. + Partial estimate due to an incomplete coverage of the subdivision (only the Spanish part).**

Table 4.4.2.5. Anchovy in Division 9.a. Southern component. Historical series of overall acoustic estimates of anchovy abundance (N, millions) by age group estimated by *PELAGO* and *ECOCADIZ* acoustic surveys.

PELAGO	**N (million)**	**N (million)**	**N (million)**	**N (million)**	**N (million)**	**N (million)**
Year	Age 0	Age 1	Age 2	Age 3	Age 4	TOTAL
1999	0	2025	54	0	0	2079
2000	-	-	-	-	-	-
2001	0	2635	65	0	0	2700
2002	0	3774	49	0	0	3823
2003	0	2077	237	0	0	2314
2004	-	-	-	-	-	-
2005	0	1245	61	0	0	1306
2006	0	2197	48	2	0	2246
2007	0	3060	85	0	0	3144
2008	0	1540	485	7	0	2032
2009	0	1735	295	38	0	2069
2010	0	951	12	0	0	963

PELAGO	N (million)	N (million)	N (million)	N (million)	N (million)	N (million)
2011	-	-	-	-	-	-
2012	-	-	-	-	-	-
2013	0	157	900	201	6	1264
2014	0	1501	1327	63	0	2890
2015	0	2999	311	0	0	3310
2016	0	6403	127	4	0	6535
2017	0	1142	117	0	0	1259
2018	0	2115	39	3	0	2157
2019	0	3105	289	0	0	3393
2020	0	5237	392	9	0	5639
2021	0	9449	3902	715	0	14065
2022	0	677	127	43	0	847

PELAGO	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Year	Age 0	Age 1	Age 2	Age 3	Age 4	TOTAL
1999	0	97.4	2.6	0	0	100
2000	-	-	-	-	-	-
2001	0	97.6	2.4	0	0	100
2002	0	98.7	1.3	0	0	100
2003	0	89.7	10.3	0	0	100
2004	-	-	-	-	-	-
2005	0	95.3	4.7	0	0	100
2006	0	97.8	2.1	0.1	0	100
2007	0	97.3	2.7	0	0	100
2008	0	75.8	23.9	0.3	0	100
2009	0	83.9	14.3	1.9	0	100
2010	0	98.7	1.3	0	0	100
2011	-	-	-	-	-	-
2012	-	-	-	-	-	-
2013	0	12.4	71.2	15.9	0.5	100

PELAGO	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
2014	0	51.9	45.9	2.2	0	100
2015	0	90.6	9.4	0	0	100
2016	0	98.0	1.9	0.1	0	100
2017	0	90.7	9.3	0	0	100
2018	0	98.1	1.8	0.1	0	100
2019	0	91.5	8.5	0	0	100
2020	0	92.9	7.0	0.2	0	100
2021	0	67,2	27,7	5,1	0	100
2022	0	80,0	15,0	5,1	0	100

Table 4.4.2.5. Anchovy in Division 9.a. Southern component. Cont'd.

ECOCADIZ	N (million)	N (million)	N (million)	N (million)	N (million)	N (million)
Year	Age 0	Age 1	Age 2	Age 3	Age 4	TOTAL
2004	0	1215	19	0	0	1235
2005	-	-	-	-	-	-
2006	0	3170	42	0.1	0	3211
2007	0	1619	167	5	0	1790
2008	-	-	-	-	-	-
2009	0	879	218	39	0	1137
2010	185	686	80	4	0	954
2011	-	-	-	-	-	-
2012	-	-	-	-	-	-
2013	169	394	33	0	0	596
2014	51	1873	36	0	0	1960
2015	1607	1053	13	0	0	2673
2016	1666	1665	354	0	0	3686
2017	892	447	149	0	0	1488
2018	1408	1609	46	0	0	3063
2019	2320	3031	134	0	0	5485

ECOCADIZ	N (million)	N (million)	N (million)	N (million)	N (million)	N (million)
2020	3792	1326	35	0	0	5153
2021	-	-	-	-	-	-

ECOCADIZ	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Year	Age 0	Age 1	Age 2	Age 3	Age 4	TOTAL
2004	0	98.5	1.5	0	0	100
2005	-	-	-	-	-	-
2006	0	98.7	1.3	0.004	0	100
2007	0	90.4	9.3	0.3	0	100
2008	-	-	-	-	-	-
2009	0	77.3	19.2	3.4	0.02	100
2010	19.4	71.8	8.4	0.4	0	100
2011	-	-	-	-	-	-
2012	-	-	-	-	-	-
2013	28.4	66.1	5.5	0	0	100
2014	2.6	95.6	1.8	0	0	100
2015	60.1	39.4	0.5	0	0	100
2016	45.2	45.2	9.6	0	0	100
2017	60.0	30.0	10.0	0	0	100
2018	46.0	52.5	1.5	0	0	100
2019	42.3	55.3	2.4	0	0	100
2020	73,6	25,7	0,7	0	0	100
2021	-	-	-	-	-	-

Table 4.4.3.1. Anchovy in Division 9.a. *SAR/JUVESAR* autumn survey series (autumn Portuguese acoustic survey in subdivisions 9.a Central–North to 9.a South - SAR - or Subdivision 9.a Central-North and Central-South - *JUVESAR* -). Historical series of overall and regional acoustic estimates of anchovy abundance (N, millions) and biomass (B, tonnes). Juvenile fish (< 10.0 cm) estimates between parentheses.

Survey	Estimate	Portugal				Spain	S (Total)	TOTAL
		C-N	C-S	S (PT)	Total	S (ES)		
Nov. 98	N	30	122	50	203	2346	2396	2549
	B	313	1951	603	2867	30092	30695	32959
Nov. 99	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Nov. 00	N	4	20	*	23	4970	4970	4994
	B	98	241	*	339	33909	33909	34248
Nov. 01	N	35	94	-	129	3322	3322	3451
	B	1028	2276	-	3304	25578	25578	28882
Nov. 02	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Nov. 03	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Nov. 04	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Nov. 05	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Nov. 06	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Nov. 07	N	0	59	475	534	1386	1862	1921
	B	0	1120	7632	8752	16091	23723	24843
Nov. 13	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Nov. 14	N	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-
Dec. 15	N	3870 (3835)	-	-	-	-	-	-

Survey	Estimate	Portugal				Spain	S (Total)	TOTAL
		C-N	C-S	S (PT)	Total	S (ES)		
	B	30000 (29000)	-	-	-	-	-	-
Dec. 16	N	2836 (2835)	-	-	-	-	-	-
	B	14397 (14367)	-	-	-	-	-	-
Dec 17	N	2145 (570)		-	-	-	-	-
	B	38000 (4700)		-	-	-	-	-

*** Due to the distribution observed during the survey, the last transect (near the border with Spain) that normally belongs to the Algarve subarea was included in Cadiz.**

Table 4.4.3.2. Anchovy in Division 9.a. *IBERAS* survey series (autumn Spanish-Portuguese acoustic survey in subdivisions 9.a North to Central-South). Historical series of overall and regional acoustic estimates of anchovy abundance (N, millions) and biomass (B, tonnes). Age 0 fish estimates between parentheses.

Survey	Estimate	Spain	Portugal			TOTAL
		N	C-N	C-S	Total	
Nov. 18	N	0.04 (0.03)	8836 (592)	0.02 (0.001)	8836 (592)	8836 (592)
	B	0.4 (0)	181576 (5894)	0.4 (0)	181577 (5894)	181577 (5894)
Sep. 19	N	0 (0)	122 (0.3)	42 (0)	164 (0.3)	164 (0.3)
	B	0 (0)	2981 (3)	1232 (0)	4212 (3)	4212 (3)
Sep. 20	N	0 (570)	12 (1)	0 (0.7)	583 (560)	583 (572)
	B	0 (4879)	289 (20)	0 (8)	5176 (4669)	5176 (4907)
Sep. 21	N	0 (0)	1429 (664)	2 (2)	1431 (666)	1431 (666)
	B	0 (0)	31206 (10591)	29 (26)	31236 (10617)	31236 (10617)

Table 4.4.3.3. Anchovy in Division 9.a. *ECOCADIZ-RECLUTAS* survey series (autumn Spanish acoustic survey in Subdivision 9.a South). Historical series of overall and regional acoustic estimates of anchovy abundance (N, millions) and biomass (B, tonnes). Age 0 fish estimates between parentheses.

Survey	Estimate	Portugal S (PT)	Spain S (ES)	TOTAL S (Total)
Nov. 12*	N	-	2649 (2619)	-
	B	-	13680 (13354)	-
Oct. 14	N	111 (3)	875 (811)	986 (814)
	B	2168 (25)	5945 (5107)	8113 (5131)
Oct. 15	N	115 (75)	5113 (5042)	5227 (5117)
	B	1335 (430)	29491 (28789)	30827 (29219)
Oct. 16	N	177 (42)	3490 (3404)	3667 (3445)
	B	3054 (463)	16807 (15506)	19861 (15969)
Oct. 17**	N	-	1492 (1433)	-
	B	-	7641 (7290)	-
Oct. 18	N	405 (96)	548 (447)	952 (543)
	B	6259 (1005)	4234 (2830)	10493 (3834)
Oct. 19	N	1217 (763)	4301 (4082)	5518 (4845)
	B	16089 (6613)	32309 (29792)	48398 (36405)
Oct. 20	N	145 (30)	3051 (2355)	3197 (2385)
	B	3290 (512)	32779 (20547)	36070 (21060)
Oct. 21	N	211 (53)	1763 (1575)	1973 (1629)
	B	4143 (923)	13370 (11140)	17512 (12063)

*** Partial estimate: only the Spanish waters were acoustically surveyed. ** Partial estimate only 70% of the Spanish waters was acoustically surveyed.**

Table 4.5.1.1. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. Mean weight-at-age in the stock (in g).

Year	Age 0	Age 1	Age 2	Age 3
1995	7,0	10,7	22,6	
1996	1,1	6,3	20,0	
1997	2,6	11,1	20,9	
1998	2,6	7,4	20,4	
1999	3,2	12,8	20,0	
2000	3,1	10,0	23,8	
2001	6,2	13,3	31,8	
2002	3,3	10,5	26,3	
2003	6,0	10,6	26,8	
2004	6,6	12,0	21,9	
2005	4,9	9,2	22,6	
2006	3,6	8,2	21,0	
2007	5,4	9,4	20,4	
2008	7,2	14,9	21,8	23,1
2009	4,1	12,2	20,3	24,2
2010	6,9	11,3	19,1	23,0
2011	8,2	10,3	22,7	
2012	8,3	14,3	22,5	
2013	6,4	11,9	21,8	
2014	6,6	10,9	19,0	
2015	7,7	10,5	20,7	
2016	8,7	12,9	18,2	
2017	6,7	9,1	19,9	
2018	10,2	12,4	18,6	
2019	10.0	11.9	20.0	
2020	9.6	12.3	17.4	26.6
2021	7.4	12.9	21.8	

Table 4.6.2.1.1.1. Anchovy in Division 9.a. Southern component. Overview of the data used in the assessment model for optimization routines (maximization of likelihood function). 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, 2013–2020
	Length distribution	Second quarter 2004, 2006 third quarter 2007, 2009, 2010, 2013–2020
	Age–length key	Second quarter 2004, 2006 third quarter 2007, 2009, 2010, 2013–2020
PELAGO acoustic survey	Biomass survey indexes	First quarter 1999, 2001–2003 second quarter 2005–2010 and 2013–2022
	Length distribution	First quarter 1999, 2001–2003 second quarter 2005–2010, 2013–2022
	Age–length key	second quarter 2014–2022

Table 4.6.2.1.3.1. Anchovy in Division 9.a. Southern component. Summary of parameters estimated by the assessment model.

Symbol	Meaning and estimated value
l_∞	Asymptotic length, l_∞=28.4296 cm
k	Annual growth rate, k =0.0772549
β	Beta-binomial parameter, β = 5000
v_a	Age factor, $v_{0=}$ 120000, v_1 = 116000, v_2 =0.0607, v_3 = 9.2e − 07
μ	Recruitment mean length, μ = 10.313cm
σ_t	Recruitment length standard deviation by quarter, σ_2 = 2.60238, σ_3 = 2.59163, σ_4 = 1.79378
$l_{50,T}$	Length with a 50% probability of predation during period T, seine: $l_{50,1}$= 12.6cm, $l_{50,2}$ = 10.8 cm, *ECOCADIZ* survey: l_{50}= 13 cm, *PELAGO* survey: l_{50}= 14.3 cm
α_T	Shape of selectivity function, purse-seine: α_1 = 0.193, α_2 = 0. 764, *ECOCADIZ* survey: α_3 = 1.31, *PELAGO* survey: α_3 = 0.406

Figure 4.2.1. Anchovy in Division 9.a. Map showing the split of Division 9a into the stock components 9a South and 9a West. Note that, in turn, the stock component 9a South is divided into Portuguese and Spanish waters, whereas stock component 9a West is divided into the subdivisions 9a North, 9a Central–North, and 9a Central–South.

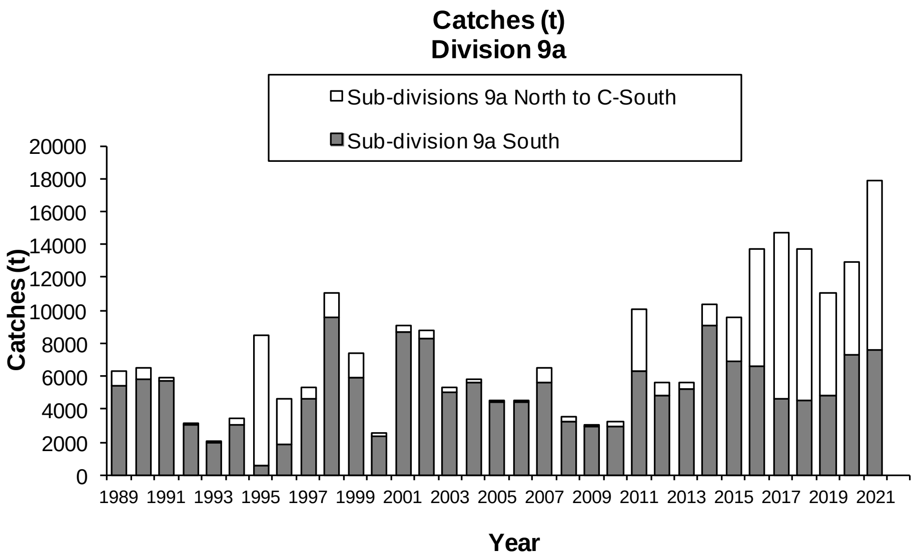


Figure 4.3.2.1.1. Anchovy in Division 9.a. Recent series of anchovy catches in Division 9.a (ICES estimates for 1989–2021, the period with data for all the subdivisions, all metiers are considered). Subdivisions are pooled in order to differentiate the anchovy fishery harvested throughout the Atlantic façade of the Iberian Peninsula (Western component: ICES subdivisions 9.a North, Central-North and Central-South) from the fishery in the Gulf of Cadiz (Southern component: Subdivision 9.a South), where both the stock and the fishery were mainly located during a great part of the time-series. Discards are considered as negligible all over the division, but since 2014 on estimates include the available discarded catches (see Section 4.3.3).

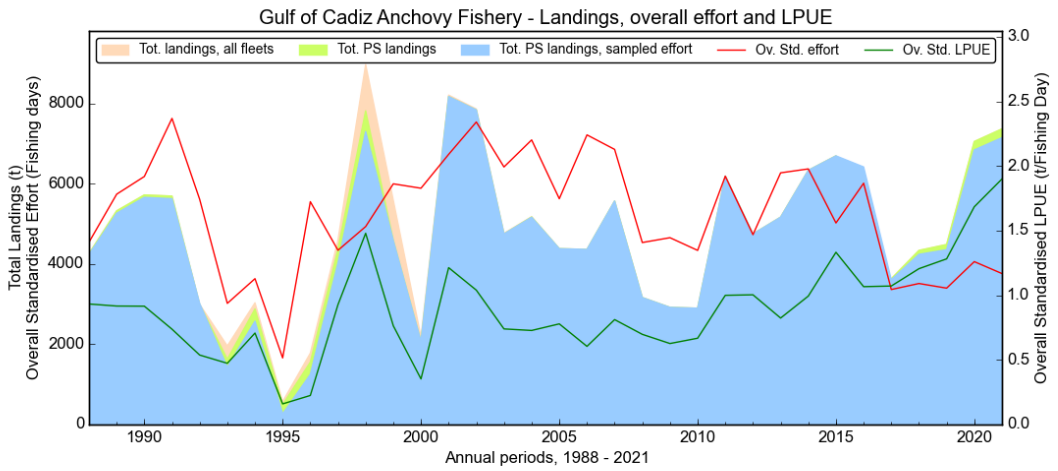


Figure 4.3.4.1. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. Spanish purse-seine fishery (métier PS_SPF_0_0_0). Trends in Gulf of Cadiz anchovy annual landings, and purse-seine fleets' standardised overall effort and lpue (1988–2021).

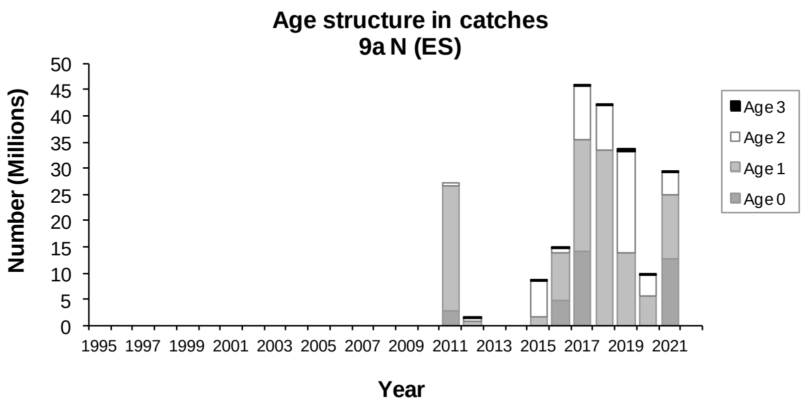


Figure 4.3.5.2.1. Anchovy in Division 9.a. Western component. Subdivision 9.a North. Spanish fishery (all métiers). Age composition in Spanish catches of SW Galician anchovy (available data provided to the WG). Although discards are still considered as negligible (hence landings are assumed as equal to catches), data since 2014 include discards estimates (see Section 4.3.3).

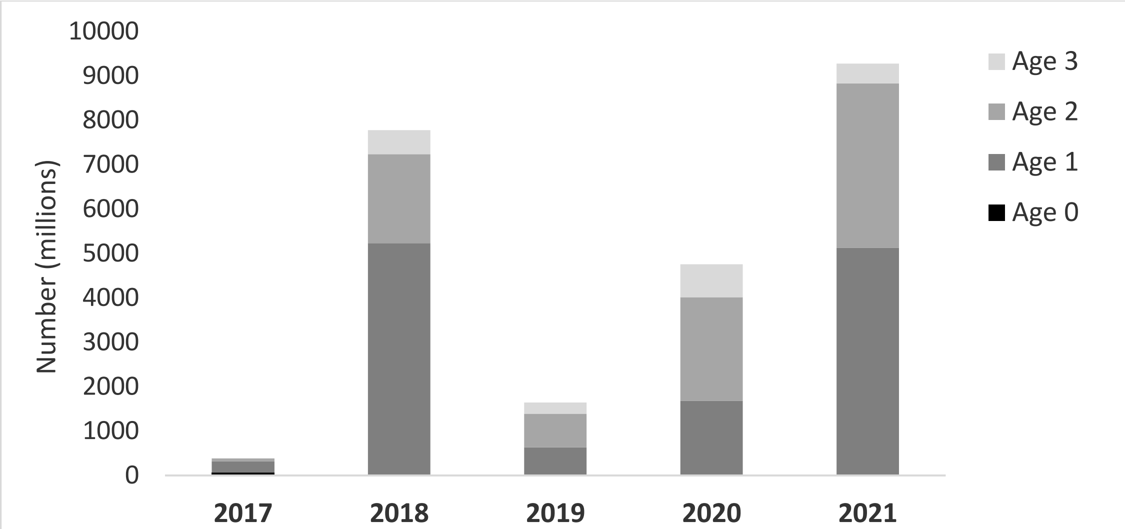


Figure 4.3.5.2.2. Anchovy in Division 9.a. Western component. Subdivision 9.a Central-North. Portuguese fishery (all métiers). Age composition in Portuguese anchovy catches (available data provided to the WG). Discards are negligible (hence landings are assumed as equal to catches). Data for 2021 are only available for the 3rd and 4th Quarters (99.5% catches).

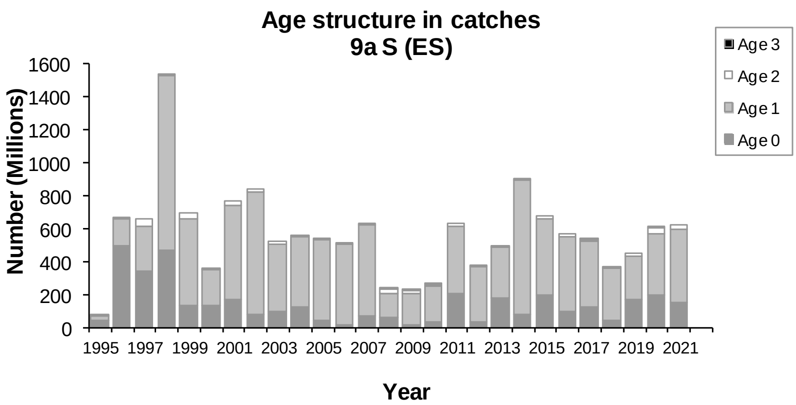
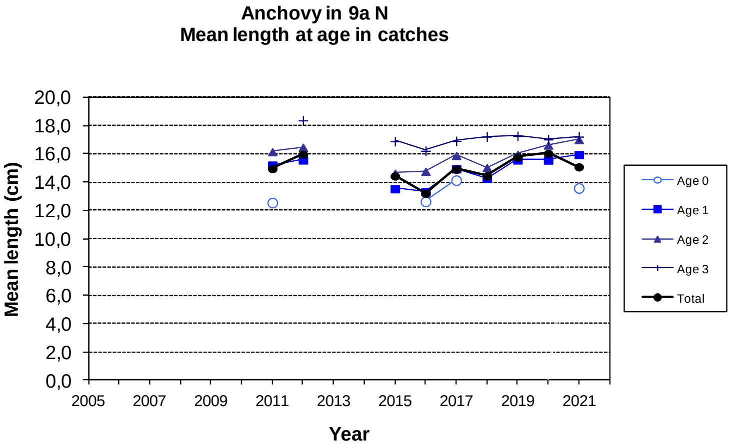


Figure 4.3.5.2.3. Anchovy in Division 9.a. Southern component. Subdivision 9.a-South. Spanish fishery (all métiers). Age composition in Spanish catches of Gulf of Cadiz anchovy (1995–2021). Discards are considered either very low or even negligible in this fishery, but since 2014 on estimates include the available discarded catches (see Section 4.3.3).



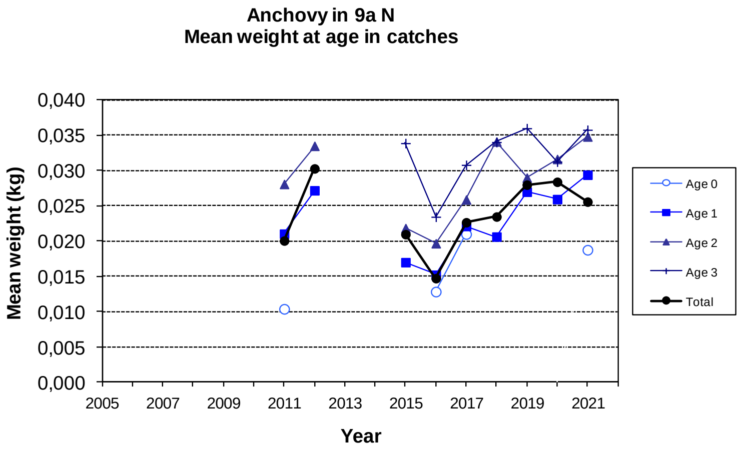


Figure 4.3.6.1. Anchovy in Division 9.a. Western component. Subdivision 9.a North. Spanish fishery (all métiers). Annual mean length (TL, in cm) and weight (kg) at-age in the Spanish catches of Western Galicia anchovy (2011–2021).

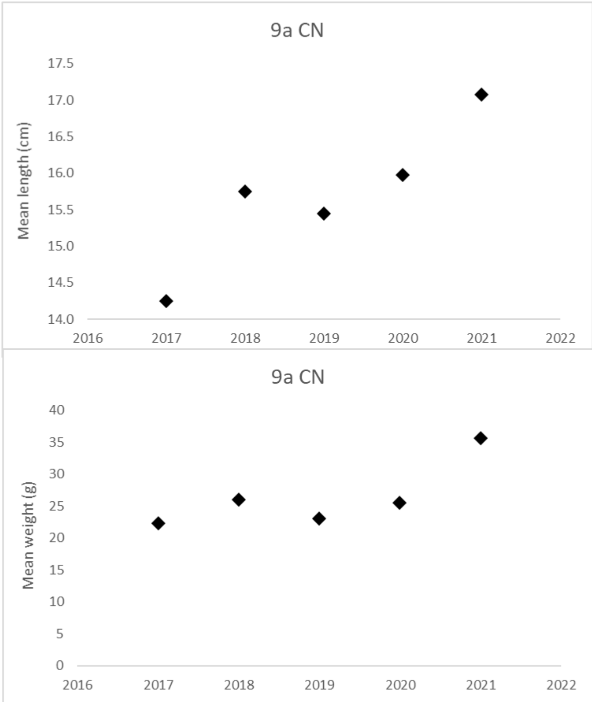


Figure 4.3.6.2. Anchovy in Division 9.a. Western component. Subdivision 9.a Central North. Portuguese fishery (all metiers). Annual mean length (TL, in cm) and weight (kg)e in the Portuguese catches of Western anchovy (2017–2021).

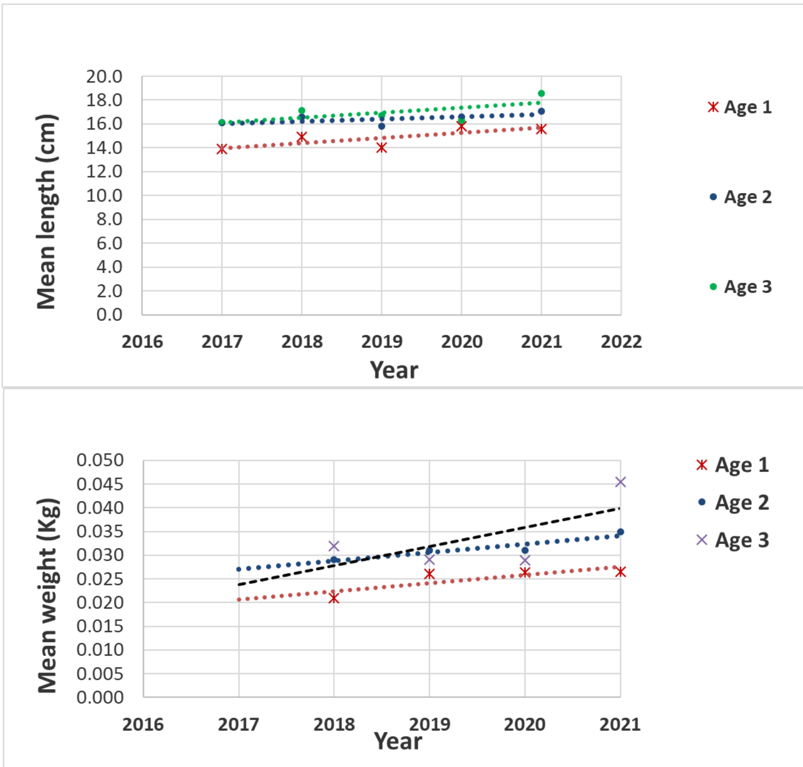
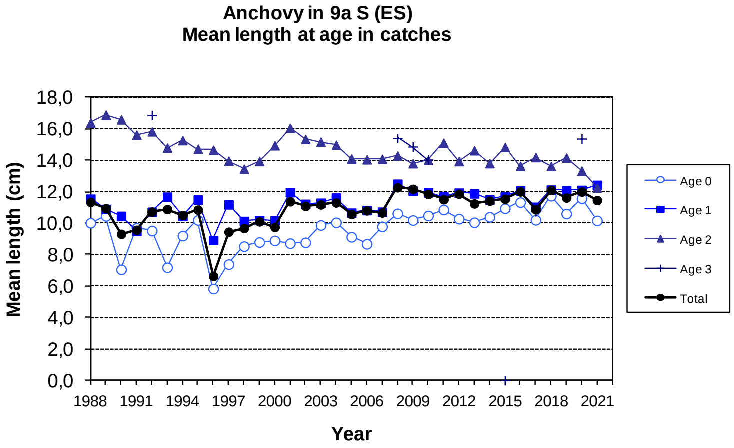


Figure 4.3.6.2. Anchovy in Division 9.a. Western component. Subdivision 9.a Central North. Portuguese fishery (all métiers). Cont'd. Annual mean length (TL, in cm) and weight (kg) at-age in the Portuguese catches of Western anchovy (2017 to 2021).



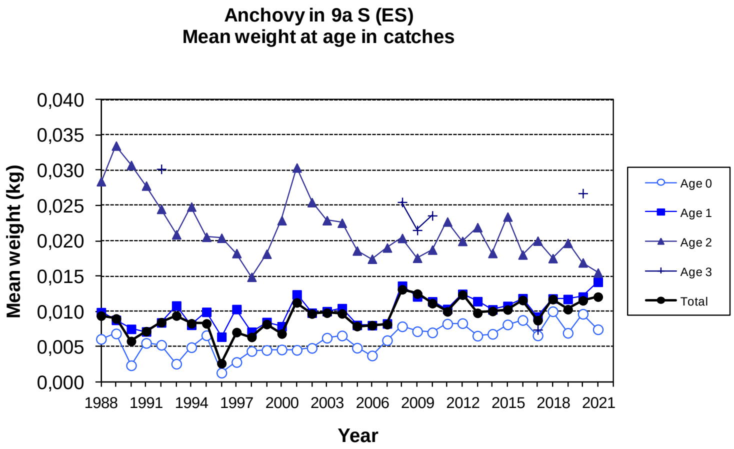


Figure 4.3.6.3. Anchovy in Division 9.a. Southern component. Subdivision 9.a-South. Spanish fishery (all métiers). Annual mean length (TL, in cm) and weight (kg) at-age in the Spanish catches of Gulf of Cadiz anchovy (1988–2021).

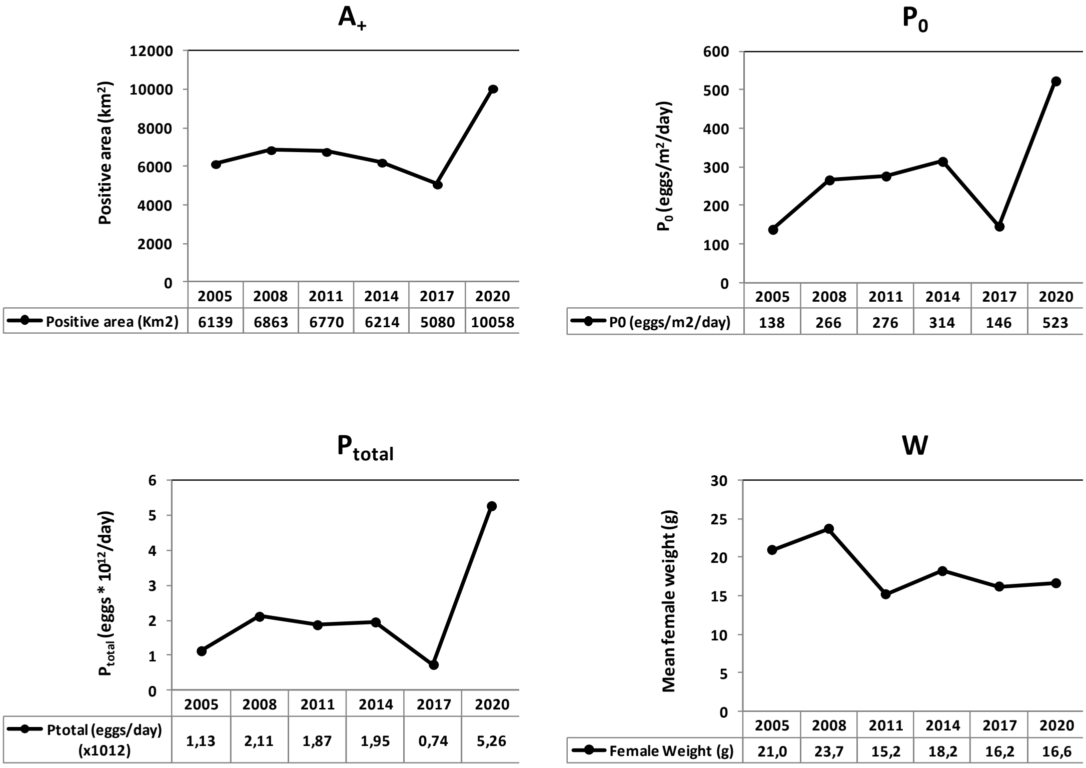


Figure 4.4.1.1. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. *BOCADEVA* survey series (summer Spanish DEPM survey in Subdivision 9.a South). Time-series of eggs and adult parameters estimates. A+ (positive area, in km^2), P_0 (daily egg production, in eggs/m^2/day), P_{total} (total egg production, in eggs 10^{12}/day), W (mean female weight, in g).

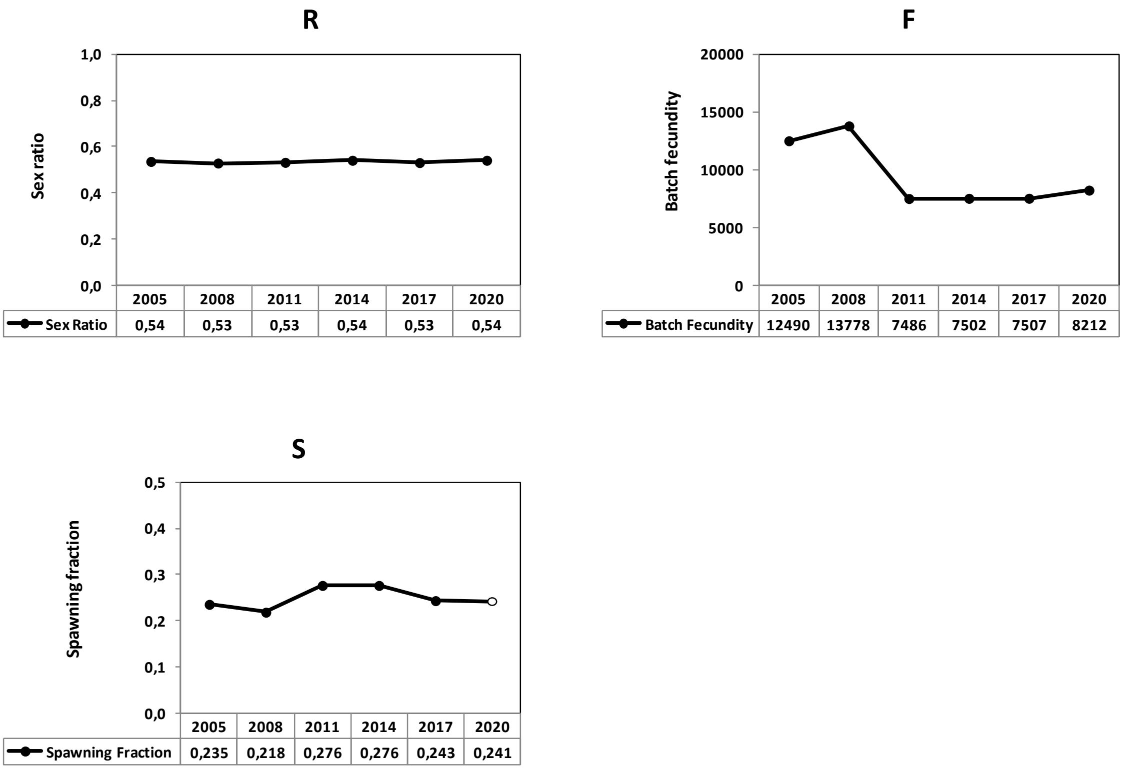


Figure 4.4.1.1. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. *BOCADEVA* survey series (summer Spanish DEPM survey in Subdivision 9.a South). Time-series of eggs and adult parameters estimates. Cont'd. R (sex ratio), F (individual batch fecundity), S (spawning fraction; the 2020 estimate is provisionally computed as the time-series average value).

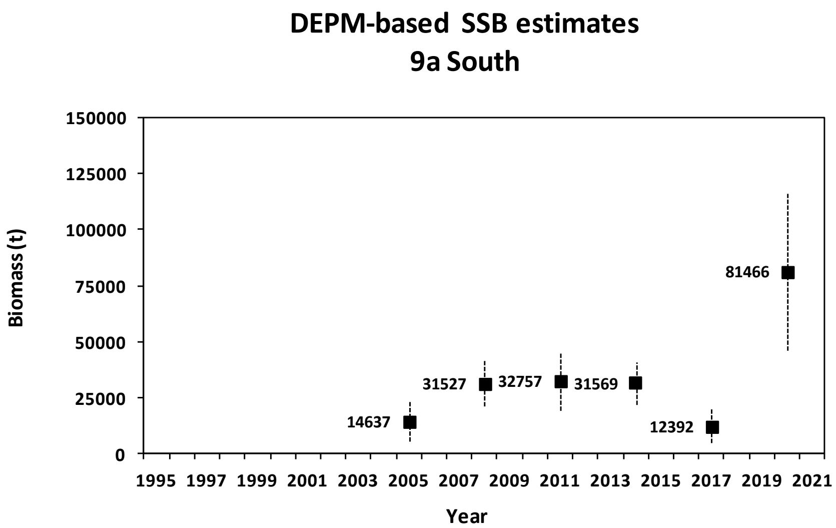


Figure 4.4.1.2. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. *BOCADEVA* survey series (summer Spanish DEPM survey in Subdivision 9.a South). Series of SSB estimates (±SD) obtained from the survey series.

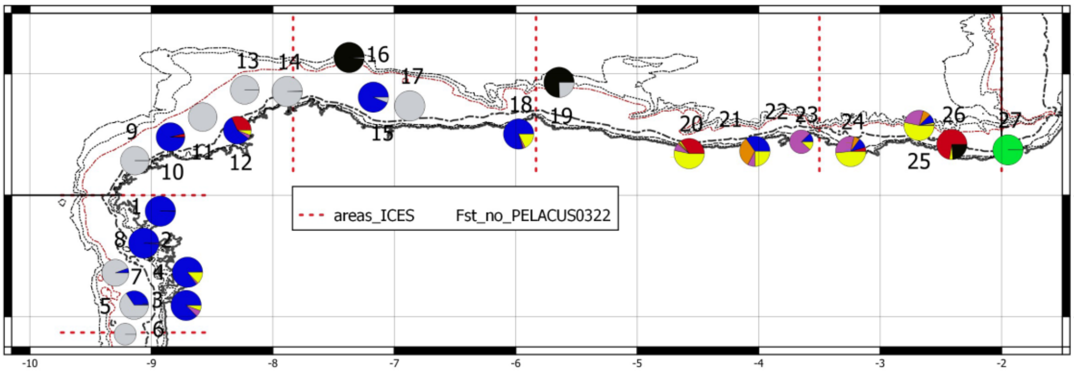


Figure 4.4.2.1. Anchovy in Division 9.a. Western component. Subdivision 9.a North. *PELACUS 0322* survey (spring Spanish acoustic survey in Sub-division 9.a North and Sub-area 8c in 2022). Distribution of pelagic hauls for echo-traces identification, with indication of the species composition.

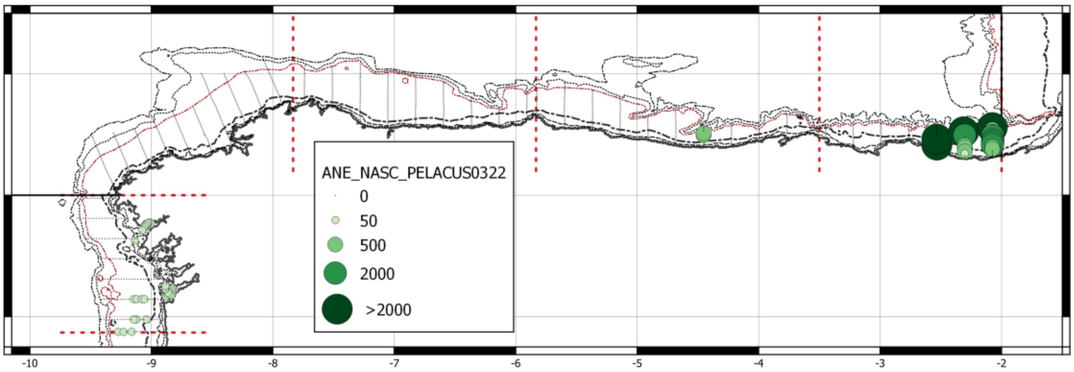


Figure 4.4.2.2. Anchovy in Division 9.a. Western component. Subdivision 9.a North. *PELACUS 0322* survey (spring Spanish acoustic survey in Sub-division 9.a North and Sub-area 8c in 2022). Spatial distribution of energy allocated to anchovy (NASC coefficients in m²/mn²).

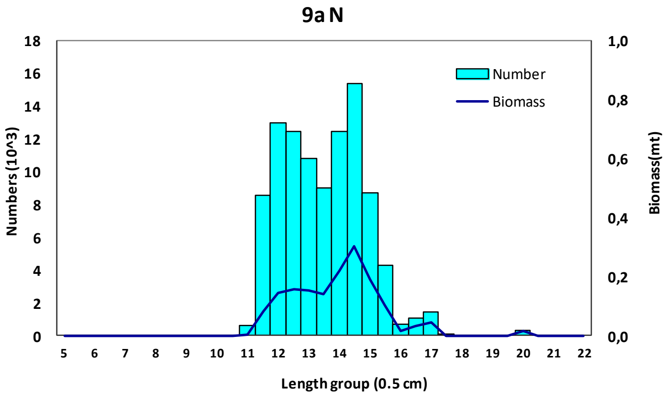


Figure 4.4.2.3. Anchovy in Division 9.a. Western component. Subdivision 9.a North. *PELACUS 0322* survey (spring Spanish acoustic survey in Subdivision 9.a North and Subarea 8c in 2022.Estimated abundance and biomass (number of fish in thousands and tonnes, respectively) in Subdivision 9.a North by size class.

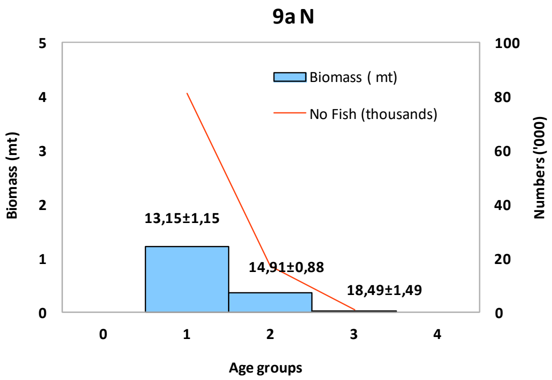


Figure 4.4.2.4. Anchovy in Division 9.a. Western component. Subdivision 9.a North. *PELACUS 0322* survey (spring Spanish acoustic survey in Subdivision 9.a North and Subarea 8c in 2022). Estimated abundance and biomass (number of fish in thousands and tonnes, respectively) in Subdivision 9.a North by age group, with indication of the mean size by age

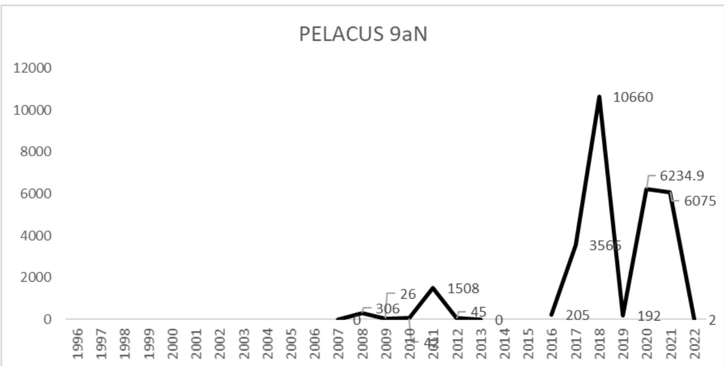


Figure 4.4.2.5. Anchovy in Division 9.a. Western component. Subdivision 9.a North. *PELACUS* survey series (spring Spanish acoustic survey in Subdivision 9.a North and Subarea 8c). Historical series of acoustic estimates of anchovy biomass (t) for the Subdivision 9.a North.

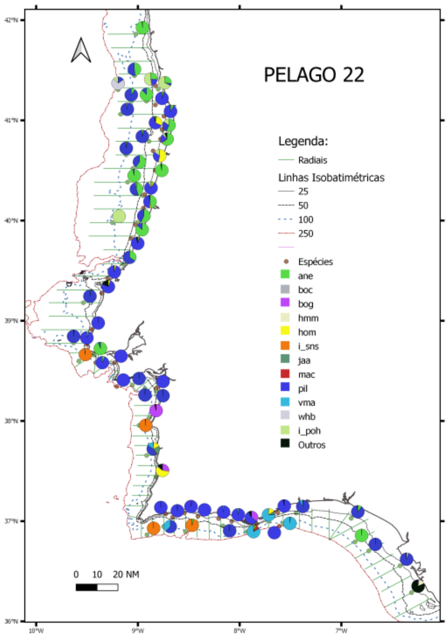


Figure 4.4.2.6. Anchovy in Division 9.a. Western and Southern components. Subdivisions 9.a Central-North to 9.a South. *PELAGO* survey series (spring Portuguese acoustic survey in Subdivisions 9.a Central-North to 9.a South). *PELAGO 22* survey. Location of valid fishing stations with indication of their species composition (percentages in number).

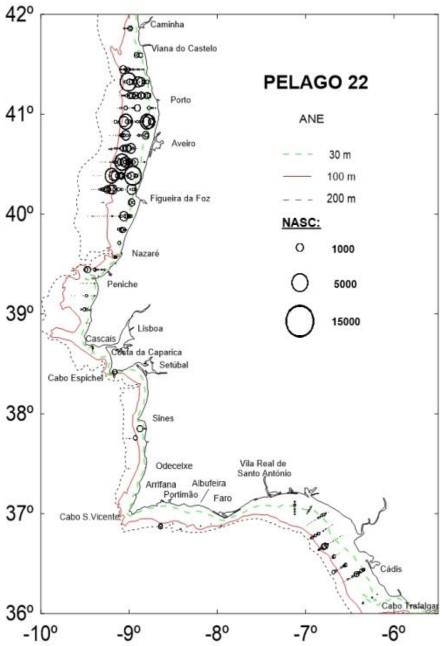


Figure 4.4.2.7. Anchovy in Division 9.a. Western and Southern components. Subdivisions 9.a Central-North to 9.a South. *PELAGO* survey series (spring Portuguese acoustic survey in Sub-divisions 9.a Central-North to 9.a South). *PELAGO 22* survey. Distribution of the NASC coefficients (m²/mn²) attributed to anchovy.

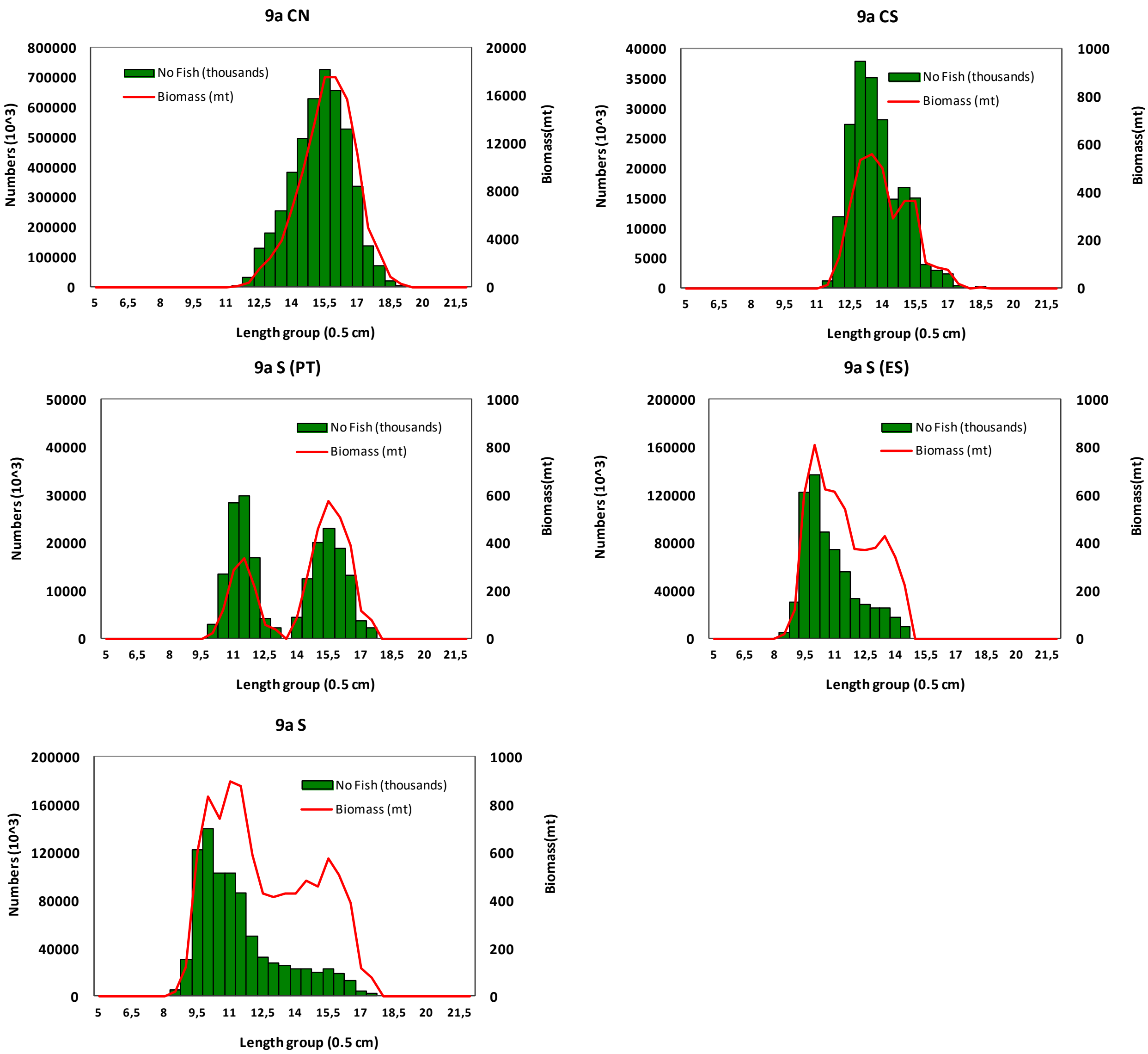


Figure 4.4.2.8. Anchovy in Division 9.a. Western and Southern components. Sub-divisions 9.a Central-North to 9.a South. *PELAGO* survey series (spring Portuguese acoustic survey in Sub-divisions 9.a Central-North to 9.a South). *PELAGO 22* survey. Estimated abundances and biomasses (number of fish in thousands and tonnes, respectively) for the surveyed area by length class (cm). Note the different scales in the y axis.

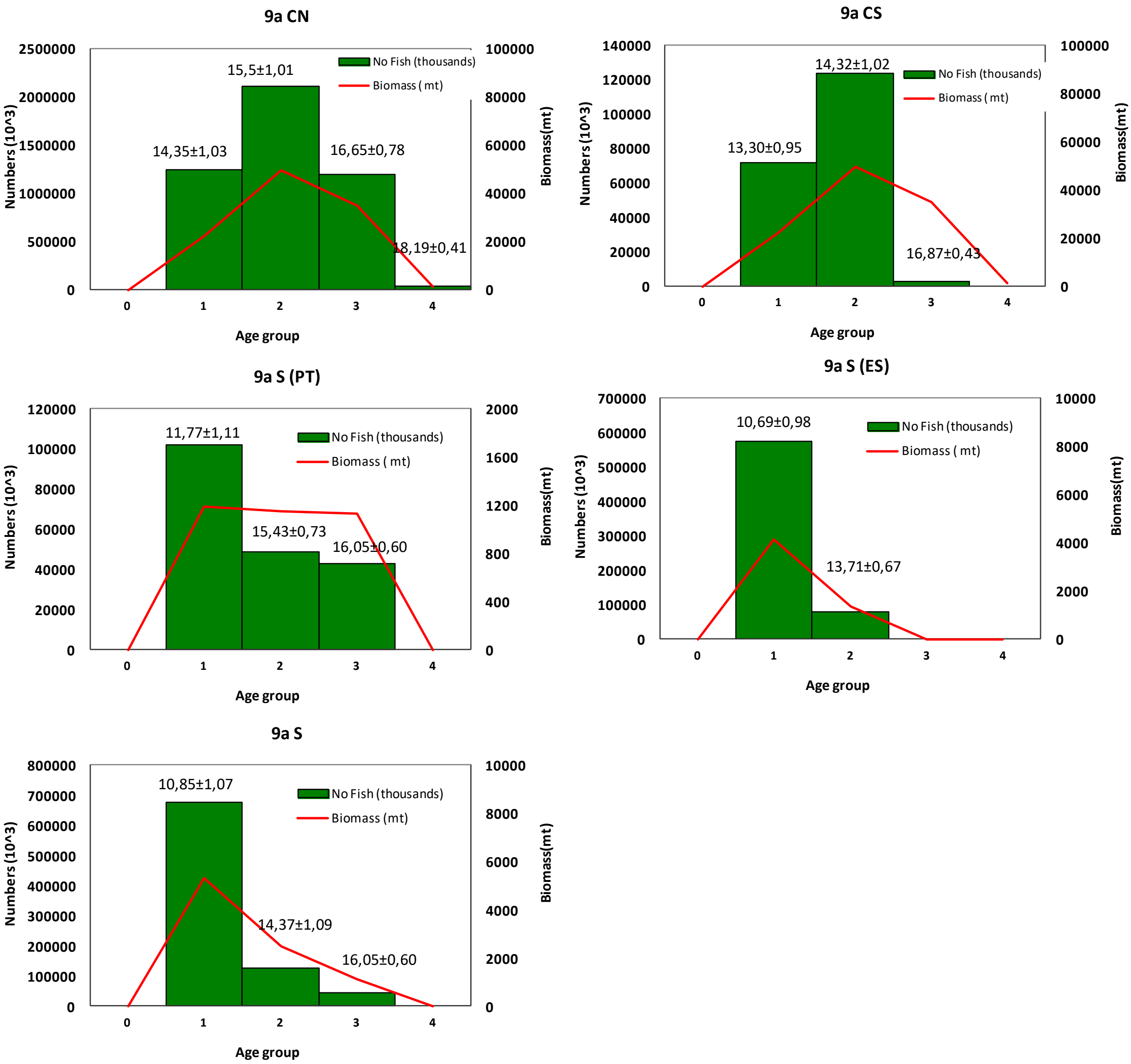


Figure 4.4.2.9. Anchovy in Division 9.a. Western and Southern components. Sub-divisions 9.a Central-North to 9.a South. *PELAGO* survey series (spring Portuguese acoustic survey in Sub-divisions 9.a Central-North to 9.a South). *PELAGO 22* survey. Estimated abundances and biomasses (number of fish in thousands and tonnes, respectively) for the surveyed area by age group, with indication of the mean size by age. Note the different scales in the y axis.

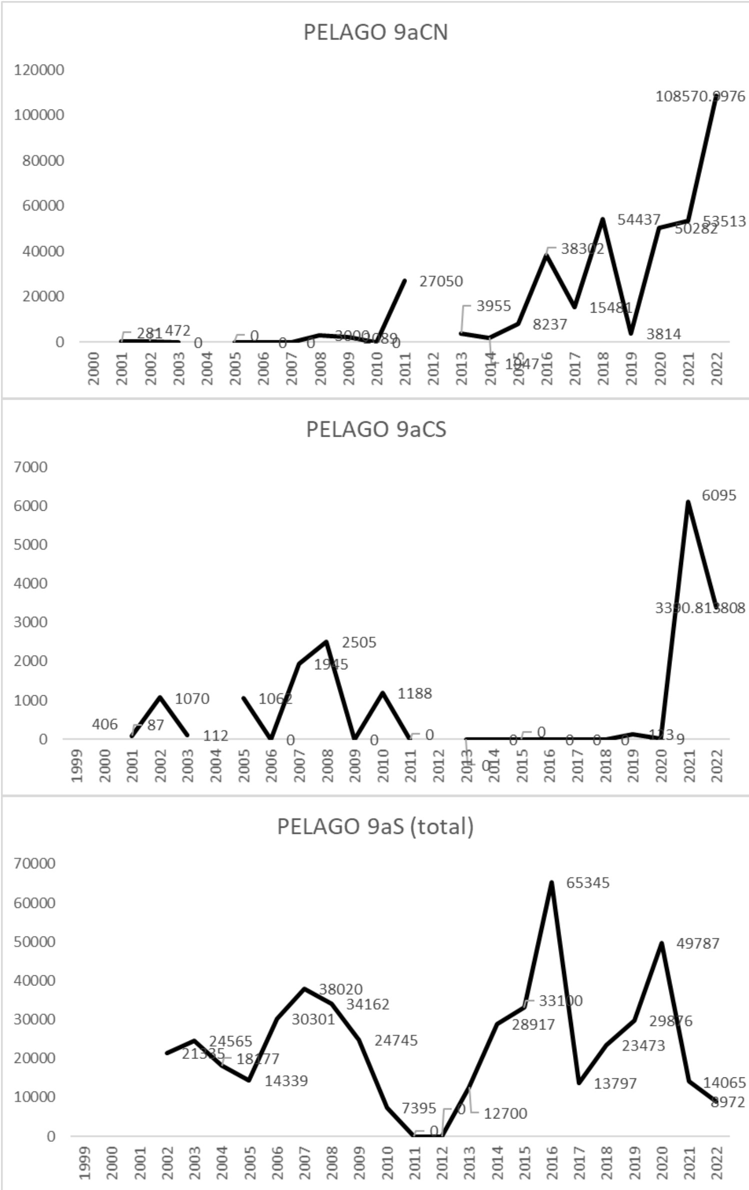
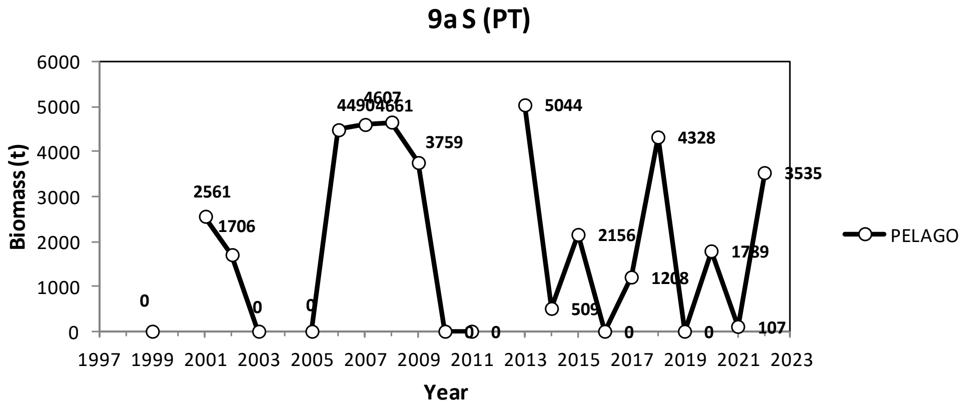


Figure 4.4.2.10. Anchovy in Division 9.a. Western and Southern components. Subdivisions 9.a Central-North to 9.a South. *PELAGO* survey series (spring Portuguese acoustic survey in Subdivisions 9.a Central-North to 9.a South). Historical series of regional acoustic estimates of anchovy biomass (t). Note the different scale of the y-axis.



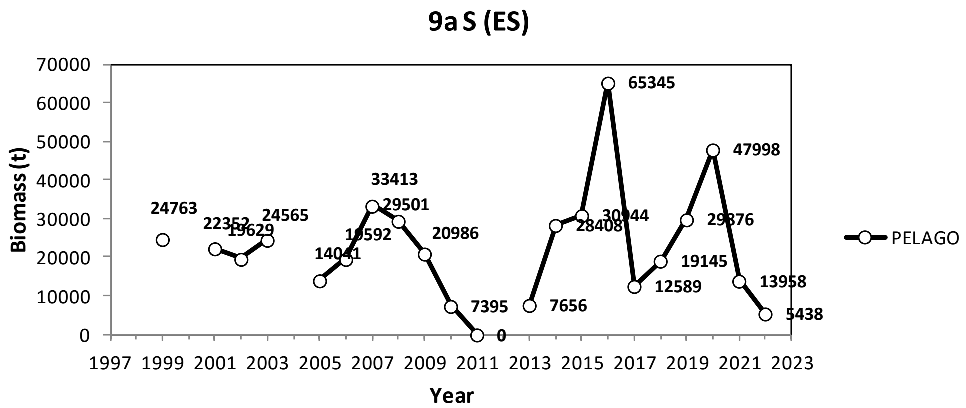


Figure 4.4.2.10. Continued. Acoustic estimates in the 9.a South differentiated by Portuguese (PT) and Spanish waters of the Gulf of Cadiz (ES). Note the different scale of the y-axis. Although estimates from Subdivision 9.a South in 2010 and 2014 were not separately provided for Algarve and Cadiz to this WG, the total estimated for the subdivision was assigned to the Cadiz area (by assuming some overestimation) according to the observed acoustic energy distribution in the area.

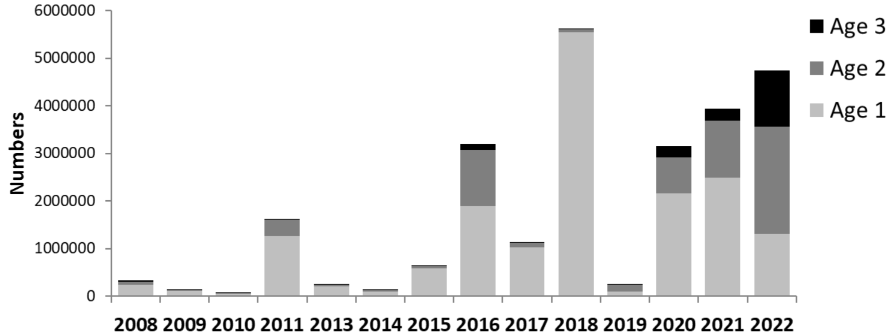
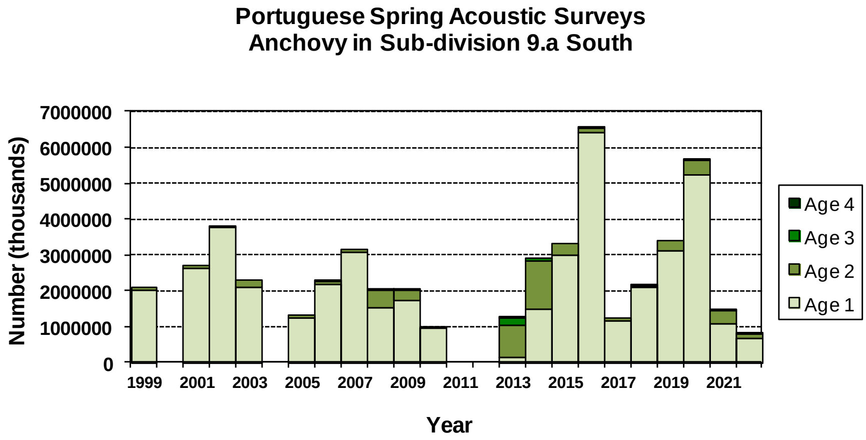


Figure 4.4.2.11. Anchovy in Division 9.a. Western component. Subdivisions 9.a North to Central-South. Annual trends of the estimated population by age class from the *PELACUS* (9a North)+*PELAGO* (9a Central-North and Central-South) Spring acoustic surveys. Age composition for 2020 only derived from the *PELAGO* survey given the *PELACUS* was not carried out.



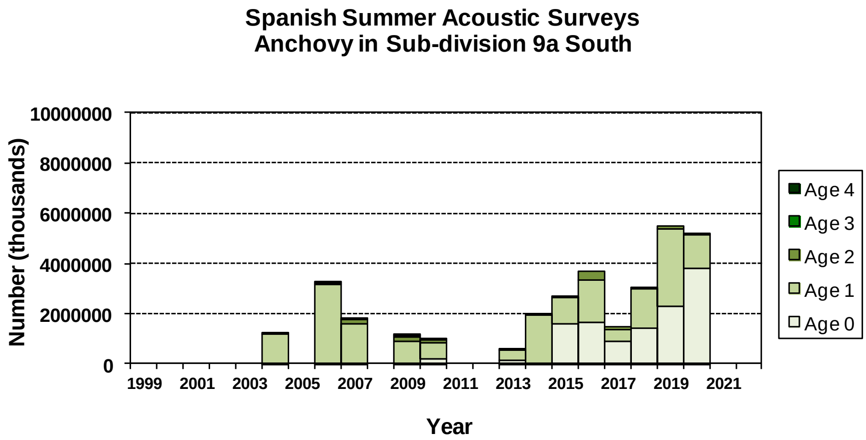


Figure 4.4.2.12. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. Annual trends of the estimated population by age class from the Algarve + Gulf of Cadiz areas by the *PELAGO* Portuguese Spring (upper plot) and *ECOCADIZ* Spanish summer (lower plot) acoustic surveys (*ECOCADIZ* 2021-07 was not finally conducted). Portuguese estimates until 2012 have been age-structured using Spanish ALKs from the commercial fishery in the second quarter in the year.

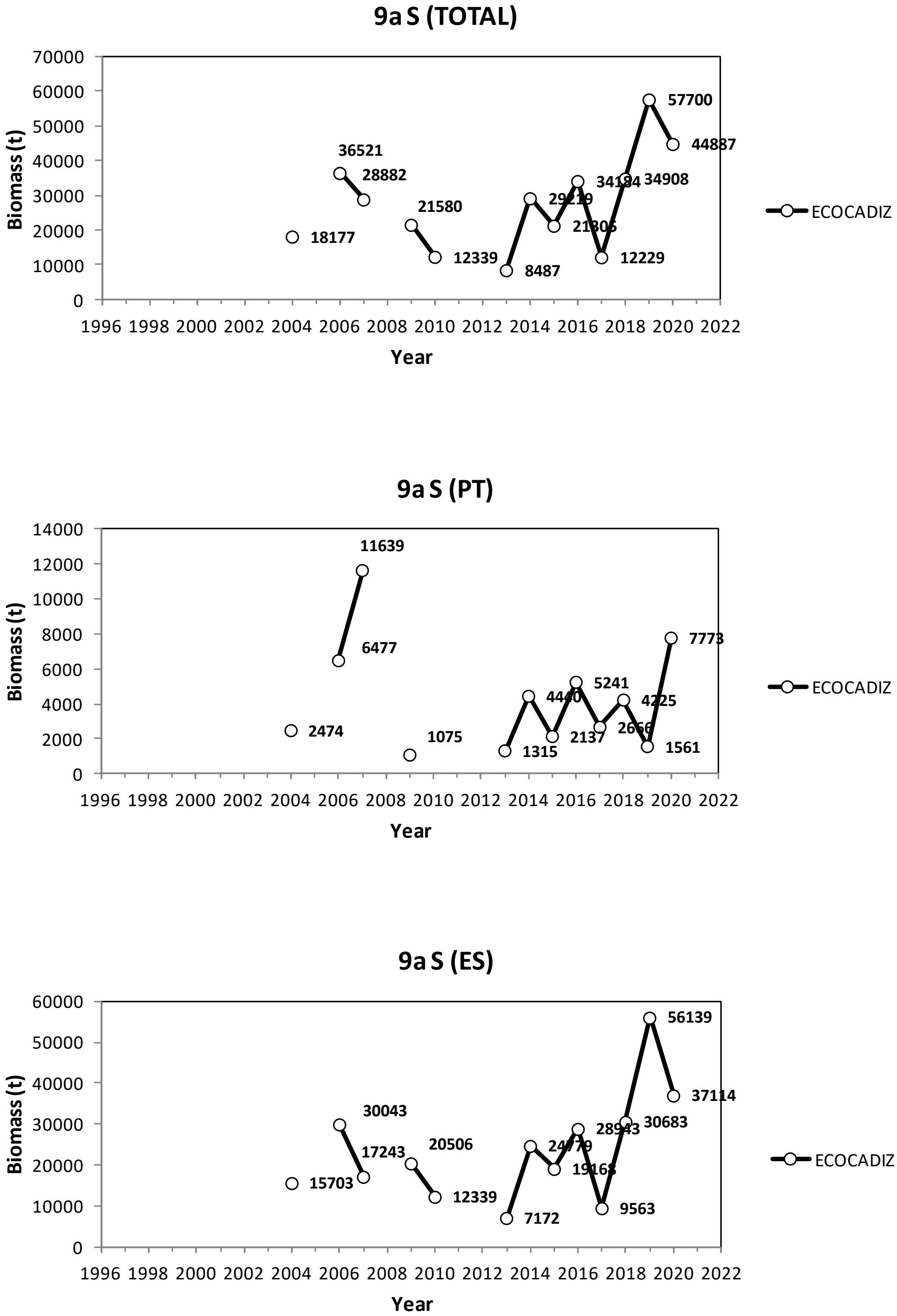


Figure 4.4.2.13. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. *ECOCADIZ* survey series (summer Spanish acoustic survey in Subdivision 9.a South). Historical series of overall and regional (Portuguese, PT, and Spanish waters of the Gulf of Cadiz, ES) acoustic estimates of anchovy biomass (t). Note the different scale of the y-axis. *ECOCADIZ* 2021-07 was not finally conducted.

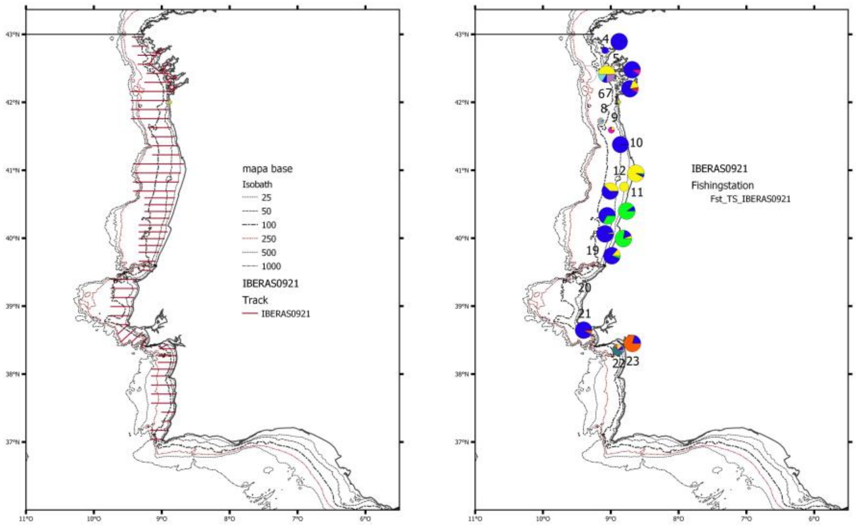


Figure 4.4.3.1. Anchovy in Division 9.a. Western component. Subdivisions 9.aNorth, 9.a Central-North and 9.a Central-South. *IBERAS 0921* survey (autumn Spanish-Portuguese acoustic survey in Subdivisions 9.aNorth to Central-South). Left: sampling grid. Right: location of valid fishing stations with indication of their species composition (percentages in number).

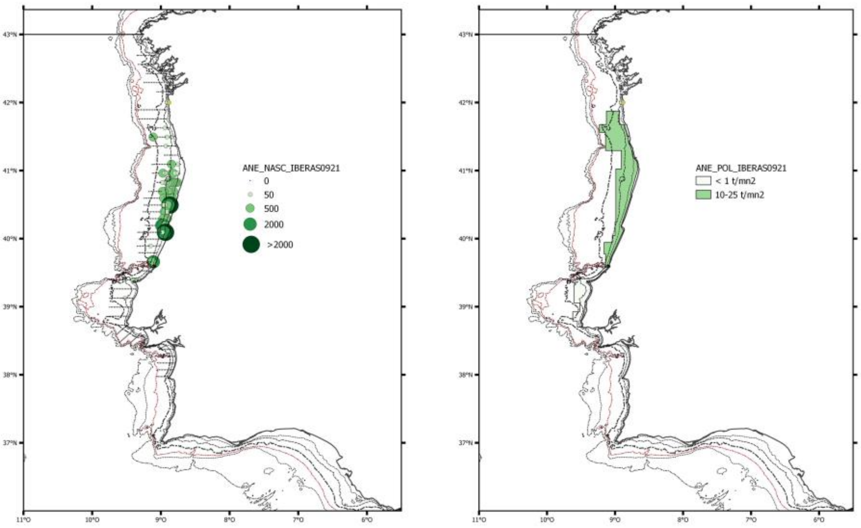


Figure 4.4.3.2. Anchovy in Division 9.a. Western component. Subdivisions 9.a North, 9.a Central-North and 9.a Central-South. *IBERAS 0921* survey (autumn Spanish-Portuguese acoustic survey in Subdivisions 9.a North to Central-South). Left: distribution of the backscattering energy (Nautical area scattering coefficient, NASC, in m^2 nmi^{-2}) attributed to the species. Right: distribution of the homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of fish density (in t nmi^{-2}) in each post-stratum.

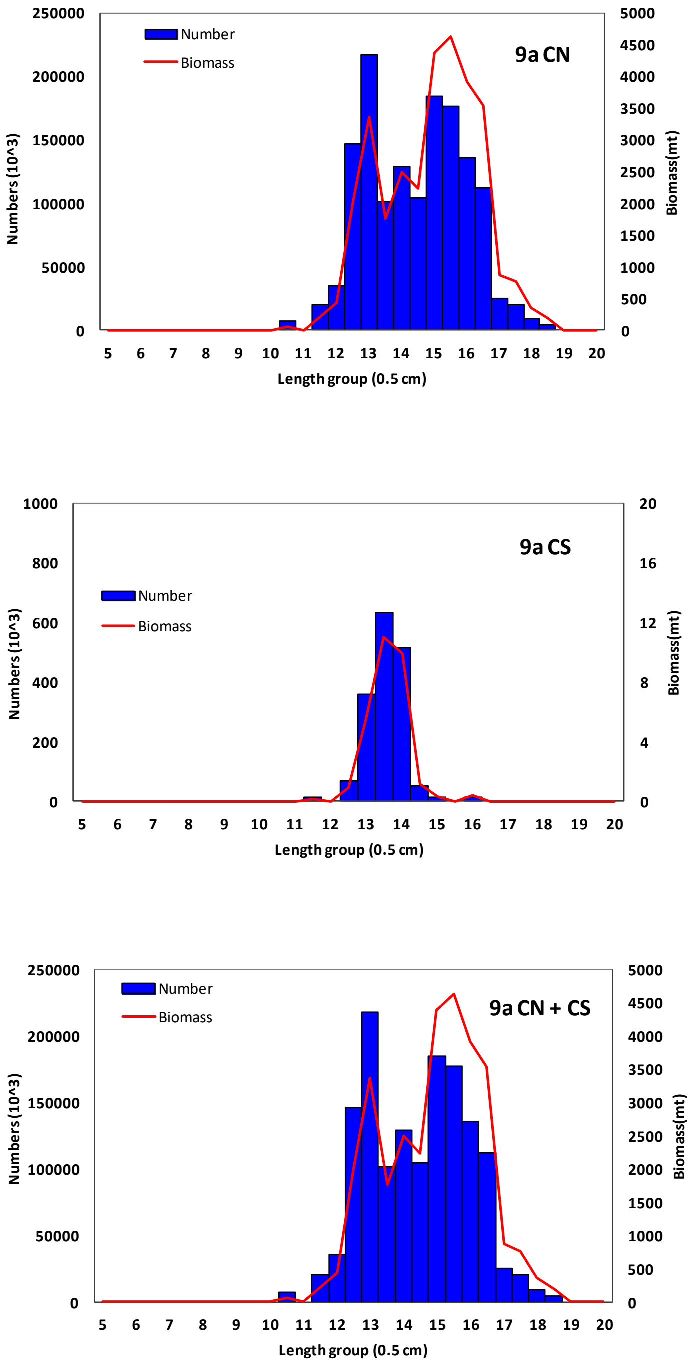


Figure 4.4.3.3. Anchovy in Division 9.a. Western component. Subdivisions 9.aNorth, 9.a Central-North and 9.a Central-South. *IBERAS 0921* survey (autumn Spanish-Portuguese acoustic survey in Subdivisions9.a North to Central-South). Estimated abundances and biomasses (number of fish in thousands and tonnes, respectively) for the surveyed area by length class (cm).Note the different scales in the y-axis.

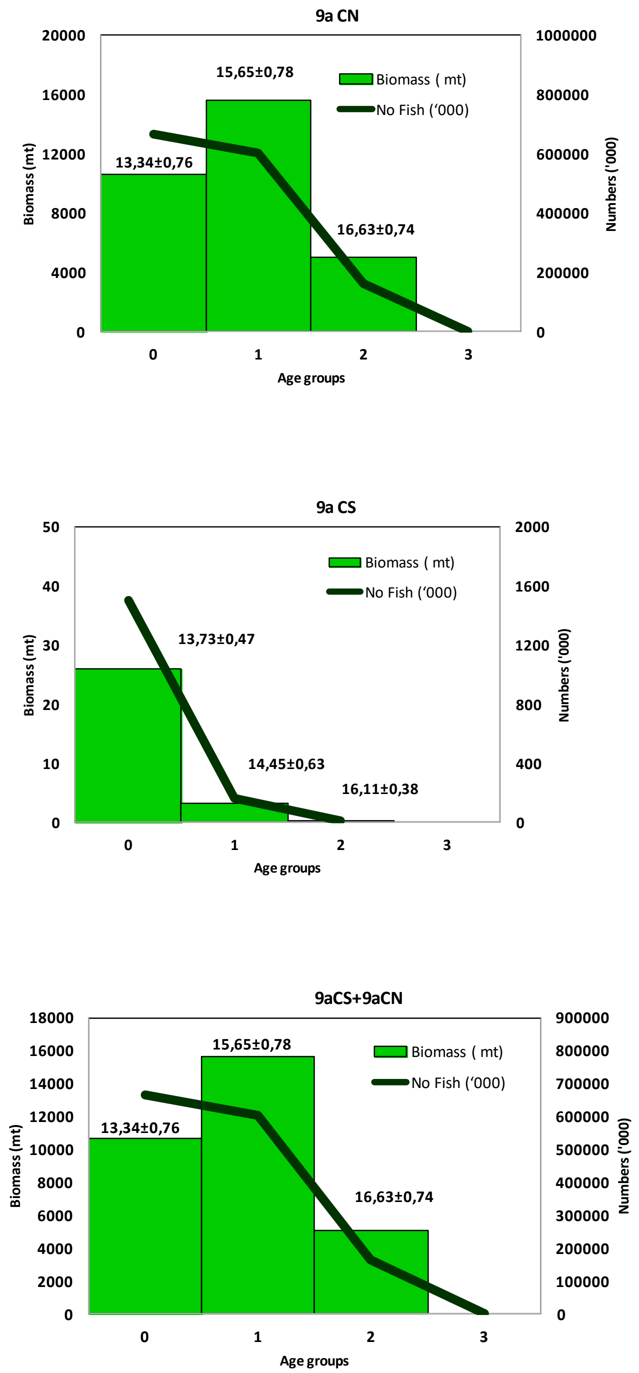


Figure 4.4.3.4. Anchovy in Division 9.a. Western component. Subdivisions 9.a North, 9.a Central-North and 9.a Central-South. *IBERAS 0921* survey (autumn Spanish-Portuguese acoustic survey in Subdivisions 9.a North to Central-South). Estimated abundances and biomasses (number of fish in thousands and tonnes, respectively) for the surveyed area by age group, with indication of the mean size by age. Note the different scales in the y-axis.

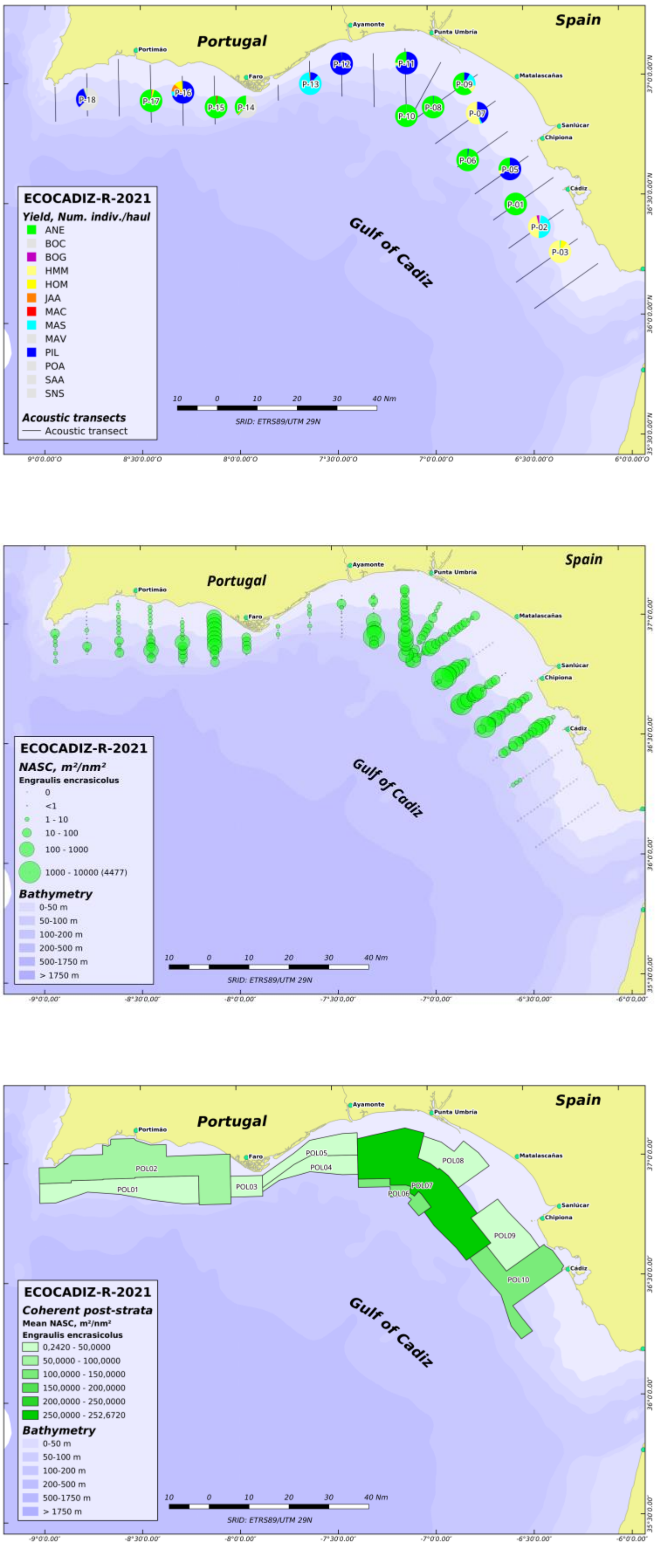


Figure 4.4.3.5. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. *ECOCADIZ-RECLUTAS 2021-10* survey (autumn Spanish acoustic survey in Subdivision 9.a South). Top: Location of valid fishing stations with indication of their species composition (percentages in number).Middle: Distribution of the backscattering energy (Nautical area scattering coefficient, NASC, in m² 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.

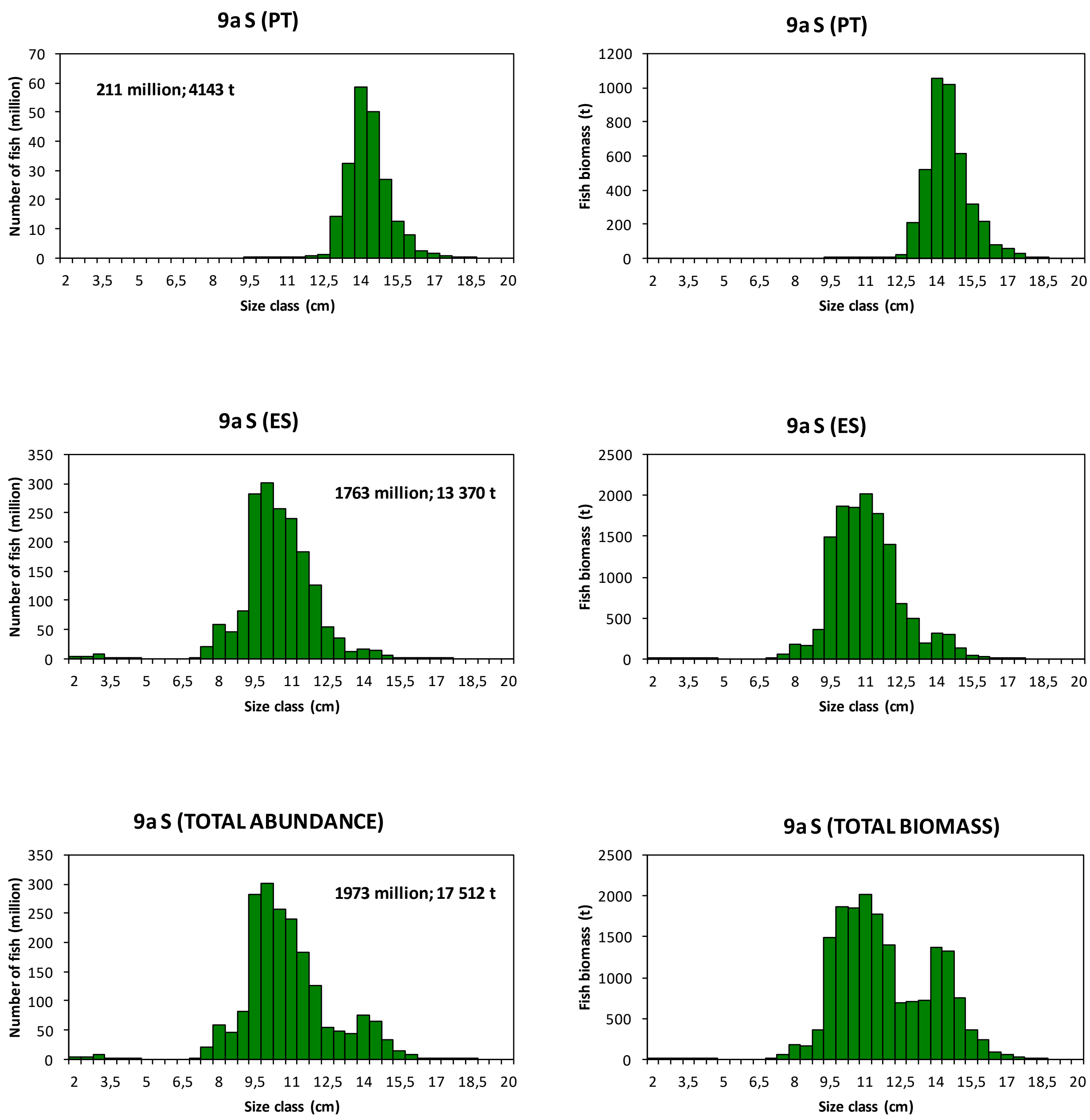


Figure 4.4.3.6. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. *ECOCADIZ-RECLUTAS 2021-10* survey (autumn Spanish acoustic survey in Subdivision 9.a South). Estimated abundances and biomasses (number of fish in millions and tonnes, respectively) for the surveyed area by length class (cm). Note the different scales in the y-axis.

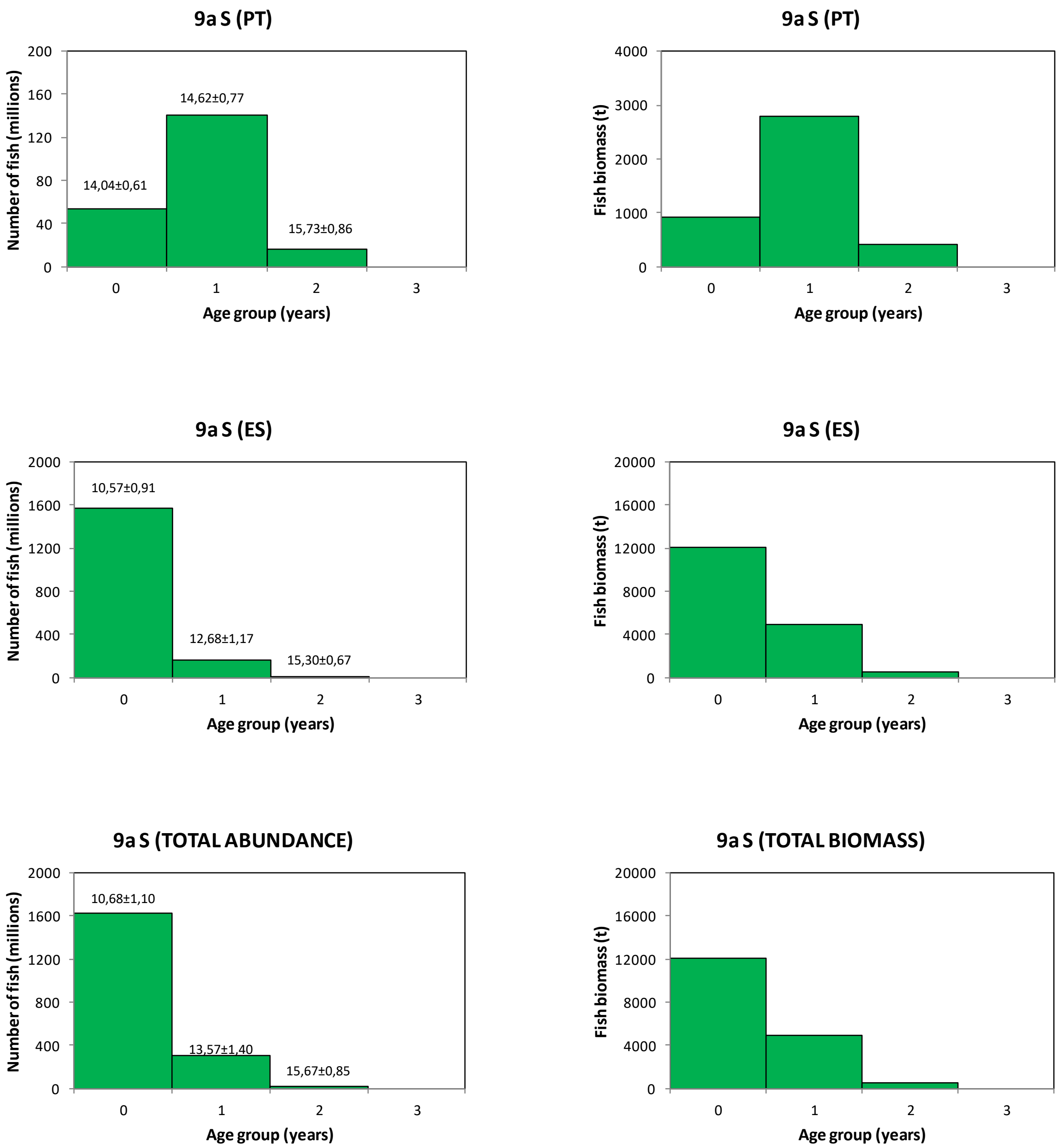
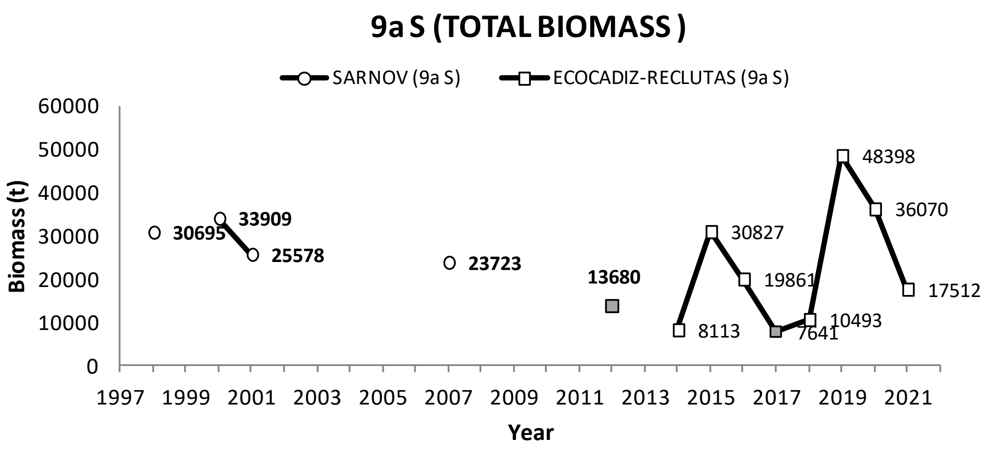
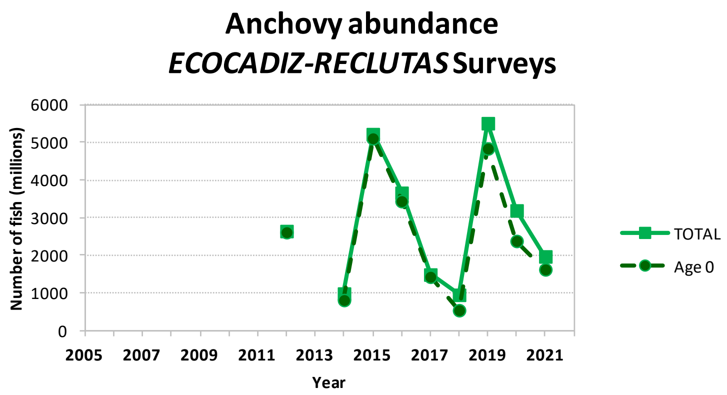


Figure 4.4.3.7. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. *ECOCADIZ-RECLUTAS 2021-10* survey (autumn Spanish acoustic survey in Subdivision 9.a South). Estimated abundances and biomasses (number of fish in millions and tonnes, respectively) for the surveyed area by age group, with indication of the mean size by age. Note the different scales in the y-axis.





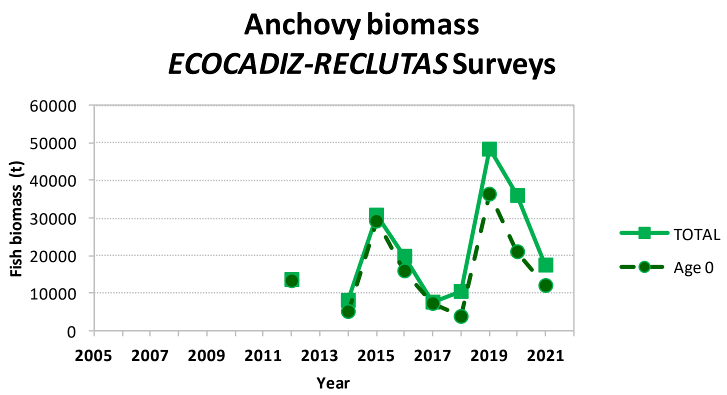
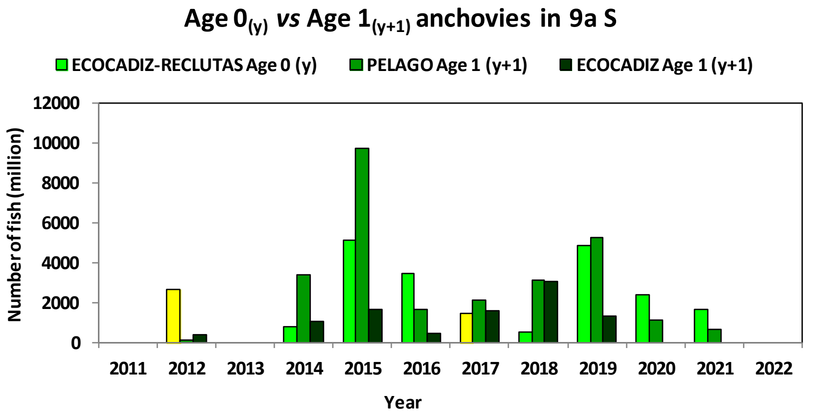
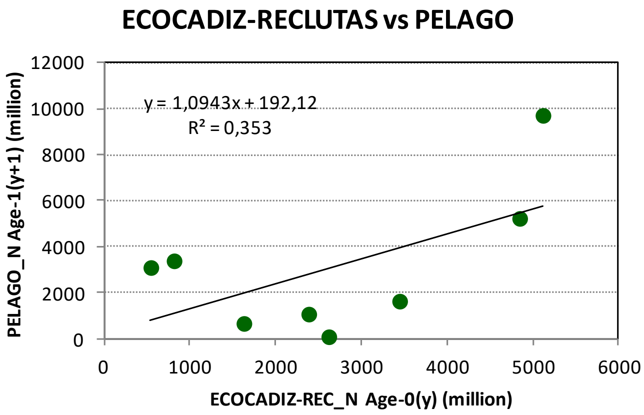


Figure 4.4.3.8. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. *ECOCADIZ-RECLUTAS* survey series (autumn Spanish acoustic survey in Subdivision 9.a South). Top: historical series of overall acoustic estimates of anchovy biomass (t), (squares). The estimates from the older Portuguese *SARNOV* survey series are also included for comparison of trends (circles). The 2012 and 2017 estimates (in dark grey) are partial ones, since the surveys either covered the Spanish waters (2012) or the seven easternmost transects (2017). Middle and bottom: time-series estimates of abundance and biomass of the total population and Age 0 fish. In this case, the 2017 has not been included. The 2012 estimate is retained because the recruitment area was almost covered.





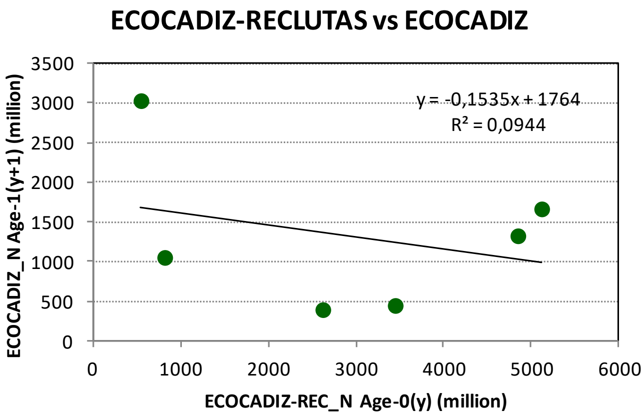


Figure 4.4.3.9. Anchovy in Division 9.a. Southern component. Subdivision 9.a South. *ECOCADIZ-RECLUTAS* survey series (autumn Spanish acoustic survey in Subdivision 9.a South). Correspondence between acoustic estimates of abundance of Age 0 anchovies from *ECOCADIZ-RECLUTAS* surveys in the autumn of 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. The *ECOCADIZ-RECLUTAS* 2012 and 2017 estimates are partial ones since the 2012 survey only covered the Spanish waters and the 2017 survey the seven easternmost transects (this last data point was removed from the regression fittings). *ECOCADIZ* 2021-07 was not finally conducted.

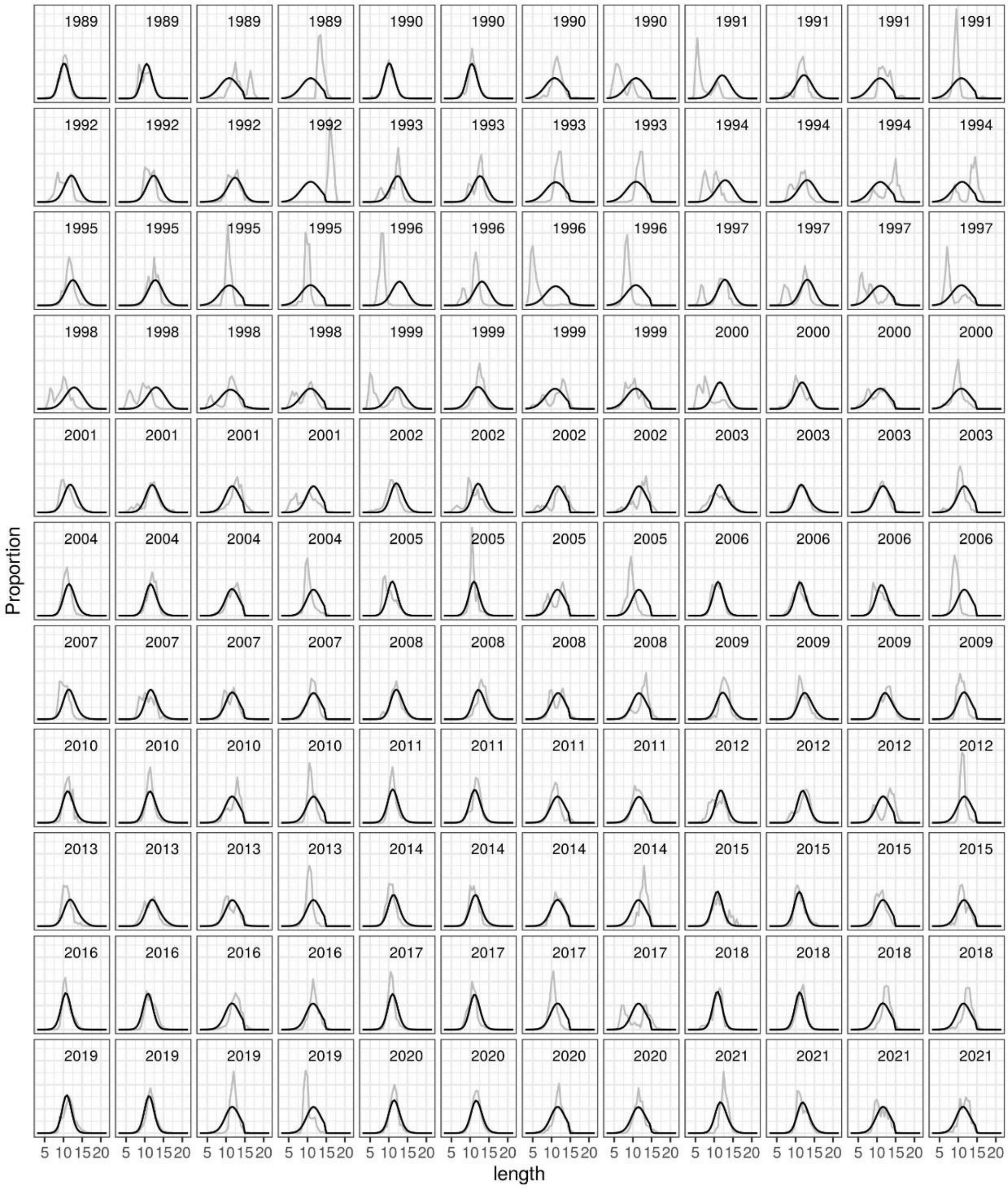


Figure 4.6.2.1.2.1. Anchovy in Division 9.a. Southern component. Comparison between observed and estimated catches length distribution by quarters from 1989 to 2021. Black lines represent estimated data while gray lines represent observed data.

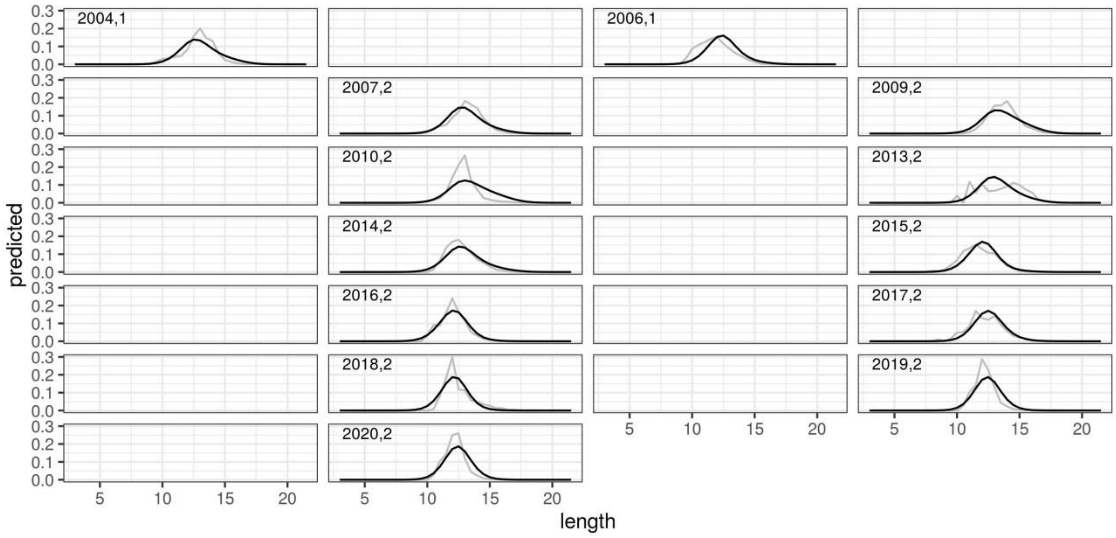


Figure 4.6.2.1.2.2. Anchovy in Division 9.a. Southern component. Comparison between observed and estimated catches length distribution for *ECOCADIZ* survey from 2004 to 2020. Black lines represent estimated data while gray lines represent observed data. The number next to the year indicates the quarter. Note that the time of the survey in the model is assumed to be one quarter before it really happens; this assumption follows from the order of calculations in the model.

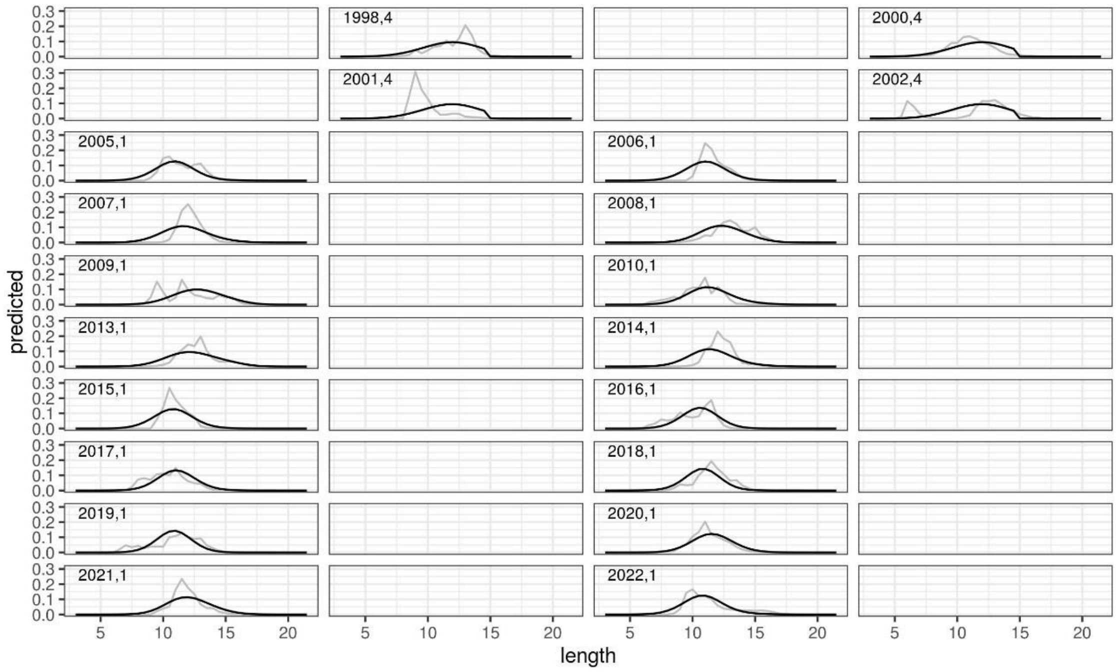


Figure 4.6.2.1.2.3. Anchovy in Division 9.a. Southern component. Comparison between observed and estimated catches length distribution for *PELAGO* survey from 1998 to 2022. Black lines represent estimated data while gray lines represent observed data. The number next to the year indicates the quarter. Note that the time of the survey in the model is assumed to be one quarter before it really happens; this assumption follows from the order of calculations in the model.

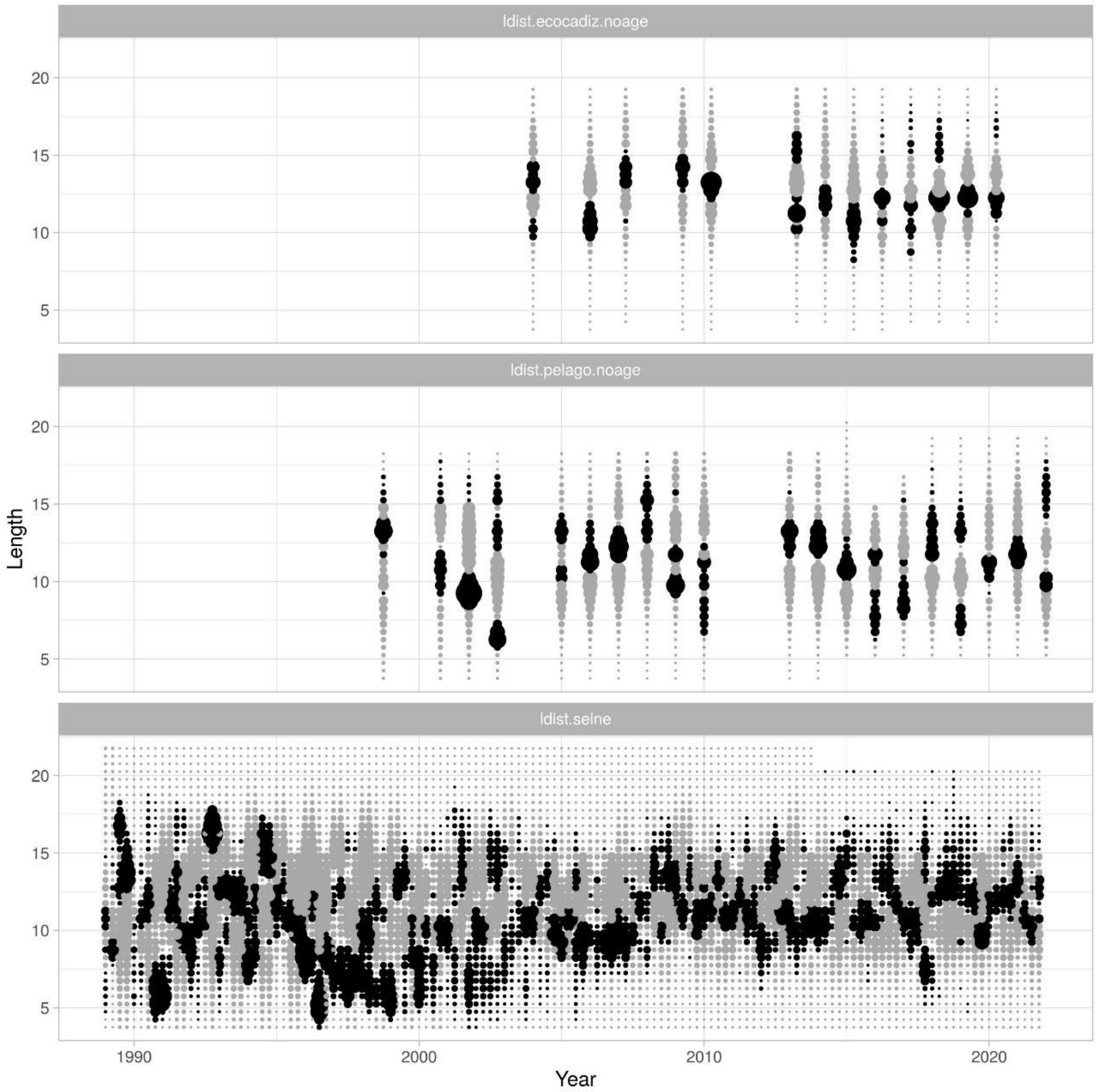


Figure 4.6.2.1.2.4. Anchovy in Division 9.a. Southern component. Standardised residual plots for the fitted length distribution from the *ECOCADIZ* survey, *PELAGO* survey and commercial fleet. Black points denote a model underestimate and gray points an overestimate. The size of the points denotes the scale of the standardised residual.

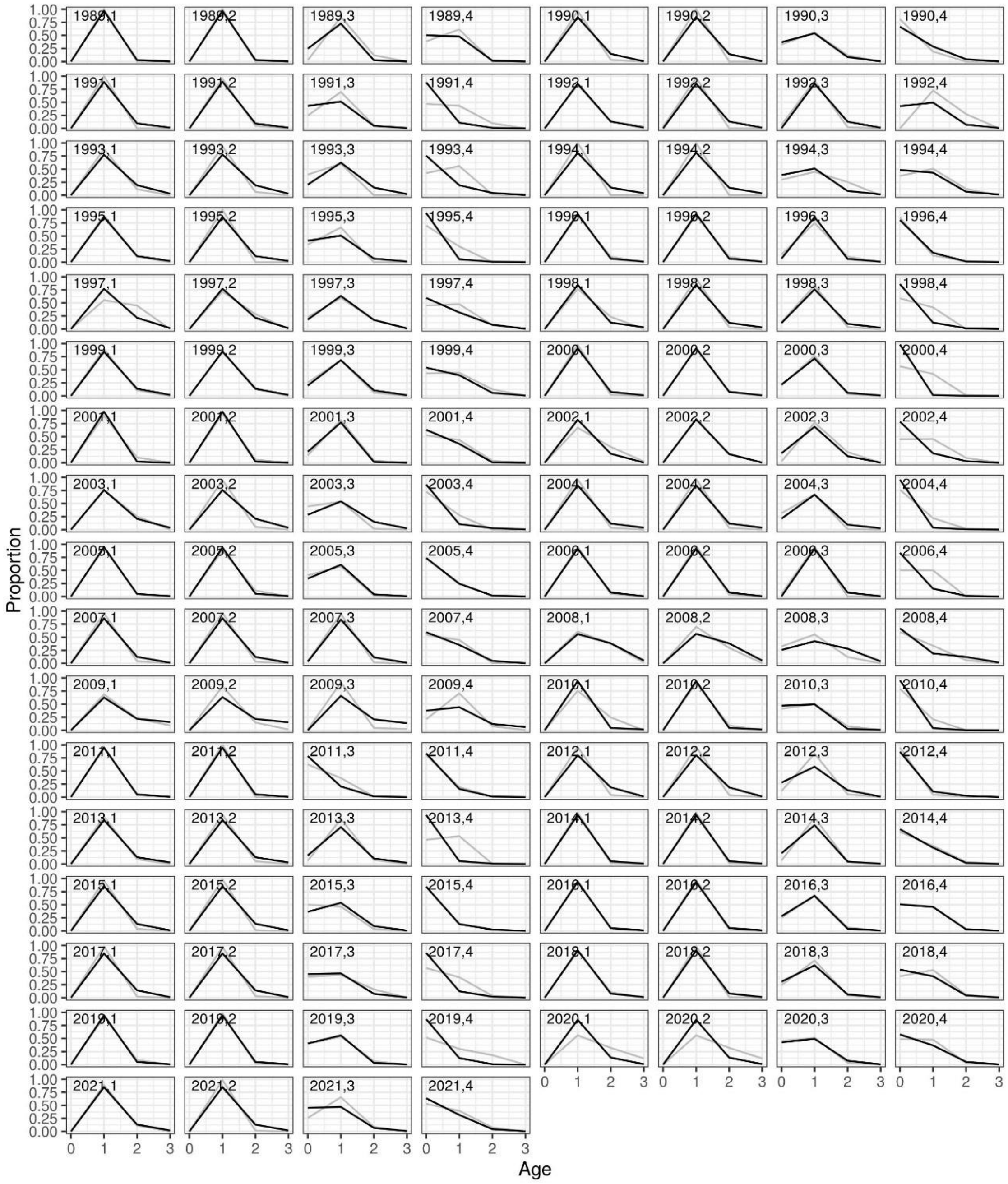


Figure 4.6.2.1.2.5. Anchovy in Division 9.a. Southern component. Comparison between observed and estimated quarterly catches age distribution from 1989 to 2021. Black lines represent estimated data while gray lines represent observed data. The number next to the year indicates the quarter.

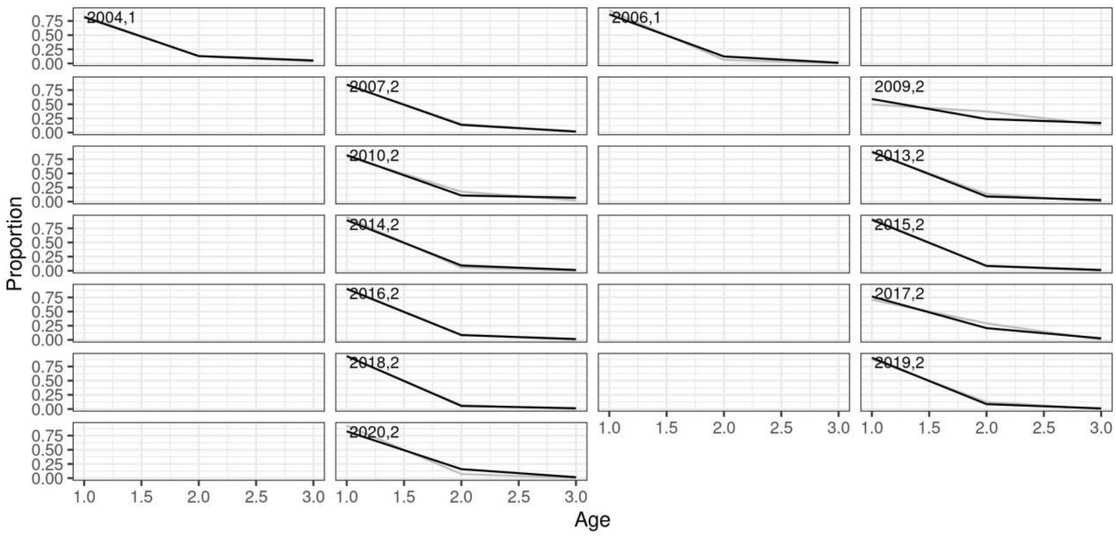


Figure 4.6.2.1.2.6. Anchovy in Division 9.a. Southern component. Comparison between observed and estimated *ECOCADIZ* survey age distribution from 2004 to 2020. Black lines represent estimated data while gray lines represent observed data. The number next to the year indicates the quarter. Note that the time of the survey in the model is assumed to be one quarter before it really happens; this assumption follows from the order of calculations in the model.

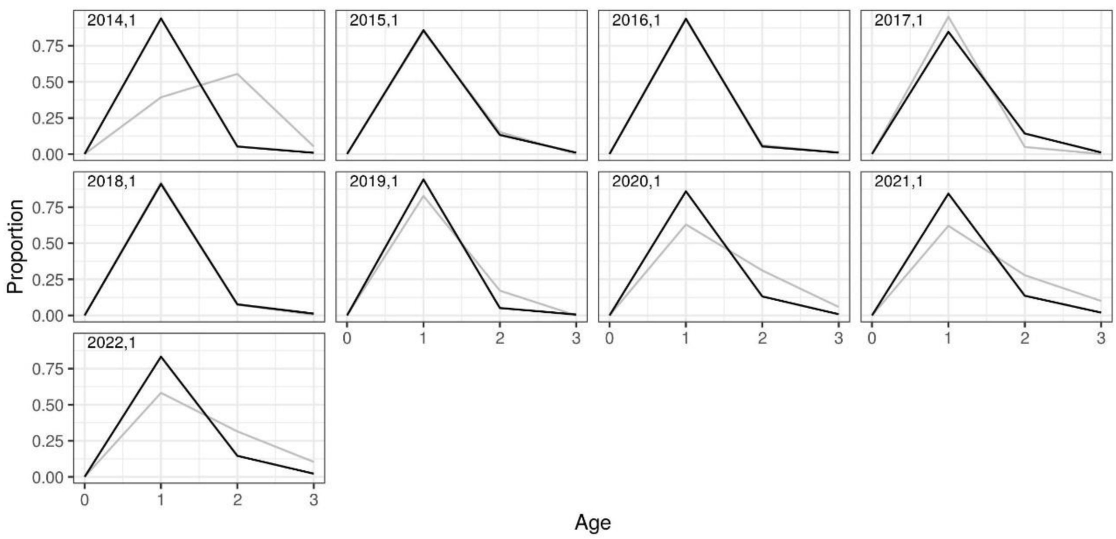


Figure 4.6.2.1.2.7. Anchovy in Division 9.a. Southern component. Comparison between observed and estimated *PELAGO* survey age distribution from 2014 to 2022. Black lines represent estimated data while gray lines represent observed data. The number next to the year indicates the quarter. Note that the time of the survey in the model is assumed to be one quarter before it really happens; this assumption follows from the order of calculations in the model.

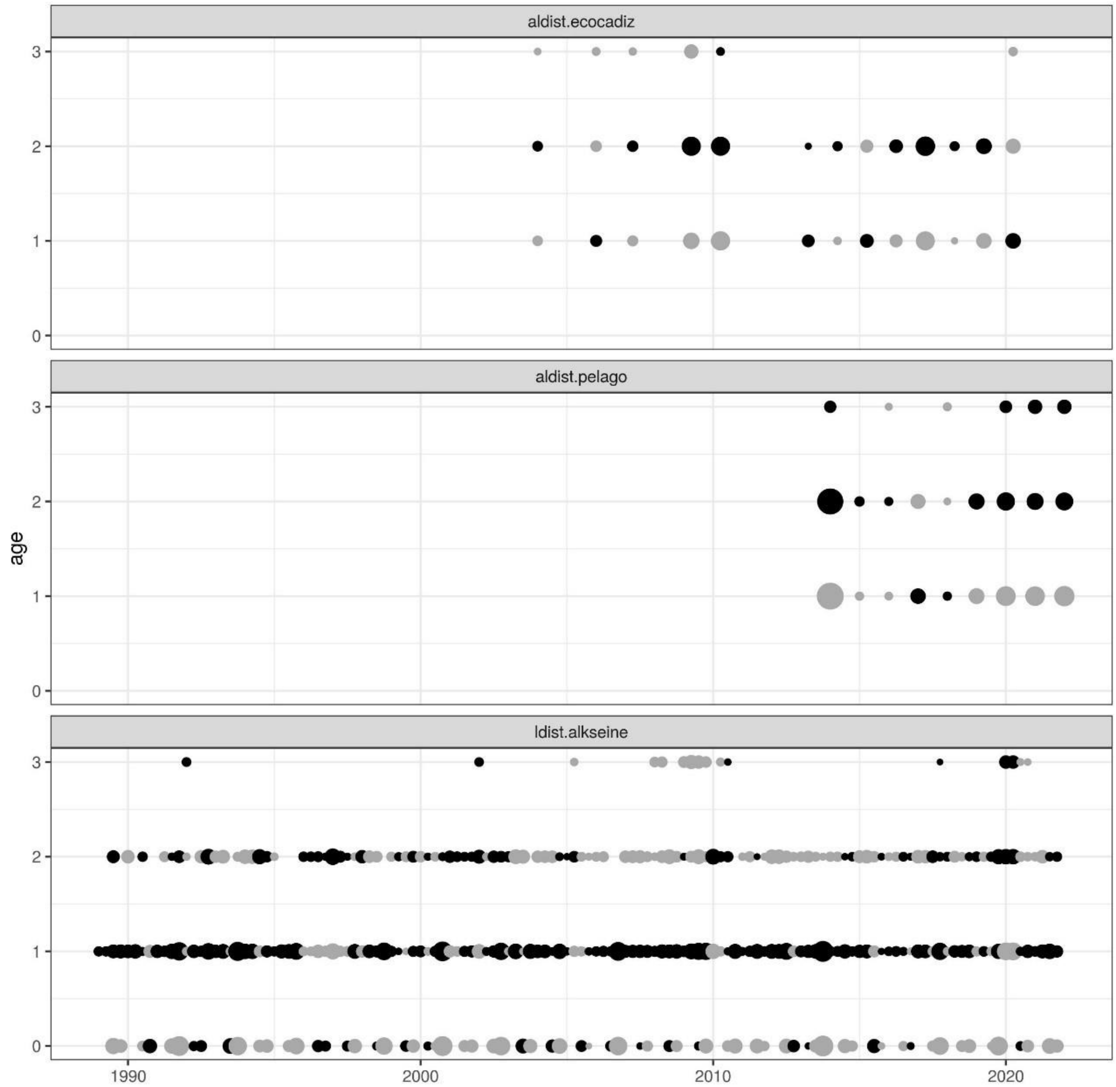


Figure 4.6.2.1.2.8. Anchovy in Division 9.a. Southern component. Standardised residual plots for the fitted age distribution from the *ECOCADIZ* survey, *PELAGO* survey and commercial fleet. Black points denote a model underestimate and gray points an overestimate. The size of the points denotes the scale of the standardised residual.

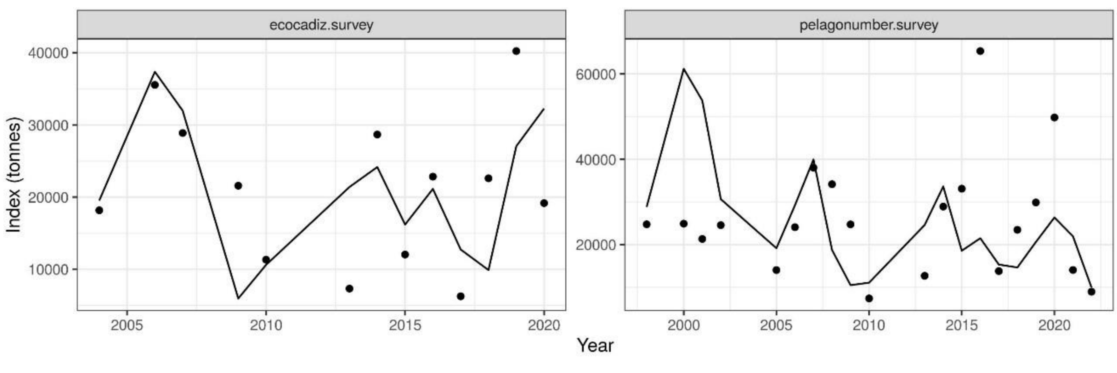


Figure 4.6.2.1.2.9. Anchovy in Division 9.a. Southern component. Comparison between observed and estimated survey biomass indices. Black points represent observed data while black line represents estimated data.

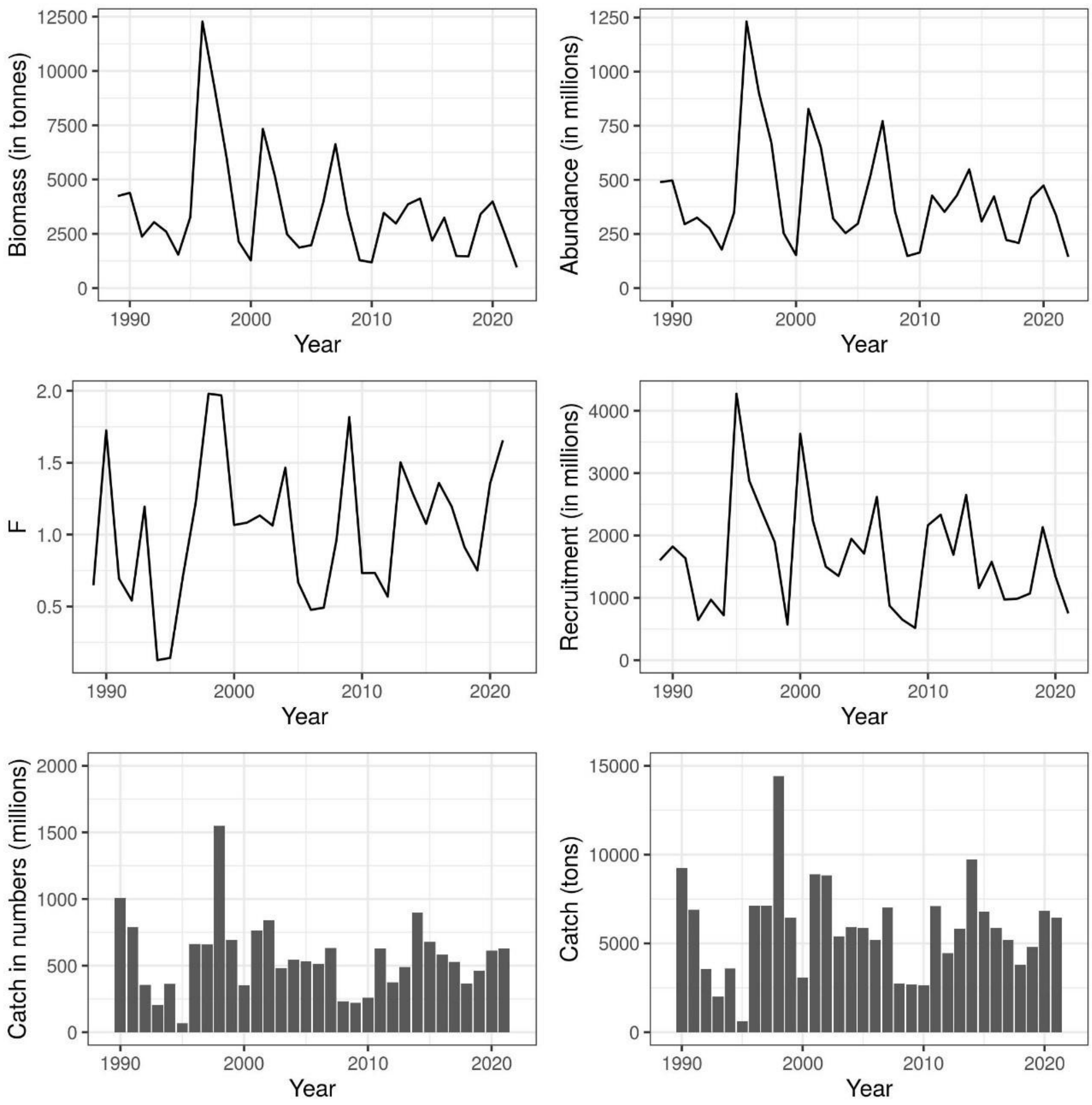


Figure 4.6.2.1.3.1. Anchovy in Division 9.a. Southern component. Annual model estimates for abundance with more than one year of age (in numbers and biomass), recruitment and fishing mortality compared with annual catch time-series (in numbers and biomass). Measures were summarised at the end of June each year, assuming that a year starts in July and ends in June of the next year.

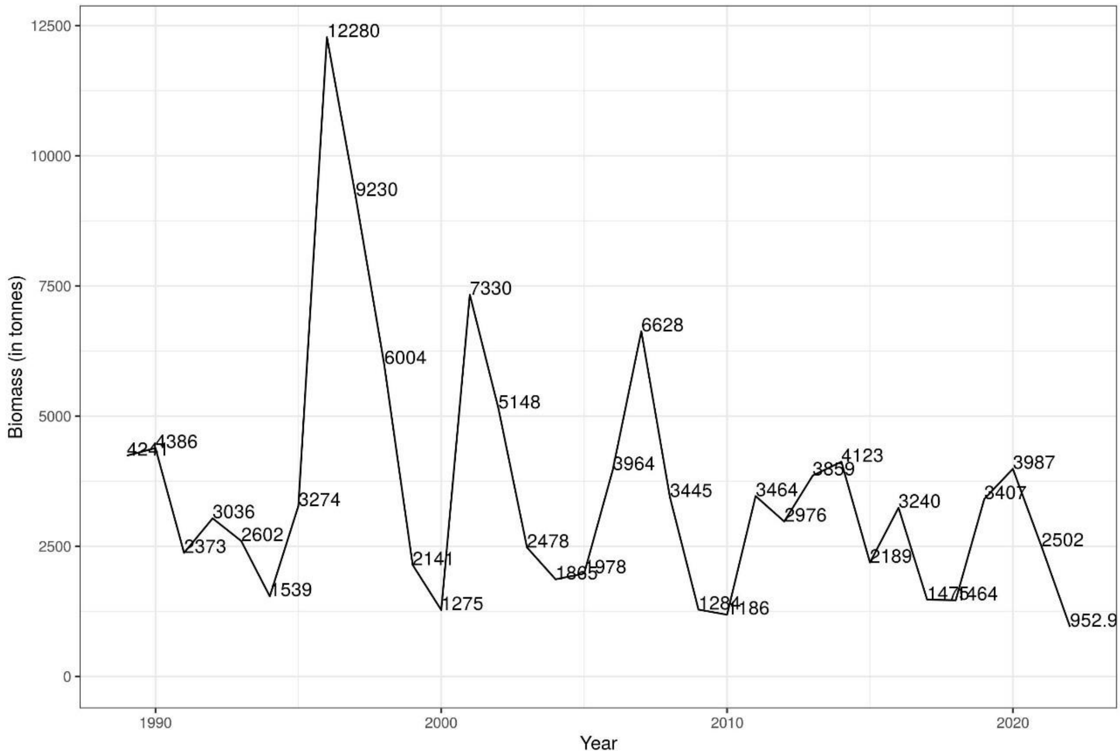


Figure 4.6.2.1.3.2. Anchovy in Division 9.a. Southern component. Time-series of estimated biomass at the end of June each year, assuming that a year starts in July and ends in June of the next year. For this stock, it is assumed that there are no individuals of age 0 at that time of the year, then this abundance estimates corresponds to individuals of age 1+. These biomass estimates are equivalent to spawning–stock biomass estimates since it is assumed that all individuals with age 1 or higher are mature.

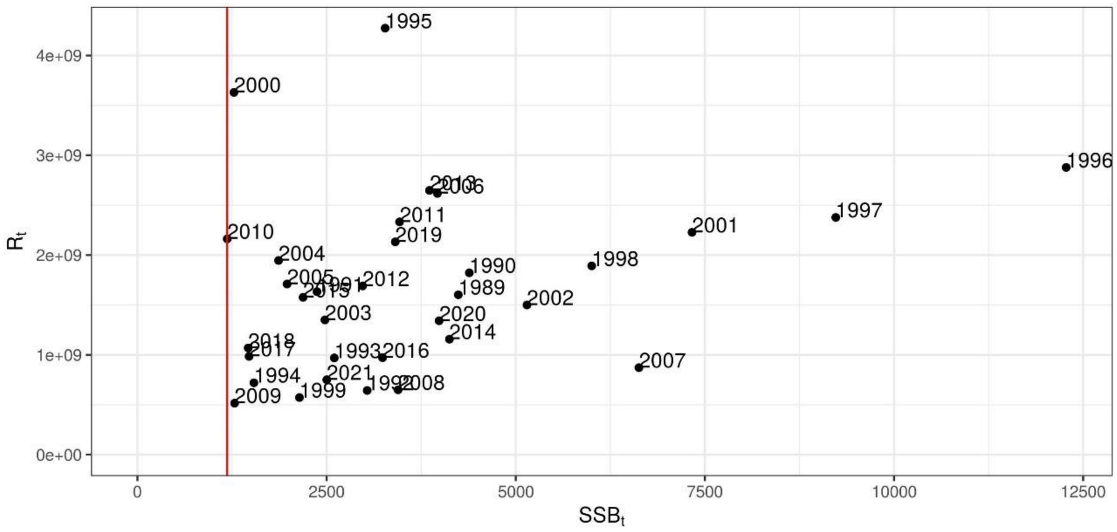


Figure 4.7.2.1. Anchovy in Division 9.a. Southern component. Estimated Stock Spawning biomass vs. Recruitment plot. Red line indicates the Blim value (Blim=Bloss=SSB_{2017}= 1483.48 t).

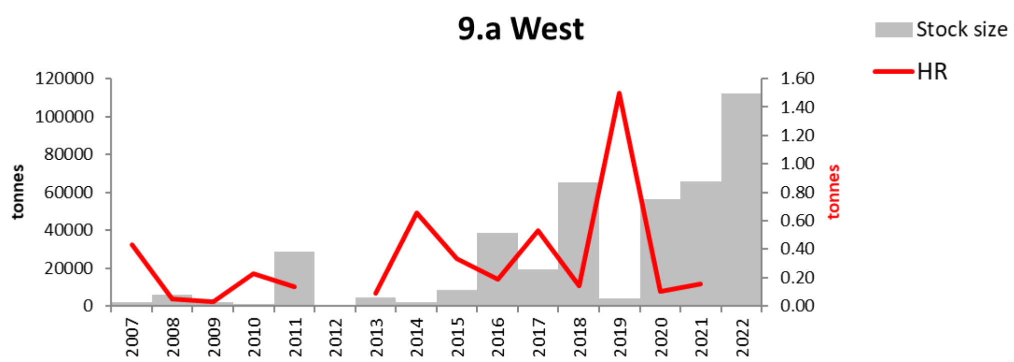


Figure 4.8.1.1. Anchovy in Division 9.a. Western Component. Stock biomass survey index and harvest rates. Harvest rates were estimated with the biomass of the surveys of a given year and the catches of the management period, i.e. 2007 corresponds to the period 07/2007 to 06/2008.

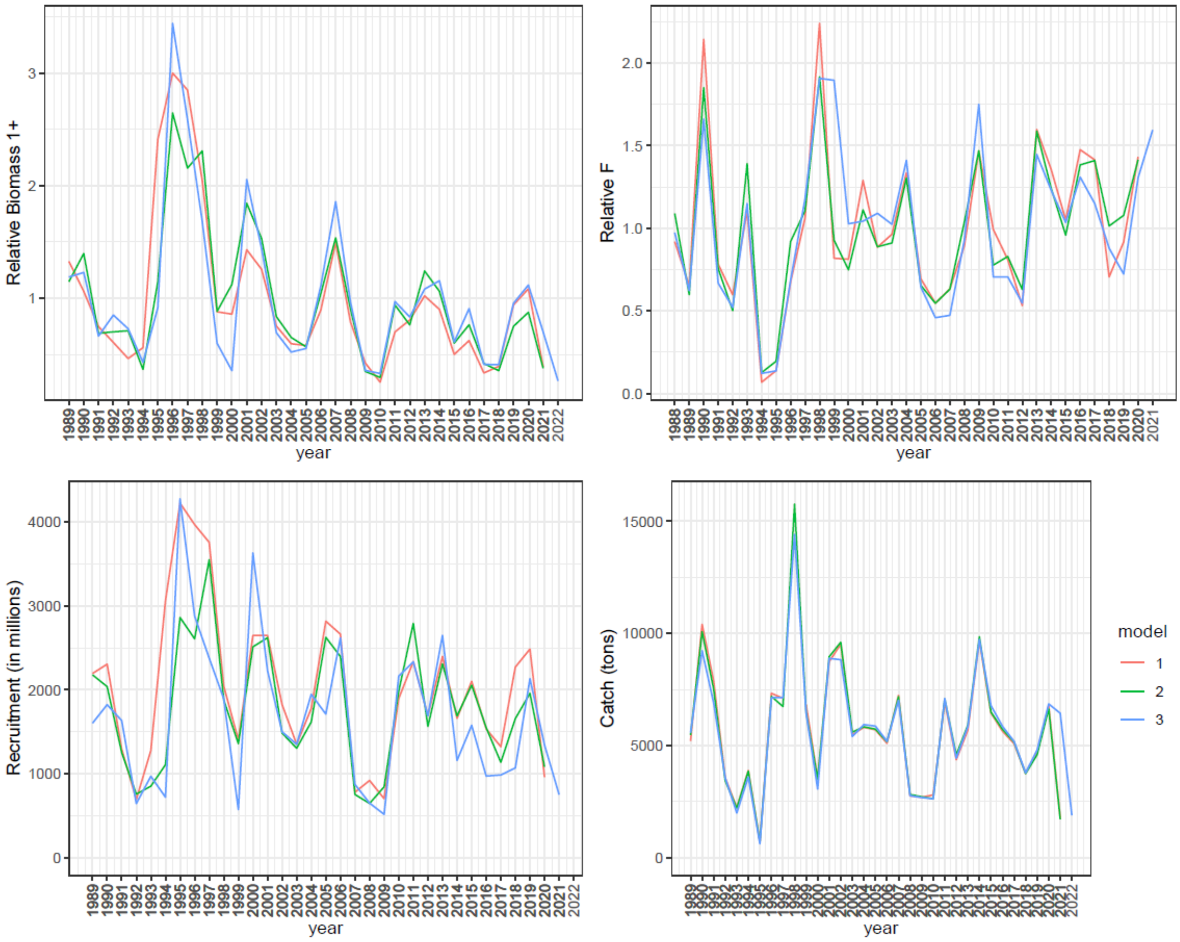


Figure 4.11.2.1: Anchovy in Division 9.a. Southern component. Comparison of estimates from different model implementations.1. Model used last year (pink), 2. Model used last year but including the ECOCADIZ length distribution in 2020 (green), 3. Model described in this document which is the reference for the advice provided in 2022 (blue): Annual model estimates for relative abundance of individuals with more than one year of age, relative fishing mortality, recruitment and catches (in numbers). 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. It is also important to remark that the number of iterations for the optimization process in the first model was 2000000, while in the others was just 1000000.

5 Sardine general

This section hasn’t been updated as there is no new information.

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 and 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 2021, they account for 61%. This is 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 2021 were 5 922 tonnes.

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 2021, 20 239 tonnes were landed. About 86.7% of French catches are taken by purse-seiners while the remaining 13% 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 (1989–2021).

	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

	8 a,b,d									
year	France	Spain	Netherlands	Ireland	UK	Denmark	Germany	Lithuania	Belgium	Total
2007	13231	1263	0	0	0	48	0	0	0	16814
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

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	31368
2021	20370	5828	26198

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. The triennial DEPM is as well available as an index since 2011. Since 2020 the SSB for sardine will be estimate annually as well as the numbers-at-age, percentage at age, weight at age and length-at-age to be available as inputs for the assessment. This year the daily egg production (P_0; eggs /m²), daily mortality rates (z) and total daily egg production (P_{tot})(eggs) estimates were as well estimate trying to obtain it for all the historical series (**Table 6.2.2.1.1**). The following years those parameters will be estimate for the previous years to complete the series and to have a historical series of a more precise egg index as a proxy of the biomass for the past in 8abd. For the time been, this estimates $P_{0,}$ z and P_{tot} are available for years 2002 and 2005 to 2022 . This year apart from the frequentist method that was applied during all the years up to now to estimate $P_{0,}$ z and P_{tot}, a Bayesian method was study (see Santos Mocoroa *et al* 2022 in annex 3 WGACEGG) with the aim to avoid incurring in incorrect sign for z. 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 5th of April to the 27th 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 2022 is attached as a working document in ICES WGACEGG 2022 in **annex** 3 (**Santos Mocoroa. M *et al.* BIOMAN 2022).**

This year the sardine eggs were found in the Cantabrian Sea all along the area almost until 200m depth isoline, more abundant at the west of the area surveyed. In the French platform, from South to North all along the East of the 100m depth isoline area. (**Figure 6.2.2.1.2**)

In the sampling with the PairoVET net (vertical sampling) from 757 stations a total of 256 (34%) had sardine eggs with an average of 150 eggs/m² per station in the positive stations, a maximum of 2550 egg m² in a station and a total number of 39390 eggs/m². In the sampling with CUFES (horizontal sampling) a total of 542 stations (32%) had sardine from 1700 stations. (**Figure 6.2.2.1.2**)

Total egg abundance for sardine was estimated as the sum of the numbers of eggs in each station multiplied by the area each station represents. This year sardine egg abundance estimate was 5.78E+12 eggs, considered the whole area surveyed. Considering the 8abd the estimate was 5.17+12 and removing part of the Northwest for assessment propose, to be consistent with the historical series, was 3.29E+12 eggs, below the time-series average (5.68E+12) (**Figure 6.2.2.1.1, Table 6.2.2.1.2**).

To estimate the reproductive parameters for sardine in the Bay of Biscay from BIOMAN survey, 16 adult hauls were available. Mean weight and mean length are showed in **Figure 6.2.2.1.3**. Age composition and mature fish expressed in times one within each haul are showed in **Figure 6.2.2.1.4**. All the adult samples were processed, and the histology analysis and oocytes count were conducted but the estimates of the batch fecundity, spawning frequency and spawning stock biomass are still in process.

Table 6.2.2.1.1. Sardine in 8abd. Daily egg production (P_0) (eggs /m2), daily mortality rates (z) and total daily egg production (P_{tot})(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 2022.

Frequentist	all area			8abd			8abdwithoutNW		
Parameter	**Value**	**S.e.**	**CV**	**Value**	**S.e.**	**CV**	**Value**	**S.e.**	**CV**
P0	120.7	19.8	0.1638	134.8	23.8	0.1766	161.6	32.7	0.2027
z	0.69	0.12	0.1795	0.75	0.13	0.1804	0.88	0.15	0.1741
Ptot	4.4.E+12	7.3.E+11	0.1638	4.2.E+12	7.3.E+11	0.1766	3.7.E+12	7.4.E+11	0.2027

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	Tot.ab.8abdwithout NW
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
mean	5.58E+12
Std.Dev	2.61E+12
CV	0.4686

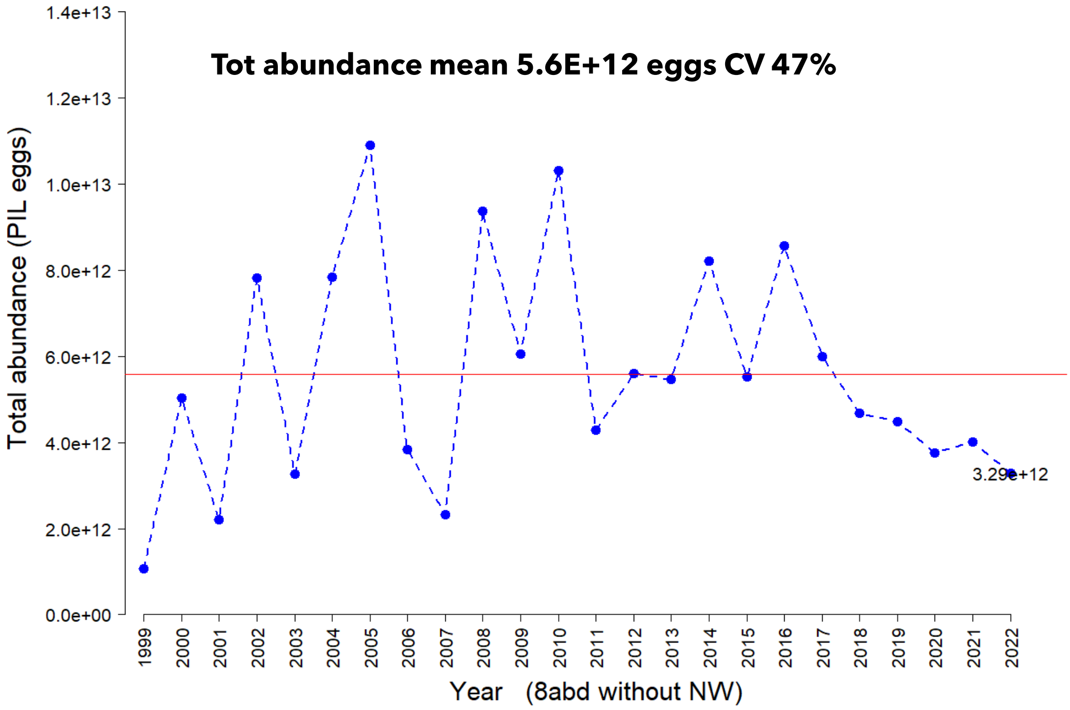


Figure 6.2.2.1.1. Sardine in 8abd. historical series for sardine egg abundances in 8abd without Northwest stations including 2022 value. The red line is the historical mean.

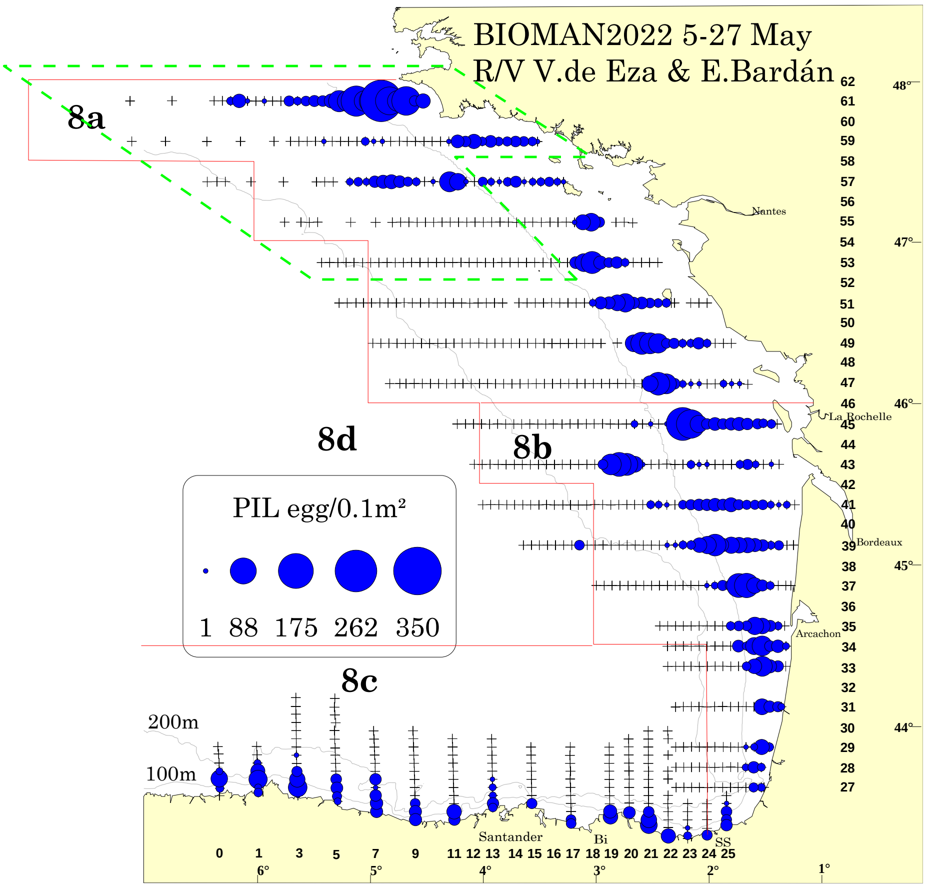


Figure 6.2.2.1.2. Sardine in 8abd. Spatial distribution and abundance of sardine eggs per 0.1m² from the DEPM survey BIOMAN2022 obtained with PairoVET (vertical sampling). The dash green line represents the stations removed for assessment propose in 8abd to be consistent with the historical series. Red lines represent the limits of 8abcd.

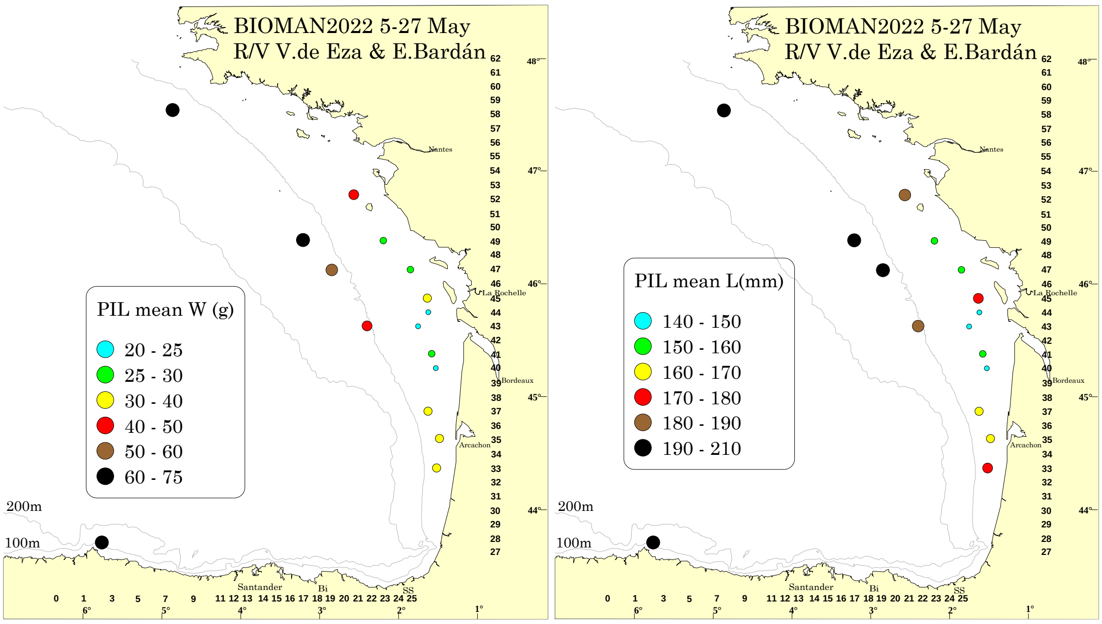


Figure 6.2.2.1.3. Sardine in 8abd. Sardine spatial distribution of mean weight (left) and mean length (right) in the Bay of Biscay from BIOMAN 2022 survey.

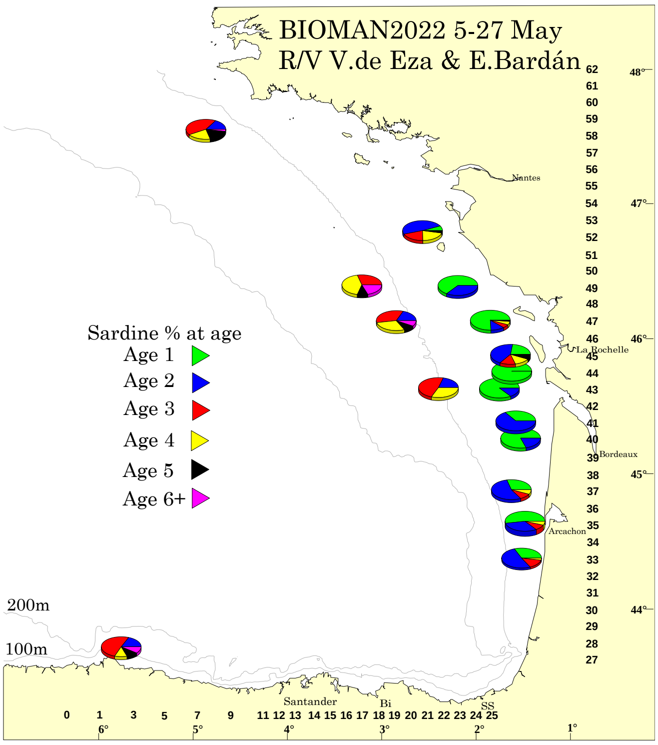


Figure 6.2.2.1.4. Sardine in 8abd. Sardine spatial distribution of percentage at age by haul in the Bay of Biscay from BIOMAN 2022 survey. The different colours are the different ages.

6.2.2.2 Acoustic spring survey (PELGAS): 8ab

The biomass estimate of sardine observed during PELGAS22 is **218 700** tons, which is a decrease compared with the previous surveys, the biomass reaching a medium level of the PELGAS series (below 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 occurs. It is also possible that sometimes, a part of the population could be present in very coastal waters, when the RV 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 sardine population.

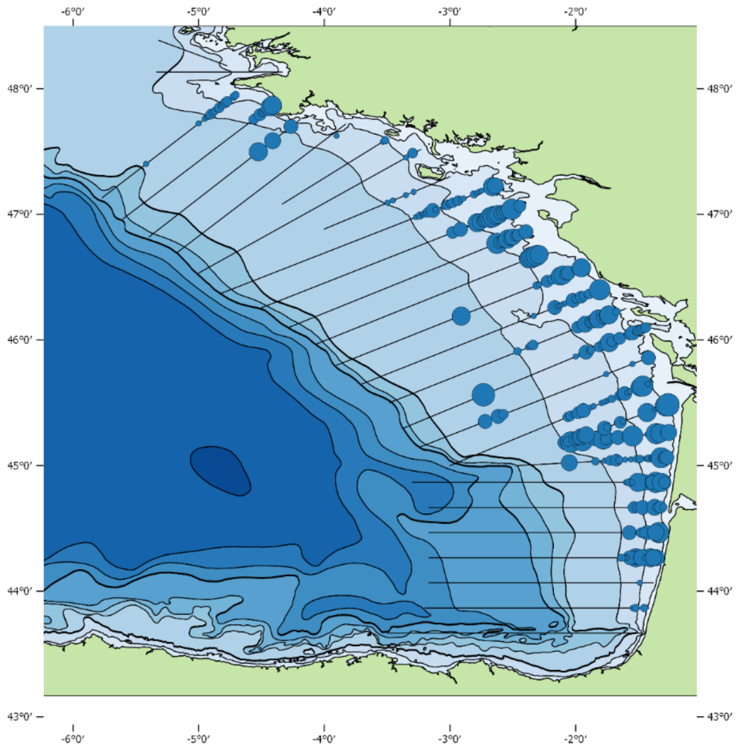


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Figure 6.2.2.2.1. Sardine in 8abd. Distribution of sardine observed by acoustics during PELGAS22.

Sardine was distributed all along the French coast of the Bay of Biscay, from the South to the Loire river. The small sardine was present this year, rarely pure, regularly mixed with sprat or mackerel along the coast while the larger individuals were a bit offshore. It must be noticed that one more year, no sardine at all were detected along the shelf break.

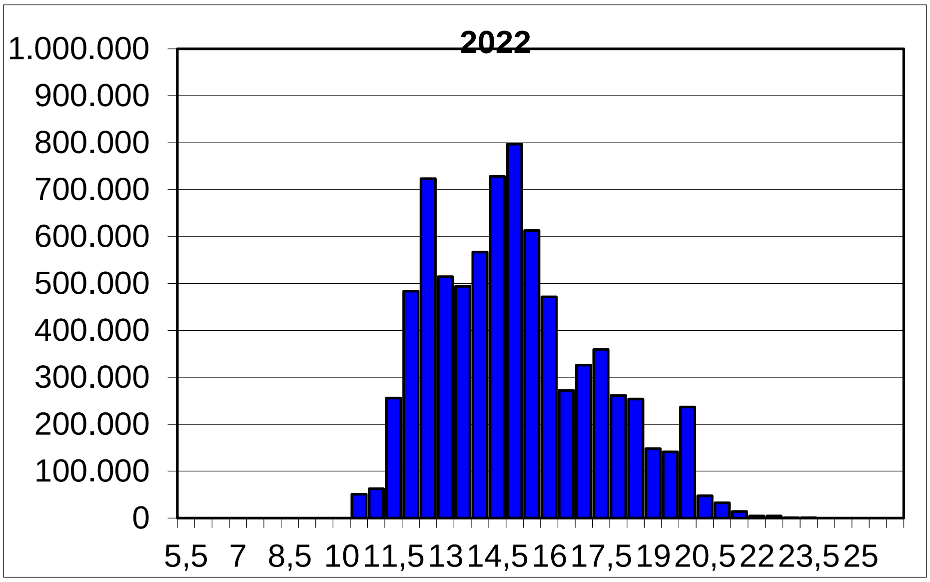

Figure 6.2.2.2.2. Sardine in 8abd. Length distribution of sardine as observed during PELGAS22.

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.

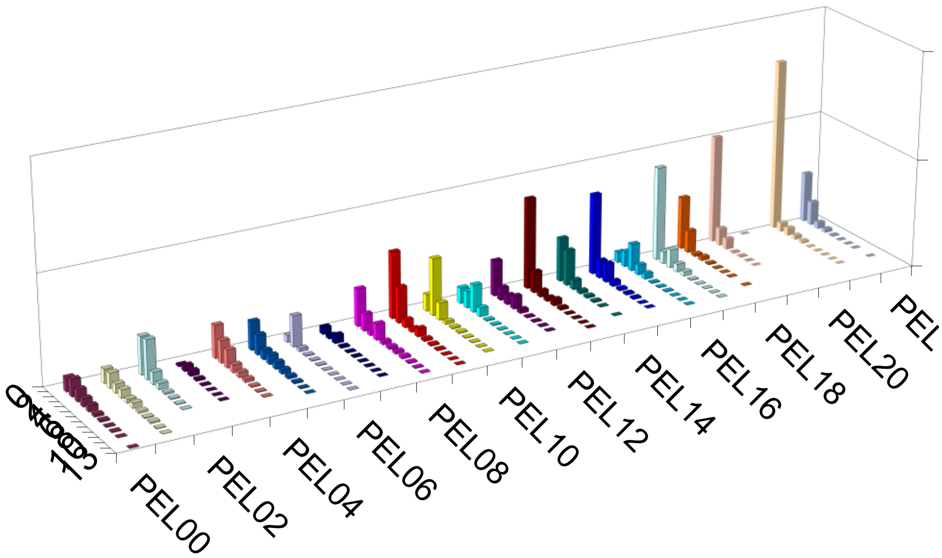

Figure 6.2.2.2.3. Sardine in 8abd. Age composition of sardine as estimated by acoustics since 2000.

PELGAS series of sardine abundances at age (2000-2021) is shown in Figure 6.2.2.2.3. 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 shows 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 serie. The population of sardine is still very young, with an age distribution largely dominated by age 1 and 2 groups (sum about 86% in numbers).

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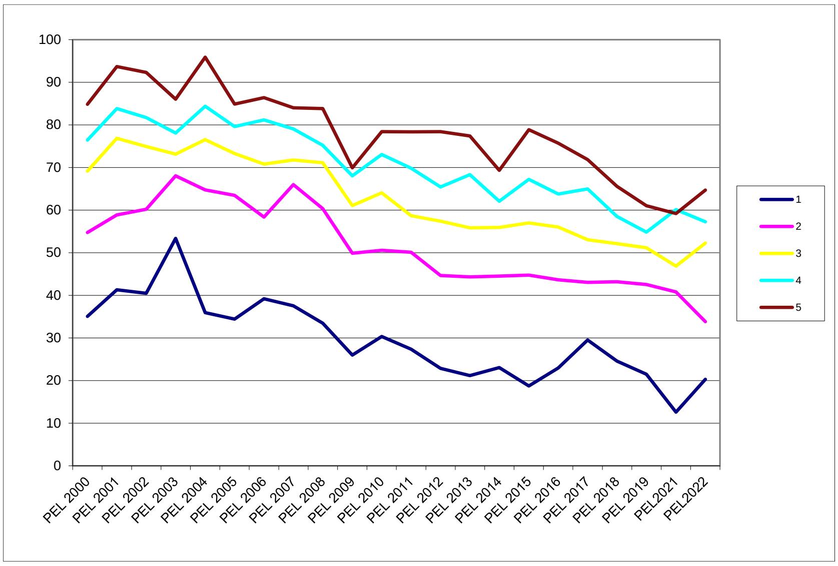


Figure 6.2.2.2.4. Sardine in 8abd. Evolution of mean weight at age (g) of sardine along PELGAS series.

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 grammes at the beginning of the serie, and reach only 20 grammes this year, with a strong minimum value in 2021 with 12.5 grammes.

Further work must be conducted to explore the causes of the fluctuation of mean weights at ages.

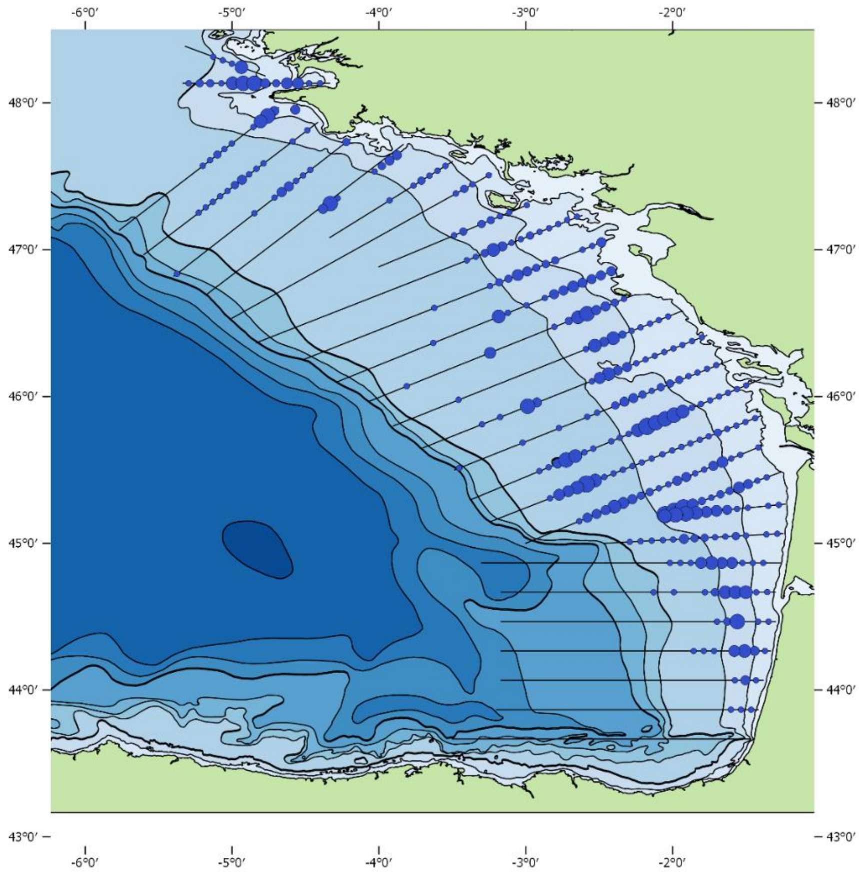


Figure 6.2.2.2.5. Sardine in 8abd. Distribution of sardine eggs observed with CUFES during PELGAS22.

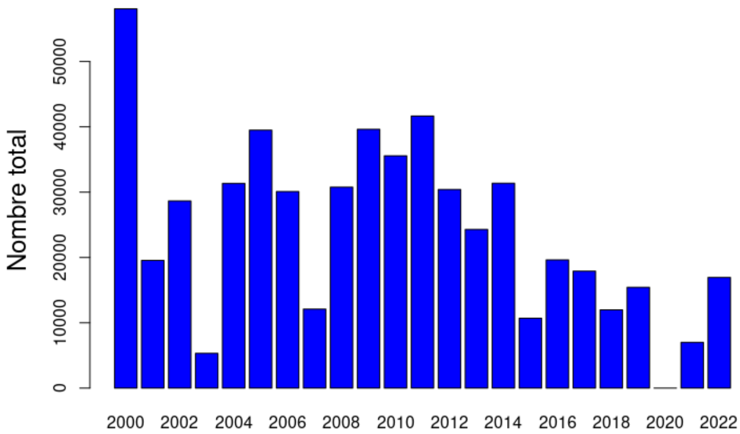


Figure 6.2.2.2.6. Sardine in 8abd. Number of eggs observed during PELGAS surveys from 2000 to 2022.

2022 was marked by a low abundance of sardine eggs as compared to the PELGAS time-series. It must be noticed that this year the one-year-old individuals were not fully mature: 48 % of the age 1 were totally immature (stage1) and 26 % were starting their maturation (stage 2 of the maturity scale) at the time of the survey. Only 25 % of 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 2021, a peak is observed in the catch-at size distributions around -18 cm length (half cm bin).

Tables 6.2.3.1.3 and Table 6.2.3.1.4 shows the catch-at-age in numbers for each quarter of 2021 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 1 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 2021 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 2021.

Length * (half cm)	Quarter 1	Quarter 2	Quarter 3	Quarter 4	All year
10					
10.5					
11					
11.5					
12			1 118		1 118
12.5		508	3 921	265	4 695
13		826	3 542		4 368
13.5		10 291	6 937	796	18 024
14	365	15 564	10 060	1 326	27 315
14.5	365	13 086	18 384	1 592	33 426
15		10 672	22 909	2 918	36 499
15.5	365	4 447	23 407	3 979	32 197
16	1 094	5 272	30 073	4 510	40 948
16.5	3 282	3 493	27 350	5 836	39 961
17	4 740	14 925	21 851	4 244	45 761
17.5	4 011	10 162	17 211	3 183	34 567
18	11 668	14 608	13 984	7 428	47 687
18.5	9 115	6 986	13 840	10 876	40 818
19	10 574	4 763	11 884	11 407	38 628
19.5	3 646	2 223	5 870	10 346	22 085
20	5 834	2 858	4 472	7 162	20 327
20.5	2 188	635	1 677	5 040	9 540
21	1 458	635	839	1 326	4 258
21.5	365		839	796	1 999
22		318	280	531	1 128
22.5					
23				265	265
23.5					
24					
24.5					
25					
Total number	59 068	122 272	240 447	83 826	505 613
Official catch (t)	2 883	4 515	9 167	4 534	**21 100**

Table 6.2.3.1.2. Sardine in 8abd. Spanish sardine catch-at-length composition (thousands) in ICES Division 8b in 2021.

Length * (half cm)	Quarter 1	Quarter 2	Quarter 3	Quarter 4	All year
10	5				5
10.5	27				27
11	94				94
11.5	187				187
12	180			78	258
12.5	271	1		213	485
13	782	1		365	1 148
13.5	1 507	5		935	2 447
14	1 474	16		1 698	3 188
14.5	988	33		1 770	2 791
15	550	82		2 115	2 747
15.5	471	115	4	2 746	3 336
16	1 300	108	18	5 575	7 000
16.5	3 606	108	36	7 632	11 382
17	7 358	71	140	12 025	19 593
17.5	8 102	50	173	12 370	20 695
18	7 517	21	179	12 645	20 361
18.5	5 645	33	129	8 966	14 773
19	3 998	10	114	7 834	11 957
19.5	2 634		84	5 053	7 770
20	1 462		53	3 548	5 062
20.5	917	2	22	1 688	2 630
21	535		5	841	1 381
21.5	192		2	349	543
22	121		1	172	295
22.5	29			66	95
23				72	72
23.5					
24					
24.5					
25					
28					
Total number	49 952	655	959	88 754	140 320
Official catch (t)	1 784	18	47	3 962	**5 811**

Table 6.2.3.1.3. Sardine in 8abd. Spanish 2021 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	0	431.399	431.399
1	6252.23	182.005	334.23	43771.5	50540
2	17417.5	334.578	284.459	20814.2	38850.7
3	16031.9	116.521	228.866	15976.3	32353.6
4	6510.51	16.5604	75.588	5390.44	11993.1
5	3743.95	5.20663	34.1033	2500.38	6283.63
6	0	0	2.03902	436.087	438.126
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0

Table 6.2.3.1.4. Sardine in 8abd. French 2021 landings in ICES Division 8b: Catch in numbers (thousands) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0			11688.1	776.269	12464.4
1	2240.13	58309.5	162902	29261.6	252713
2	17556.9	29186.4	48077.6	32188.8	127010
3	21175.3	24045.2	13430.8	14079.5	72730.8
4	10510.4	6612.27	3585.52	5771.13	26479.4
5	6195.37	3385.72	543.576	980.238	11104.9
6	496.643	262.748	219.588	770.46	1749.44
7	330.925	218.544			549.469
8	440.93	198.633			639.563
9	121.49	52.9053			174.395

Table 6.2.3.2.1. Sardine in 8abd. Spanish 2021 landings in divisions 8a,b: Mean length (cm) -at-age.

	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	0	0	0	12.501	12.501
1	14,04	15.225	17,539	16.742	16.408
2	17,54	16.573	18,507	18.401	17.999
3	18,072	17.543	18,928	18.922	18.496
4	19,198	18.694	19,722	19.799	19.471
5	20,198	19.172	19,926	20.045	20.135
6	0	0	21,754	22.004	22.002
7	0	0	0	0	0
8					
9					

Table 6.2.3.2.2. Sardine in 8abd. Spanish 2021 landings in divisions 8a,b: Mean weight (kg) -at-age.

	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	0	0	0	0.0153	0.0152
1	0.0175	0,022094911	0.0418	0.0368	0.0344
2	0.0340	0,028638209	0.0491	0.0484	0.0418
3	0.03716	0,034003392	0.0525	0.0525	0.0448
4	0.0447	0,041164158	0.0593	0.0601	0.0517
5	0.0522	0,044446833	0.0611	0.0622	0.0562
6	0	0	0.0791	0.082	0.0820
7	0	0	0	0	0
8					
9					

Table 6.2.3.2.3. Sardine in 8abd. French 2021 landings in ICES Division 8a,b: mean length (cm) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	15.51		13.09	13.35	13.11
1	17.89	14.4	15.75	16.34	15.51
2	18.34	17.3	18.18	18.85	18.11
3	19.37	17.9	18.93	19.34	18.49
4	19.45	19.1	20.01	20.07	19.54
5	20.49	19.2	20.29	20.32	19.49
6	20.17	20.8	21.45	13.96	17.78
7	19.00	20.8			20.42
8	21.00	19			19.00
9	15.51	21			21.00

Table 6.2.3.2.4. Sardine in 8abd. French 2021 landings in ICES Division 8a,b: mean weight (kg) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0			0.01765	0.01874	0.01771
1	0.02980	0.02377	0.03123	0.03499	0.02993
2	0.04629	0.04198	0.04858	0.05434	0.04821
3	0.04991	0.04615	0.05511	0.05882	0.05135
4	0.05916	0.05648	0.06537	0.06596	0.06081
5	0.05986	0.05748	0.06827	0.06849	0.06031
6	0.07036	0.07379	0.08105	0.02150	0.05070
7	0.06703	0.07369			0.06968
8	0.05570	0.05570			0.05570
9	0.07587	0.07587			0.07587

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). In2022 about 49% (66% in 2021) 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 51%% 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 fourth 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 2022. 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 (50141.7 tons). In 2022, SSB show a very small increase with a value of 62 534 tons 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 2021 is lower than in 2020. Also, the downwards revision of recruitment in 2020 calculated during the 2021 assessment (ICES. 2021) is due to large age 1 estimates in the PELGAS survey in 2018, 2019 and 2021 that could not be tracked consistently in the age 2 estimates of the following year.

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	4289250	136348	15097	0.152
2001	5212970	154389	15005	0.156
2002	3459770	167059	18277	0.184
2003	3822350	175678	16607	0.149
2004	7041850	146755	14197	0.142
2005	2311460	174396	16360	0.139
2006	3545680	153484	16741	0.153
2007	6900310	137456	17323	0.161
2008	8431470	157525	21821	0.23
2009	3451450	134492	20855	0.185
2010	2632200	150272	20127	0.183
2011	4302900	120974	23208	0.24
2012	7501940	88608.7	30900	0.43
2013	5216840	94728	32938	0.47
2014	6956530	98464.7	35704	0.59
2015	2590210	88334.8	28756	0.50
2016	gpurse	80949.4	29754	0.60
2017	4689770	101761	30435	0.59
2018	5153780	87847.1	32299	0.66
2019	4595980	70586.9	24579	0.50
2020	6253460	83678.2	31368	0.66
2021	4728130	50716.1	26198	0.60

***Geometric mean (2002–2021).**

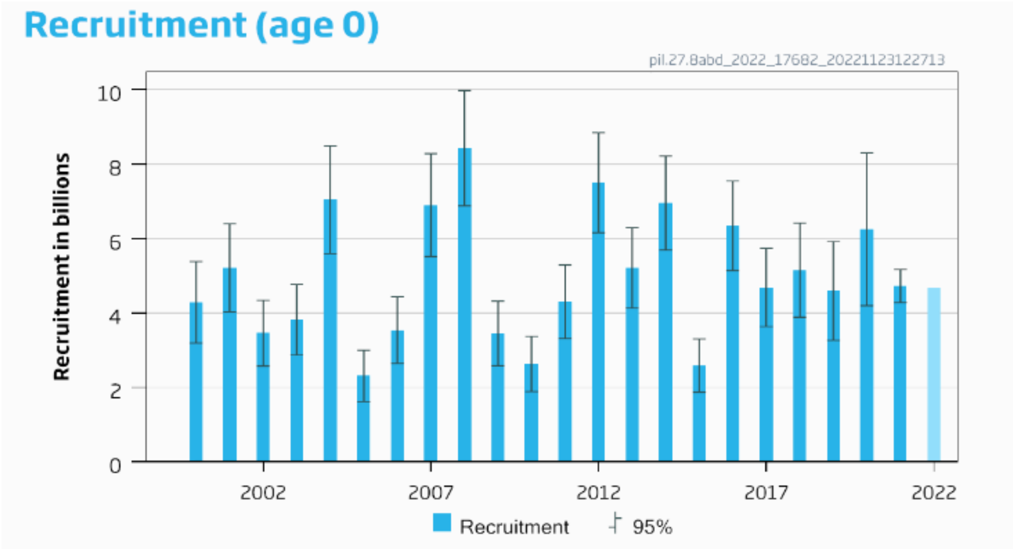


Figure 6.3.2.1. Sardine in 8abd. Recruitment estimates from SS3 outputs for sardine 8abd. Last year's value is estimated from the geometric mean (2002-2021).

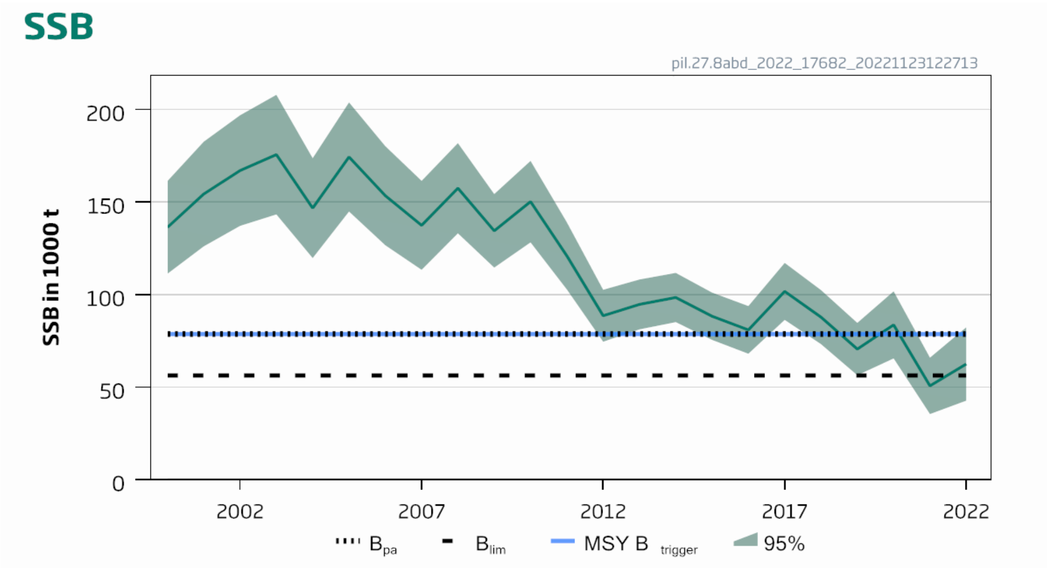


Figure 6.3.2.2. Sardine in 8abd. Spawning–stock biomass from SS3 outputs for sardine 8abd. Last year's value is estimated from the model.

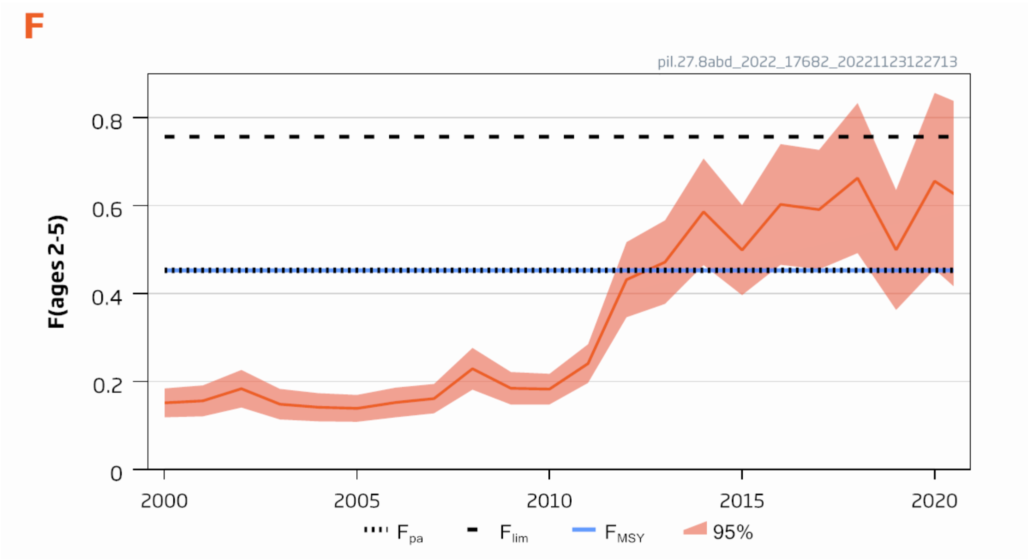


Figure 6.3.2.3. Sardine in 8abd. Fishing mortality for ages 2 to 5 derived from SS3 outputs for sardine 8abd.

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.

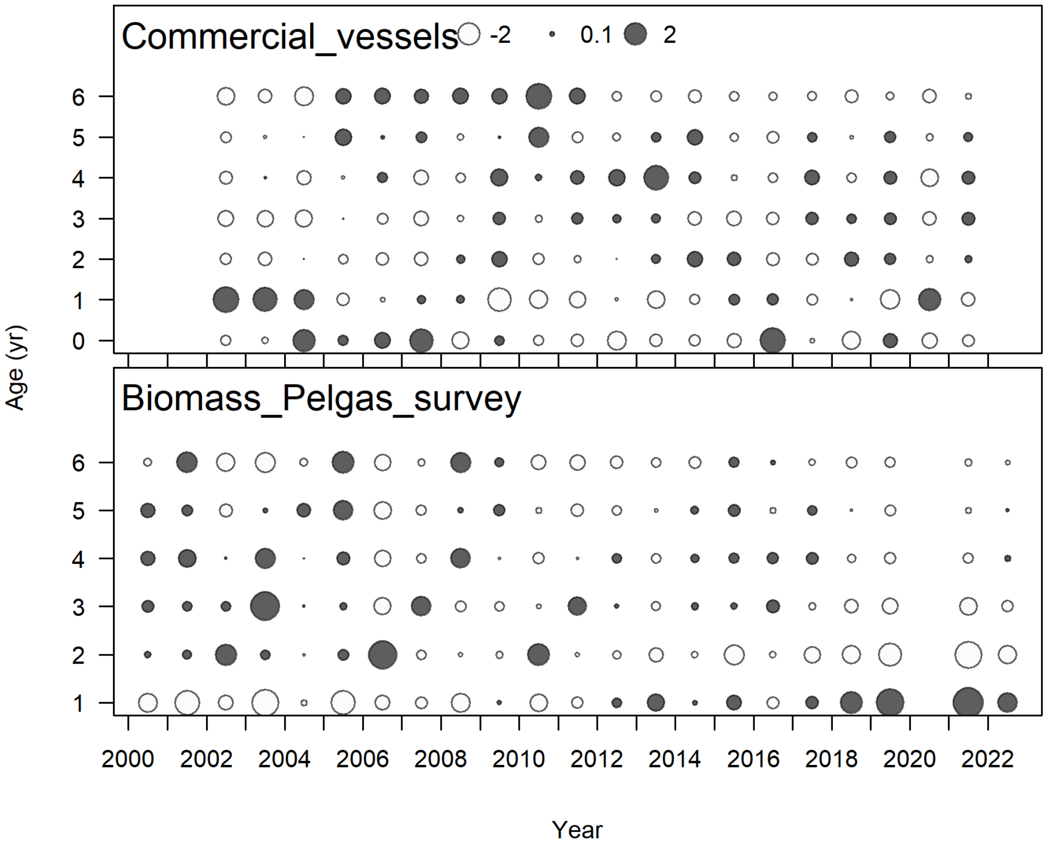


Figure 6.3.3.1. Sardine in 8abd. Fit between model and age composition from the PELGAS survey (bottom) and commercial vessels (top) up to 2022.

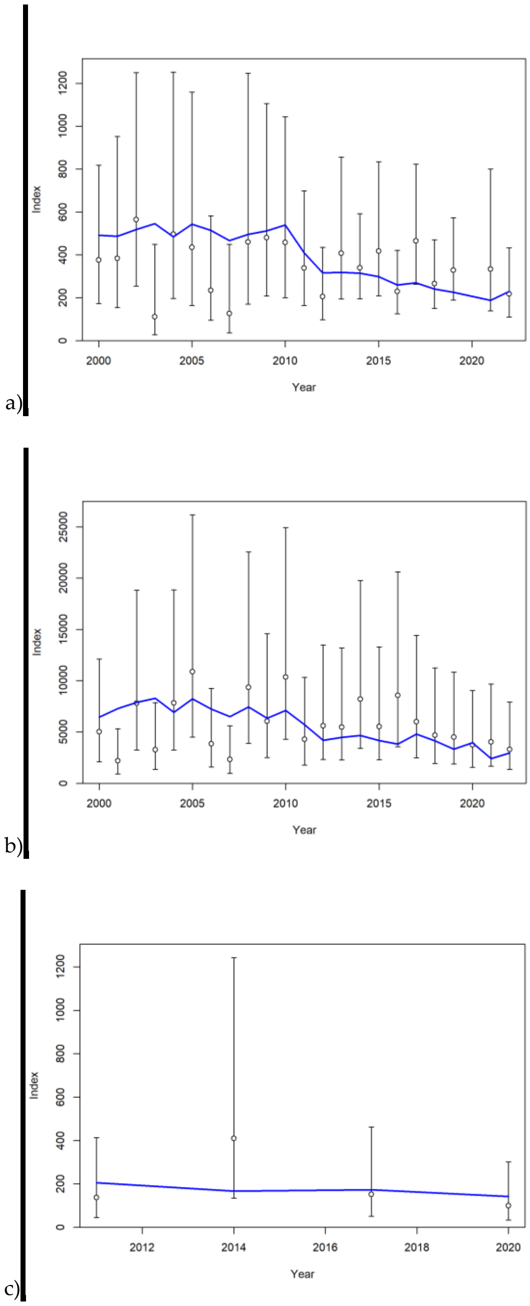


Figure 6.3.3.2. Sardine in 8abd. Fit between model and survey indices: a - Acoustic (PELGAS), b - egg count (BIOMAN), c - DEPM.

6.3.4 Retrospective pattern

Retrospective patterns for SSB, F_{bar}(2–5), apical F and recruitment were computed for years 2015–2022 (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 (2022).

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 0.372 (previously 0.420).
- Mohn's rho for F is -0.301 (previously -0.232).
- Mohn's rho for R is 0.080 (previously 0.512).

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 2022 is more in line with the 2021 assessment in terms of stock structure. Recruitment estimate in 2020 has been scaled down in the current assessment. This reduces the erratic pattern seen previously.

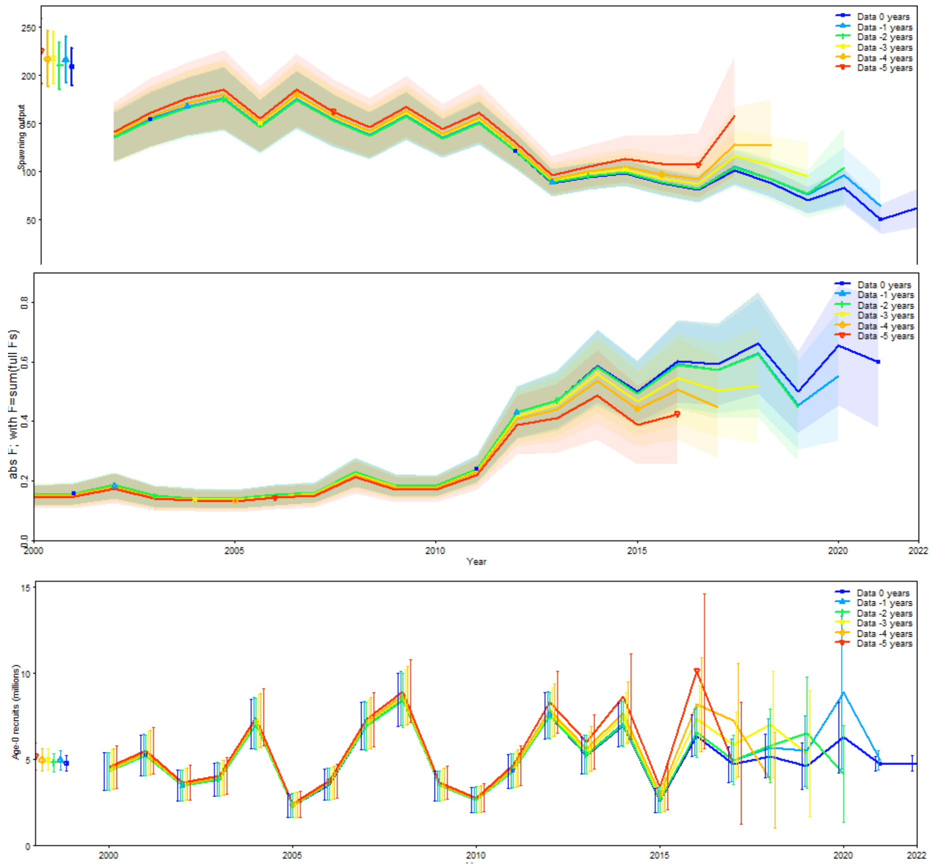


Figure 6.3.4.1. Sardine in 8abd. Summary of retrospective plots.

6.3.5 Comparison with previous assessment

The comparison is done with the run carried out at WGHANSA last year (Figures 6.3.5.1–6.3.5.3).

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 and F. 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 2016 for F and 2017 for the SSB. Both runs stay very close for SSB as well for F. For recent years, SSB seems overestimated and F underestimated compared with the last year's run. There is no clear pattern for recruits. The median recruitments start to differ from 2017.

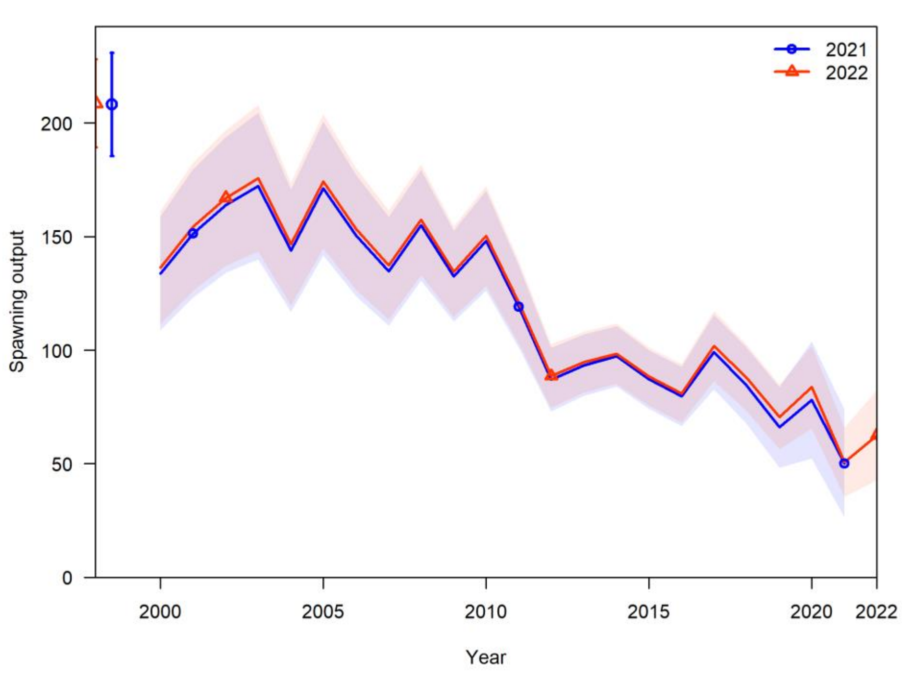


Figure 6.3.5.1. Sardine in 8abd. Comparison of SSB estimates between this year and the 2021 run.

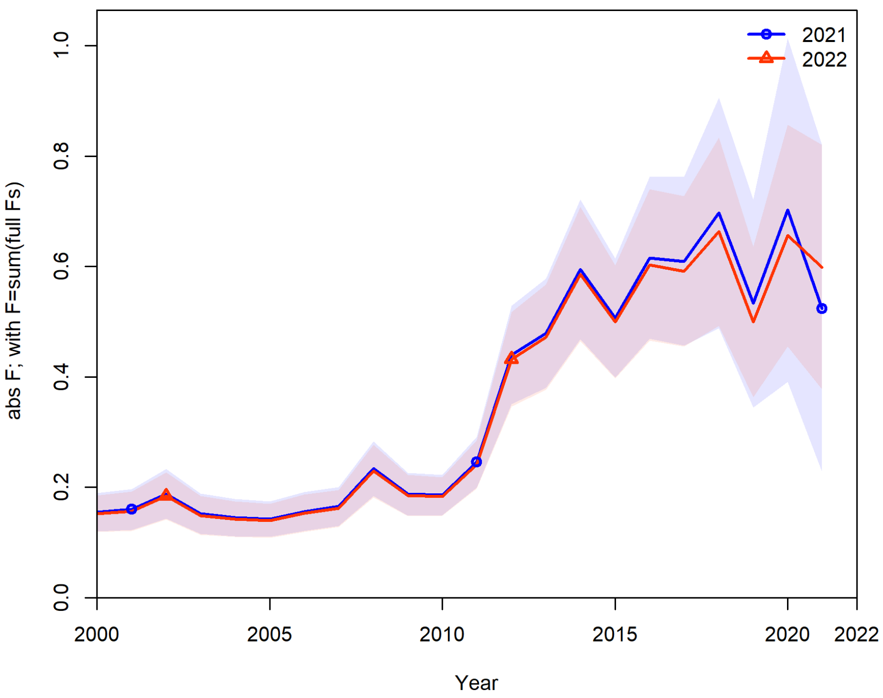


Figure 6.3.5.2. Sardine in 8abd. Comparison of fishing mortality estimates between this year and the 2021 run.

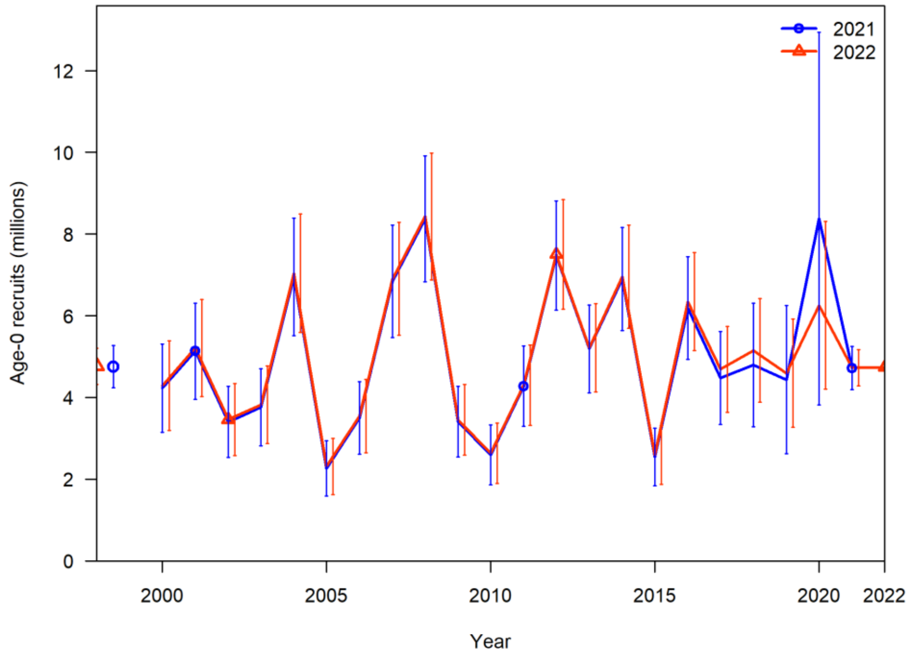


Figure 6.3.5.3. Sardine in 8abd. Comparison of Recruitment estimates between this year and the 2021 run.

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 2022 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 (2002-2021). Recruitment for 2021 was assumed to be 4681 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 2022 relies on preliminary catch statistics available from Q1-Q3 of 2022. Q4 is estimated from the average proportion of Q4 catches in last 3 years (2019-2021). The assumed catches for 2022 are 22 608 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 2022.

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

Variable	Value	Notes
Fages 2–5 (2022)	0.55	Based on assumed catches for 2022
SSB (2023)	69 828	Short term forecast; tonnes
Rage 0 (2022-2023)	4681	Geometric mean (2002–2021); millions
Total catch (2022)	22 608	Preliminary value based on reported catches in Quarters 1 to 3 and assumed catches for Quarter 4; tonnes
Discards (2022)	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
2022	0	4680.978	0.000000	0.023967	0	1.071	0.0064865
	1	1606.337	0.019767	0.034800	0.59646	0.6912	0.2017255
	2	814.584	0.042067	0.046567	0.98366	0.5463	0.3453382
	3	214.577	0.050067	0.054067	1	0.4752	0.4529299
	4	84.184	0.058100	0.065000	0.99556	0.4356	0.4529299
	5	26.965	0.062100	0.066900	0.99155	0.4122	0.4529299
	6+	18.495	0.073433	0.075133	1	0.3978	0.4529299
2023	0		0.000000	0.023422	0	1.071	0.0081517
	1		0.019189	0.034333	0.57977	0.6912	0.2535105
	2		0.041922	0.045589	0.97821	0.5463	0.4339901
	3		0.049689	0.053222	1	0.4752	0.5692016
	4		0.059200	0.064267	0.99408	0.4356	0.5692016
	5		0.062467	0.066033	0.98874	0.4122	0.5692016
	6+		0.072811	0.074978	1	0.3978	0.5692016
2024	0		0.000000	0.023422	0	1.071	0.0081517
	1		0.019189	0.034333	0.57977	0.6912	0.2535105
	2		0.041922	0.045589	0.97821	0.5463	0.4339901
	3		0.049689	0.053222	1	0.4752	0.5692016
	4		0.059200	0.064267	0.99408	0.4356	0.5692016
	5		0.062467	0.066033	0.98874	0.4122	0.5692016
	6+		0.072811	0.074978	1	0.3978	0.5692016

Table 6.4.3. Sardine in 8abd. Catch option table for 2023.

Basis	Catch (2023)	F (2023)	SSB (2024)	% SSB change *	% catch change **	% advice change
ICES advice basis						
MSY approach: F = F_{MSY} * SSB(2023)/ MSY $B_{trigger}$	21 497	0.40	70 347	+0.74	-17.9	-24
Other scenarios						
F = 0	0	0	87 731	+26	-100	-100
F = F_{pa}	23 820	0.45	68 507	-1.89	-9.1	-15.5
F = F_{lim}	36 127	0.76	58 912	-15.6	+38	+28
SSB(2024) = B_{lim}	39 545	0.85	56 300	-19.4	+51	+40
SSB(2024) = B_{pa} = MSY $B_{trigger}$	11 077	0.193	78 700	+12.7	-58	-61
F = F(2022)	28 021	0.55	65 201	-6.6	+7.0	-0.59

*** SSB 2024 relative to SSB 2023.**

**** Advised catch for 2023 relative to catch in 2021 (26 198 tonnes).**

***** Advised catch for 2023 relative to advised catch for 2022 (28 187 tonnes).**

The catch options for 2023 are substantially lower than the advice for 2022, due to a revision downwards of the 2020 recruitment.

Based on the GM recruitment and *catch assumption* in 2022, for all catch options for 2023, SSB in 2024 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 2024 is expected to decrease compared with the one of 2023 for F=Fpa, F=Flim, F=F(2022), Blim target SSB expected to increase when catch options are the most limiting for 2023: closure, Bpa target and MSY approach.

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 use 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.

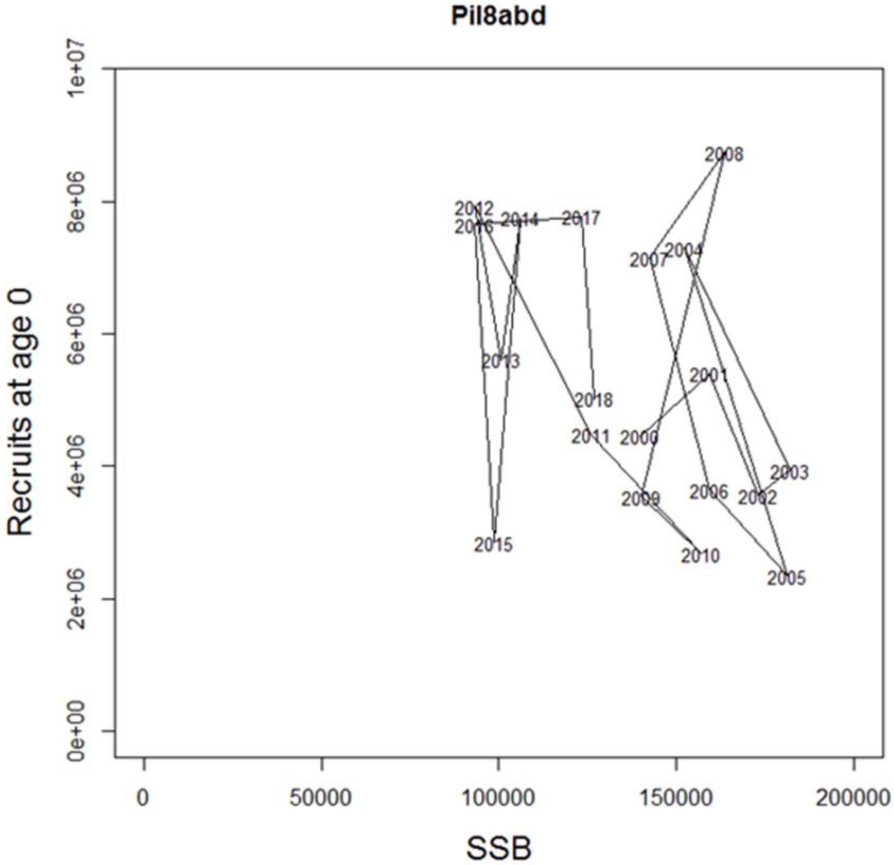


Figure 6.6.1. Sardine in 8abd. Stock–recruitment relationship for sardine in 8abd.

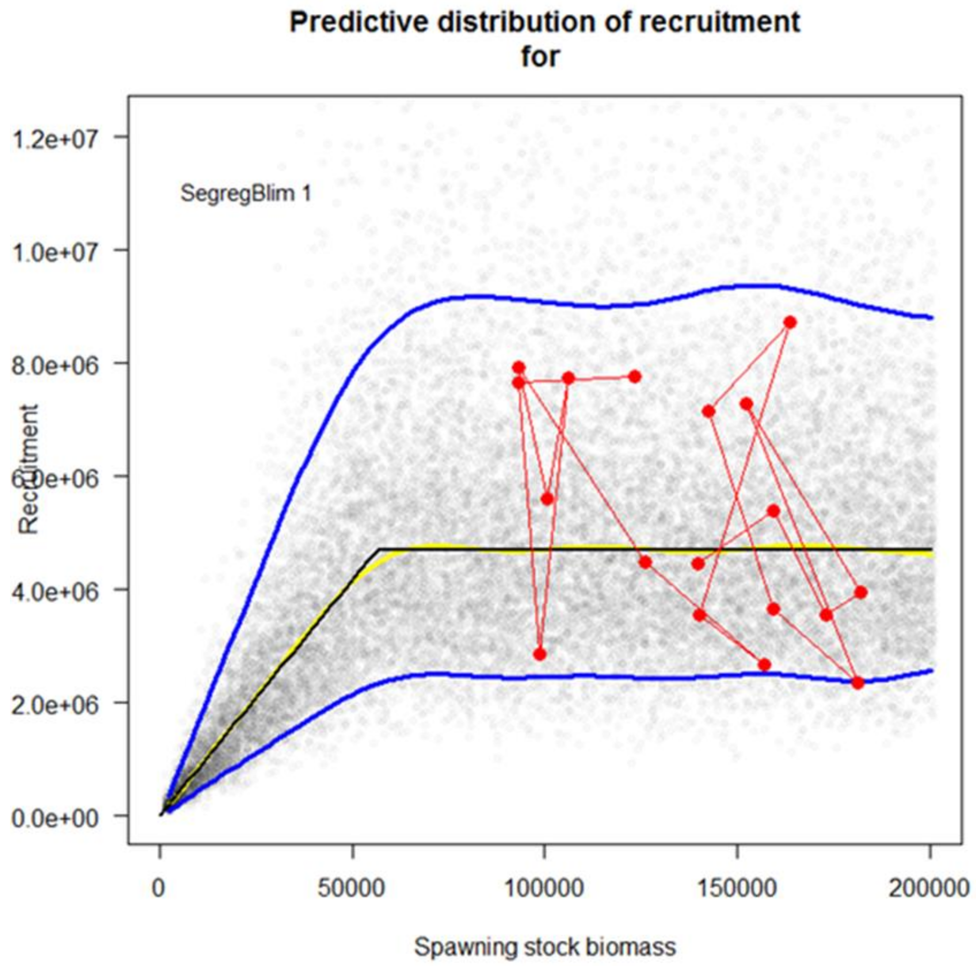


Figure 6.6.2. Sardine in 8abd. Segmented regression model with the breakpoint fixed at B_{lim} for sardine in 8abd.

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 of the 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 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 8026t), whereas the contribution from the other countries has diminished. Landings in 2021 were 58% lower than in 2020, primarily because Danish landings have decreased from 3217t to 89t and UK landings have decreased from 9500t to 7074t.

The fleet and seasonality of the fishery has also changed over the years. The main fleet in the 2000s was midwater otter trawlers, which used to fish 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. In 2021, the fishing activity of the Danish vessels was greatly reduced relative to 2020.

7.3 Biological data

7.3.1 Size composition of the catch

Historically, 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 length or age information due to the lack of national biological sampling scheme and no DCF (data collection framework) requirement regarding that species in Subarea 7.

In 2017, 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 had to be discarded because part of their staff measured the samples with 1 cm precision instead of 0.5 cm, which created multiple peaks in the distributions. Figure 7.3.1.1 shows the combined size distribution provided by the fishing industry since 2018 after tidying up the data. The mean size of fish in the landings between 2018 and 2020 was consistently around 19.6 cm, however mean size in 2021 was lower (18.7 cm).

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.

7.4.2 Estimation of biomass in the Total area

The Working Group decided to estimate the biomass that would have been in the total area based on the biomass estimated for the restricted area. The estimation involved two processes, raising the restricted area to the core area and then raising that estimate to the total area.

The raising factor for the restricted to core area used the average ratio of biomass (1.267) in the two areas for the years 2020-2021 (Table 7.4.2.1). The second step involved raising the core biomass to the total biomass using the average ratio of measured biomasses (1.509) for 2017 to 2021. This resulted in an estimated total biomass in the total area for 2022 of 336,306 t. This constitutes a 48% increase from 2021.

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 was done in 2021, a quarterly SPiCT model was 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 2021 and the biomass derived from PELTIC for the core area from 2013 to 2020 (Figure 7.5.1.1, Table 7.5.1.1). The 2021 PELTIC index was not included as it could not be fully estimated from the survey. The landing time time-series was shortened to cover only the period where biomass index was available to help model convergence and produce a reliable output (ICES, 2021). 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 2021 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, a longer time-series is needed to analyse temporal patterns in successive assessments (Figure 7.5.1.4).

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:

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

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 20% 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 2023 is 8 306 tonnes.

7.6 Short-term projections

No projections have been carried out for this stock.

7.7 Reference points

The table below summarizes the reference points for sardine in Subarea 7 and their technical basis. 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. This reference point has been recalculated because the time-series is still too short and it was judged convenient to include all years now available for its estimate.

This year as the index value is just inferred from a restricted coverage, this rescaled index has not been included as input for the SPICT and therefore the relative status of the stock versus the MSY reference points has not been assessed (Table 7.7.1).

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).

As this is the second year of implementing the 1-over-2 rule the advised catch for 2022 is used to provide the advice for 2023.

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 may be subject to change for next year after further examination, through the year, on the efficacy of the raising factors.

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 2021 the catches reallocated were larger than the remaining 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.

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

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

	France**	UK	Nether-lands	Ireland	Germany	Denmark	Lithuania	Belgium	Spain	Poland	TOTAL
2007	7315	2655	1106	28	0	4	0	0	0	0	11108
2008	8562	3470	2073	473	43	53	0	0	0	0	14674
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

***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

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			

*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 series. Raising factors and biomass estimates for the core and total area for 2022 are given.

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 in-dex (total area)	High	Low	Landings	Discards	BMS landing
2002				29287	190	

Year	Biomass index (total area)	High	Low	Landings	Discards	BMS landing
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*	**	**			

* 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: 39.4218027
Euler time step (years):  1/16 or 0.0625
Nobs C: 36,  Nobs I1: 9

Residual diagnostics (p-values)
    shapiro   bias    acf   LBox shapiro bias acf LBox
 C   0.9573 0.5431 0.1950 0.3385       -    -   -    -
 I1  0.6275 0.4151 0.1706 0.3462       -    -   -    -

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  3.482069e+00    0.3497584 3.466623e+01  1.2476267
 beta   1.046500e+00    0.3060176 3.578753e+00  0.0454509
 r      2.108605e+00    0.2589977 1.716700e+01  0.7460265
 rc     1.220768e+00    0.2272336 6.558337e+00  0.1994801
 rold   8.590580e-01    0.1277162 5.778286e+00 -0.1519189
 m      1.451811e+04 8088.2668612 2.605943e+04  9.5831524
 K      3.941406e+04 5020.7169772 3.094116e+05 10.5818779
 q      4.952085e+00    0.5673832 4.322150e+01  1.5998088
 n      3.454555e+00    0.7057811 1.690885e+01  1.2396936
 sdb    8.951700e-02    0.0092624 8.651436e-01 -2.4133270
 sdf    3.695138e-01    0.1295738 1.053765e+00 -0.9955673
 sdi    3.117043e-01    0.1800924 5.394985e-01 -1.1657003
 sdc    3.866960e-01    0.2814888 5.312248e-01 -0.9501163
 phi1   1.940576e-01    0.0719572 5.233439e-01 -1.6396005
 phi2   2.666740e-02    0.0149176 4.767200e-02 -3.6243122
 phi3   1.087537e+00    0.4215446 2.805719e+00  0.0839151

Deterministic reference points (Drp)
           estimate        cilow        ciupp    log.est
 Bmsyd 23785.216373 2825.7609943 2.002068e+05 10.0768195
 Fmsyd     0.610384    0.1136168 3.279168e+00 -0.4936671
 MSYd  14518.114375 8088.2668612 2.605943e+04  9.5831524
Stochastic reference points (Srp)
           estimate        cilow        ciupp  log.est rel.diff.Drp
 Bmsys 2.355173e+04 2770.6600228 2.001992e+05 10.06695 -0.009913912
 Fmsys 6.064154e-01    0.1112378 3.305888e+00 -0.50019 -0.006544280
 MSYs  1.428120e+04 8039.7749760 2.536797e+04  9.56670 -0.016589005

States w 95% CI (inp$msytype: s)
                    estimate        cilow        ciupp    log.est
 B_2021.94      3.179737e+04 3322.4748664 3.043131e+05 10.3671389
 F_2021.94      2.464822e-01    0.0261756 2.320999e+00 -1.4004656
 B_2021.94/Bmsy 1.350108e+00    0.9847599 1.851001e+00  0.3001844
 F_2021.94/Fmsy 4.064576e-01    0.1599493 1.032876e+00 -0.9002756

Predictions w 95% CI (inp$msytype: s)
                  prediction        cilow        ciupp    log.est
 B_2023.00      3.250799e+04 3412.3777338 3.096872e+05 10.3892413
 F_2023.00      2.464823e-01    0.0231926 2.619526e+00 -1.4004652
 B_2023.00/Bmsy 1.380281e+00    0.9632868 1.977786e+00  0.3222869
 F_2023.00/Fmsy 4.064578e-01    0.1230850 1.342226e+00 -0.9002752
 Catch_2022.00  8.326637e+03 3965.3251430 1.748479e+04  9.0272150
 E(B_inf)       3.601612e+04           NA           NA 10.4917219
```

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

Index A (2022)	336 306 tonnes
Index B (2020–2021)	279 607 tonnes
Index ratio (A/B)	1.20
Biomass safeguard (Istat)	Not applicable
Uncertainty cap	Not applied
Advised catch for 2022	6906 tonnes
Discard rate	Negligible
Catch advice 2023 **	8 306 tonnes
% advice change	+20 %

* 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 2022] 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)); lhist is the available historical series of the abundance index (2017–2021)	(ICES, 2022b)
	B_{lim}, B_{pa}	Not de-		
	F_{lim}	Not defined		
	F_{pa}	Not defined		
Management plan	SSB_{MGT}	Not defined		
	F_{MGT}	Not defined		

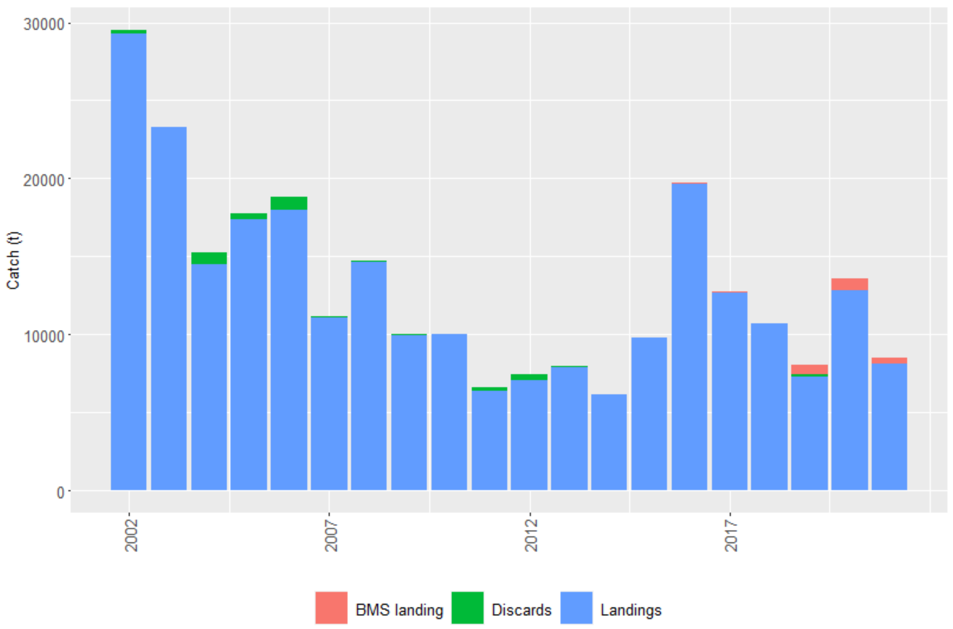


Figure 7.2.1.1. Sardine in Subarea 7. Catches by category (tonnes).

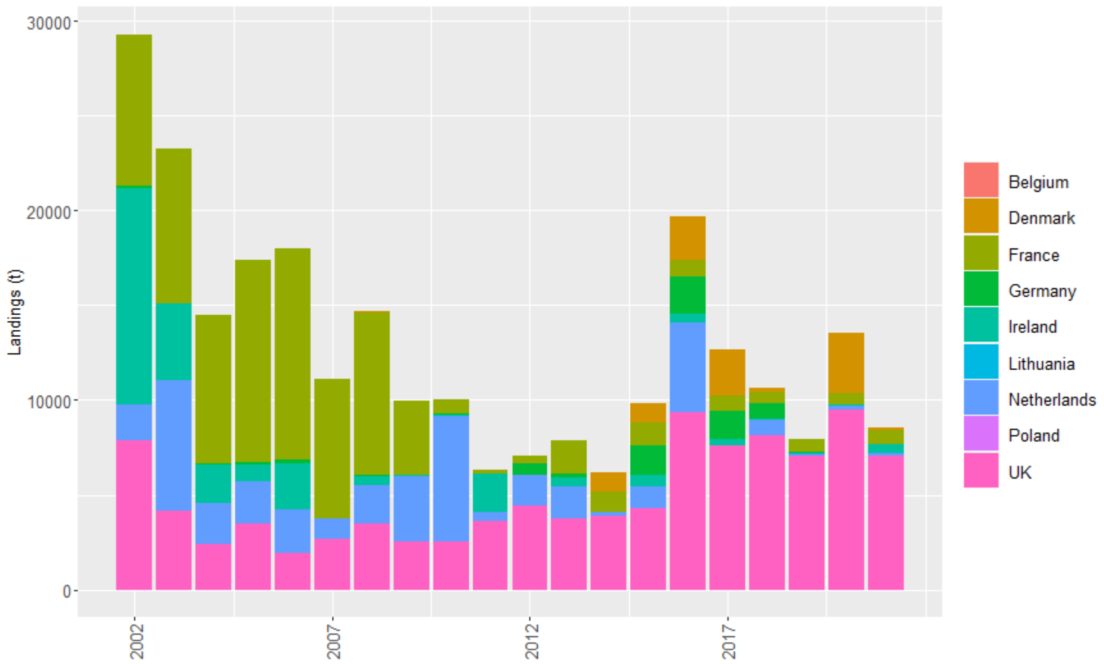


Figure 7.2.1.2. Sardine in Subarea 7. Landings reported by country (tonnes).

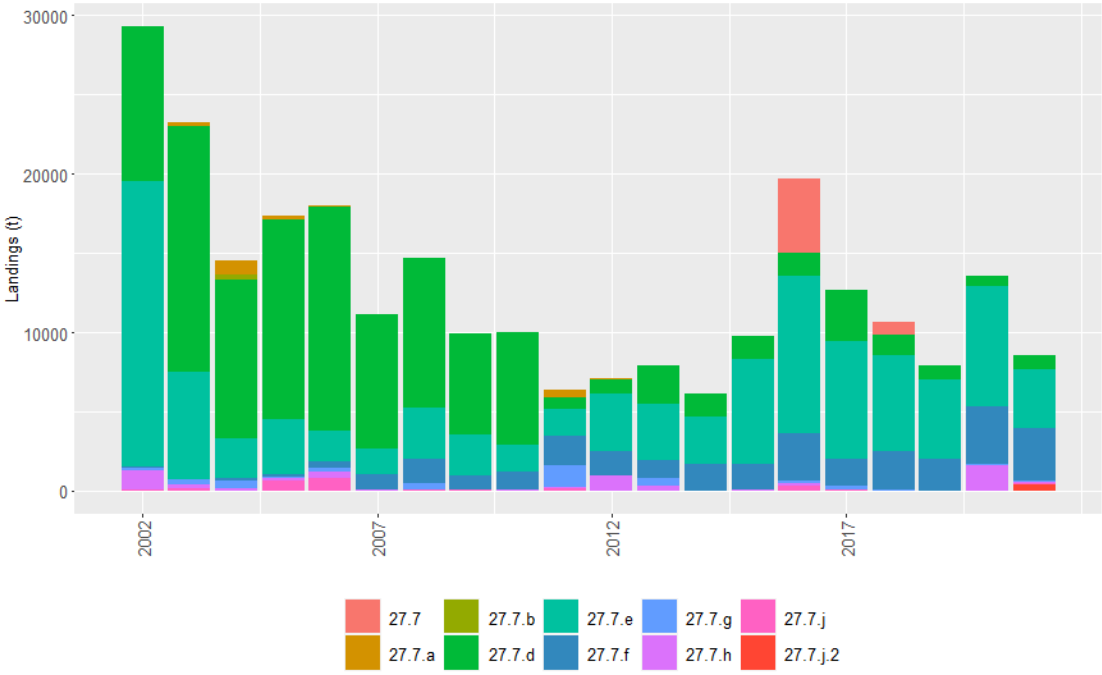


Figure 7.2.1.3. Sardine in Subarea 7. Landings by ICES division (tonnes).

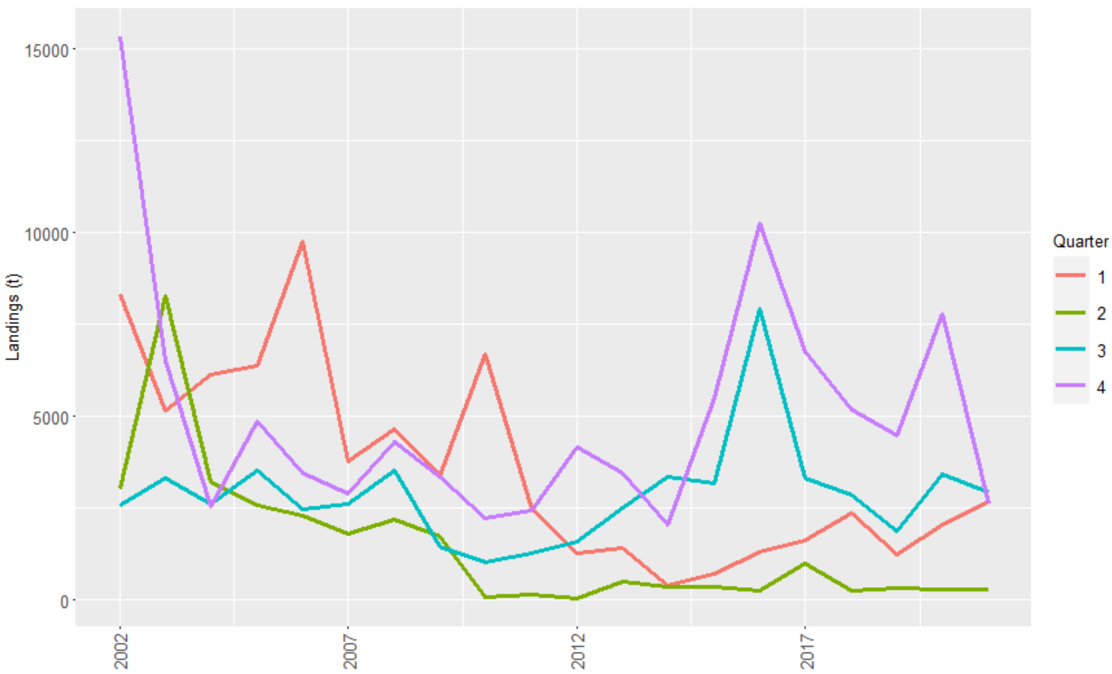


Figure 7.2.1.4. Sardine in Subarea 7. Landings by quarter (tonnes).

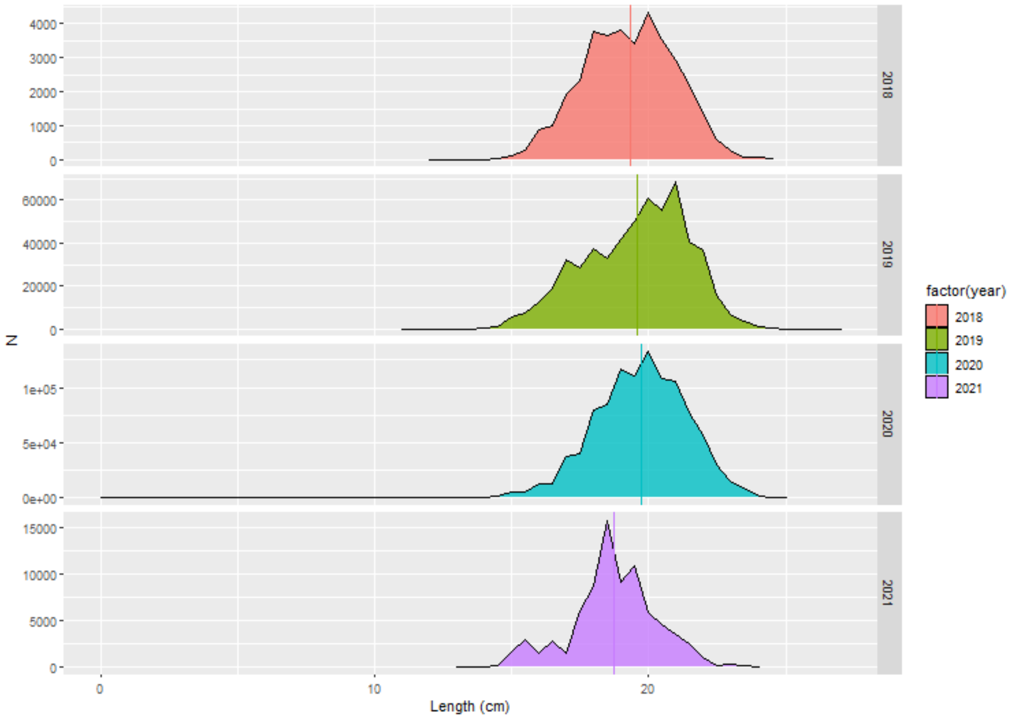


Figure 7.3.1.1. Sardine in Subarea 7. Length distribution of landings provided by the English fishing industry.

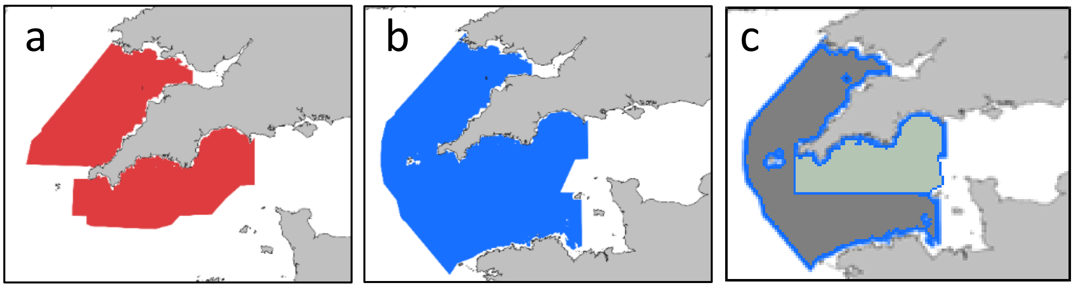


Figure 7.4.1.1. Sardine in Subarea 7. PELTIC coverage of core area a. since 2013, b. total area since 2017 and c. in 2022.

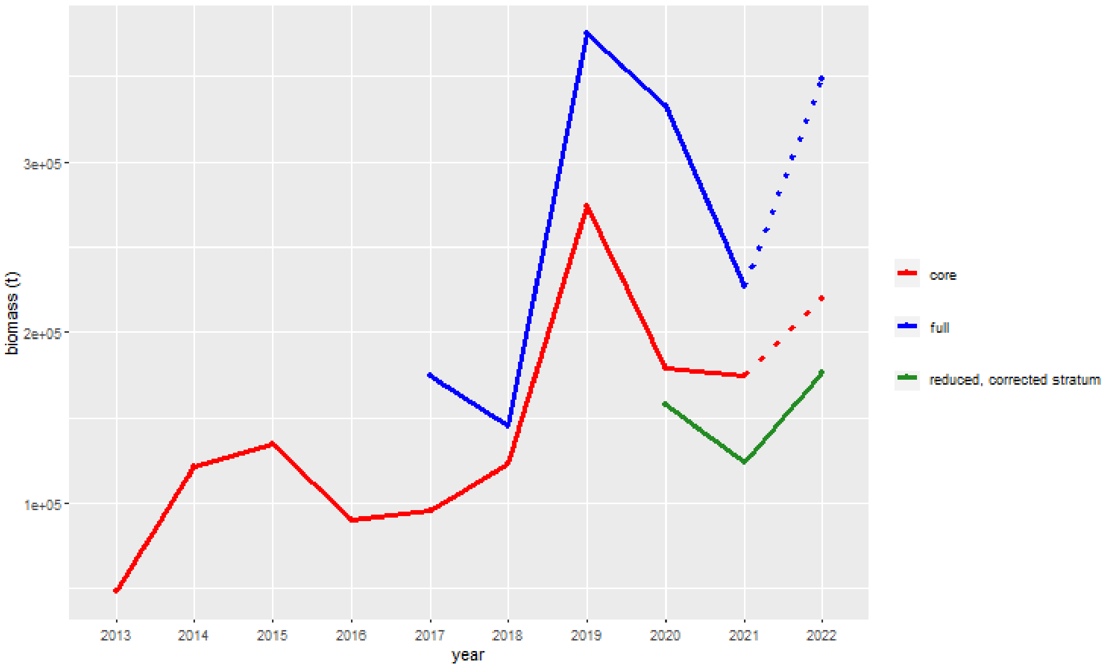


Figure 7.4.1.2. Sardine in Subarea 7. Sardine biomass in tonnes estimated from PELTIC survey in the core area (red line), covering division 7.f and English waters of 7.e, in the total area (blue line), covering division 7.f and 7.e (also French side), and in the restricted area covered in 2022 (green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

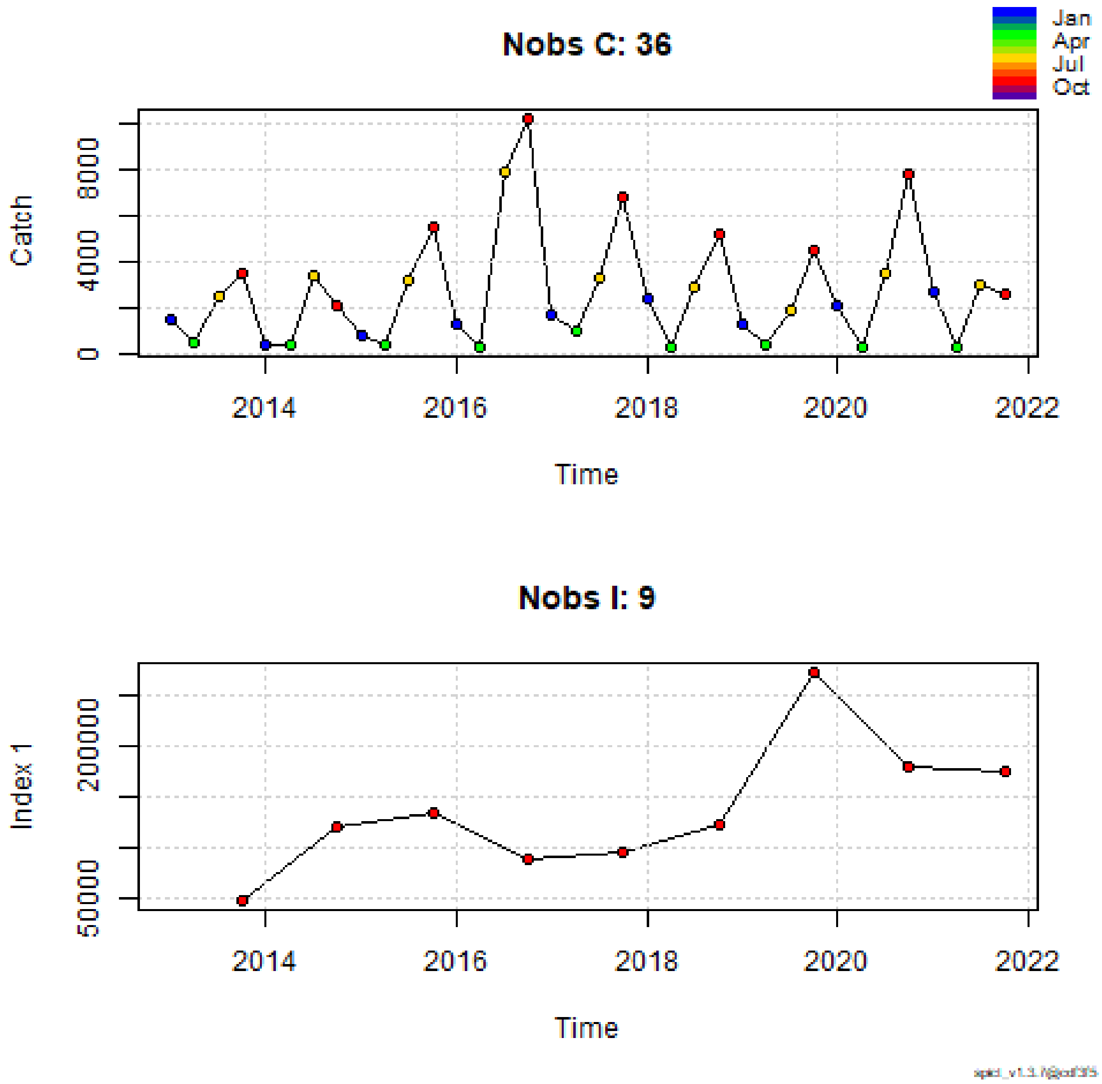


Figure 7.5.1.1. Sardine in Subarea 7. Input data of the SPiCT model. Top: landings by quarter (2013-2021). Bottom: biomass estimates in the core area (2013-2021). Blue represents quarter 1, green represents quarter 2, yellow represents quarter 3, and red represents quarter 4.

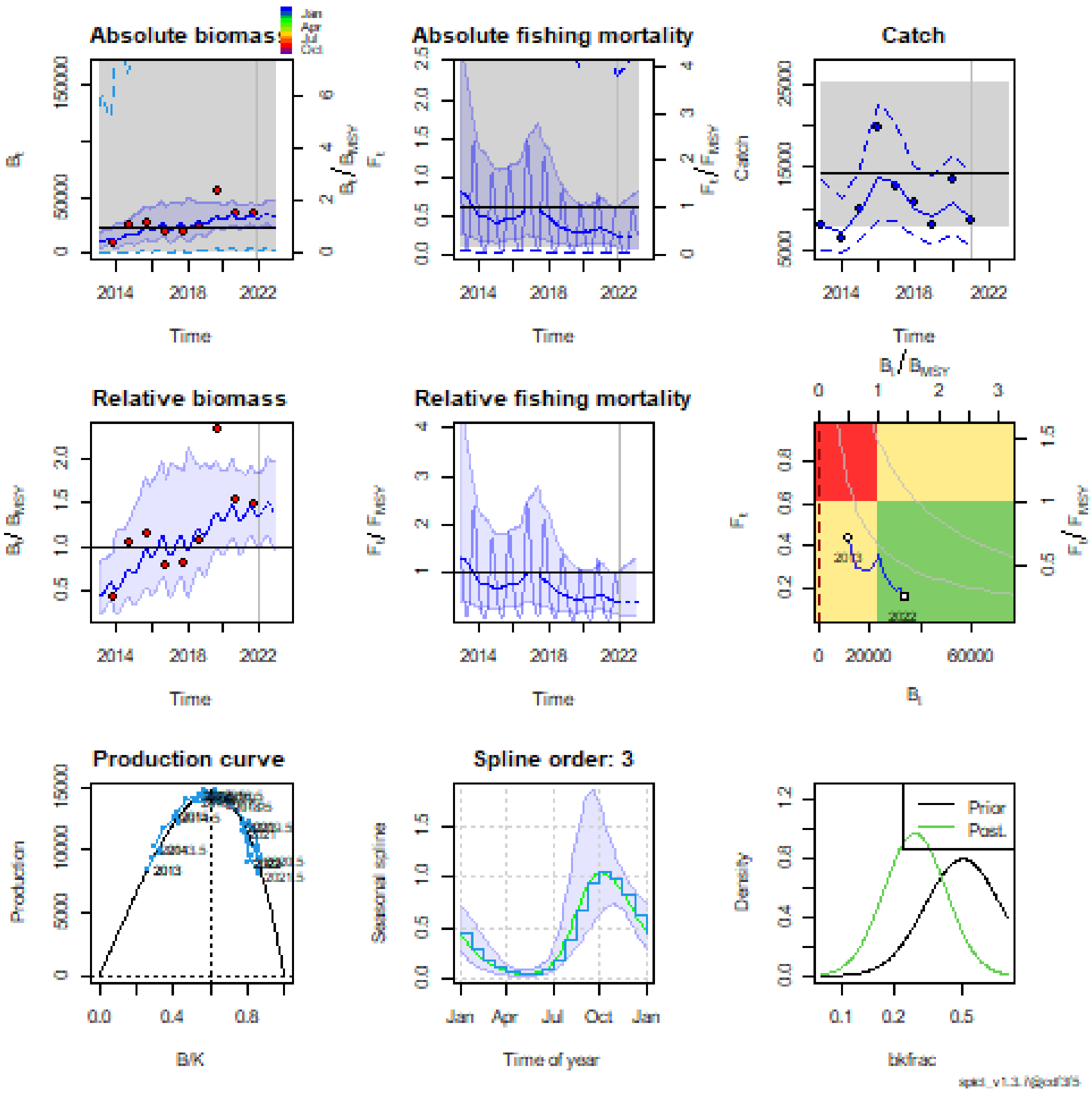


Figure 7.5.1.2. Sardine in Subarea 7. SPiCT model results. Top row: absolute biomass, absolute F estimates, and fitted catch. Middle row: relative biomass and F, and a Kobe plot comparing biomass and F. The grey area in the Kobe plot represents the uncertainty in the relative biomass and F estimates. 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).

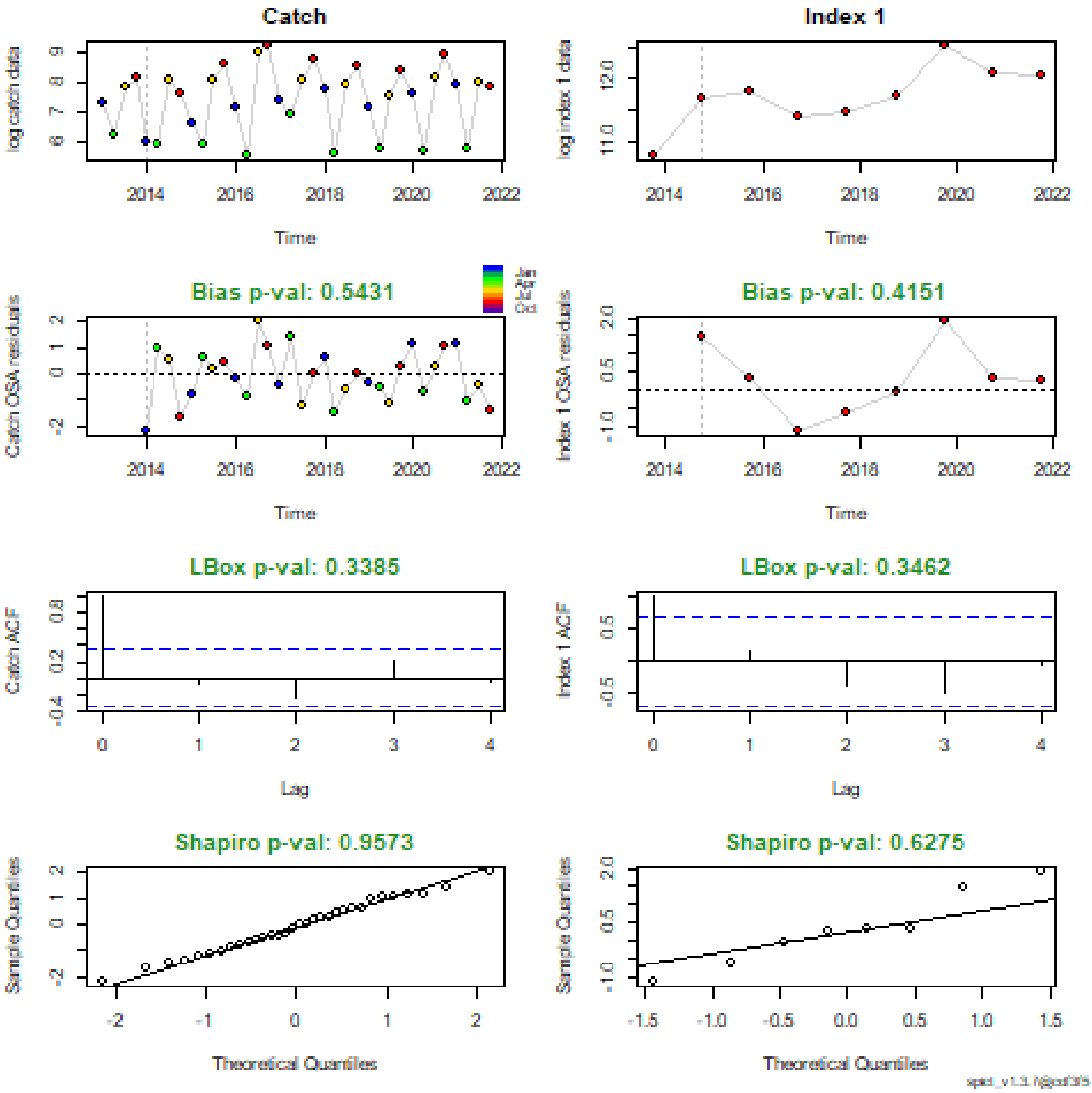


Figure 7.5.1.3. Sardine in Subarea 7. SPiCT model diagnosis.

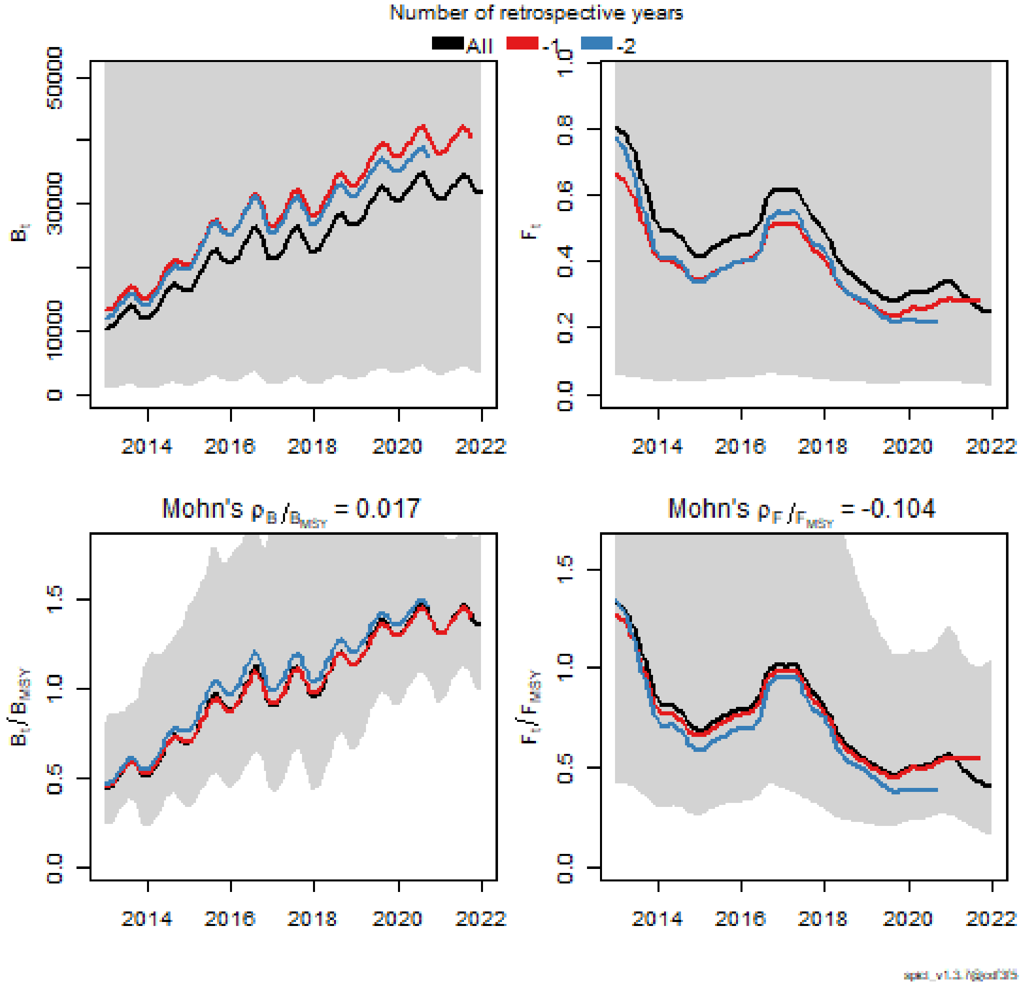


Figure 7.5.1.4. Sardine in Subarea 7. Retrospective analysis of the SPiCT model. Top row: absolute biomass and absolute F; bottom row: relative biomass and relative F.

8 Sardine in 8c and 9a

8.1 ACOM Advice Applicable to 2022, STECF advice and Political decisions

ICES advises that when the MSY approach is applied that catches in 2022 should be no more than 41 777 tonnes (ICES, 2021a). This advice for 2022 replaces the advice provided in June 2021 and was issued in December 2021 after the Interbenchmark carried out in October 2021 (ICES, 2021b) in which the assessment model was revised to include a recruitment index for the first time.

In 2022 the fishery was managed according to a bilateral agreement between Portugal and Spain (Despacho n.º 5126-A/2022; BOE-A-2022-5783). Portugal and Spain agreed to implement a total catch of 44 262 tonnes, based on the harvest control rules of the Management Plan assessed as precautionary by ICES (ICES, 2021c)

In Spain, purse-seine fishery for sardine remained closed since November 2021 and reopened on April 4th 2022 (with a planned closure in December 1st; BOE-A-2022-5783), with a quota allowing to catch a total of 14 828 tonnes.

In Portugal, the purse-seine sardine fishery was closed on the 30th November (Despacho n.º 11820-A/2021),) when the national quota limit for 2021 was reached. In 2022, the fishery was opened on May 2nd with a quota allowing a total catch of 29 400 tonnes (Despacho n.º 5126-A/2022).

8.2 The fishery in 2021

8.2.1 Fishing fleets in 2021

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 2021 indicate that the number of purse-seiners taking sardine were 478, with mean power of 236 Kw. In Portuguese waters, fleet data indicate that 174 vessels landed sardine with mean vessel tonnage of 70.0 GT and engine power category of 358 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 2021 are shown in Tables 8.2.2.1, 8.2.2.2 and Figure 8.2.2.1. Total 2021 landings in divisions 8c and 9a were of 40 685 tonnes, which represents an increase of 84% with respect to total 2020 landings (22 143 tonnes). The bulk of the landings (99%) were made by purse-seiners.

In Spain, sardine landings, 13 835 tonnes, represent a 106% increase in relation to values from 2020 (6 727 tonnes). In all ICES subdivisions catches experienced a large increment, but especially in the western area (9aN, with an increase of 162%), compared to the other areas (increase by 74% in 8c and by 95% in 9aSouth subdivisions).

In Portugal, sardine landings were of 26 851tonnes, which represents an increase of 74% compared to 2020 landings, 15 416 tonnes. The increase in landings was generalized, but as with Spanish catches, the largest increase occurred close to the area of highest recruitment (with an increase of 158% in 9aCN) compared to the rest of the subdivisions (increase by 80% in Algarve and by 16% in 9aCS).

Table 8.2.2.1 summarizes the quarterly landings and their relative distribution by ICES subdivisions. In 2021, due to management regulations implemented in Spain and Portugal (see section 8.1.), the sardine fishery opened late in the year and it closed in November for having reached the total catches admitted. For that reason, the sums of the second and third quarter landings represent almost 75% of the annual catches.

The relative contribution of the different areas to the total catch was similar to 2020, being the western Portuguese Atlantic coast (9aCN and 9aCS subdivisions) the areas that obtained 54% 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 (Table 8.2.4.1) were unimodal in Spain in 8cE, 9aN and 9aS-Cadiz subdivisions (with modes at 18.5 cm in northern areas and as usual, smaller individuals were caught in 9aS-Cádiz subdivision, with mode at 14.5 cm). In 8cW, length distribution was bimodal, with a smaller mode at 15.5 cm and another at 19 cm.

For Portugal, sardine annual length distributions were unimodal in 9aCN and 9aS-Algarve, with modes at 17.5 and 18.5 cm, respectively. For 9aCS, length distribution was bimodal with modes at 18 and 19.5 cm.

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. the relative contribution of each age group in each Subdivision is shown as well as their relative contribution to the catches.

Dominance of age-3 (2019 strong year class) individuals in all areas except Cádiz, where age-0 and age 1 represent 87% of catches. Age-3 had the higher contribution, with a 52% to the total biomass in catches, followed by age 1, with the 20% of the catches. By areas, age 0 showed a clear predominance in 9aS-Cádiz and older individuals (age-5 and age-6+) were particularly landed in 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 from the two surveys is used in the assessment.

The DEPM survey is planned and discussed within WGACEGG where final results were presented and fully discussed (ICES, 2021d).

The latest DEPM data available corresponds to 2020. There is no new information regarding DEPM surveys after the last assessment (November 2021) and a new DEPM is rescheduled for 2023.

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, 2022). 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, RV Miguel Oliver.

In 2022, due to electrical problems on the RV Miguel Oliver during the start of the PELAGO survey, a change of vessel took place and the second part of the Portuguese survey and the entire PELACUS survey were carried out on board RV Vizconde de Eza, a vessel with the same acoustic equipment.

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 RV Noruega, a 49 m trawl vessel. Since 2020 this survey is planned on-board RV Miguel Oliver.

The PELAGO2022 survey was conducted between the 1st and 31tht of March. First leg (01/03 – 09/03) was carried out on board RV Miguel Oliver and second leg (12/03 – 31/03) on board RV Vizconde de Eza.

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 42 pelagic trawl hauls were carried out by the research vessel and 29 additional hauls were done by purse-seiners. Sardine was present in most of the fishing hauls (88%) 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 9aCS subdivision (between Cascais and Setúbal; 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 2022 PELAGO survey, age 0 sardine individuals were not detected.

In 9aCN the length distribution was bimodal with modes at 15.5 and 18 cm. The main mode (18.5 cm) corresponds to age 3 individuals, still showing signs of the strong 2019 cohort.

In 9aCS and in 9aSouth-Cadiz, the modal age corresponds to age 1 (2021 cohort), with modes at 16.5 and 17 cm respectively. In 9aS-Algarve, the modal age was age 4 and a secondary mode of age 1 individuals was observed. For the total area sampled during PELAGO, age 1 accounted for

48% in abundance, indicating a strong age class of 2021. This fact is in controversy with IBERAS index in 2021, which in relation to previous years showed weak recruitment (age 0 individuals; see section 8.3.3).

In relation to total abundance in PELAGO2021, 2022 sardine estimation (18907 million individuals) showed a strong increase by 73%.

The sardine B1+ was estimated to be 808.6 thousand tonnes for the whole area, representing a very important increase of 94% in relation to the PELAGO2021 survey.

8.3.2.2 Spanish spring acoustic survey

Spanish PELACUS0422 survey was conducted on board RV Vizconde de Eza. The first leg of the survey was delayed one week (due to the change of vessel) and started in Vigo on 1st April. This first part of the survey was characterized by very bad weather and had to be stopped 11 days due to COVID issues. Second part of PELACUS started on 24th April and finished on 31th April. Despite the reduction in the number of days, it was possible to cover the target area and meet the objectives.

Sampling design and methodology was similar to that of the previous surveys and is summarized in Massé *et al* (2018) with supplementary material available online. Tracks were placed at 10 nautical mile, with a random start and only steamed during day hours. The survey progressed eastwards (Figure 8.3.2.2.1).

A total of 27 fishing stations were carried out, which represents a decrease with respect to previous years (i.e. 45 fishing hauls in 2021), in part related to the decrease in the number of days available, but especially due to the reduction in the number of schools present in the study area during the 2022 survey. Figure 8.3.2.2.2 shows the species proportion (% in number) in the fishing stations. Unlike previous years, when mackerel was the main species in the catch, this year, due to the delay of PELACUS, the migration of this species in the Cantabrian Sea had already ended. Sardine was the most important species in the fisheries, accounting for 34% in weight and 38% in abundance of the catch and was mainly located in the area of Galicia (8cWest and 9aNorth subdivisions), where the bulk of the sardine NASC distribution was recorded (Figure 8.3.2.2.3).

A total of 252 thousand tonnes, corresponding to 4081 million fish were estimated, most of them in the western part (9aN-8cW; Table 8.3.2.2). Compared to the previous year, the sardine abundance estimated by PELACUS showed a decrease of 39%, which was reflected in a decrease in biomass of 27%. Age group 1 only accounted for l% of the total biomass, with the bulk of the fish belonging to age group 3 (70% in number and biomass); which is consistent with the strong cohort of 2019 (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, 2021b) 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 2022, was carried out on board Angeles Alvariño RV. Due to logistical problems IBERAS0922 survey suffered some delay and the duration had to be reduced from 17 to 9 days (from 30th September to 8th October). Due to the time constraint, the survey sampling focused on the main recruitment area (used as an index in the assessment model) and mainly on juvenile sardine, without extending the sampling to areas where other age classes were present (Figure 8.3.3.1).

Sampling design and methodology was similar to that of the previous surveys and is summarized in Doray *et al*., 2021.

A total of 16 fishing stations were carried out and additional samples were obtained from 9 fishing stations carried out by purse-seiner vessels (Figure 8.3.3.2). Sardine was present in almost all tracks, as long as most of the fishing stations were targeted on this species.

Sardine distribution showed a wide distribution area, with its centre of gravity stable around Figueira da Foz, in 9aCN subdivision, and approximately at 20m depth. (Figures 8.3.3.3 and 8.3.3.4).

2022 recruitment for the whole surveyed area, was estimated to be 8 $x10^9$ age 0 individuals ($158x10^3$ million tonnes) and represents the highest value in the time-series (Figure 8.3.3.5).

Age 0 abundance in the 9aCN subdivision, which will be used in the assessment model, corresponds to 7020 x 106 individuals ($137x10^3$ tonnes).

During IBERAS22 many of the juvenile sardine schools showed a near-surface occurrence. In some cases, as shown in the Figure 8.3.3.6, thick fish schools were at the blind area, outside the echosounder detection area. For this reason, the recruitment index in 2022 may be underestimated.

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 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.

Since 2021, 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 (2020) 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 (2020) 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 Figure 8.3.8.1.

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 2022
Catch	Catch biomass 1978–2022 (tonnes)
	Catch-at-age 1978–2021 (thousands of individuals)
Spring acoustic survey (Joint SP+PT) *	Total numbers 1996–2022 (thousands of individuals)
	Numbers-at-age 1996–2022 (thousands of individuals)

DEPM survey (Joint SP+PT)	SSB 1997, 1999, 2002, 2005, 2008, 2011, 2014, 2017, 2020 (tonnes)
Autumn acoustic survey (recruitment index)	Numbers at age 0 in 9aCN 1997-2022 (thousands of individuals)
Weight-at-age in the catch	Yearly averages 1978–2021 (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, 2020 onwards), kg
Maturity-at-age	From DEPM surveys in DEPM years, linear interpolation for years in-between (constant 1978–1998, 2020 onwards), 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 $R_{0,2022}$ = 20 662 800 (CV = 3.8%) and the initial F was estimated as $initF_{2022}$ = 0.39 year^{-1}. Catchability parameters are close to 1 for both the acoustic (Q = 1.34, RMSE = 0.33) and the DEPM (Q=1.22, RMSE=0.30) surveys. Catchability parameter for the recruitment index is 1.72e-06 (RMSE = 1). The extra standard deviation parameters are low for the spring acoustic and the DEPM surveys (0.08 and 0.05 respectively) but higher for the recruitment index (0.78). 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 $Q_{acoustic\ survey}$ (-0.57) 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, 0.33 and 0.30. The harmonic mean of the fishery age composition sample size, 73, 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 22).

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. All are similar to the fit of the 2021 assessment model. The assessment of 2022 still shows a poor fit to the 2022 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 recruitment 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 2021 are positive for ages 1, 2 and 4 and negative for all the other ages. The acoustic survey residuals in 2022 are positive for age four and older and negative for the 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 (2006–2021) 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 lower.

The summary of the 2022 assessment results is shown in Table 8.4.1.4 and Figure 8.4.1.6 (in the Figure compared to the 2021 assessment model results). The estimate of B1+ in 2022 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. Catches assumption for 2022 are based on the EU members published legislation (see Section 8.1). The model estimates standard errors of SSB, recruitment and ApicalF (maximum F over age within years). We assume the CVs of SSB and ApicalF apply to B1+ and F(2–5), respectively.

B1+ in 2022 is estimated as 432 379 t (CV = 16%), assuming that the stock weights are equal to the mean of the last six years. This represents an increase of 2% when compared with B1+ in 2021 = 424 514 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). Total numbers of individuals increased by 37% from 2021 to 2022.

$F_{bar\ 2–5}$ in 2021 is estimated to be 0.098 year^{-1} (CV = 17%) which represents an increase of 58% when compared to $F_{bar\ 2-5}$ in 2020. $F_{bar\ 2–5}$ is now just above F_{MSY} = 0.092.

The series of historical recruitments 1978–2022 shows a marked downward trend until 2006 and since then, has been fluctuating around historically low values. The 2019 recruitment estimate (R_{2019} = 26 171 500, CV = 16%) constitutes the highest value since 2004. The 2022 recruitment estimate (R_{2021} = 19 424 400, CV = 47%) represents a decreased of 78% when compared to the recruitment estimate of 2021.

8.5 Retrospective pattern

Retrospective patterns for Biomass 1+, $F_{ages2-5}$ and recruitment were computed for years 2017–2022. 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 (2022). This range of runs include a run prior the benchmark (ICES, 2017) and three runs prior the Inter-benchmark (ICES, 2021c). 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 -0.333) and recruitment (Mohn's rho of -0.139) while it overestimates $F_{ages2–5}$ (Mohn's rho of 0.350). Differences in the estimation of these parameters between runs are more pronounced for $F_{ages2–5}$ 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. However, trends do not change between runs. 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, 2021b) 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 (2022) is now the estimate from the assessment model. Recruitment in the forecast year (2023) was set to the geometric mean of the last five years (2018–2022), R_{2023} = 13 330 753 thousand individuals. Fishing mortality in the interim year is the fishing mortality that corresponds to a catch constrain. The catch assumption for 2022 was assumed to be 44 262 tonnes based on the official documents published in Portugal and Spain prior to WGHANSA-2 (Despacho n.º 5126-A/2022; BOE-A-2022-5783). This corresponds to a $F_{ages2–5}$, 2022 = 0.101.

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 TAF github repository.

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 a 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 (ICES, 2021e). 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.

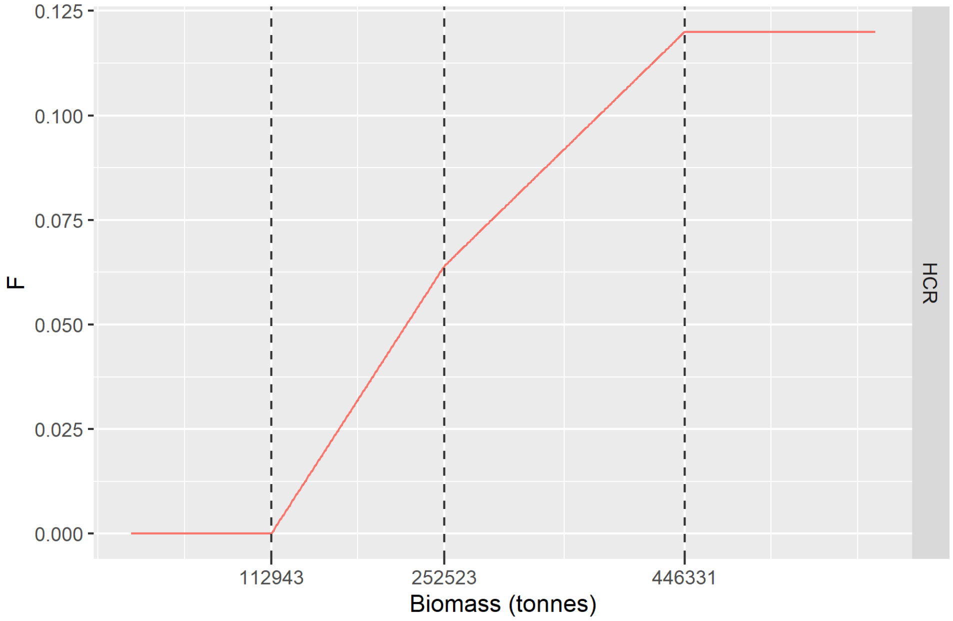


Figure 8.8.1. Sardine in 8c and 9a. Proposed HCR. The biomass reference levels of biomass (B1+) reported correspond to $B_{loss(2018)}$ = 112 943 t, MSY $B_{trigger\_low}$ = B_{pa_low} = 252 523 t and MSY $B_{trigger\_medium}$ = B_{pa_medium} = 446 331 t.

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, 2021c). For 2022, 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.

8.9 References

Doray, M., Boyra, G., and van der Kooij, J. (Eds.). 2021. ICES Survey Protocols – Manual for acoustic surveys coordinated under 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

ICES. 2017. Report of the Benchmark Workshop on Pelagic Stocks, 6–10 February 2017, Lisbon, Portugal. ICES CM 2017/ACOM:35. 294 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. 639 pp.

ICES. 2021a. Sardine (Sardina pilchardus) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters). In Report of the ICES Advisory Committee, 2021. ICES Advice 2021, pil.27.8c9a. https://doi.org/10.17895/ices.advice.7816

ICES. 2021b. Inter-Benchmark Protocol for Iberian sardine (IBPIS). ICES Scientific Reports. 3:108. 57 pp. https://doi.org/10.17895/ices.pub.8144

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. Working Group on Acoustic and Egg Surveys for small pelagic fish in NE Atlantic (WGACEGG; outputs from 2020 meeting). ICES Scientific Reports. 3:76. 706 pp. https://doi.org/10.17895/ices.pub.8234

ICES. 2021e. 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.8163

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. BOE 2022. 5783. Resolución de 2 de abril de 2022, 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.

Ministério da Agricultura e Alimentação. 2022. Despacho n.º 5126/2022, de 6 de maio de 2021 Determina a reabertura, a partir das 00:00 horas do dia 2 de maio de 2022, da pesca da sardinha (Sardina pilchardus). Diário da República, 2.ª série. https://www.dgrm.mm.gov.pt/documents/20143/121101/Despacho+5126-A-2022sardinha.pdf/a143d36a-0553-a4cf-f751-863445c320b8

Ministério da Agricultura e Alimentação. 2021. Despacho n.º 11820-A/2022, de 29 de Novembro de 2021 Determina a proibição a partir das 24:00 horas do dia 30 de novembro da captura, manutenção a bordo e descarga de sardinha (Sardina pilchardus), com qualquer arte de pesca, na zona 9 definida pelo Conselho Internacional para a Exploração do Mar. Diário da República, 2.ª série. https://dre.pt/dre/detalhe/despacho/11820-a-2021-175129331

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.

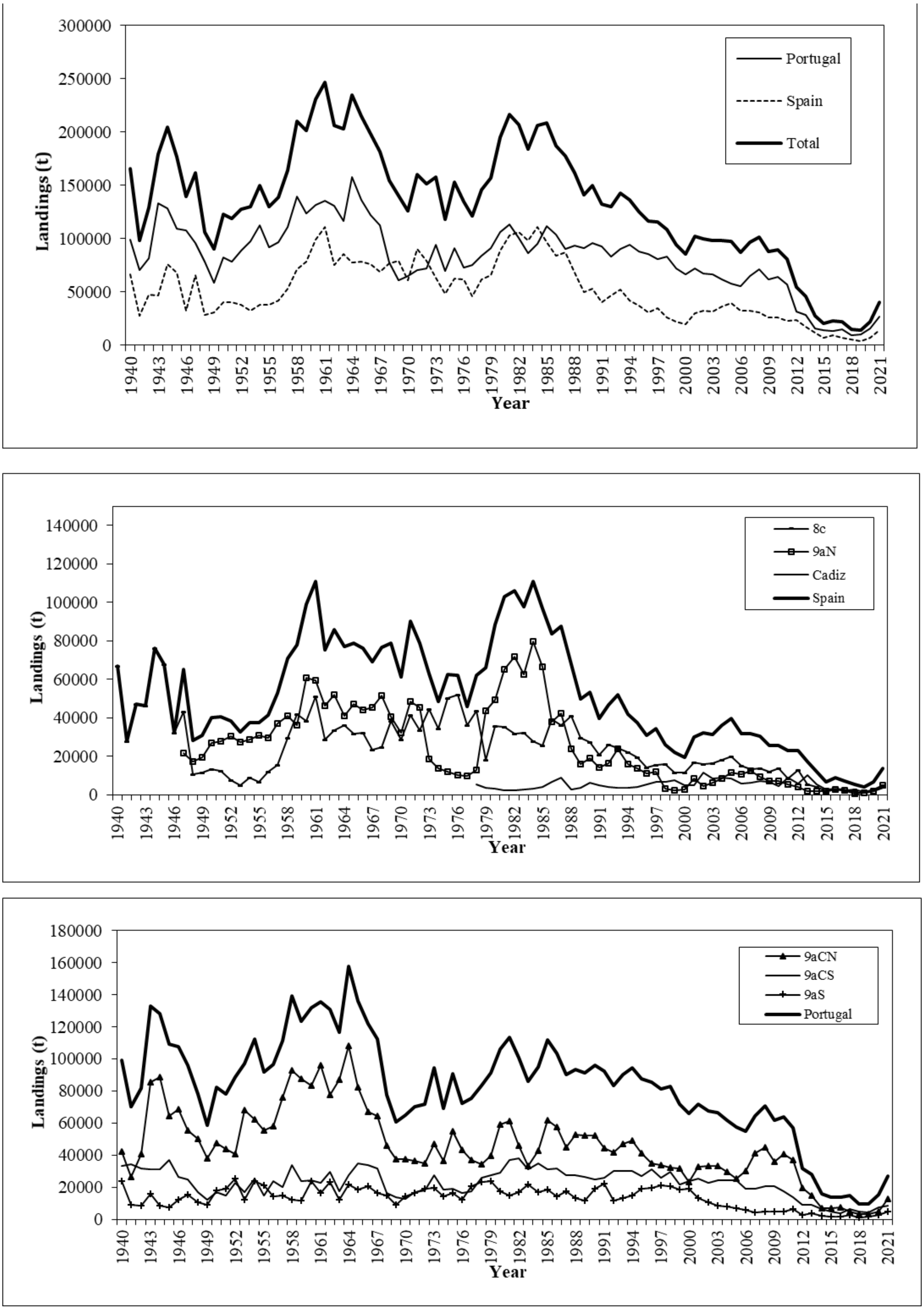


Figure 8.2.2.1. Sardine in 8c and 9a. WG estimates of annual landings of sardine, by country (upper pannel) and by ICES subdivision and country.

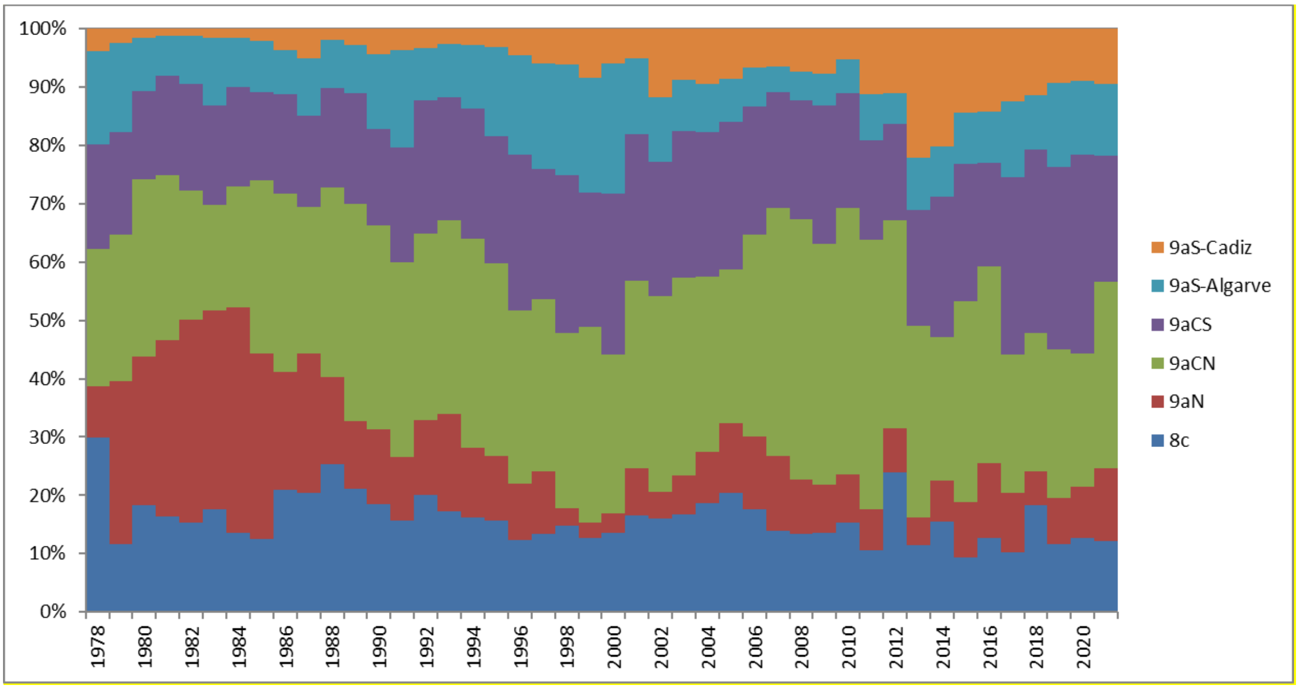


Figure 8.2.2.2. Sardine in 8c and 9a. Historical relative contribution of the different subdivisions to the total catches (1978-2021).

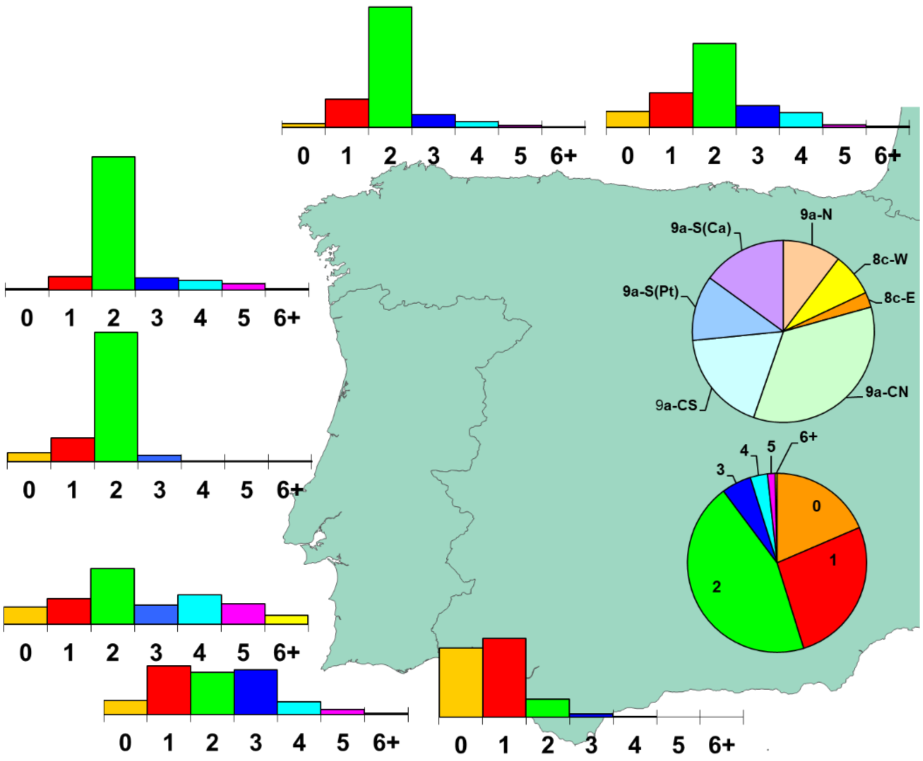
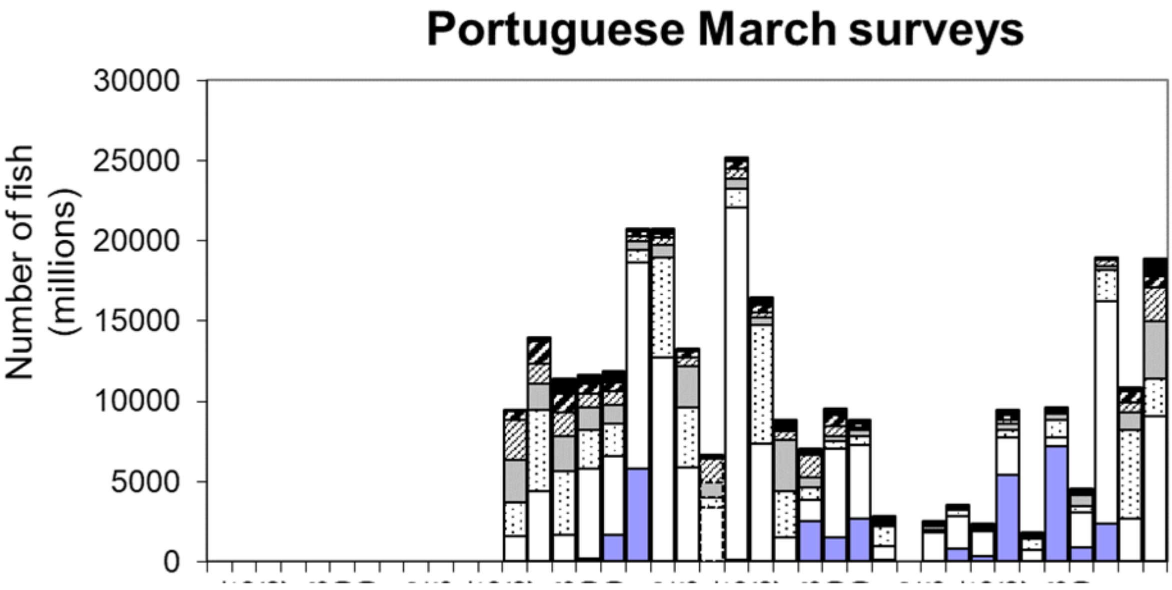


Figure 8.2.4.1. Sardine in 8c and 9a. Relative contribution of each age-class by subdivisions as well as their relative contribution to the 2021 catches (pie-chart).



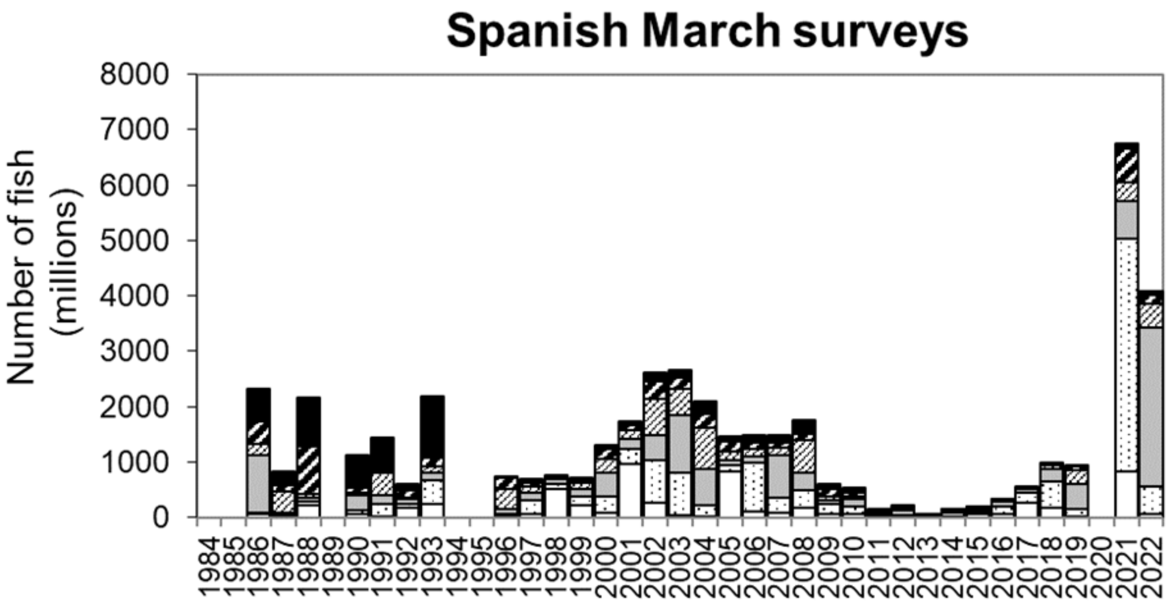


Figure 8.3.1. Sardine in 8c and 9a. Total abundance and age structure (numbers) of sardine estimated in the acoustic surveys. The Spanish March survey series covers area 8c and 9a-N (top panel) and the Portuguese March surveys covers 9aCN, 9a-CS, 9aS-Algarve and 9aS-Cadiz subdivisions (bottom panel). 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).

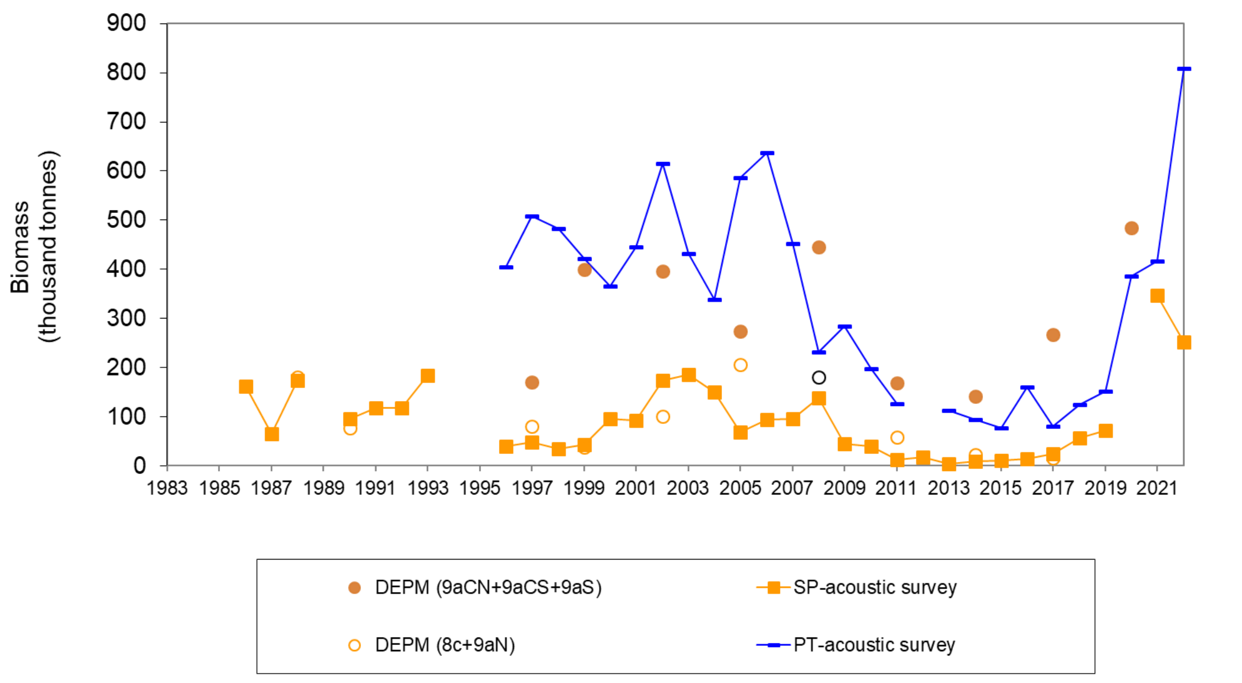


Figure 8.3.2. Sardine in 8c and 9a. Total sardine biomass (thousand tonnes) estimated in the different series of acoustic surveys and SSB estimates from the DEPM series covering the northern area and the west and southern area of the stock.

Figure 8.3.3. Sardine in 8c and 9a. Recruitment index. Age 0 Individuals (thousands) estimated in SAR-PT-AUT, JUVESAR and IBERAS autumn acoustic survey time series 1997-2021 (thousand tonnes) in 9aCN subdivision.

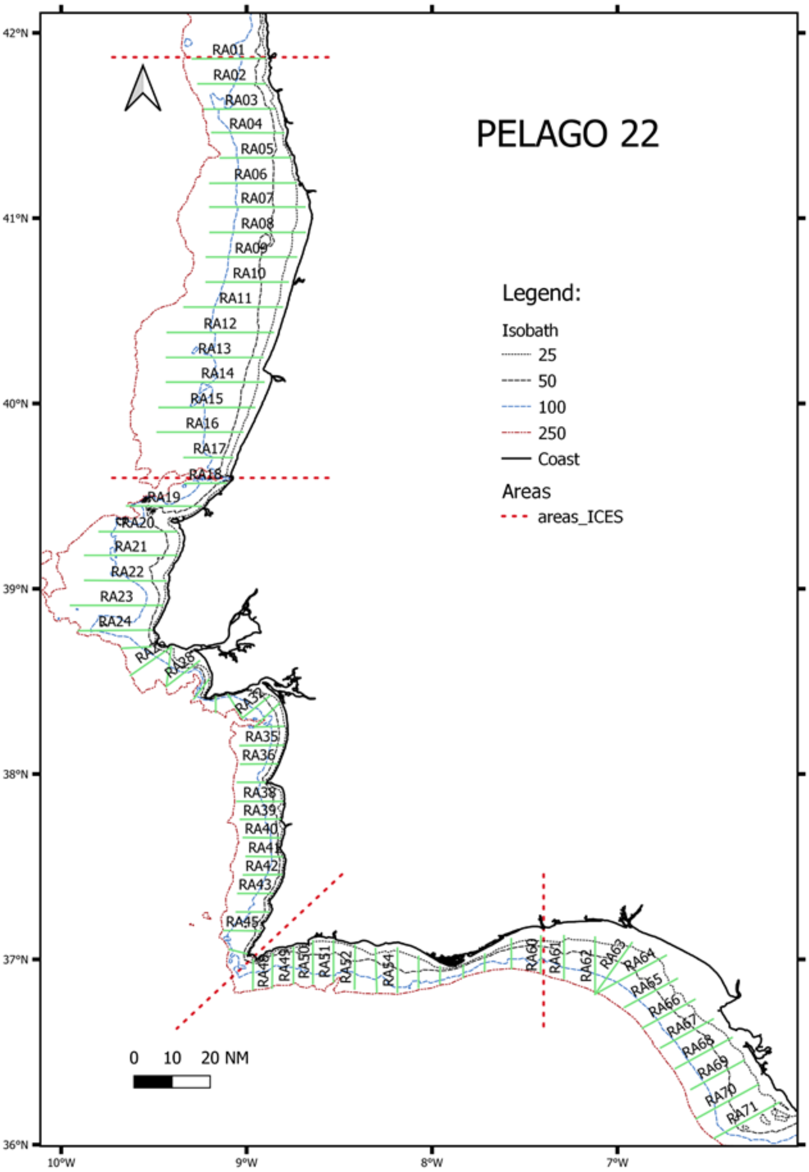
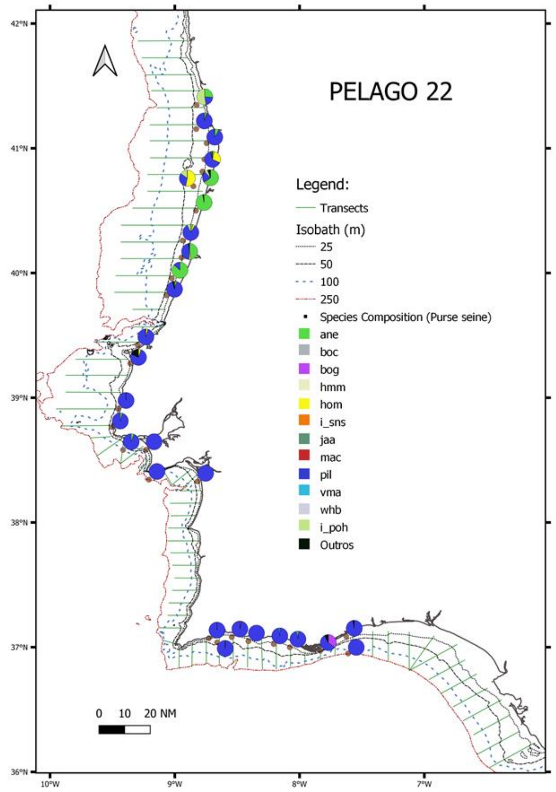


Figure 8.3.2.1.1. Sardine in 8c and 9a. acoustic transects during PELAGO 2022 survey.



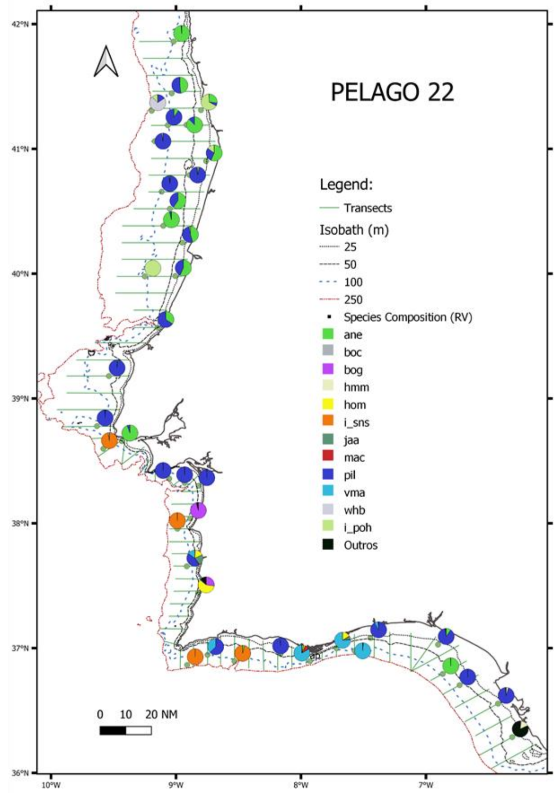


Figure 8.3.2.1.2. Sardine in 8c and 9a. Fishing haul operations during PELAGO 2022 survey. Left) Purse seiners hauls. Right) Research vessels hauls.

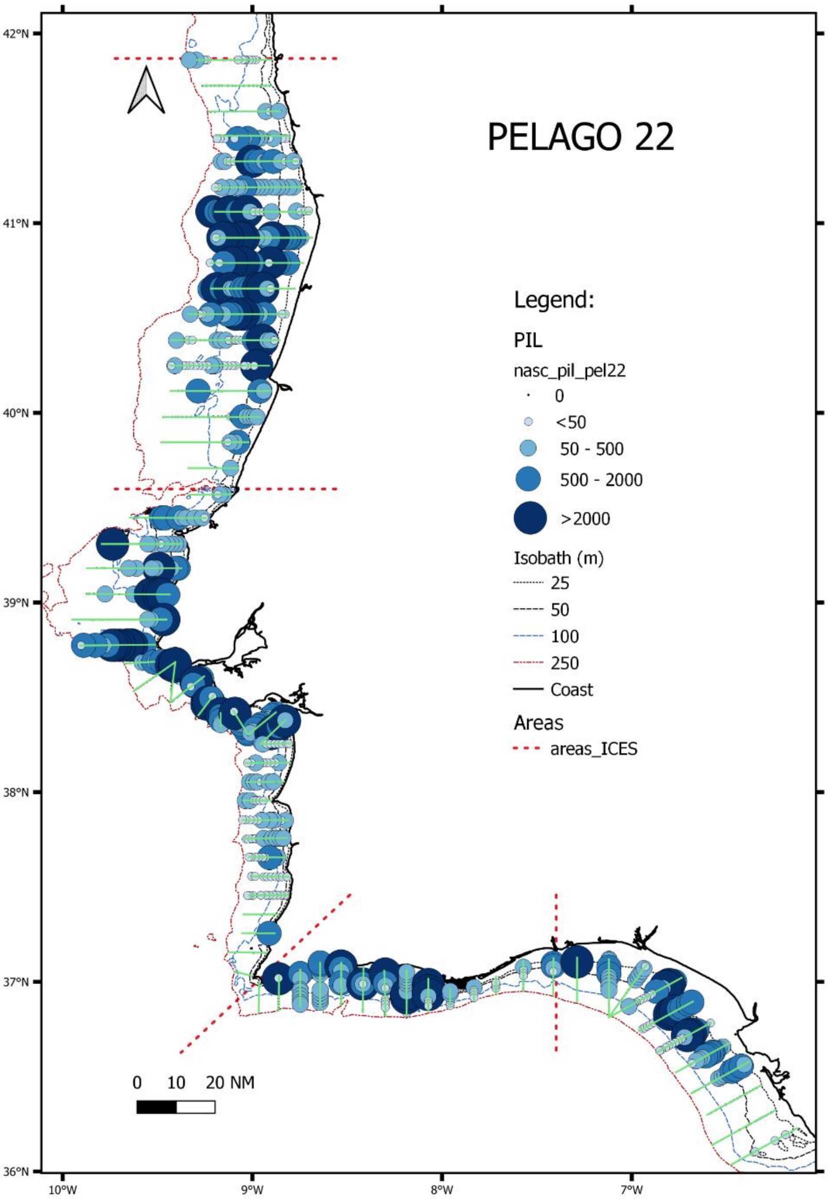


Figure 8.3.2.1.3. Sardine in 8c and 9a. Acoustic energy during PELAGO2022.

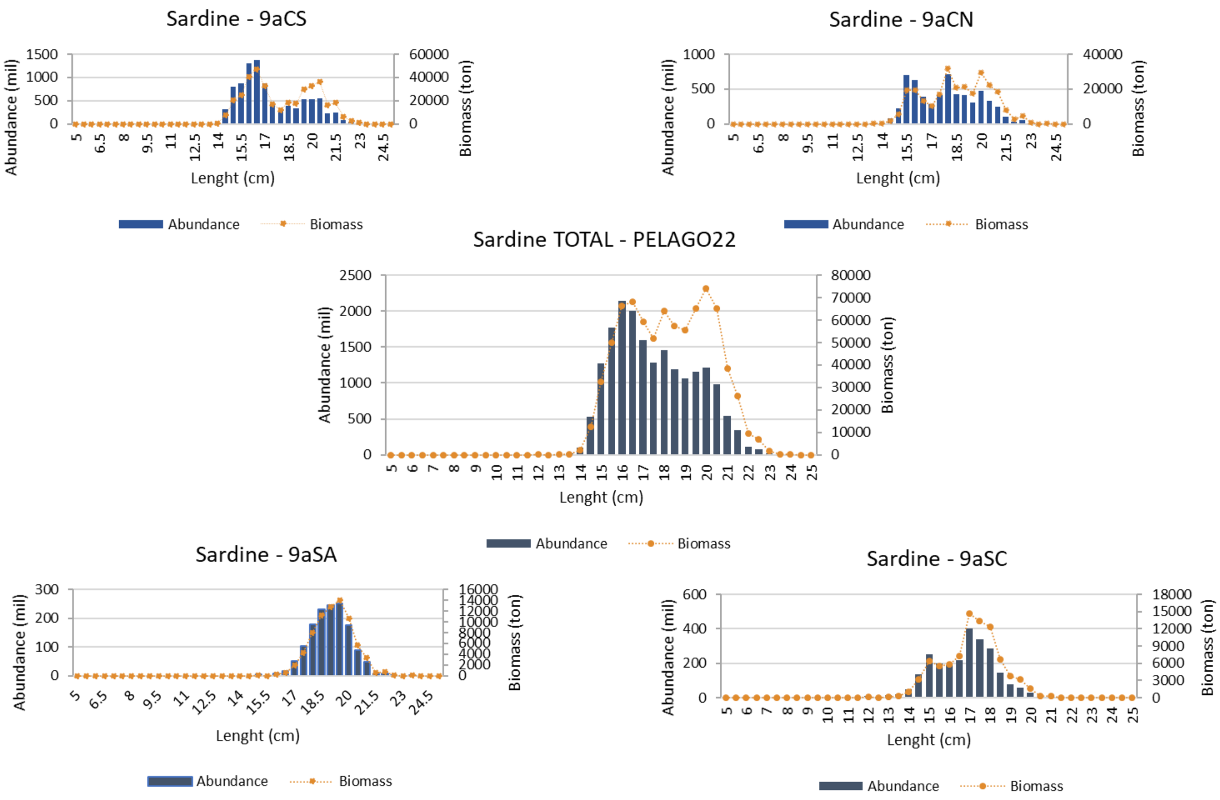


Figure 8.3.2.1.4. Sardine in 8c and 9a. Size composition during PELAGO2022.

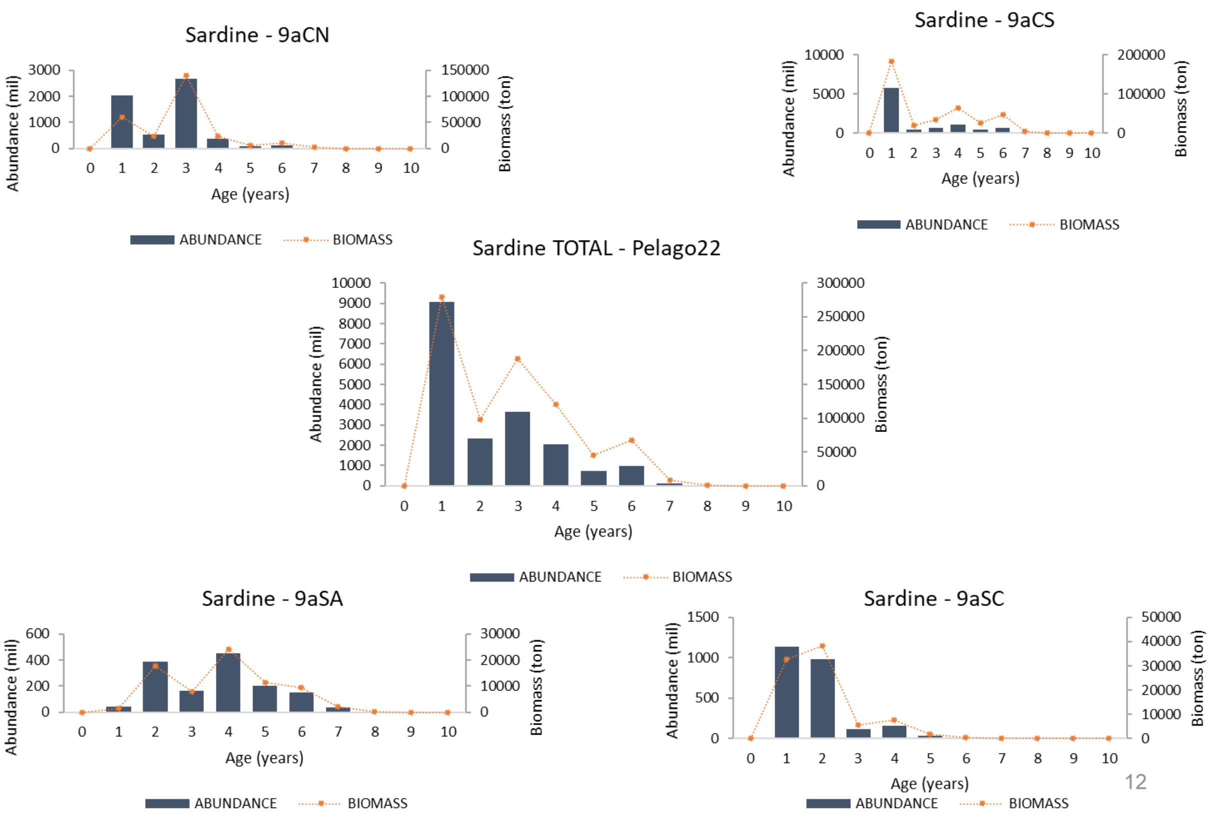


Figure 8.3.2.1.5. Sardine in 8c and 9a. Age composition during PELAGO2022.

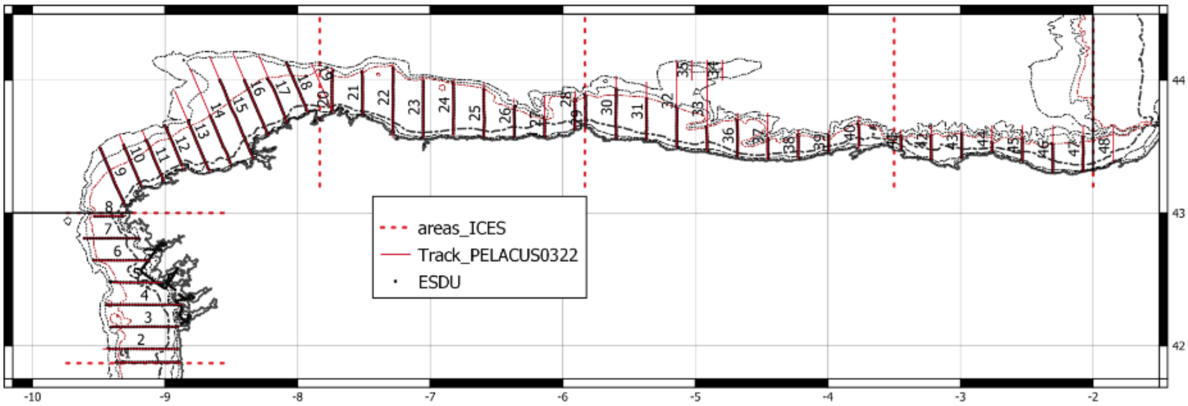


Figure 8.3.2.2.1 Sardine in 8c and 9a. Survey track of PELACUS0422 survey.

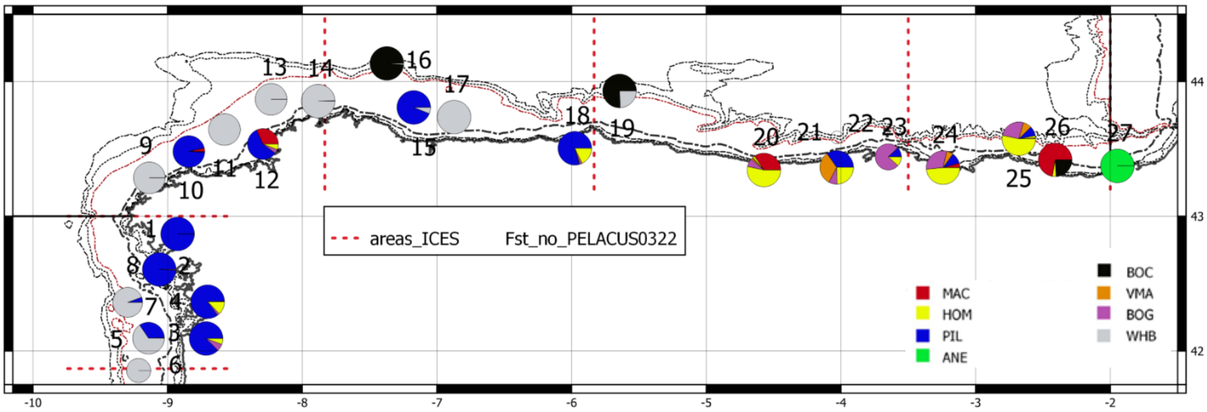


Figure 8.3.2.2.2. Sardine in 8c and 9a. Fishing stations and catch composition (% in number of fish caught) in PELACUS0422 survey.

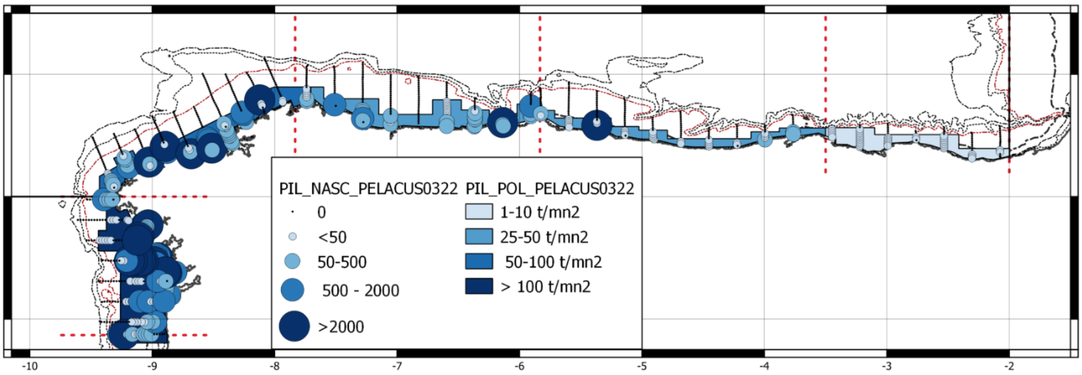


Figure 8.3.2.2.3. Sardine in 8c and 9a. Sardine spatial distribution in PELACUS0422 survey.

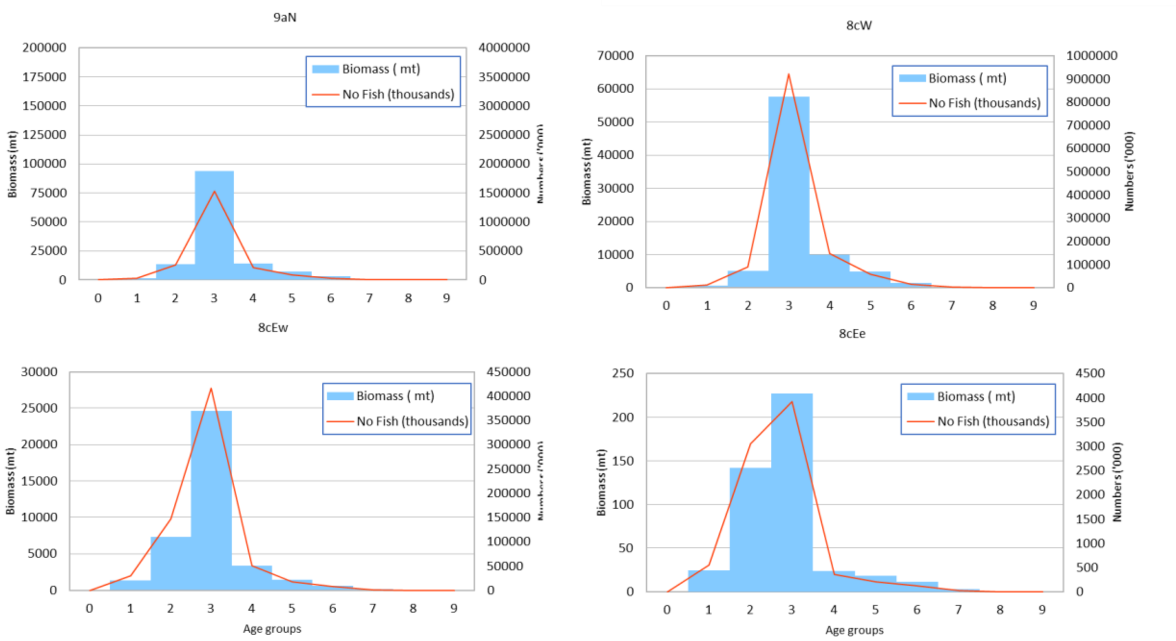


Figure 8.3.2.2.4. Sardine in 8c and 9a. Sardine abundance by age group and area, estimated in PELACUS 0422.

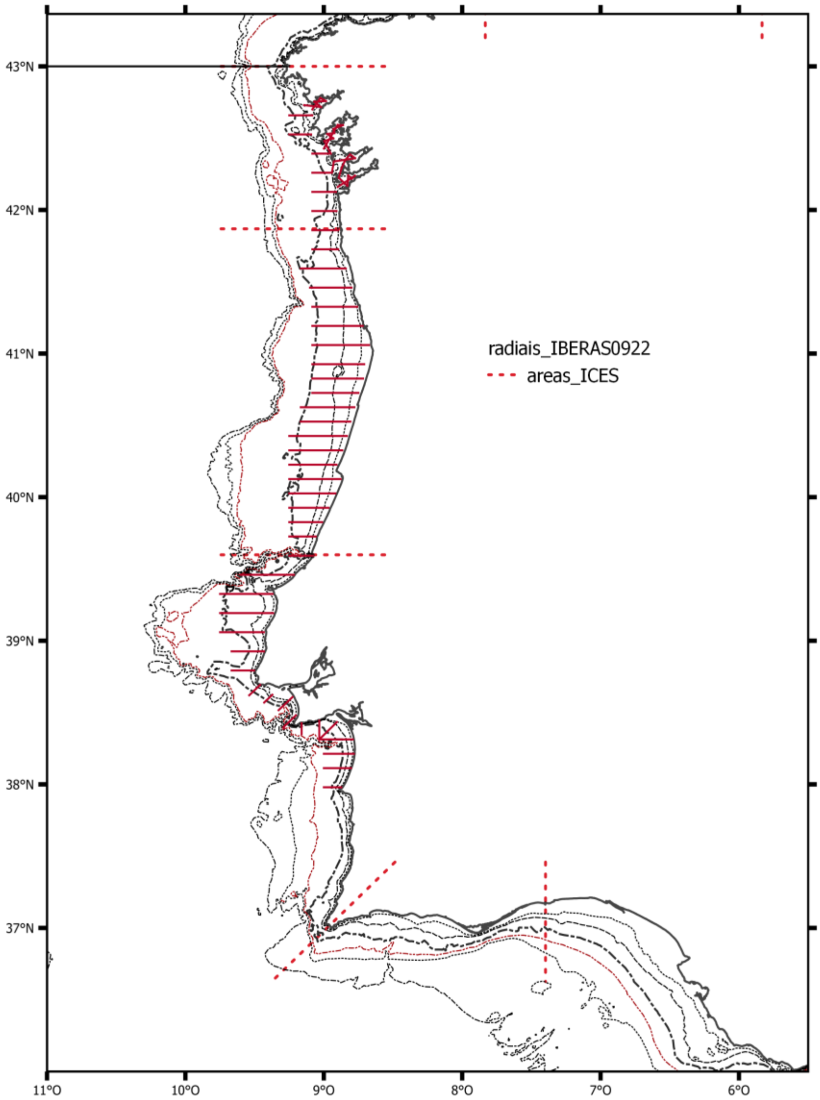


Figure 8.3.3.1. Sardine in 8c and 9a. Survey track of IBERAS0922 survey.

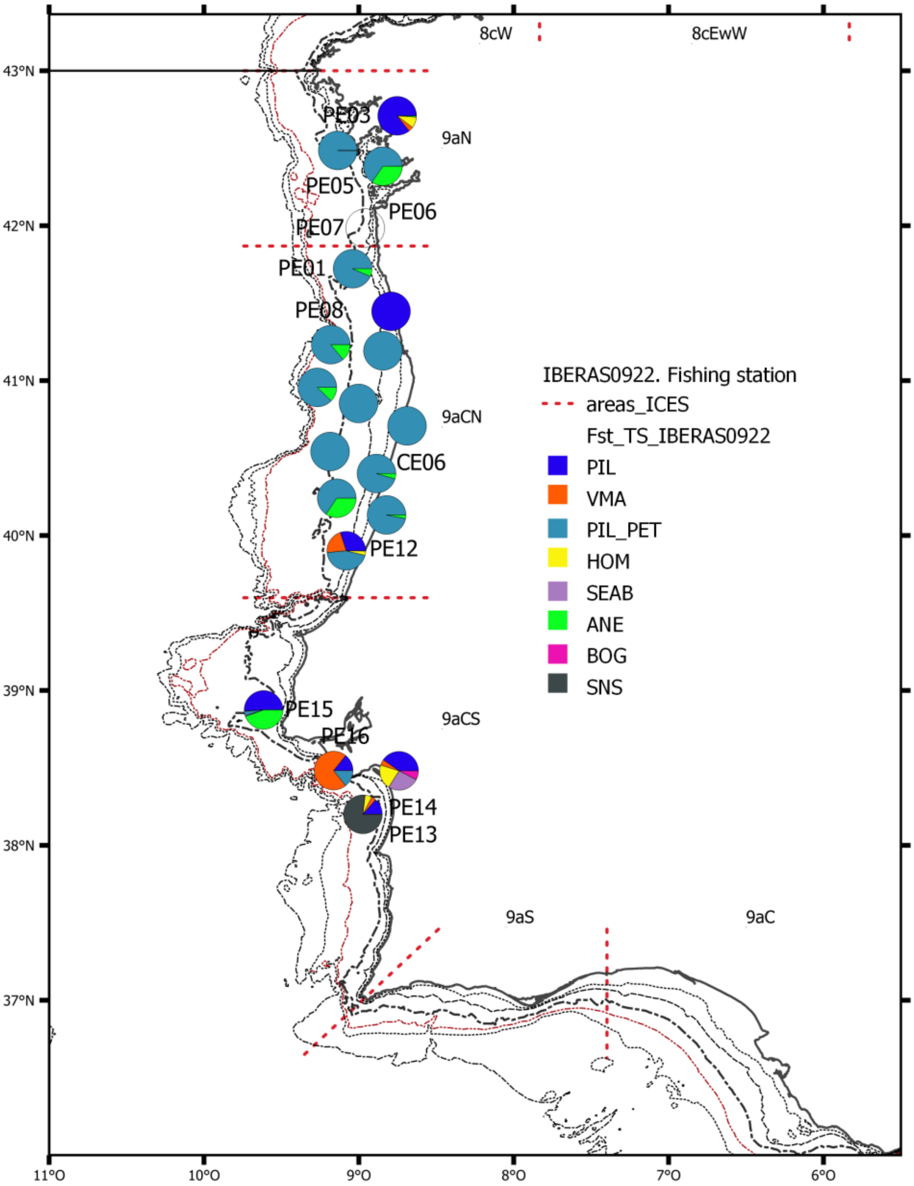


Figure 8.3.3.2. Sardine in 8c and 9a. Fishing stations and catch composition (% in number of fish caught) in IBERAS2022 survey; PIL: adult sardine; PIL_PET: juvenile sardine.

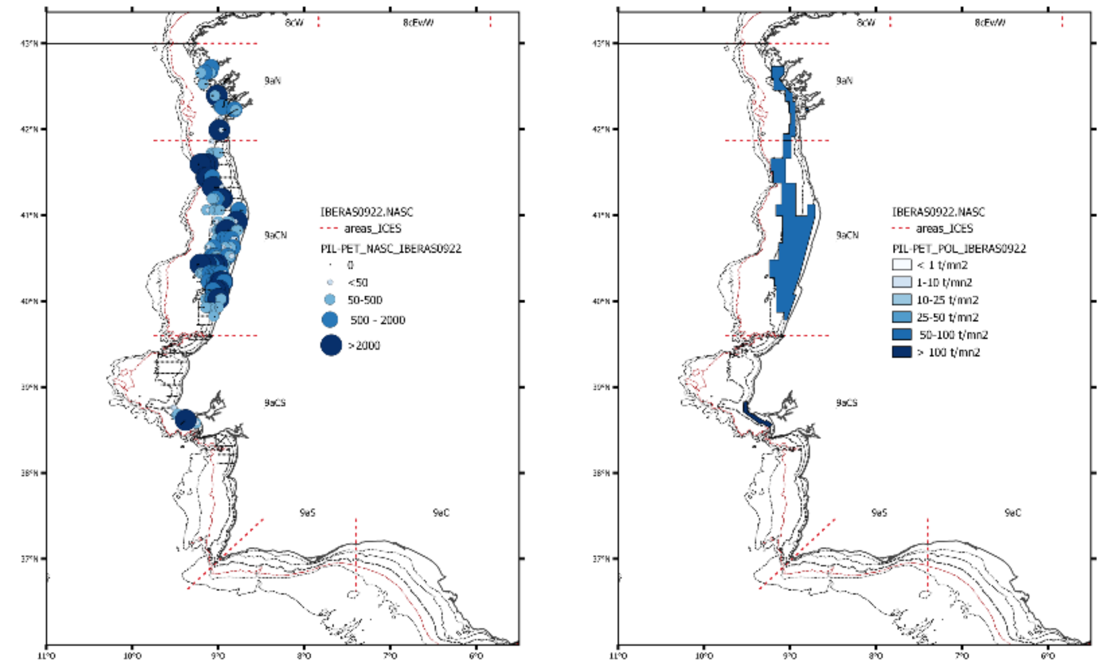


Figure 8.3.3.3. Sardine in 8c and 9a. Sardine spatial distribution in IBERAS2022 survey, a) Allocated NASC b) Conversion to biomass.

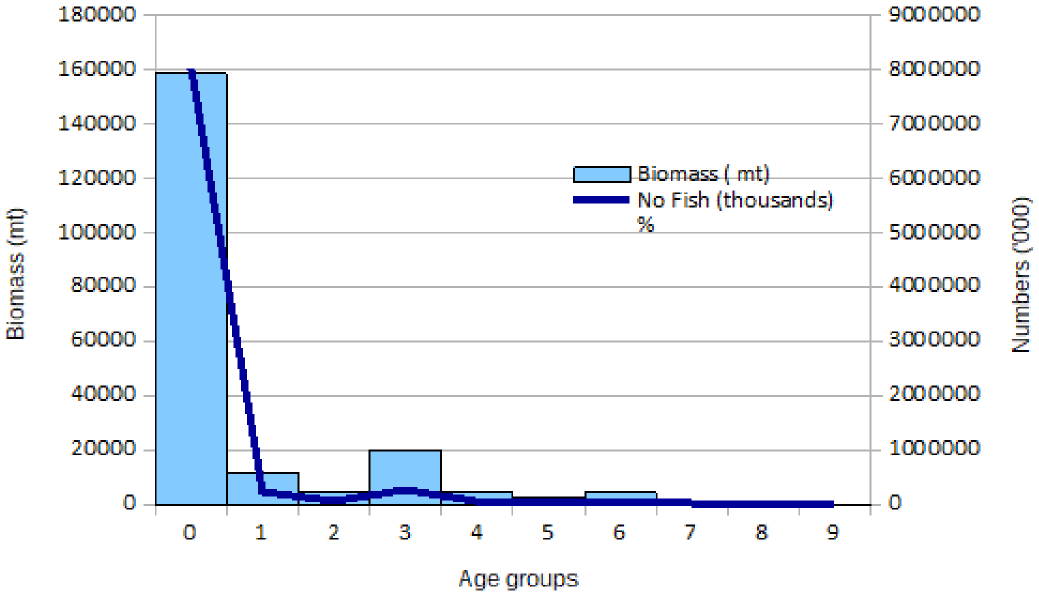


Figure 8.3.3.4. Sardine in 8c and 9a. Sardine abundance and biomass by age group estimated in IBERAS2022 survey.

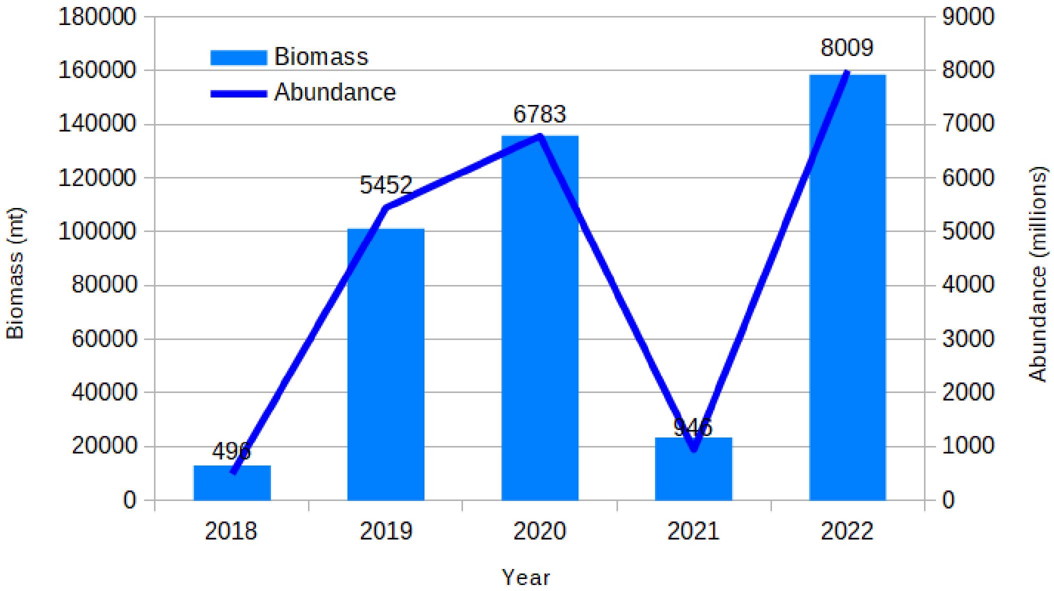


Figure 8.3.3.5. Sardine in 8c and 9a. Age 0 Sardine abundance and biomass in the IBERAS time series.

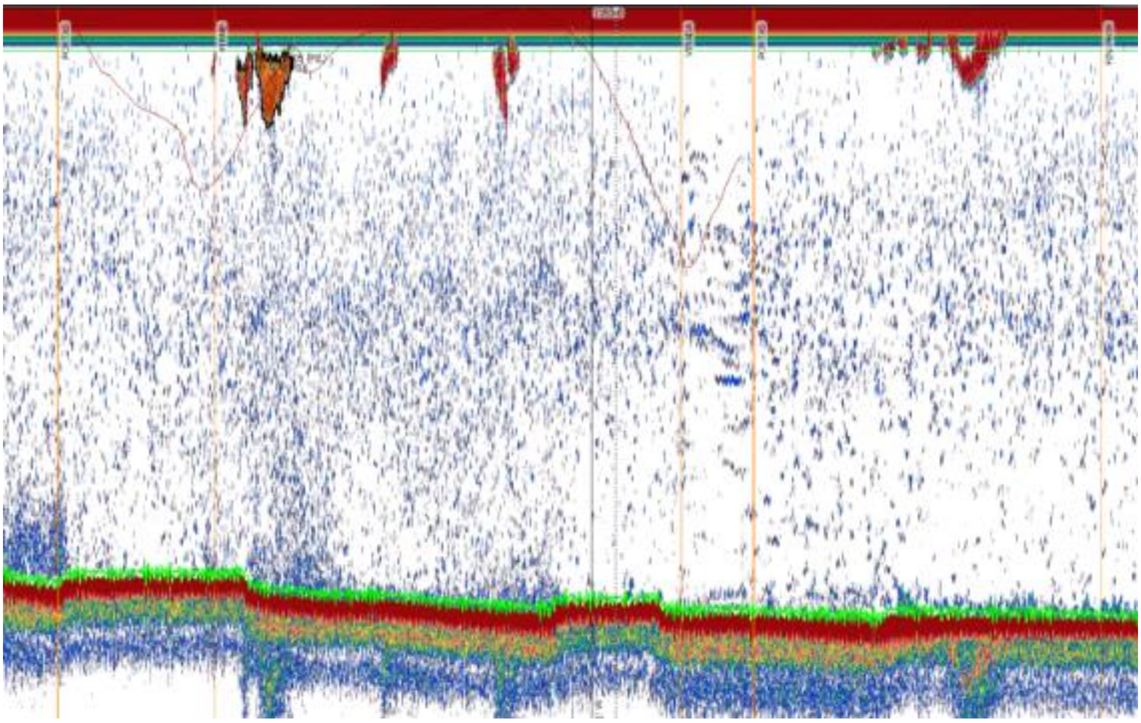


Figure 8.3.3.6. Sardine in 8c and 9a. Echogram showing the location of juvenile sardine schools during the IBERAS22 survey.

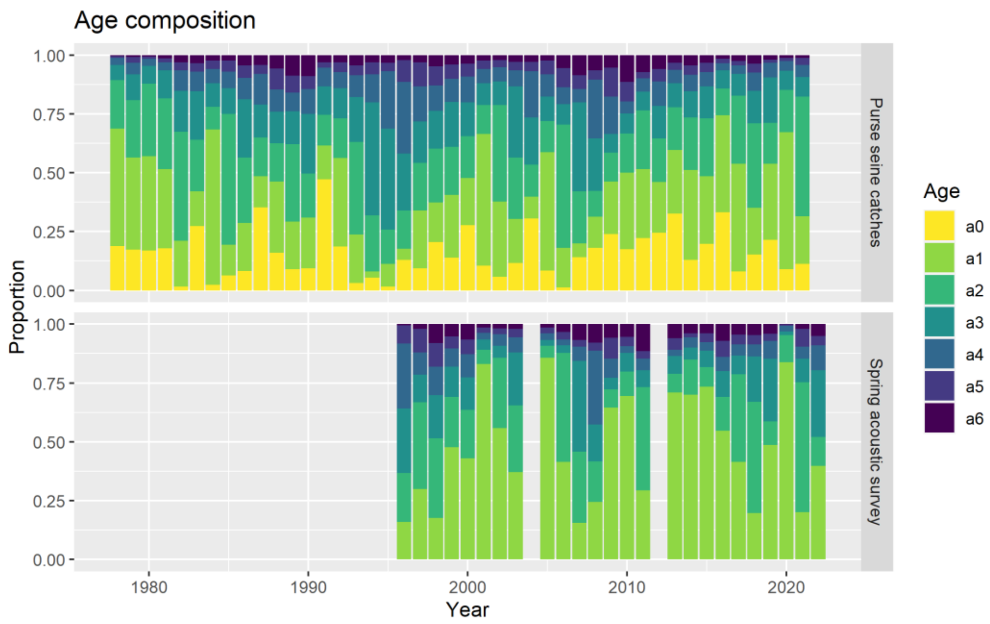


Figure 8.3.8.1. Sardine in 8c and 9a. Catches-at-age for 1978–2021 (top panel) and abundance-at-age in the joint Spanish-Portuguese spring acoustic survey 1996–2022 (bottom panel).

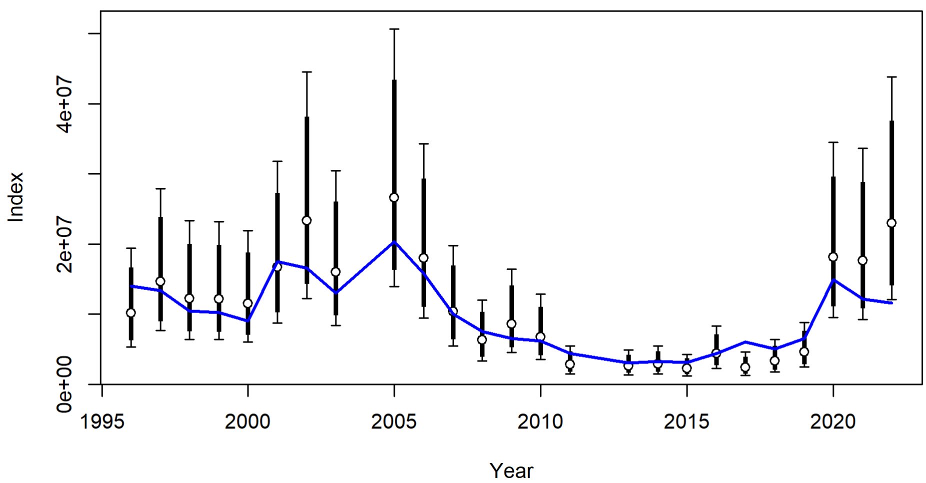


Figure 8.4.1.1. Sardine in 8c and 9a. Model fit to the acoustic survey series. The index is total abundance (in thousands of individuals). Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

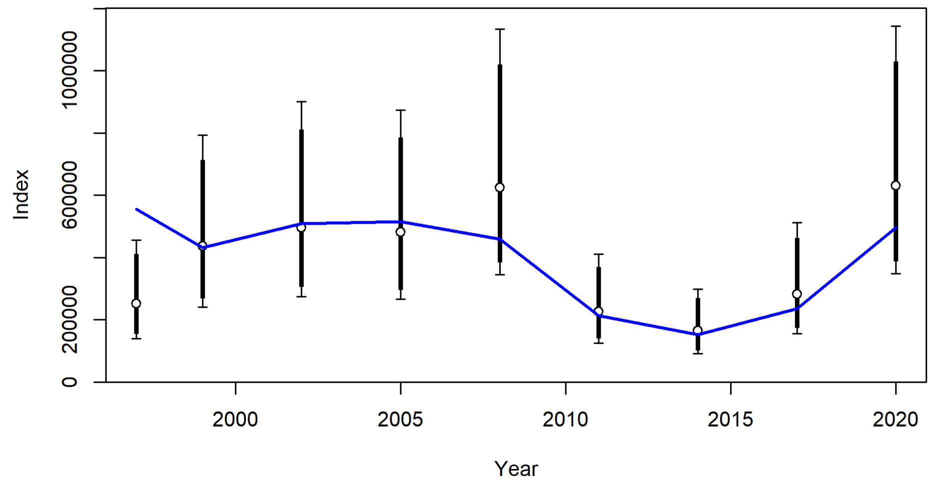


Figure 8.4.1.2. Sardine in 8c and 9a. Model fit to the DEPM survey series. The index is SSB (in thousand tonnes). Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

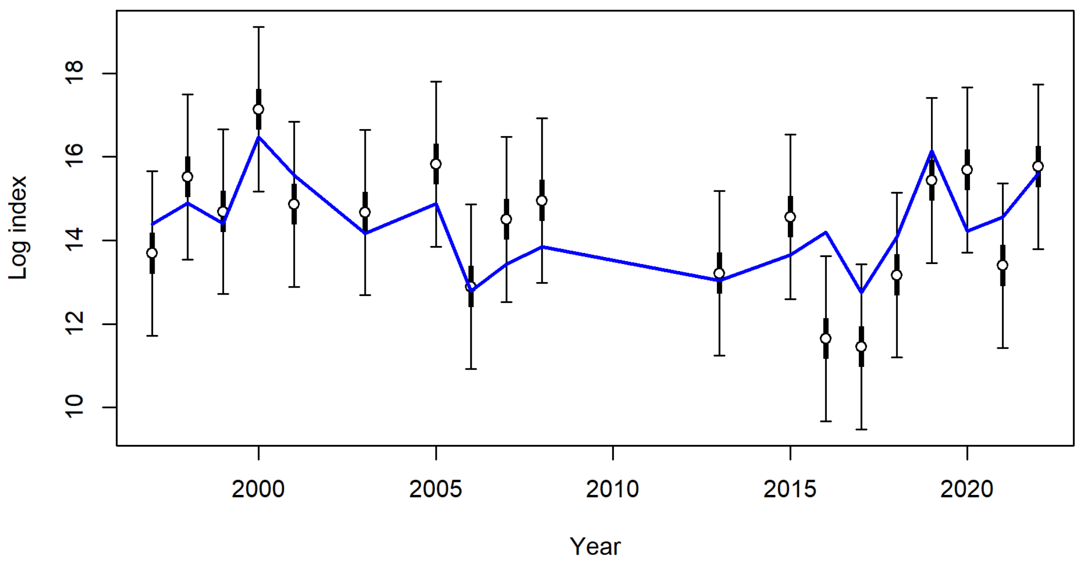
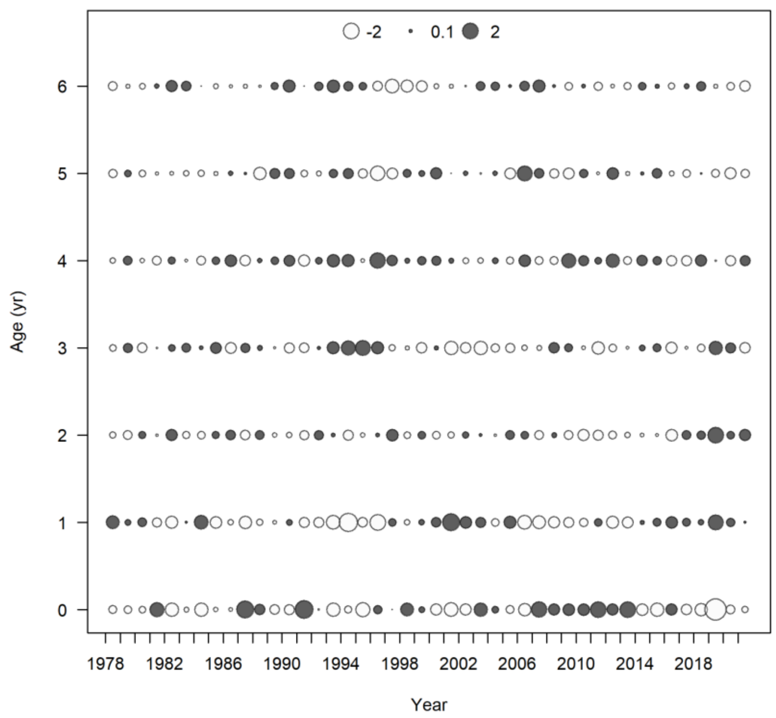


Figure 8.4.1.3. Sardine in 8c and 9a. Model fit to the log autumn acoustic survey series data on log scale. The index is age 0 abundance in subarea 9aCN (in thousand individuals). Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.



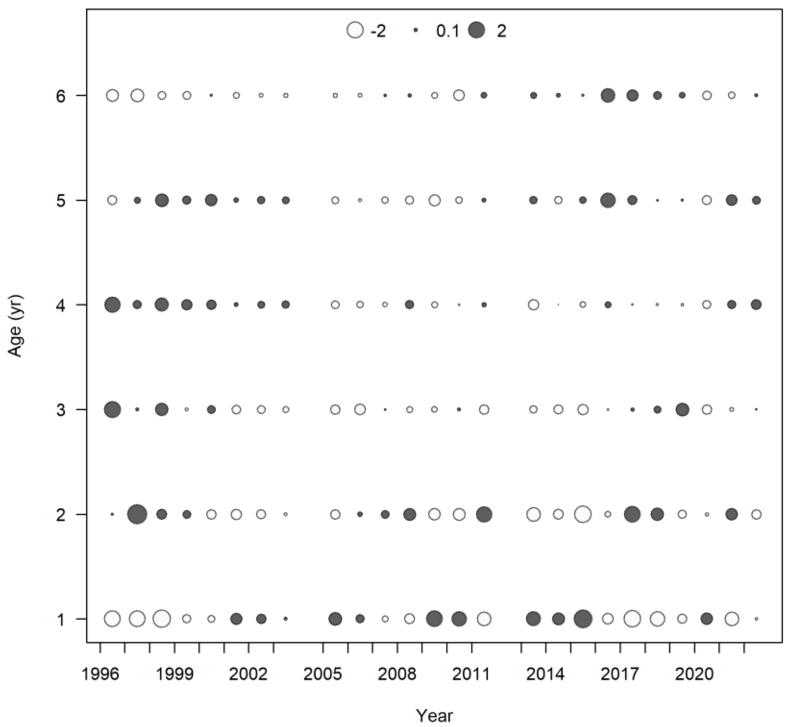


Figure 8.4.1.4. Sardine in 8c and 9a. Model residuals from the fit to the catch-at-age composition (top) and the acoustic survey age composition (bottom).

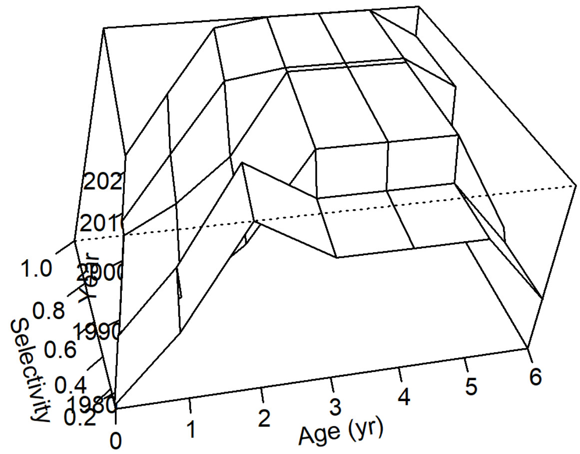


Figure 8.4.1.5. Sardine in 8c and 9a. Selectivity-at-age in the fishery showing the three blocks of fixed selectivity, 1978–1987, 1988–2005 and 2006–2022.

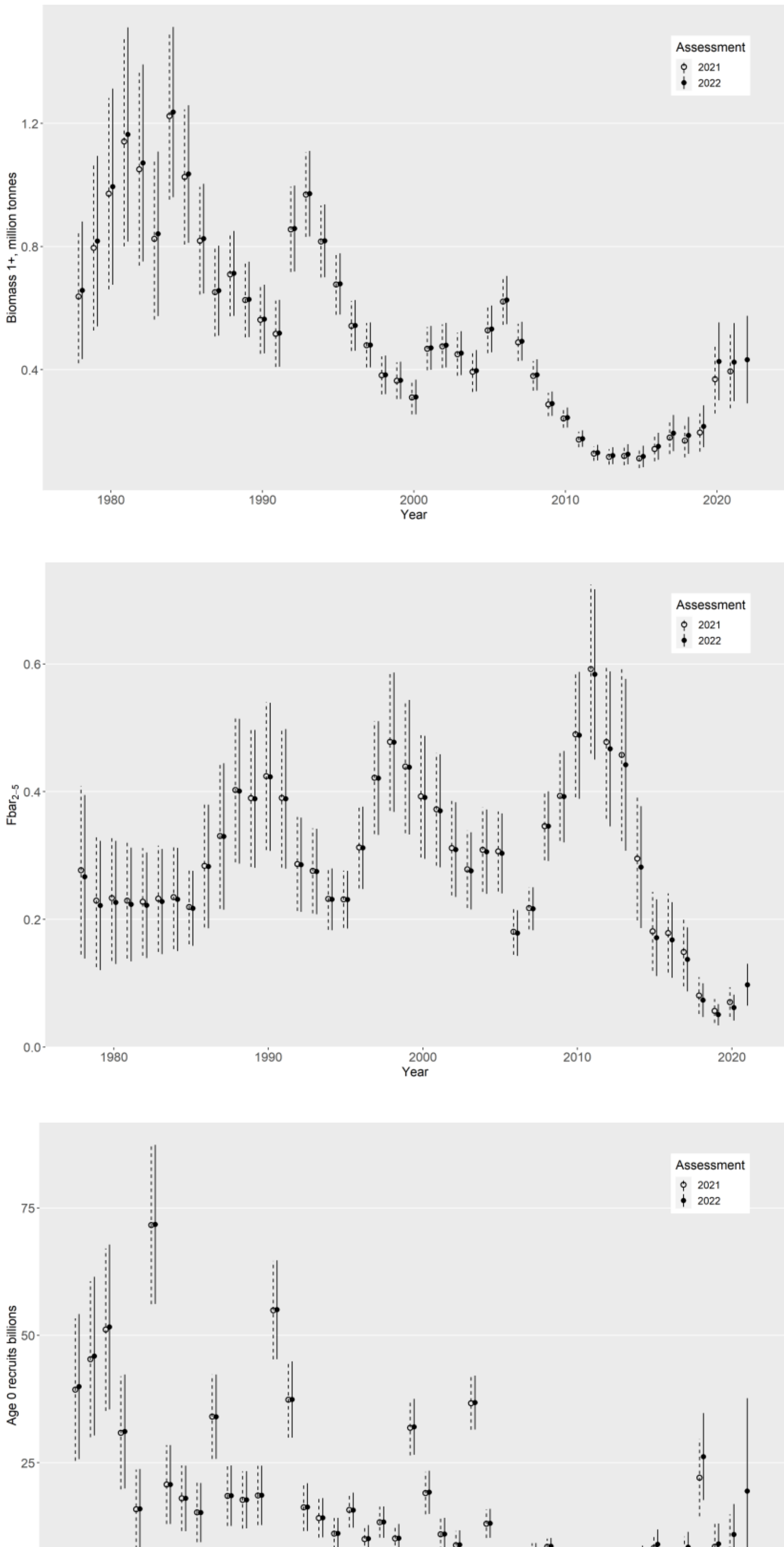


Figure 8.4.1.6. Sardine in 8c and 9a. Historical B1+ (top), $F_{bar(2–5)}$ (middle) and recruitment (bottom) trajectories in the period 1978–2022 (B1+ and recruitment is estimated up to 2022). The updated assessment of 2021 is shown for comparison (open dots and dashed lines).

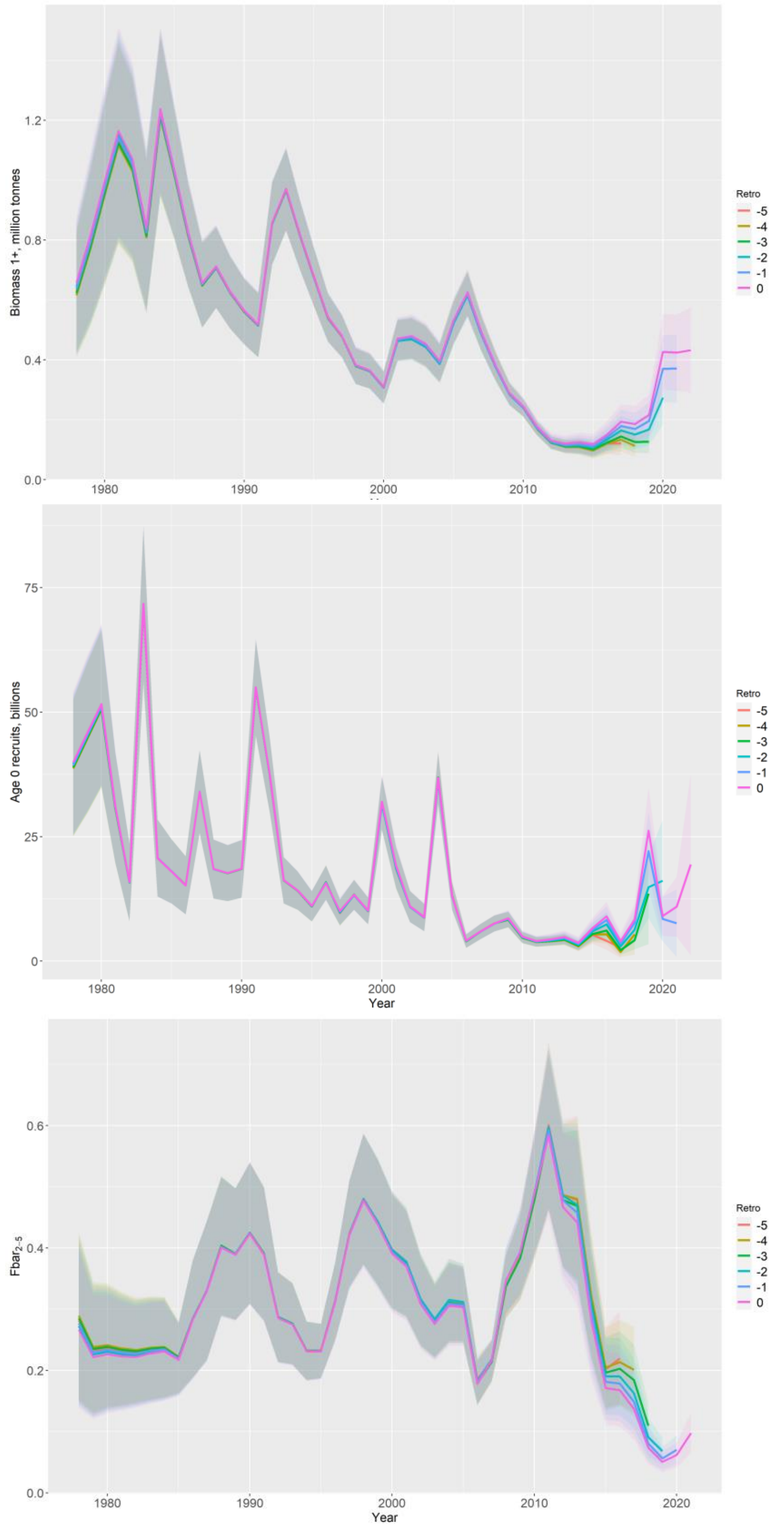


Figure 8.5.1. Sardine in 8c and 9a. Retrospective error for Biomass 1+ (top), recruitment (middle) and $F_{bar\ 2\text{-}5}$ (bottom) in the assessment.

Table 8.2.2.1. Sardine in 8c and 9a. Quarterly distribution of sardine landings (t) in 2021 by ICES Subdivision. Above absolute values; below, relative numbers.

Sub-Div	1st	2nd	3rd	4th	Total
8cE	35	506	389	221	**1152**
8cW	2.6	1306	2414	43	**3766**
9aN	5	1608	3229	268	**5109**
9aCN		2254	5491	5285	**13030**
9aCS		2296	4061	2412	**8768**
9aS-Algarve		1248	2448	1358	**5053**
9aS-Cadiz	27	598	2462	719	**3808**
Total	**70**	**9817**	**20493**	**10305**	**40685**

Sub-Div	1st	2nd	3rd	4th	Total
8cE	0.09	1.24	0.96	0.54	**2.83**
8cW	0.01	3.21	5.93	0.11	**9.26**
9aN	0.01	3.95	7.94	0.66	**12.56**
9aCN	0.00	5.54	13.50	12.99	**32.03**
9aCS	0.00	5.64	9.98	5.93	**21.55**
9aS-Algarve	0.00	3.07	6.02	3.34	**12.42**
9aS-Cadiz	0.07	1.47	6.05	1.77	**9.36**
Total	**0.17**	**24.13**	**50.37**	**25.33**	

Table 8.2.2.2. Sardine in 8c and 9a. Iberian Sardine Landings (tonnes) by subdivision for the period 1940-2021.

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	
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
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

Table 8.2.2.2 (cont.). Sardine in 8c and 9a. Iberian Sardine Landings (tonnes) by subdivision for the period 1940-2021.

Year	Subdivision					
	8c	9aNorth	9a Central North	9a Central South	9a South Algarve	9a South Cadiz
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
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

Table 8.2.4.1. Sardine in 8c and 9a. Sardine length composition (thousands), mean length (cm) and catch (t) by ICES subdivision in 2021.

	Subdivision							Total
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S (Ca)**	
6.5								
7								
7.5							6	6
8							27	27
8.5							20	20
9							29	29
9.5							47	47
10							144	144
10.5							589	589
11	7						577	584
11.5							897	897
12	34						1 431	1 466
12.5	55				245		2 998	3 299
13	128				403		5 860	6 391
13.5	246			205	1 706		10 364	12 522
14	447	211	3	473	3 145	153	14 019	18 450
14.5	287	351	10	3 646	2 226		18 440	24 961
15	237	702	28	4 671	2 264	268	13 451	21 620
15.5	215	1 334	61	8 947	3 618	2 022	14 149	30 347
16	553	941	75	18 564	6 560	5 194	7 638	39 525
16.5	906	726	374	16 354	3 929	10 050	8 519	40 858
17	1 569	716	2 383	41 723	7 418	11 964	5 473	71 245
17.5	1 721	2 143	7 164	64 132	11 240	11 293	3 089	100 781
18	2 626	3 974	13 348	48 924	13 356	11 963	1 630	95 821
18.5	2 688	9 288	16 022	24 050	9 904	12 219	1 261	75 431
19	2 684	12 648	11 196	17 236	13 257	10 858	1 640	69 520
19.5	2 233	11 569	8 026	8 621	17 340	6 268	548	54 606
20	1 502	6 797	5 610	3 674	14 558	3 429	588	36 158
20.5	871	3 244	3 486	969	11 079	1 306	211	21 166
21	611	1 639	2 985	151	5 073	739	49	11 246
21.5	269	924	2 560	244	3 219	326	13	7 554
22	302	538	2 495	126	2 672	13		6 146
22.5	84	180	1 665		1 964	13		3 905
23	107	275	686	21	1 404			2 493
23.5	11	29	128	21	586			775
24		2	30		240			272
24.5					125			125
25								
25.5								
26								
26.5								
Total	20 394	58 230	78 336	262 750	137 530	88 078	113 708	759 026
Mean L	18.6	19.2	NA	17.7	18.8	18.1	15.2	17.9
sd	1.83	1.36	NA	1.11	2.07	1.24	1.62	1.95
Catch	**1152**	**3766**	**5109**	**13031**	**8767**	**5052**	**3808**	**40685**

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 2021.

				First Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S (Ca)**	**Total**
7								
7.5								
8								
8.5								
9								
9.5								
10								
10.5								
11	7							7
11.5								
12	34							34
12.5	49							49
13	71							71
13.5	122							122
14	234							234
14.5	148						47	195
15	63						125	188
15.5	16						362	378
16	21	1					196	218
16.5	43		1				113	157
17	174	5	5				21	205
17.5	124		9				17	150
18	66	10	18					94
18.5	32		16				33	81
19	15	14	13					42
19.5	6		5					11
20	12	12	6					31
20.5	3		2					5
21	4	6	4					14
21.5			2					2
22		1	2					3
22.5			1					1
23								
23.5								
24								
24.5								
25								
25.5								
26								
26.5								
Total	1 245	50	82				914	2 291
Mean L	15.5	19.4	19.0				16.0	15.9
sd	1.99	1.31	1.24				0.79	1.78
Catch	**35**	**2. 637**	**5**				**27**	**4 597**

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 2021.

Second Quarter								
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
7								
7.5								
8								
8.5								
9								
9.5								
10								
10.5							5	5
11							10	10
11.5							379	379
12							859	859
12.5	7						2 349	2 356
13	16						4 745	4 761
13.5	44						5 940	5 984
14	63	211	3				5 277	5 553
14.5	59	351	10				2 828	3 249
15	62	702	28			240	1 702	2 734
15.5	56	1 334	61		42	1 468	1 336	4 297
16	125	894	75	130	600	2 622	132	4 577
16.5	219	605	233	4 118	956	3 487	242	9 861
17	351	229	1 359	14 238	4 922	3 606		24 706
17.5	525	796	3 540	19 386	6 863	4 318		35 427
18	1 197	2 140	6 378	9 186	4 358	3 945	8	27 211
18.5	1 339	4 545	6 552	2 081	2 450	2 979		19 947
19	1 298	3 898	3 991	337	2 832	1 513		13 869
19.5	1 038	4 256	1 933	41	2 875	744		10 886
20	868	2 193	1 288	20	3 848	578		8 795
20.5	509	1 019	865		2 916	307		5 616
21	369	276	963		2 195	246		4 047
21.5	182	264	816		1 240	129		2 632
22	256	228	638		668	13		1 803
22.5	78	33	265		511	13		901
23	107	99	42		206			453
23.5	11		23		66			100
24					21			21
24.5					21			21
25								
25.5								
26								
26.5								
Total	8 778	NA	NA	49 537	37 589	26 209	NA	201 061
Mean L	19.2	NA	NA	17.7	19.	17.7	NA	17.8
sd	1.63	NA	NA	0.51	1.60	1.24	NA	2.03
Catch	**506**	**1 306**	**1 608**	**2 254**	**2 296**	**1 248**	**598**	**9 817**

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 2021.

				Third Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
7								
7.5								
8							7	7
8.5							6	6
9							10	10
9.5							41	41
10							116	116
10.5							540	540
11							537	537
11.5							505	505
12							275	275
12.5					245		519	764
13					403		719	1 121
13.5				205	1 573		4 059	5 837
14				454	2 877	153	8 344	11 829
14.5				279	2 077		15 021	17 377
15	2			351	998	28	11 080	12 460
15.5	11			821	2 428	554	12 104	15 919
16	108	46		1 939	4 175	2 572	6 414	15 253
16.5	200	119	141	6 506	2 194	6 563	6 410	22 133
17	358	473	1 019	23 131	832	8 357	3 605	37 776
17.5	496	1 324	3 615	35 393	785	6 087	999	48 699
18	725	1 791	6 952	27 402	2 214	6 144	2	45 231
18.5	872	4 659	9 454	9 328	3 332	5 492	13	33 150
19	1 009	8 582	7 192	3 327	7 962	4 118	83	32 274
19.5	959	7 183	6 089	749	11 887	1 481		28 347
20	506	4 511	4 316	218	9 306	385		19 241
20.5	287	2 185	2 590	91	6 969	210		12 331
21	205	1 333	1 960		2 306			5 804
21.5	76	648	1 535		686			2 946
22	40	304	939	84	281			1 648
22.5		144	602		85			831
23		173	231		28			432
23.5		29	16					45
24		2	1		11			14
24.5								
25								
25.5								
26								
26.5								
Total	5 855	33 505	46 652	110 277	63 654	42 145	71 411	373 499
Mean L	19.0	19.6	19.4	17.8	18.6	17.8	15.2	17.8
sd	1.21	1.01	1.23	0.76	2.21	1.03	1.22	1.92
Catch	**389**	**2 414**	**3 229**	**5 491**	**4 061**	**2 448**	**2 462**	**20 493**

Table 8.2.4.1d. Sardine in 8c and 9a. Sardine length composition (thousands) by ICES subdivision in the fourth quarter 2021.

				Fourth Quarter				
Length	**8c E**	**8c W**	**9a N**	**9a CN**	**9a CS**	**9a S**	**9a S-C**	**Total**
6.5								
7								
7.5							6	6
8							20	20
8.5							14	14
9							19	19
9.5							6	6
10							28	28
10.5							44	44
11							30	30
11.5							12	12
12							297	297
12.5							130	130
13	40						397	437
13.5	80				134		365	579
14	150			19	267		398	834
14.5	80			3 367	149		544	4 140
15	110			4 319	1 266		543	6 238
15.5	132			8 125	1 148		347	9 753
16	300	1		16 496	1 785		895	19 476
16.5	443	2		5 730	778		1 754	8 707
17	686	9		4 354	1 664		1 847	8 558
17.5	576	24		9 353	3 593	888	2 073	16 506
18	639	32		12 336	6 784	1 874	1 620	23 285
18.5	444	84		12 640	4 122	3 748	1 215	22 253
19	362	154		13 573	2 463	5 227	1 557	23 336
19.5	230	129		7 832	2 579	4 043	548	15 362
20	117	81		3 436	1 404	2 466	588	8 091
20.5	73	39	30	878	1 194	789	211	3 214
21	33	24	59	151	572	493	49	1 380
21.5	10	12	207	244	1 293	197	13	1 974
22	6	5	915	42	1 723			2 692
22.5	6	3	797		1 368			2 173
23		3	413	21	1 170			1 607
23.5		1	89	21	520			630
24			30		208			238
24.5					104			104
25								
25.5								
26								
26.5								
Total	4 516	602	2 539	102 936	36 286	19 724	15 570	182 174
Mean L	17.6	19.6	22.6	17.7	19.	19.4	17.2	18.2
sd	1.61	1.01	.58	1.55	2.19	.81	2.04	1.89
Catch	**221**	**43**	**268**	**5 285**	**2 412**	**1 358**	**719**	**10 305**

Table 8.2.4.2. Sardine in 8c and 9a. Catch in numbers (thousands) at age by quarter and by subdivision in 2021.

							First Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-C**	**Total**
0								
1	836		1				384	1 221
2	345	2	68				415	831
3	52	35	7				76	170
4	10	6	3				36	56
5	1	3	3				3	10
6		3						3
7								
8								
9								
10								
11								
12								
Total	1 245	50	83				914	2 291
Catch (Tons)	35	3	5				27	70

							Second Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-C**	**Total**
0								
1	761	4 137	282	7	7 946	4 751	23 219	41 104
2	5 785	16 607	24 202	46 440	11 812	8 819	2 163	115 828
3	1 136	1 899	2 395	3 090	3 897	8 902	268	21 587
4	886	817	976		2 393	2 546	156	7 774
5	134	553	1 083		9 153	967	6	11 896
6	38	59	124		1 362	224		1 807
7	38	2			924			964
8					73			73
9					28			28
10								
11								
12								
Total	8 778	24 073	29 062		37 589	26 209	25 813	201 061
Catch (Tons)	506	1 306	1 608	2 254	2 296	1 248	598	4 928

							Third Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-C**	**Total**
0	516	1 369	560	4 128	8 288	7 245	42 939	65 045
1	1 135	5 283	5 545	27 127	8 659	17 424	23 327	88 501
2	2 351	22 999	34 783	77 570	14 476	10 573	4 703	167 455
3	940	2 468	2 348	1 436	8 755	5 215	441	21 603
4	648	1 108	2 266		18 678	1 688	2	24 390
5	164	208	894		3 808			5 074
6	101	71	140		727			1 039
7					197			197
8					64			64
9								
10								
11								
12								
Total	5 855	33 505	46 536	110 261	63 654	42 145	71 411	373 368
Catch (Tons)	389	2 414	3 229	5 491	4 061	2 448	2 462	20 493

							Fourth Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-C**	**Total**
0	1 364	25		9 921	5 042	3 140	3 414	22 906
1	1 297	95	3	9 338	3 275	2 661	5 839	22 508
2	1 191	414	74	76 959	16 983	9 271	4 519	109 409
3	413	44	601	5 255	2 168	2 547	1 443	12 471
4	189	20	986	851	1 969	1 760	312	6 086
5	44	4	651	467	3 097	345	43	4 652
6	19	1	12	124	1 751			1 906
7			23		2 002			2 025
8				21				21
9								
10								
11								
12								
Total	4 516	602	2 348	102 936	36 286	106 462	15 570	181 983
Catch (Tons)	221	43	268	5 285	2 412	1 358	719	10 305

							Whole Year	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-C**	**Total**
0	1 880	1 394	560	14 049	13 330	10 384	46 353	87 950
1	4 029	9 515	5 830	36 473	19 880	24 837	52 769	153 333
2	9 672	40 022	59 127	200 969	43 272	28 663	11 801	393 524
3	2 541	4 445	5 351	9 781	14 821	16 664	2 227	55 831
4	1 734	1 951	4 231	851	23 040	5 994	506	38 306
5	343	768	2 631	467	16 058	1 312	52	21 632
6	158	133	276	124	3 840	224		4 755
7	38	2	23		3 123			3 186
8				21	137			159
9					28			28
10								
11								
12								
Total	20 394	58 230	78 030	262 734	137 530	88 078	113 708	758 704
Catch (Tons)	1 152	3 766	5 109	13 030	8 768	5 053	3 808	40 685

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

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	9%	2%	1%	5%	10%	12%	41%	12%
1	20%	16%	7%	14%	14%	28%	46%	20%
2	47%	69%	76%	76%	31%	33%	10%	52%
3	12%	8%	7%	4%	11%	19%	2%	7%
4	9%	3%	5%	0%	17%	7%	0%	5%
5	2%	1%	3%	0%	12%	1%	0%	3%
6+	1%	0%	0%	0%	5%	0%	0%	1%
	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	2%	2%	1%	16%	15%	12%	53%	100%
1	3%	6%	4%	24%	13%	16%	34%	100%
2	2%	10%	15%	51%	11%	7%	3%	100%
3	5%	8%	10%	18%	27%	30%	4%	100%
4	5%	5%	11%	2%	60%	16%	1%	100%
5	2%	4%	12%	2%	74%	6%	0%	100%
6+	2%	2%	4%	2%	88%	3%	0%	100%

Table 8.2.5.1. Sardine 8c and 9a. Sardine Mean length (cm) at age by quarter and by subdivision in 2021.

						First Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0							
1	14.4	17.3	16.9				15.9
2	17.9	19.0	18.7				16.1
3	17.9	20.1	19.7				16.5
4	19.5	21.2	21.4				16.2
5	20.3	21.3	21.7				16.8
6		21.3	22.2				
7		22.8					
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	16.1	15.9	17.0	16.3	17.7	16.3	13.8
2	19.0	19.1	18.7	17.7	17.9	17.3	15.4
3	20.0	20.0	19.6	17.7	19.4	18.3	15.5
4	20.7	20.9	21.5		20.3	19.2	15.5
5	21.6	21.5	21.8		20.5	19.7	16.8
6	23.0	22.2	22.2		21.6	20.9	
7	22.6	22.8			22.5		
8					23.0		
9					22.8		
10							
11							
12							

						Third Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0	17.5	17.8	18.3	15.7	14.4	16.4	14.7
1	18.0	19.2	18.7	17.6	16.6	17.6	16.0
2	19.2	19.5	19.1	17.9	18.8	18.3	16.6
3	19.4	20.4	20.8	19.3	19.8	18.9	17.3
4	20.2	21.4	21.7		20.2	19.4	19.2
5	20.5	22.2	22.1		20.5		21.3
6	21.5	22.5	21.3		21.3		
7			23.3		22.1		
8					22.0		
9							
10							
11							
12							

						Fourth Quarter	
Age	**8c-E**	**8c-W**	**9a-N**	**9a-CN**	**9a-CS**	**9a-S**	**9a-S-C**
0	16.1	17.8		15.2	15.7	18.4	14.4
1	17.6	19.2	20.8	16.3	18.0	19.0	17.4
2	18.5	19.5	21.3	18.1	18.5	19.4	18.3
3	18.9	20.4	22.5	18.8	20.1	20.1	19.0
4	19.7	21.3	22.6	19.1	20.8	20.1	20.0
5	20.3	22.2	22.5	20.0	21.4	20.5	21.0
6	21.7	22.5	23.2	22.2	22.5		
7			23.3		23.6		
8				23.8			
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 2021.

						First Quarter	
Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-S-C
0							
1	0.022	0.038	0.036				0.029
2	0.041	0.050	0.048				0.030
3	0.042	0.059	0.056				0.033
4	0.054	0.069	0.071				0.031
5	0.061	0.070	0.074				0.034
6		0.069	0.079				
7		0.085					
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	0.035	0.033	0.041	0.036	0.049	0.037	0.022
2	0.056	0.056	0.053	0.045	0.051	0.044	0.030
3	0.065	0.064	0.062	0.046	0.063	0.051	0.031
4	0.072	0.073	0.079		0.071	0.059	0.031
5	0.081	0.078	0.082		0.074	0.064	0.039
6	0.095	0.087	0.086		0.085	0.075	
7	0.090	0.092			0.094		
8					0.100		
9					0.097		
10							
11							
12							

						Third Quarter	
Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-S-C
0	0.051	0.054	0.059	0.035	0.032	0.046	0.031
1	0.056	0.068	0.063	0.048	0.047	0.056	0.039
2	0.068	0.072	0.067	0.051	0.064	0.062	0.044
3	0.070	0.082	0.087	0.063	0.073	0.067	0.049
4	0.079	0.093	0.098		0.077	0.073	0.068
5	0.083	0.105	0.103		0.080		0.092
6	0.095	0.109	0.092		0.088		
7			0.120		0.097		
8					0.095		
9							
10							
11							
12							

						Fourth Quarter	
Age	8c-E	8c-W	9a-N	9a-CN	9a-CS	9a-S	9a-S-C
0	0.036	0.049		0.0	0.0	0.1	0.026
1	0.047	0.063	0.080	0.041	0.055	0.065	0.046
2	0.057	0.067	0.088	0.054	0.059	0.069	0.055
3	0.060	0.077	0.105	0.059	0.076	0.076	0.061
4	0.068	0.088	0.105	0.062	0.084	0.076	0.072
5	0.076	0.101	0.104	0.069	0.091	0.080	0.083
6	0.093	0.104	0.116	0.091	0.105		
7			0.116		0.120		
8				0.1			
9							
10							
11							
12							

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 PELAGO2022. Mean Weight in grams and Mean Length in cm.

AREA 9aCN

AGE	1	2	3	4	5	6	7	8	9	TOTAL
Biomass (ton)	60019	23262	140319	23661	6349	10494	1841			265946
%Biomass	23	9	53	9	2	4	1			100
Abundance (10^3)	2046865	537287	2678367	377904	88489	128522	21128			5878562
%Abundance	35	9	46	6	2	2	0			100
Mean Weight (gr)	28.2	38.6	48.9	61.6	66.5	75.9	83.3			
Mean Length (cm)	15.8	17.5	18.8	20.2	20.7	21.6	22.2			

AREA 9aCS

AGE	1	2	3	4	5	6	7	8	9	TOTAL
Biomass (ton)	184806	19417	34709	64752	26242	47192	4324	631	116	382190
%Biomass	48	5	9	17	7	12	1	0	0	100
Abundance (10^3)	5826360	432151	684641	1073836	422125	676634	54716	6954	1241	9178657
%Abundance	63	5	7	12	5	7	1	0	0	100
Mean Weight (gr)	30.0	42.9	48.2	57.8	59.6	67.0	76.2	87.7	90.5	
Mean Length (cm)	16.0	18.0	18.7	19.9	20.1	20.9	21.7	22.8	23.0	

AREA 9aS-ALG

AGE	1	2	3	4	5	6	7	8	9	TOTAL
Biomass (ton)	1418	17650	7889	24291	11483	9352	2090	54		74226
%Biomass	2	24	11	33	15	13	3	0		100
Abundance (10^3)	40834	385762	161594	452181	202135	148867	33431	740		1425543
%Abundance	3	27	11	32	14	10	2	0		100
Mean Weight (gr)	33.2	43.8	46.8	51.6	54.6	60.5	60.1	71.0		
Mean Length (cm)	16.5	18.1	18.6	19.2	19.6	20.3	20.3	21.5		

AREA 9aS-CAD

AGE	1	2	3	4	5	6	7	8	9	TOTAL
Biomass (ton)	32714	38355	5409	7736	1823	210				86247
%Biomass	38	44	6	9	2	0				100
Abundance (10^3)	1136297	979141	117163	154762	33042	4216				2424621
%Abundance	47	40	5	6	1	0				100
Mean Weight (gr)	27.2	37.5	44.4	48.0	53.1	48.0				
Mean Length (cm)	15.6	17.4	18.5	19.0	19.7	19.0				

TOTAL PELAGO22

AGE	1	2	3	4	5	6	7	8	9	TOTAL
Biomass (ton)	278957	98683	188325	120440	45898	67249	8256	685	116	808609
%Biomass	34	12	23	15	6	8	1	0	0	100
Abundance (10^3)	9050357	2334341	3641764	2058682	745791	958239	109275	7694	1241	18907384
%Abundance	48	12	19	11	4	5	1	0	0	100
Mean Weight (gr)	30.8	42.3	51.7	58.5	61.5	70.2	75.6	89.1	93.6	
Mean Length (cm)	15.9	17.7	18.8	19.7	20.0	20.9	21.4	22.6	23.0	

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 PELACUS0422. Mean Weight in grams and Mean Length in cm.

AREA 8cE

AGE	1	2	3	4	5	6	7	TOTAL
Biomass (ton)	1311	7303	24612	3360	1462	598	123	38768
%Biomass	3	19	63	9	4	2	0	100
Abundance (10^3)	29120	147364	416747	50371	18015	7103	1384	670104
% Abundance	4	22	62	8	3	1	0	100
Mean Weight (gr)	42.8	47.4	56.6	63.8	78.0	81.2	85.4	55.1
Mean Lenght (cm)	17.5	18.2	19.3	20.1	21.5	21.8	22.2	19.1

AREA 8cW

AGE	1	2	3	4	5	6	7	TOTAL
Biomass (ton)	608	4965	57657	9941	4748	1325	176	79420
%Biomass	1	6	73	13	6	2	0	100
Abundance (10^3)	11076	89619	921339	145869	58901	15491	1971	1244266
% Abundance	1	7	74	12	5	1	0	100
Mean Weight (gr)	52.6	53.2	60.1	65.4	77.4	82.3	86.3	60.2
Mean Lenght (cm)	18.8	18.9	19.7	20.3	21.5	21.9	22.3	19.8

AREA 9aN

AGE	1	2	3	4	5	6	7	TOTAL
Biomass (ton)	1651	13596	93716	14381	7441	2924	546	134254
%Biomass	1	10	70	11	6	2	0	100
Abundance (10^3)	31736	257263	1534383	214201	90395	33339	5906	2167224
% Abundance	1	12	71	10	4	2	0	100
Mean Weight (gr)	51.7	52.7	60.8	66.7	81.7	87.3	92.2	61.5
Mean Lenght (cm)	19	19	20	20	22	22	22.77	19.84

TOTAL PELACUS22

AGE	1	2	3	4	5	6	7	TOTAL
Biomass (ton)	3569	25864	175984	27681	13651	4847	845	252442
%Biomass	1	10	70	11	5	2	0	100
Abundance (10^3)	71933	494246	2872468	410440	167312	55933	9261	4081593
% Abundance	2	12	70	10	4	1	0	100
Mean Weight (gr)	47.3	50.1	58.8	64.7	78.4	83.4	88.1	59.3
Mean Lenght (cm)	18.1	18.5	19.5	20.2	21.5	22.0	22.4	19.6

Table 8.3.5.1a. 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

Table 8.3.5.1b. 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
2020	0	0.027	0.042	0.050	0.058	0.068	0.078
2021	0	0.027	0.042	0.050	0.058	0.068	0.078

Table 8.4.1.1. Sardine in 8c and 9a. Parameters and asymptotic standard deviations estimated in the 2022 assessment model.

Label	Value	Parm_StDev	Phase	Min	Max	Init
SR_LN(R0)	16.844	0.038	1	1	20	16.00
Early_InitAge_4	0.063	0.537	2	-5	5	0.00
Early_InitAge_3	0.139	0.443	2	-5	5	0.00
Early_InitAge_2	0.355	0.289	2	-5	5	0.00
Early_InitAge_1	0.799	0.198	2	-5	5	0.00
Main_RecrDev_1978	0.965	0.164	2	-5	5	0.00
Main_RecrDev_1979	1.076	0.158	2	-5	5	0.00
Main_RecrDev_1980	1.173	0.148	2	-5	5	0.00
Main_RecrDev_1981	0.652	0.174	2	-5	5	0.00
Main_RecrDev_1982	-0.013	0.240	2	-5	5	0.00
Main_RecrDev_1983	1.515	0.112	2	-5	5	0.00
Main_RecrDev_1984	0.241	0.187	2	-5	5	0.00
Main_RecrDev_1985	0.111	0.180	2	-5	5	0.00
Main_RecrDev_1986	-0.035	0.192	2	-5	5	0.00
Main_RecrDev_1987	0.798	0.127	2	-5	5	0.00
Main_RecrDev_1988	0.184	0.160	2	-5	5	0.00
Main_RecrDev_1989	0.154	0.158	2	-5	5	0.00
Main_RecrDev_1990	0.217	0.155	2	-5	5	0.00
Main_RecrDev_1991	1.318	0.090	2	-5	5	0.00
Main_RecrDev_1992	0.868	0.101	2	-5	5	0.00
Main_RecrDev_1993	0.020	0.143	2	-5	5	0.00
Main_RecrDev_1994	-0.105	0.137	2	-5	5	0.00
Main_RecrDev_1995	-0.326	0.138	2	-5	5	0.00
Main_RecrDev_1996	0.050	0.112	2	-5	5	0.00
Main_RecrDev_1997	-0.369	0.132	2	-5	5	0.00
Main_RecrDev_1998	-0.045	0.116	2	-5	5	0.00
Main_RecrDev_1999	-0.310	0.135	2	-5	5	0.00
Main_RecrDev_2000	0.881	0.089	2	-5	5	0.00
Main_RecrDev_2001	0.300	0.110	2	-5	5	0.00
Main_RecrDev_2002	-0.264	0.144	2	-5	5	0.00
Main_RecrDev_2003	-0.481	0.161	2	-5	5	0.00
Main_RecrDev_2004	0.968	0.079	2	-5	5	0.00
Main_RecrDev_2005	-0.092	0.112	2	-5	5	0.00
Main_RecrDev_2006	-1.302	0.173	2	-5	5	0.00
Main_RecrDev_2007	-0.910	0.135	2	-5	5	0.00
Main_RecrDev_2008	-0.619	0.115	2	-5	5	0.00
Main_RecrDev_2009	-0.426	0.102	2	-5	5	0.00
Main_RecrDev_2010	-0.937	0.124	2	-5	5	0.00
Main_RecrDev_2011	-1.036	0.130	2	-5	5	0.00
Main_RecrDev_2012	-0.834	0.118	2	-5	5	0.00
Main_RecrDev_2013	-0.695	0.114	2	-5	5	0.00
Main_RecrDev_2014	-0.991	0.136	2	-5	5	0.00

Label	Value	Parm_StDev	Phase	Min	Max	Init
Main_RecrDev_2015	-0.370	0.116	2	-5	5	0.00
Main_RecrDev_2016	-0.180	0.122	2	-5	5	0.00
Main_RecrDev_2017	-1.071	0.165	2	-5	5	0.00
Main_RecrDev_2018	-0.321	0.144	2	-5	5	0.00
Main_RecrDev_2019	0.775	0.130	2	-5	5	0.00
Main_RecrDev_2020	-0.454	0.200	2	-5	5	0.00
Main_RecrDev_2021	-0.292	0.252	2	-5	5	0.00
Main_RecrDev_2022	0.216	0.455	2	-5	5	0.00
InitF_seas_1_flt_1purse_seine	0.395	0.057	1	-1	2	0.30
LnQ_base_Acoustic_survey(2)	0.293	0.096	1	-3	3	0.75
Q_extraSD_Acoustic_survey(2)	0.079	0.056	1	0	1	0.30
LnQ_base_DEPM_survey(3)	0.199	0.122	1	-3	3	0.26
Q_extraSD_DEPM_survey(3)	0.054	0.079	1	0	1	0.30
LnQ_base_Rec_survey(4)	-13.274	6.818	1	-30	3	0.00
Q_power_Rec_survey(4)	0.800	0.445	1	0	3	1.00
Q_extraSD_Rec_survey(4)	0.758	0.180	1	0	3	1.00
AgeSel_P2_purse_seine(1)	1.636	0.153	2	-3	3	0.90
AgeSel_P3_purse_seine(1)	0.738	0.137	2	-4	4	0.40
AgeSel_P4_purse_seine(1)	-0.254	0.169	2	-4	4	0.10
AgeSel_P7_purse_seine(1)	-0.694	0.437	2	-4	4	-0.50
AgeSel_P2_purse_seine(1)_BLK1delta_1988	-0.328	0.183	2	-4	4	0.90
AgeSel_P2_purse_seine(1)_BLK1delta_2006	0.093	0.138	2	-4	4	0.90
AgeSel_P3_purse_seine(1)_BLK1delta_1988	-0.002	0.167	2	-4	4	0.40
AgeSel_P3_purse_seine(1)_BLK1delta_2006	-0.187	0.133	2	-4	4	0.40
AgeSel_P4_purse_seine(1)_BLK1delta_1988	0.896	0.191	2	-4	4	0.10
AgeSel_P4_purse_seine(1)_BLK1delta_2006	-0.596	0.136	2	-4	4	0.10
AgeSel_P7_purse_seine(1)_BLK1delta_1988	-0.114	0.469	2	-4	4	-0.50
AgeSel_P7_purse_seine(1)_BLK1delta_2006	0.593	0.369	2	-4	4	-0.50

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	0.267	0.030	0.153	0.320	0.249	0.249	0.249	0.124
1979	0.222	0.025	0.127	0.266	0.207	0.207	0.207	0.103
1980	0.227	0.025	0.130	0.272	0.211	0.211	0.211	0.106
1981	0.223	0.025	0.128	0.268	0.208	0.208	0.208	0.104
1982	0.222	0.025	0.128	0.267	0.207	0.207	0.207	0.103
1983	0.228	0.025	0.131	0.274	0.212	0.212	0.212	0.106
1984	0.231	0.026	0.133	0.278	0.216	0.216	0.216	0.108
1985	0.217	0.024	0.125	0.261	0.202	0.202	0.202	0.101
1986	0.283	0.032	0.162	0.340	0.264	0.264	0.264	0.132
1987	0.330	0.037	0.189	0.396	0.307	0.307	0.307	0.154
1988	0.401	0.031	0.114	0.239	0.455	0.455	0.455	0.202
1989	0.389	0.030	0.111	0.232	0.441	0.441	0.441	0.196
1990	0.423	0.033	0.121	0.252	0.480	0.480	0.480	0.214
1991	0.389	0.030	0.111	0.232	0.441	0.441	0.441	0.196
1992	0.286	0.022	0.082	0.170	0.324	0.324	0.324	0.144
1993	0.275	0.021	0.079	0.164	0.312	0.312	0.312	0.139
1994	0.231	0.018	0.066	0.138	0.262	0.262	0.262	0.117
1995	0.231	0.018	0.066	0.138	0.262	0.262	0.262	0.117
1996	0.312	0.024	0.089	0.186	0.354	0.354	0.354	0.158
1997	0.421	0.033	0.120	0.251	0.478	0.478	0.478	0.213
1998	0.477	0.037	0.136	0.285	0.542	0.542	0.542	0.241
1999	0.438	0.034	0.125	0.261	0.497	0.497	0.497	0.222
2000	0.391	0.030	0.112	0.233	0.444	0.444	0.444	0.198
2001	0.370	0.029	0.106	0.221	0.420	0.420	0.420	0.187
2002	0.309	0.024	0.088	0.184	0.351	0.351	0.351	0.156
2003	0.276	0.021	0.079	0.165	0.313	0.313	0.313	0.139
2004	0.306	0.024	0.087	0.182	0.347	0.347	0.347	0.155
2005	0.303	0.023	0.087	0.181	0.344	0.344	0.344	0.153
2006	0.178	0.024	0.099	0.172	0.180	0.180	0.180	0.145
2007	0.217	0.030	0.121	0.209	0.219	0.219	0.219	0.177
2008	0.346	0.047	0.193	0.334	0.350	0.350	0.350	0.282
2009	0.392	0.054	0.218	0.379	0.397	0.397	0.397	0.320
2010	0.488	0.067	0.272	0.471	0.494	0.494	0.494	0.398
2011	0.584	0.080	0.325	0.563	0.590	0.590	0.590	0.476
2012	0.467	0.064	0.260	0.451	0.472	0.472	0.472	0.381
2013	0.442	0.061	0.246	0.427	0.447	0.447	0.447	0.360
2014	0.282	0.039	0.157	0.272	0.285	0.285	0.285	0.230
2015	0.171	0.024	0.095	0.165	0.173	0.173	0.173	0.140
2016	0.168	0.023	0.093	0.162	0.170	0.170	0.170	0.137
2017	0.137	0.019	0.076	0.133	0.139	0.139	0.139	0.112
2018	0.073	0.010	0.041	0.071	0.074	0.074	0.074	0.060
2019	0.051	0.007	0.028	0.049	0.051	0.051	0.051	0.041
2020	0.062	0.008	0.034	0.060	0.063	0.063	0.063	0.050
2021	0.098	0.013	0.054	0.094	0.099	0.099	0.099	0.080

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. Estimates of survivors in 2022 are also shown.

Year	Age						
	0	1	2	3	4	5	6+
1978	39924000	12539500	3708790	1309170	621151	315363	407647
1979	45898500	14313600	5822900	1666300	677221	334428	429344
1980	51643000	16578700	6829040	2769230	901317	381264	468276
1981	31102600	18689100	7890830	3231430	1492000	505427	518635
1982	15918800	11291600	8916270	3752380	1747800	839915	623320
1983	71747800	5795500	5392980	4249810	2033240	985701	882574
1984	20690500	26208400	2760320	2555550	2292270	1141450	1129750
1985	17986700	7568330	12465400	1304220	1375270	1283930	1375570
1986	15194700	6598260	3631020	5997970	711970	781397	1632220
1987	34003400	5535800	3052150	1618140	3082930	380884	1451130
1988	18512600	12313200	2493580	1286340	796063	1578580	1090640
1989	17706100	6725340	5965090	1226150	546117	351762	1348480
1990	18572000	6437420	3269930	2955520	528142	244829	960666
1991	55007800	6731770	3099410	1587290	1224320	227710	667528
1992	37396700	19998500	3272810	1535430	683495	548711	499732
1993	16273400	13706500	10013700	1724380	743481	344467	592479
1994	14164000	5969030	6884140	5309840	845198	379286	550829
1995	11099400	5212760	3035870	3747490	2736040	453286	560502
1996	15666800	4077980	2651530	1653020	1931870	1468020	607006
1997	10064600	5755660	2026780	1375470	777050	945196	1100780
1998	13343000	3633020	2772950	985176	571253	335891	1056150
1999	10160500	4819140	1722510	1303510	383896	231686	737404
2000	32028000	3677330	2310300	828661	530810	162709	526408
2001	19178800	11591200	1786530	1142780	355797	237212	385831
2002	10999600	6938160	5664090	894493	502146	162721	340954
2003	8854750	4009850	3449590	2940500	421104	246045	291485
2004	36781900	3224420	2012550	1826500	1437260	214228	309868

Year	Age						
	0	1	2	3	4	5	6+
2005	13091800	13429800	1604300	1046370	862318	706246	298293
2006	4108130	4772860	6686980	835430	495494	425001	536625
2007	5917160	1492780	2343640	3522800	466016	287674	582366
2008	7554220	2145010	717994	1192280	1892650	260589	512617
2009	8587540	2696910	960005	323448	562077	928667	404829
2010	4929990	3018140	1175380	413510	145308	262816	647534
2011	4022290	1698870	1246100	462089	168396	61590	419872
2012	4372840	1364790	662354	444731	169596	64327	206142
2013	4847640	1492380	567324	263404	183358	72776	126763
2014	3684980	1642910	627431	229967	110854	80316	94079
2015	6671120	1258840	756528	296569	114163	57277	94791
2016	8974360	2306490	617902	398298	165318	66236	92378
2017	4020510	3021750	1133870	326153	222641	96181	96373
2018	8386620	1309080	1510450	615575	187911	133508	119757
2019	26171500	2842840	679865	874699	380144	120779	167760
2020	9054920	8209850	1496550	402820	553614	250420	196359
2021	10905000	3158530	4288170	875050	251351	359542	298400
2022	19424400	4038350	1734130	2912930	588645	182988	479151

Table 8.4.1.4. Sardine in 8c and 9a. Summary table of the WGHANSA 2022 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 2022 are an assumption based on the Member States agreement.

Year	Biomass 1+	SSB	CV SSB	Recruits	CV Recruits	F (2-5)	F Apical	CV F Apical	Landings
1978	657632	602823	0.170	39924000	0.178	0.266	0.320	0.200	145609
1979	817320	753199	0.169	45898500	0.169	0.221	0.266	0.190	157241
1980	994416	920241	0.160	51643000	0.157	0.226	0.272	0.177	194802
1981	1163880	1080280	0.149	31102600	0.180	0.223	0.268	0.166	216517
1982	1071120	1016550	0.149	15918800	0.246	0.222	0.267	0.155	206946
1983	841018	812261	0.159	71747800	0.109	0.228	0.274	0.151	183837
1984	1236710	1128930	0.112	20690500	0.187	0.232	0.278	0.146	206005

Year	Biomass 1+	SSB	CV SSB	Recruits	CV Recruits	F (2-5)	F Apical	CV F Apical	Landings
1985	1035250	992492	0.108	17986700	0.179	0.218	0.261	0.112	208439
1986	825534	795550	0.108	15194700	0.192	0.283	0.340	0.142	187363
1987	656435	631291	0.111	34003400	0.122	0.329	0.396	0.145	177696
1988	712528	660845	0.097	18512600	0.160	0.401	0.455	0.125	161531
1989	628315	595410	0.097	17706100	0.159	0.389	0.441	0.122	140961
1990	564253	535183	0.099	18572000	0.157	0.423	0.480	0.121	149429
1991	518225	488135	0.105	55007800	0.088	0.389	0.441	0.124	132587
1992	858187	774769	0.082	37396700	0.100	0.286	0.324	0.114	130250
1993	971286	906336	0.072	16273400	0.144	0.275	0.312	0.107	142495
1994	818474	787660	0.072	14164000	0.136	0.231	0.262	0.092	136582
1995	678479	654551	0.073	11099400	0.139	0.231	0.262	0.086	125280
1996	543623	524598	0.076	15666800	0.110	0.312	0.354	0.091	116736
1997	480136	455142	0.076	10064600	0.133	0.421	0.478	0.093	115814
1998	382755	365364	0.082	13343000	0.115	0.478	0.542	0.101	108924
1999	365180	353794	0.083	10160500	0.137	0.438	0.497	0.106	94091
2000	310849	293789	0.091	32028000	0.086	0.391	0.444	0.109	85786
2001	470738	398969	0.076	19178800	0.110	0.370	0.420	0.105	101957
2002	479413	417749	0.075	10999600	0.144	0.310	0.351	0.106	99673
2003	453653	417926	0.078	8854750	0.161	0.276	0.313	0.097	97831
2004	396396	368346	0.084	36781900	0.072	0.306	0.347	0.095	98020
2005	532057	422579	0.071	13091800	0.108	0.303	0.344	0.091	97345
2006	625847	574013	0.063	4108130	0.173	0.178	0.180	0.099	87023
2007	492322	480934	0.064	5917160	0.132	0.216	0.219	0.077	96469
2008	383172	375980	0.066	7554220	0.109	0.346	0.350	0.078	101464
2009	289500	283127	0.068	8587540	0.095	0.392	0.397	0.090	87740
2010	244284	241230	0.066	4929990	0.122	0.488	0.494	0.101	89571
2011	175986	174256	0.076	4022290	0.130	0.583	0.590	0.113	80403
2012	130430	129037	0.097	4372840	0.127	0.466	0.472	0.128	54857
2013	120558	119019	0.113	4847640	0.135	0.442	0.447	0.151	45818
2014	124843	124843	0.131	3684980	0.165	0.282	0.285	0.167	27937
2015	118110	117315	0.147	6671120	0.151	0.171	0.173	0.173	20595
2016	150952	150952	0.146	8974360	0.163	0.168	0.170	0.175	22704
2017	193853	192643	0.152	4020510	0.198	0.138	0.139	0.180	21911
2018	186097	184440	0.161	8386620	0.179	0.073	0.074	0.178	15062
2019	215772	209539	0.158	26171500	0.163	0.050	0.051	0.164	13759

Year	Biomass 1+	SSB	CV SSB	Recruits	CV Recruits	F (2-5)	F Apical	CV F Apical	Landings
2020	426676	407167	0.148	9054920	0.220	0.062	0.063	0.162	22143
2021	424514	417774	0.149	10905000	0.274	0.098	0.099	0.166	40686
2022	432379	428340	0.164	19424400	0.470	-	-	-	44262

Table 8.6.1. Sardine in 8c and 9a. Input data for short-term catch predictions. Number-at-age for 2022 and recruitment for 2023. Input values for stock weight, catch weight, natural mortality (M) and fishing mortality (F) at-age. Input units are thousands and kg.

Year = 2022						
Age	Numbers	Stock weights	Catch weights	Maturity	M	F
0	7860940	0.000	0.030	0.000	0.98	0.015
1	3158530	0.028	0.046	0.988	0.61	0.060
2	4288170	0.045	0.059	0.989	0.47	0.102
3	875050	0.058	0.073	1.000	0.40	0.109
4	251351	0.063	0.082	1.000	0.36	0.109
5	359542	0.068	0.091	1.000	0.35	0.109
6	298400	0.073	0.097	1.000	0.32	0.093
Recruitment in 2023 = 13 330 753						
Stock weights, catch weights, maturity and mortality are the same as in 2022						

Table 8.6.2. Sardine in 8.c and 9.a. Output data for short-term catch predictions.

B1+ 2023 = 423 378 tonnes; Catch 2022 = 44 262 tonnes ; F 2022 = 0.101					
F (2023)	Catch (2023)	Biomass 1+ (2024)	Catch2024	% Biomass 1+ change[1]	% Catch change[2]
0.092	43841	515423	45960	2	8
0.093	44301	515100	46413	2	9
0.094	44761	514777	46865	2	10
0.095	45221	514455	47316	1	11
0.096	45680	514132	47766	1	12
0.097	46139	513810	48215	1	13
0.098	46598	513488	48663	1	15
0.099	47056	513167	49110	1	16
0.100	47514	512846	49556	1	17
0.101	47972	512525	50001	1	18
0.102	48429	512204	50446	1	19
0.103	48886	511883	50889	1	20
0.104	49343	511563	51332	1	21
0.105	49799	511243	51773	1	22
0.106	50255	510924	52214	1	24
0.107	50711	510604	52654	1	25
0.108	51166	510285	53093	1	26
0.109	51621	509966	53531	1	27
0.110	52076	509647	53968	1	28
0.111	52530	509329	54404	0	29
0.112	52984	509011	54839	0	30
0.113	53438	508693	55273	0	31
0.114	53891	508375	55706	0	32
0.115	54344	508058	56139	0	34
0.116	54797	507741	56570	0	35
0.117	55249	507424	57001	0	36
0.118	55701	507107	57431	0	37
0.119	56153	506791	57860	0	38
0.120	56604	506475	58288	0	39
1.390	437165	252523	238275	-50	974
1.960	530585	196334	241559	-61	1204
0.260	116651	464655	110108	-8	187
0.062	30000	525149	30000	4	-26
0.073	35000	521633	35000	3	-14
0.084	40000	518120	40000	2	-2
0.095	45000	514610	45000	2	11
0.105	50000	511102	50000	1	23

[1]Biomass 1+ in 2024 relative to Biomass 1+ in 2023 (506 858 tonnes). [2]Advised catches in 2023 compared to 2022

B1+ 2023 = 423 378 tonnes; Catch 2022 = 44 262 tonnes ; F 2022 = 0.101					
F (2023)	Catch (2023)	Biomass 1+ (2024)	Catch2024	% Biomass 1+ change[1]	% Catch change[2]

catches (44 262 tonnes) .

9 Horse Mackerel in Division 9.a (Atlantic Iberian waters)

9.1 ACOM Advice Applicable to 2022, STECF advice and Political decisions

The fishing mortality (F) has been below F_{MSY} over the Bwhole 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 2011–2020 has been 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 2022 should not exceed 143 505 t. ICES also recommended that the TAC for this stock should only apply to *Trachurus trachurus*. The TAC of 143 505 t in 2022 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 traverses the majority of the stock area, the combined survey index could not be estimated. The assessment was performed without fishery-independent data. Estimated recruitment since 2018 is considered uncertain.

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 2021

9.2.1 Fishing fleets in 2021

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 lesser 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 2021 overall landings and catches-at-age 1 from the Spanish purse-seine fleet decreased. Portuguese purse-seiners had an increase in catches for 2021. The Portuguese artisanal fleet is mainly composed by small size vessels licensed to operate with several gears (gill and trammelnets, 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 decrease in 2021. Horse mackerel is one of the main target species in the Portuguese bottom trawl fleet, in 2021 accounted for 43% of the Portuguese catches, while purse-seine accounted for 50%. In Spain main catches are from the purse-seine fleet (87%). Portuguese catches from the artisanal fleet are very small (7%) and Spanish artisanal fishery is negligible (2%). 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 1% 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 (1992–2021) shows a peak in 1998, of 41 564 t, a steady increase since 2011 to 2016 and a decrease was observed in 2021 with catches of 26 745 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 8.2.2.2. Until 2011 the highest contribution to the total catches was, in general, from the trawl fleets. Since 2012 there has been a significant increase in the catches from the purse-seine. The Spanish purse-seine contributions to catches remained high but decreased from last year (-36%). Catches from the Spanish bottom trawl are relatively low and decreased 58% from 2020 to 2021. Catches from the Portuguese purse-seine has a significant 75% increase and bottom trawl decreased in 18% from 2020 to 2021. The contribution of the artisanal fleet from both Portugal and Spain is very small and in 2021 decreased 4% and 47%, respectively, when compared to 2020.

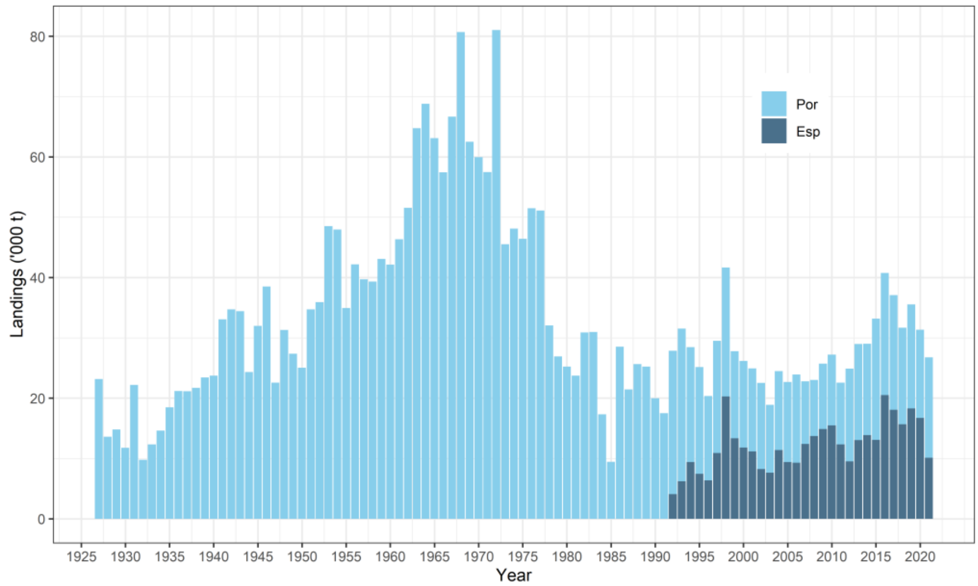


Figure 9.2.2.1. Horse mackerel in Division 9.a. Historical time-series of landings (1927-2021) for southern horse mackerel (Div. 27.9.a). Light blue bars are Portuguese landings and dark blue bars are Spanish landings.

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)*
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)*

Year	Total Catch
2019	35,520///(36,536)*
2020	30,177///(31,344)*
2021	26,320///(26,745)*

(*) 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 1992–2021 (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%
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%

Year	Bottom trawl	Purse-seine	Artisanal
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%
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%

Year	Bottom trawl	Purse-seine	Artisanal
2021	8,074	16,869	1,378
	30.68%	64.09%	5.23%

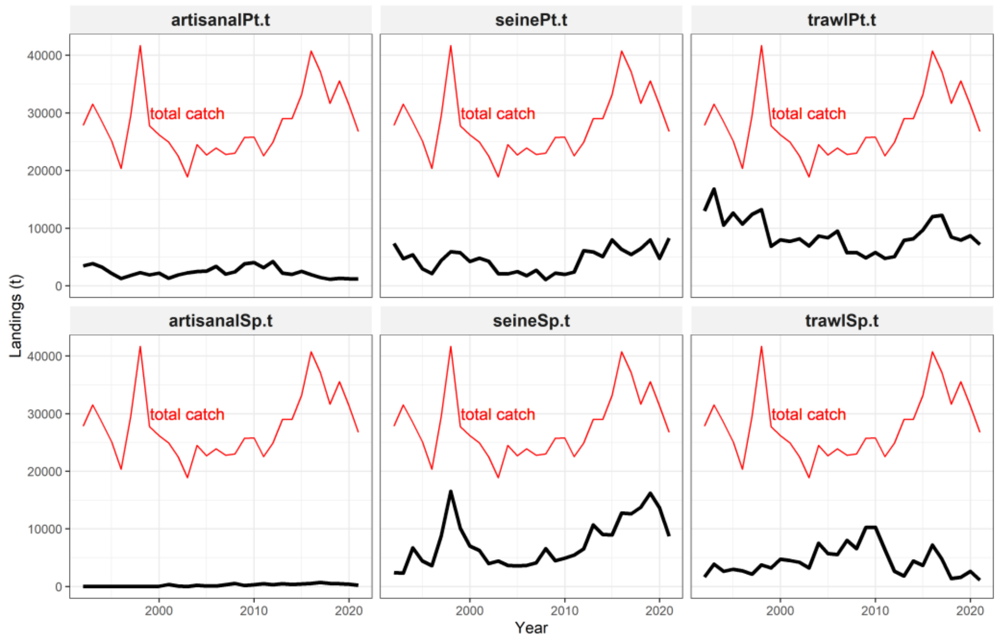


Figure 9.2.2.2. Horse mackerel in Division 9.a. Time-series (1992-2021) of southern horse mackerel catches (in tonnes) by country (Pt – Portugal; Sp – Spain) and gear (artisanal; purse-seine, trawl).

Discards are estimated by both countries (Portugal since 2014, 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 (253.7 t), the total discards from the Spanish fleets were estimated at 262 t.

Table 9.2.2.3. Horse mackerel in Division 9.a. Discard estimates (tonnes) of southern horse mackerel in 2021 by country (SP – Spain, PT - Portugal), fleet/métier, ICES subdivision and quarter.

Country	Fleet	Metier	Fishing Area	Quarter_1	Quarter_2	Quarter_3	Quarter_4	Total
SP	artisanal	GNS_DEF_80-99_0_0	27.9.a.n	0.0	0.2	0.0	0.0	0.2
SP	trawl	OTB_DEF_>=55_0_0	27.9.a.n	1.0	0.0	0.0	1.2	2.2
SP	trawl	OTB_MPD_>=55_0_0	27.9.a.n	0.0	5.1	0.0	0.0	5.1
SP	trawl	PTB_MPD_>=55_0_0	27.9.a.n	0.0	0.1	0.0	0.0	0.1
SP	trawl	OTB_MCD_>=55_0_0	27.9.a.s	139.0	40.3	32.0	42.3	253.7
SP	purse seine	PS_SPF_0_0_0	27.9.a.s	0.0	0.0	0.0	0.7	0.7
PT	trawl	OTB_CRU_>=55_0_0 (Loa >=12m)	27.9.a	0.0	0.0	0.0	0.0	0.0
PT	trawl	OTB_DEF_>=55_0_0 (Loa >=24m)	27.9.a	0.0	0.0	0.0	0.0	0.0

9.2.3 Effort and catch per unit of effort

A preliminary CPUE (catch per unit effort) is being 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 1992-2021. 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. 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 1992–2021, with age range 0–11+.

In general, catches are dominated by juveniles and young adults in the available time-series (1992-2021). Catches-at-age-1 had a significant decrease in 2021 probably resulting from the steep decrease in Spanish purse-seine catches (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 1992–2021 (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

	AGES											
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
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

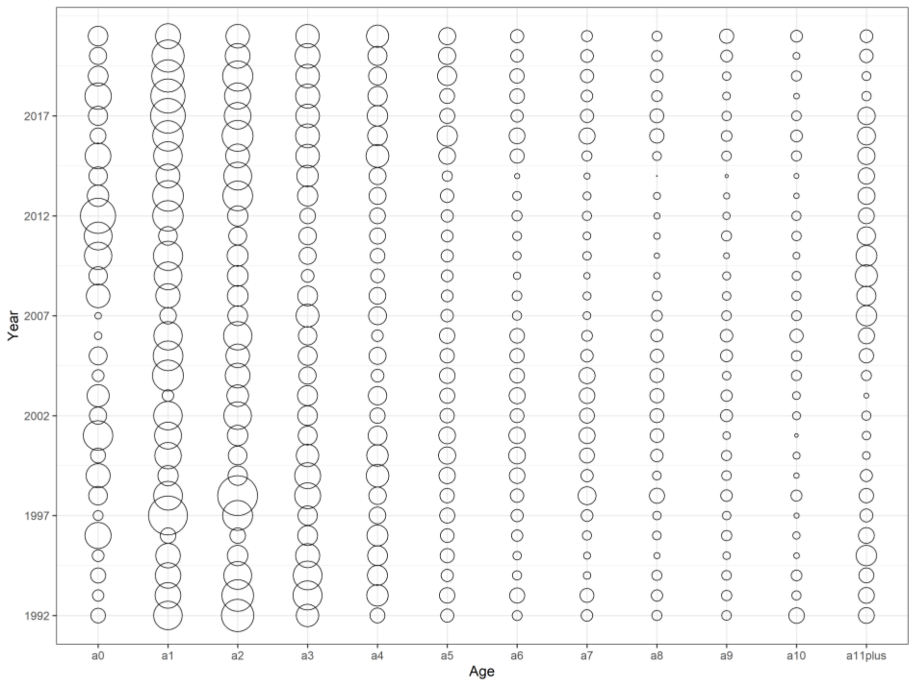


Figure 9.2.4.1. Horse mackerel in Division 9.a. Bubble plot of proportions of southern horse mackerel catch in numbers-at-age in each year (1992–2021).

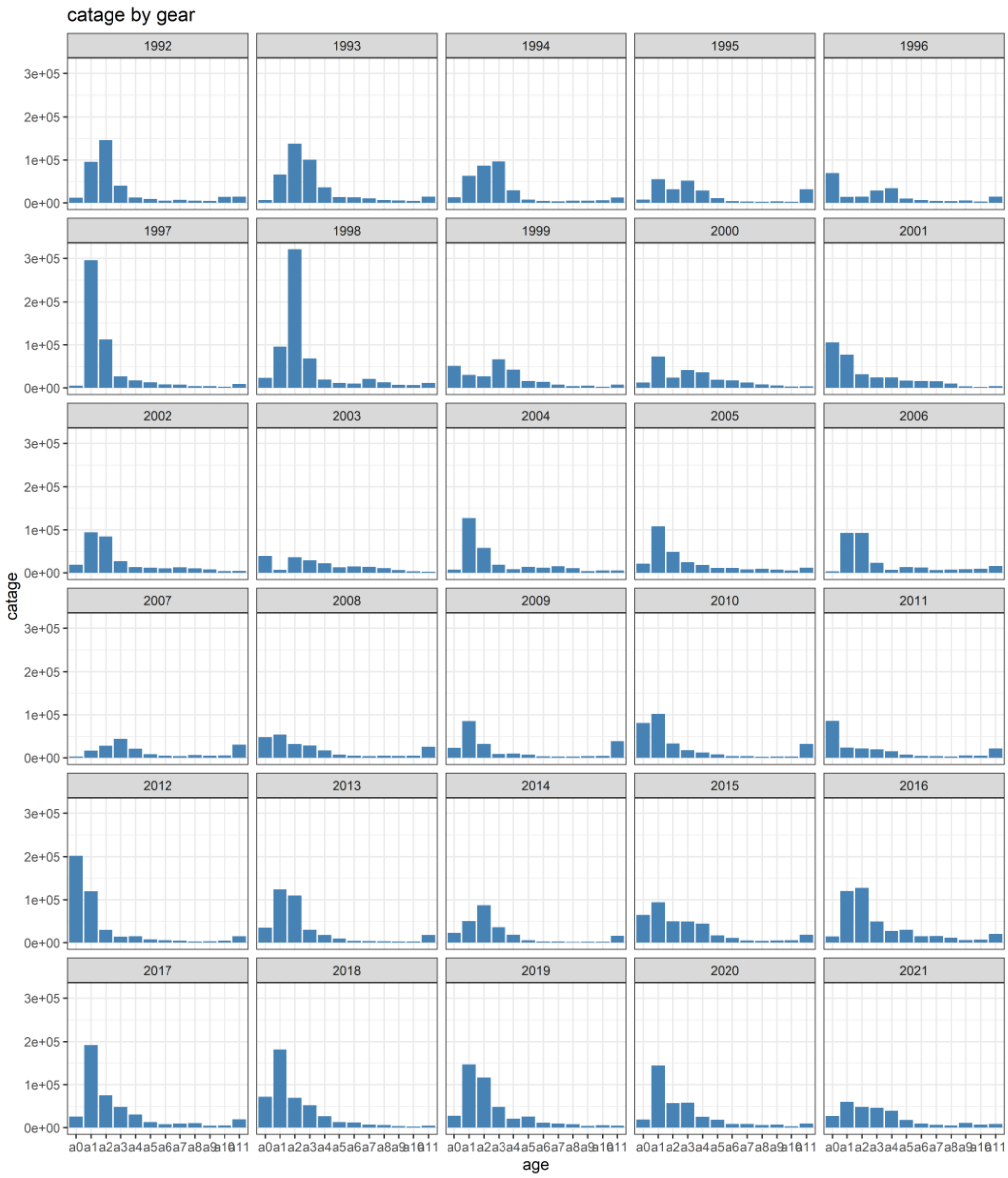


Figure 9.2.4.2. Horse mackerel in Division 9.a. Catch in numbers-at-age in each year (1992–2021).

Table 9.2.4.2 presents the southern horse mackerel catch in numbers-at-age by fishing fleet and Figure 9.2.4.2 shows the proportion of catch-at-age by fleet and country in the period 1992–2021. The Portuguese and Spanish purse-seine fleet and the Portuguese trawl and artisanal fleets caught mainly juveniles and young adults. In 2021, the catch-at-age 1 showed a significant decrease resulting from the lower catches observed in the Spanish purse-seine fleet and a slight increase in age 0 from the Portuguese purse-seine fleet and artisanal fleet (mainly from the "tucas", small seiners from the Portuguese artisanal polyvalent fleet). The pattern for the remainder of ages is similar to other years.

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 1992–2021.

Bottom trawl												
	AGES											
YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
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

Bottom trawl												
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

Purse-seine												
	AGES											
YEAR	**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
2012	193478	96833	12558	5530	7261	3945	1375	1991	1106	1282	1279	1268

Purse-seine												
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
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
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

Purse-seine												
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

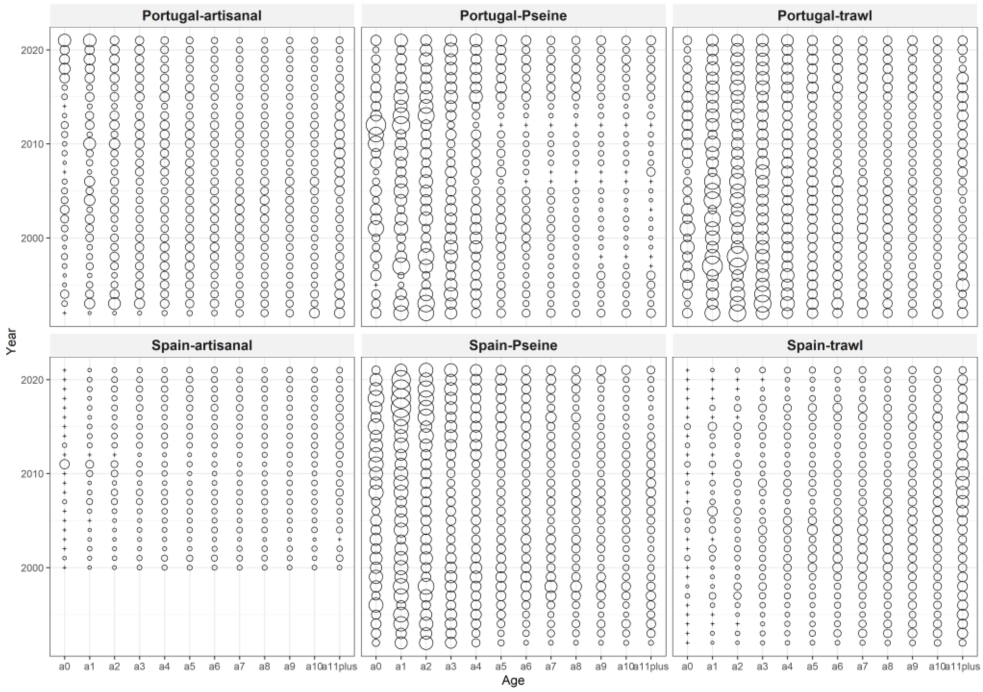


Figure 9.2.4.2. Horse mackerel in Division 9.a. Bubble plot of proportions of southern horse mackerel catch in numbers-at-age by country and fleet in each year (1992-2021).

9.2.5 Mean weight-at-age in the catch

Detailed information on the way 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 2021.

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 1992-2021. From 2018 to 2021 there was an increase from age 2 to age 3. The mean age composition fluctuates around ages 2 to 4 in the available time-series.

Table 9.2.5.1. Horse mackerel in Division 9.a. Mean weight-at-age (kg) in the catch (1992-2021).

	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

	AGES											
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
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

Table 9.2.5.2. Horse mackerel in Division 9.a. Mean length-at-age (cm) in the catch from 1992-2021 (age range: 0–15 and older).* Mean length-at-age from 2019 onward is only shown for 0 to 11+, plus group used for assessment.

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
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

Year \ Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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	-	-	-	-

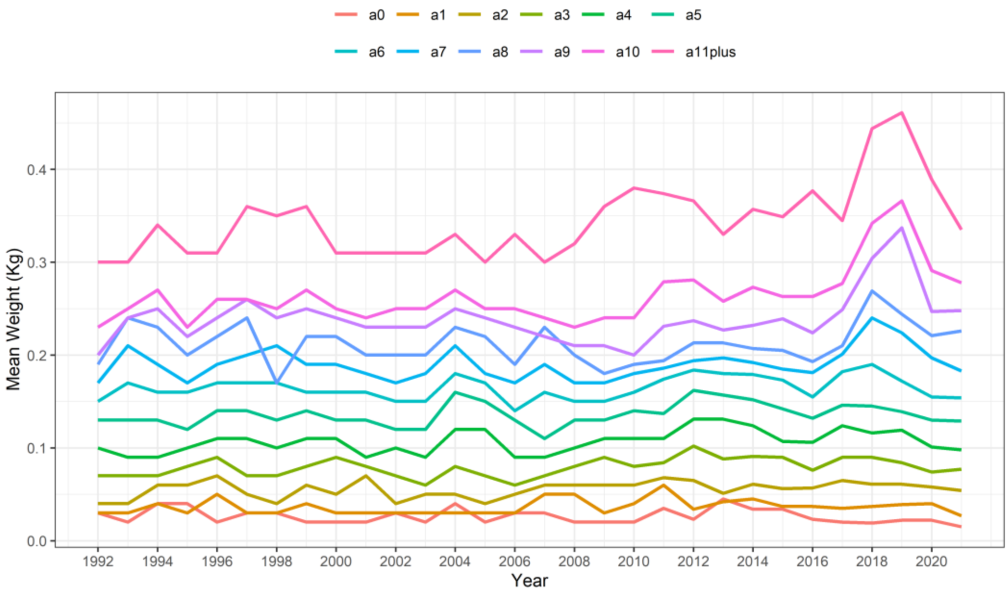


Figure 9.2.5.1. Horse mackerel in Division 9.a. Mean weight-at-age (kg) in the catch (age range: 0 to 11+, plus group; 1992-2021).

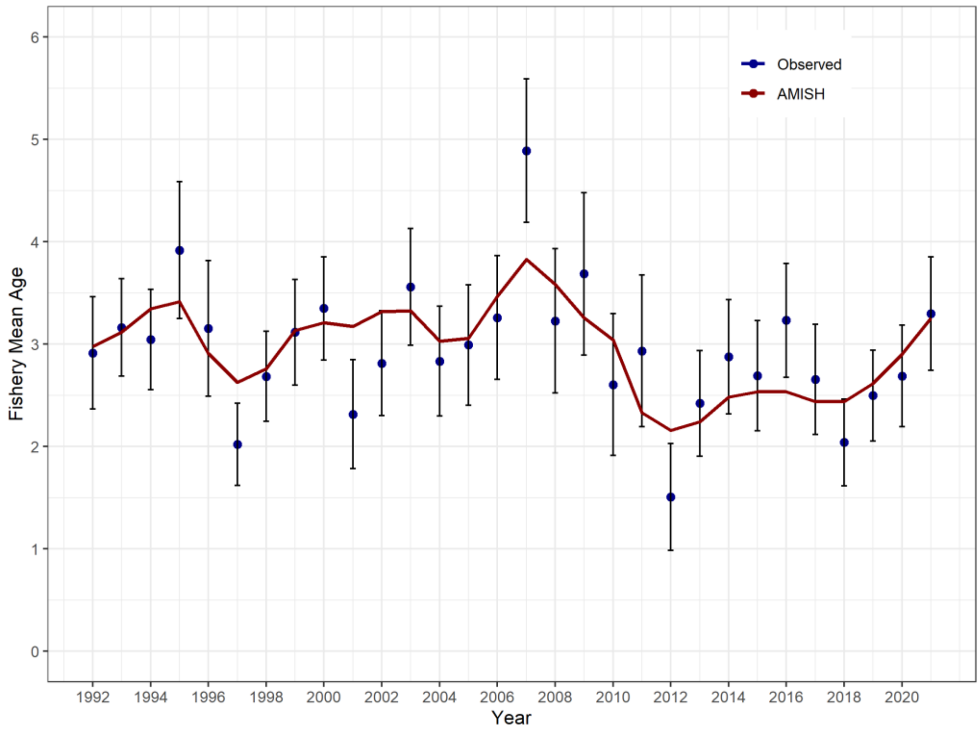


Figure 9.2.5.2. Horse mackerel in Division 9.a. Mean age in the catch in the period 1992–2021 (age range: 0 to 11+, plus group).

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-WI-BTS-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 of 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 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 1992-2021. 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 2021 (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. Southern horse mackerel CPUE-at-age (number/hour) by the Portuguese and Spanish surveys, in the period 1992–2021 (age range: 0 to 11+, plus group). The Portuguese IBTS (October) survey was not conducted in 2012, 2019 and 2020.

Portuguese October Survey

	AGES															
YEAR	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

Spanish October Survey (only Subdivision IXa North)

	AGES															
YEAR	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

(*) The surveys were carried out with a different research vessel.

(**) Since 1997 another stratification design in the Spanish surveys.

([1]) In 2002 the duration of the trawling hauls changed from one hour to 30 minutes.

Table 9.3.1.2. Horse mackerel in Division 9.a. Stratified mean abundance-at-age (number/hour) in the period 1992–2021. There were no Portuguese surveys in 2012, 2019 and 2020 and therefore the combined survey indices for 2012, 2019 and 2020 are not estimated. *age 0 is not used in the stock assessment.

	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										
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

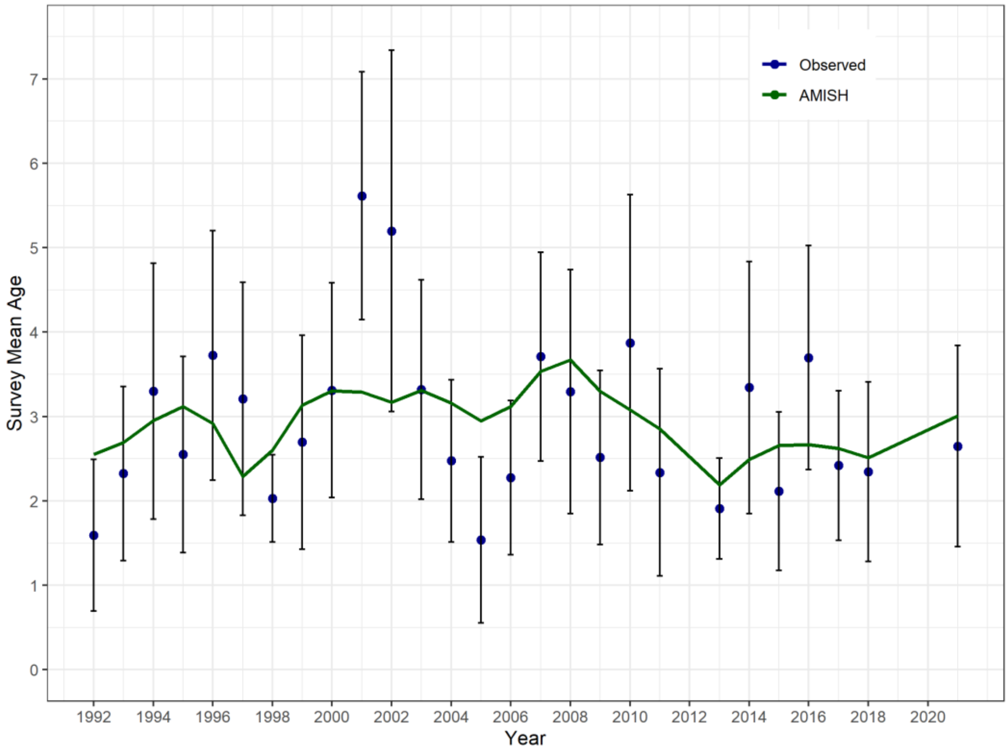


Figure 9.3.1.1. Horse mackerel in Division 9.a. Mean age in the survey in the period 1992–2021 (age range used in the assessment uses only age 1 to 11+, plus group).

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 (1992–2021).

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 1992–2021 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 dataseries 1992-2021.

Name	Year range	Age range	Assumptions/settings
Catch in weight	1992–2021		Variable in time
Catch-at-age	1992–2021	0–11+	Variable by age and time; assuming a constant CV of 5%
IBTS (Spanish-Portuguese) mean stratified abundance-at-age	1992–2021 (except 2012, 2019,2020)	1–11+	Variable by age and time; assuming a constant CV of 30%
Mean weight-at-age (catch and stock)	1992–2021	0–11+	Variable by age and time
Proportion of F and M before spawning	1992–2021	0–11+	Fixed at 0.04 (mid-January)
Natural Mortality	1992–2021	0–11+	Age-dependent; time invariant
Catch-at-age selectivity	1992–2021	0–11+	Dome-shaped; constant at age 7+ Three blocks 1992–1997; 1998–2011; 2012–2020
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	1992–2021 (except 2012, 2019,2020)	1–11+	Dome-shaped; constant at age 7+ One time-block 1992–2019 (no survey index in 2012, 2019 and 2020)
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	1992–2021	0–11+	Multinomial distribution
Proportion-at-age in the survey	1992–2021	1–11+	Multinomial distribution
Effective sample size catch			100
Effective sample size survey			10

Figure 9.4.1.1 presents the estimated selectivity in the survey (age range 1–11+) and in the catch-at-age (age range 0–11+) for the period 1992–2021.

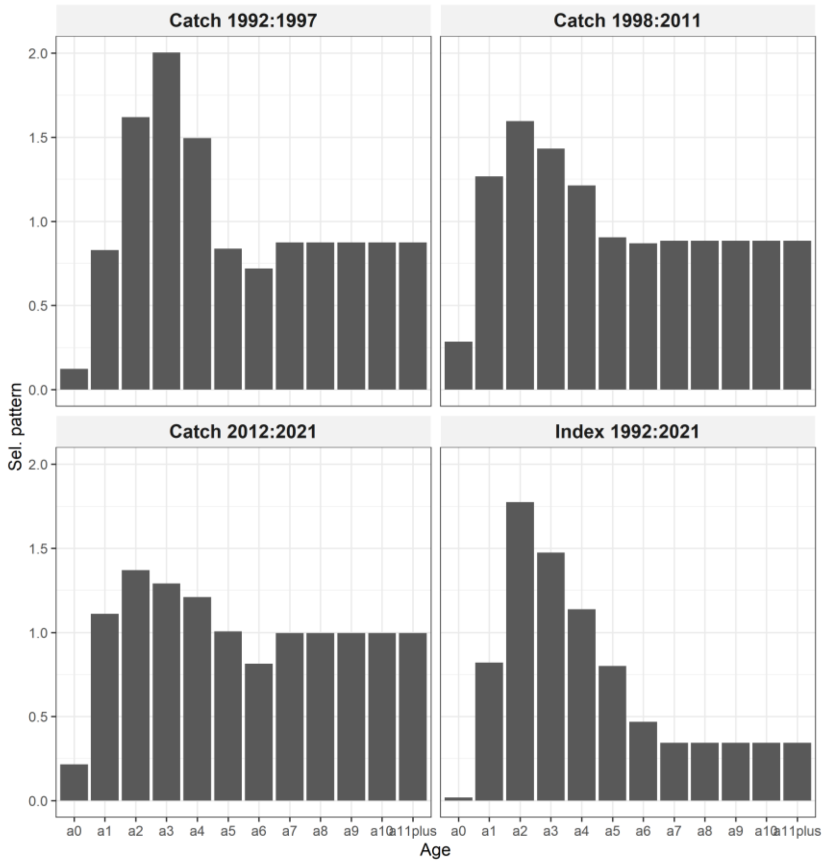
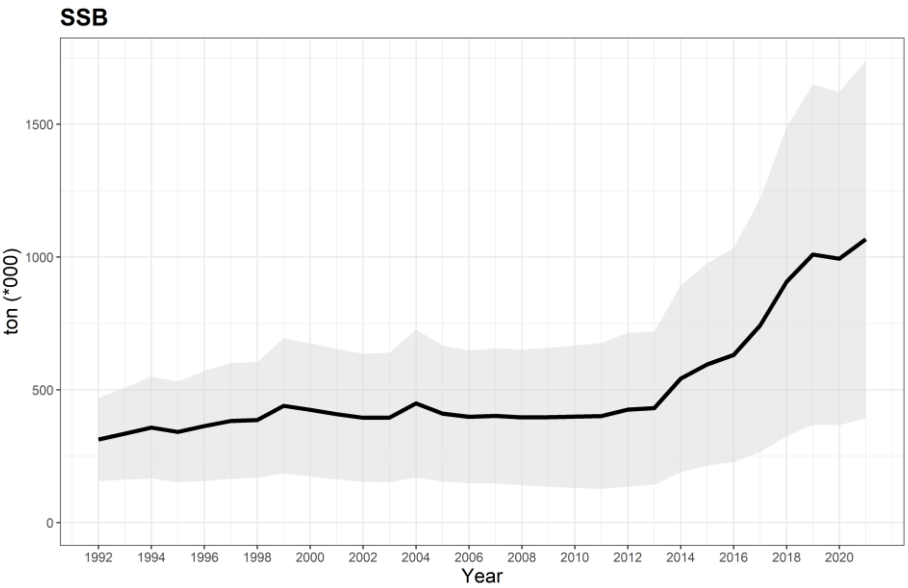


Figure 9.4.1.1. Horse mackerel in Division 9.a. Estimated selectivity for the catch-at-age (three time-blocks) and for the IBTS combined stratified mean abundance-at-age (one time block).

The summarized 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 (1992-2021). Stock summary table (SSB at spawning time in mid-January).

Year	Recruits (10*3)	SD	CV	SSB (t)	SD	CV	mean F_{2-10}	SD	CV	Catch (t)
1992	4511750	934423	0.21	312644	80063	0.26	0.082	0.021	0.25	27858
1993	3157140	686762	0.22	334915	88192	0.26	0.088	0.023	0.26	31521
1994	3116640	683905	0.22	357692	97896	0.27	0.071	0.019	0.26	28441
1995	4262840	910077	0.21	341582	96540	0.28	0.068	0.018	0.27	25147
1996	11485300	2241050	0.2	363614	105623	0.29	0.050	0.013	0.27	20400
1997	3776370	802118	0.21	382830	111404	0.29	0.069	0.019	0.27	29491
1998	2422560	548789	0.23	386496	110971	0.29	0.092	0.025	0.27	41564
1999	3698310	800907	0.22	439734	129696	0.29	0.056	0.016	0.28	27733
2000	3376760	749361	0.22	424627	127836	0.30	0.058	0.016	0.28	26160
2001	3990810	880863	0.22	407941	125201	0.31	0.057	0.016	0.28	24910
2002	2255730	538408	0.24	395041	122940	0.31	0.056	0.016	0.29	22506
2003	4477560	998960	0.22	395506	124369	0.31	0.047	0.013	0.28	18887
2004	4941720	1101440	0.22	448590	141937	0.32	0.051	0.014	0.28	23252
2005	3106400	727188	0.23	410485	130863	0.32	0.052	0.015	0.29	22695
2006	1619040	418725	0.26	398318	127110	0.32	0.057	0.017	0.29	23902
2007	2400310	600235	0.25	401867	129840	0.32	0.055	0.016	0.29	22790
2008	3804480	938670	0.25	396024	130331	0.33	0.057	0.017	0.3	22993
2009	3549020	917780	0.26	396981	133406	0.34	0.064	0.020	0.31	25737
2010	4443340	1180210	0.27	398639	136785	0.34	0.063	0.020	0.32	26556
2011	11032300	2844830	0.26	401282	140131	0.35	0.040	0.013	0.32	21875
2012	13050500	3370780	0.26	425006	147861	0.35	0.043	0.014	0.33	24868
2013	7131340	1940760	0.27	430724	146927	0.34	0.042	0.014	0.33	28993
2014	9551120	2584930	0.27	541959	179353	0.33	0.037	0.012	0.33	29017
2015	10503000	2900760	0.28	595386	194130	0.33	0.041	0.014	0.33	32723
2016	11724300	3344990	0.29	630963	205517	0.33	0.050	0.016	0.33	40741
2017	15568400	4560440	0.29	742574	243441	0.33	0.039	0.013	0.33	36946
2018	14186700	4345030	0.31	907062	296806	0.33	0.028	0.009	0.32	31661
2019	12849300	4145040	0.32	1009547	326679	0.32	0.028	0.009	0.32	35520
2020	8679670	3165230	0.36	993801	319950	0.32	0.024	0.008	0.32	30177
2021	9009310	4280480	0.48	1066959	343328	0.32	0.022	0.007	0.32	26320
Average	6589401	1804771	0.26	504626	159838	0.31	0.053	0.015	0.30	27713



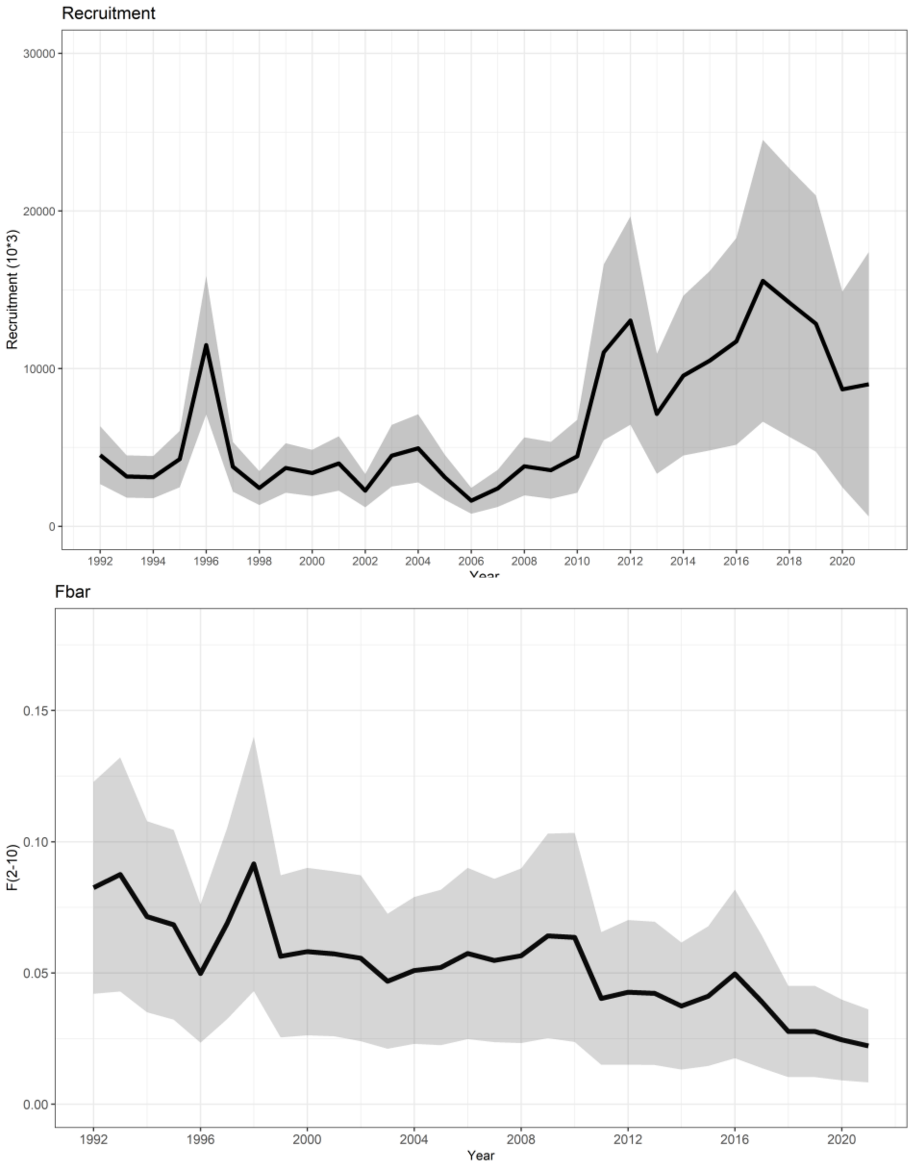


Figure 9.4.1.2. Horse mackerel in Division 9.a. Final assessment (1992-2021). Plots of SSB (top), Recruitment (middle) and Fishing mortality (bottom, mean F_{2-10}). Grey shaded area shows 95% confidence bounds and average CV is 32% for SSB, 32% for F_{2-10} and 48% for Recruitment. SSB and are in thousand tonnes and recruitment in thousands.

The estimated SSB shows a significant increase from 2013 to 2021 from 431 thousand tonnes to 1 066 959 thousand tonnes. Confidence intervals of SSB are in the range 26-35% with an average 31%. The fishing mortality has been below F_{MSY} over the whole time-series and after the slight increase in 2016, showed a decrease in 2017-2021. F_{2-10} in 2021 was estimated at 0.0.022 lower than the observed value in 2020. Confidence intervals of F are in the range 25-33%.

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 present a high uncertainty showed in the wide confidence intervals (Figure 9.4.1.2). In 2021, recruitment was estimated at 9009 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 1992–2021.

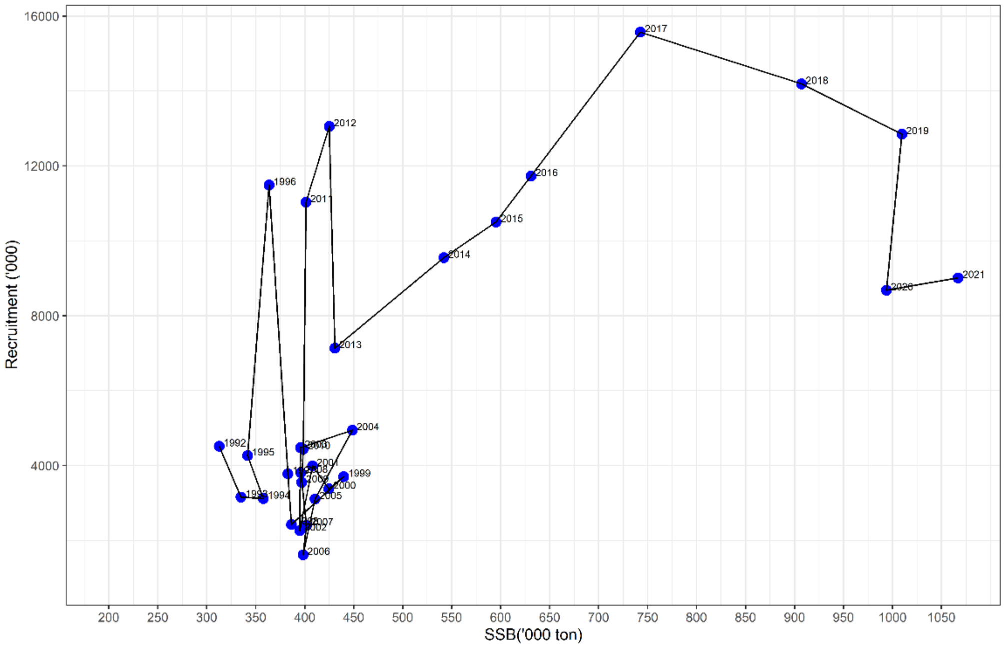


Figure 9.4.1.3. Horse mackerel in Division 9.a. Stock–recruitment data for southern horse mackerel (1992-2021).

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 dataseries 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. In 2021, the Portuguese Bottom Trawl Survey was carried out and the combined survey index estimate was used in the assessment. However, the assessment still shows high uncertainty, reflected in the large confidence intervals for SSB and recruitment (Figure 9.4.1.2).

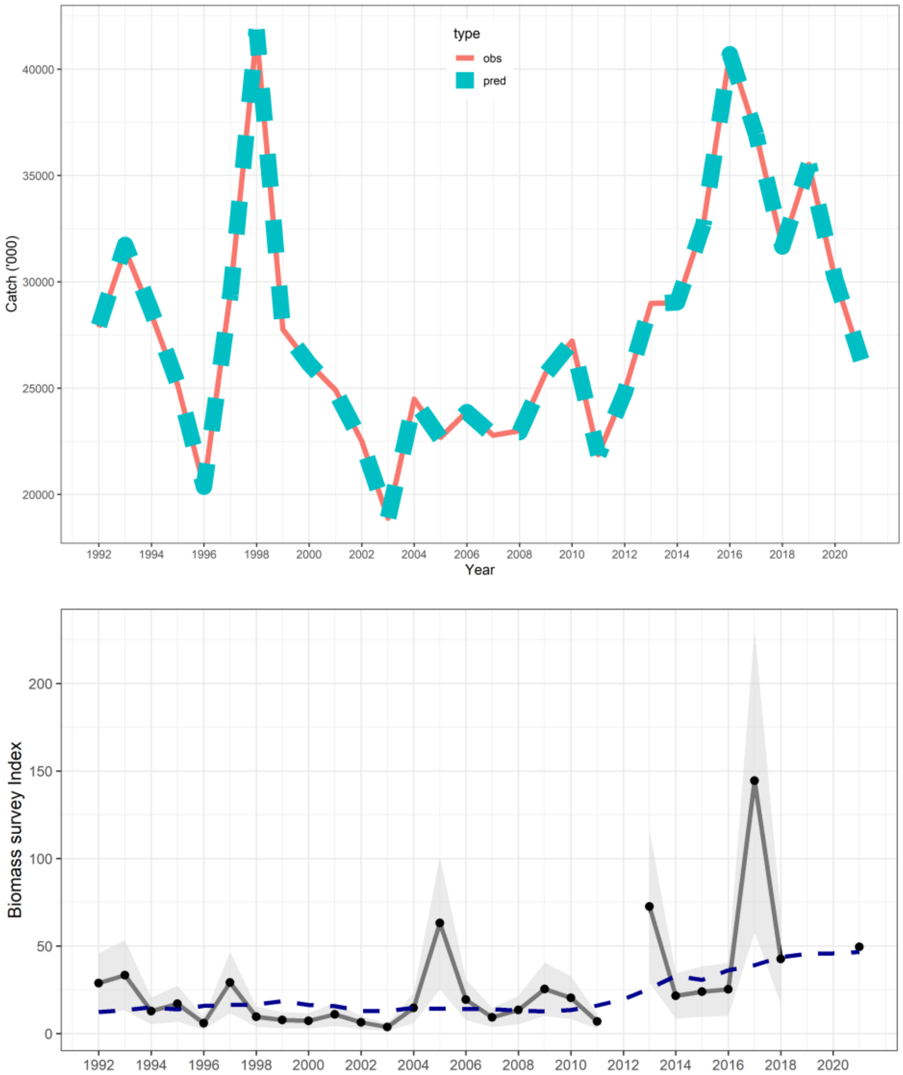


Figure 9.4.2.1. Horse mackerel in Division 9.a. . Catch biomass (top) and survey biomass index (bottom) for the period 1992-2021: observed (solid black line) and estimated values (dashed blue line). The grey shaded area shows 95% confidence bounds of survey biomass index.

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.

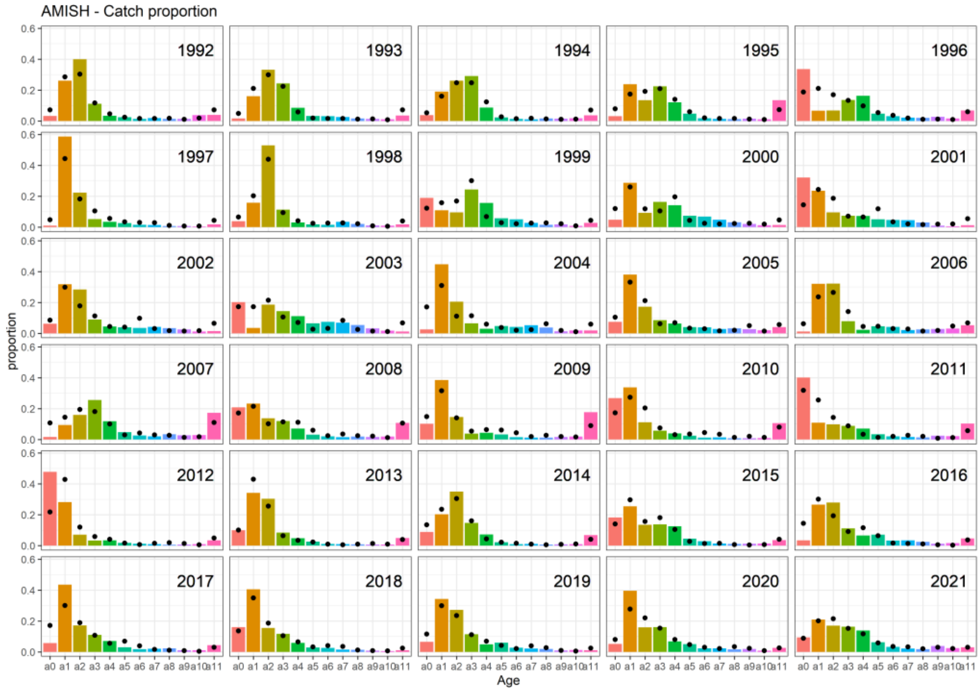


Figure 9.4.2.2. Horse mackerel in Division 9.a. Comparison of proportions-at-age of the observed and fitted catch data (observed values=dots; fitted values=solid lines).

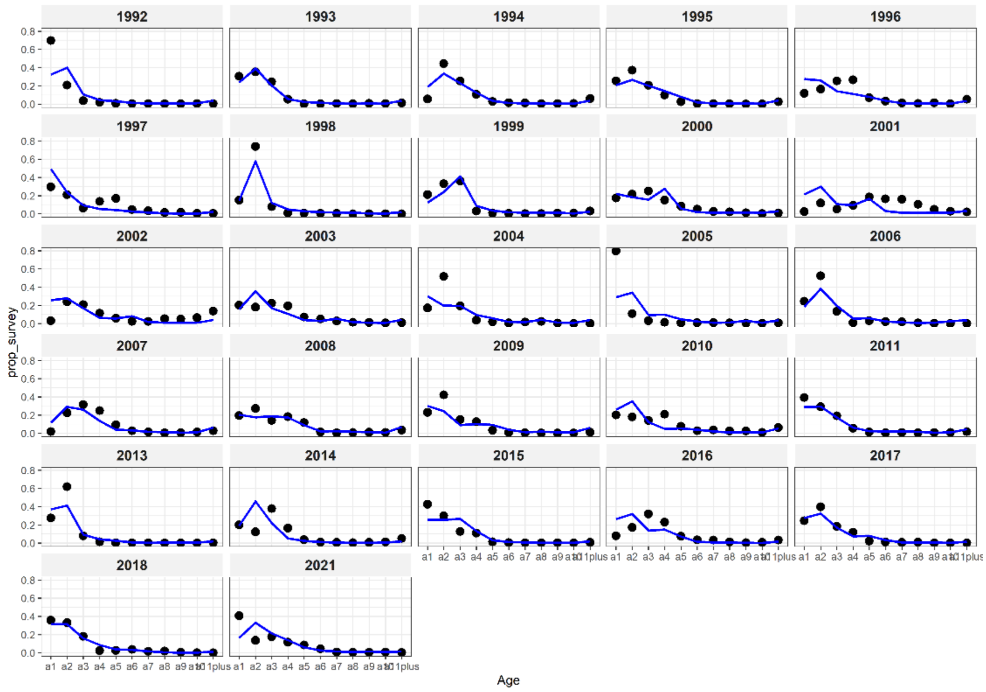


Figure 9.4.2.3. Horse mackerel in Division 9.a. . Comparison of proportions-at-age of the observed and fitted survey data (observed values=dots; fitted values=solid lines).

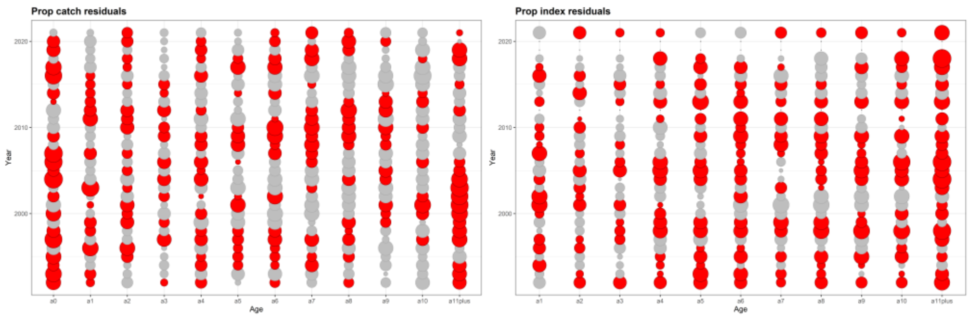


Figure 9.4.2.4. Horse mackerel in Division 9.a. . Bubble plot of catch (left, age range 0–11+) and survey (right, age range: 1–11+) proportion-at-age residuals (negative residuals=red bubbles).

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 32% (coefficient of variation). The slight decrease in catches observed in 2021 and the continuous increase in estimated stock abundance in the last few years resulted in a lower estimate of F_{bar} in 2021 than in the previous year. The uncertainty in the estimated F_{bar} is of similar magnitude around 32% (coefficient of variation). In 2019 and 2020 the survey was not carried out in the Portuguese area of Division 9.a. Because of this, the stock assessment was performed without the 2019 and 2020 survey index values. In 2021, the combined survey index estimate was used in the assessment. However, the assessment still shows high uncertainty, reflected in the large confidence intervals recruitment in 2020 and 2021 with 36% and 48%, 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 which has led to a change in the age composition of catches, with an increase in the proportion of 1-2 year old fish (juveniles and young immature fish). In 2021, the catch-at-age 1 showed a contrasting behaviour with a significant decrease resulting from the lower catches observed in the Spanish purse-seine fleet. Changes in the relative contribution to the catch from bottom trawls and purse-seines have led to changes in the age composition of catches (Figure 9.4.2.5). This may lead to inconsistency in estimating selectivity for the last period of the assessment. WGHANSA performed exploratory analysis using different selectivity patterns to explore if the assumptions of selectivity for the last period of the assessment (2012-2021 selectivity block) were incorrect. The results were inconclusive and require continued monitoring and further exploration.

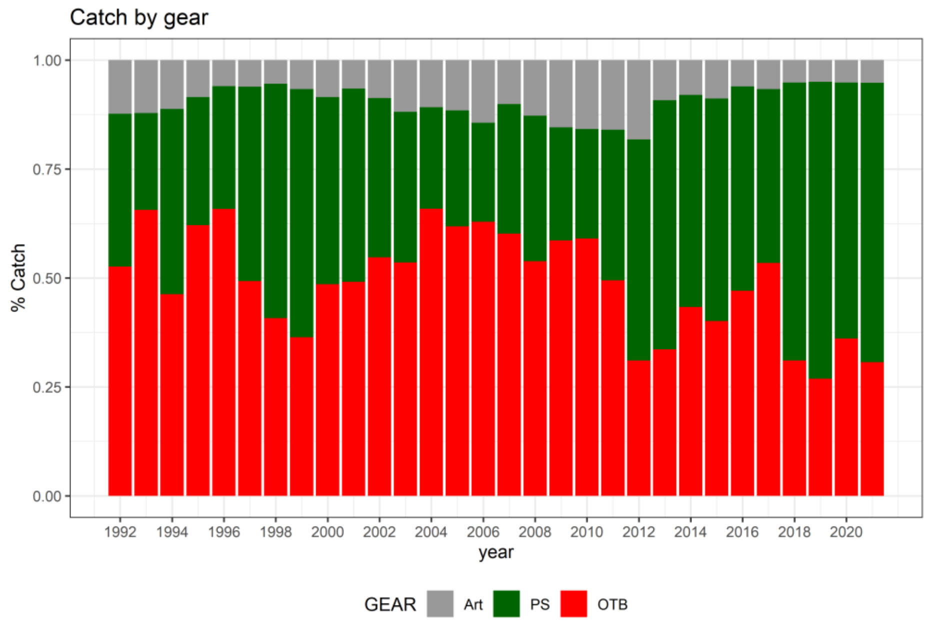


Figure 9.4.2.5. Horse mackerel in Division 9.a. Contribution of southern horse mackerel catches by gear (PS – Purse-seine, OTB – bottom trawl, Art - Artisanal) from 1992-2021.

The retrospective analysis on SSB, recruitment and F_{bar} (mean F ages 2–10) was performed for a five-year period, from 1992–2016 to 1992–2021 time-series. The Mohn´s rho estimated for each retrospective peel and the average Mohn´s rho are shown in Table 9.4.2.1. They indicate a negligible overestimation of the SSB (0.06), a slight overestimation of F (0.15) and a minor underestimation of Recruitment (-0.08). Because of the very high uncertainty observed in the last recruitment estimate, the Mohn´s rho for recruitment is calculated without the terminal year. The Mohn´s rho results are below the critical value (± 0.30) and the observed retrospectives are mostly inside the confidence intervals of the last assessment estimates (Figure 9.4.2.5).

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 (*relbias*). The adopted Monh´s rho is the average of the five last year bias.

F Mohn's rho

	base	retro	relbias
2016	0.0496	0.07735548	0.558853612
2017	0.03907	0.04404278	0.127262003
2018	0.02767	0.02939894	0.062519853
2019	0.02768	0.02832511	0.023151612
2020	0.02447	0.02432783	-0.005849108

F average rho
0.1531876

SSB Mohn's rho

	base	retro	relbias
2016	605.806	487.950	-0.19454413
2017	663.872	737.556	0.11099128
2018	738.490	888.422	0.20302509
2019	846.726	992.092	0.17168009
2020	963.126	983.374	0.02102321

SSB average rho
0.06243511

Recruitment Mohn's rho (last year removed)

	base	retro	relbias
2015	10503.0	4875.99	-0.53575264
2016	11724.3	11141.40	-0.04971725
2017	15568.4	13087.80	-0.15933558
2018	14186.7	16394.60	0.15563168
2019	12849.3	15326.40	0.19278093

R average rho
-0.07927857

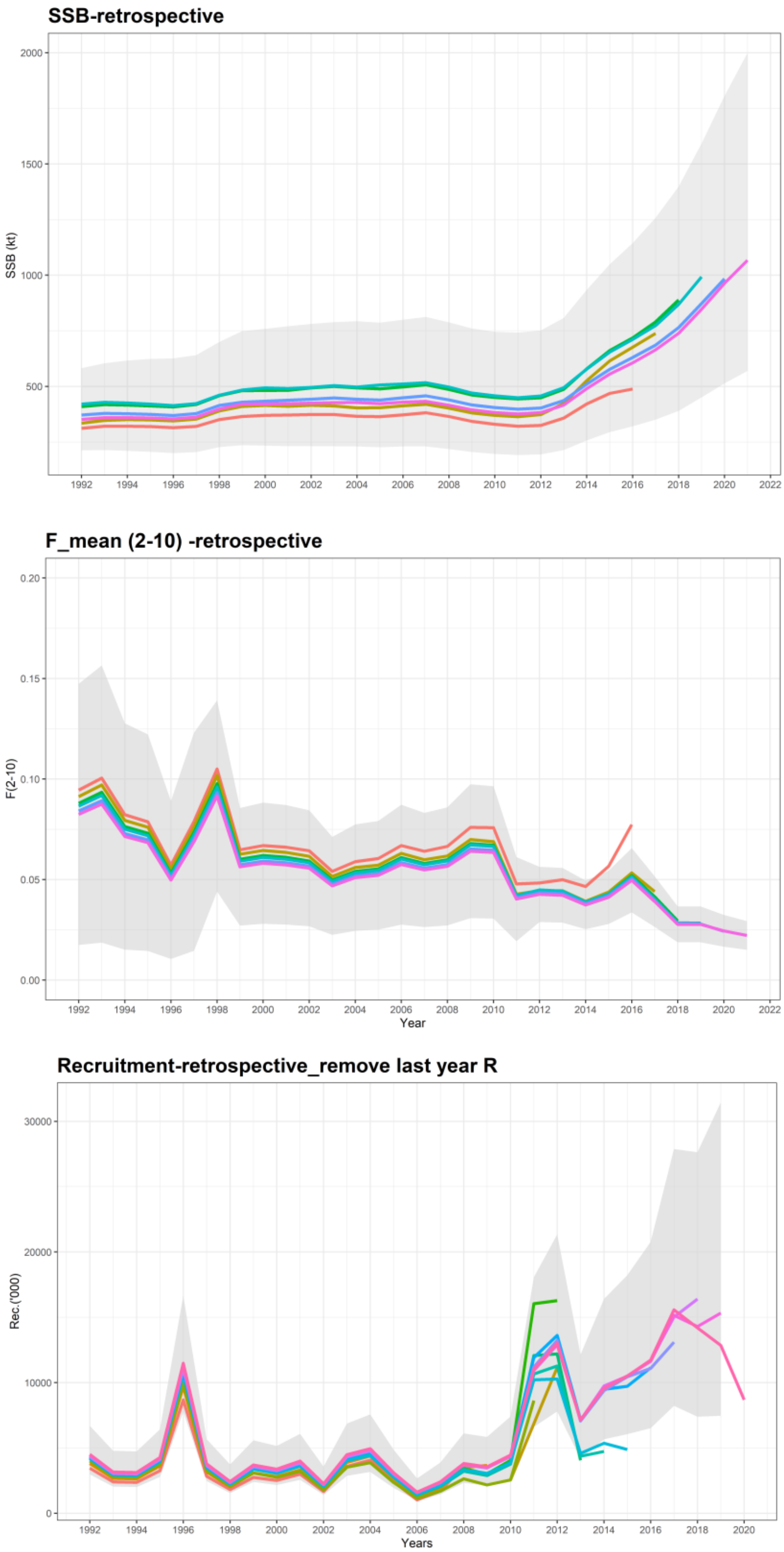


Figure 9.4.2.5. Horse mackerel in Division 9.a. Retrospective analysis results. Trajectories of SSB, Recruitment and Fbar (grey=95% confidence intervals for the current assessment and the retrospective assessments.

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 2021 and 2022, corresponding to the geometric mean recruitment of 1992–2020 (5 310 million fish). The abundance-at-age-1 in 2022 are the survivors of the geometric mean recruitment assumed for 2021. Weight-at-age in the catch and in the stock and fishing mortality of the last assessment year are assumed for the interim year. The input data used for the forecasts are presented in Table 9.5.1.

Table 9.5.2 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 0.022), 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 are the recruitment assumed for 2020-2022, the assumptions on a stable mean fishing mortality and the likely changes in the fishery selection pattern in most recent years (see section 9.4.2).

Table 9.5.1. Horse mackerel in Division 9.a. Input for southern horse mackerel short-term forecast (2022–2024) scenarios. N – number of fish;(in thousands), Sel – Selectivity (F-at-age), SWt and CWt – mean weight in the stock and in the catch (in kg).

2022						
Age	N	M	Mat	SWt	Sel	CWt
0	5309945	0.9	0	0.015	0.004	0.015
1	2149252	0.6	0	0.027	0.023	0.027
2	1883495	0.4	0.36	0.054	0.028	0.054
3	1811502	0.3	0.82	0.077	0.027	0.077
4	1433753	0.2	0.95	0.098	0.025	0.098
5	1245009	0.15	0.97	0.129	0.021	0.129
6	774518	0.15	0.99	0.154	0.017	0.154
7	570179	0.15	1	0.183	0.021	0.183
8	427534	0.15	1	0.226	0.021	0.226
9	264801	0.15	1	0.248	0.021	0.248
10	401431	0.15	1	0.278	0.021	0.278
11	682284	0.15	1	0.335	0.021	0.335
2023						
Age	N	M	Mat	SWt	Sel	CWt
0	5309945	0.9	0	0.015	0.004	0.015
1	-	0.6	0	0.027	0.023	0.027
2	-	0.4	0.36	0.054	0.028	0.054
3	-	0.3	0.82	0.077	0.027	0.077
4	-	0.2	0.95	0.098	0.025	0.098
5	-	0.15	0.97	0.129	0.021	0.129
6	-	0.15	0.99	0.154	0.017	0.154
7	-	0.15	1	0.183	0.021	0.183
8	-	0.15	1	0.226	0.021	0.226
9	-	0.15	1	0.248	0.021	0.248
10	-	0.15	1	0.278	0.021	0.278
11	-	0.15	1	0.335	0.021	0.335

2022						
2024						
Age	N	M	Mat	SWt	Sel	CWt
0	5309945	0.9	0	0.015	0.004	0.015
1	-	0.6	0	0.027	0.023	0.027
2	-	0.4	0.36	0.054	0.028	0.054
3	-	0.3	0.82	0.077	0.027	0.077
4	-	0.2	0.95	0.098	0.025	0.098
5	-	0.15	0.97	0.129	0.021	0.129
6	-	0.15	0.99	0.154	0.017	0.154
7	-	0.15	1	0.183	0.021	0.183
8	-	0.15	1	0.226	0.021	0.226
9	-	0.15	1	0.248	0.021	0.248
10	-	0.15	1	0.278	0.021	0.278
11	-	0.15	1	0.335	0.021	0.335

Table 9.5.2. Horse mackerel in Division 9.a. Short-term forecast (2022–2024) for southern horse mackerel. Catch and SSB (at spawning time) in tonnes.

			2022		2023		2024
	Fmult	Fbar	SSB	Catch	SSB	Catch	SSB
F=0	0.00	0.00			1202540	0	1241548
$F_{sq} = F_{2020}$	1.00	0.02	1155488	24155	1201486	25956	1214321
F_{sq}*1.2	1.20	0.03			1201275	31083	1208949
F_{sq}*1.6	1.60	0.04			1200854	41273	1198277
F_{sq}*2.0	2.00	0.04			1200432	51378	1187701
F_MP	4.95	0.11			1197330	123365	1112580
$F_{MSY;}$ F_{pa}	6.75	0.15			1195440	165173	1069137
F_{lim}	8.55	0.19			1193554	205452	1027417
SSB_{2024}=MSY $B_{trigger}$=B_{pa}	88.20	1.96			1113050	1074965	181000
SSB_{2024}=B_{lim}	114.50	2.54			1087697	1169479	103000

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}) were 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 lead 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 2022 of 165 173 tonnes. The catch advice for 2023 under the MSY approach, represents a significant increase of 528% compared with catches observed in 2021. 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 based on Ftarget=0.11 (previous F_{MSY}), developed within the PELAC-SWWAC framework, that has been evaluated as precautionary by ICES(ICES, 2018). 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 2023 TAC is not based on the plan and the stability clause does not apply. Last year, ICES has redefined Fpa as Fp0.5 (the F that leads to SSB ≥ Blim with 95% probability) (ICES, 2021) and this lead 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 2021, 21% of the catch consisted of

Trachurus spp. (5757 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.

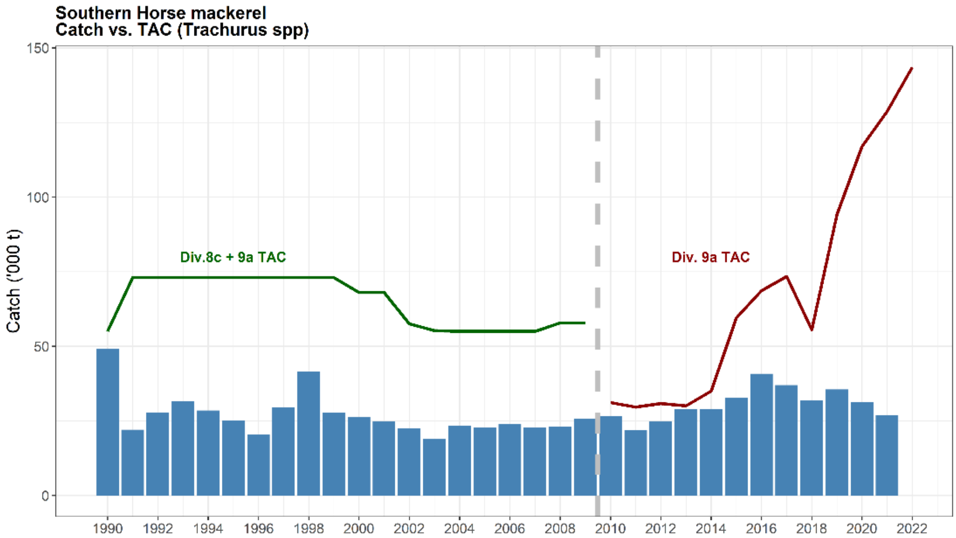


Figure 9.7.1. Horse mackerel in Division 9.a. Catch and TAC for southern horse mackerel. Blue bars show catches for southern horse mackerel, green line shows combined TAC for horse mackerel in division 8c and 9a and red line shows TAC for horse mackerel in division 9a.

9.8 References

Costa, A. M. 2009. Macroscopic vs. microscopic identification of the maturity stages of female horse mackerel. – ICES Journal of MarineScience, 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.

10 Blue jack mackerel (*Trachurus picturatus*) in Subdivision 10.a.2 (Azores grounds)

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.

10.1.1 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.

10.1.2 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.

10.1.3 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.

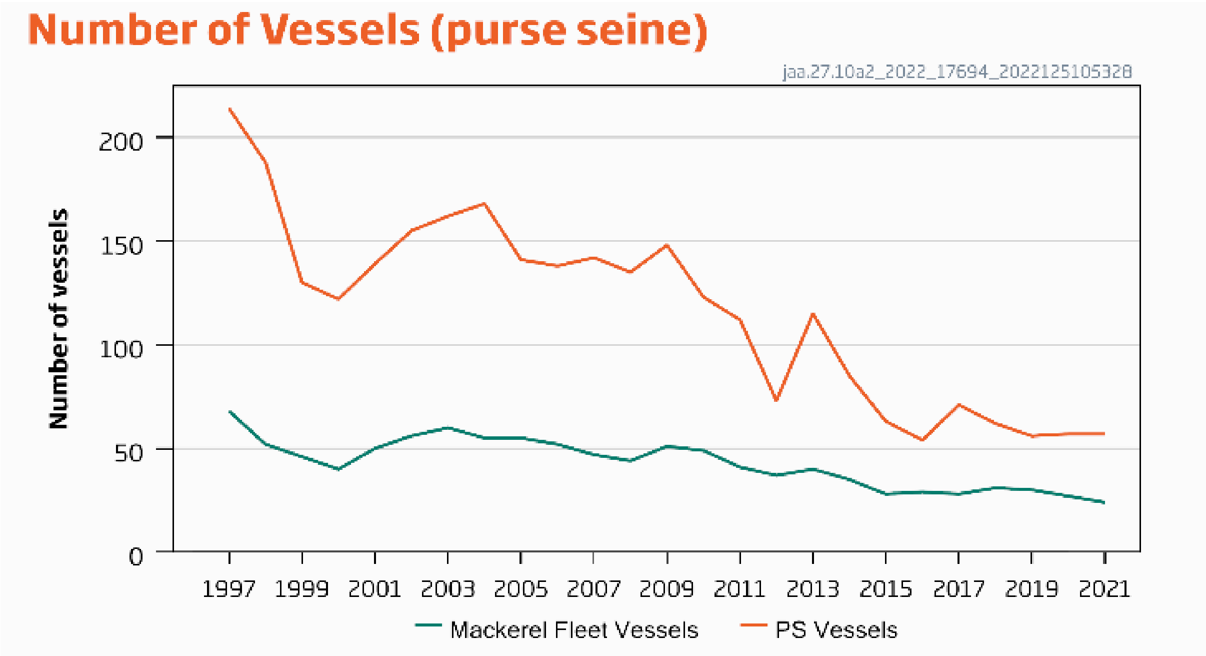


Figure 10.2.1.1. Blue jack mackerel in Azores grounds. Number of small purse-seine vessels and the number of vessels of the "Mackerel fleet" in the Azores (ICES Subdivision 10.a2) from 1997 to 2021.

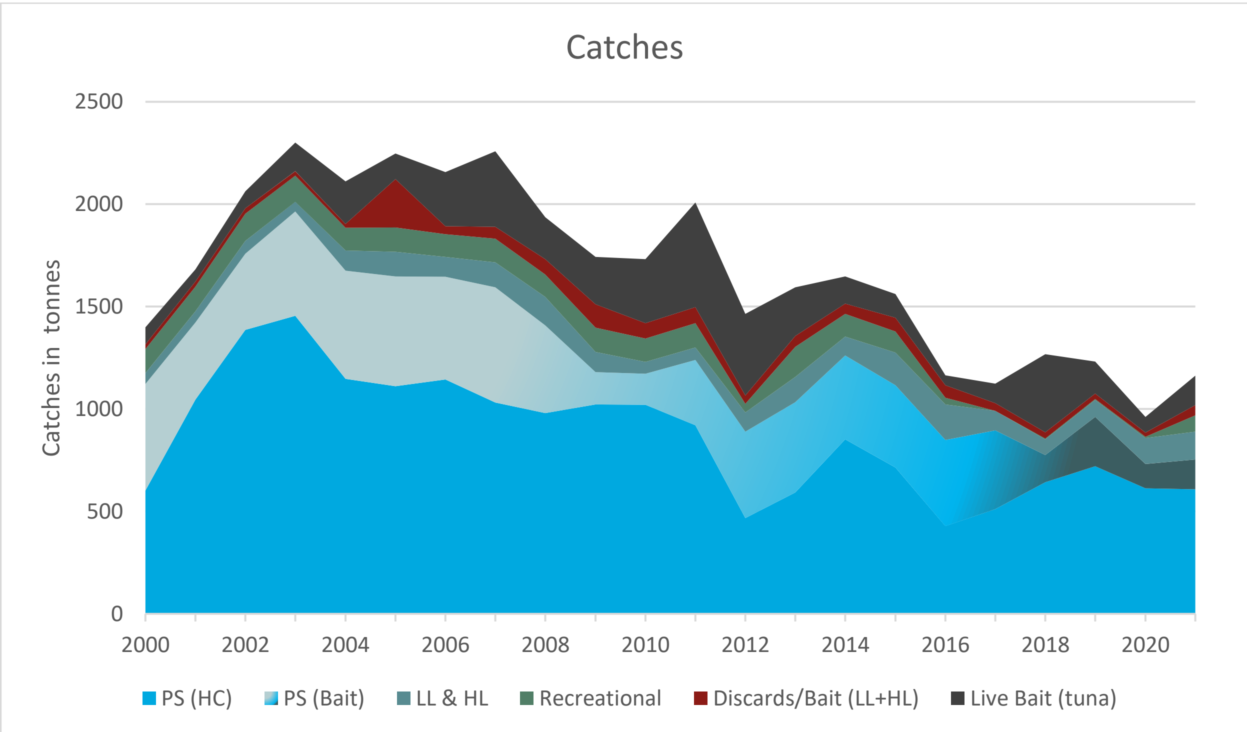


Figure 10.2.2.1. Blue jack mackerel in Azores grounds. Landings and other catches. Landings include purse-seine catches for human consumption – PS (HC) – purse-seine catches for bait – PS (Bait) – and have unsold purse-seine landings withdrawn at the port as well as longline and handline landings (LL & HL). Other catches include recreational catches, discards/longline bait, and tuna live bait.

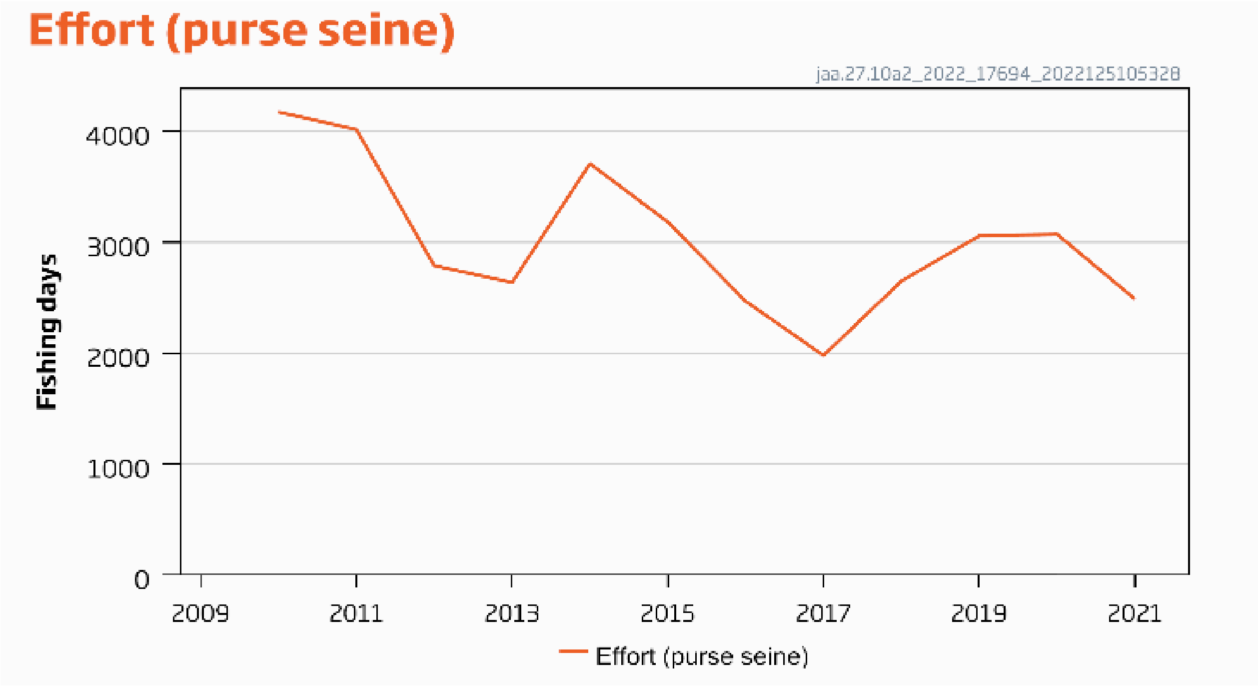


Figure 10.2.3.1. Blue jack mackerel in Azores grounds. Nominal effort (number of Fishing days) of the "Mackerel fleet" for 2010 – 2021.

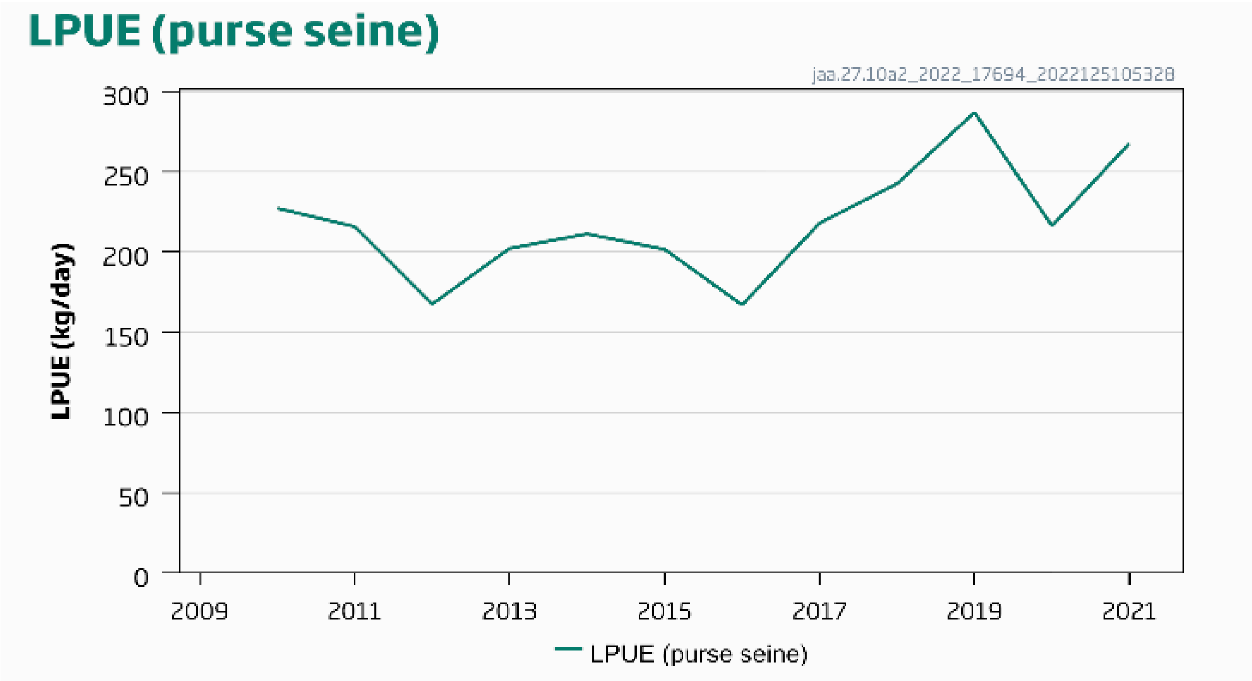


Figure 10.2.3.2. Blue jack mackerel in Azores grounds. Nominal LPUE (kg/day) of the "Mackerel fleet" for 2010 – 2021.

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)[1]	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
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
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

[1] 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.

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Annex 2: Working Documents

The following working documents were presented to WGHANSA 2021 and are presented in full in Annex 2:

Derhy G., Macías D., Khalil K., Elkalay K., Rincón, M.M. Assessing the impact of external environmental drivers on Atlantic Chub Mackerel (Scomber colias) population dynamics Garrido et al. Anchovy ID

Garrido S., Costa A.M., Nunes C., Pechirra P., Mendes H., Silva R., Milhazes R., Silva A.V., Silva C., Wise L., Silva A. Reproductive characteristics of western component 27.9.a anchovy.

Garrido S., Rodríguez-Ezpeleta N., Ramos F., Rincón M., Feijó D., Moreno A., Castilho R., Díaz N., Da Fonseca R.R., Francisco S.M., Manuzzi A., Silva G., Uriarte A. Population structure of the European anchovy (Engraulis encrasicolus) in ICES Division 9.a.

Ramos F., Córdoba P., Tornero J., Sánchez M.J. and Navarro, R. Acoustic assessment and distribution of the main pelagic fish species in ICES Subdivision 9.a South during the ECOCADIZ-RECLUTAS 2021-10 Spanish survey (October 2021).

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 2022).

Silva A.A., Wise L., Ramos F., Rincón M.M., Garrido S., Uriarte A. and Mildenberger T. Exploratory assessment of anchovy 27.9.a West using a surplus production model.

Wise L., Silva A. A., Uriarte A. and Garrido S. Life-history parameters of anchovy 9.a western component.

Gadget for anchovy 9a South: Model description and results to provide catch advice and reference points (WGHANSA-1 2022)

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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 $y = 1989, \ldots, 2022$, 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-**2021** and $T = 3$ to 1989-**2021**.

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-**2021**) 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 **2021** and **2022** 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 technical problems there are no data available for ECOCADIZ survey in 2021.
- The model was implemented quarterly from 1989 to the second quarter of **2022**.
- All commercial fleets where grouped into only one from 1989 to **2022** 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 **2022**, 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 **2021**. 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 **2021**.
- 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.

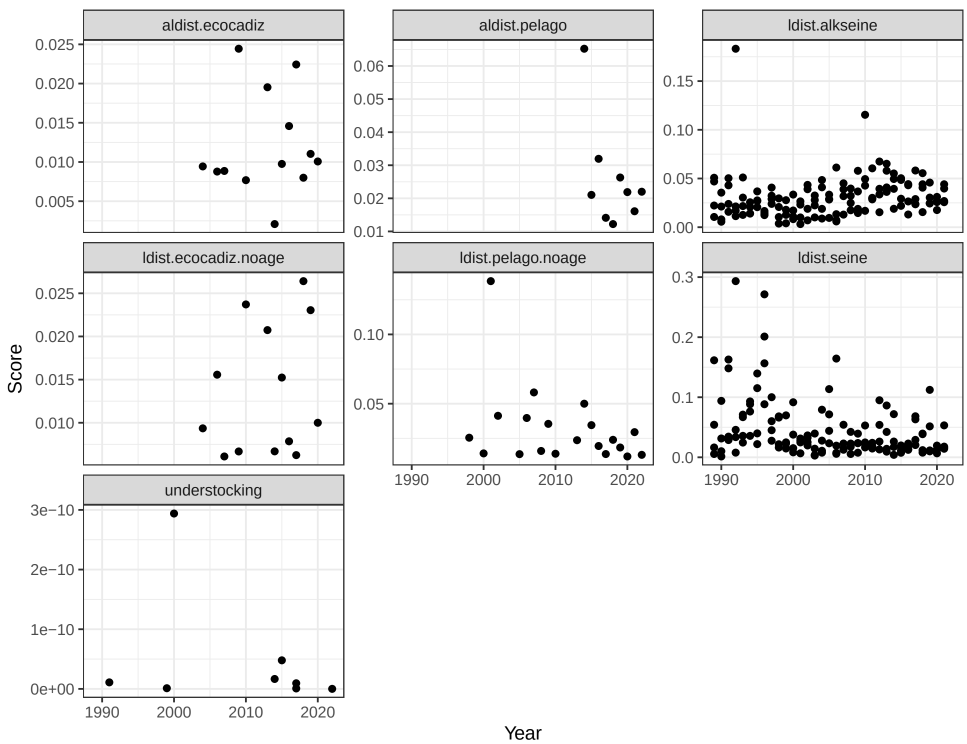

Figure 1: Likelihood scores for age-length key of ECOCADIZ survey, PELAGO survey and commercial landings (Upper panel) and length distribution of ECOCADIZ survey, PELAGO survey and landings. Dots represent the score for each quarter.

Index	
a	Age, $a = 0,\ldots,3$
l	Length, $l = 3,3.5,4,4.5,\ldots,22$
y	Years, $y = 1989,\ldots,2022$
t	Quartely timestep, $t = 1,\ldots,4$
T	$T = 1$ for period 1989-2000, $T = 2$ for period 2001-2021
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_∞=28.4296
k	Annual growth rate, $k = 0.0772549$
β	Beta-binomial parameter, $\beta = 5000$
ν_a	Age factor, $\nu_0 = 120000, \nu_1 = 116000,$
	$\nu_2 = 0.0607, \nu_3 = 9.2e-07$
μ	Recruitment mean length, $\mu = 10.313$
σ_t	Recruitment length standard deviation by quarter, $\sigma_2 = 2.60238$, $\sigma_3 = 2.59163$, $\sigma_4 = 1.79378$
$l_{50,T}$	Length with a 50% probability of predation during period T,
	$l^{seine}_{50,1} = 12.6$, $l^{seine}_{50,2} = 10.8$, $l^{ECO}_{50,3} = 13$, $l^{PEL}_{50,3} = 14.3$
α_T	Shape of function, $\alpha^{seine}_1 = 0.193$, $\alpha^{seine}_2 = 0.764$, $\alpha^{ECO}_3 = 1.31$, $\alpha^{PEL}_3 = 0.406$
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-**2021**	See eq. 7
(discards from 2014 onwards)	Age-length key	All quarters, 1989-**2021**	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 2013-2022	
	length distribution	First quarter 1999, 2001-2003	see eq. 7
		second quarter 2005-2010, 2013-2022	
	Age-length key	second quarter 2014-2022	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

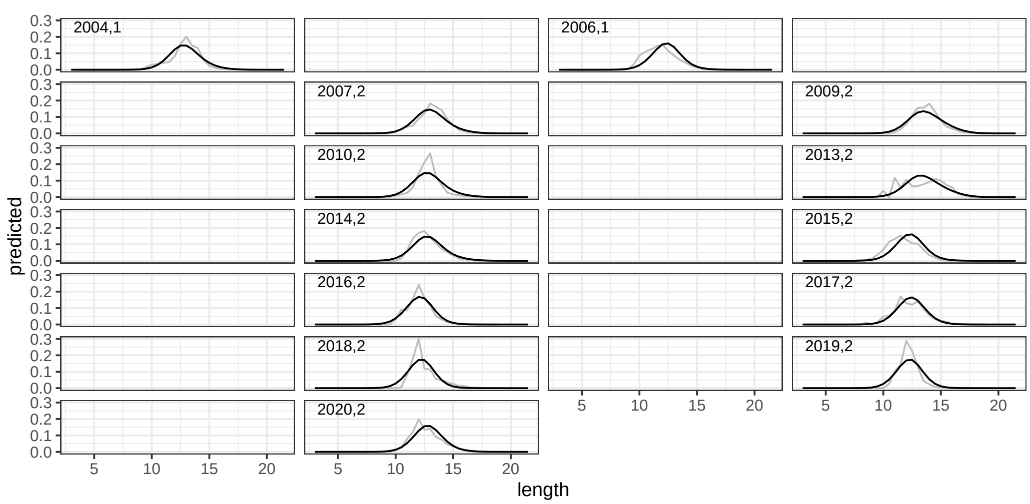

Figure 3: Comparison between observed and estimated catches length distribution for ECOCADIZ survey. Black lines represent estimated data while gray lines represent observed data

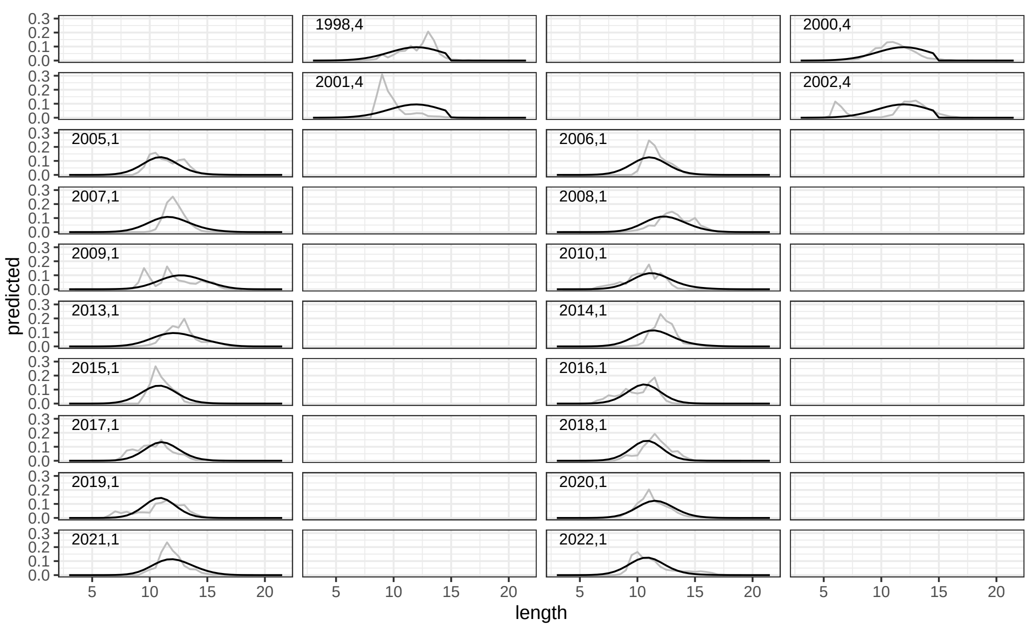

Figure 4: Comparison between observed and estimated catches length distribution for PELAGO survey. Black lines represent estimated data while gray lines represent observed data

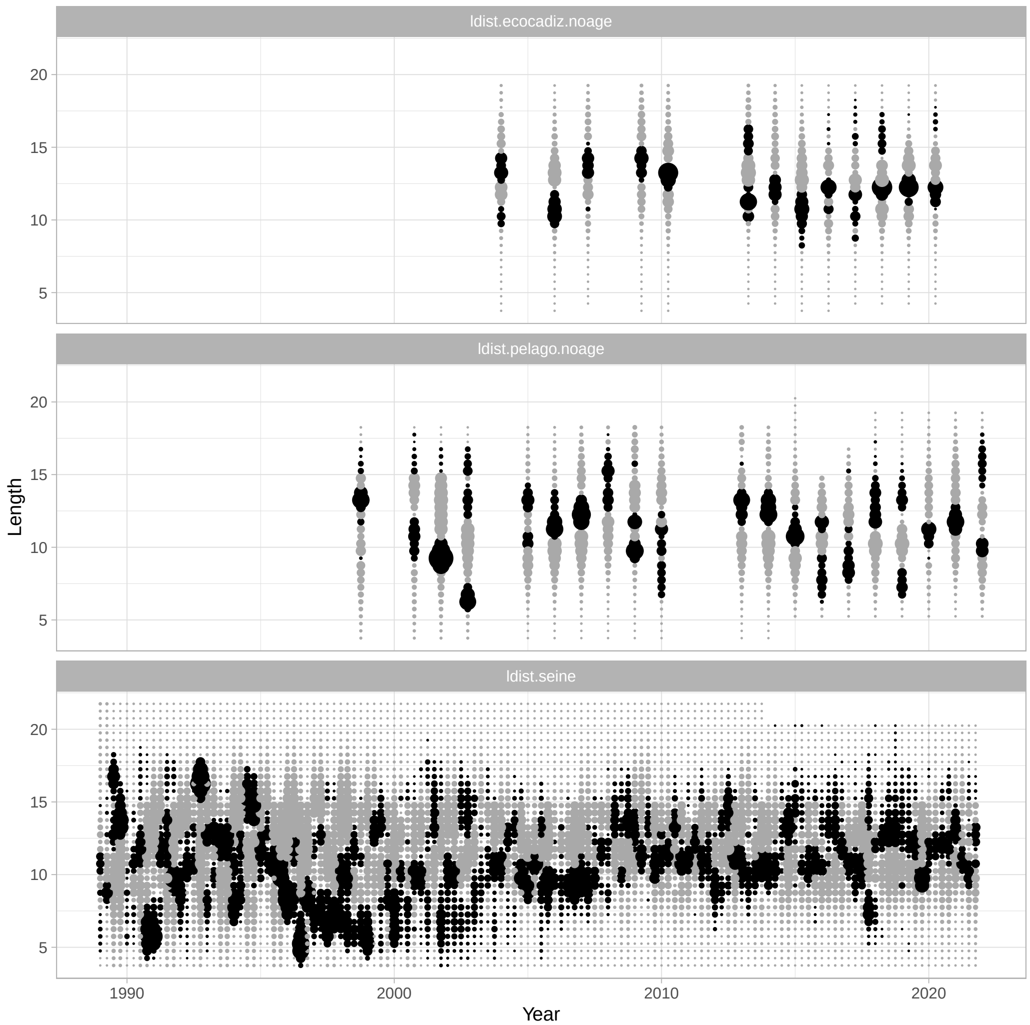

Figure 5: Standardised residual plots for the fitted length distribution from the ECOCADIZ survey, PELAGO survey and commercial landings. Black points denote a model underestimate and gray points an overestimated. The size of the points denote the scale of the standardised residual.

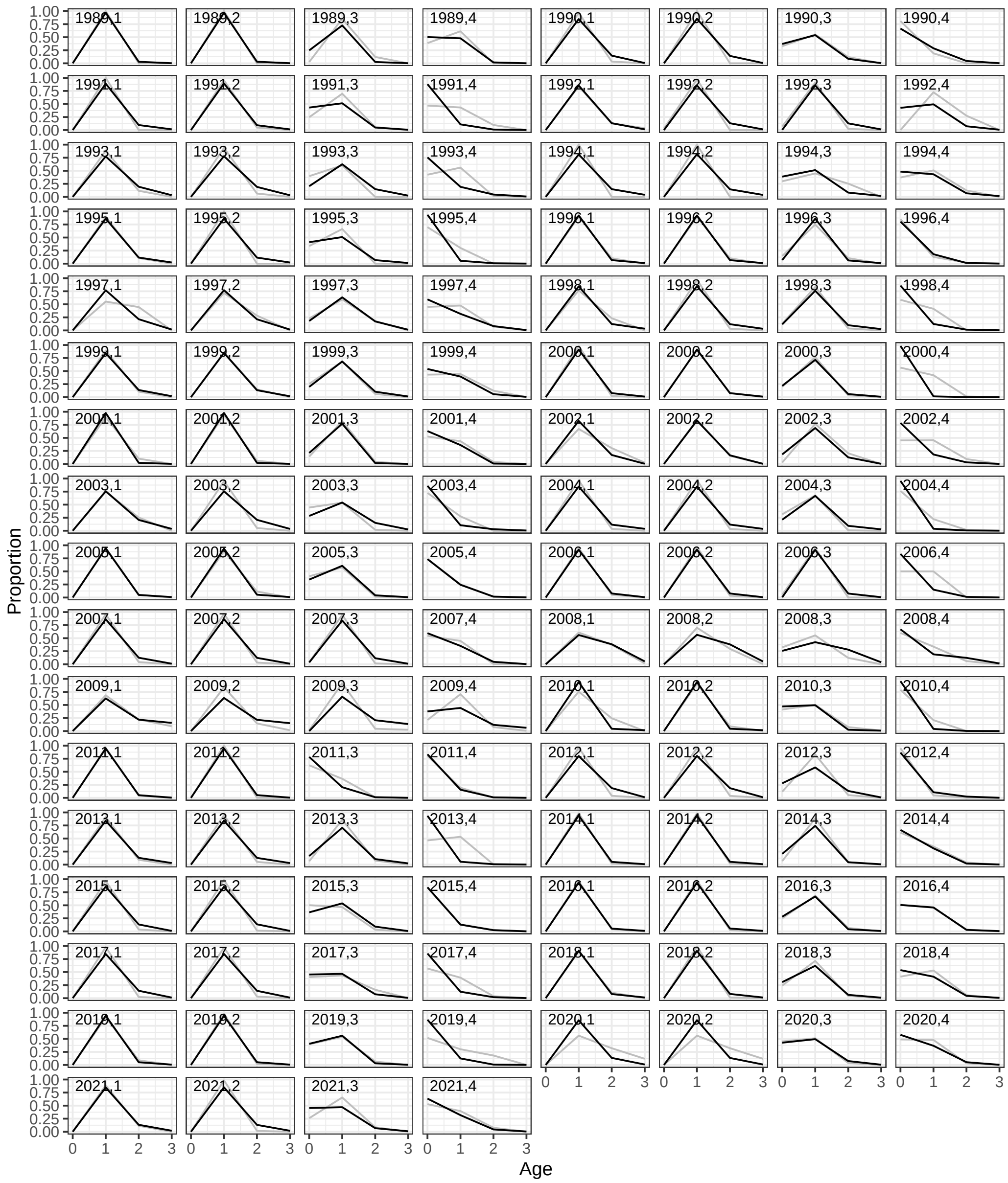

Figure 6: Comparison between observed and estimated catches age distribution. Black lines represent estimated data while gray lines represent observed data.

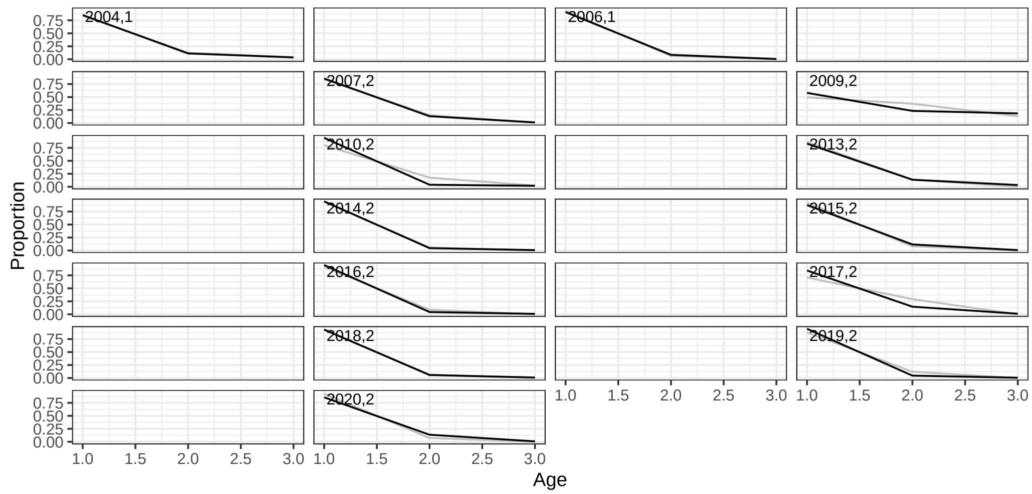

Figure 7: Comparison between observed and estimated ECOCADIZ survey age distribution. Black lines represent estimated data while gray lines represent observed data.

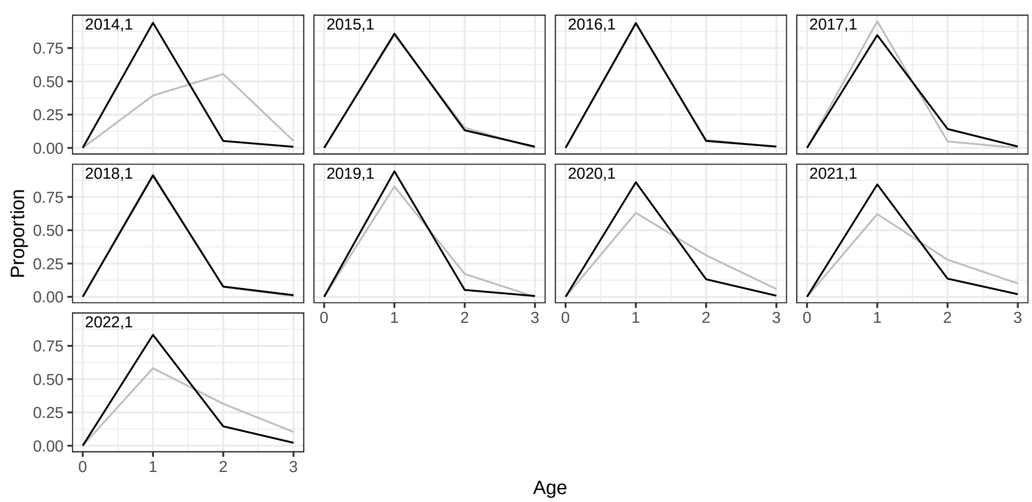

Figure 8: Comparison between observed and estimated PELAGO survey age distribution. Black lines represent estimated data while gray lines represent observed data.

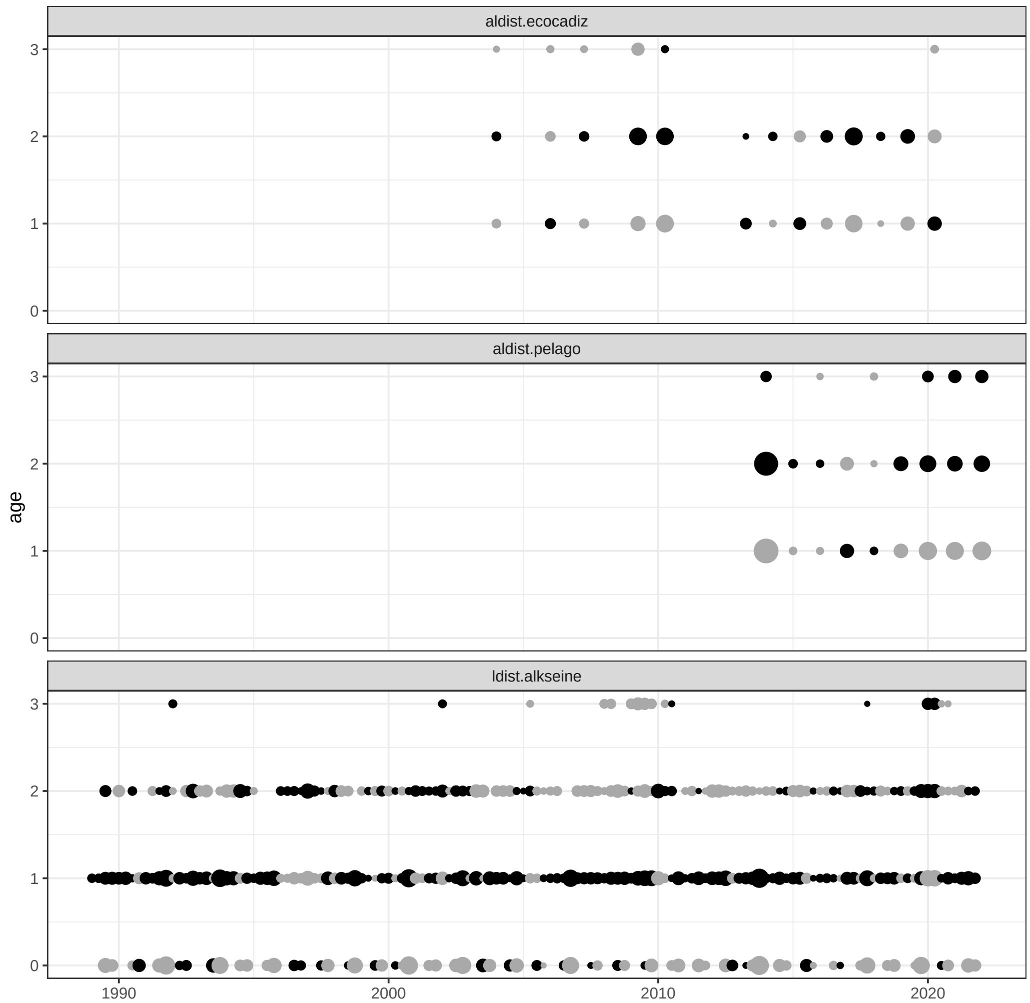

Figure 9: Standardised residual plots for the fitted age distribution from the ECOCADIZ survey, PELAGO survey and commercial fleet. Black points denote a model underestimate and gray points an overestimated. The size of the points denote the scale of the standardised residual.

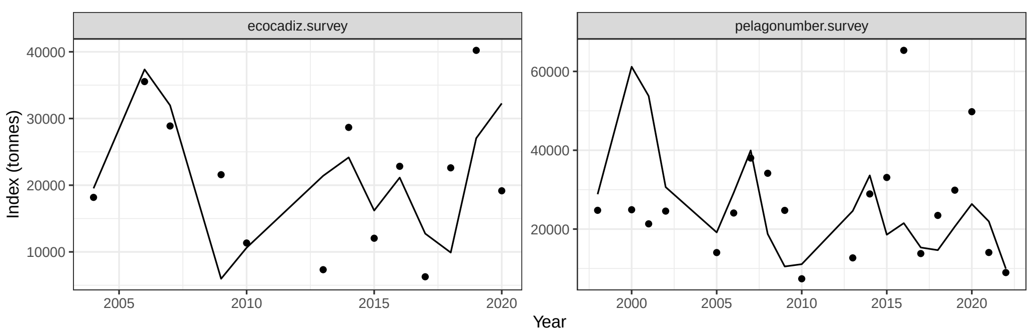

Figure 10: Comparison between observed and estimated survey indices. Black points represent observed data while black line represent estimated data

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

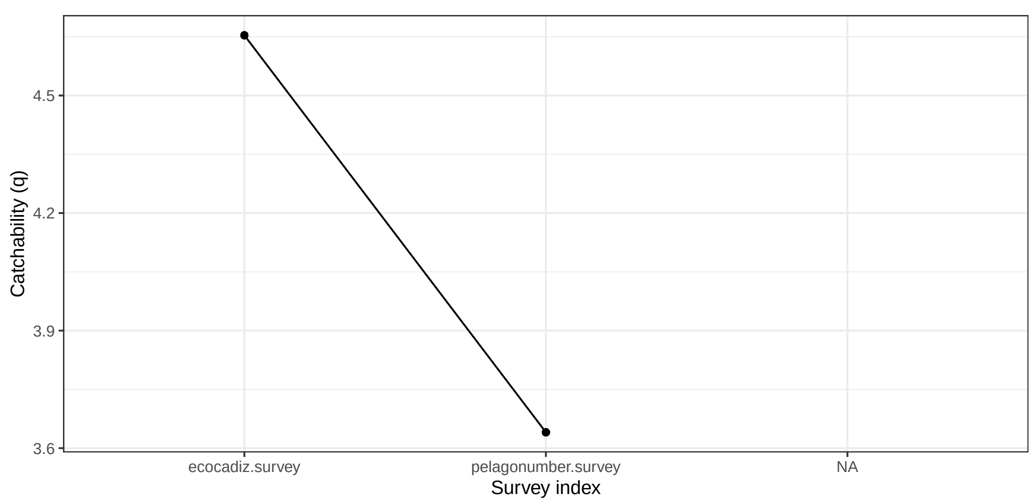

Figure 11: Estimated catchability parameters for the different survey indices

6.2. Estimated age composition

Figure 12 shows the estimated age composition of the population.

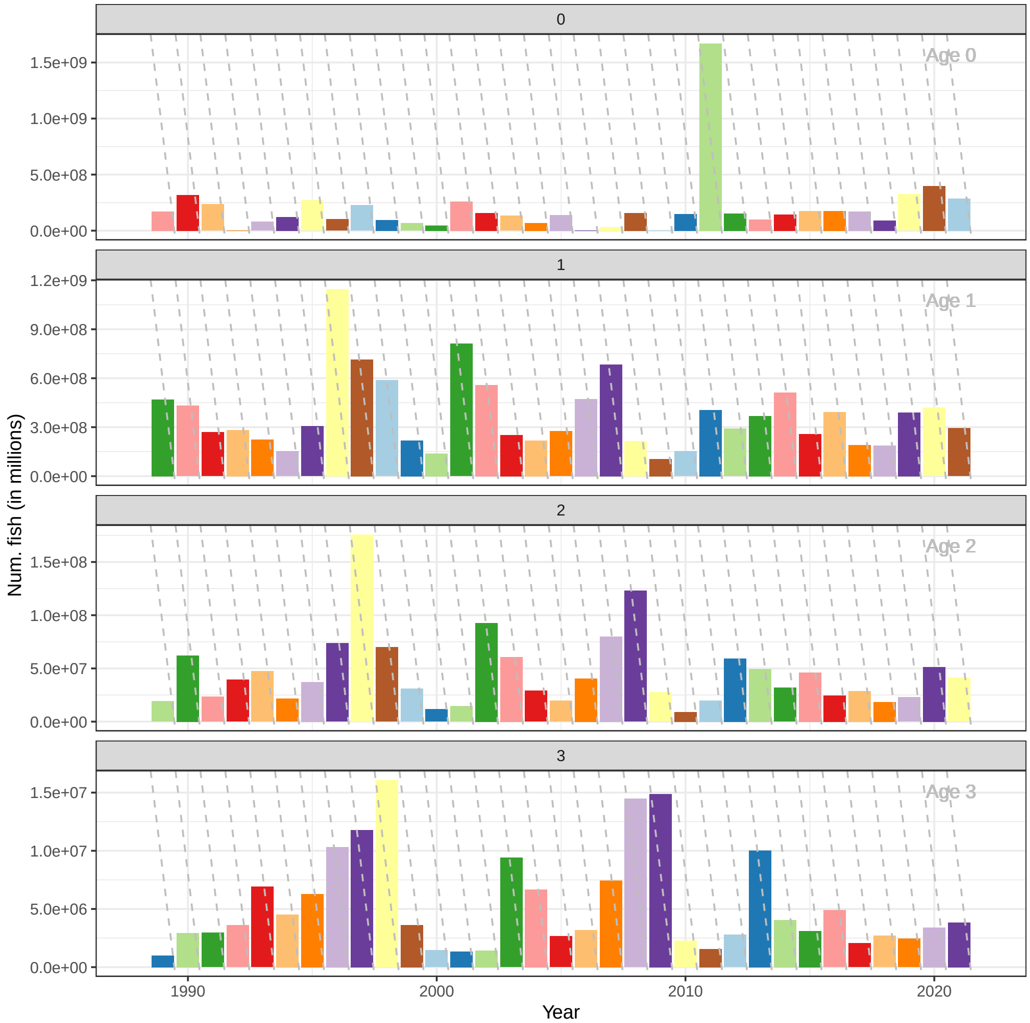

Figure 12: Estimated age composition of the population at the end of the second quarter for each year

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.

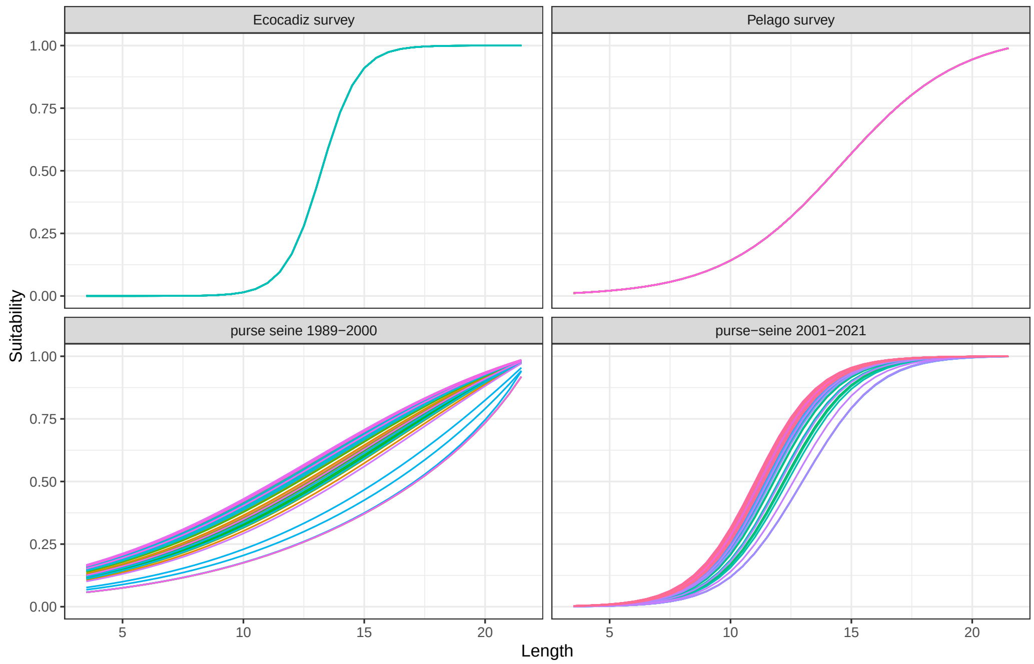

Figure 13: Estimated fleet suitability functions for the commercial fleet and different surveys.

6.5. Comparison with last year estimated time series and sensitivity analysis regarding missing information on the model used corresponding to the length distribution of ECOCADIZ survey in year 2020

A comparison with last year estimated time series, and also with those estimated by a model implementation with length distribution for ECOCADIZ survey in 2020 (that was missing in the last year model) is presented in Figure 16. The pink line represents last year estimated time series, the green line, the estimated by the same model but including the ECOCADIZ length distribution in 2020 and the blue line, the estimated by the model used this year (the one described in this document). It was observed that the estimated biomass for some of the last years is smaller when including the length distribution missing (green line) but population trend remains very similar. It is also important to remark that the number of iterations for the optimization process in the first model was 2000000, while in the others was just 1000000.

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

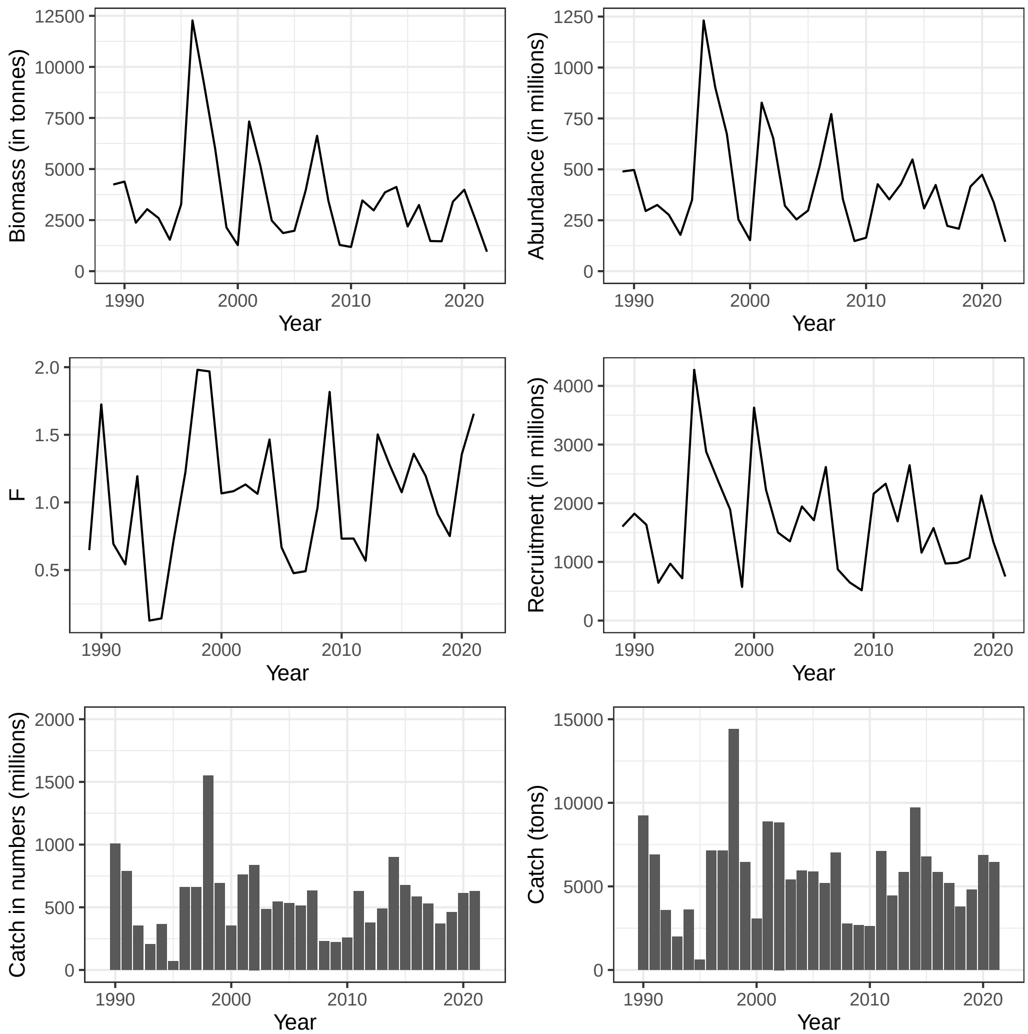

Figure 14: Annual catches time series (in numbers and biomass) compared with annual model estimates for abundance of individuals with more than one year of age(in numbers and biomass) recruitment and fishing mortality. Measures were summarized at the end of June each year, assuming that a year starts 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

possible according to the standard method and it is assumed to be equal to $Bloss$ ($B_{lim} = B_{loss}$). For **2022** the value of B_{loss} for the 9a South anchovy corresponds to the estimated SSB in **2010** (1186.34 t), hence B_{lim} is set at 1186.34 t and the relative B_{lim} (divided by the mean value of B_1+) results equal to 0.325. 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).

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

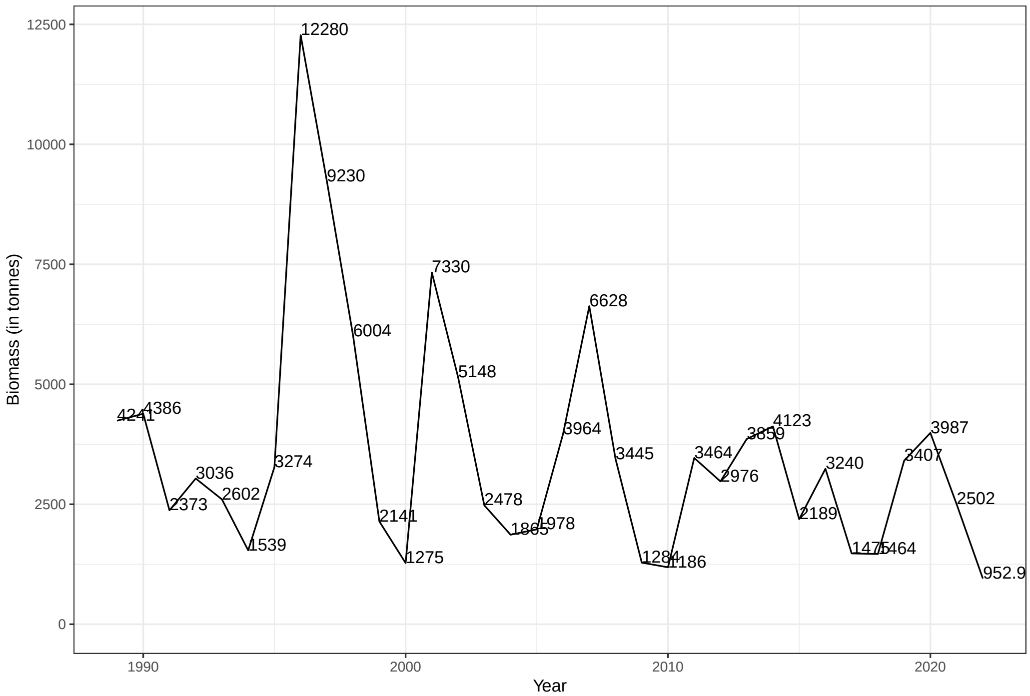

Figure 15: Estimated biomass time series at the end of quarter two (Age 0 removed to be consistent with recruitment at the end of the second quarter of the year). Note that under the assumption that all individuals in $B1+$ class are mature, this biomass is equivalent to SSB

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 1945.5976 t.

8. Catch advice for July 2022 to June 2023

The ratio between the last year biomass estimate and the mean of the two previous years is:

$$\frac{B_y}{B_{y-1} + B_{y-2}} = \frac{953}{(3987 + 2502)/2} = 0.2937$$

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:

$$C_{y+1} = \hat{C}_y * \min\left(1.8, \frac{B_y}{(B_{y-1} + B_{y-2})/2}\right) * \frac{B_y}{B_{lim}}$$

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 2022 to June 2023) would be:

$$C_{y+1} = 7181 * 0.294 * 0.803 = 1694.$$

This procedure modification has been implemented since this year and it is not specified in the Stock annex.

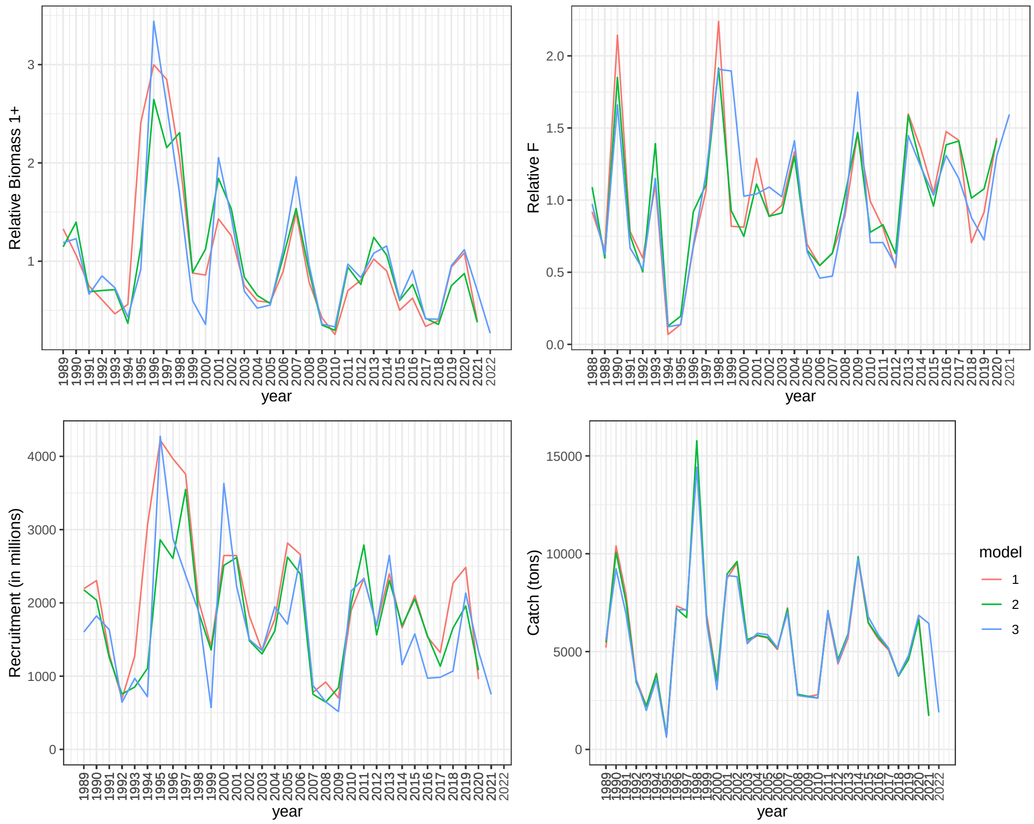

Figure 16: Comparison of estimates from different model implementations.1. Model used last year (pink), 2. Model used last year but including the ECOCADIZ length distribution in 2020 (green), 3. Model described in this document which is the reference for the advice provided in 2022 (blue): Annual model estimates for relative abundance of individuals with more than one year of age, relative fishing mortality, recruitment and catches (in numbers). 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. It is also important to remark that the number of iterations for the optimization process in the first model was 2000000, while in the others was just 1000000.

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.

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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.

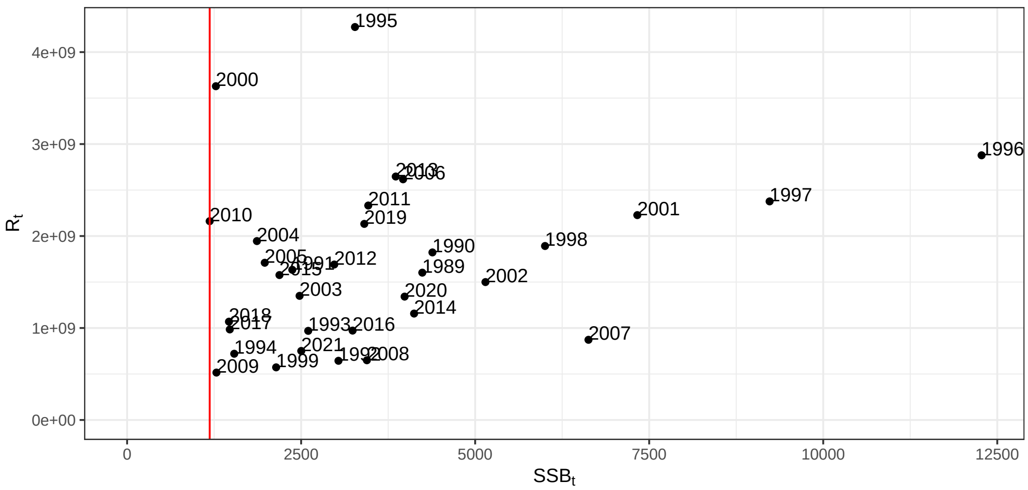

Figure 17: Estimated Stock Spawning biomass (SSB_t) vs. Recruitment (R_t), SSB_t corresponds to the Stock Spawning Biomass at the end of quarter 2 of year t, while R_t corresponds to the sum of the recruitment at the beginning of quarters 3,4 and 1 of years t and $t+1$, respectively.

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`.

Assessing the impact of external environmental drivers on Atlantic Chub Mackerel (*Scomber colias*) population dynamics

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Abstract:

Small pelagic fish populations are characterized by considerable inter-annual and inter-decadal fluctuation dynamics forced by fishing pressure and environmental factors. Nevertheless, knowledge of this environmental forcing remains very limited. The Northwestern African waters from Morocco to Mauritania are known as one of the most productive ecosystems in the world due to the upwelling, resulting in a significant abundance and variation of the catches of small pelagic species. Their population dynamics are strongly modulated by different environmental covariates. Therefore, the assessment of stock status considering the impact of environmental conditions on the population dynamics is a key issue for fisheries management. In the case of the Moroccan Atlantic coast, the chub mackerel represents one of the most important small pelagic fishery resources. To assess population abundance, it is necessary to use Data-Limited Methods (DLM) considering the limited biological data availability for this species in this region and also poor understanding of the effects of environmental forcing on stock size and distribution. The objective of this study is to evaluate the correlation between different environmental factors and population trend estimated by a DLM approach for stock assessment. To achieve this aim, the Surplus Production model in Continuous Time (SPiCT) is implemented to analyze the population fluctuations of the chub mackerel stock based on surveys and landing data. The estimated relative biomass trend is used to explore the influence of external environmental drivers on stock dynamics, which is considered in a second step of this study. The correlation analysis results show a significant correlation with salinity, net primary production, oxygen, nitrate and chlorophyll concentrations that are also consistent with spatio-temporal variations of the chub mackerel. The years with high biomass (above 75% of the mean) are linked to the very high physical variability of the upwelling, accompanied by specific variations of other environmental parameters that are also tested. Based on these results, the SPiCT model in which environmental covariates are modeled as random variability can be developed by integrating these relationships. The development of this model can help managers to improve stock assessment results to achieve a sustainable management and exploitation of the stock considering all external factors.

Working document presented to the:

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POPULATION STRUCTURE OF THE EUROPEAN ANCHOVY (*ENGRAULIS ENCRASICOLUS*) IN ICES DIVISION 9A

By

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ABSTRACT

The present WD summarizes the state-of-the art and presents new information on the stock structure of anchovy in the Division 27.9.a (Atlantic Iberian waters). This stock of 9a started to be assessed after its first benchmark in February 2018 (WKPELA 2018, ICES, 2018a). According to the information provided by WGHANSA, WKPELA 2018 supported considering two different stock components due to different fisheries and populations dynamics: The Western component – in ICES Sub-divisions 9a.N, 9aCN and 9aCS, and the Southern component – in ICES Sub-divisions 9a.S, for which advice is given separately. During the benchmark, it was advised to gather more information regarding the population structure of anchovy Iberian populations, namely genetic information, to decide if the two components should be managed as independent stocks. 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 most Portuguese landings (>90%) occurring in Subdivision 9a CN. Moreover, no correlation of anchovy catches was found between the Western and Southern components, further suggesting independent dynamics, and refuting the hypothesis of western population(s) arising from the southern component. A review of studies conducted in Portuguese estuaries show the persistent occurrence of recruits in numerous estuaries, mainly in the Subdivision 9a CN, 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. The information presented in this WD leads the WGHANSA to consider the anchovy populations inhabiting the southern and western Iberian regions and their exploited populations as spatially separated with independent dynamics (via their recruitment pulses) and therefore, should be considered separate stocks for management.

1. INTRODUCTION

The European anchovy, *Engraulis encrasicolus*, is a small pelagic coastal marine fish distributed from the North Sea to Southeast Africa, including the entire Mediterranean basin. This species supports an important fisheries and economic activities for the countries bordering the Iberian Peninsula and Mediterranean Sea (Uriarte *et al*., 1996; Lleonart and Maynou, 2002). Due to its market value, production, and wide distribution in several East Atlantic and Mediterranean countries, anchovy is a major shared resource in the region. For management purposes, the European anchovy was separated in two distinct stock units, one distributed in the Bay of Biscay (Subarea 8) and the other distributed in ICES Division 9a (Portuguese coast and Spanish waters of the Gulf of Cadiz). Further north this species is not assessed. However, these stock limits were essentially based on administrative considerations.

A review on the sub-stock structure of the European anchovy in the Bay of Biscay and Iberian-Atlantic waters was provided by Ramos (2015) to the ICES Stock Identification Methods Working Group (SIMWG) in 2015. The evidence presented in that document suggested the existence of a stable population in the Gulf of Cadiz that seems to be relatively independent of the remaining populations in Division 9a. At that time, the ICES SIMWG (ICES, 2015a) considered that there was evidence to support a self-sustained population of anchovy located in the Gulf of Cadiz (ICES Subdivision 9a South, 9aS), but there was a lack of information regarding the origin of European anchovy in ICES Subdivisions 9a North (9aN), 9a Central-North (9aCN) and 9a Central-South (9aCS) (Fig. 1). At the time the stock was benchmarked (WKPELA 2018), an updated review of anchovy stock structure was provided (Garrido et al. 2018), including new information of the potential connectivity of anchovy population of the 9a West subdivisions with the South Iberian population. Data on spatial distribution of surveys and landings identified a discontinuity of anchovy distribution in the southwestern Iberia, separating the western and southern populations. Different dynamics of western and southern populations were identified. A summary of studies on genetics and morphometry was presented, pointing to a differentiation of western and southern anchovy populations. These evidences led WKPELA to support the proposal of considering two different components of the stock (western and southern components) for which the advice should be given separately, but the evidence was not consensually considered sufficient to modify the current stock structure. New studies on genetics and otolith microchemistry, aimed at elucidating the identity and structure of anchovy populations in the western component were still in progress. WKPELA suggested to present both, the available evidences and the resulting new evidence from these undergoing studies to the ICES Stock Identification Methods Working Group for future consideration. Still, 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.

In the present WD we i) compile and summarize the information presented previously on the stock structure of anchovy, ii) update the analysis of the historical dynamics of landings and surveys, iii) describe new evidence that point to independent dynamics of western and southern Iberian anchovy populations.

2. SPATIAL DISTRIBUTION OF ANCHOVY IN DIVISION 27.9.A

The distribution of anchovy in Division 9.a (Fig. 1) was investigated by using all the available information of the scientific cruises carried out regularly in the area, and covering several life-stages (eggs, juveniles and adults) and seasons of the year (spring, summer, fall). In what follows, the historical data of the distribution of the species will be shown for the indices derived from those cruises and those covering most of the division 9.a (PELAGO, PT-DEPM, Portuguese Trawl Surveys).

Figure 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)).

2.1. HISTORIC DYNAMICS OF SURVEY DATA

2.1.1. SPRING ACOUSTIC SURVEYS

There are 3 spring acoustic surveys 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 Portugal and the Gulf of Cadiz (Fig. 2). 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 north western Portuguese coast, North of Cape Mondego (~40°N).

There is a gap in the distribution of adult anchovy in the western side of the Cantabrian Sea and in the southwestern Portuguese coast.

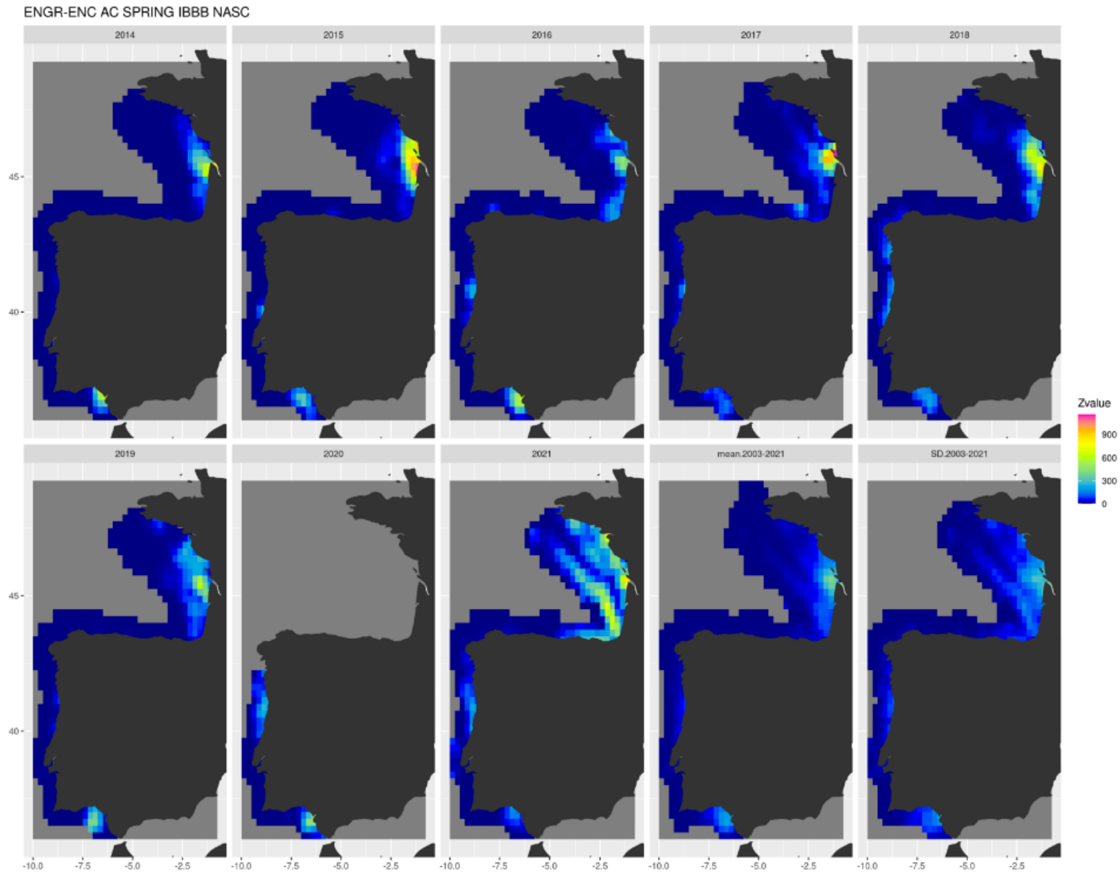

Figure 2 Mean acoustic density (NASC, m².NM-²) of anchovy in surveys PELGAS, PELACUS and PELAGO 2014 to 2021. Last two maps: mean and standard deviation from 2003 to 2021. Source: ICES WGACEGG 2021 Report.

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 north western coast of Portugal (Fig. 3). However, it should be noted that peak spawning for anchovies in Division 9a generally occurs two months after these surveys.

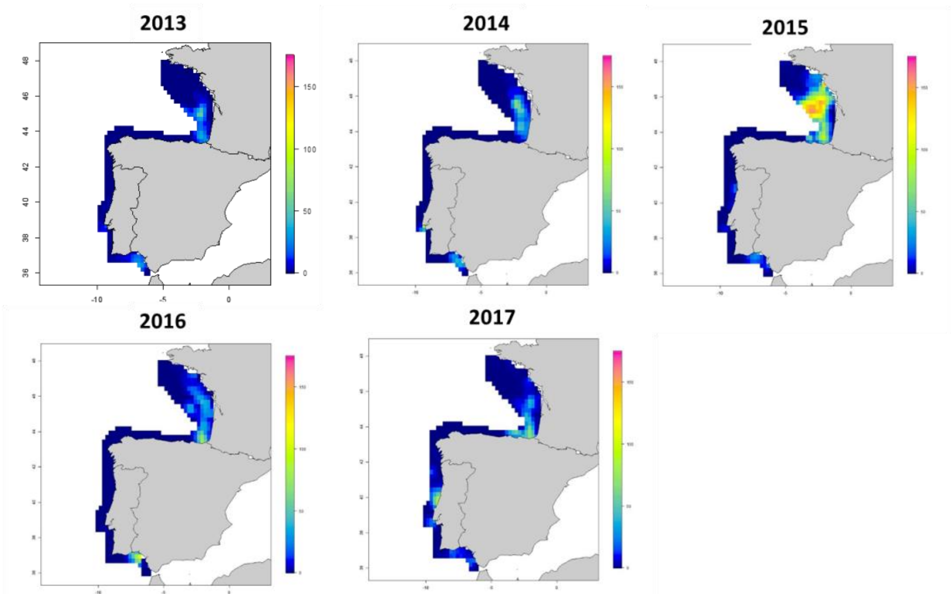

Figure 3. Anchovy egg density (eggs m^{-3}) distribution derived from CUFES sampling during the spring acoustic surveys, PELGAS (Ifremer), PELACUS (IEO) and PELAGO (IPMA) for the period 2013-2017. Source: ICES WGACEGG 2017 Report.

2.1.1.1. PELAGO SURVEY SERIES

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). Acoustic surveying is undertaken along 71 transects perpendicular to the coast, covering the whole platform, and separated approximately 6 (south) or 8 nm (west). Fishing hauls are carried out for species ground-truthing and fish size composition. Zooplankton samples are collected underway every 3 nm, with the CUFES system (water pumped from 3m from the surface, system fitted with a 335 µm mesh size net), concurrently to the acoustic surveying along the trajectory of the acoustic transects. As described above, detailed observation of the PELAGO results (Fig. 4) allows the identification of two main centres of anchovy distribution, in Cadiz and in the north western Portuguese coast.

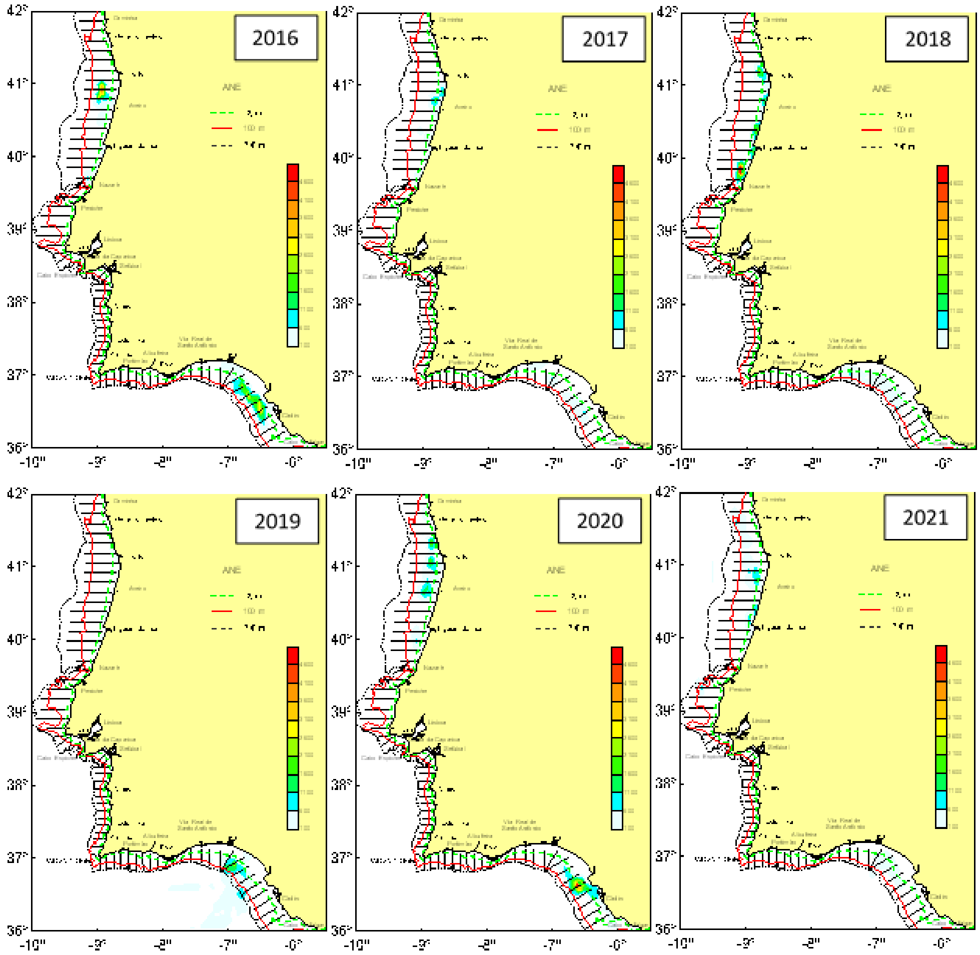

Figure 4 – Acoustic density (NASC, m².nm-²) of anchovy in PELAGO survey series from 2016 to 2021.

Egg distribution assessed in the PELAGO survey (conducted near or at the beginning of anchovy spawning season) shows a recurrent concentration of eggs in the Gulf of Cadiz and in the area from Cape Carvoeiro to Cape Espichel (North-western Portugal) (Fig 5). Occasionally, some eggs are detected off River Mira (south of Cape Sines) in the southwestern coast. The major egg densities in the western Iberia occur more often in the central region off Ria de Aveiro – River Mondego area. The anchovy egg distribution is highly variable between years. During years of high abundance, the southern coast appears almost entirely occupied, with observations from the inner Cadiz Bay to Cape S. Vincente, while during low abundance periods the distribution is retracted to the Spanish waters. Likewise, in the west coast during years of higher abundances anchovy eggs may be observed in a larger area occupying the northwestern and the north part of the southwestern Portuguese coast (e.g. in 2017) while during low density periods may only be observed in the core areas. It is worth noting that the spawning period for anchovy in the area covered by the PELAGO survey is from May to July. Unplanned delays that occurred in the 2016 and 2017 surveys have contributed to the higher anchovy egg abundances observed since the survey was conducted. In fact, 2017 was the year with the record high anchovy egg abundances during the PELAGO survey series and the following year (2018) the second highest peak on anchovy abundance was registered. The highest egg densities were observed on the northwest coast and in good agreement with the detection of anchovy, where high fish abundances were also registered during the previous spring.

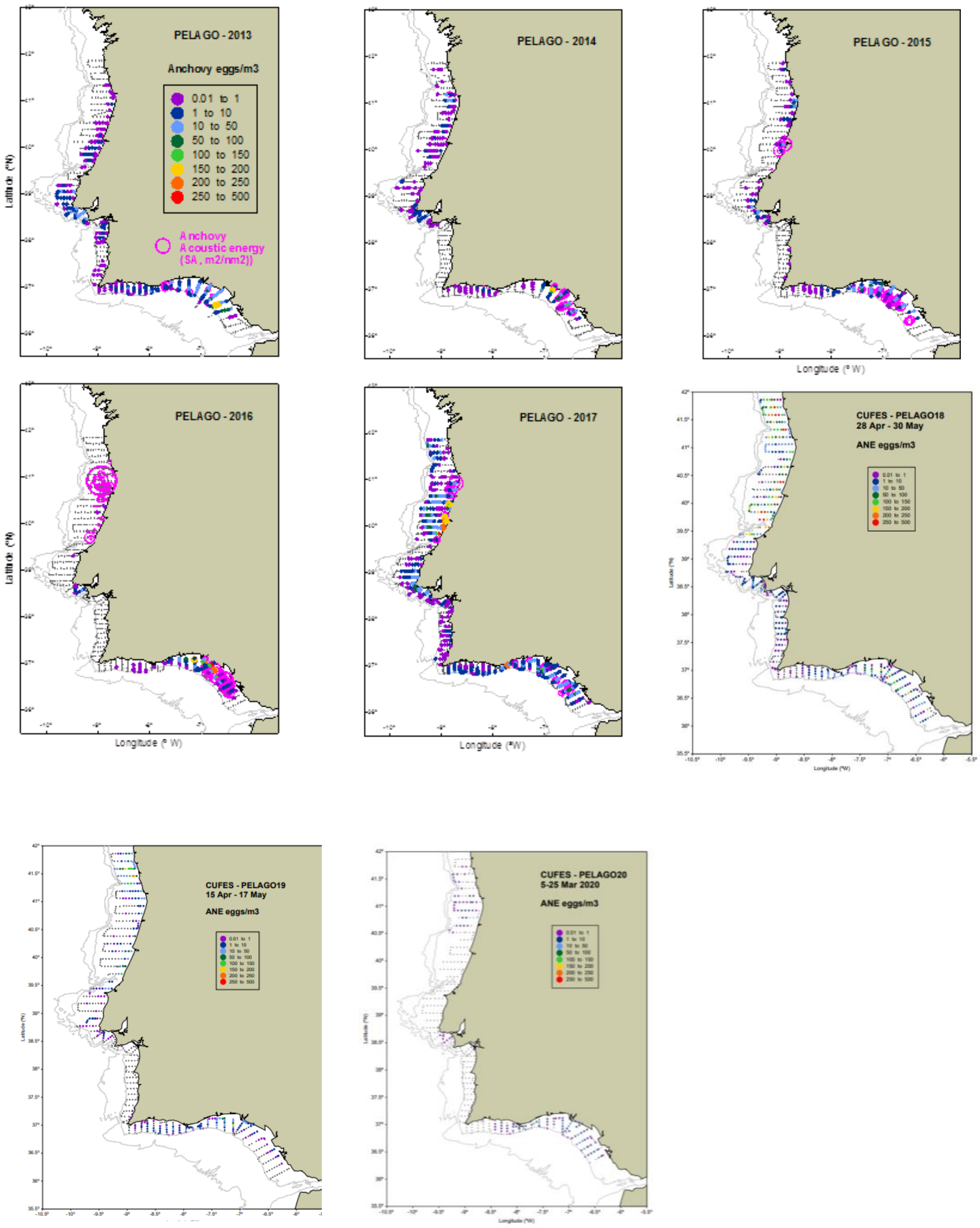

Figure 5 - Anchovy egg density (eggsm-^{3}), from CUFES sampling, and acoustic energy (SA m^2/nm^2) distributions, during the acoustic surveys of the PELAGO series (IPMA) for the period 2013-2020. Egg distributions are represented by density classes according to the colour scale depicted. Acoustic energy of adult anchovy is shown in pink circles with areas proportional to SA in maps from 2013-2017. Source: ICES WGACEGG.

The PELAGO survey series has data of anchovy abundance and distribution since 1998. In the beginning of the survey series, the majority of anchovy in the 9a Division was in the southern component, mainly in the Spanish waters. From 2011 onwards, no clear trend was found in anchovy abundance in the southern component, but a sharp increase was observed in western Iberia, with peak abundances registered in 2021 followed by 2018 (Figure 6).

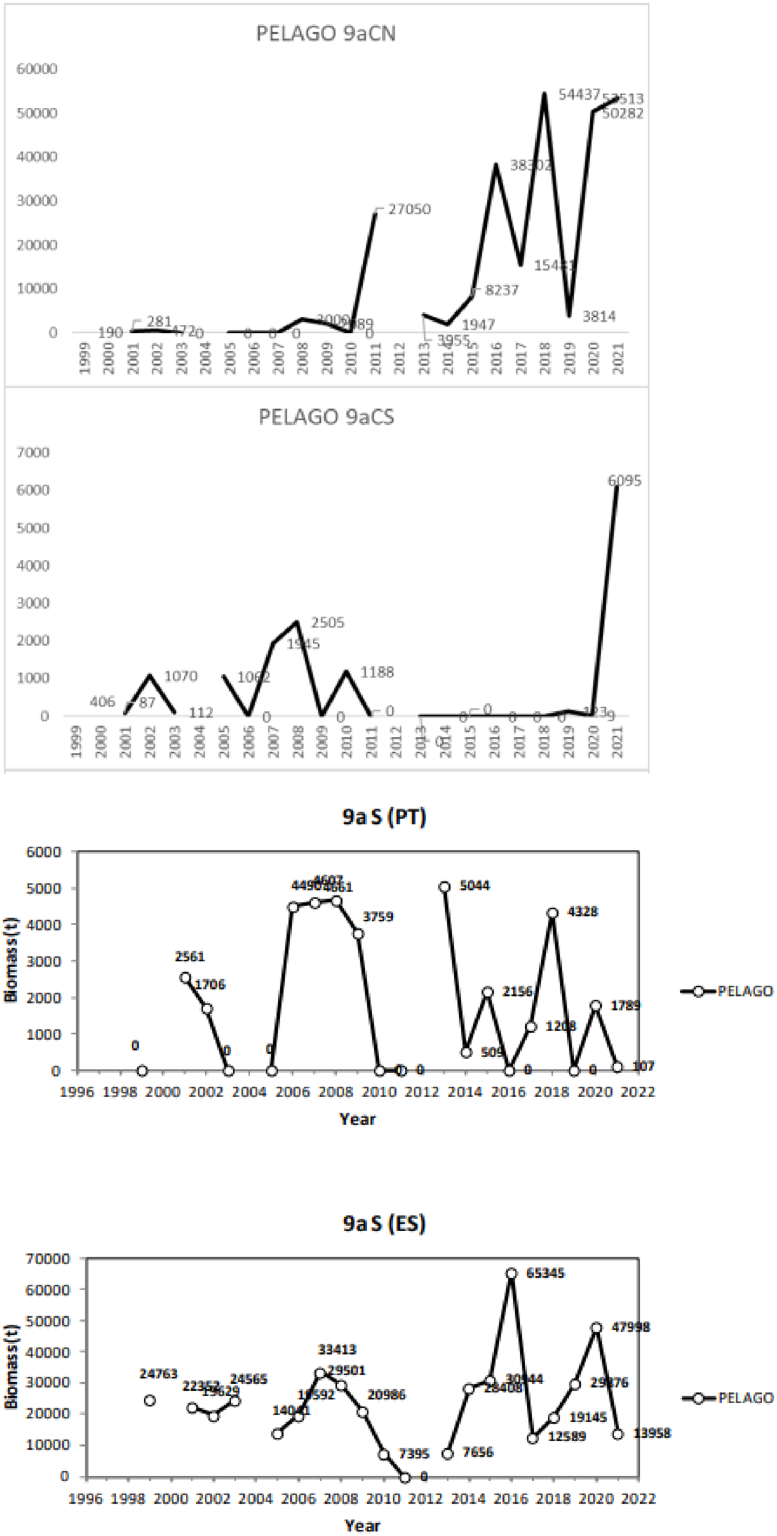

Figure 6 - Anchovy in Division 9.a. Western and Southern components. Subdivisions 9.a Central-North to 9.a South. PELAGO survey series (spring Portuguese acoustic survey in Subdivisions 9.a Central-North to 9.a South). Historical series of regional acoustic estimates of anchovy biomass (t). Note the different scale of the y-axis.

Focusing on the western Iberia, in the beginning of the PELAGO survey series, when anchovy abundance was very low in in the western Portuguese coast (Fig. 7), the species was largely found in the northern part of the southwestern Iberia – 9aCS (or OCS in Figure 7) - (mostly near Lisbon). Since 2011, when the abundance of anchovy started to sharply increase until present levels, anchovy was absent from the southwestern area during 10 surveys, from 2011 to 2018, and its biomass was very low in the remaining 3 surveys, carried out in 2019, 2020 and 2021, being 3, 0.02 and 10% of the total biomass in the western Portuguese coast, respectively.

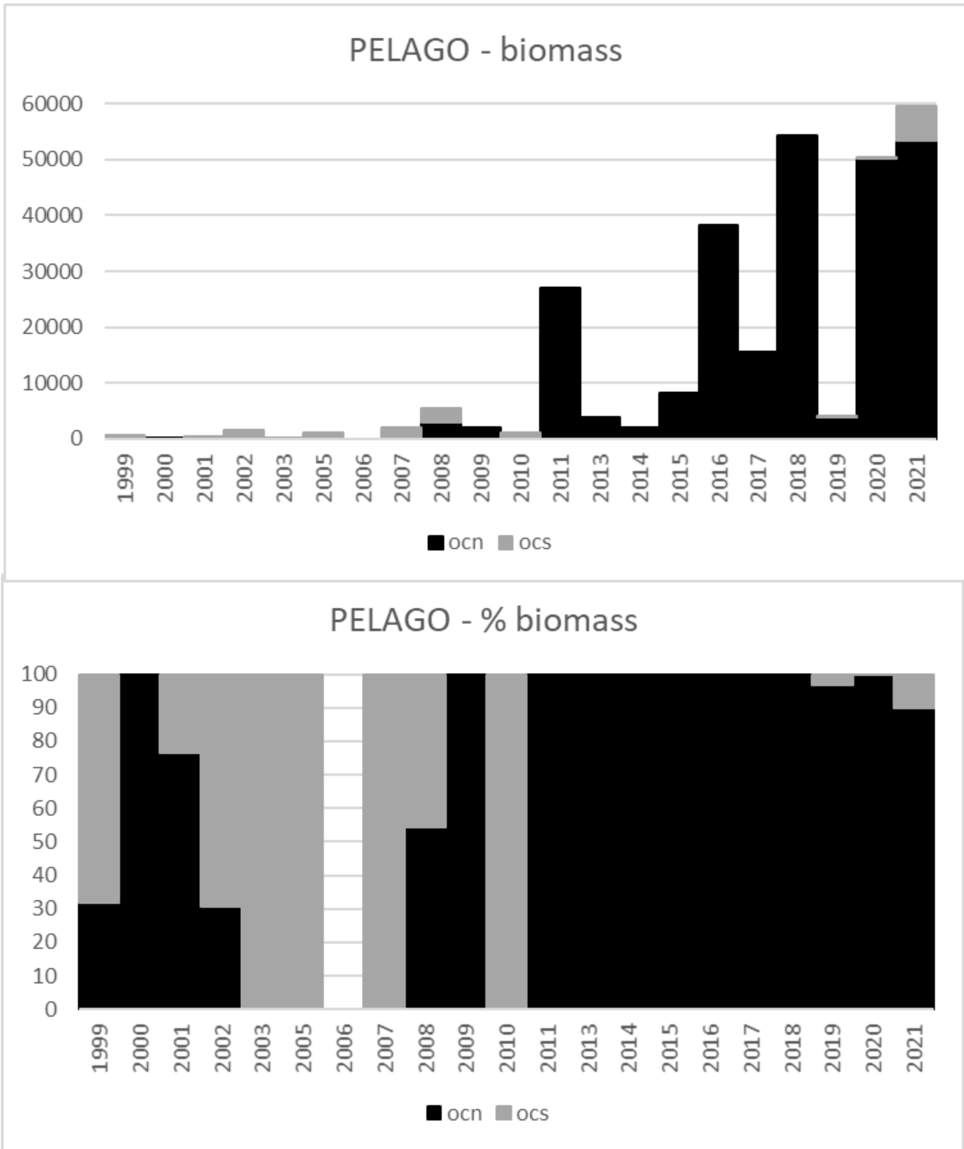

Figure 7 - Anchovy in Division 9.a. Western component. Subdivisions 9.a Central-North to 9.a Central-South. PELAGO survey series. Historical series of regional acoustic estimates of anchovy biomass (t).

2.1.2. AUTUMN ACOUSTIC SURVEYS

According to the estimates provided by the autumn acoustic surveys from 2018 to 2021 targeting sardine and anchovy recruitment (CSHAS, PELTIC, JUVENA, IBERAS and ECOCADIZ-RECLUTAS surveys, Fig. 8), the core distribution areas of adult anchovies are similar to those detected in the spring-time. Anchovy biomass is concentrated, by decreasing order of importance: along the coastal areas of the Bay of Biscay, followed by the Gulf of Cadiz and the north western Portuguese coast. Again, there are gaps in the distribution anchovy the western side of the Cantabrian Sea and in the southwestern Portuguese coast.

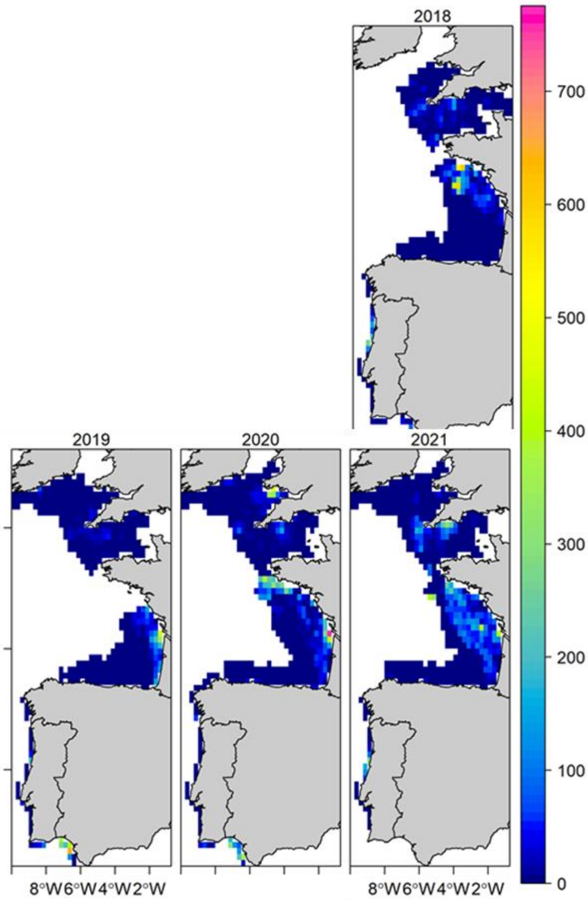

Figure 8. Adult anchovy mean acoustic density (NASC, $m^2.nm^{-2}$) maps derived from the CSHAS, PELTIC, JUVENA, IBERAS and ECOCADIZ-R surveys, 0.25° map cells. No data yet available for the last survey series when information for the current WD was compiled. Source: ICES WGACEGG.

2.1.2.1 IBERAS SURVEYS

Until 2017, an acoustic survey series carried out during autumn to estimate sardine and anchovy recruitment strength 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 (Fig. 9 and 10).

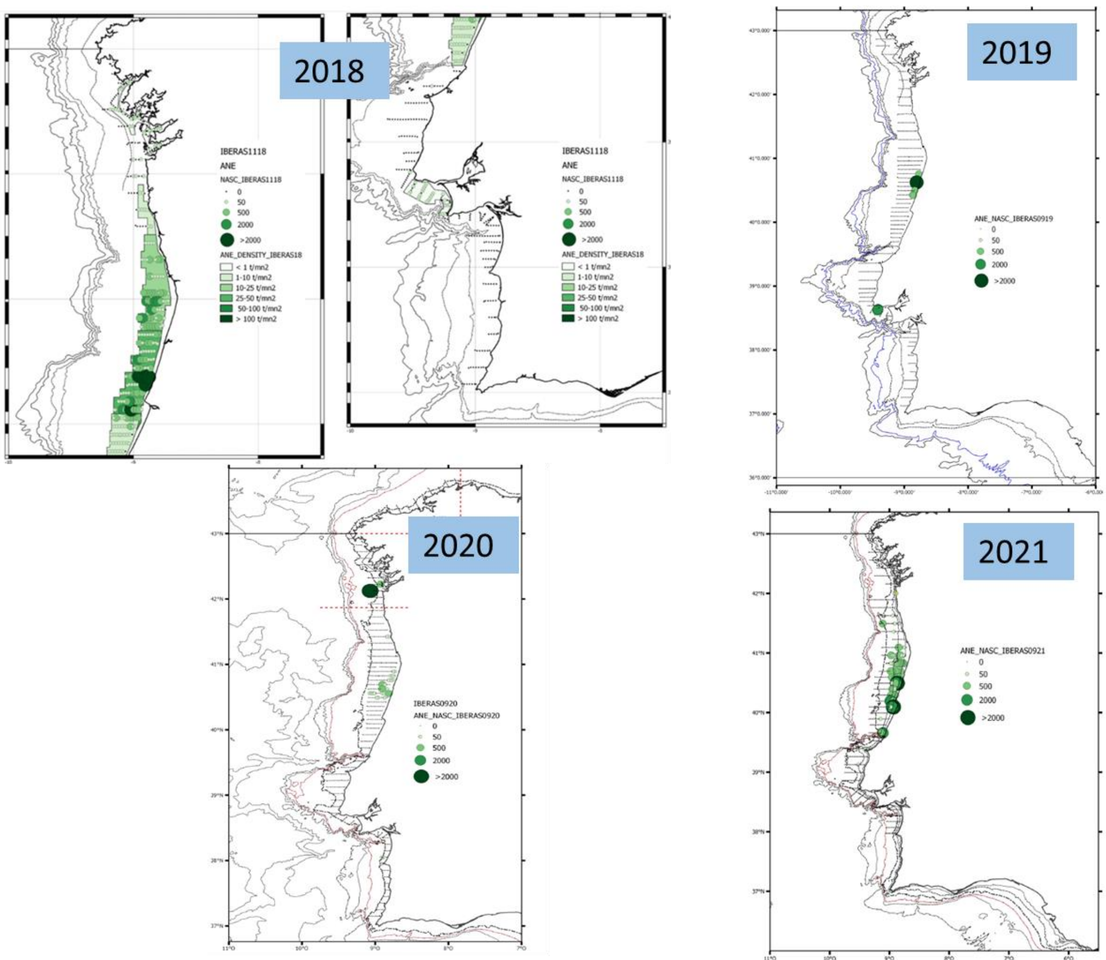

Figure 9 - Map of anchovy in the IBERAS survey series from 2018 to 2021 (allocated NASC at 38 kHz).

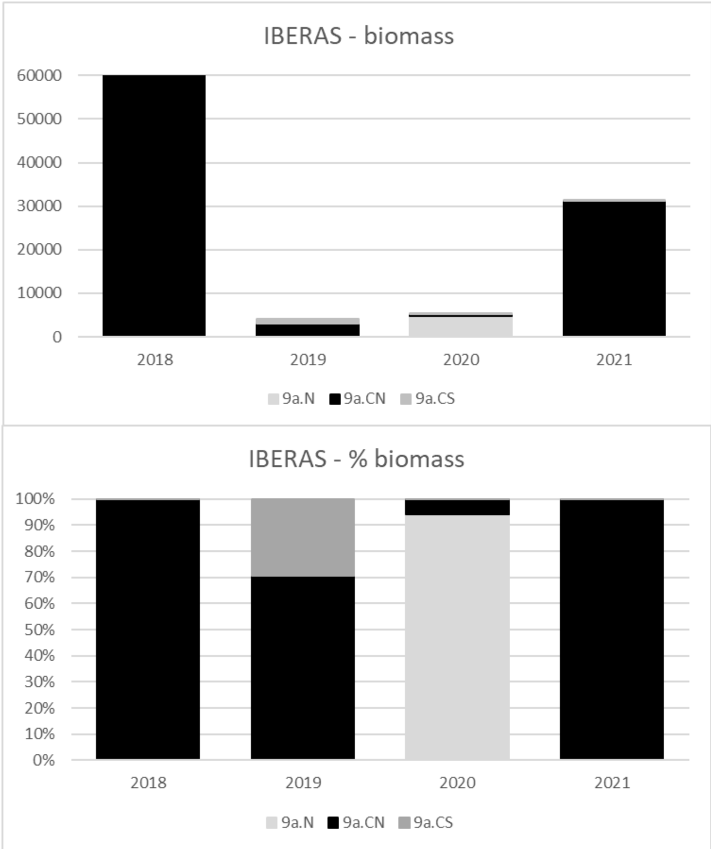

Figure 10 – Biomass of anchovy in the IBERAS survey series from 2018 to 2021, by sub-division (subdivisions 9.a North, 9.a Central-North and 9.a Central-South, total biomass in the upper panel and proportion in the lower panel).

2.1.3. TRAWL SURVEY SERIES – PORTUGUESE CONTINENTAL COAST

Data on the occurrence of anchovy in the time series of demersal trawl surveys since 1990 until 2017 was analysed to investigate the distribution of the species in seasons different from that analysed in the spring acoustic survey series. The surveys follow a fixed grid of 97 sampling stations, spread throughout the shelf between 36 and 710 m. The time series of data (1990–2017) collected by 43 surveys conducted in the fall (26 surveys), summer (10 surveys), spring and winter (5 and 1 survey, respectively). The fishing gear used is a bottom trawl (type Norwegian Campell Trawl 1800/96 NCT) with a 20 mm codend mesh size. The target duration of each tow was 60 min and further details on the methodology of the surveys can be found in Cardador et al. (1997).

Most of fish caught in the Portuguese demersal trawl surveys are distributed in the subdivision 9aCN, particularly near Aveiro - Figueira da Foz and in the southern coast (Algarve) (Fig. 11 and 12). The occurrence of anchovy in subdivision 9aCS is almost limited to the area around Lisbon, which has a similar trend to that found in the spring acoustic survey series. A persistent gap in distribution in southwestern Iberian waters is evident during all years, including the recent ones when anchovy abundance reached peak values (Fig. 12).

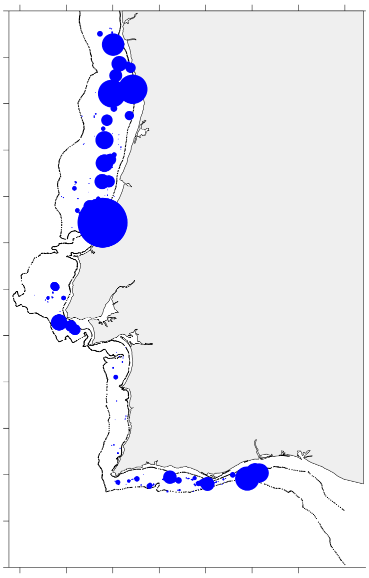

Figure 11. Distribution of the anchovy in demersal research trawl surveys conducted in the Portuguese continental margin since 1990 until 2017 during summer and autumn months. Symbol is proportional to the square root of the catch rate (number of fish caught per hour). Source: IPMA data.

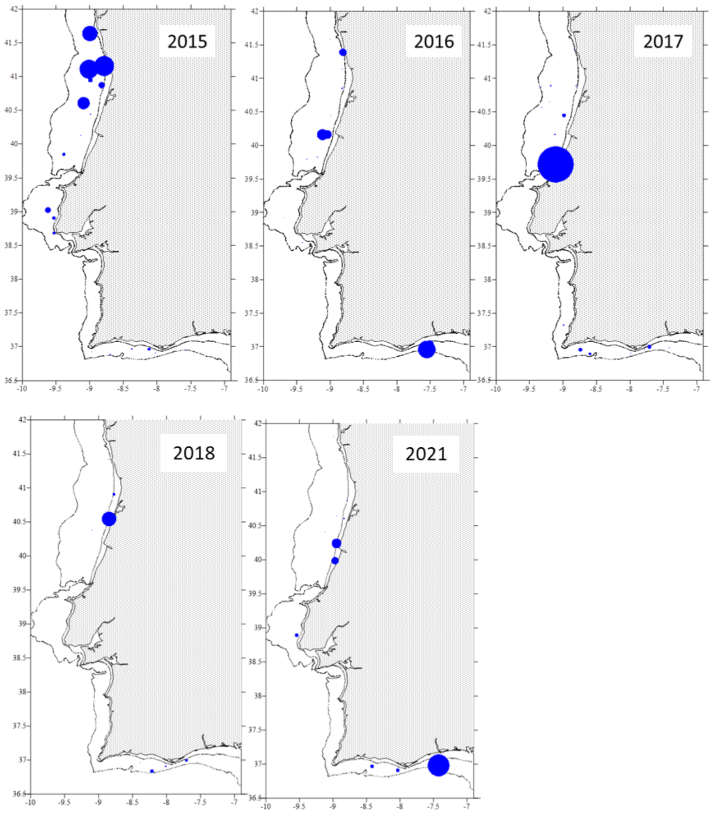

Figure 12. Distribution of the anchovy in demersal research trawl surveys conducted in the Portuguese west and south coasts in 2015 to 2021 autumn surveys. No survey was carried out in 2019 and 2020. Symbol is proportional to the square root of the catch rate (number of fish caught per hour). Source: IPMA data.

3. HISTORIC DYNAMICS OF STOCK BIOMASS SIZE INDICATORS

The distribution of anchovy biomass between the western and southern components of the 9a stock, as shown from the PELACUS and PELAGO spring acoustic survey series (Fig. 13) shows that, in the beginning of the time series (2007 to 2015), most anchovy biomass was recorded in the southern Iberia (>70%), with the exception of 2011 when anchovy increased in the west and comprised 34% of anchovy biomass in the 9a Division. Since 2016, the biomass in the western component has increased sharply and a similar biomass estimate was registered for the two components during 2016, 2017 and 2020 but significantly higher in the west in 2018 and 2021, the peak biomass years for the western component, representing > 70% of anchovy biomass in the 9a Division.

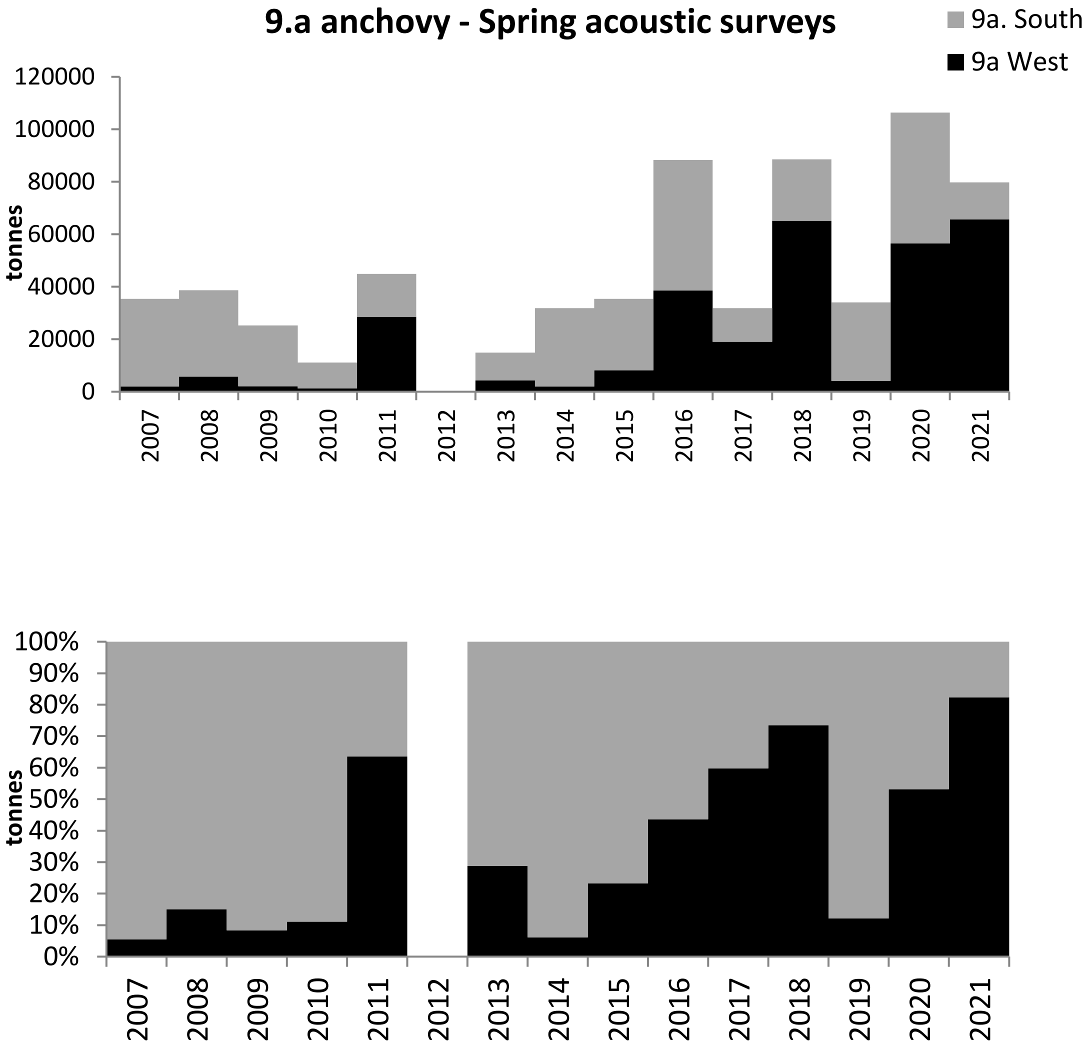

Figure 13. Distribution of anchovy biomass between the western and southern components of the 9a stock. Upper graphs represent total biomass (tons) and lower panel represents proportion between the two components.

Within the western Iberia, most anchovy is concentrated in the 9a-Central North, followed by the 9a. North while anchovy is absent or has residual abundance in the 9a Central South during most years. In the Southern Iberia, most anchovy is located in the 9a South Cadiz area, and anchovy in the 9a South Algarve has a residual abundance (Fig. 14).

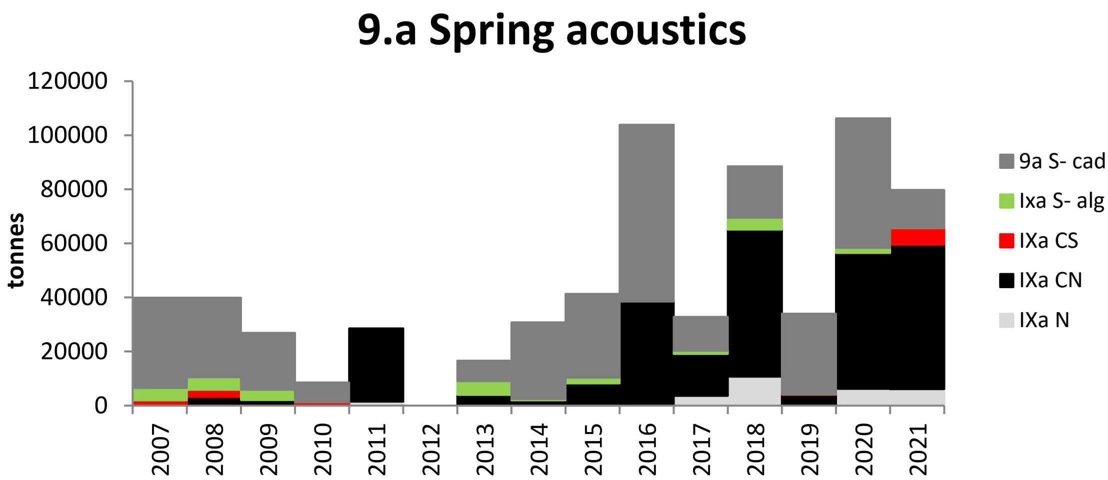

Figure 14. Biomass estimates for all the 9a sub-divisions estimated in the spring acoustic surveys PELACUS (Subdivision 9a N) and PELAGO (Subdivisions 9a CN, 9a CS 9a S alg, 9a S cad).

4. OTHER INDEPENDENT DATA OF ANCHOVY DISTRIBUTION: PORTUGUESE ESTUARIES

According to different works with seasonal sampling in the Portuguese estuaries were conducted during different years: small anchovy (<10 cm) is frequently detected in estuaries, namely in estuaries of rivers Lima, Douro, Mondego, Tejo, Sado, Mira, Arade and Guadiana (Figure 15) (França et al. 2011, Ramos et al. 2006, Pombo et al. 2002, Nyitrai et al. 2012, Marques et al. 2006, Ribeiro et al. 1996, Marques 2003, Cardoso et al. 2011, Chicharo et al. 2006, Chicharo et al. 2012), only 1 study did not detect the species, in River Minho estuary (Mota et al. 2014).

Figure 15 – Location of Portuguese estuaries.

Frequency of occurrence of anchovy during several years in the Aveiro estuary (several studies throughout the 1900' until 2000) showed a persistence of the species in the estuary (Nyitrai et al. 2012) as reproduced in Table 1.

Table 1 – Occurrence of several species including anchovy in the Portuguese estuary of Ria de Aveiro, summarized in Nyitrai et al. (2012).

TABLE II. Fish species, grouped by families, that have occurred in the Ria de Aveiro.

Family	Species	1912	1915	1981	1988	1997	1999	2000
Ammodytidae	*Ammodytes tobianus*	×	×	×	×		×	
Ammodytidae	*Gymnammodytes cicerelus*							
Ammodytidae	*Hyperophus lanceolatus*	×		×	×		×	
Anguillidae	*Anguilla anguilla*	×	×	×	×	×	×	×
Atherinidae	*Atherina boyeri*				×	×	×	×
Atherinidae	*Atherina presbyter*	×	×	×	×	×	×	×
Balistidae	*Balistes carolinensis*						×	
Belonidae	*Belone belone*	×	×	×	×	×		
Blennidae	*Lipophrys pholis*	×	×					
Blennidae	*Parablennius gattorugine*	×	×	×	×		×	×
Blennidae	*Parablennius sanguinolentus*	×			×		×	
Callionymidae	*Callionymus lyra*		×	×	×	×	×	×
Carangidae	*Trachurus trachurus*	×		×		×	×	×
Centrarchidae	*Micropterus salmoides*			×				
Clupeidae	*Alosa alosa*	×	×			×	×	×
Clupeidae	*Alosa fallax*	×	×	×	×	×	×	×
Clupeidae	*Sardina pilchardus*	×	×	×	×	×	×	×
Clupeidae	*Sprattus sprattus*	×	×	×				
Cobitidae	*Cobitis taenia*			×	×			
Congridae	*Conger conger*	×	×	×			×	
Cottidae	*Taurulus bubalis*	×			×			
Cyprinidae	*Barbus bocagei*		×	×				
Cyprinidae	*Carassius auratus*	×						
Cyprinidae	*Carassius carassius*	×	×	×	×	×		×
Cyprinidae	*Rutilus macrolepidotus*	×	×	×				
Engraulidae	*Engraulis encrasicholus*		×	×	×	×	×	×
Gadidae	*Ciliata mustela*	×	×	×	×		×	×
Gadidae	*Gaidropsarus mediterraneus*	×	×		×			

A comparative study of many of these estuaries revealed very high abundance in the Sado estuary from May to July 2006 (França et al. 2011).

5. HISTORIC DYNAMICS OF LANDINGS

Anchovy in Division 9a is mostly harvested by purse-seine fleets (generally 99% of total catches). For the period with complete data for the whole Division (from 1989 to present), landings have ranged from 1,984 t (1993) to 13,775 t (2018) (Fig. 15). Landings have been dominated by those done in the Gulf of Cadiz (Subdivision 9a South – Cadiz) for most 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 (Fig. 16).

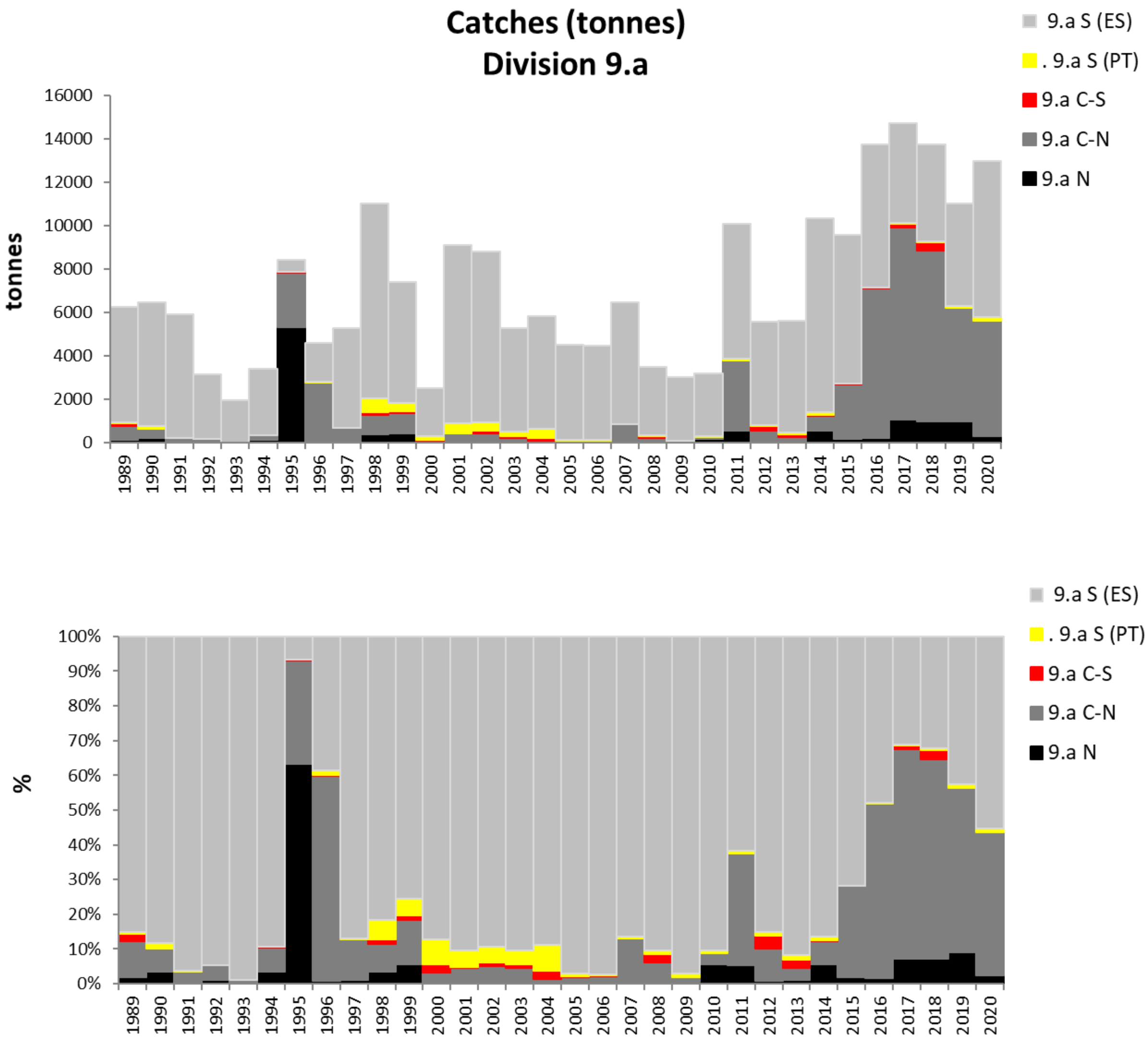

Figure 16. Time series of anchovy landings in Division 9a (1989-2020) in ICES Subdivisions 9a North, Central-North and Central-South (western component) and Subdivisions 9a South-Alg and 9a South-Cad (Southern Component).

The annual contribution observed in each fishing zone in the Portuguese landing of anchovy from 2003 to 2020 shows an increasing trend in northwestern and southwestern Iberia, which is not as clear in southern Portugal. In the first three years of the time series most catches occurred in the south while in recent years, the large majority of catches occurs in northwestern Portugal (Fig. 17 and 18).

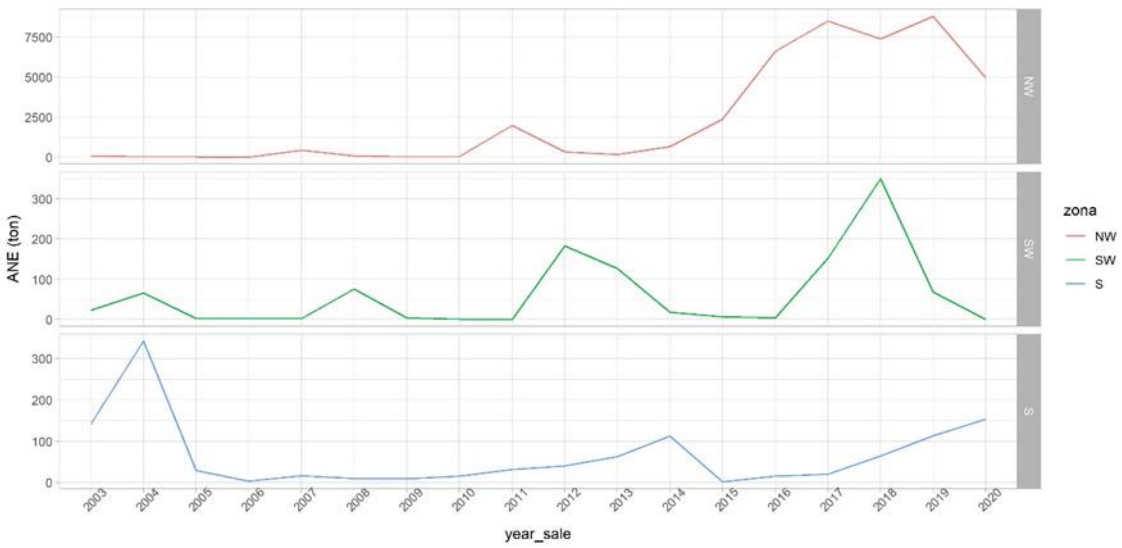

Figura 17 - Time series of anchovy landings carried out by the purse seine fleet in Portugal by zone (Northwest, Southwest and South Portugal) from 2003 to 2020.

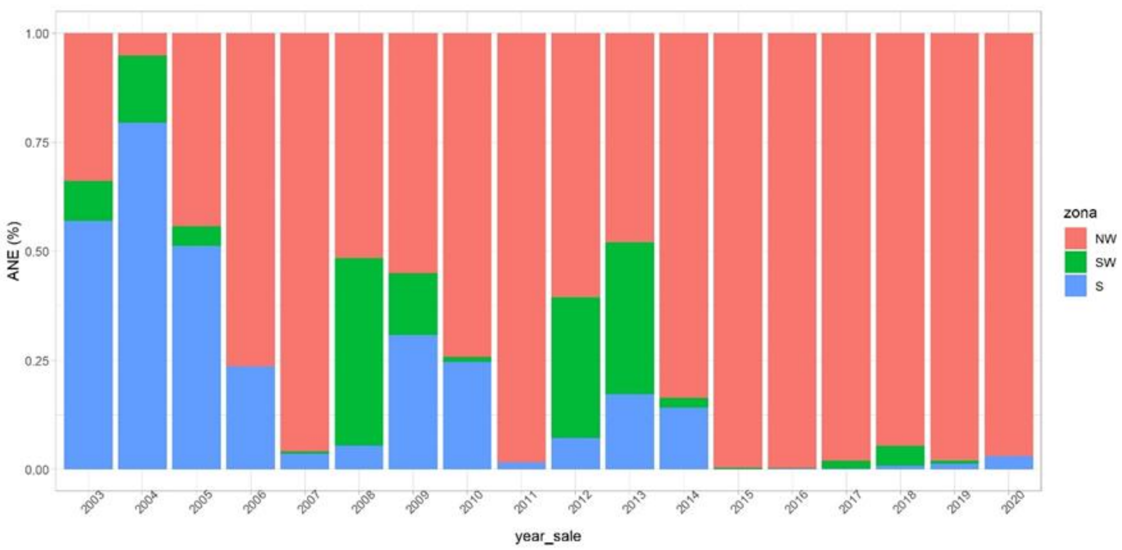

Figure 18 - Annual proportion of anchovy landings in Portuguese ports carried out by the purse seine fleet in each zone (Northwest - NW, Southwest - SW and South – S Portugal), in the period from 2003 to 2020.

The distribution of catches by main fishing ports in Portugal reveals that the great majority of catches concentrate in the northern part of the northwestern Iberia (north of 9aCN area), followed by the area around Lisbon (port of Sesimbra) with catches 1 order of magnitude lower, catches while those in southwestern south Iberia and significantly lower (Fig. 19).

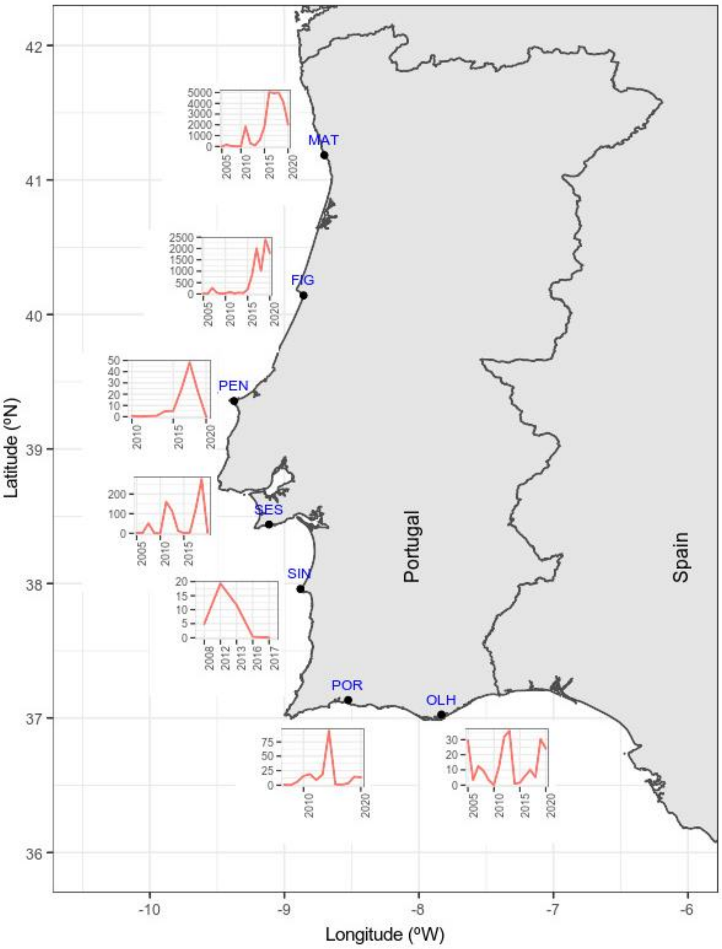

Figure 19 – Distribution of catches (tons) in the main fishing ports (Matosinhos - MAT, Figueira da Foz – FIG, Peniche – PEN, Sesimbra – SES, Sines – SIN, Portimão – POR, Olhão – OLH) of Portugal from 2005 to 2020.

Correlation analysis of the historical series of catches per Subdivision, previously analysed by Ramos et al. (2001) and Garrido et al. (2018), comparing the western and southern components of the stock were updated until present days. Annual landings per Subdivision (period 1989-2021) were analysed with the Spearman correlation test showing no significant correlation between the landings for the two components (Spearman correlation=0.33, p=0.06). An alternative correlation analysis was done to test whether the fluctuations of catches along the Division were the result of a potential northward migration (theoretically from Gulf of Cadiz to northern areas). In this second approach, correlations were estimated by comparing catches in the year y from the southern area (Algarve and Gulf of Cadiz) with the ones landed in the year y+1 in the western area (9a-N+9-CN+9-CS). No significant correlation (Spearman correlation=0.7, p=0.07) was found accounting for with this one-year lag, which would be consistent with a northward migration between areas. On the other hand, the correlation between landings and anchovy abundance in the western coast was found to be highly significant (Spearman correlation=0.71, p=0.008).

6. POPULATION DIFFERENCES IN ANCHOVY LIFE HISTORY TRAITS IN DIVISION 9A.

6.1 BIOLOGICAL DATA

Mean length and weight of anchovy in spring acoustic surveys was generally lower in the Gulf of Cadiz (Fig. 18) when compared to the other Subdivisions, followed by the 9aCN Subdivision, which may indicate the presence of two different recruitment areas for this species; whereas the mean length in the Algarve (9a-S Alg) and in Galician waters (9aN) were generally higher. Mean length data for the 9aCS Subdivision are only available for five years, when mean length was comparable to that of the 9a CN Subdivision. Similarly, anchovy weight at age was lower in the 9a S Cadiz Subdivision, while similar values were found in the other areas (Fig. 20).

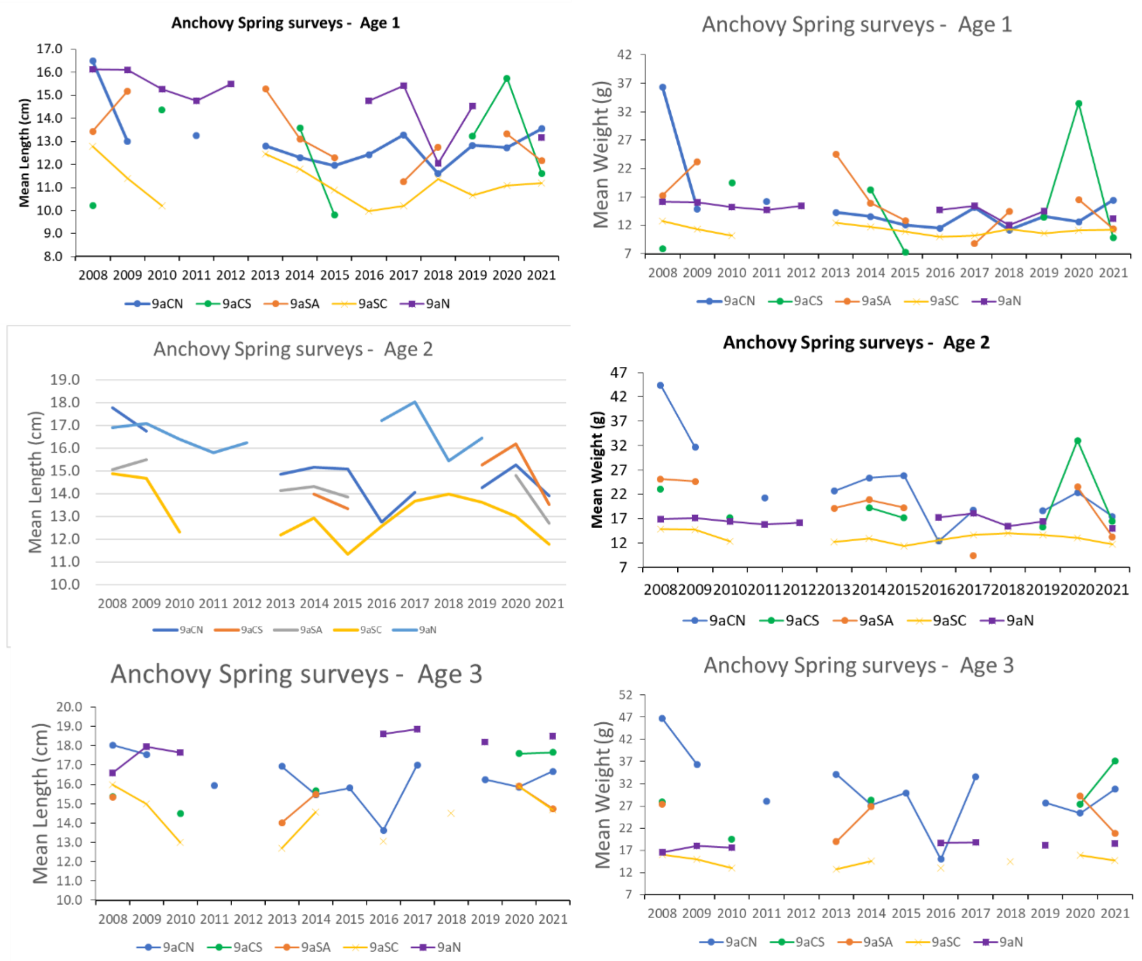

Figure 20. Anchovy mean length (left panels) and mean weight (right panels) estimated for fish captured during the spring acoustic surveys (PELACUS and PELAGO) for each area of ICES Division 9a.

Continuous information on mean length and mean weight at age in catches from the Portuguese fishery (9a.C.N) started to be available in 2017 whereas time series for areas 9a.N and 9a.S-Cadiz are longer. Comparing the period when there is information for Portuguese and Spanish fisheries, it can be seen that, similarly to spring acoustic surveys, mean length and weight at age in the catches are smaller in the 9a South Cadiz area while data from 9a North and Central North are similar (Fig. 19). Due to the residual catches, there is no length and age data for the 9a Central South and 9a South Algarve areas.

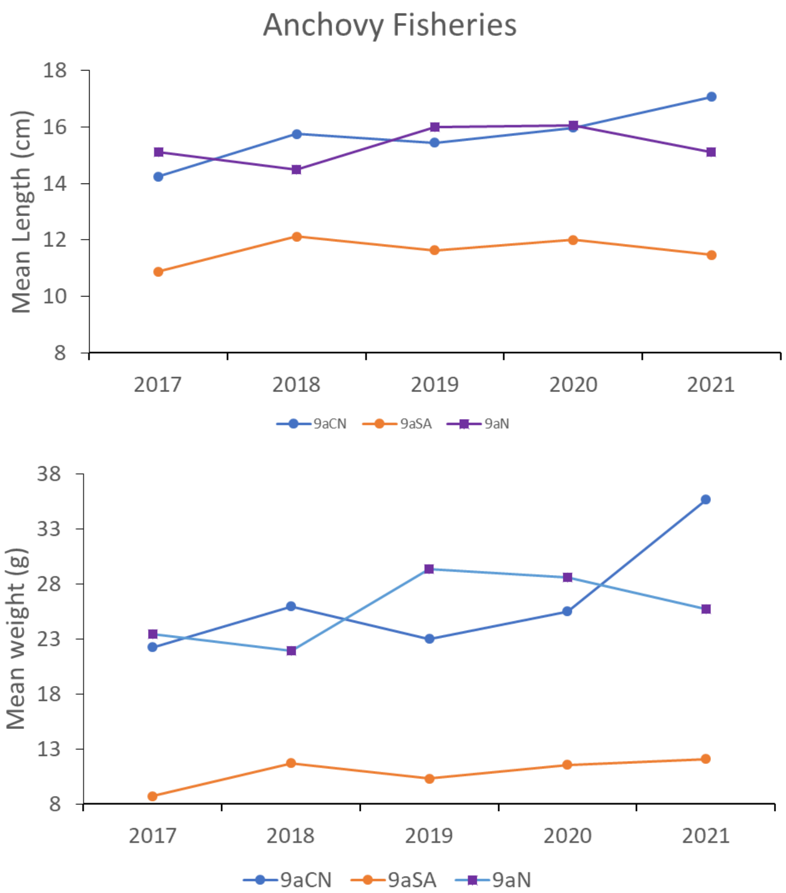

Figure 20. Anchovy mean length (upper panel) and weight (lower panel) in catches from the Spanish fishery in subdivisions 9a-N and 9a-S.

Potential connectivity of anchovy populations from the Western and South Iberia was investigated by cohort tracking. No significant correlation was found in the abundance of fish of the same age between the areas. Moreover, no correlation was found between age 1 individuals in the South component with age 2 individuals of the western component in the following year (Fig. 21).

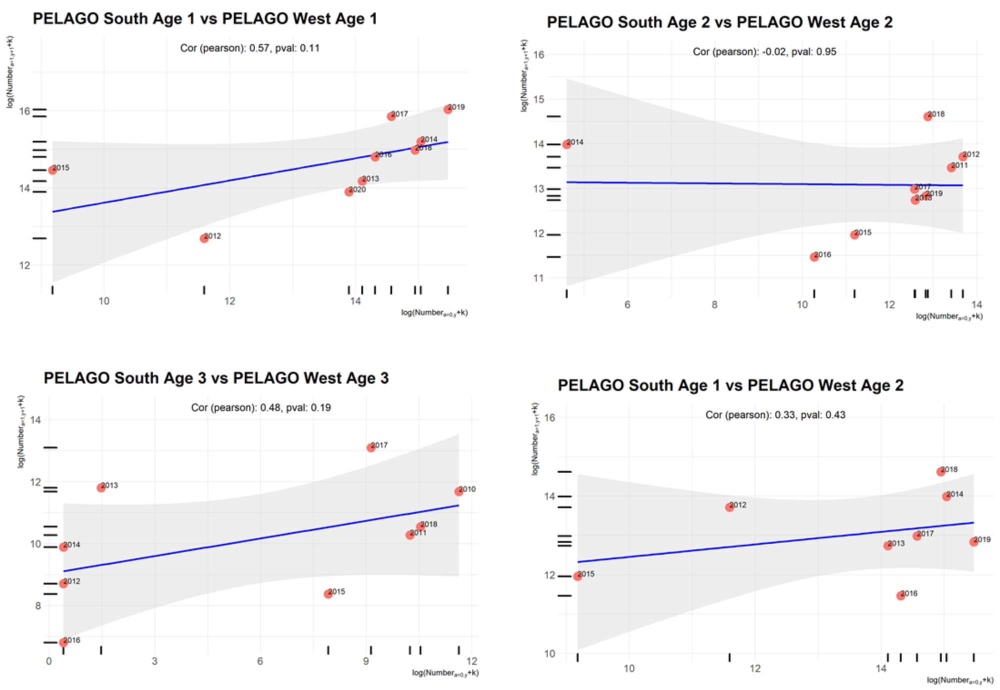

Figure 21. Relationship between the abundance of Age 1, 2 and 3 individuals estimated in the PELAGO survey series and in the West and South Iberian coasts, and with Age 1 in the south and Age 2 in the West Iberian coast. Units for both axes are Log the number of individuals + K, being K half the minimum N observed, method described in ICES, 2004; Payne et al., 2009).

The same type of analysis was carried out on the potential connectivity of anchovy populations in the western Iberia with those of the Bay of Biscay (Subarea 8, different stock). No significant correlation was found in the abundance of fish of the same age between the areas. Moreover, no correlation was found between age 1 individuals in the Bay of Biscay with age 2 individuals of the western Iberia in the following year (Fig. 22).

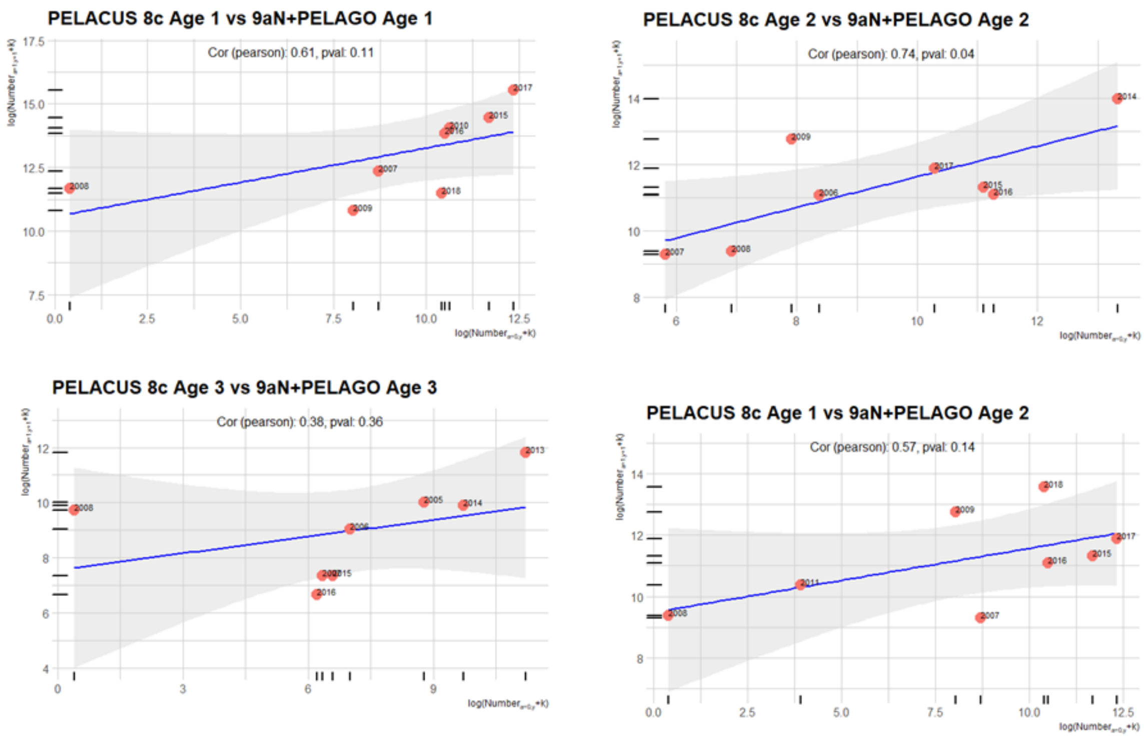

Figure 22. Relationship between the abundance of Age 1, 2 and 3 individuals estimated in the PELAGO+PELACUS survey series and in the Cantabrian Sea (sub-division 8c), and with Age 1 in the Cantabric and Age 2 in the West Iberian coast. Units for both axes are Log the number of individuals + K, being K half the minimum N observed, method described in ICES, 2004; Payne et al., 2009).

6.2 SYNOPSIS OF PUBLISHED WORKS ON POPULATION STRUCTURE

Several studies have been conducted on the population structure of the anchovy in Atlantic waters, namely using morphometrics, otolith shape analysis and genetic analysis.

MORPHOMETRICS

Morphometric differentiation between anchovy populations from north of Division 9a (Sub-division 9a North) and populations from the Bay of Biscay were obtained by Junquera and Pérez-Gándaras (1993), also suggesting the existence of an intermediate population in the Cantabrian area (west of the 8c). Subsequent studies of morphometrics and genetics have failed to sample fish in the western Cantabrian, which is probably related to the low abundance of the species in this area. Morphometric analysis conducted in fish collected during 2000 and 2001 from the Bay of Biscay to the Southern Iberia in the algarve (Caneco et al. 2004) point to a clear separation between anchovies from the Bay of Biscay (ICES Divisions 8b, 8c) and those from Division 9a, as well as a north-south cline along the Portuguese and Gulf of Cadiz area, with fish from the Gulf of Cadiz being mostly different from those in northern 9a area. The group of fish from the Algarve (E) was the one whose separation was less robust, given that the classification by cross-validation attributed most of its fish on western Portuguese coast groups than on itself. Results from this study indicate that fish from the Iberian area (i.e. Division 9a) have larger heads and smaller medium-posterior body dimensions than the ones from Bay of Biscay (Divisions 8b,c).

These differences were more pronounced in the Spanish waters of the Gulf of Cadiz (Subdivision 9a-South, Cadiz). Anchovies from the Spanish waters of the Gulf of Cadiz had the greater head-to-body ratios, having shown the greater divergence from the Biscay populations. The Iberian samples had also greater dorsal fin base lengths.

OTOLITH SHAPE ANALYSES

Bacha (2014) showed that the Alborán Sea anchovy population is distinct from the Northeast Atlantic populations, including neighbouring populations (e.g. Gulf of Cadiz) using otolith shape analyses. Anchovies were analysed from seven locations in the SW Mediterranean Sea and Atlantic Ocean along the northwestern African (Morocco) and Portuguese (Bay of Cadiz) coasts (Bacha et al. 2014). According to this study, three distinct anchovy stocks were identified: the Algero-Provençal Basin, the southern Alborán Sea, and the Atlantic Ocean (Morocco and Gulf of Cadiz). Shape variability of anchovy otoliths was associated with the presence of the Almeria-Oran front (AOF), and the strait of Gibraltar. The Southern Alborán stock was distinct from the Algero-Provençal Basin and from the closest Atlantic stocks (Gulf of Cadiz or Atlantic coast of Morocco).

GENETIC ANALYSIS

The European anchovy exhibits a complex evolutionary history that has produced conflicting results regarding its population structure within the Atlantic Ocean (Table 2). The presence of two ecotypes (hereinafter, oceanic, and coastal) that differ both genetically and morphologically was first documented in the Mediterranean Sea (Borsa, 2004). Additional analyses based on comprehensive datasets in terms of genetic markers and number of samples have confirmed presence of these two ecotypes also in the Atlantic Ocean (LeMoan et al. 2016, Montes et al. 2016). Interestingly, there is more differentiation between ecotypes (oceanic/coastal) than between Atlantic Ocean and Mediterranean Sea locations within the same ecotype (LeMoan et al. 2016; Catanese et al. 2017). Besides, both ecotypes hybridize, although it is not known in which proportions (LeMoan et al. 2016; Montes et al 2016). Additionally, analyses based on mitochondrial DNA have found presence of two lineages with different proportions in each area and which are not related to the oceanic and coastal ecotypes (Magoulas et al. 2006; Borrell et al. 2012, Viñas et al. 2013, Silva et al. 2014a, Silva et al. 2014b). Adding a further layer of complexity, Zarraonaindia et al. (2012) suggested the presence of other two ecotypes (unrelated to the coastal/oceanic ones) associated with narrow or wide oceanic platforms respectively. This complex evolutionary history makes inferences of population connectivity among locations difficult without further studies considering presence of ecotypes and mitochondrial lineages. From the studies available thus far, there seems to be population differentiation between the North Sea+English Channel populations and the Bay of Biscay (Petitgas et al. 2012; Montes et al. 2016, Huret et al. 2020), although some studies suggest otherwise (Zarraonaindia et al. 2012, Silva et al 2014a). Concerning the connection between West Galicia and North of Portugal with the Gulf of Cadiz anchovies, two studies suggest differentiation (Silva et al. 2014a, Zarraonaindia et al. 2012), but results might be biased by the small number of markers used and/or by the different proportions of each ecotype in the samples used.

Thus, population structure studies aiming at understanding European anchovy connectivity should consider the presence of the two ecotypes and consider the different scenarios causing the presence of non-ecotype related mitochondrial lineages. Additionally, it is important to understand the proportion of each ecotype in the scientific surveys used for assessment and in the commercial catches in order to evaluate if assessing population structure within one ecotype (*e.g.* oceanic) would suffice to support assessment. Yet, the fact that both ecotypes hybridize should be considered, as hybrids seem to be less fit or suffer from strong negative selection pressures, which could indicate that they contribute less to spawning stock biomass estimations.

Table 2: Summary of the genetic studies trying to decipher the population structure of European anchovy who include the area of interest for this WD.

Reference	Number of individuals	Locations	Number and type of markers	Results	Sampling
Magulas et al. (2006). MPE 39: 734–746	24	Bay of Biscay, Portuguese coast; Gulf of Cádiz; Canary Islands; Senegal; Alboran Sea; other regions in Med	mitochondrial RFLP	Two co-occurring mitochondrial genetic lineages; BoB about 40-60%; rest of the Atlantic locations, one more dominant	Fishing vessels and fish markets
Zarraonaindia *et al.* (2012). PLOS ONE 7(7): e42201	626	North Sea, English Channel, Bay of Biscay, Coast of Portugal, Gulf of Cádiz, Canary Islands, South Africa, Alboran Sea, other regions in the Med	47 nuclear and mitochondrial SNPs (not clear how they were selected)	Patterns compatible with two ecotypes: one group included samples from the North Sea and English Channel, the Bay of Biscay and the Mediterranean (excluding Alboran Sea); the other group included samples from eastern Atlantic locations from Galicia to south Africa (and Alboran Sea)	Acoustic surveys (BIOMAN, PELGAS, ECOCADIZ, ECOMED, PELACUS)
Petitgas et al (2012). MEPS 444: 1–13	797	Bay of Biscay, English Channel, North Sea	49 nuclear SNPs (extracted from Zarraonaindia et al. 2012)	Differentiation between North Sea/English Channel and Bay of Biscay; conflicting interpretations with respect to Zarraonandia et al. 2012, despite using common samples and same SNPs.	not specified
Borrell et al (2012). IJMS 69: 1357–1371	141	Bay of Biscay, Med	mitochondrial cytb & 16S/14 microsats	Two co-occurring genetic groups; BoB about 50-50% in the French coast and one coastal location in the Cantabrian sea; 75-25% in offshore Cantabrian sea and and 25-75% in Getarian coast	not specified
Viñas et al. (2013). 71: 391–397	563	Bay of Biscay, Cadiz, Med, Canarias	mitochondrial Control Region	Two genetic groups; Bay of Biscay about 50-50%, Cadiz, one more dominant	Mediterranean, fishing vessels; BoB (THALES, AZTI)
Silva et al. (2014). J. Biogeogr. 41: 1171-1182.	312/462	Eastern Atlantic: Norway to Ghana	mitochondrial cytb/9 microsats	2 co-occurring mitochondrial lineages whose frequency vary along the distribution area; 4 nuclear genetic clusters (ecotypes not considered): Norway+English Channel+Bay of Biscay/Portugal north+Malaga/Gulf Cadiz +Canaries+GuineaBissau+Ghana/Tangier+Senegal.	fish markets and scientific surveys (IMR, IFREMER, AZTI, CCMAR, IEO, WRI)

Silva et al. (2014). Proc. R. Soc. B. 28120141093 20141093	2776 (455 new)	North Sea, Baltic sea, English Channel, Bay of Biscay, Coast of Portugal, Gulf of Cadiz, Canary Islands, eastern Atlantic African coast to South Africa, Mediterranean Sea	mitochondrial cytb	Two co-occurring genetic groups, one is present all over the distribution area, whereas the other one is absent from the tropics; Temperature and dissolved oxygen are significantly correlated with the latest (particularly from the BoB to the North Sea).	fish markets and scientific surveys (IMR, IFREMER, AZTI, CCMAR, IEO, WRI)
Le Moan *et al.* (2016). Mol. Ecol. 25: 3187–3202	128	Coastal and marine locations from Atlantic and Mediterranean French coast (Bay of Biscay for the Atlantic, Bay of Leon for the Med)	5,638 SNPs (RADseq)	2 ecotype which hybridize. Higher differentiation between ecotypes than between Mediterranean and Atlantic. Lower differentiation between offshore ecotypes than between coastal ecotypes. Gene flow between ecotypes; limited enough to maintain high differentiation between the ecotypes.	ad-hoc for study
Montes *et al.* (2016). Mar. Biol. 163:205	851	Whole distribution: North Sea, Bay of Biscay, NW and S Iberian Peninsula, Mediterranean Sea and Canary Islands	456 SNPs (exons, might not have power to detect fine population structure)	Presence of two ecotypes in the Bay of Biscay. The Bay of Biscay offshore population is closely related to Mediterranean populations and secondarily to northern populations in the Irish, Norwegian and Baltic seas	Scientific Surveys (PELGAS, EVHOE, CAMANOC, CGFS, French IBTS, NOURDEM)
Catanese et al (2017). Sci. Rep. 7: 4180	1008	Bay of Biscay, Cadiz, Med, Canarias	96 SNPs (Catanese et al. 2016; most differentiating pops within Med and btw Atlantic and Med. Sea)	Confirm the presence of two ecotypes. Partial overlap in habitat use for ecotypes in the Med. Most outlier SNPs identified for the Med are shared with the Atlantic. Confirm higher difference between ecotypes than between Med vs Atlantic.	ad-hoc for study
Huret *et al*. (2020). Fish Res. 229: 105619	602	Atlantic French coast, English Channel North Sea and Irish Sea (In total 25 sampling locations, 4 in estuaries)	308 SNPs from Montes et al 2016 select as a trade-off between number of samples and number of SNPs	Two ecotypes. Within the oceanic ecotype, genetic differentiation between the subareas 8abd stock and further north locations, with populations boundary located west of Brittany. Anchovy from the English Channel cluster together with samples form the North Sea, both showing high differentiation from the Bay of Biscay for both ecotypes.	Scientific Surveys Professional vessels for Irish Sea. Samples from Montes et al. 2016.

7. IMPLICATIONS FOR MANAGEMENT

Currently, advice for the west and south components of the 9a stock is given separately, but a single TAC is set for the 9a Division, resulting from the sum of the advices for each component. Given the independent dynamics of the two components, in the short time series when the stock is being assessed (2018-2022), it is frequently observed opposite trends of biomass for the two components in several years, resulting in very different advices (Table 3). The fact that fishing opportunities are set for the whole 9a Division can result in overfishing the component with limited fishing opportunities.

Table 3 - 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.

8. CONCLUSIONS

Data of the spatial distribution of anchovy in division 9a shows a discontinuity of the western and south components of the stock (around 9aCS), in several life stages (eggs, juveniles and adults) and seasons of the year based on research cruises covering the whole 9a subdivision (spring, fall) or the entire Portuguese waters (summer).

No correlation was found between anchovy catches between the two stock components, 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 landings or abundance in the western Iberia with anchovy landings or abundance in the southern Iberia in the following year. On the contrary, anchovy landings in the western coast were significantly related to the abundance of the species in that area, demonstrating the independent dynamics of anchovy fishery from the two components.

The spatial discontinuity and the independent dynamics between the western and southern anchovy populations are likely related to the presence of a self-sustained anchovy population in the western Iberia, independent of the southern component.

Morphometric and genetic studies are not conclusive as they might be confounded by the presence of the coastal and marine ecotypes, often not considered in these studies. Thus, although some genetic and morphometric evidences for the separation of the Gulf of Cadiz anchovy population from that in the western Iberia (although results from the Algarve are generally absent) exists, this need to be confirmed with additional studies considering the complex evolutionary history of this species.

Despite the complex genetic evolutionary history of the species that deserves future dedicated studies, there are a large number of evidences presented in this working document, that leads WGHANSA to supports the separation of the western and southern components of the anchovy 27.9a into two stock units; the population in Subdivision 9a South and the populations from Subdivisions in the western coast (9a North, Central-North and Central-South), and therefore submits this WD to the ICES Stock Identification Methods Working Group (SIMWG) for consideration.

REFERENCES

Bacha, M., Jemaa, S., Hamitouche, A., Rabhi, K., and Amara, R, 2014. Population structure of the European anchovy, *Engraulis encrasicolus*, in the SW Mediterranean Sea, and the Atlantic Ocean: evidence from otolith shape analysis. ICES Journal of Marine Science, 71: 2429–2435.

Chicharo, M. A.; Chicharo, L. M. Z.; Morais, P. Inter-annual differences of ichthyofauna structure of the Guadiana estuary and adjacent coastal area (SE Portugal/SW Spain): before and after Alqueva dam construction, Estuarine Coastal and Shelf Science, 70, 1-2, 39-51, 2006.

Cardoso I, Pessanha Pais M, Henriques S, Cancela da FonsecaL, N. Cabral H (2011) Ecological quality assessment of small estuaries from the Portuguese coast based on fish assemblages índices. Marine Pollution Bulletin 62, Issue 5: 992-1001. https://doi.org/10.1016/j.marpolbul.2011.02.037.

Chairi, H., Idaomar, M., Rebordinos, L. 2007. Mitochondrial DNA analysis of the European Anchovy in the Southern Mediterranean and Northern Atlantic Coasts. Journal of Fisheries and Aquatic Science, 2: 206–215.

Chicharo, M. A.; Amaral, A.; Faria, A.; Morais, R.; Mendes, C.; Pilo, D.; Ben-Hamadou, R.; Chicharo, L. M. Z.. "Are tidal lagoons ecologically relevant to larval recruitment of small pelagic fish? An approach using nutritional condition and growth rate". Estuarine Coastal and Shelf Science 112 (2012): 265-279. http://hdl.handle.net/10400.1/2416.

França S, Costa MJ, N. Cabral H (2011) Inter- and intra-estuarine fish assemblage variability patterns along the Portuguese coast. Estuarine, Coastal and Shelf Science 91, Issue 2: 262-271. https://doi.org/10.1016/j.ecss.2010.10.035.

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. In press. Pelagic surveys series for sardine and anchovy in ICES Areas VIII and IX (WGACEGG) – Towards an ecosystem approach. ICES Cooperative Research Report.

Junquera, S.1986. Pêche de l'anchois (*Engraulis encrasicolus*) dans le golfe de Gascogne et sur le littoral atlantique de Galice depuis 1920. Variations quantitatives. Rev Trav Inst Pêches Marit 48: 133–142.

Junquera, S., Pérez-Gándaras, G. 1993. Population diversity in Bay of Biscay anchovy (*Engraulis encrasicolus* L. 1758) as revealed by multivariate analysis of morphometric and meristic characters. ICES J. mar. Sci., 50: 383-391.

Marques SC, Azeiteiro UM, Martinho F, Pardal MA (2007) Climate variability and planktonic communities: the effect of an extreme event (severe drought) in a southern European estuary. Estuar Coast Shelf Sci 73:725–734

Nyitrai, D., Martinho, F., Dolbeth, M. et al. Trends in estuarine fish assemblages facing different environmental conditions: combining diversity with functional attributes. Aquat Ecol 46, 201–214 (2012). https://doi.org/10.1007/s10452-012-9392-1

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.

Patarnello, T., Volckaert, F.A.M., Castilho, R. 2007. Pillars of Hercules: is the Atlantic–Mediterranean transition a phylogeographical break? Molecular Ecology, 16: 4426–4444.

Pestana, G. 1989. Manancial Ibero Atlântico de Sardinha (*Sardina pilchardus* Walb) sua avaliaçâo e medidas de gestâo. Ph.D. thesis. Univ. Lisboa.

Pestana, G. 1996. Anchovy in Portuguese waters (IXa): landings and length distribution in surveys. Working Document presented to the ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (WGMHSA). ICES, C.M. 1996/Assess: 07.

Pombo, L., Rebelo, J.E., 2002. Spatial and temporal organization of a coastal lagoon fish community - Ria de Aveiro, Portugal. Cybium 26 (3), 185e196.

Marques, J. C., Nielsen, S. N., Pardal, M. A. et al. (2003) Impact of eutrophication and river management within a framework of ecosystem theories. Ecol. Model. 166, 147–168.

Ramos, F., Uriarte, A., Millán, M., Villamor, B., 2001.Trial analytical assessment for anchovy (*Engraulis encrasicolus*, L.) in ICES Subdivision IXa-South. Working Document presented to the ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (WGMHSA). ICES, C.M. 2002/ACFM: 06.

Ramos S, Cowen R. K., Paris C, Ré P, Bordalo A.A. (2006) Environmental forcing and larval fish assemblage dynamics in the Lima River estuary (northwest Portugal). Journal of Plankton Research 28, Issue 3, 275–286, https://doi.org/10.1093/plankt/fbi104.

Ribeiro J, Bentes L, Coelho R, Gonçalves JMS, Lino PG, Monteiro P, Erzini K (2006) Seasonal, tidal and diurnal changes in fish assemblages in the Ria Formosa lagoon (Portugal). Estuar Coast Shelf Sci 67:461–474.

Vignon, M. 2012. Ontogenetic trajectories of otolith shape during shift in habitat use: interaction between otolith growth and environment. Journal of Experimental Marine Biology and Ecology, 420–421:26–32.

Vignon, M., Morat, F. 2010. Environmental and genetic determinant of otolith shape revealed by a non-indigenous tropical fish. Marine Ecology Progress Series, 411: 231–241.

Viñas, J., Sanz, N., Peñarrubia, L., Araguas, R.M., García-Marín, J.L., Roldán, M.I., Pla, C. 2014. Genetic population structure of European anchovy in the Mediterranean Sea and the Northeast Atlantic Ocean using sequence analysis of the mitochondrial DNA control region. ICES Journal of Marine Science, 71: 391–397.

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: e42201. doi:10.1371/journal.pone.0042201

Life history parameters of Anchovy 9a - western component

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Last compiled on 06 June, 2022

Contents

1 Background

The anchovy stock in the ICES division 27.9a is managed as a single stock but two different components are considered: -Southern component comprises the southern Portuguese coast and the Gulf of Cadiz. -Western component distributed from Cape Finisterra to Cape S. Vincente, along the west coast of Spain and Portugal; Fishing opportunities for both components are advised following category 3 data limited short-lived stocks of ICES - 1-over-2 rule constrained by a cap of +/- 80%. However, it's acknowledged that the current 1-over-2 rule cannot accommodate the huge fluctuations in biomass of the western component of this anchovy stock. Moreover, the 1-over-2 rule does not guarantee an MSY exploitation, therefore ICES recommends to use it as a provisional harvest control rule until it can be replaced by a better approach, such as a constant harvest rate derived from a management strategy evaluation or F_{MSY} obtained from a surplus production model. In this sense, a dedicated working group was assembled to compile new data to revise the anchovy stock structure and evaluate alternative assessment and harvest rule approaches.

This working document presents the work developed so far to build a Management Strategy Evaluation simulation framework (MSE) to evaluate the performance of an alternative harvest control rule for the western component of the stock. The simulations will be carried out using the FLBEIA software and the operating model will be based on life-history parameters. Specifically, this working document presents a biology model that tries to capture the dynamics of the population (maturity information will be presented in a separate WD).

2 Growth model

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 later is presented in this working document because it had the best fit.

Figure 1 shows the length density distribution of the anchovy population in the Spring (joint index from PELACUS 9aN area and PELAGO 9aCN and 9aCS areas) and the Autumn (first JUVESAR then IBERAS) acoustic surveys since 2008. The smaller and younger anchovies are usually observed in the Autumn acoustic surveys (Figure 2).

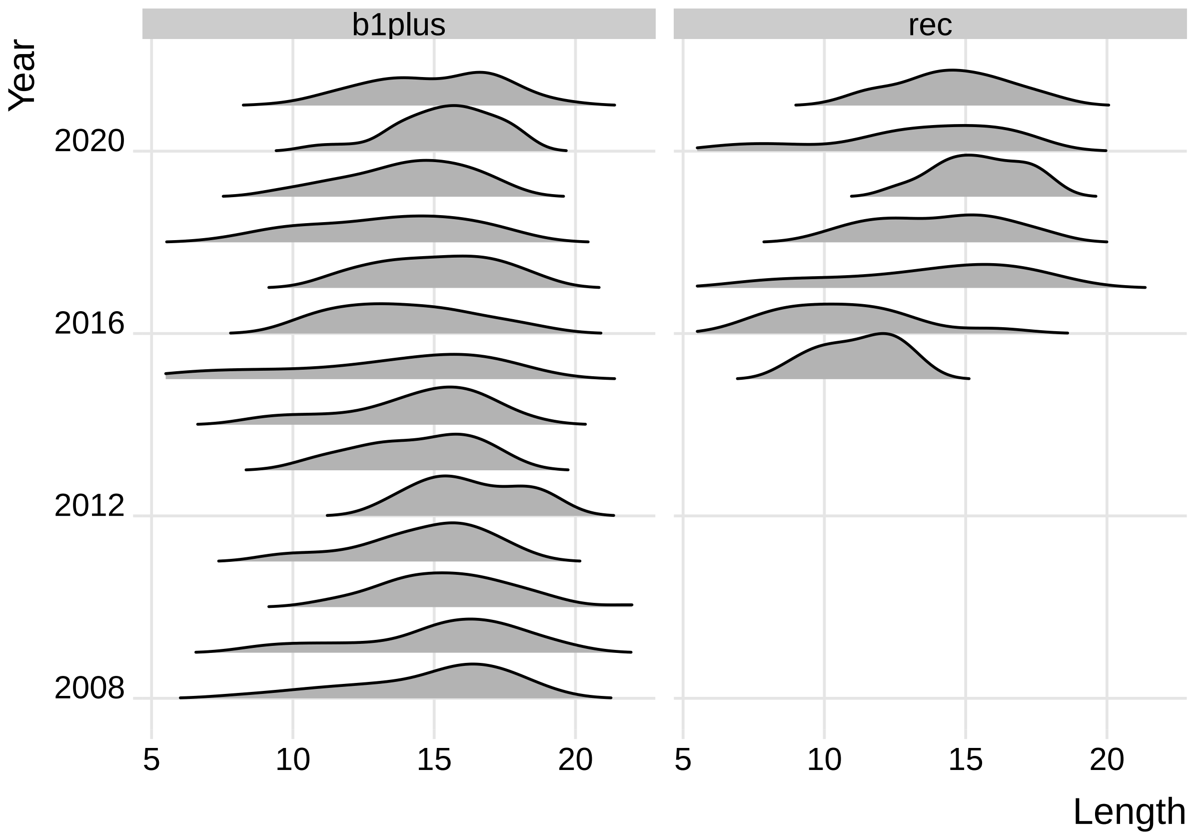

Figure 1: Length density distribution of the western component of the 9a anchovy population in the Spring (left) and the Autumn (right) acoustic surveys.

2.1 Observed mean length at age

Mean length at age within areas is stable along years (Figure 3). Differences observed between mean length at age in PELAGO and JUVESAR/IBERAS are probably due to the timing of the survey. In the recruitment surveys mean length at age increases from north to south (9aN -> 9aCN -> 9aCS). However, in the spring surveys mean length at age are higher in 9aN (Figure 4).

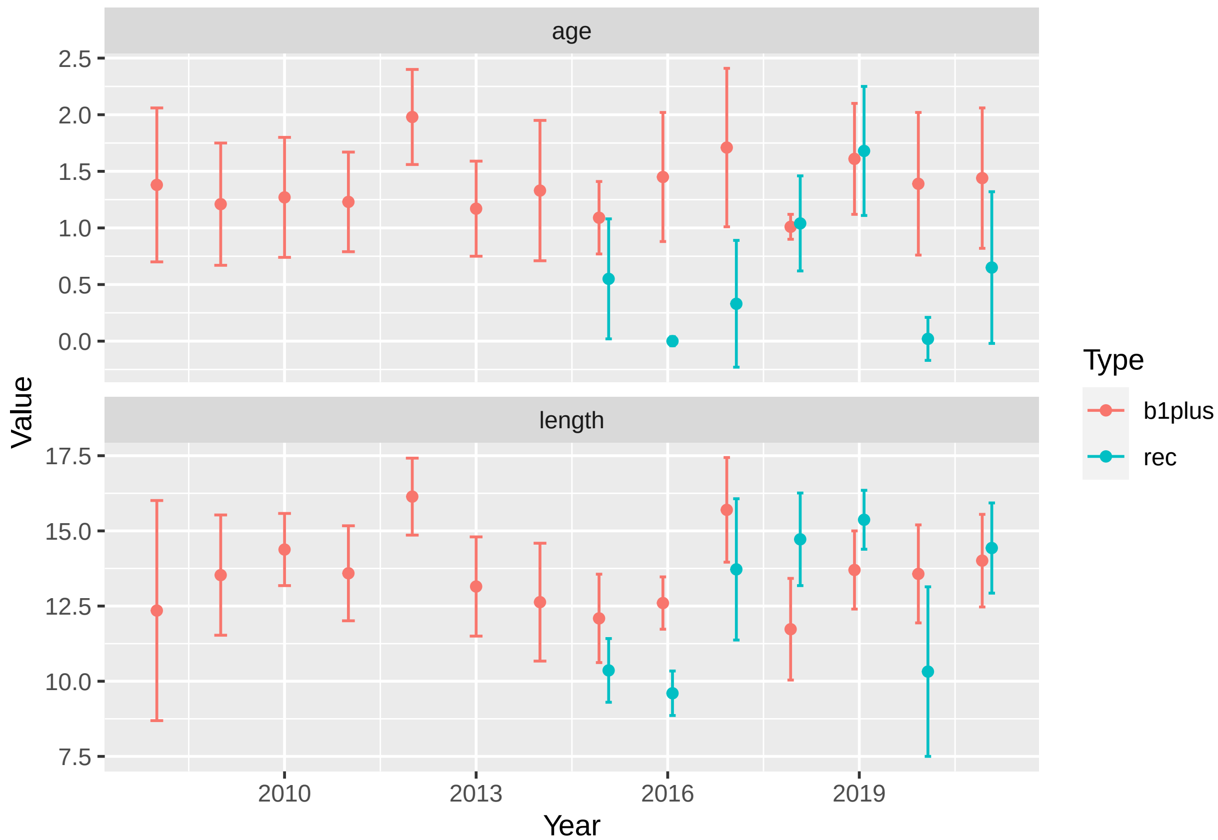

Figure 2: Mean age (top panel) and length (bottom panel) of the western component of the 9a anchovy observed in the Spring (red) and Autumn (blue) acoustic surveys. Error bars represent mean values plus/minus the standard deviation.

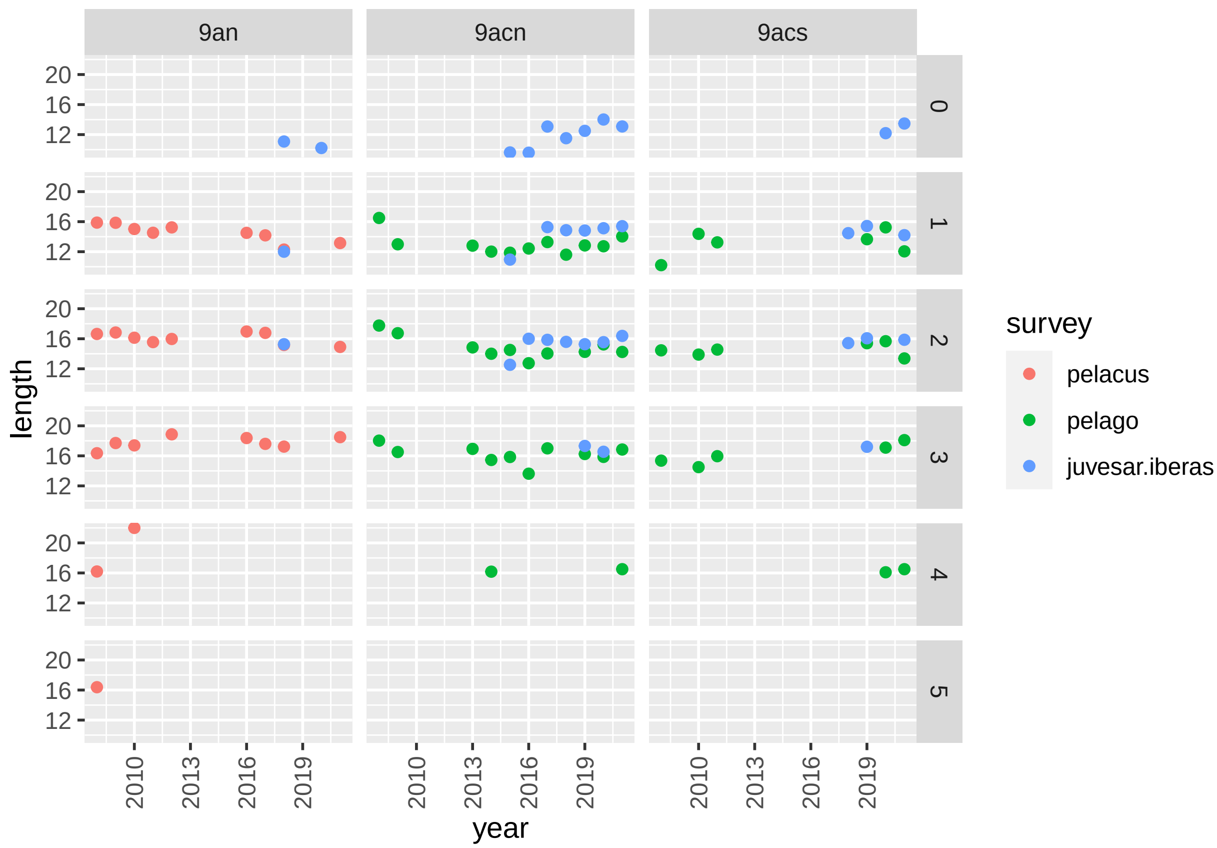

Figure 3: Mean length at age of the western component of the 9a anchovy by survey (color) and area (columns).

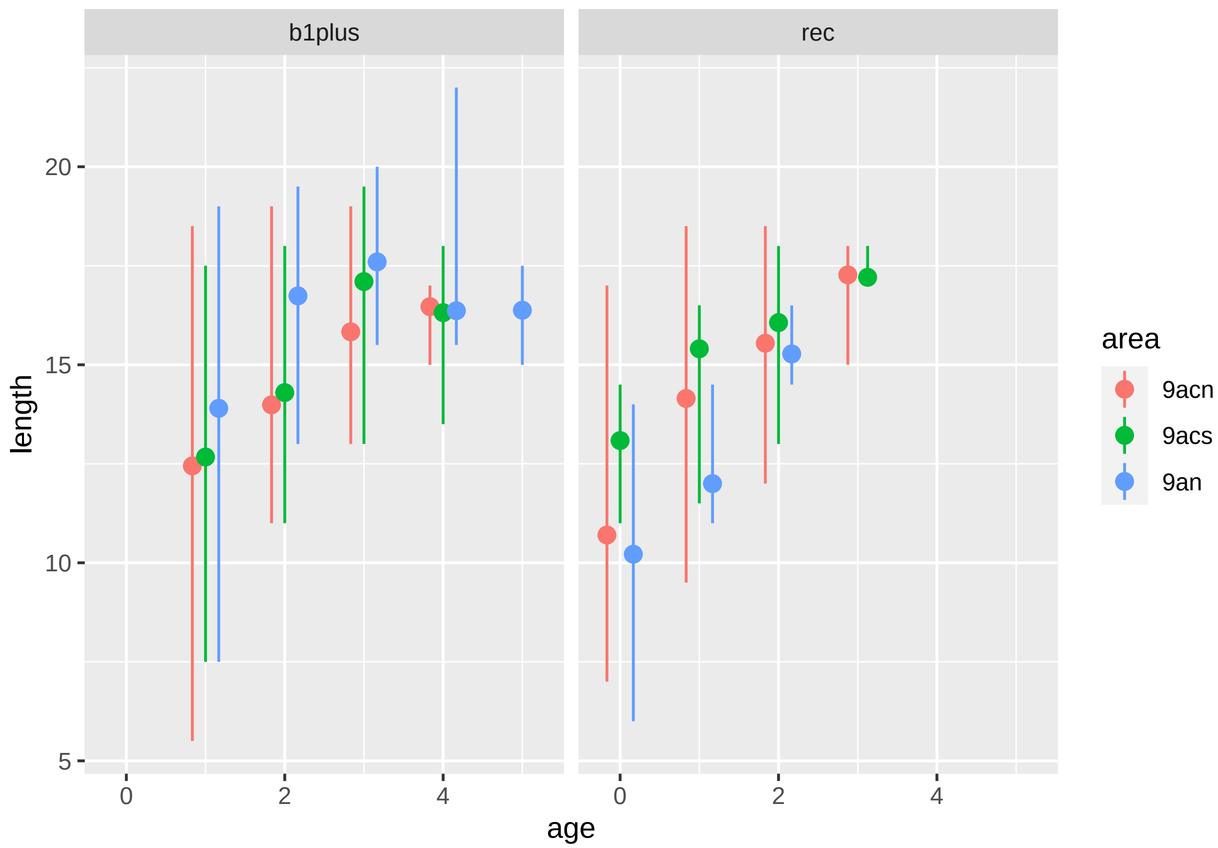

Figure 4: Mean length at age of the western component of the 9a anchovy in the Spring (left) and Autumn (right) surveys by area (colors). Error bars represent mean values plus/minus the standard deviation.

2.2 Cohort tracking

Annual autumn acoustic surveys were conducted in different times of the year (Nov/Dec/Sep) and there is a potential spatial mismatch between juvenile anchovy distribution - known to expand beyond the shelf in other areas such as Bay of Biscay - and survey coverage by JUVESAR/IBERAS (shelf waters only), although this has not been tested in WGACEGG. However, in general, both Spring and Autumn acoustic surveys can follow cohorts (Figure 5).

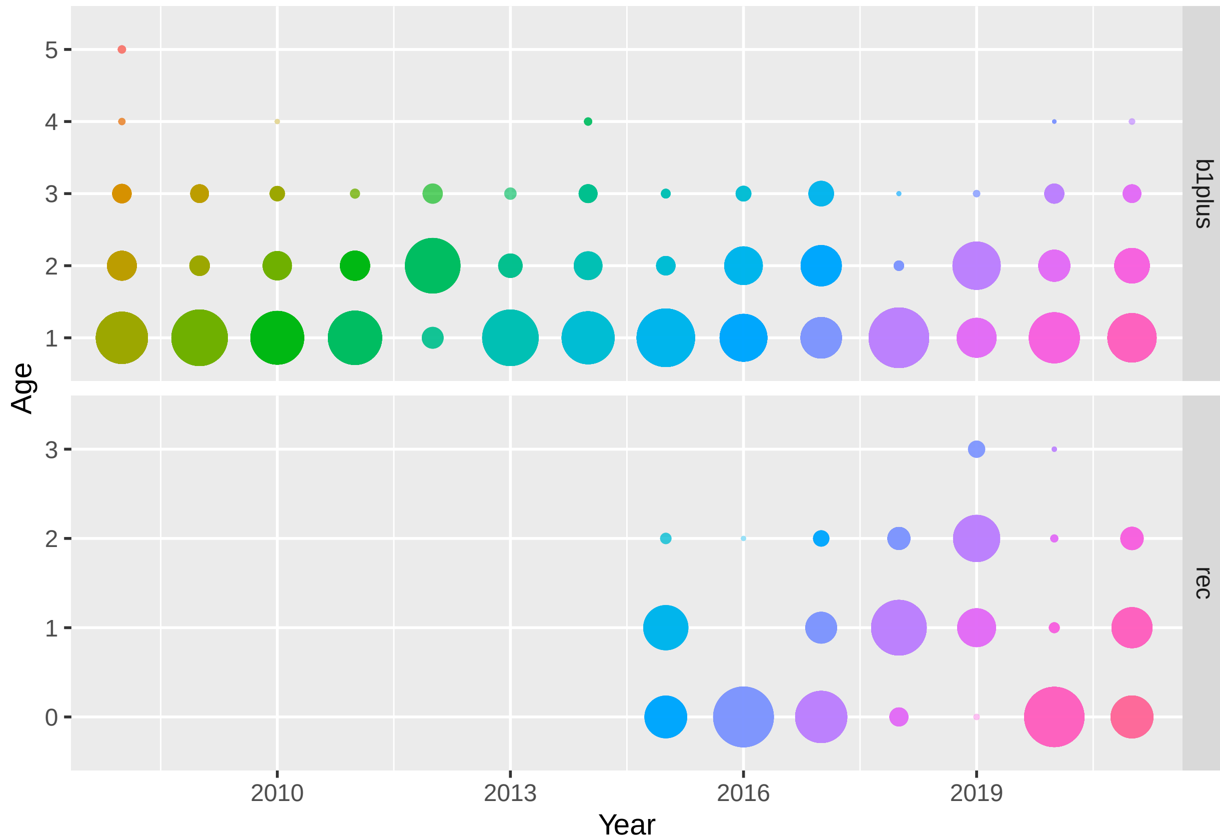

Figure 5: Age structure of the estimated population (proportion observed in the survey) of the western component of the 9a anchovy observed in the Spring (top panel) and Autumn (bottom panel) acoustic surveys. Colors correspond to cohorts.

2.3 Survey consistency

Survey consistency was evaluated by estimating the Pearson correlation between Age zero in the Autumn acoustic surveys in year y and Age one in the Spring acoustic surveys of the following year $(y + 1)$ (Figure 5). No correlation was found mainly due to the cohort of 2019. Even when the data from the 2019 cohort is removed the Pearson correlation is not significant (Figure 6).

2.4 von Bertalanfy growth model

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 was used. Starting values for k, $t0$ and $Linf$ were estimated using the function vbStarts().

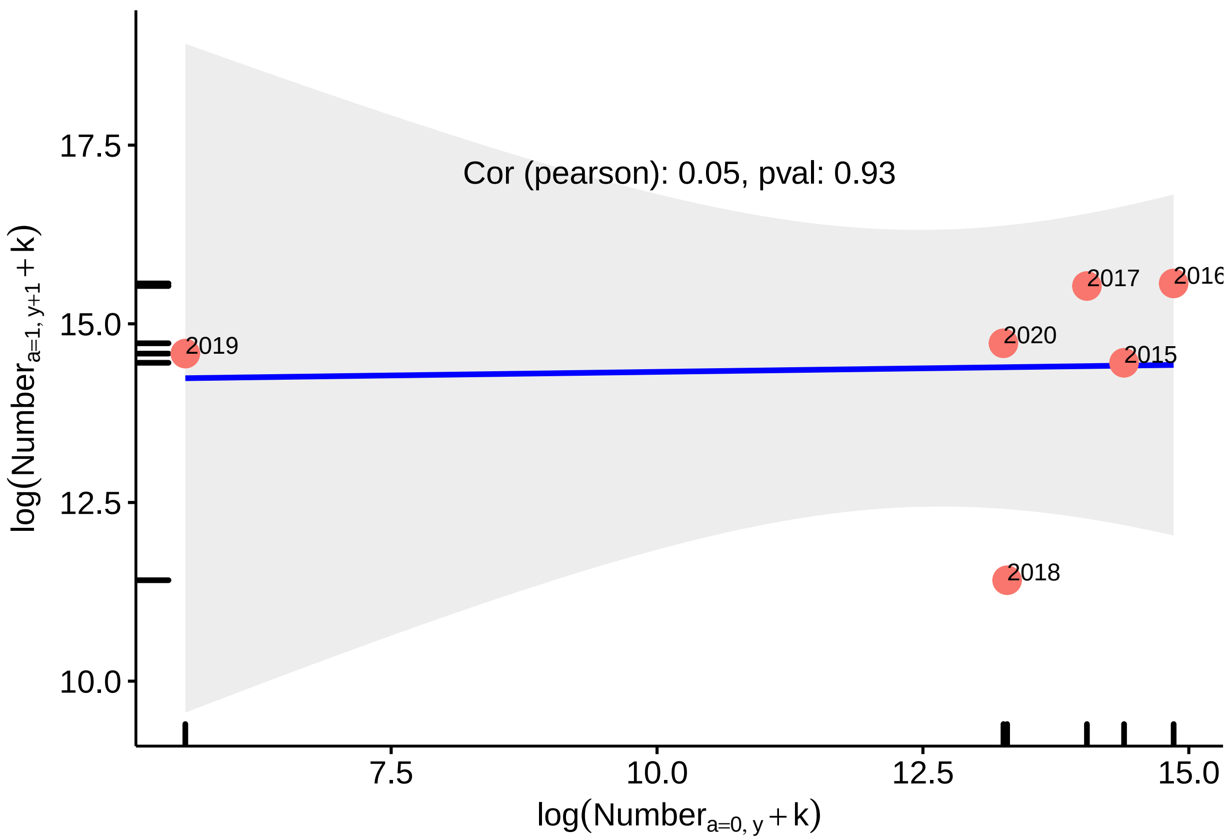

Figure 6: Pearson correlation between the abundance of anchovy in the western Iberia Age zero in the Autumn acoustic surveys in year y and Age one in the Spring acoustic surveys of the following year $(y+1)$.

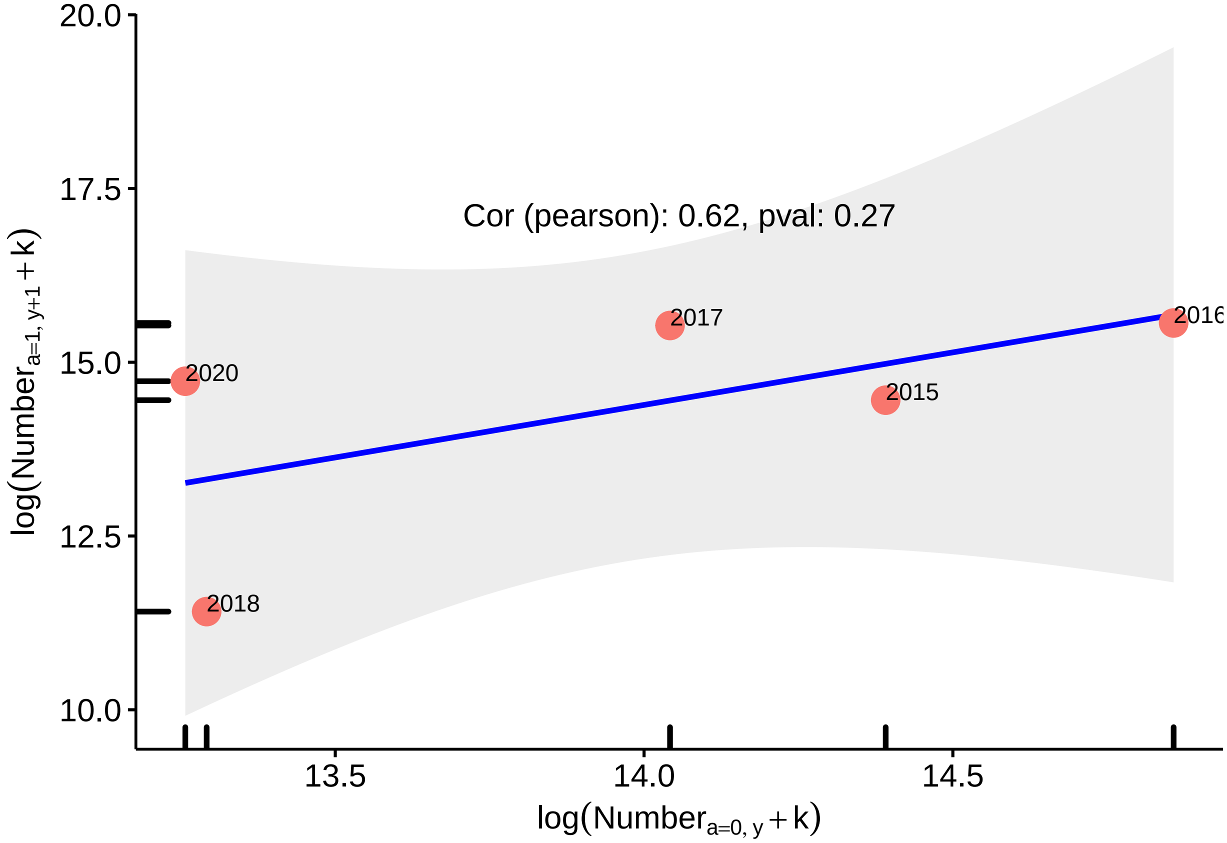

Figure 7: Pearson correlation between the abundance of anchovy in the western Iberia Age zero in the Autumn acoustic surveys in year y and Age one in the Spring acoustic surveys of the following year $(y + 1)$ without the 2019 cohort data.

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 the bigger individuals (subset ss22) since they only appeared in one survey and area (PELACUS 2010) and then we also fitted the model using decimal years (ss22D). 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. Finnaly, we combined both survey and removed individuals equal or bigger than 22 cm; subset all).

The starting values estimated from the different data sets using vbStarts() are shown in Table 1 while The point estimate, standard error and respective t-value and p-value for the VBGM parameters are shown in Table 2.

Table 1 - Initial parameters of the VBGM used for the different subsets.

Parameters	Linf	K	t0
pp	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 2 - Fitted parameters of the VBGM for the different subsets.

Parameter	Data Set	Estimate	Std Error	t-value	Pr(>|t|)
rs					
Linf	rs	17.80	3.64	4.88	0.00
K	rs	0.50	0.53	0.93	0.36
t0	rs	−2.20	1.64	−1.34	0.20
ss22D					
Linf	ss22D	17.54	1.19	14.76	0.00
K	ss22D	0.68	0.35	1.92	0.06
t0	ss22D	−1.01	0.80	−1.26	0.21
ss22					
Linf	ss22	17.20	1.06	16.23	0.00
K	ss22	0.73	0.38	1.92	0.06
t0	ss22	−0.88	0.78	−1.13	0.27
ss					
Linf	ss	19.69	3.73	5.28	0.00
K	ss	0.37	0.31	1.18	0.24
t0	ss	−1.89	1.56	−1.21	0.23
all					
Linf	pp	17.77	1.13	15.70	0.00
K	pp	0.59	0.23	2.59	0.01
t0	pp	−1.26	0.58	−2.18	0.03

Residual plots of each fit are shown in the next Figures (Figures 8-12).

```
##
##  Number of bootstraps was 995 out of 999 attempted

##
```

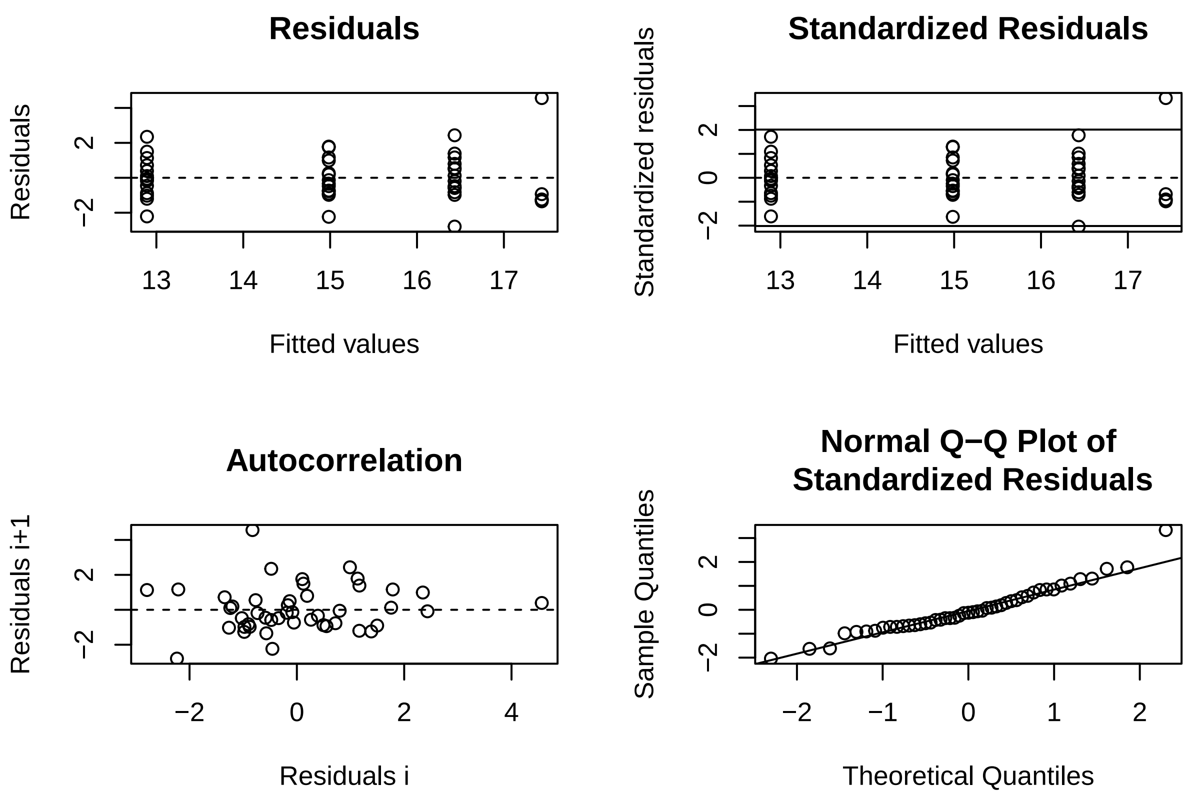

Figure 8: Residuals plots of fit to data subset ss.

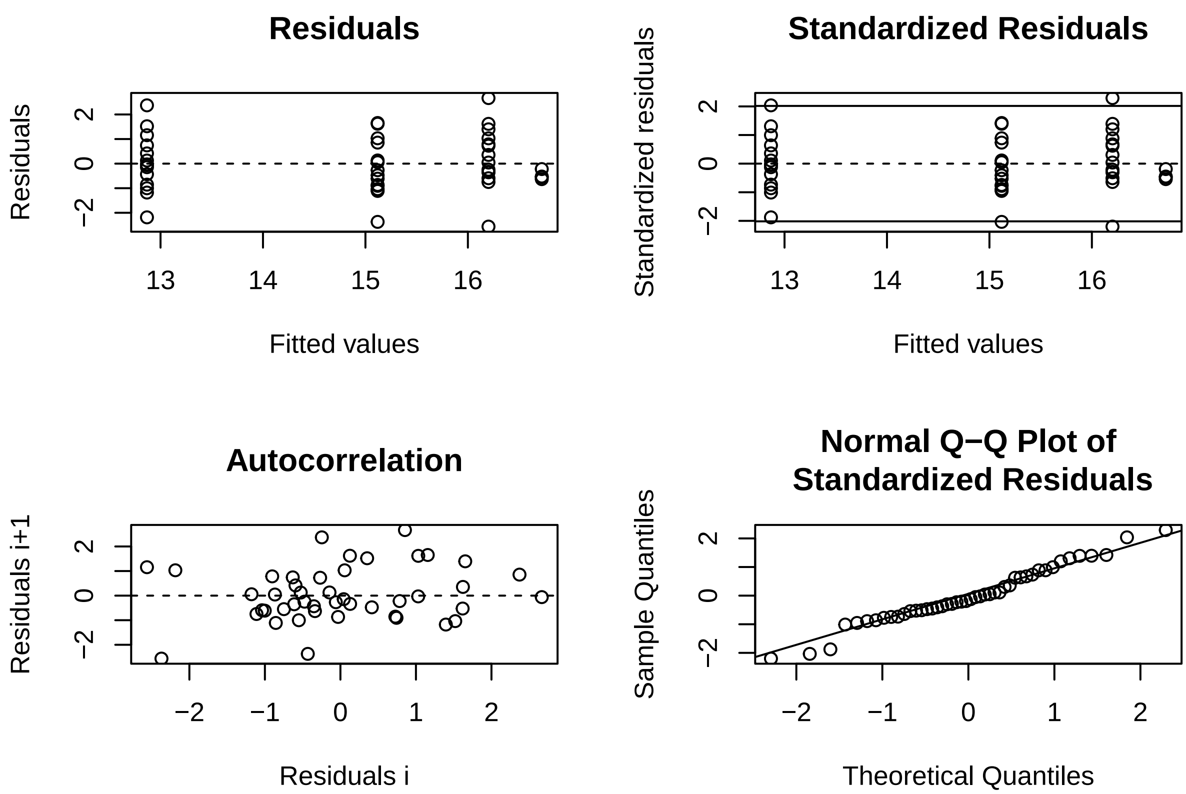

Figure 9: Residuals plots of fit to data subset ss22.

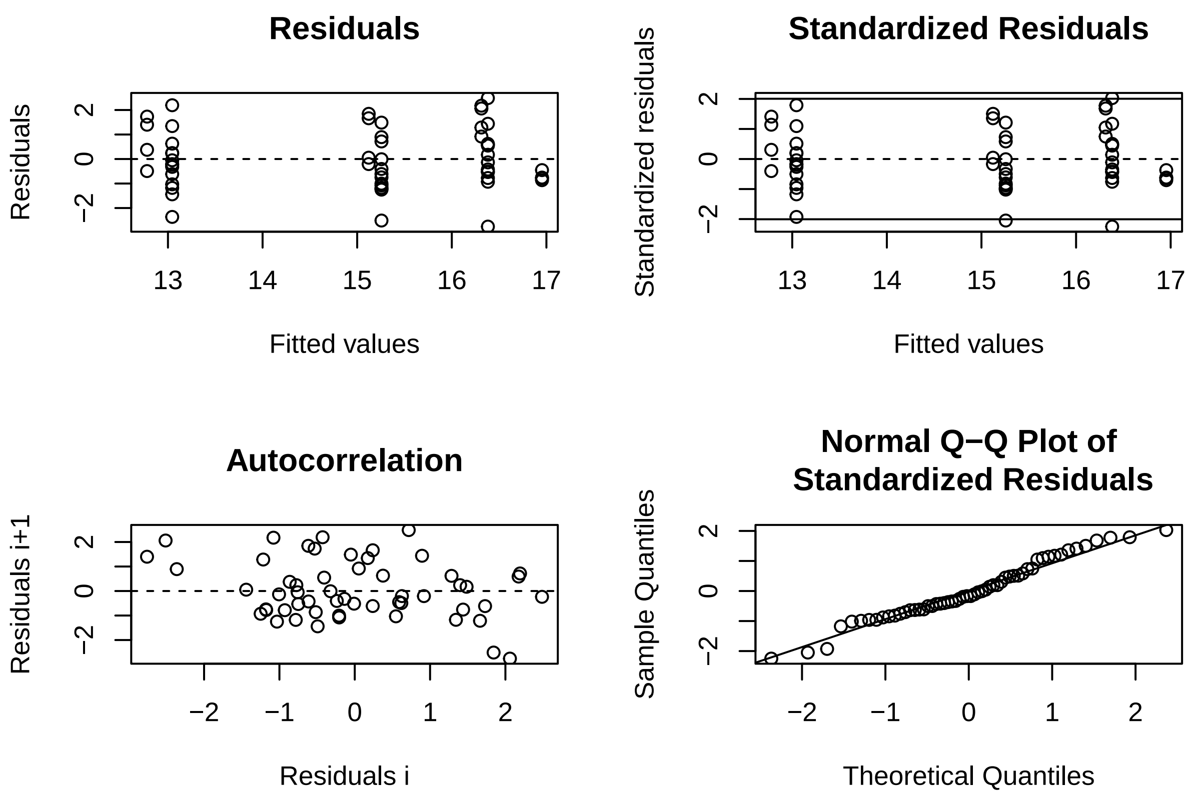

Figure 10: Residuals plots of fit to data subset ss22D.

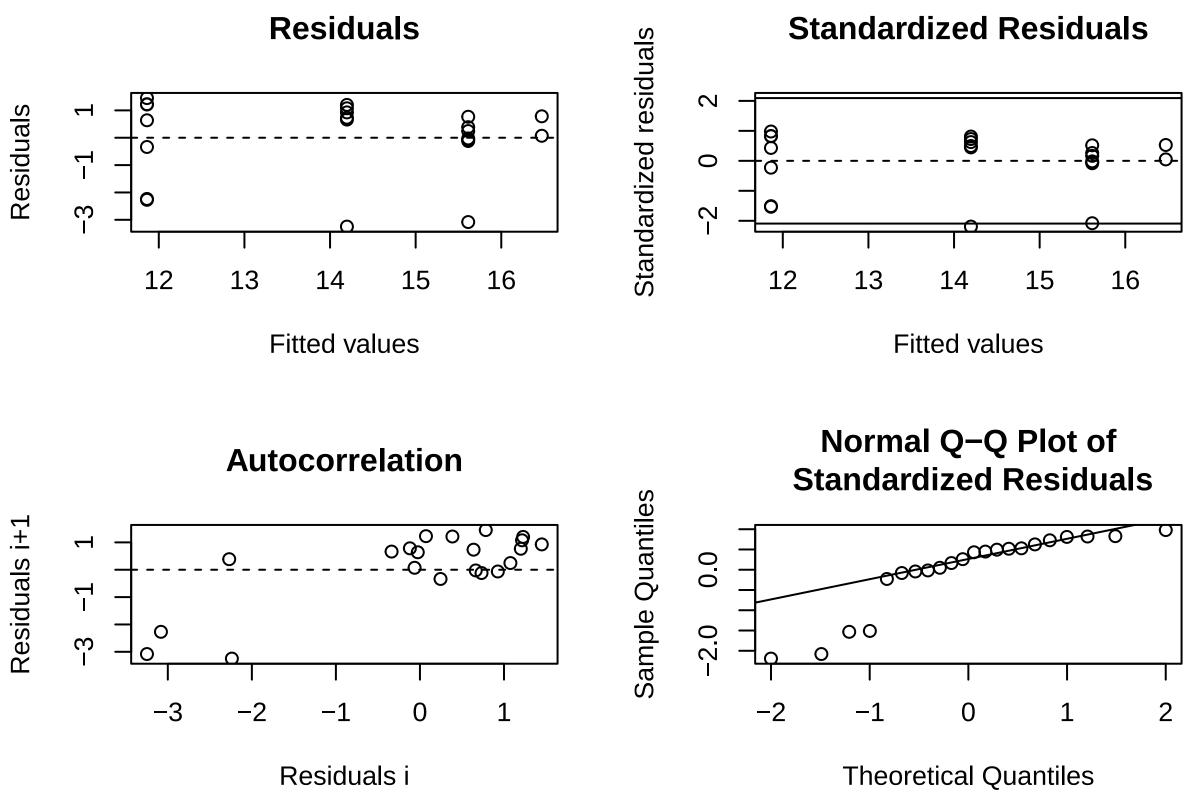

Figure 11: Residuals plots of fit to data subset rs.

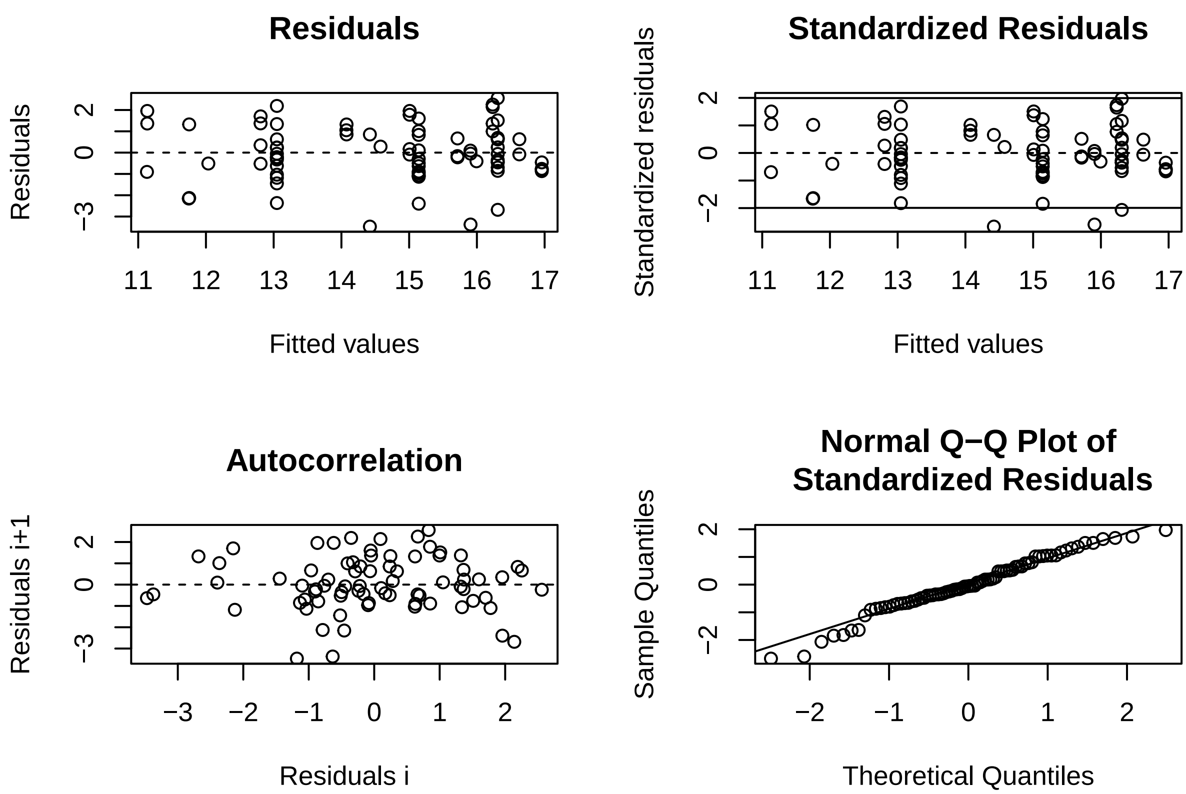

Figure 12: Residuals plots of fit to data subset all.

```
##   Number of bootstraps was 794 out of 999 attempted

##
##   Number of bootstraps was 996 out of 999 attempted

##
##   Number of bootstraps was 992 out of 999 attempted

##
##   Number of bootstraps was 801 out of 999 attempted
```

Figure 13 shows the fit of the different estimated VBGM with confidence intervals estimated with bootstrap. Since only the model fitted to all data (red line and text) has significant estimated parameters, we propose this model as one candidate model for the base operating model of the MSE.

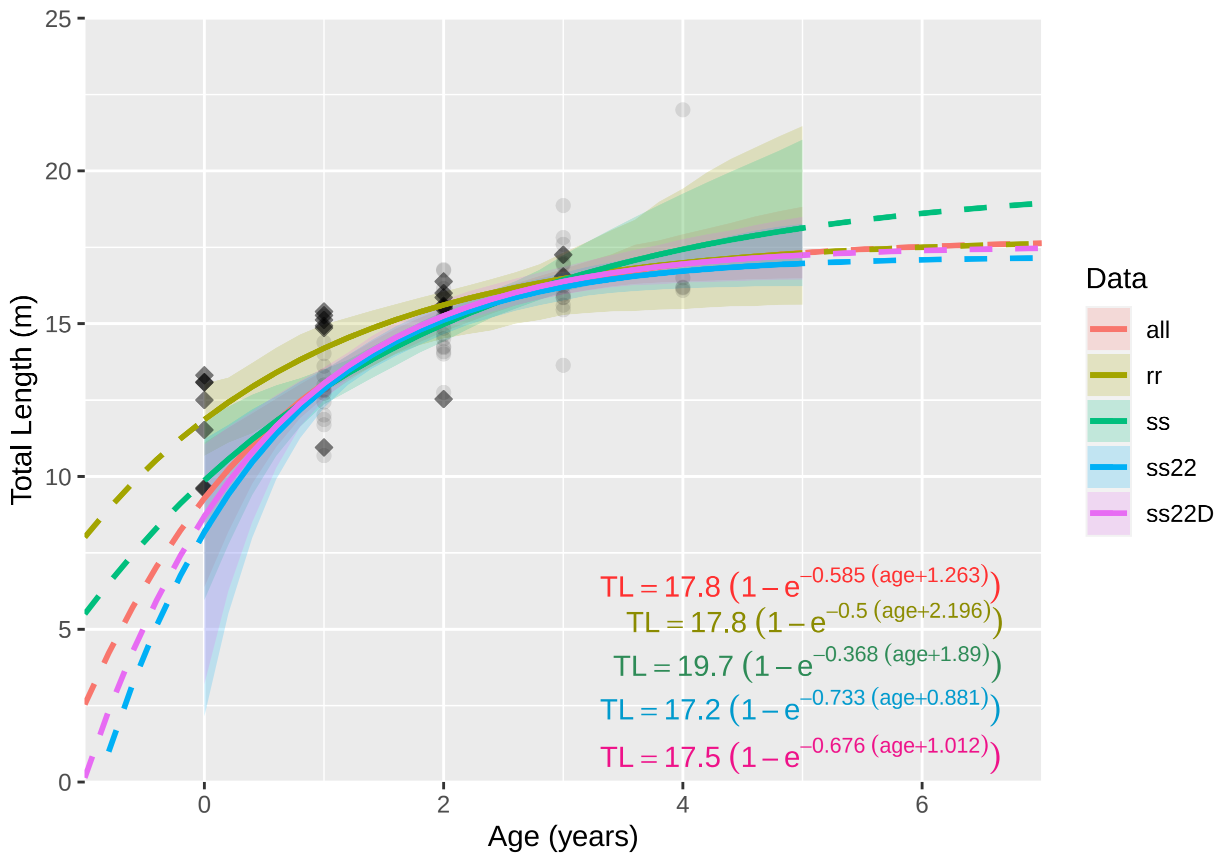

Figure 13: Fitted VBGM.

The parameters estimated with bootstrap sampling and their corresponding standard deviation are showned in Table 3.

Table 3 - Estimated parameters with bootstrap sampling and their standard deviation.

	Estimate	Std Error	Median	2.5%	97.5%
Linf					
all	18.30	1.97	17.81	16.45	23.26

ss	20.67	4.68	19.15	16.66	34.65
ss22	17.78	1.93	17.24	15.96	23.22
ss22D	18.09	2.21	17.46	16.23	24.09
rs	19.54	5.51	17.68	15.14	35.81
K					
all	0.60	0.22	0.58	0.18	1.04
ss	0.49	0.31	0.43	0.09	1.22
ss22	0.80	0.43	0.72	0.19	1.80
ss22D	0.77	0.48	0.72	0.18	1.63
rs	0.70	0.59	0.55	0.08	2.18
t0					
all	−1.40	0.69	−1.26	−3.32	−0.50
ss	−1.85	1.25	−1.59	−4.73	−0.13
ss22	−1.07	0.91	−0.88	−3.32	0.14
ss22D	−1.14	0.92	−0.90	−3.50	0.06
rs	−2.26	1.18	−2.01	−5.17	−0.64

2.5 Other growth models

Other growth models (Gompertz and Logistic) were fitted and compared with the VBGM fitted to all the data subset (Figure 14). The model with the best AIC was the logistic model but differences between AIC are so small that are considered negligible (Table 4).

Table 4 - AIC estimated for each growth model.

Model	AICc	AIC diff	Weight
VB	267.67	0.33	0.30
Log	267.34	0.00	0.36
Gom	267.48	0.14	0.34

3 Length - weight relationship

A length-weight relationship was fitted to the transformed data $log_{10}(weight) - log_{10}(length)$ from the biological samples collected during the Spring and Autumn surveys (Figure 15). Both coefficients of the estimated model were significant ($p < 2e^{-16}$) and the model adjusted R-squared value is 0.97.

4 Natural mortality

Natural mortality was estimated with classical indirect formulations based on life history parameters. The R package FSA was used 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 the model estimated in section 2.4 (Table 2) (L_{inf} = 17.77, k = 0.59, t_0 = -1.26). For the maximum observed age we assumed age 4 as adequate. A total of 13 estimators were produced using the R package FSA and the mean value of $M = $1.134 was chosen.

Table 5 - Estimaded natural mortality rate estimated with a VBGM estimated in previous section and the VBGM estimated by Bellido et al (2000).

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Model
0.88	1.05	1.08	1.13	1.24	1.38	VB all surveys
0.93	1.08	1.33	1.28	1.44	1.52	Bellido et al.

Natural mortality at age was then estimated assuming two different length-at-age vectors, the first with the mean length-at-age observed in the data and the second one with the mean length-at-age estimated with the VBGM estimated in section 2.4 (Table 6). Two methods were used, the Gislason and the Charnov methods, both implemented within the FSA R package (Figure 16).

Table 6 - Length at age vectors (observed and estimated).

Age	Observed	VB
0	11.38	9.32
1	13.07	13.09
2	14.96	15.17
3	16.54	16.33
4	16.24	16.97

5 Discussion

The following bullet points reflect the discussion in the group plenary:

- When estimating a growth model using decimal years the spawning time and birth date assumed must be in accordance with what will be the assumptions made in the MSE. In this WD, spawning time was assumed to be in March. If a different spawning time is assumed in the MSE the growth model must be re-estimated accordingly;
- The MSE may consider different operating models so there might not be necessary to choose just one natural mortality vector. The same comment may be applied to the growth model estimated.

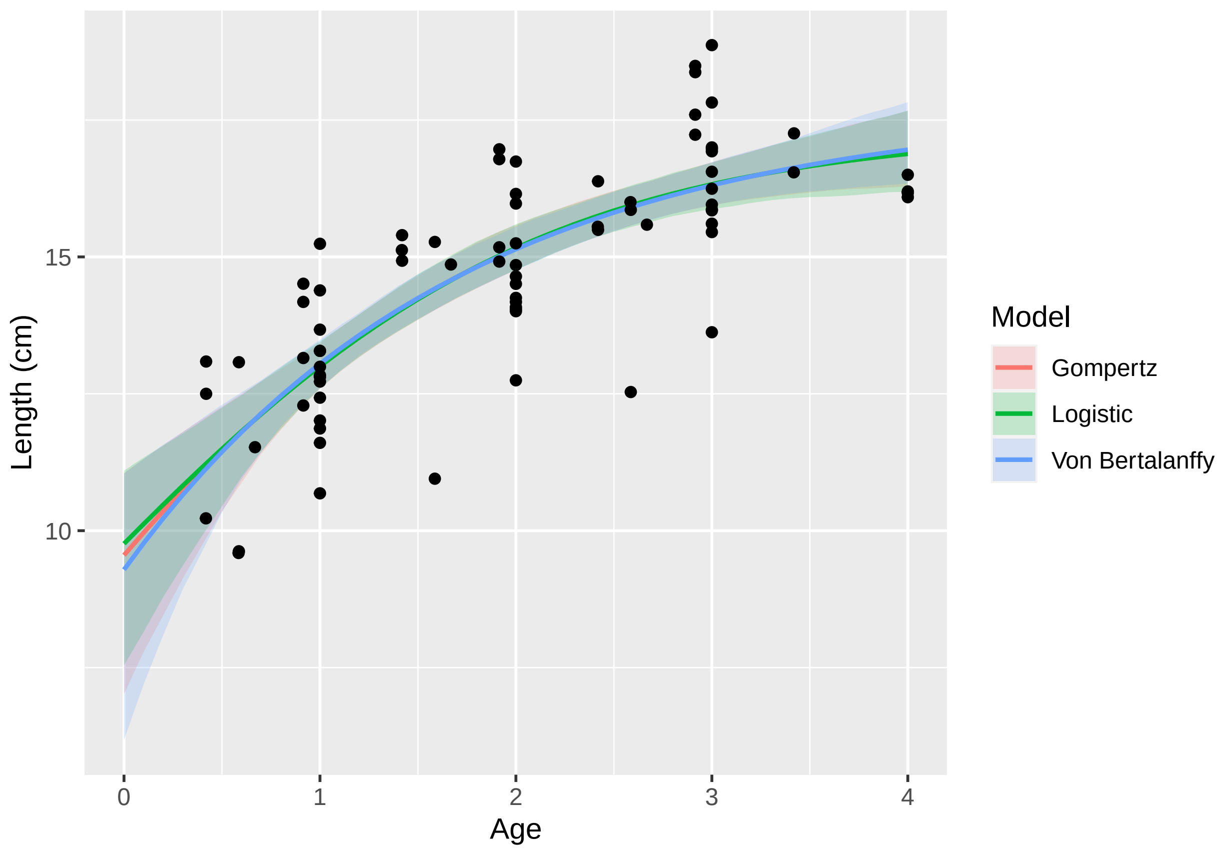

Figure 14: Von Bertalanffy, Gompertz and Logistic models.

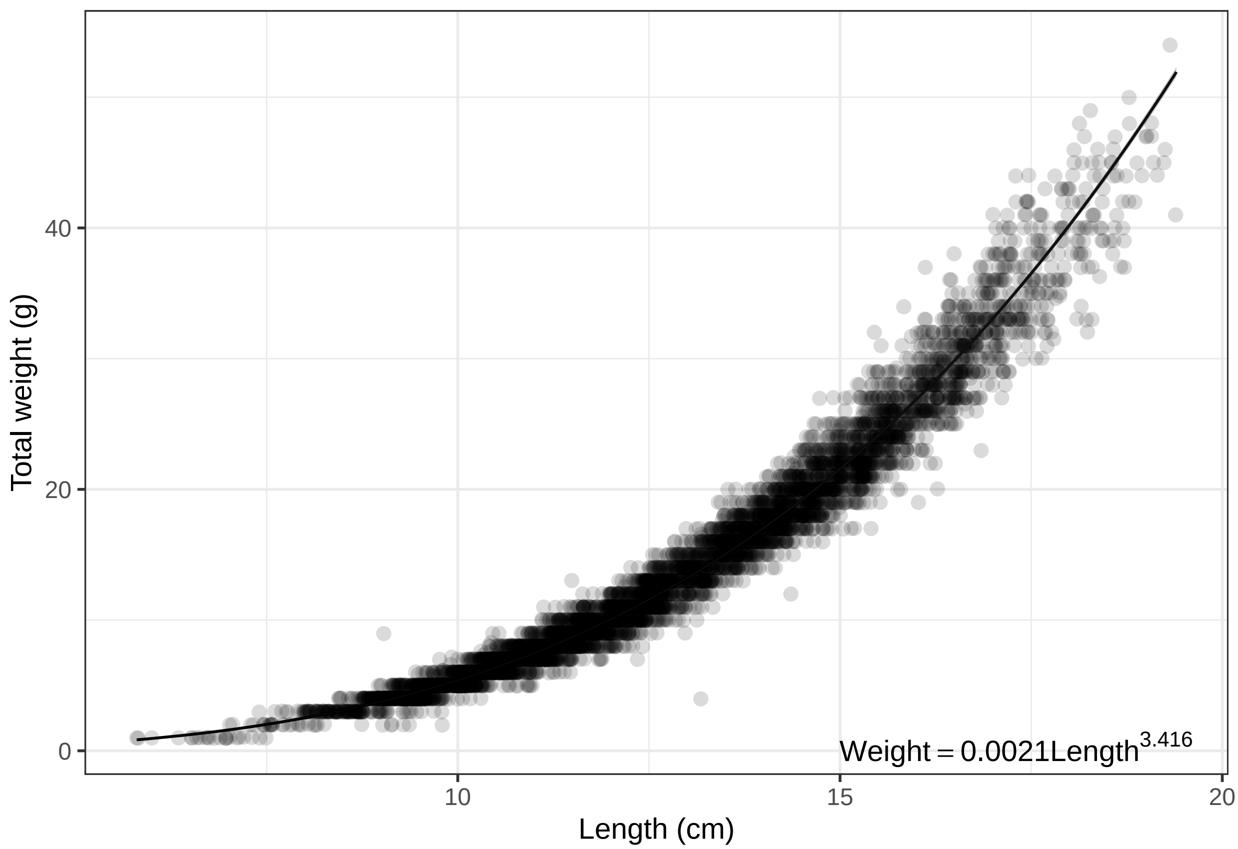

Figure 15: Length-weight relationship estimated for the western component of the 9a anchovy stock.

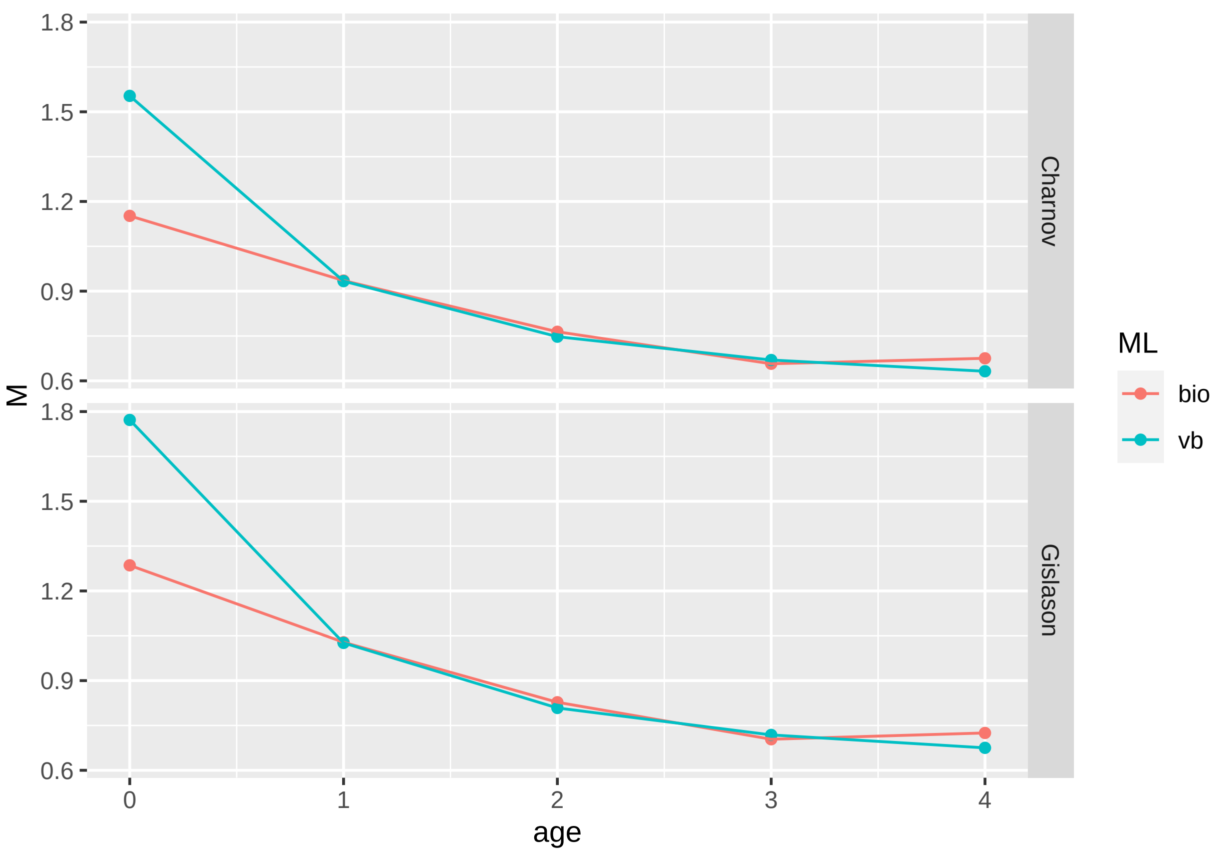

Figure 16: Natural mortality at age estimated with the Gislason (bottom panel) and the Charnov (top panel) methods assuming two different mean length at age vectors (observed in red and estimated in blue).

Working document presented to the:

ICES Working Group on Horse mackerel, anchovy and sardine (WGHANSA 2022). 23-27 May 2022.

REPRODUCTIVE CHARACTERISTICS OF WESTERN COMPONENT 27.9.A ANCHOVY

Susana Garrido, Ana Maria Costa, Cristina Nunes, Pedro Pechirra, Hugo Mendes, Dina Silva Raquel Milhazes, Andreia V. Silva, Carmo Silva, Laura Wise, Alexandra Silva

ABSTRACT

Information on the reproductive biology is key for the assessment of the fraction of the population that is mature, contributing for the stock reproductive output, and the population renewal. Currently, there is no information on the reproductive biology of anchovy in the western Iberian coast. In this work, we have collected juvenile and adult fish from the Portuguese western coast and analysed gonads for histology to: 1) try to validate the macroscopic scale of maturity, 2) describe the seasonal cycle of reproduction and 3) estimate the percentage of mature and immature individuals by size and age. As for other fish species, the macroscopic maturity scale did not validate, failing to correctly distinguish immature from resting females and males, meaning that anchovy reproductive state should be assessed histologically. Seasonality of spawning assessed by the monthly variation of gonadosomatic index and by the percentage of active females (microscopic stages 2,3 and 4) identified a similar spawning season as for other anchovy populations in the Iberia, ranging from April/May to July. The proportion of active females and males during the spawning season was very high for all fish analysed (ranging from 9.5 to 17 cm total length) which strongly affected the fitting of the logistic curve relating maturity with length class or age. An extra sampling effort will be carried out in the current year to try to collect smaller fish to improve the fitting of the maturity ogive.

1. SAMPLE COLLECTION

Anchovy individuals were collected from January 2018 to July 2019 from commercial landings and IPMA's research surveys off the Portuguese west coast. Biological information was recorded for each fish (total length, total weight, gutted and gonad weights, age, sex, macroscopic maturity stage (Appendix I), fat content, stomach fullness). Gonads were collected and processed for histology embedded in parafin, stained with hematoxylin and eosin. Two readers analysed the histological slides and microscopically identified maturity stages.

In total, 375 individuals were analysed microscopically, mostly collected from the 9a.CN sub-division (351 individuals), while the remaining 24 individuals were collected from the 9a.CS sub-division. Sexes were equally represented, with 190 females and 185 males, ranging from 9.5 to 17 cm (median 14.0 cm, mean 13.79 ± 2.21 cm).

2. Validation of the maturity scale

Most fish analysed in this study were mature (78%) and only 10% were immature. For the remaining 10% of the individuals it was not possible to attribute a consensual maturity stage with microscopic analysis.

Comparing the results of the macroscopic and microscopic staging of gonads (Table 1), it is shown that for anchovy, as for many other species, it is not possible to distinguish immature individuals from resting females and males macroscopically, therefore their reproductive state should be assessed histologically. Only 22% and 50% of the immature females and males were correctly assigned as immature, respectively. Regarding mature fish, 98% and 86% of mature females and males were correctly assigned as mature, respectively. Main problems encountered were in the incorrect assignment of immature fish as stage 2 and 5.

Table 1 – Number of anchovy individuals classified as 1 (immature) and 2-5 (mature) by macroscopically staging and classified as mature, immature or in doubt using microscopically examination, by sex. Last two columns show percentage of correct/incorrect classification.

Number of fish

		Macroscopical maturity stage					% correct	% incorrect
sex	**Microscopic maturity stage**	**1**	**2**	**3**	**4**	**5**		
female	**Stage 1 - immat**	8	24			5	22	78
	mat	2	16	57	22	27	98	2
	doubt	6	14			9		
male	**Stage 1 - immat**	2	1			1	50	50
	mat	23	24	96		26	86	14
	doubt	6	3			3		

3. Seasonality of spawning

Anchovy reproduce off the Portuguese West coast mostly in spring-summer months (April to July), with a peak in May-July (Fig. 1). Males and females are synchronized and at peak spawning, nearly all fish in the population are reproductively active (Fig. 2).

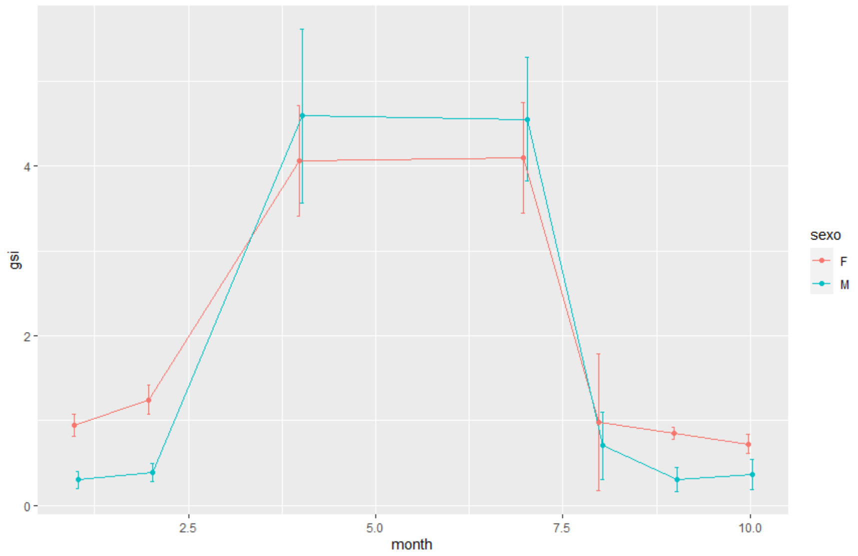

Figure 1 - Monthly values (mean ± CI) of gonadossomatic index of male and female anchovy collected in the western Portuguese coast.

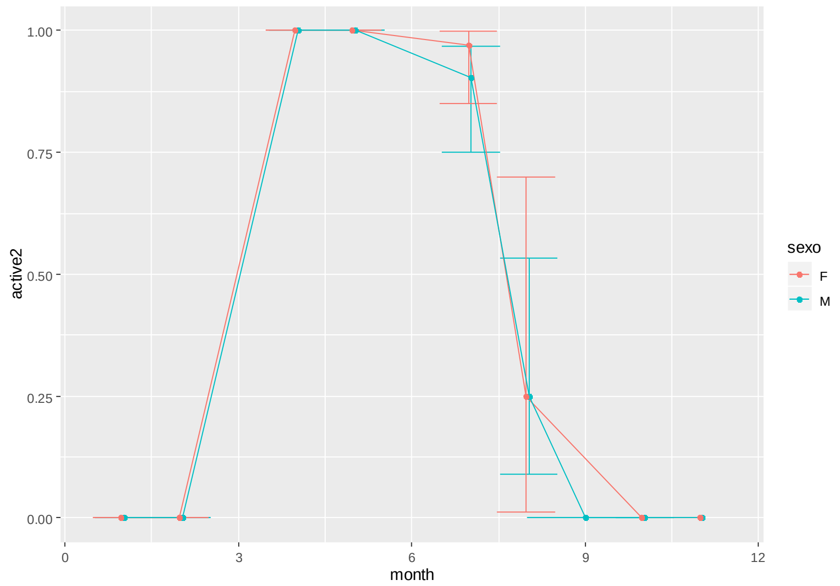

Figure 2 - Monthly values (mean ± CI Wilson) of active (1) and inactive (0) anchovy collected in the western Portuguese coast, by sex.

4. Maturity Ogive

In order to construct the maturity ogive, only fish collected in the spawning season (April to July) were selected. In total, 193 fish were collected during this period, ranging from length class 9.5 to 17 cm and ages 0 to 2 (Tables 2 and 3). Fish in stage 1 and 2 were classified as immature and those in stage 3,4 and 5 classified as mature, following Millan et al. (1999).

Table 2 – Percentage of fish classified microscopically as mature or immature and number of fish collected during the spawning season by size class

length class	imatur 1+2	matur 3+
9.5		5
10	1	5
10.5	1	13
11		15
11.5	1	11
12		8
12.5		15
13	1	10
13.5		15
14		16
14.5		18
15	1	17
15.5		12
16		6
16.5		12
17		4
Total Geral	**17**	**891**

Table 3 – Percentage of fish classified microscopically as mature or immature and number of fish collected during the spawning season by age

Age	1+2	3+
0	1	5
1	7	103
2	2	59
no age info		16
Total Geral	**11**	**182**

The proportion of mature fish is assumed to increase with size and age. Data was adjusted to a logistic function following the method described in Silva *et al.* (2017), using the software R (R Core Team, 2021) with a glm function using the binomial as the response variable distribution and a logit link.

The majority of fish collected from the smallest length class were classified as mature (71%), while the percentage was >80% for the following length classes (Table 2). For this reason, the fitted logistic regression is highly uncertain reflected in the large confidence intervals of smaller fish and the maturity ogive should be considered unreliable (Fig. 3).

Most fish collected during the spawning season were age 1 and 2 individuals, only 3.4% (6 fish) were age 0 and no fish age 3 was collected. Most of age 0 fish analysed were mature, which is probably related to their large size (>9 cm). Again, confidence interval for age 0 are very large (Fig. 4).

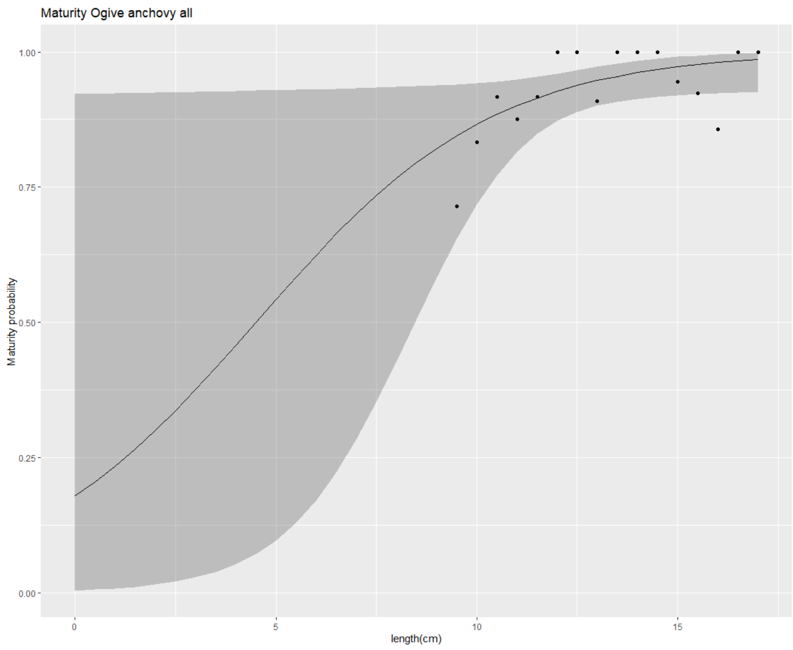

Figure 3 – Fitted logistic regression for combined proportion of male and female anchovy mature by length from samples collected in the western Portuguese coast in 2018 and 2019. The shaded area represents the 95% confidence interval.

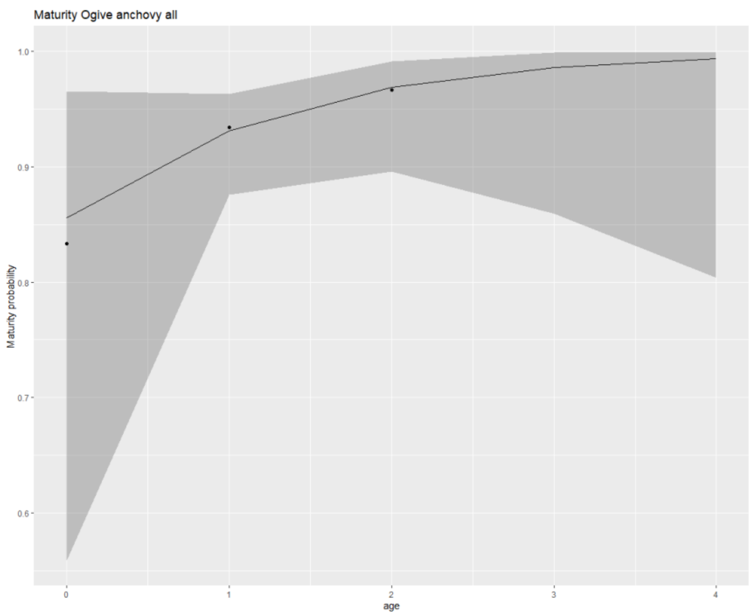

Figure 4 – Fitted logistic regression for combined proportion of male and female anchovy mature by age from samples collected in the western Portuguese coast in 2018 and 2019. The shaded area represents the 95% confidence interval.

5. Maturity Ogive - Stage 1 as immature

Some studies consider only stage 1 as immature and stage 2 as mature, since the development of anchovy gonads is very fast and it is possible that fish in stage 2 can complete development within the spawning season. Therefore, an alternative, the maturity ogive was constructed as explained in section 3 of the current WD, but this time fish in stage 1 were classified as immature and those in stage 2, 3,4 and 5 classified as mature. Again, only fish collected in the spawning season (April to July) were selected and in total, 193 fish were analysed during this period, ranging from length class 9.5 to 17 cm and ages 0 to 2 (Tables 4 and 5).

Table 4 – Percentage of fish classified microscopically as mature or immature and number of fish collected during the spawning season by size class.

length class	imatur 1	matur 2+
9.5		7
10	1	5
10.5	1	13
11		17
11.5	1	11
12		8
12.5		15
13	1	10
13.5		15
14		16
14.5		18
15	1	17
15.5		13
16		7
16.5		12
17		4
Total Geral	**5**	**14**

Table 5 – Percentage of fish classified microscopically as mature or immature and number of fish collected during the spawning season by age.

Age	1	2+
0	1	5
1	4	106
2		61
no age info		16
Total Geral	**5**	**188**

The proportion of mature fish is assumed to increase with size and age. Data was adjusted to a logistic function following the method described in Silva *et al.* (2017), using the software R (R Core Team, 2021) with a glm function using the binomial as the response variable distribution and a logit link.

The majority of fish collected from the smallest length class were classified as mature (71%), while the percentage was >80% for the following length classes (Table 2). For this reason, the fitted logistic regression is highly uncertain reflected in the large confidence intervals of smaller fish and the maturity ogive should be considered unreliable (Fig. 5).

Most fish collected during the spawning season were age 1 and 2 individuals, only 3.4% (6 fish) were age 0 and no fish age 3 was collected. Most of age 0 fish analysed were mature, which is probably related to their large size (>9 cm). Again, confidence interval for age 0 are very large (Fig. 6).

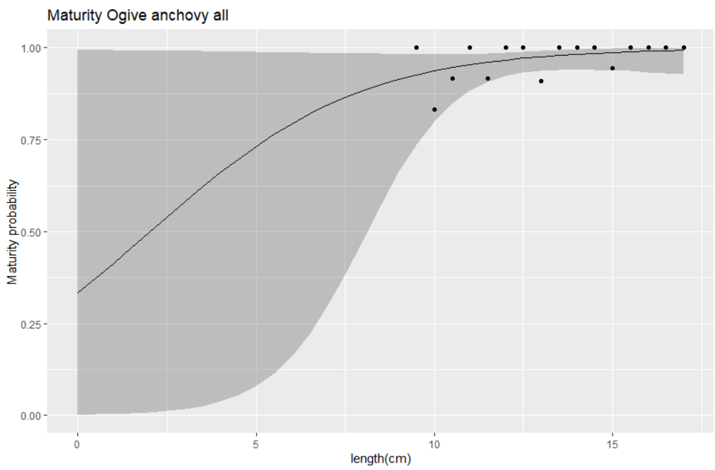

Figure 5 – Fitted logistic regression for combined proportion of male and female anchovy mature by length from samples collected in the western Portuguese coast in 2018 and 2019. The shaded area represents the 95% confidence interval.

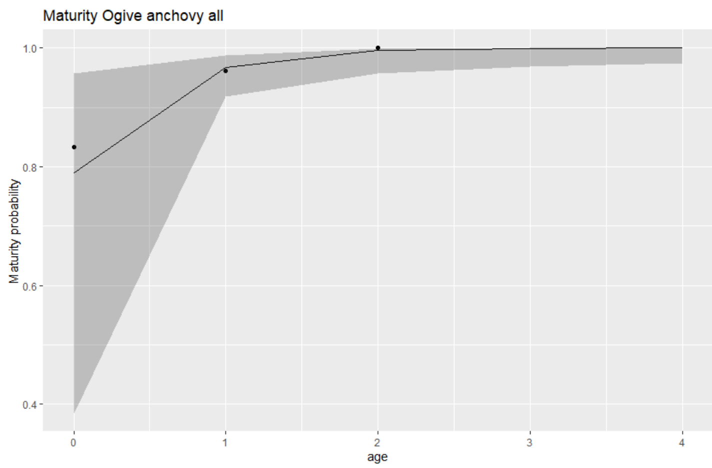

Figure 6 – Fitted logistic regression for combined proportion of male and female anchovy mature by age from samples collected in the western Portuguese coast in 2018 and 2019. The shaded area represents the 95% confidence interval.

There are additional data from the Gulf of Cadiz (unpublished, F Ramos pers. Comm.) that point to maturation at smaller sizes than those presented in Millan et al. 1999, and similar to those found for the western Iberia in the present work.

6. Data from neighbour population

There is data of the maturity at length and age for nearby areas, such as the Gulf of Cadiz (Millan *et al*. 1999, Fig. 7). In this study, length at first maturity (L50) was estimated as 11.09 ± 1.35 cm for males, and 11.20 ± 1.84 cm for females, although no significant differences were found between sexes. Length range at maturation (L25–75) was estimated as 10.25–11.93 cm for males, and 10.41–11.99 cm for females. Length at full maturity (L95) was 13.3 cm in both sexes.

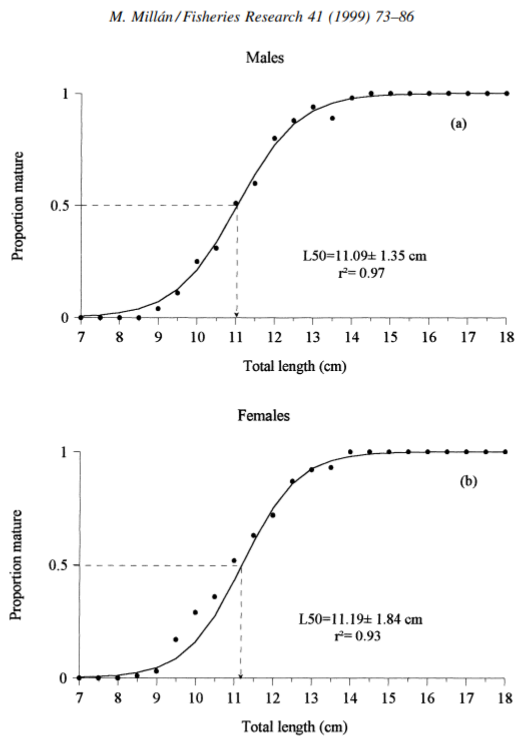

Figure 7. Maturity ogive and length at first maturity (L50) in (a) males and (b) females of *E. encrasicolus* for the whole study period (1989–1992). Millan *et al.* 1999, https://doi.org/10.1016/S0165-7836(99)00010-7

7. Conclusion

The macroscopic scale of reproduction does not validate for the anchovy, as for many other fish species, which means the reproductive biology of the species should be studied by microscopic analysis.

Spawning seasonality for western anchovy is similar to other anchovy populations in the Iberia, ranging from April/May to July, as observed by the monthly variation of gonadosomatic index and by the percentage of active females

The proportion of active females and males during the spawning season was very high for all fish analysed (ranging from 9.5 to 17 cm) which strongly affected the fitting of the logistic curve relating maturity with length class or age.

Uncertain results of maturity at age/size for younger fish are mainly a consequence of the absence of small fish in this study. An extra sampling effort will be carried out during the current spawning season of 2022 to try to collect smaller fish to improve the fitting of the maturity ogive.

An intercalibration with colleagues analysing histological sampled of anchovy is foreseen, and doubts of staging gonads based on microscopic analysis is expected to decrease.

The maturity data to be used in the MSE approach can use values of the neighbour population for the smaller size classes until data is available for the western component.

References

M Millán (1999) Reproductive characteristics and condition status of anchovy Engraulis encrasicolus L. from the Bay of Cadiz (SW Spain). Fisheries Research 41 Issue 1: 73-86. https://doi.org/10.1016/S0165-7836(99)00010-7.

Silva C, Azevedo M, Chaves C, Coelho R, Costa AMC, Dinis D, Dores S, Fernandes ACF, Gonçalves P, Lino PG, Mendes H, Moura T, Nunes C, Oroszlányová M, Pinto D, Silva MC, 2017. Report of the Workshop on Sampling Effort for Biological Parameters (WKSEBP), IPMA, Lisbon 18 – 20 April. Relat. Cient. Téc. do IPMA (http://ipma.pt), nº 17, 55 p + 4 Anexes.

APPENDIX I – Maturity scale used in this study

Males Maturity stage		Macroscopic description
1	Virgin or resting	Lamella shape testicles with sharp edge in the inferior side; variable size in adults and small in virgin specimens; almost transparent; sperm not visible.
2	Maturing	Testicles very firm in texture; ivory white to grayish colored; no blood vessels or other structures.
3	Pre-spawning or post- spawning/ recovery	Testicles taking up all visceral cavity; white-pink color to red color; Sperm is free-running or freed with light pressure in the gonads
4	Spawning	Bloated and vascularized testicles; white marble color; visible sperm.
5	Post-spawning	Testicles are flaccid; color changes between white-rose or grey; residual or no sperm.

Females Maturity stage		Macroscopic description
1	Virgin or resting	Small ovaries; translucent; taking up ¼ of the visceral cavity
2	Maturing	Ovary granular and opaque; visible oocytes in development.
3	Pre-spawning or post- spawning/ recovery	Ovaries with granular appearance; oocytes visible and distributed in parallel bands.
4	Spawning	Big ovaries, taking up all the visceral cavity; translucid oocytes.
5	Post-spawning	Ovaries flaccid and very vascularized; reddish color; oocytes visible or not.

Working document presented in the ICES Working Group on Southern horse mackerel, Anchovy and Sardine (WGHANSA). On-line meeting, 23-27 May 2022.

Acoustic assessment and distribution of the main pelagic fish species in ICES Subdivision 9a South during the *ECOCADIZ-RECLUTAS 2021-10* Spanish survey (October 2021).

By

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ABSTRACT

The present working document summarises the main results obtained from the *ECOCADIZ-RECLUTAS 2021-10* Spanish (pelagic ecosystem-) acoustic-trawl survey conducted by IEO between 21st October and 07th November 2021 in the Portuguese and Spanish shelf waters (20-200 m isobaths) off the Gulf of Cadiz (GoC) onboard the R/V *Ramón Margalef*. The survey suffered a ten-day delay in relation to the usual starting dates. 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. Chub mackerel, anchovy and sardine were the most frequent captured species in the fishing hauls, followed by horse mackerel, bogue, Atlantic mackerel, Mediterranean horse mackerel and blue jack mackerel. Boarfish, 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 and Spanish estimates of total NASC allocated to the "pelagic fish species assemblage" in this survey showed lower values than those recorded last year, whereas the Portuguese estimates showed an increasing trend. GoC anchovy was widely distributed in the surveyed area, although avoided the easternmost waters. Higher densities were recorded between Alfanzina and west of Cape Santa Maria, in the Algarve, and between Isla Cristina and Bay of Cadiz. Anchovy acoustic estimates in autumn 2021, 17 512 t and 1973 million fish, experienced 38% and 51% decreases in abundance and biomass, respectively, in relation to the last year's autumn estimates and they were 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 83% (1629 million) and 69% (12 063 t) of the total estimated abundance and biomass, respectively. Age-0 estimates experienced a similar decreasing trend than the one showed by the whole population 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) and recorded a relatively high acoustic echo-integration in autumn 2021 as a consequence of the occurrence of dense mid-water schools in the Algarve coastal and inner shelf waters (20-78 m). Abundance (2986 million fish) and biomass (151 320 t) estimates were the second historical records within its respective series, although they represented 83% and 38% decreases in relation to the last year's estimates. GoC sardine population was mainly concentrated in Portuguese waters. 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. Juvenile sardines (age-0 group) were not the dominant group, accounting for 21% (638 million) and 9% (12 854 t) of the total abundance and biomass, respectively. The bulk of this juvenile fraction was recorded in Spanish coastal waters. Chub mackerel was also widely distributed in the surveyed area, but showing higher densities in three between Cape San Vicente and Mazagón. Chub mackerel estimates were of 13 115 t and 106 million fish, accounting for 64% and 43% strong decreases in relation to the estimates in the previous year and with the above values being lower than their time-series average. The population was mainly concentrated in Portuguese waters and it was composed by fishes not older than 5 years, with the age-1 group being the dominant one. Age-0 fish was the second most important age group in the estimated population ((24%, 26 million

fish, and 13%, 1689 t, of the total abundance and biomass estimates). The bulk of the age-0 and age-1 groups were recorded in the Portuguese waters, whereas older age-groups were more frequent in Spanish waters.

INTRODUCTION

The first attempt by the IEO of acoustically assessing the abundance of anchovy and sardine juveniles in their main recruitment areas off the Gulf of Cadiz dates back to 2009 (*ECOCADIZ-RECLUTAS 1009* survey). However, that survey was unsuccessful as to the achievement of their objectives because of the succession of a series of unforeseen problems which led to drastically reduce the foreseen sampling area to only the 6 easternmost transects. The continuation of this survey series was not guaranteed for next years and, in fact, no survey of these characteristics was carried out in 2010 and 2011. In 2012, the *ECOCADIZ-RECLUTAS 1112* survey was financed by the Spanish Fisheries Secretariat and planned and conducted by the IEO with the aim of obtaining an autumn estimate of Gulf of Cadiz anchovy biomass and abundance. The survey was conducted with the R/V *Emma Bardán*. Although the survey was restricted to the Spanish waters only it has been considered as the first survey within its series (Ramos *et al*., 2013). *ECOCADIZ-RECLUTAS 2014-10* re-started the series and it was conducted with the R/V *Ramón Margalef*. The 2017 survey should be the fifth survey within its series. However, an unexpected a serious breakdown of the vessel's propulsion system led to an early termination of the survey, which restricted the surveyed area to the one comprised by the seven easternmost transects only.

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 the Division 9a. The long term objective of the surveys would be to be able to assess the strength of the incoming recruitment to the fishery of these species the next year.

The present Working Document reports the main results from the *ECOCADIZ-RECLUTAS 2021-10* survey (the seventh survey within its 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 2021-10* survey was conducted between 21st October and 07th November onboard the Spanish R/V *Ramón Margalef* covering a survey area which comprised the waters of the Gulf of Cadiz, both Spanish and Portuguese, between the 20 m and 200 m isobaths. The survey design consisted in a systematic parallel grid with tracks equally spaced by 8 nm, normal to the shoreline (**Figure 1**).

The survey suffered a ten-day delay in relation to the usual starting dates, resulting in ending dates very close to the starting ones of the WGACEEG meeting. Causes for such a delay were of logistic (a delay in R/V's dry-dock repair works) and unforeseen (monitoring of the *Cumbre Vieja* volcano eruption) nature. Furthermore, the ship-time available was shortened in two days, and one day more was lost because stormy weather and rough sea.

Echo-integration was carried out with a recently installed *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 (ESDU). Raw acoustic data were stored for further post-processing using *Myriax Software Echoview™* software package. Acoustic equipment was calibrated between 23rd and 24th October in the Bay of Algeciras following the ICES standard procedures (Demer *et al*., 2015; see also Foote *et al*., 1987).

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.

The following TS/length relationship table was used for acoustic estimation of assessed species (recent IEO standards after ICES, 1998; and recommendations by ICES, 2006a,b):

Species	**b_{20}**
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)

*Boarfish b_{20} estimate following to Fässler *et al.* (2013). Between parentheses the usual IEO value considered in previous surveys.

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 $CTDO_2$ casts over 22 transects (from the 23-transect planned grid) using a *Sea-bird Electronics™ SBE 911+ SEACAT* (with coupled *Datasonics* altimeter, *SBE 43* oximeter, *WetLabs ECO-FL-NTU* fluorimeter and *WetLabs C-Star 25 cm* transmissometer sensors) profiler (**Figure 2**). *VMADCP RDI 150 kHz* records were also continuously recorded by night between CTD stations. Census of top predators was not recorded during the survey.

A detailed description of protocols and methods followed in this survey series is reported in Doray *et al*. (2021).

RESULTS

Acoustic sampling

The acoustic sampling was restricted to the period comprised between 25th October and 06th November. The complete grid (21 transects) was acoustically sampled (**Table 1**; **Figure 1**). The sampling scheme followed to accomplish this grid was conditioned by the conduction of Spanish Navy and Army exercises (*FLOTEX 21*) during the survey, which occupied all the Spanish shelf waters. The sampling experienced one “jump” looking for space-time opportunity windows for the acoustic surveying trying to avoid such military exercises. Thus, the order and/or direction of the realization of the acoustic transects RA01 to RA04 had to be modified on 25th and 26th October. The acoustic sampling was partially interrupted on 28th-29th October in order to satisfy the R/V’s refueling and provisioning needs. All works at sea were totally interrupted on 30th October because a stormy weather and rough sea. In order to perform the acoustic sampling with daylight, the acoustic sampling started at 06:40-06:45 UTC until 31st October, and at 07:15-07:20 UTC later on, 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 (18) fishing operations for echo-trace ground-truthing (all of them were valid according to a correct gear performance and resulting catches), were carried out during the survey (**Table 2**, **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. Only one haul was 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 25 and 202 m.

During the survey were captured 3 Chondrichthyan, 44 Osteichthyes, 8 Cephalopod, 3 Echinoderm, and several Cnidarian and Ascidian species. The percentage of occurrence of the fish species (sharks excluded) in the hauls is shown in the enclosed Text Table below (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 chub mackerel and anchovy (both with 78% presence index) and sardine (61%) were the most frequent species in the valid hauls, followed by horse mackerel and bogue (both 56%), mackerel (44%), Mediterranean horse mackerel (39%) and Blue jack mackerel (28%). Round sardinella (17%) and blue whiting (11%) showed very low occurrences. Boarfish, longspine snipefish and pearlside showed an incidental occurrence (6% each) 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, 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 10 889 kg and 182 thousand fish (**Table 3**). Forty nine per cent (49%) of this “total” fished biomass corresponded to sardine, 38% to chub mackerel, 5% to anchovy, 4% to Mediterranean horse mackerel, 1% to horse mackerel and contributions lower than 1% for the remaining species. The most abundant species in ground-truthing trawl hauls was sardine (50%), followed by anchovy (24%), chub mackerel (21%), and horse mackerel (3%), 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**.

Species	OCCURRENCE (Number of valid hauls)	OCCURRENCE (% over Total valid hauls)	Total weight (Kg)	Total number
Scomber colias	14	78 %	4167,685	37825
Engraulis encrasicolus	14	78 %	559,681	44176
Sardina pilchardus	11	61 %	5357,42	90324
Trachurus trachurus	10	56 %	141,529	1361
Boops boops	10	56 %	15,798	108
Merluccius merluccius	10	56 %	4,072	34
Scomber scombrus	8	44 %	18,903	133
Trachurus mediterraneus	7	39 %	388,923	2007
Spondyliosoma cantharus	7	39 %	13,401	105
Pagellus erythrinus	7	39 %	7,605	44
Trachurus picturatus	5	28 %	66,589	1462
Lepidopus caudatus	5	28 %	0,107	12
Diplodus vulgaris	4	22 %	7,720	41
Spicara flexuosa	4	22 %	3,402	99
Pagellus bellottii bellottii	4	22 %	2,540	29
Pagellus acarne	4	22 %	2,038	15
Sardinella aurita	3	17 %	3,712	15
Pomatomus saltatrix	3	17 %	3,450	10
Diplodus annularis	3	17 %	0,221	5
Brama brama	2	11 %	6,605	15
Diplodus bellottii	2	11 %	4,785	107
Pomadasys incisus	2	11 %	3,875	44
Caranx rhonchus	2	11 %	2,580	8
Stromateus fiatola	2	11 %	1,955	3
Liza ramada	2	11 %	1,620	6
Zeus faber	2	11 %	0,905	2
Sparus aurata	2	11 %	0,862	2
Micromesistius poutassou	2	11 %	0,209	7
Mola mola	1	6 %	49,850	2
Macroramphosus scolopax	1	6 %	18,705	1849
Dentex gibbosus	1	6 %	10,770	2
Sarda sarda	1	6 %	5,455	3
Zenopsis conchifer	1	6 %	1,79	1
Maurolicus muelleri	1	6 %	1,62	1684
Spicara maena	1	6 %	1,55	40
Capros aper	1	6 %	0,962	129
Alosa fallax	1	6 %	0,625	4
Parapristipoma octolineatum	1	6 %	0,262	1
Trachinotus ovatus	1	6 %	0,19	1
Umbrina canariensis	1	6 %	0,131	1
Mullus barbatus	1	6 %	0,128	1
Trachinus draco	1	6 %	0,054	1
Chelidonichthys obscurus	1	6 %	0,038	1

Back-scattering energy attributed to the "pelagic assemblage" and individual species

A total of 305 nmi (ESDU) from 21 transects has been acoustically sampled by echo-integration for assessment purposes. The enclosed text table below provides the nautical area-scattering coefficients attributed to each of the selected target species and for the whole "pelagic fish assemblage".

S_A (m^2 nmi^{-2})	TOTAL	PIL	ANE	MAC	VMA	HOM	HMM	JAA	BOG	BOC	SNS	MAV
TOTAL AREA	149445	82051	24291	22	13402	6722	8536	3590	603	197	5337	4693
%	100	54,9	16,3	0,01	9,0	4,5	5,7	2,4	0,4	0,1	3,6	3,1
Portugal	108617	73657	6033	18	9497	6603	148	3590	421	197	5337	3116
%	72,7	89,8	24,8	82,2	70,9	98,2	1,7	100	69,7	100	100	66,4
Spain	40828	8394	18258	4	3905	119	8388	0	182	0	0	1577
%	27,3	10,2	75,2	17,8	29,1	1,8	98,3	0	30,3	0	0	33,6

For this "pelagic fish assemblage" has been estimated a total of 149 445 m^2 nmi^{-2}, a lower value than the maximum value recorded throughout the time-series the last year (229 241 m^2 nmi^{-2}), but still above the historical mean (120 817 m^2 nmi^{-2}). The highest NASC value (15 415 m^2 nmi^{-2}) was recorded in the inner-shelf waters (50 m) in front of Vila Real de Sto. Antonio (transect R12, **Figure 5**), with relatively high values being also recorded in the inner- and mid-shelf waters (20-123 m depth) of transects R06, R07, R13, R19 and R20. By species, sardine accounted for 55% of this total back-scattered energy, followed by anchovy (16%) and chub mackerel (9%), and the remaining species with 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, the species acoustically assessed in the present survey finally were anchovy, sardine, mackerel, chub mackerel, blue jack mackerel, horse mackerel, Mediterranean horse mackerel, bogue, boarfish, snipefish and pearlside.

Spatial distribution and abundance/biomass estimates

Anchovy

Parameters of the survey's length-weight relationship for anchovy are given in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 6**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent strata considered for the acoustic estimation are shown in **Figure 7**. The estimated abundance and biomass by size class are given in **Table 5** and **Figure 8**. **Figure 9** shows the acoustic estimates by age group. **Table 6** shows the time-series of estimates for the whole population and Age-0 fish.

Gulf of Cadiz anchovy (16% of the total NASC attributed to fish) was widely distributed in the surveyed area, although avoided the easternmost waters. Higher densities were mainly recorded in two areas: between Alfanzina and west of Cape Santa Maria, in the Algarve, and between Isla Cristina and Bay of Cadiz (**Figure 7**). The whole size class range for the pooled catches varied between the 2.0 and 18.5 cm size classes, with 3 modal classes, the main mode at 10.0 cm, a secondary mode at 14.5 cm and a third mode at 3.0 cm.

Ten (10) 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

2021 were of 1973 million fish and 17 512 tones (**Table 5**; **Figure 8**), entailing 38% and 51% decreases in abundance and biomass, respectively, in relation to the last year's estimates (3197 million, 36 070 t). The current overall estimates are lower than the time-series average (i.e. 3258 million; 25 627 t), (see **Table 6** and **Figure 42**). By geographical strata, the Spanish waters yielded 89% (1763 million) and 76% (13 370 t) of the total estimated abundance and biomass in the Gulf, confirming the importance of these waters in the species' distribution. The estimates for the Portuguese waters were 211 million and 4143 t (**Table 5; Figure 8**).

The size class range of the assessed anchovy population in autumn 2021 varied between the 2.0 and 18.5 cm size classes. The size distribution showed a mixed composition, with several modal classes, the main mode at 10.0 cm, a secondary mode at 14.0 cm, and less important modes at 8.0 and 3.0 cm size class. It is noticeable the occurrence of this last modal size, as a consequence of the record of very tiny juveniles (size class range: 2.0 – 4.5 cm) in the coastal waters located between Mazagón and Punta Umbría. 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 6** and **8**).

The population was composed by fishes not older than 2 years. Age 0 fish accounted for 83% (1629 million) and 69% (12 063 t) of the total estimated abundance and biomass, respectively (**Table 6**; **Figure 9**). Spanish waters concentrated the bulk (97%) of this juvenile fraction. The estimates of age-0 fish experienced a similar decreasing trend than the one showed by the whole population in relation to the historical peak recorded in 2019 and the values recorded in 2020, but with values close to the time-series average (**Table 6**). Age 1 fish represented 16% and 28% of the total abundance and biomass (**Figure 9**).

The 2021 autumn estimates of mean size and weight of the whole population (11.2 cm, 8.9 g) were somewhat lower than their respective time-series averages (11.3 cm, 9.5 g). Regional mean size and weights in the estimated population were estimated at 14.6 cm and 19.6 g in Portuguese waters and 10.7 cm and 7.6 g in Spanish ones.

Sardine

Parameters of the survey's size-weight relationship for sardine are shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 10**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 11**. Estimated abundance and biomass by size class are given in **Table 7** and **Figure 12**. **Figure 13** shows the acoustic estimates by age group. **Table 8** shows the time-series of estimates for the whole population and Age-0 fish.

GoC sardine recorded a relatively high acoustic echo-integration in autumn 2021 (55% of the total NASC attributed to pelagic fish species assemblage), as a consequence of the occurrence of dense mid-water schools in the Algarve coastal and inner shelf waters (20-78 m), with a main hotspot between Cape Santa María and the Guadiana river mouth and another one between Burgau and Portimão (**Figure 11**). Sardine was widely distributed all over the surveyed area (avoiding the easternmost waters) 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 whole size class range for the pooled catches varied between the 10.0 and 21.5 cm size classes, with 2 modal classes, the main mode at 19.0 cm and a secondary mode at 12.5 cm. The size composition of sardine catches 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 Portuguese waters and the smallest (and youngest) ones concentrated in the coastal waters between Chipiona and El Rompido (**Figure 10**).

Five (5) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 11**). GoC sardine abundance and biomass in autumn 2021 were estimated at 2986 million fish and 151 320 t, the second historical record within its respective series, values which, however, entailed 83% and 38% decreases in relation to the last year's estimates (5451 million and 208 400 t, the historical record in the series; **Table 7**, **Figure 12**). Portuguese waters concentrated 82% and 94% of the total estimated abundance and biomass, respectively (2448 million and 142 532 t). The estimates for the Spanish waters were 538 million and 8 788 t.

Sizes of the assessed sardine population in autumn 2021 ranged between 10.0 and 21.5 cm size classes. The length frequency distribution of the population was clearly bimodal, with one main mode at 18.0 cm size class and a secondary one at 12.5 cm (**Table 7**; **Figure 12**).

Age-5 group was the oldest age group occurring in the population, although the occurrence of fishes older than 4 years was relatively low. The population was mainly composed by fishes belonging to the age-0 to age-2 groups. Juvenile sardines (age-0 group) were not the dominant group, accounting for 21% (638 million) and 9% (12 854 t) of the total abundance and biomass, respectively. The bulk of the juvenile fraction (82% of the juvenile total abundance) was recorded in Spanish waters, especially in the relatively shallow waters along the coastal fringe comprised between the Guadiana river mouth and the Bay of Cadiz (**Table 8**; **Figures 10** and **13**).

The 2021 autumn estimates of mean length and weight of the whole population (17.7 cm, 50.6 g), are both higher than both the last year's estimates and the time-series averages (i.e. 15.6 cm, 37.4 g).

Mackerel

Parameters of the survey's length-weight relationship are shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 14**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 15**. Estimated abundance and biomass by size class are given in **Table 9** and **Figure 16**.

Atlantic mackerel (0.01% of the total NASC) showed a main density nucleus in the westernmost Algarve and a relatively lower density in the outer shelf waters off the central zone of the surveyed area (**Figure 15**).

Two (2) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing stations (**Figure 15**). Mackerel abundance and biomass in autumn 2021 in the GoC shelf waters were estimated at only 6 million fish and 803 t (**Table 9**; **Figure 16**). Almost the whole estimated population (84.0% of the total abundance) was located in Portuguese waters (5 million, 675 t). The estimates for the Spanish waters were c.a. 1 million and 128 t.

The size range of the estimated population in autumn 2021 varied between 24.0 and 35.5 cm size classes, with a dominant mode at 24.5 cm size class and a secondary mode at 27.0 cm (**Table 9**; **Figure 16**). No clear spatial pattern in mean size was observed; perhaps the smallest fish were more common in Portuguese waters.

Chub mackerel

Parameters of the survey's length-weight relationship are shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 17**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 18**. Estimated abundance and biomass by size class are given in **Table 10** and **Figure 19**. **Figure 20** shows the acoustic estimates by age group. **Table 11** shows the time-series of estimates for the whole population and Age-0 fish.

Chub mackerel (9% of the total NASC) was widely distributed in the surveyed area, but showing higher densities in three between Cape San Vicente and Mazagón (**Figure 18**). The species' positive hauls did not show a clear spatial pattern in (mean) size. The largest fish were commonly captured in Spanish waters, with smaller fish occurring in Portuguese waters and the smallest ones in the middle-outer shelf waters between Albufeira and Alfanzina (**Table 10**; **Figures 17** and **19**).

Five (5) 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 106 million fish and 13 115 t, accounting for 64% and 43% strong decreases in relation to the estimates in the previous year (295 million, 22 918 t; **Table 10**, **Figure 19**). Portuguese waters accounted for 81% (86 million) and 62% (8075 t) of the total abundance and biomass, respectively. Spanish waters yielded a population of 21 million and 5040 t.

The size range recorded for the estimated population was comprised between 17.0 and 37.5 cm size classes, showing a very mixed composition, with a dominant modal class at 24.0 cm, a secondary mode at 20.0 cm and less represented modes at 28.0 cm and 32.0 cm size classes. A rather similar size composition is also recorded for the estimated biomass, although the mode at 24.0 cm clearly dominates over the smaller modes (**Table 10**, **Figure 19**). Regional size compositions showed different shapes, with larger modes dominating in the size distribution off Spanish waters whereas smaller modes are the most important in the Portuguese shelf.

The population was composed by fishes not older than 5 years, with the age-1 group being the dominant one (54%, 57 million, and 47%, 6134 t, of the total abundance and biomass estimated in the surveyed area, respectively; **Figure 20**). Age-0 fish was the second most important age group in the estimated population (24%, 26 million fish, and 13%, 1689 t, of the total abundance and biomass estimates). The bulk of the age-0 (99.8%) and age-1 groups (94%) was recorded in the Portuguese waters, whereas older age-groups were more frequent in Spanish waters.

Horse mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 21**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 22**. Estimated abundance and biomass by size class are given in **Table 12** and **Figure 23**.

Horse mackerel (4.5% of the total NASC) showed a very scattered distribution, with the main density nucleus being located in the western Algarve shelf waters (**Figure 22**).

The size range recorded in positive hauls was comprised between 7.5 and 28.5 cm size classes, with a dominant mode at 18.5 cm size class and a secondary mode at 23.0 cm. Small fish were recorded in the Spanish waters (**Figure 21**).

Six (6) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 22**). Horse mackerel abundance and biomass in the surveyed area were estimated in 59 million fish and 6141 t (**Table 12**, **Figure 23**). Portuguese waters accounted for 97% (57 million) and 99% (6066 t) of the total abundance and biomass, respectively. Spanish waters yielded a population of 2 million and 75 t.

The size range recorded for the estimated population was comprised between 15.5 and 30.5 cm size classes, with two distinct modes, the dominant one at 23.0 cm (exclusively recorded in Portuguese waters) and a secondary mode at 18.0 cm size class (mainly distributed in Spanish waters; **Table 12**, **Figure 23**).

Mediterranean horse-mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 24**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 25**. Estimated abundance and biomass by size class are given in **Table 13** and **Figure 26**.

Mediterranean horse mackerel (5.7% of the total NASC) was a typically Spanish species in autumn 2021. The species distributed over the Spanish eastern and central waters, not further west than Fuzeta, mainly over the inner-mid shelf waters (**Figure 25**). The size class range for the pooled catches varied between the 20.0 and 39.0 cm size classes, with one modal class at 27.0 cm. No clear spatial pattern in mean size was observed, although the largest fish occurred in the easternmost Spanish waters (**Figure 24**).

Four (4) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 25**). Mediterranean horse mackerel abundance and biomass in the surveyed area were estimated in 47 million fish and 9711 t, with the bulk of the population (99% of abundance and biomass; 47 million, 9595 t) being located in Spanish waters, as usual (**Table 13**, **Figure 26**).

The size range recorded for the estimated population was comprised between 20.0 and 39.0 cm size classes, with at least one clearly distinct mode at 27.0 cm size class, and other secondary modes at 29.5 44.5 cm size class. Largest fish occurred in the easternmost waters of the Spanish shelf, as previously evidenced by the positive hauls raw data (**Table 13**, **Figure 26**).

Blue jack mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 27**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 28**. Estimated abundance and biomass by size class are given in **Table 14** and **Figure 29**.

Blue jack mackerel (2.4% of the total NASC) was restricted exclusively to the Portuguese waters, showing the highest acoustic densities in the western Algarve shelf waters (**Figure 28**). The size class range for the pooled catches varied between the 15.5 and 23.0 cm size classes. No clear spatial pattern in mean size was observed (**Figure 27**).

Two (2) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 28**). Blue Jack mackerel abundance and biomass in the surveyed area were estimated in 53 million fish and 2236 t, with all the estimated population being located in Portuguese waters (**Table 14**, **Figure 29**).

The size range recorded for the estimated population was comprised between 15.5 and 20.5 cm size classes, with a single modal size class at 17.0 cm (**Table 12**, **Figure 23**).

Bogue

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 30**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 31**. Estimated abundance and biomass by size class are given in **Table 15** and **Figure 32**.

Bogue (0.4% of the total NASC) showed a scattered distribution, showing relatively low acoustic densities, although the highest densities were recorded in the westernmost Algarve shelf waters (**Figure 31**). The size class range for the pooled catches varied between the 10.5 and 34.5 cm size classes, with one modal class at 23.0 cm. No clear spatial pattern in mean size was observed, although the largest fish occurred in the easternmost Spanish waters (**Figure 30**).

Five (5) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 31**). Bogue abundance and biomass in the surveyed area were estimated in about 4 million fish and 412 t (**Table 15**, **Figure 32**). Portuguese waters accounted for 71% of both total abundance (3 million) and biomass (291 t), respectively. Spanish waters yielded a population of 1 million and 121 t.

The size range recorded for the estimated population was comprised between 18.5 and 25.0 cm size classes, with one mode at 23.0 cm size class (**Table 15**, **Figure 32**).

Boarfish

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 33**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 34**. Estimated abundance and biomass by size class are given in **Table 16** and **Figure 35**.

The occurrence of boarfish (0.1%) was incidental and restricted to the westernmost Algarve outer shelf waters, co-occurring with longspine snipefish (**Figure 34**). The size range recorded in the only positive haul was comprised between 5.0 and 9.0 cm size classes, with one single modal class at 6.5 cm (**Figure 33**).

One (1) coherent post-stratum has been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 31**). Boarfish abundance and biomass in the surveyed area were estimated in 11 million fish and 21 t, with the whole population being restricted to the westernmost Algarve outer shelf waters (**Table 16**, **Figure 35**).

The size range recorded for the estimated population was comprised between 5.0 and 9.0 cm size classes, with a single mode at 7.5 cm size class (**Table 16**, **Figure 35**).

Longspine snipefish

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 36**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 37**. Estimated abundance and biomass by size class are given in **Table 17** and **Figure 38**.

Comparatively, longspine snipefish (3.6%) showed relatively high acoustic densities, although they were restricted to the westernmost Algarve outer shelf waters (**Figure 37**). The species showed a concurrent distribution with boarfish. The size range recorded in the only positive haul was comprised between 9.0 and 14.5 cm size classes, with 2 modal classes, the main mode at 12.0 cm and a secondary mode at 9.0 cm. No spatial pattern in mean size was observed (**Figure 36**).

One (1) coherent post-stratum, located in the westernmost Algarve outer shelf waters, has been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 37**). Longspine snipefish abundance and biomass in the surveyed area were estimated in 2454 million fish and 78 026 t, as a consequence of the occurrence of a very dense aggregation located over the shelf break in the R20 transect (**Table 17**, **Figure 38**).

The size range recorded for the estimated population was comprised between 9.0 and 14.5 cm size classes, with 2 modal classes, the main mode at 12.0 cm and a secondary mode at 9.0-9.5 cm size classes (**Table 17**, **Figure 38**).

Pearlside

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 39**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 40**. Estimated abundance and biomass by size class are given in **Table 18** and **Figure 41**.

Pearlside (3.1%) was relatively common over the shelf break, especially in the western Algarve waters (**Figure 40**). The size range in the only positive haul (Cape Santa Maria area in Portuguese waters) varied between 3.5 and 5.5 cm size class (mode at 4.5 cm size class; **Figure 39**).

Two (2) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 40**). Pearlside abundance and biomass in the surveyed area were estimated in 1907 million fish and 2013 t. Portuguese waters accounted for 54% (1023 million, 1080 t) of both the total abundance and biomass, respectively. Spanish waters yielded a population of 884 million and 933 t. (**Table 16**, **Figure 35**).

The size range 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 18**, **Figure 41**).

(SHORT) DISCUSSION

The time series of anchovy, sardine and chub mackerel estimates from this survey series are described in **Tables 6**, **8** and **11** and **Figure 42**.

GoC anchovy population in autumn 2021 (1973 million fish, 17 512 t) experienced 38% and 51% decreases in abundance and biomass, respectively, in relation to the last year's autumn estimates (3197 million, 36 070 t; **Table 6**; **Figure 42**). Spanish waters concentrated the bulk of the total estimated abundance and biomass in the Gulf, confirming the importance of these waters in the species' distribution. The current overall estimates are lower than the time-series average (i.e. 3258 million; 25 627 t). Age 0 fish accounted for 83% (1629 million) and 69% (12 063 t) of the total estimated abundance and biomass, respectively (**Table 6**; **Figure 9**). Spanish waters concentrated the bulk (97%) of this juvenile fraction. The estimates of age-0 fish experienced a similar decreasing trend than the one showed by the whole population in relation to the historical peak recorded in 2019 and the values recorded in 2020, but with values close to the time-series average (**Table 6**).

GoC sardine abundance (2986 million fish) and biomass (151 320 t) in autumn 2021 peaked at their second historical maximum within its series, representing however 83% and 38% decreases in relation to the last year's estimates (5451 million and 208 400 t, the historical record in the series; **Table 7**, **Figure 12**). Portuguese waters concentrated the bulk of the total estimated abundance and biomass. The GoC sardine population was mainly composed by fishes belonging to the age-0 to age-2 groups and in a lesser extent by age-3 fish (incidental occurrence of 4 to 5 year old fishes). Juvenile sardines (age-0 group) were not the dominant group, accounting for 21% (638 million) and 9% (12 854 t) of the total abundance and biomass, respectively. The bulk of the juvenile fraction (82% of the juvenile total abundance) was recorded in Spanish waters, especially in the relatively shallow waters along the coastal fringe comprised between the Guadiana river mouth and the Bay of Cadiz (**Table 8**; **Figures 10** and **13**).

Chub mackerel abundance (106 million fish) and biomass (13 115 t) in autumn 2021 experienced 64% and 43% strong decreases in relation to the estimates in the previous year (295 million, 22 918 t; **Table 10**, **Figure 19**), and they are below their respective time-series averages (i.e. 214 million, 15 487 t) (**Table 11**, **Figure 42**). Portuguese waters concentrated the great part of the total population abundance and biomass. The population was composed by fishes not older than 5 years, with the age-1 group being the dominant one (54%, 57 million, and 47%, 6134 t, of the total abundance and biomass estimated in the surveyed area, respectively; **Figure 20**). Age-0 fish was the second most important age group in the estimated population (24%, 26 million fish, and 13%, 1689 t, of the total abundance and biomass estimates). The bulk of the age-0 (99.8%) and age-1 groups (94%) was recorded in the Portuguese waters, whereas older age-groups were more frequent in Spanish waters.

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REFERENCES

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., C. O'Donnell, J.M. Jech, 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., H.P. Knudsen, G. Vestnes, D.N. MacLennan, E.J. Simmonds, 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.

Nakken, O., A. Dommasnes, 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., M. Iglesias, J. Miquel, D. Oñate, J. Tornero, A. Ventero, N. Díaz, 2013. Acoustic assessment and distribution of the main pelagic fish species in the ICES Subdivision IXa South during the *ECOCÁDIZ-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 2021-10* 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)
R01	**Trafalgar**	26/10/21	36º 02.01’ N	06º 29.12’ W	13:30	240	36º 13.03’ N	06º 08.84’ W	15:35	23
R02	**Sancti-Petri**	26/10/21	36º 19.31’ N	06º 14.93’ W	6:50	26	36º 08.79’ N	06º 34.30’ W	10:35	204
R03	**Cádiz**	25/10/21	36º 17.40º N	06º 36.24’ W	11:23	181	36º 29.79’ N	06º 18.93’ W	15:09	23
R04	**Rota**	25/10/21					36º 24.53’ N	06º 40.80’ W	10:34	199
R05	**Chipiona**	27/10/21	36º 40.36’ N	06º 29.41’ W	6:46	21	36º 31.25’ N	06º 46.24’ W	10:15	193
R06	**Doñana**	27/10/21	36º 38.00’ N	06º 51.65’ W	11:10	200	36º 46.60’ N	06º 35.70’ W	14:46	19
R07	**Matalascañas**	29/10/21	36º 54.45’ N	06º 38.95’ W	12:20	16	36º 43.90’ N	06º 58.32’ W	16:15	220
R08	**Mazagón**	31/10/21	36º 49.39’ N	07º 06.06’ W	7:25	198	36º 01.08’ N	06º 44.78’ W	11:37	20
R09	**Punta Umbría**	31/10/21	37º 04.30’ N	06º 56.08’ W	13:53	23	36º 49.68’ N	07º 06.55’ W	15:34	198
R10	**El Rompido**	01/11/21	36º 50.03’ N	07º 07.21’ N	7:22	191	37º 07.93’ N	07º 07.21’ W	11:18	18
R11	**Isla Cristina**	01/11/21	37º 06.84’ N	07º 17.06’ W	13:57	22	36º 53.47’ W	07º 17.14’ W	15:16	200
R12	**V.R. do Sto. Antonio**	02/11/21	37º 06.35’ N	7º 17.26’ W	7:16	18	36º 56.26’ N	07º 27.11’W	10:18	202
R13	**Tavira**	02/11/21	36º 57.10’ N	07º 37.12’ W	11:05	189	37º 05.19’ N	07º 37.17’ W	11:55	16
R14	**Fuzeta**	02/11/21	36º 59.27’ N	07º 46.96’ W	14:33	42	36º 55.48’ N	07º 47.02’ W	14:55	193
R15	**Cabo Sta. María**	03/11/21	36º 56.13’ N	07º 56.99’ W	7:21	51	36º 52.15’ N	07º 56.91’ W	7:46	187
R16	**Cuarteira**	03/11/21	37º 01.77’ N	08º 07.05’ W	10:19	19	36º 49.82’ N	08º 06.85’ W	11:41	162
R17	**Albufeira**	04/11/21	36º 49.39’ N	08º 16.83’ W	7:22	196	36º 01.8’ N	08º 17.01’ W	8:36	21
R18	**Alfanzina**	04/11/21	37º 04.30’ N	08º 26.99’ W	11:34	24	36º 50.23’ W	08º 26.69’ W	14:57	209
R19	**Portimão**	05/11/21	37º 06.02’ N	08º 37.07’ W	7:36	21	36º 51.88’ W	08º 36.62’ W	9:01	148
R20	**Burgau**	05/11/21	36º 51.17’ N	08º 46.68’ W	9:52	217	37º 02.47’ N	08º 46.96’ W	13:31	45
R21	**Punta de Sagres**	06/11/21	36º 59.13’ N	08º 56º.79’ W	7:07	24	36º 50.56’ N	8º 56.58’ W	8:01	206

Table 2. *ECOCADIZ-RECLUTAS 2021-10* survey. Descriptive characteristics of the fishing hauls.

Fishing haul	Date	Start		End		UTC Time		Depth (m)		Duration (min)		Trawled Distance (nm)	Acoustic Transect	Zone (landmark)
		Latitude	Longitude	Latitude	Longitude	Start	End	Start	End	Effective Trawling	Total Manoeuvre			
1	25-10-2021	36º 27.8394 N	6º 34.7840 W	83,46	36º 28.9480 N	6º 32.7166 W	68,48	08:47	09:14	00:27	01:13	2,002	R04	Rota
2	25-10-2021	36º 23.6390 N	6º 24.7175 W	51,45	36º 21.5517 N	6º 28.5754 W	69,28	12:53	13:44	00:50	01:24	3,748	R03	Cádiz
3	26-10-2021	36º 15.6718 N	6º 21.7453 W	47,41	36º 16.7514 N	6º 19.0876 W	40,79	08:09	08:41	00:32	01:11	2,404	R02	Sancti-Petri
4	26-10-2021	36º 09.3423 N	6º 33.4767 W	156,46	36º 10.5130 N	6º 31.3233 W	116,12	11:17	11:46	00:28	01:27	2,099	R02	Sancti-Petri
5	27-10-2021	36º 36.3974 N	6º 36.7585 W	57,78	36º 38.0278 N	6º 33.7723 W	38,16	07:54	08:34	00:39	01:17	2,903	R05	Chipiona
6	27-10-2021	36º 40.5672 N	6º 46.9273 W	94,71	36º 38.8771 N	6º 49.7937 W	120,81	12:05	12:46	00:40	01:28	2,858	R06	Doñana
7	29-10-2021	36º 50.6064 N	6º 46.4508 W	41,17	36º 52.1859 N	6º 43.6623 W	24,89	13:35	14:12	00:37	01:13	2,738	R07	Matalascañas
8	31-10-2021	36º 53.9092 N	6º 56.8250 W	79,98	36º 52.3850 N	7º 00.6593 W	101,41	08:42	09:20	00:38	01:26	3,432	R08	Mazagón
9	30-10-2021	36º 59.6417 N	6º 47.3898 W	26,91	36º 57.9788 N	6º 50.3552 W	36,97	12:06	12:46	00:40	01:10	2,899	R08	Mazagón
10	01-11-2021	36º 52.3377 N	7º 07.1216 W	123,59	36º 49.9269 N	7º 07.0607 W	201,96	08:10	08:42	00:32	01:26	2,408	R10	El Rompido
11	01-11-2021	37º 05.5373 N	7º 07.0416 W	26,3	37º 03.0531 N	7º 06.5738 W	42,23	12:02	12:36	00:33	01:04	2,509	R10	El Rompido
12	02-11-2021	37º 03.4301 N	7º 27.0741 W	59,9	37º 05.4515 N	7º 27.0567 W	29,39	08:03	08:29	00:26	01:24	2,019	R12	Vila Real do Santo Antonio
13	02-11-2021	37º 00.4410 N	7º 36.9744 W	94,78	36º 58.6553 N	7º 36.9066 W	108,48	12:33	12:57	00:24	01:18	1,784	R13	Tavira
14	03-11-2021	36º 52.6355 N	7º 56.9689 W	102,88	36º 55.2322 N	7º 57.3097 W	66,44	08:13	08:51	00:37	01:22	2,608	R15	Cabo de Santa María
15	03-11-2021	36º 53.9360 N	8º 06.0203 W	87,49	36º 53.9802 N	8º 07.0103 W	84,58	12:48	12:58	00:10	00:55	0,795	R16	Cuarteira
16	04-11-2021	36º 59.1968 N	8º 16.8204 W	45,5	36º 56.3192 N	8º 16.8261 W	72,19	09:09	09:49	00:40	01:22	2,874	R17	Albufeira
17	04-11-2021	36º 54.3264 N	8º 26.7825 W	115,8	36º 57.0316 N	8º 26.7953 W	89,08	13:01	13:39	00:37	01:23	2,702	R18	Alfanzina
18	05-11-2021	36º 54.5772 N	8º 46.6952 W	110,12	36º 57.6744 N	8º 46.7128 W	92,32	11:59	12:41	00:42	01:23	3,093	R20	Burgau

Table 3. *ECOCADIZ-RECLUTAS 2021-10* survey. Catches by species in number (upper panel) and weight (in kg, lower panel) from valid fishing stations.

Fishing haul	CATCH IN NUMBER														
	Anchovy	***Sardine***	***Round sardin.***	***Chub mack.***	***Mackerel***	***Blue Jack mack.***	***Horse-mack.***	***Medit. Horse-mack.***	***Atlantic pomfret***	***Bogue***	***Boarfish***	***Snipefish***	***Pearlside***	**Other spp.**	**TOTAL**
01	1629	1	0	0	0	0	0	0	0	0	0	0	0	1	**1631**
02	0	0	12	244	0	0	0	229	0	19	0	0	0	1	**505**
03	0	0	0	1	0	0	8	81	0	0	0	0	0	155	**245**
04	0	0	0	0	0	0	0	0	0	0	0	0	0	2	**2**
05	820	2024	0	3	0	0	0	168	0	4	0	0	0	22	**3041**
06	17535	238	0	0	4	0	0	0	0	0	0	0	0	7	**17784**
07	0	780	2	44	0	0	14	997	0	1	0	0	0	141	**1979**
08	3181	20	0	2	4	0	0	0	0	0	0	0	0	3	**3210**
09	2776	362	1	879	0	0	3	464	0	5	0	0	0	115	**4605**
10	8505	0	0	0	2	0	0	0	14	0	0	0	0	2	**8523**
11	250	712	0	15	0	0	4	36	0	1	0	0	0	14	**1032**
12	170	74413	0	130	0	0	10	32	0	22	0	0	0	85	**74862**
13	94	4860	0	35853	0	509	55	0	0	12	0	0	0	9	**41392**
14	988	0	0	27	6	25	30	0	0	2	0	0	1684	18	**2780**
15	902	0	0	1	17	0	0	0	1	0	0	0	0	4	**925**
16	66	5979	0	554	9	925	1010	0	0	39	0	0	0	30	**8612**
17	7247	0	0	56	81	1	224	0	0	3	0	0	0	21	**7633**
18	13	935	0	16	10	2	3	0	0	0	129	1849	0	8	**2965**
TOTAL	**44176**	**90324**	**15**	**37825**	**133**	**1462**	**1361**	**2007**	**15**	**108**	**129**	**1849**	**1684**	**638**	**181726**

Table 3. *ECOCADIZ-RECLUTAS 2021-10* survey. Cont'd.

Fishing haul	CATCH IN WEIGHT (kg)													
	Anchovy	***Sardine***	***Round sardin.***	***Chub mack.***	***Mackerel***	***Blue Jack mack.***	***Horse-mack.***	***Medit. Horse-mack.***	***Atlantic pomfret***	***Bogue***	***Boarfish***	***Snipefish***	***Pearlside***	**Other spp.**	**TOTAL**
01	15,780	0,022	0	0	0	0	0	0	0	0	0	0	0	0,089	**15,891**
02	0	0	3,220	89,325	0	0	0	49,020	0	5,700	0	0	0	0,090	**147,355**
03	0	0	0	0,422	0	0	0,432	17,636	0	0	0	0	0	27,855	**46,345**
04	0	0	0	0	0	0	0	0	0	0	0	0	0	49,850	**49,850**
05	2,790	37,940	0	0,277	0	0	0	38,880	0	0,800	0	0	0	6,935	**87,622**
06	118,21	5,740	0	0	0,615	0	0	0	0	0	0	0	0	5,435	**130,000**
07	0	14,600	0,380	9,386	0	0	0,902	182,860	0	0,109	0	0	0	14,186	**222,423**
08	21,860	0,352	0	0,235	0,730	0	0	0	0	0	0	0	0	0,338	**23,515**
09	10,340	6,080	0,112	194,720	0	0	0,070	87,990	0	0,735	0	0	0	14,484	**314,531**
10	156,310	0	0	0	0,270	0	0	0	6,205	0	0	0	0	0,018	**162,803**
11	2,0150	11,690	0	4,230	0	0	0,230	6,765	0	0,070	0	0	0	2,532	**27,532**
12	2,048	4527,074	0	13,880	0	0	0,261	5,772	0	2,113	0	0	0	3,719	**4554,867**
13	1,678	324,842	0	3806,339	0	24,425	2,349	0	0	1,431	0	0	0	1,101	**4162,165**
14	17,130	0	0	2,830	1,115	1,330	4,950	0	0	0,405	0	0	1,620	2,743	**32,123**
15	17,600	0	0	0,083	2,530	0	0	0	0,400	0	0	0	0	0,066	**20,679**
16	1,230	359,620	0	37,650	1,470	40,600	105,910	0	0	4,045	0	0	0	6,283	**556,808**
17	192,260	0	0	6,675	10,945	0,059	26,020	0	0	0,390	0	0	0	1,391	**237,740**
18	0,430	69,460	0	1,633	1,228	0,175	0,405	0	0	0	0,962	18,705	0	3,305	**96,303**
TOTAL	**559,681**	**5357,420**	**3,712**	**4167,685**	**18,903**	**66,589**	**141,529**	**388,923**	**6,605**	**15,798**	**0,962**	**18,705**	**1,620**	**140,42**	**10888,552**

Table 4. *ECOCADIZ-RECLUTAS 2021-10* 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*; POA: *Brama brama*; BOC: *Capros aper*; SNS: *Macroramphosus scolopax*; MAV: *Maurolicus muelleri*.

Parameter	ANE	PIL	SAA	VAM	MAC	JAA	HOM	HMM	POA	BOG	BOC	SNS	MAV
Size range (mm)	27 - 193	104 - 216	260 - 344	182 - 374	240 - 357	162 - 232	69 - 308	200 - 415	342 - 400	181 - 345	91 - 141	54 - 90	35 - 55
n	685	464	13	406	101	128	180	301	14	85	150	129	151
a	0.003213570	0.002008436	0.002717708	0.001264585	0.002786321	0.005100145	0.008084745	0.066215667	0.017383890	0.006246972	0.005225102	0.027534889	0.037865257
b	3.250660	3.503799	3.311204	3.577470	3.296999	3.133309	3.011662	2.386548	2.803991	3.144430	3.014743	2.856752	2.086193
r^2	0.9947721	0.9607988	0.8205893	0.9885517	0.9343625	0.9502970	0.9817678	0.9156734	0.8094138	0.9726588	0.8784573	0.9309560	0.7588735

Table 5. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*E. encrasicolus*). 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 7**.

ECOCADIZ-RECLUTAS 2021-10. *Engraulis encrasicolus*. ABUNDANCE (in numbers and million fish)															
Size class	POL01	POL02	POL03	POL04	POL05	POL06	POL07	POL08	POL09	POL10	*n*			Millions		
											PORTUGAL	SPAIN	TOTAL	PORTUGAL	SPAIN	TOTAL
2	0	0	0	0	0	0	0	3712239	0	0	0	3712239	3712239	0	4	4
2,5	0	0	0	0	0	0	0	4242559	0	0	0	4242559	4242559	0	4	4
3	0	0	0	0	0	0	0	8485117	0	0	0	8485117	8485117	0	8	8
3,5	0	0	0	0	0	0	0	1590959	0	0	0	1590959	1590959	0	2	2
4	0	0	0	0	0	0	0	2651599	0	0	0	2651599	2651599	0	3	3
4,5	0	0	0	0	0	0	0	1590959	0	0	0	1590959	1590959	0	2	2
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5,5	0	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	0
6,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	563418	0	0	563418	563418	0	1	1
7,5	0	0	0	0	0	0	1750645	0	18592806	0	0	20343451	20343451	0	20	20
8	0	0	0	0	0	0	2848854	0	56905254	0	0	59754108	59754108	0	60	60
8,5	0	0	0	0	0	0	13466076	0	32114847	0	0	45580923	45580923	0	46	46
9	0	0	0	0	0	0	76785171	655922	5070765	0	0	82511858	82511858	0	83	83
9,5	0	0	0	0	60520	0	279735115	990861	1126837	0	60520	281852813	281913333	0,1	282	282
10	0	0	0	0	30260	0	296143954	1646783	0	3060960	30260	300851697	300881957	0,03	301	301
10,5	0	0	0	0	121041	0	230410511	1646783	1126837	23416342	121041	256600473	256721514	0,1	257	257
11	0	0	0	0	60520	0	153764282	4605409	0	82645912	60520	241015603	241076123	0,1	241	241
11,5	0	0	0	0	166431	0	115494696	2302705	0	65504538	166431	183301939	183468370	0,2	183	183
12	0	95104	0	76	469034	25685	79573472	3628504	0	42853436	564214	126081097	126645311	1	126	127
12,5	0	895993	0	713	499294	241983	33933387	990861	0	18671854	1396000	53838085	55234085	1	54	55
13	100950	13469141	17531	10712	817026	3637636	21629070	0	0	9335927	14415360	34602633	49017993	14	35	49
13,5	988946	30978548	171742	24638	257212	8366434	1750645	0	0	2295720	32421086	12412799	44833885	32	12	45
14	3486321	54263641	605439	43157	90781	14655082	2848854	0	0	0	58489339	17503936	75993275	58	18	76
14,5	6467734	42698538	1123196	33959	0	11531673	1750645	0	0	1530480	50323427	14812798	65136225	50	15	65
15	7711698	18013336	1339224	14326	0	4864895	1098209	0	0	0	27078584	5963104	33041688	27	6	33
15,5	5960717	5557637	1035146	4420	0	1500961	0	0	0	0	12557920	1500961	14058881	13	2	14
16	3474428	3700093	603374	2943	0	999291	0	0	0	0	7780838	999291	8780129	8	1	9
16,5	1905543	330377	330919	263	0	89225	0	0	0	0	2567102	89225	2656327	3	0,1	3
17	1317458	188787	228792	150	0	50986	0	0	0	0	1735187	50986	1786173	2	0,1	2
17,5	522423	94393	90725	75	0	25493	0	0	0	0	707616	25493	733109	1	0,03	1
18	68523	0	11900	0	0	0	0	0	0	0	80423	0	80423	0,1	0	0,1
18,5	33156	0	5758	0	0	0	0	0	0	0	38914	0	38914	0,04	0	0,04
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	32037897	170285588	5563746	135432	2572119	45989344	1312983586	38741260	115500764	249315169	210594782	1762530123	1973124905	**211**	**1763**	**1973**
Millions	**32**	**170**	**6**	**0,1**	**3**	**46**	**1313**	**39**	**116**	**249**	**211**	**1763**	**1973**			

Table 5. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*E. encrasicolus*). Cont'd.

***ECOCADIZ-RECLUTAS 2021-10 . Engraulis encrasicolus* . BIOMASS (t)**													
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	**POL07**	**POL08**	**POL09**	**POL10**	**PORTUGAL**	**SPAIN**	**TOTAL**
2	0	0	0	0	0	0	0	0,167	0	0	0	0,167	0,167
2,5	0	0	0	0	0	0	0	0,365	0	0	0	0,365	0,365
3	0	0	0	0	0	0	0	1,258	0	0	0	1,258	1,258
3,5	0	0	0	0	0	0	0	0,376	0	0	0	0,376	0,376
4	0	0	0	0	0	0	0	0,940	0	0	0	0,940	0,940
4,5	0	0	0	0	0	0	0	0,810	0	0	0	0,810	0,810
5	0	0	0	0	0	0	0	0	0	0	0	0	0
5,5	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
6,5	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	1,134	0	0	1,134	1,134
7,5	0	0	0	0	0	0	4,375	0	46,468	0	0	50,843	50,843
8	0	0	0	0	0	0	8,724	0	174,269	0	0	182,993	182,993
8,5	0	0	0	0	0	0	49,932	0	119,081	0	0	169,013	169,013
9	0	0	0	0	0	0	341,086	2,914	22,525	0	0	366,525	366,525
9,5	0	0	0	0	0,319	0	1474,526	5,223	5,940	0	0,319	1485,689	1486,008
10	0	0	0	0	0,188	0	1836,582	10,213	0	18,983	0,188	1865,778	1865,966
10,5	0	0	0	0	0,876	0	1668,200	11,923	8,158	169,537	0,876	1857,818	1858,694
11	0	0	0	0	0,508	0	1290,573	38,654	0	693,663	0,508	2022,890	2023,398
11,5	0	0	0	0	1,609	0	1116,552	22,262	0	633,269	1,609	1772,083	1773,692
12	0	1,053	0	0,001	5,192	0,284	880,879	40,168	0	474,388	6,246	1395,719	1401,965
12,5	0	11,296	0	0,009	6,295	3,051	427,812	12,492	0	235,403	17,60	678,758	696,358
13	1,442	192,429	0,250	0,153	11,673	51,970	309,007	0	0	133,379	205,947	494,356	700,303
13,5	15,937	499,211	2,768	0,397	4,145	134,823	28,211	0	0	36,995	522,458	200,029	722,487
14	63,098	982,102	10,958	0,781	1,643	265,238	51,561	0	0	0	1058,582	316,799	1375,381
14,5	130,944	864,463	22,740	0,688	0	233,467	35,443	0	0	30,986	1018,835	299,896	1318,731
15	173,999	406,434	30,217	0,323	0	109,766	24,779	0	0	0	610,973	134,545	745,518
15,5	149,361	139,261	25,938	0,111	0	37,611	0	0	0	0	314,671	37,611	352,282
16	96,370	102,63	16,736	0,082	0	27,717	0	0	0	0	215,818	27,717	243,535
16,5	58,326	10,112	10,129	0,008	0	2,731	0	0	0	0	78,575	2,731	81,306
17	44,372	6,358	7,706	0,005	0	1,717	0	0	0	0	58,441	1,717	60,158
17,5	19,308	3,489	3,353	0,003	0	0,942	0	0	0	0	26,153	0,942	27,095
18	2,772	0	0,481	0	0	0	0	0	0	0	3,253	0	3,253
18,5	1,464	0	0,254	0	0	0	0	0	0	0	1,718	0	1,718
19	0	0	0	0	0	0	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**757,393**	**3218,838**	**131,530**	**2,561**	**32,448**	**869,317**	**9548,242**	**147,765**	**377,575**	**2426,603**	**4142,770**	**13369,502**	**17512,272**

Table 6. *ECOCADIZ-RECLUTAS* surveys series. Anchovy (*E. encrasicolus*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cadiz 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**
Biomass (t)	13680 (13354)	8113 (5131)	30827 (29219)	19861 (15969)	7642 (7290)	10493 (3834)	48357 (36405)	36070 (21060)	17512 (12063)
Abundance (millions)	2469 (2619)	986 (814)	5227 (5117)	3667 (3445)	1492 (1433)	953 (543)	5505 (4845)	3197 (2385)	1973 (1629)

Table 7. *ECOCADIZ-RECLUTAS 2021-10* 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 11**.

***ECOCADIZ-RECLUTAS 2021-10*. *Sardina pilchardus*. ABUNDANCE (in numbers and million fish)**											
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	***n***			**Millions**		
						PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
8	0	0	0	0	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0	0	0,0	0	0
10	0	0	0	371003	0	0	371003	371003	0,00	0	0
10,5	0	0	0	1669512	0	0	1669512	1669512	0,0	2	2
11	0	0	0	9779828	0	0	9779828	9779828	0,0	10	10
11,5	0	63241	95937	46569152	121920	159178	46691072	46850250	0,2	47	47
12	0	84321	127916	122853804	284481	212237	123138285	123350522	0	123	123
12,5	0	252964	383749	151718034	1137925	636713	152855959	153492672	1	153	153
13	0	1016070	1541390	108500302	1584966	2557460	110085268	112642728	3	110	113
13,5	0	1058231	1605348	29847214	934724	2663579	30781938	33445517	3	31	33
14	0	1226873	1861180	13805319	1300485	3088053	15105804	18193857	3	15	18
14,5	0	695650	1055308	9588810	1219205	1750958	10808015	12558973	2	11	13
15	0	274044	415728	8847975	650243	689772	9498218	10187990	1	9	10
15,5	0	2174073	3298093	12217421	812803	5472166	13030224	18502390	5	13	19
16	0	4813326	7301869	4733619	447042	12115195	5180661	17295856	12	5	17
16,5	0	38113987	57819343	3378984	487682	95933330	3866666	99799996	96	3,9	100
17	0	96855106	146930276	2389888	528322	243785382	2918210	246703592	244	2,9	247
17,5	924790	138311454	209820019	756386	162561	349056263	918947	349975210	349	0,92	350
18	2774369	148113529	224689876	1095045	0	375577774	1095045	376672819	375,6	1	376,7
18,5	12106338	137508501	208601931	0	0	358216770	0	358216770	358,22	0	358,22
19	17823220	136821379	207559559	0	0	362204158	0	362204158	362	0	362,204158
19,5	21522378	126992904	192649652	185501	0	341164934	185501	341350435	341	0	341,350435
20	15553281	61232531	92890433	0	0	169676245	0	169676245	170	0	169,676245
20,5	5464666	41658883	63196990	0	0	110320539	0	110320539	110	0	110,320539
21	2017723	3921788	5949396	0	0	11888907	0	11888907	12	0	11,888907
21,5	420359	0	0	0	0	420359	0	420359	0	0	0,420359
22	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	78607124	941188855	1427793993	528307797	9672359	2447589972	537980156	2985570128	**2448**	**538**	**2986**
Millions	**79**	**941**	**1428**	**528**	**10**	**2448**	**538**	**2986**			

Table 7. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . Sardina pilchardus . BIOMASS (t)								
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**PORTUGAL**	**SPAIN**	**TOTAL**
8	0	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0	0
10	0	0	0	2,539	0	0	2,539	2,539
10,5	0	0	0	13,523	0	0	13,523	13,523
11	0	0	0	93,050	0	0	93,050	93,050
11,5	0	0,702	1,065	516,834	1,353	1,767	518,187	519,954
12	0	1,085	1,645	1580,237	3,659	2,730	1583,896	1586,626
12,5	0	3,749	5,687	2248,472	16,864	9,436	2265,336	2274,772
13	0	17,255	26,177	1842,601	26,917	43,432	1869,518	1912,950
13,5	0	20,490	31,083	577,914	18,099	51,573	596,013	647,586
14	0	26,958	40,895	303,340	28,575	67,853	331,915	399,768
14,5	0	17,270	26,199	238,055	30,268	43,469	268,323	311,792
15	0	7,656	11,614	247,183	18,166	19,270	265,349	284,619
15,5	0	68,086	103,287	382,615	25,455	171,373	408,070	579,443
16	0	168,378	255,432	165,590	15,638	423,810	181,228	605,038
16,5	0	1484,314	2251,721	131,591	18,992	3736,035	150,583	3886,618
17	0	4185,950	6350,133	103,288	22,833	10536,083	126,121	10662,204
17,5	44,223	6614,047	10033,584	36,170	7,774	16691,854	43,944	16735,798
18	146,383	7814,854	11855,221	57,777	0	19816,458	57,777	19874,235
18,5	702,913	7983,954	12111,748	0	0	20798,615	0	20798,615
19	1135,908	8719,888	13228,168	0	0	23083,964	0	23083,964
19,5	1502,028	8862,722	13444,847	12,946	0	23809,597	12,946	23822,543
20	1185,918	4668,901	7082,775	0	0	12937,594	0	12937,594
20,5	454,259	3462,957	5253,345	0	0	9170,561	0	9170,561
21	182,480	354,681	538,055	0	0	1075,216	0	1075,216
21,5	41,280	0	0	0	0	41,280	0	41,280
22	0	0	0	0	0	0	0	0
TOTAL	**5395,392**	**54483,897**	**82652,681**	**8553,725**	**234,593**	**142531,970**	**8788,318**	**151320,288**

Table 8. *ECOCADIZ-RECLUTAS* surveys series. Sardine (*Sardina pilchardus*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cadiz 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**
Biomass (t)	22119 (9182)	36571 (705)	30992 (8645)	35173 (21899)	12119 (8778)	20679 (15224)	36465 (7858)	208400 (49259)	151320 (12854)
Abundance (millions)	603 (359)	507 (26)	861 (509)	2379 (1940)	591 (483)	1134 (1036)	937 (384)	5451 (2454)	2986 (638)

Table 9. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). 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 15**.

***ECOCADIZ-RECLUTAS 2021-10*. *Scomber scombrus*. ABUNDANCE (in numbers and million fish)**								
Size class	**POL01**	**POL02**	***n***			**Millions**		
			PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
14	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
16,5	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
17,5	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
18,5	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
20,5	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0
21,5	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
22,5	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0
23,5	0	0	0	0	0	0	0	0
24	506504	96128	506504	96128	602632	0,506504	0,1	1
24,5	949694	180240	949694	180240	1129934	0,949694	0,2	1
25	886381	168224	886381	168224	1054605	0,886381	0,2	1
25,5	823068	156208	823068	156208	979276	0,823068	0,2	1
26	633130	120160	633130	120160	753290	0,63313	0,1	1
26,5	316565	60080	316565	60080	376645	0,316565	0,1	0,4
27	506504	96128	506504	96128	602632	0,506504	0,1	1
27,5	189939	36048	189939	36048	225987	0,2	0,04	0,2
28	0	0	0	0	0	0	0	0
28,5	126626	24032	126626	24032	150658	0,1	0,02	0,2
29	0	0	0	0	0	0	0	0
29,5	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
30,5	0	0	0	0	0	0	0	0
31	63313	12016	63313	12016	75329	0,063313	0,01	0,1
31,5	63313	12016	63313	12016	75329	0,063313	0,01	0,1
32	0	0	0	0	0	0	0	0
32,5	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0
33,5	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0
34,5	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0
35,5	63313	12016	63313	12016	75329	0,1	0,01	0,1
36	0	0	0	0	0	0	0	0
36,5	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0
37,5	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0
TOTAL *n*	5128350	973296	5128350	973296	6101646	**5**	**1**	**6**
Millions	**5**	**1**						

Table 9. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). Cont'd.

***ECOCADIZ-RECLUTAS 2021-10 . Scomber scombrus* . BIOMASS (t)**					
Size class	**POL01**	**POL02**	**PORTUGAL**	**SPAIN**	**TOTAL**
14	0	0	0	0	0
14,5	0	0	0	0	0
15	0	0	0	0	0
15,5	0	0	0	0	0
16	0	0	0	0	0
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	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
22	0	0	0	0	0
22,5	0	0	0	0	0
23	0	0	0	0	0
23,5	0	0	0	0	0
24	51,881	9,846	51,881	9,846	61,727
24,5	104,047	19,747	104,047	19,747	123,794
25	103,731	19,687	103,731	19,687	123,418
25,5	102,754	19,501	102,754	19,501	122,255
26	84,216	15,983	84,216	15,983	100,199
26,5	44,810	8,504	44,810	8,504	53,314
27	76,211	14,464	76,211	14,464	90,675
27,5	30,345	5,759	30,345	5,759	36,104
28	0	0	0	0	0
28,5	22,734	4,315	22,734	4,315	27,049
29	0	0	0	0	0
29,5	0	0	0	0	0
30	0	0	0	0	0
30,5	0	0	0	0	0
31	14,964	2,840	14,964	2,840	17,804
31,5	15,768	2,993	15,768	2,993	18,761
32	0	0	0	0	0
32,5	0	0	0	0	0
33	0	0	0	0	0
33,5	0	0	0	0	0
34	0	0	0	0	0
34,5	0	0	0	0	0
35	0	0	0	0	0
35,5	23,317	4,425	23,317	4,425	27,742
36	0	0	0	0	0
36,5	0	0	0	0	0
37	0	0	0	0	0
37,5	0	0	0	0	0
38	0	0	0	0	0
TOTAL	**674,778**	**128,064**	**674,778**	**128,064**	**802,842**

Table 10. *ECOCADIZ-RECLUTAS 2021-10* 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 18**.

***ECOCADIZ-RECLUTAS 2021-10 . Scomber colias* . ABUNDANCE (in numbers and million fish)**											
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	***n***			**Millions**		
						PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
14	0	0	0	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
16,5	0	0	0	0	0	0	0	0	0	0	0
17	0	52029	0	0	0	52029	0	52029	0,1	0	0,1
17,5	0	52029	0	0	0	52029	0	52029	0,1	0	0,1
18	339195	208116	2864	0	0	547311	2864	550175	1	0,003	1
18,5	0	52029	0	0	0	52029	0	52029	0,1	0	0,1
19	46622	1664924	394	0	0	1711546	394	1711940	2	0,0004	2
19,5	46622	5463033	394	0	0	5509655	394	5510049	6	0,0004	6
20	479249	7023899	4047	0	0	7503148	4047	7507195	8	0,004	8
20,5	1239291	5723177	10465	0	0	6962468	10465	6972933	7	0,01	7
21	1310195	4058253	11063	0	0	5368448	11063	5379511	5	0,01	5
21,5	2654696	2341300	22417	0	0	4995996	22417	5018413	5	0,02	5
22	3982044	728404	33625	0	0	4710448	33625	4744073	5	0,03	5
22,5	5279736	780433	44583	0	0	6060169	44583	6104752	6	0,04	6
23	4759739	312173	40192	0	0	5071912	40192	5112104	5	0,04	5
23,5	6635979	156087	56035	0	0	6792066	56035	6848101	7	0,1	7
24	10518954	52029	88823	16389	0	10570983	105212	10676195	11	0,1	11
24,5	9863779	156087	83291	90138	0	10019866	173429	10193295	10	0,2	10
25	3602220	0	30418	40972	0	3602220	71390	3673610	4	0,1	4
25,5	3723927	0	31445	335782	0	3723927	367227	4091154	4	0,4	4
26	1251070	0	10564	466892	0	1251070	477456	1728526	1	0,5	2
26,5	479592	0	4050	467078	0	479592	471128	950720	0,5	0,5	1
27	432969	0	3656	688139	0	432969	691795	1124764	0,4	1	1
27,5	46622	0	394	1793445	0	46622	1793839	1840461	0,05	2	2
28	0	0	0	2333714	23062	0	2356776	2356776	0	2	2
28,5	0	0	0	2153624	0	0	2153624	2153624	0	2	2
29	292229	0	2468	1981543	0	292229	1984011	2276240	0,3	2	2
29,5	0	0	0	2031081	0	0	2031081	2031081	0	2	2
30	0	0	0	630779	92249	0	723028	723028	0	1	1
30,5	0	0	0	557030	207560	0	764590	764590	0	1	1
31	0	0	0	483280	253685	0	736965	736965	0	1	1
31,5	0	0	0	73749	576556	0	650305	650305	0	1	1
32	0	0	0	204673	922490	0	1127163	1127163	0	1	1
32,5	0	0	0	40972	945552	0	986524	986524	0	1	1
33	0	0	0	0	876365	0	876365	876365	0	1	1
33,5	0	0	0	0	530432	0	530432	530432	0	1	0,5
34	0	0	0	16389	415120	0	431509	431509	0	0,4	0,4
34,5	0	0	0	0	276747	0	276747	276747	0	0,3	0,3
35	0	0	0	0	138373	0	138373	138373	0	0,1	0,1
35,5	0	0	0	0	207560	0	207560	207560	0	0,2	0,2
36	0	0	0	0	69187	0	69187	69187	0	0,1	0,1
36,5	0	0	0	0	23062	0	23062	23062	0	0,02	0,02
37	0	0	0	0	46124	0	46124	46124	0	0,05	0,05
37,5	0	0	0	0	23062	0	23062	23062	0	0,02	0,02
38	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	56984730	28824002	481188	14405669	5627186	85808732	20514043	106322775	**86**	**21**	**106**
Millions	**57**	**29**	**0,5**	**14**	**6**						

Table 10. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Cont'd.

***ECOCADIZ-RECLUTAS 2021-10 . Scomber colias* . BIOMASS (t)**								
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**PORTUGAL**	**SPAIN**	**TOTAL**
14	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
16,5	0	0	0	0	0	0	0	0
17	0	1,749	0	0	0	1,749	0	1,749
17,5	0	1,937	0	0	0	1,937	0	1,937
18	13,949	8,558	0,118	0	0	22,507	0,118	22,625
18,5	0	2,357	0	0	0	2,357	0	2,357
19	2,320	82,862	0,020	0	0	85,182	0,020	85,202
19,5	2,543	298,013	0,021	0	0	300,556	0,021	300,577
20	28,589	419,009	0,241	0	0	447,598	0,241	447,839
20,5	80,670	372,545	0,681	0	0	453,215	0,681	453,896
21	92,869	287,657	0,784	0	0	380,526	0,784	381,310
21,5	204,495	180,354	1,727	0	0	384,849	1,727	386,576
22	332,726	60,863	2,810	0	0	393,589	2,810	396,399
22,5	477,662	70,606	4,033	0	0	548,268	4,033	552,301
23	465,445	30,527	3,930	0	0	495,972	3,930	499,902
23,5	700,243	16,471	5,913	0	0	716,714	5,913	722,627
24	1195,875	5,915	10,098	1,863	0	1201,79	11,961	1213,751
24,5	1206,328	19,089	10,186	11,024	0	1225,417	21,210	1246,627
25	473,224	0	3,996	5,382	0	473,224	9,378	482,602
25,5	524,763	0	4,431	47,317	0	524,763	51,748	576,511
26	188,852	0	1,595	70,479	0	188,852	72,074	260,926
26,5	77,451	0	0,654	75,430	0	77,451	76,084	153,535
27	74,711	0	0,631	118,742	0	74,711	119,373	194,084
27,5	8,586	0	0,073	330,268	0	8,586	330,341	338,927
28	0	0	0	458,111	4,527	0	462,638	462,638
28,5	0	0	0	450,144	0	0	450,144	450,144
29	64,967	0	0,549	440,528	0	64,967	441,077	506,044
29,5	0	0	0	479,768	0	0	479,768	479,768
30	0	0	0	158,153	23,129	0	181,282	181,282
30,5	0	0	0	148,098	55,184	0	203,282	203,282
31	0	0	0	136,122	71,454	0	207,576	207,576
31,5	0	0	0	21,986	171,883	0	193,869	193,869
32	0	0	0	64,525	290,824	0	355,349	355,349
32,5	0	0	0	13,648	314,961	0	328,609	328,609
33	0	0	0	0	308,175	0	308,175	308,175
33,5	0	0	0	0	196,758	0	196,758	196,758
34	0	0	0	6,408	162,302	0	168,71	168,710
34,5	0	0	0	0	113,960	0	113,96	113,960
35	0	0	0	0	59,967	0	59,967	59,967
35,5	0	0	0	0	94,600	0	94,60	94,600
36	0	0	0	0	33,140	0	33,14	33,140
36,5	0	0	0	0	11,601	0	11,601	11,601
37	0	0	0	0	24,352	0	24,352	24,352
37,5	0	0	0	0	12,771	0	12,771	12,771
38	0	0	0	0	0	0	0	0
TOTAL	**6216,268**	**1858,512**	**52,491**	**3037,996**	**1949,588**	**8074,780**	**5040,075**	**13114,855**

Table 11. *ECOCADIZ-RECLUTAS* surveys series. Chub mackerel (*Scomber colias*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cadiz 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**
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)
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)

Table 12. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). 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 22**.

***ECOCADIZ-RECLUTAS 2021-10 . Trachurus trachurus* . ABUNDANCE (in numbers and million fish)**												
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	***n***			**Millions**		
							PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
12	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
13	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
14	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
15	0	0	0	0	0	0	0	0	0	0	0	0
15,5	0	0	0	22704	61674	118316	22704	179990	202694	0,02	0,2	0,2
16	0	0	0	22704	61674	118316	22704	179990	202694	0,02	0,2	0,2
16,5	0	0	0	22704	61674	118316	22704	179990	202694	0,02	0,2	0,2
17	0	0	0	22704	61674	118316	22704	179990	202694	0,02	0,2	0,2
17,5	83765	0	0	22704	61674	118316	106469	179990	286459	0,1	0,2	0,3
18	0	0	0	60544	164463	315509	60544	479972	540516	0,1	0,5	1
18,5	0	0	0	22704	61674	118316	22704	179990	202694	0,0	0,2	0,2
19	83765	0	0	11352	30837	59158	95117	89995	185112	0,1	0,1	0,2
19,5	614276	0	0	0	0	0	614276	0	614276	1	0	1
20	530511	0	0	0	0	0	530511	0	530511	1	0	1
20,5	1689507	0	0	0	0	0	1689507	0	1689507	2	0	2
21	1564109	0	0	0	0	0	1564109	0	1564109	2	0	2
21,5	2779946	8810	6212	0	0	0	2794968	0	2794968	3	0	3
22	4679115	8810	6212	0	0	0	4694137	0	4694137	5	0	5
22,5	9767830	0	0	0	0	0	9767830	0	9767830	10	0	10
23	12983803	0	0	0	0	0	12983803	0	12983803	13	0	13
23,5	9547948	0	0	0	0	0	9547948	0	9547948	10	0	10
24	5340010	8810	6212	0	0	0	5355032	0	5355032	5	0	5
24,5	2739310	17619	12425	0	0	0	2769354	0	2769354	3	0	3
25	1537684	35239	24849	0	0	0	1597772	0	1597772	2	0	2
25,5	1327523	26429	18637	0	0	0	1372589	0	1372589	1	0	1
26	671116	0	0	0	0	0	671116	0	671116	1	0	1
26,5	209661	17619	12425	0	0	0	239705	0	239705	0,2	0	0,2
27	125897	35239	24849	0	0	0	185985	0	185985	0,2	0	0,2
27,5	0	35239	24849	0	0	0	60088	0	60088	0,1	0	0,1
28	0	35239	24849	0	0	0	60088	0	60088	0,1	0	0,1
28,5	125897	17619	12425	0	0	0	155941	0	155941	0,2	0	0,2
29	0	0	0	0	0	0	0	0	0	0	0	0
29,5	0	0	0	0	0	0	0	0	0	0	0	0
30	0	8810	6212	0	0	0	15022	0	15022	0,02	0	0,02
30,5	0	8810	6212	0	0	0	15022	0	15022	0,02	0	0,02
31	0	0	0	0	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	56401673	264292	186368	208120	565344	1084563	57060453	1649907	58710360	**57**	**2**	**59**
Millions	**56**	**0,3**	**0,2**	**0,2**	**1**	**1**						

Table 12. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Cont'd.

***ECOCADIZ-RECLUTAS 2021-10 . Trachurus trachurus* . BIOMASS (t)**									
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	**PORTUGAL**	**SPAIN**	**TOTAL**
12	0	0	0	0	0	0	0	0	0
12,5	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
13,5	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
15,5	0	0	0	0,741	2,012	3,859	0,741	5,871	6,612
16	0	0	0	0,814	2,210	4,240	0,814	6,450	7,264
16,5	0	0	0	0,891	2,422	4,645	0,891	7,067	7,958
17	0	0	0	0,974	2,646	5,076	0,974	7,722	8,696
17,5	3,916	0	0	1,062	2,884	5,532	4,978	8,416	13,394
18	0	0	0	3,078	8,36	16,039	3,078	24,399	27,477
18,5	0	0	0	1,252	3,401	6,525	1,252	9,926	11,178
19	5	0	0	0,678	1,841	3,531	5,678	5,372	11,050
19,5	39,613	0	0	0	0	0	39,613	0	39,613
20	36,887	0	0	0	0	0	36,887	0	36,887
20,5	126,427	0	0	0	0	0	126,427	0	126,427
21	125,745	0	0	0	0	0	125,745	0	125,745
21,5	239,706	0,760	0,536	0	0	0	241,002	0	241,002
22	432,049	0,813	0,574	0	0	0	433,436	0	433,436
22,5	964,348	0	0	0	0	0	964,348	0	964,348
23	1368,587	0	0	0	0	0	1368,587	0	1368,587
23,5	1073,026	0	0	0	0	0	1073,026	0	1073,026
24	638,987	1,054	0,743	0	0	0	640,784	0	640,784
24,5	348,566	2,242	1,581	0	0	0	352,389	0	352,389
25	207,812	4,762	3,358	0	0	0	215,932	0	215,932
25,5	190,324	3,789	2,672	0	0	0	196,785	0	196,785
26	101,953	0	0	0	0	0	101,953	0	101,953
26,5	33,713	2,833	1,998	0	0	0	38,544	0	38,544
27	21,405	5,991	4,225	0	0	0	31,621	0	31,621
27,5	0	6,329	4,463	0	0	0	10,792	0	10,792
28	0	6,678	4,709	0	0	0	11,387	0	11,387
28,5	25,154	3,52	2,482	0	0	0	31,156	0	31,156
29	0	0	0	0	0	0	0	0	0
29,5	0	0	0	0	0	0	0	0	0
30	0	2,052	1,447	0	0	0	3,499	0	3,499
30,5	0	2,155	1,520	0	0	0	3,675	0	3,675
31	0	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
TOTAL	**5983,218**	**42,978**	**30,308**	**9,490**	**25,776**	**49,447**	**6065,994**	**75,223**	**6141,217**

Table 13. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). 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 25**.

ECOCADIZ-RECLUTAS 2021-10. *Trachurus mediterraneus*. ABUNDANCE (in numbers and million fish)										
Size class	POL01	POL02	POL03	POL04	*n*			Millions		
					PORTUGAL	SPAIN	TOTAL	PORTUGAL	SPAIN	TOTAL
4	0	0	0	0	0	0	0	0	0	0
4,5	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
5,5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
6,5	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
10,5	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
11,5	0	0	0	0	0	0	0	0	0	0
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	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
18,5	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0	0	0	0
20	4281	154727	0	0	4281	154727	159008	0,004	0,2	0,2
20,5	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0
21,5	664	24009	17583	31218	664	72810	73474	0,001	0,1	0,1
22	4946	178736	0	0	4946	178736	183682	0,005	0,2	0,2
22,5	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0
23,5	0	0	0	0	0	0	0	0	0	0
24	1546	55869	0	0	1546	55869	57415	0,002	0,1	0,1
24,5	1546	55869	17583	31218	1546	104670	106216	0,002	0,1	0,1
25	1592	57531	38698	68707	1592	164936	166528	0,002	0,2	0,2
25,5	7226	261152	197095	349935	7226	808182	815408	0,01	1	1
26	40170	1451746	123231	218793	40170	1793770	1833940	0,04	2	2
26,5	84793	3064407	296982	527280	84793	3888669	3973462	0,1	4	4
27	136444	4931068	293450	521009	136444	5745527	5881971	0,1	6	6
27,5	119786	4329029	494077	877215	119786	5700321	5820107	0,1	6	6
28	60646	2191750	531848	944276	60646	3667874	3728520	0,1	4	4
28,5	30554	1104213	594266	1055096	30554	2753575	2784129	0,03	3	3
29	49507	1789187	769797	1366744	49507	3925728	3975235	0,05	4	4
29,5	31774	1148314	1353617	2403295	31774	4905226	4937000	0,03	5	5
30	6738	243515	969346	1721036	6738	2933897	2940635	0,01	3	3
30,5	8399	303538	1164886	2068209	8399	3536633	3545032	0,01	4	4
31	8399	303538	751059	1333476	8399	2388073	2396472	0,01	2	2
31,5	464	16761	411847	731219	464	1159827	1160291	0,0005	1	1
32	0	0	381365	677099	0	1058464	1058464	0	1	1
32,5	1993	72028	159549	283273	1993	514850	516843	0,002	1	1
33	4281	154727	119699	212522	4281	486948	491229	0,004	0,5	0,5
33,5	464	16761	70332	124871	464	211964	212428	0,0005	0,2	0,2
34	664	24009	52749	93654	664	170412	171076	0,001	0,2	0,2
34,5	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0
35,5	0	0	0	0	0	0	0	0	0	0
36	9633	348135	0	0	9633	348135	357768	0,01	0,3	0,4
36,5	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0
37,5	0	0	0	0	0	0	0	0	0	0
38	0	0	17583	31218	0	48801	48801	0	0,05	0,05
38,5	0	0	0	0	0	0	0	0	0	0
39	0	0	35166	62436	0	97602	97602	0	0,1	0,1
39,5	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0
40,5	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0
41,5	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0
42,5	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0
43,5	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0
44,5	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0
45,5	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0
46,5	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0
47,5	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0
48,5	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0
49,5	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	616510	22280619	8861808	15733799	616510	46876226	47492736	0,6	47	47
Millions	1	22	9	16						

Table 13. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . Trachurus mediterraneus. BIOMASS (t)							
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**PORTUGAL**	**SPAIN**	**TOTAL**
4	0	0	0	0	0	0	0
4,5	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
5,5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6,5	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
10,5	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
11,5	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
12,5	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0
13,5	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0
16	0	0	0	0	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	0,372	13,439	0	0	0	13,439	13,811
20,5	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
21,5	0,068	2,473	1,811	3,216	0,068	7,500	7,568
22	0,538	19,437	0	0	0,538	19,437	19,975
22,5	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0
23,5	0	0	0	0	0	0	0
24	0,206	7,461	0	0	0,206	7,461	7,667
24,5	0,217	7,834	2,465	4,377	0,217	14,676	14,893
25	0,234	8,461	5,691	10,105	0,234	24,257	24,491
25,5	1,114	40,248	30,375	53,931	1,114	124,554	125,668
26	6,482	234,245	19,884	35,303	6,482	289,432	295,914
26,5	14,312	517,230	50,126	88,998	14,312	656,354	670,666
27	24,071	869,906	51,768	91,913	24,071	1013,587	1037,658
27,5	22,069	797,567	91,027	161,615	22,069	1050,209	1072,278
28	11,660	421,382	102,252	181,545	11,660	705,179	716,839
28,5	6,125	221,372	119,138	211,525	6,125	552,035	558,160
29	10,342	373,762	160,811	285,514	10,342	820,087	830,429
29,5	6,912	249,786	294,444	522,775	6,912	1067,005	1073,917
30	1,525	55,120	219,412	389,558	1,525	664,090	665,615
30,5	1,977	71,448	274,194	486,820	1,977	832,462	834,439
31	2,055	74,251	183,724	326,195	2,055	584,170	586,225
31,5	0,118	4,258	104,636	185,777	0,118	294,671	294,789
32	0,000	0,000	100,573	178,563	0	279,136	279,136
32,5	0,545	19,705	43,649	77,498	0,545	140,852	141,397
33	1,214	43,889	33,953	60,283	1,214	138,125	139,339
33,5	0,136	4,927	20,673	36,705	0,136	62,305	62,441
34	0,202	7,309	16,059	28,512	0,202	51,880	52,082
34,5	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0
35,5	0	0	0	0	0	0	0
36	3,358	121,359	0	0	3,358	121,359	124,717
36,5	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0
37,5	0	0	0	0	0	0	0
38	0	0	6,968	12,371	0	19,339	19,339
38,5	0	0	0	0	0	0	0
39	0	0	14,820	26,313	0	41,133	41,133
39,5	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0
40,5	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0
41,5	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0
42,5	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0
43,5	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0
44,5	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0
45,5	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0
46,5	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0
47,5	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0
48,5	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0
49,5	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0
TOTAL	**115,852**	**4186,869**	**1948,453**	**3459,412**	**115,852**	**9594,734**	**9710,586**

Table 14. *ECOCADIZ-RECLUTAS 2021-10* 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 28**.

ECOCADIZ-RECLUTAS 2021-10. *Trachurus picturatus*. ABUNDANCE (in numbers and million fish)								
Size class	POL01	POL02	*n*			Millions		
			PORTUGAL	SPAIN	TOTAL	PORTUGAL	SPAIN	TOTAL
14	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
15,5	170332	0	170332	0	170332	0,2	0	0,2
16	3917647	7573	3925220	0	3925220	4	0	4
16,5	8403070	34077	8437147	0	8437147	8	0	8
17	13853709	126842	13980551	0	13980551	14	0	14
17,5	9425064	160919	9585983	0	9585983	10	0	10
18	7381075	213928	7595003	0	7595003	8	0	8
18,5	4428645	187424	4616069	0	4616069	5	0	5
19	1873657	153347	2027004	0	2027004	2	0	2
19,5	2043990	53009	2096999	0	2096999	2	0	2
20	681330	26504	707834	0	707834	1	0	1
20,5	340665	0	340665	0	340665	0,3	0	0,3
21	0	0	0	0	0	0	0	0
21,5	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
22,5	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0
23,5	0	0	0	0	0	0	0	0
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	0	0	0	0	0	0
26,5	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0
27,5	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0
28,5	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0
29,5	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
30,5	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0
32,5	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0
33,5	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0
34,5	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0
35,5	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0
36,5	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0
37,5	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0
TOTAL *n*	52519184	963623	53482807	0	53482807	**53**	**0**	**53**
Millions	**53**	**1**						

Table 14. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue Jack mackerel (*Trachurus picturatus*). Cont'd.

***ECOCADIZ-RECLUTAS 2021-10 . Trachurus picturatus* . BIOMASS (t)**					
Size class	**POL01**	**POL02**	**PORTUGAL**	**SPAIN**	**TOTAL**
14	0	0	0	0	0
14,5	0	0	0	0	0
15	0	0	0	0	0
15,5	4,901	0	4,901	0	4,901
16	124,333	0,240	124,573	0	124,573
16,5	293,249	1,189	294,438	0	294,438
17	530,140	4,854	534,994	0	534,994
17,5	394,449	6,735	401,184	0	401,184
18	336,999	9,767	346,766	0	346,766
18,5	220,069	9,314	229,383	0	229,383
19	101,109	8,275	109,384	0	109,384
19,5	119,529	3,100	122,629	0	122,629
20	43,090	1,676	44,766	0	44,766
20,5	23,256	0	23,256	0	23,256
21	0	0	0	0	0
21,5	0	0	0	0	0
22	0	0	0	0	0
22,5	0	0	0	0	0
23	0	0	0	0	0
23,5	0	0	0	0	0
24	0	0	0	0	0
24,5	0	0	0	0	0
25	0	0	0	0	0
25,5	0	0	0	0	0
26	0	0	0	0	0
26,5	0	0	0	0	0
27	0	0	0	0	0
27,5	0	0	0	0	0
28	0	0	0	0	0
28,5	0	0	0	0	0
29	0	0	0	0	0
29,5	0	0	0	0	0
30	0	0	0	0	0
30,5	0	0	0	0	0
31	0	0	0	0	0
31,5	0	0	0	0	0
32	0	0	0	0	0
32,5	0	0	0	0	0
33	0	0	0	0	0
33,5	0	0	0	0	0
34	0	0	0	0	0
34,5	0	0	0	0	0
35	0	0	0	0	0
35,5	0	0	0	0	0
36	0	0	0	0	0
36,5	0	0	0	0	0
37	0	0	0	0	0
37,5	0	0	0	0	0
38	0	0	0	0	0
TOTAL	**2191,124**	**45,150**	**2236,274**	**0**	**2236,274**

Table 15. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). 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 31**.

***ECOCADIZ-RECLUTAS 2021-10 . Boops boops* . ABUNDANCE (in numbers and million fish)**											
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	***n***			**Millions**		
						PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
14	0	0	0	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
16,5	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
17,5	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
18,5	118198	18853	16907	36452	3423	137051	56782	193833	0,1	0,1	0,2
19	59099	9426	8453	18226	1712	68525	28391	96916	0,1	0,03	0,1
19,5	118198	18853	16907	36452	3423	137051	56782	193833	0,1	0,1	0,2
20	59099	9426	8453	18226	1712	68525	28391	96916	0,1	0,03	0,1
20,5	177297	28279	25360	54678	5135	205576	85173	290749	0,2	0,1	0,3
21	295495	47132	42267	91130	8558	342627	141955	484582	0,3	0,1	0,5
21,5	59099	9426	8453	18226	1712	68525	28391	96916	0,1	0,03	0,1
22	413692	65985	59173	127582	11981	479677	198736	678413	0,5	0,2	1
22,5	118198	18853	16907	36452	3423	137051	56782	193833	0,1	0,1	0,2
23	531890	84838	76080	164034	15404	616728	255518	872246	1	0,3	1
23,5	59099	9426	8453	18226	1712	68525	28391	96916	0,1	0,03	0,1
24	0	0	0	0	0	0	0	0	0	0	0
24,5	177297	28279	25360	54678	5135	205576	85173	290749	0,2	0,1	0,3
25	118198	18853	16907	36452	3423	137051	56782	193833	0,1	0,1	0,2
25,5	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0
26,5	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0
27,5	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0
28,5	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0
29,5	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0
30,5	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0
32,5	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0
33,5	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0
34,5	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	2304859	367629	329680	710814	66753	2672488	1107247	3779735	**3**	**1**	**4**
Millions	**2**	**0,4**	**0,3**	**1**	**0,1**						

Table 15. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . Boops boops . BIOMASS (t)								
Size class	POL01	POL02	POL03	POL04	POL05	PORTUGAL	SPAIN	TOTAL
14	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
16,5	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
17,5	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
18,5	7,433	1,186	1,063	2,292	0,215	8,619	3,570	12,189
19	4,037	0,644	0,577	1,245	0,117	4,681	1,939	6,620
19,5	8,752	1,396	1,252	2,699	0,253	10,148	4,204	14,352
20	4,734	0,755	0,677	1,460	0,137	5,489	2,274	7,763
20,5	15,334	2,446	2,193	4,729	0,444	17,780	7,366	25,146
21	27,543	4,393	3,940	8,494	0,798	31,936	13,232	45,168
21,5	5,926	0,945	0,848	1,828	0,172	6,871	2,848	9,719
22	44,559	7,107	6,374	13,742	1,290	51,666	21,406	73,072
22,5	13,653	2,178	1,953	4,210	0,395	15,831	6,558	22,389
23	65,783	10,493	9,409	20,287	1,905	76,276	31,601	107,877
23,5	7,815	1,246	1,118	2,410	0,226	9,061	3,754	12,815
24	0	0	0	0	0	0	0	0
24,5	26,691	4,257	3,818	8,232	0,773	30,948	12,823	43,771
25	18,949	3,022	2,711	5,844	0,549	21,971	9,104	31,075
25,5	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0
26,5	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0
27,5	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0
28,5	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0
29,5	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
30,5	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0
32,5	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0
33,5	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0
34,5	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0
TOTAL	**251,209**	**40,068**	**35,933**	**77,472**	**7,274**	**291,277**	**120,679**	**411,956**

Table 16. *ECOCADIZ-RECLUTAS 2021-10* survey. Boarfish (*Capros aper*). 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 34**.

ECOCADIZ-RECLUTAS 2021-10 . *Capros aper* . ABUNDANCE (in numbers and million fish)							
Size class	**POL01**	***n***			**Millions**		
		PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
4	0	0	0	0	0	0	0
4,5	0	0	0	0	0	0	0
5	81515	81515	0	81515	0,1	0	0,1
5,5	570602	570602	0	570602	1	0	1
6	1548776	1548776	0	1548776	2	0	2
6,5	2608464	2608464	0	2608464	3	0	3
7	2445435	2445435	0	2445435	2	0	2
7,5	2363921	2363921	0	2363921	2	0	2
8	652116	652116	0	652116	1	0	1
8,5	163029	163029	0	163029	0,2	0	0,2
9	81515	81515	0	81515	0,1	0	0,1
9,5	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
TOTAL *n*	10515373	10515373	0	10515373	**11**	**0**	**11**
Millions	11						

ECOCADIZ-RECLUTAS 2021-10 . *Capros aper* . BIOMASS (t)				
Size class	**POL01**	**PORTUGAL**	**SPAIN**	**TOTAL**
4	0	0	0	0
4,5	0	0	0	0
5	0,063	0,063	0	0,063
5,5	0,582	0,582	0	0,582
6	2,030	2,030	0	2,030
6,5	4,311	4,311	0	4,311
7	5,014	5,014	0	5,014
7,5	5,926	5,926	0	5,926
8	1,974	1,974	0	1,974
8,5	0,589	0,589	0	0,589
9	0,348	0,348	0	0,348
9,5	0	0	0	0
10	0	0	0	0
TOTAL	**20,837**	**20,837**	**0**	**20,837**

Table 17. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). 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 37**.

ECOCADIZ-RECLUTAS 2021-10 . Macroramphosus scolopax . ABUNDANCE (in numbers and million fish)							
Size class	POL01	*n*			Millions		
		PORTUGAL	SPAIN	TOTAL	PORTUGAL	SPAIN	TOTAL
5	0	0	0	0	0	0	0
5,5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6,5	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0
9	217676774	217676774	0	217676774	218	0	218
9,5	217676774	217676774	0	217676774	218	0	218
10	163257581	163257581	0	163257581	163	0	163
10,5	108838387	108838387	0	108838387	109	0	109
11	217676774	217676774	0	217676774	218	0	218
11,5	327842459	327842459	0	327842459	328	0	328
12	491100039	491100039	0	491100039	491	0	491
12,5	327842459	327842459	0	327842459	328	0	328
13	327842459	327842459	0	327842459	328	0	328
13,5	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
14,5	54419194	54419194	0	54419194	54	0	54
15	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0
16	0	0	0	0	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	0	0	0	0	0	0	0
TOTAL *n*	2454172900	2454172900	0	2454172900	2454	0	2454
Millions	2454						

Table 17. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . M. scolopax . BIOMASS (t)				
Size class	**POL01**	**PORTUGAL**	**SPAIN**	**TOTAL**
5	0	0	0	0
5,5	0	0	0	0
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	3449,235	3449,235	0	3449,235
9,5	4009,003	4009,003	0	4009,003
10	3468,520	3468,520	0	3468,520
10,5	2649,376	2649,376	0	2649,376
11	6033,614	6033,614	0	6033,614
11,5	10289,195	10289,195	0	10289,195
12	17361,542	17361,542	0	17361,542
12,5	12993,226	12993,226	0	12993,226
13	14502,438	14502,438	0	14502,438
13,5	0	0	0	0
14	0	0	0	0
14,5	3270,276	3270,276	0	3270,276
15	0	0	0	0
15,5	0	0	0	0
16	0	0	0	0
16,5	0	0	0	0
17	0	0	0	0
17,5	0	0	0	0
18	0	0	0	0
18,5	0	0	0	0
19	0	0	0	0
19,5	0	0	0	0
20	0	0	0	0
TOTAL	**78026,425**	**78026,425**	**0**	**78026,425**

Table 18. *ECOCADIZ-RECLUTAS 2021-10* 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 40**.

***ECOCADIZ-RECLUTAS 2021-10*. *Maurolicus muelleri*. ABUNDANCE (in numbers and million fish)**								
Size class	**POL01**	**POL02**	***n***			**Millions**		
			PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
1	0	0	0	0	0	0	0	0
1,5	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
2,5	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
3,5	19445714	16794850	19445714	16794850	36240564	19	17	36
4	144627500	124911698	144627500	124911698	269539198	145	125	270
4,5	446036073	385231876	446036073	385231876	831267949	446	385	831
5	321461965	277639867	321461965	277639867	599101832	321	278	599
5,5	91759465	79250699	91759465	79250699	171010164	92	79	171
6	0	0	0	0	0	0	0	0
6,5	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
TOTAL *n*	1023330717	883828990	1023330717	883828990	1907159707	**1023**	**884**	**1907**
Millions	**1023**	**884**						

***ECOCADIZ-RECLUTAS 2021-10*. *Maurolicus muelleri*. BIOMASS (t)**					
Size class	**POL01**	**POL02**	**PORTUGAL**	**SPAIN**	**TOTAL**
1	0	0	0	0	0
1,5	0	0	0	0	0
2	0	0	0	0	0
2,5	0	0	0	0	0
3	0	0	0	0	0
3,5	11,604	10,022	11,604	10,022	21,626
4	112,055	96,780	112,055	96,780	208,835
4,5	435,837	376,423	435,837	376,423	812,260
5	387,045	334,283	387,045	334,283	721,328
5,5	133,569	115,361	133,569	115,361	248,930
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
TOTAL	**1080,110**	**932,869**	**1080,110**	**932,869**	**2012,979**

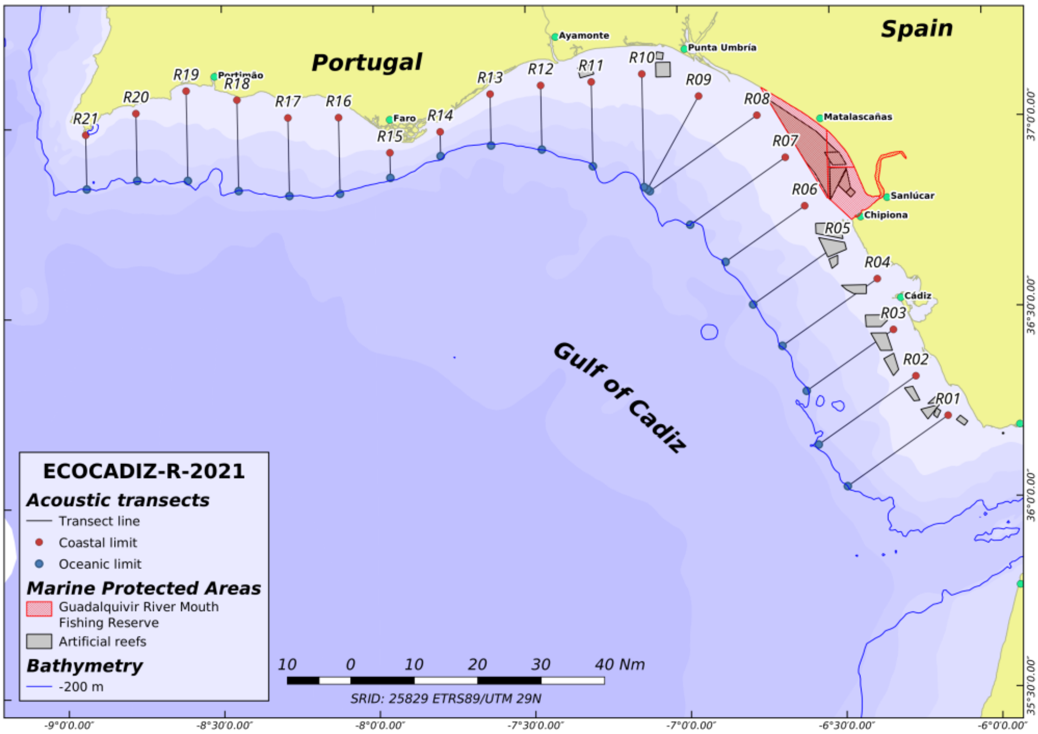


Figure 1. *ECOCADIZ-RECLUTAS 2021-10* survey. Location of the acoustic transects sampled during the survey. The different protected areas inside the Guadalquivir river mouth Fishing Reserve and artificial reef polygons are also shown.

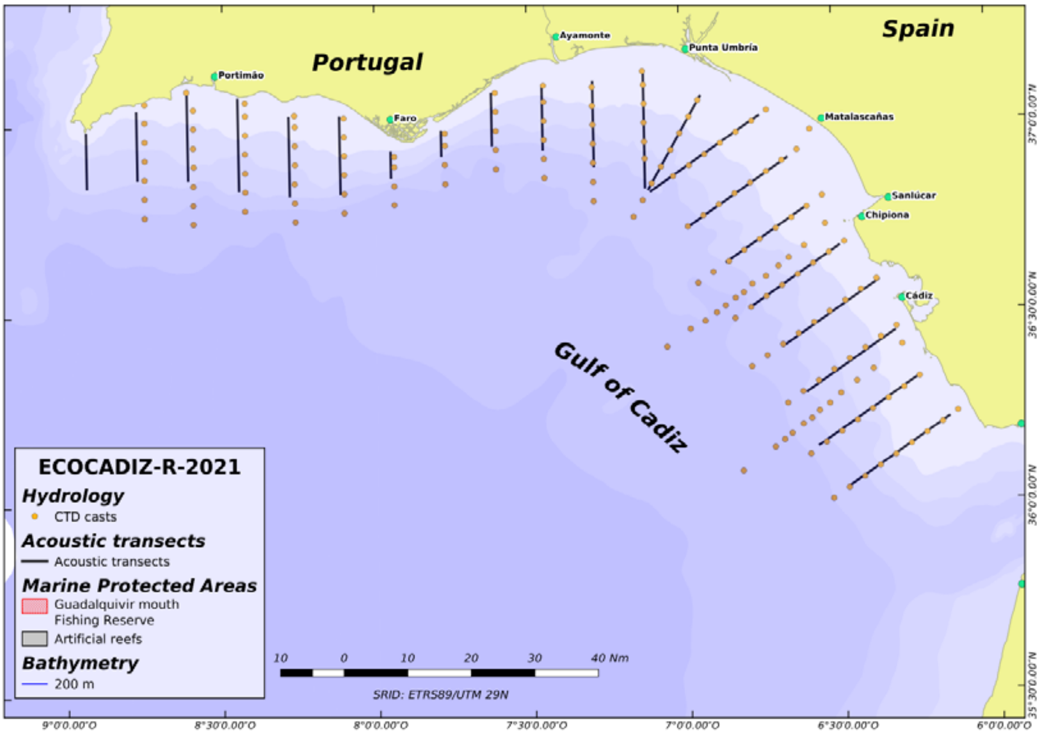


Figure 2. *ECOCADIZ-RECLUTAS 2021-10* survey. Location of CTD stations.

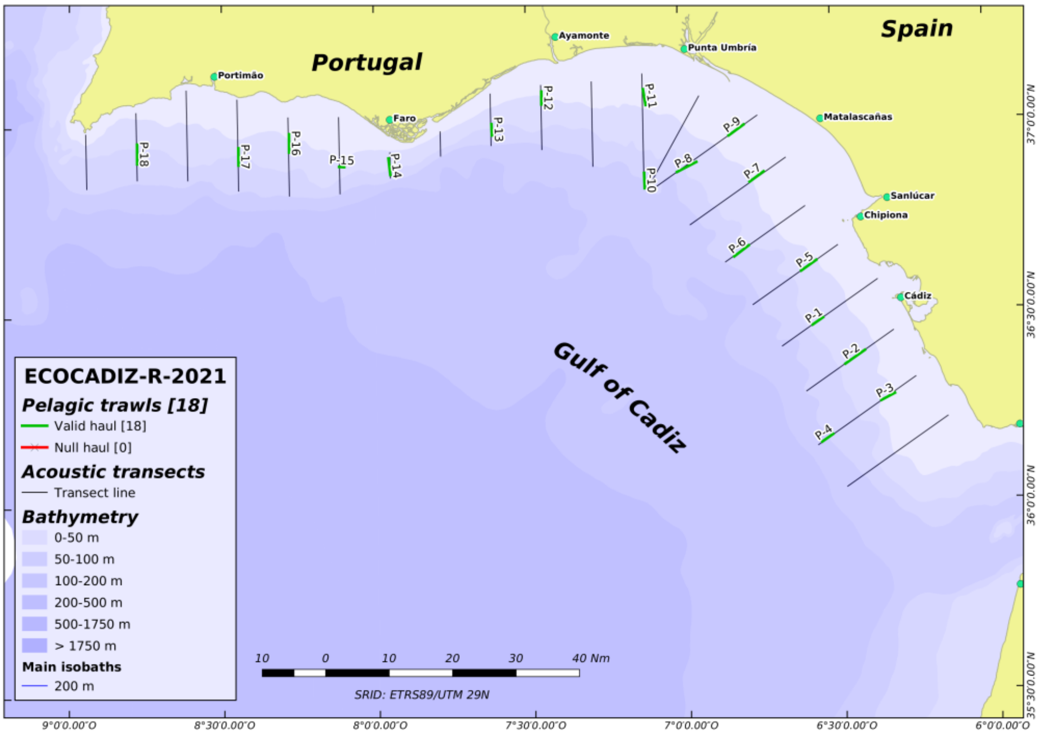


Figure 3. *ECOCADIZ-RECLUTAS 2021-10* survey. Location of ground-truthing fishing hauls.

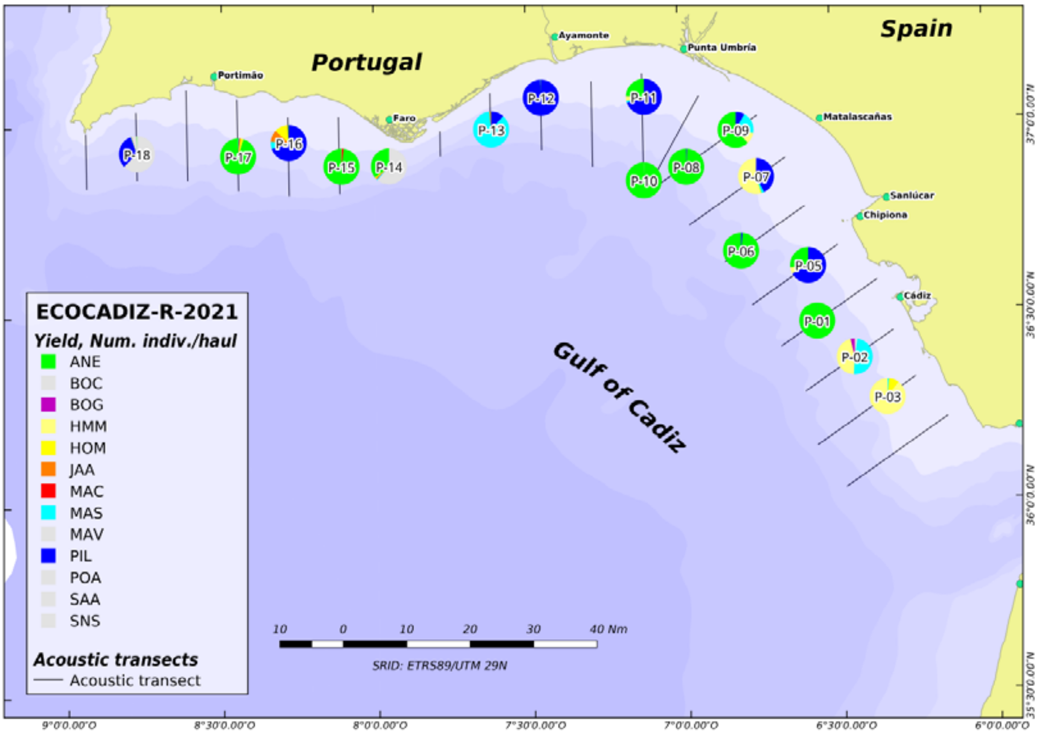


Figure 4. *ECOCADIZ-RECLUTAS 2021-10* survey. Species composition (percentages in number) in valid fishing hauls.

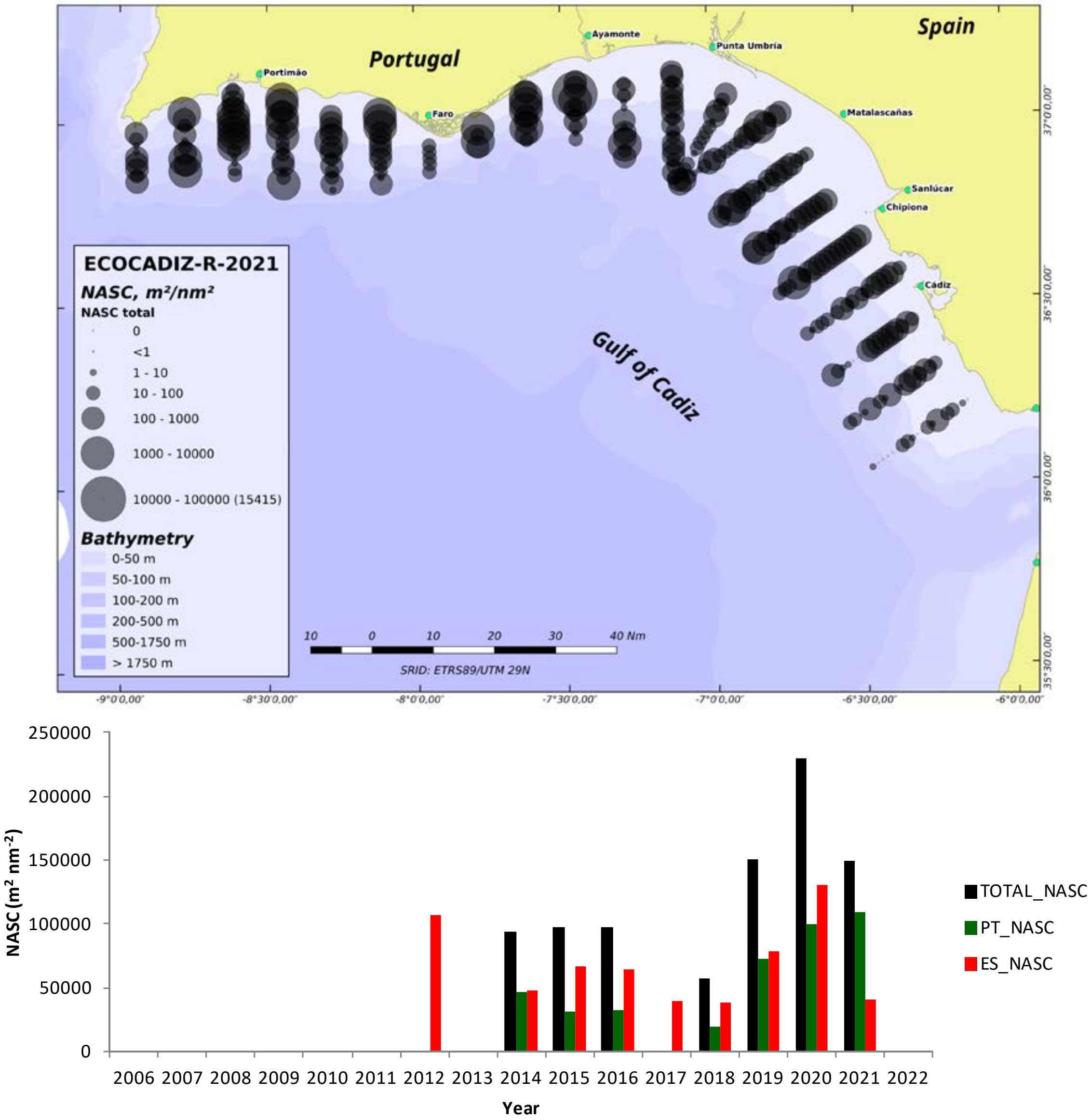


Figure 5. *ECOCADIZ-RECLUTAS 2021-10* survey. Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the pelagic fish species assemblage.

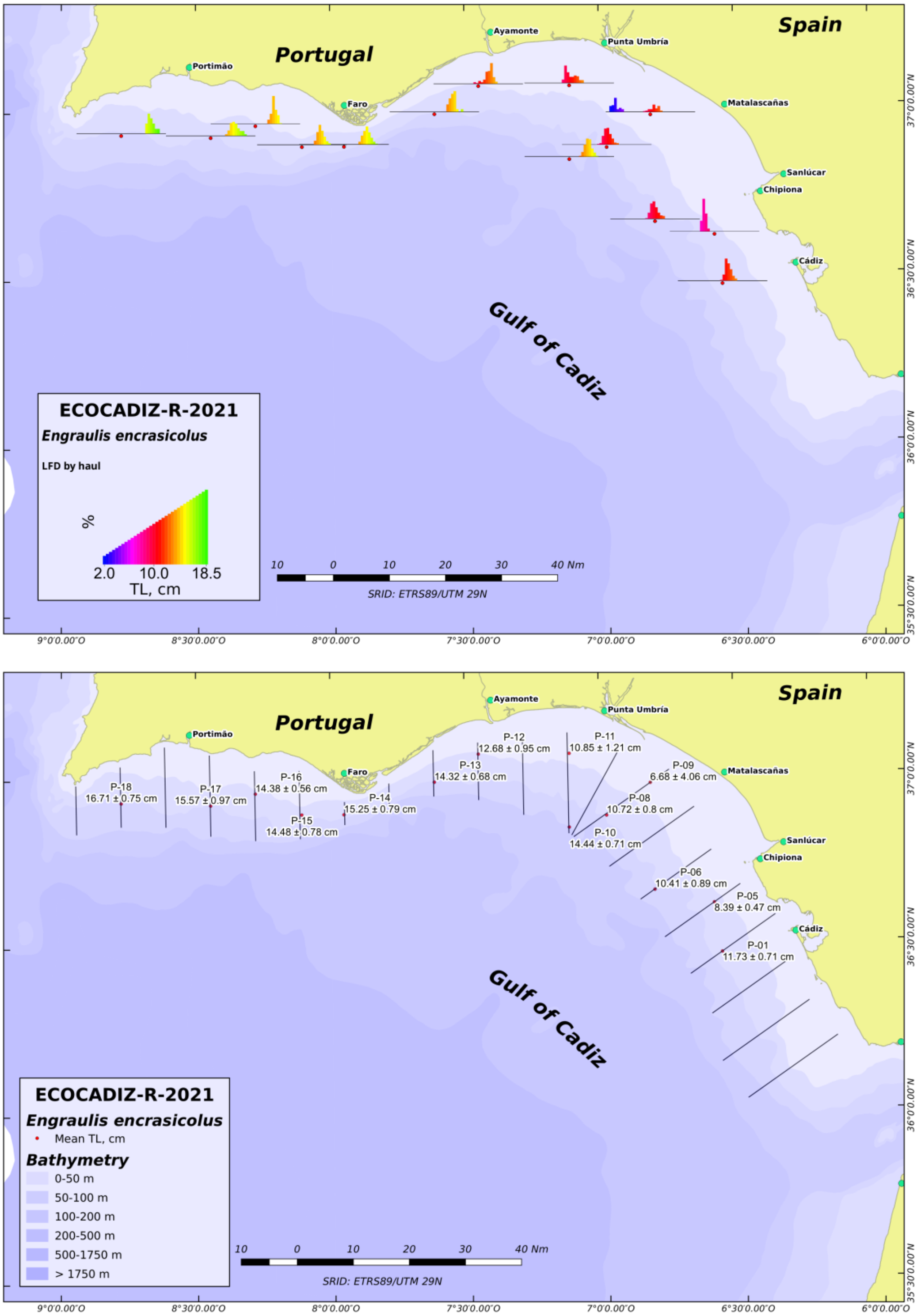


Figure 6. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

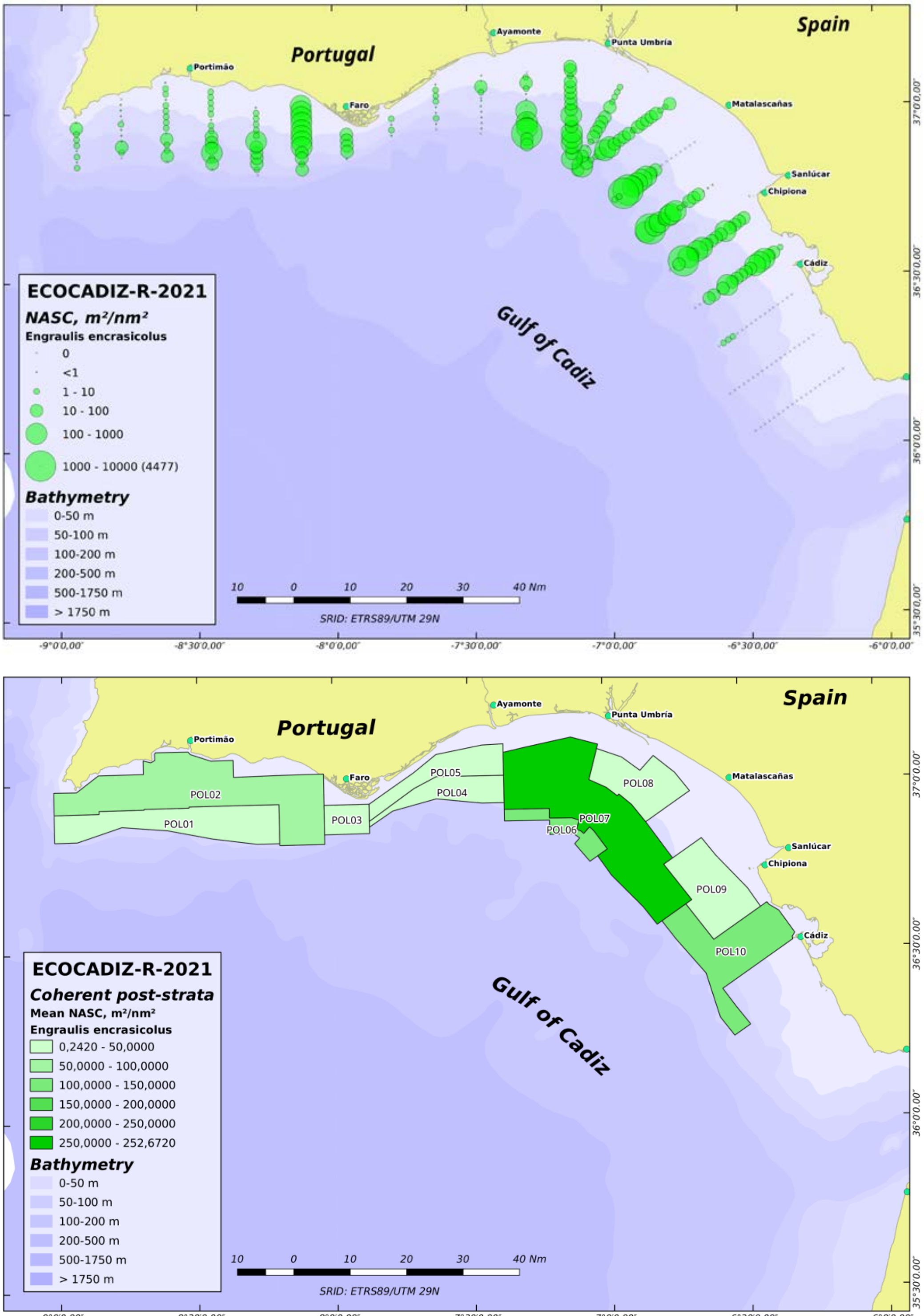


Figure 7. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

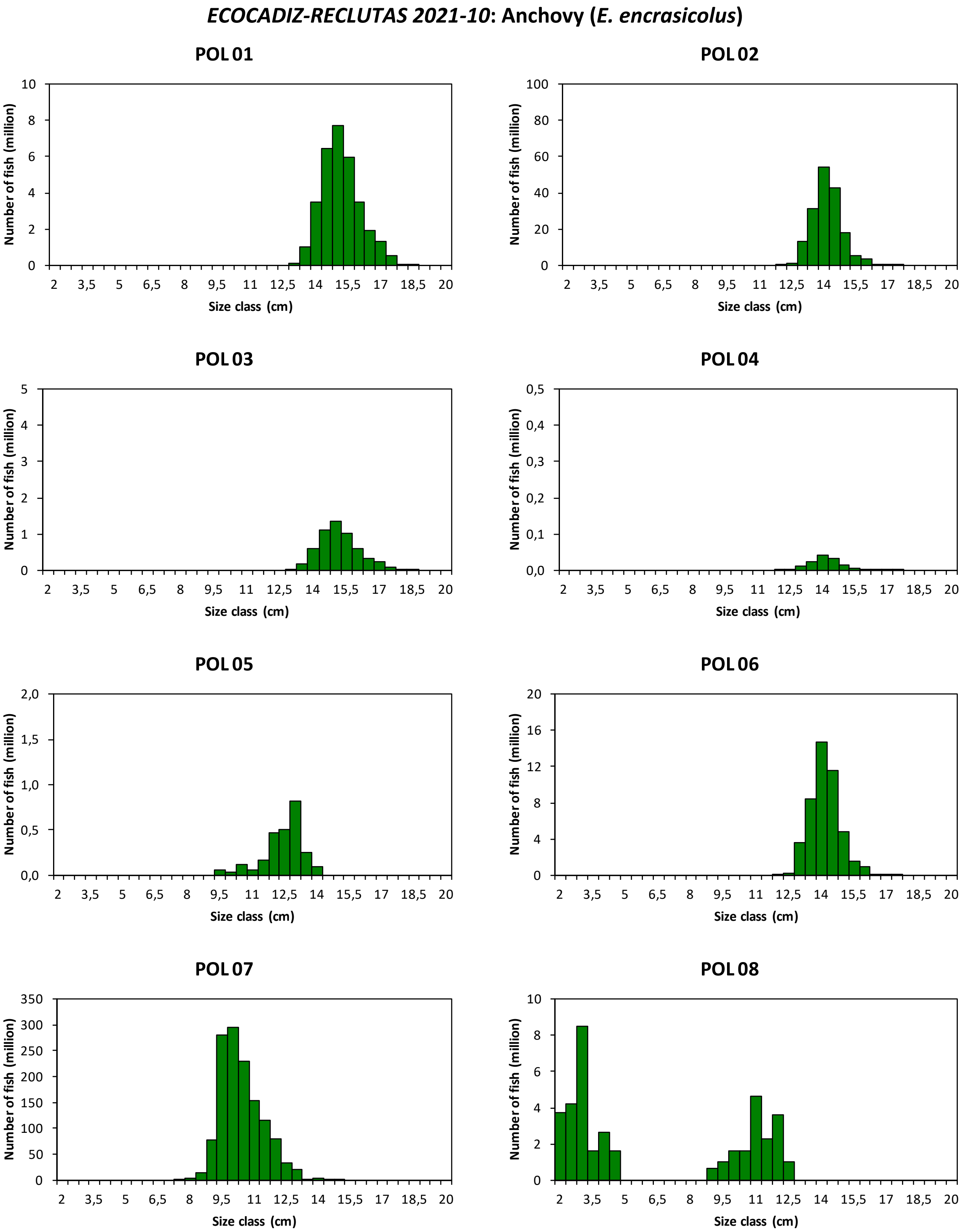


Figure 8. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 7**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

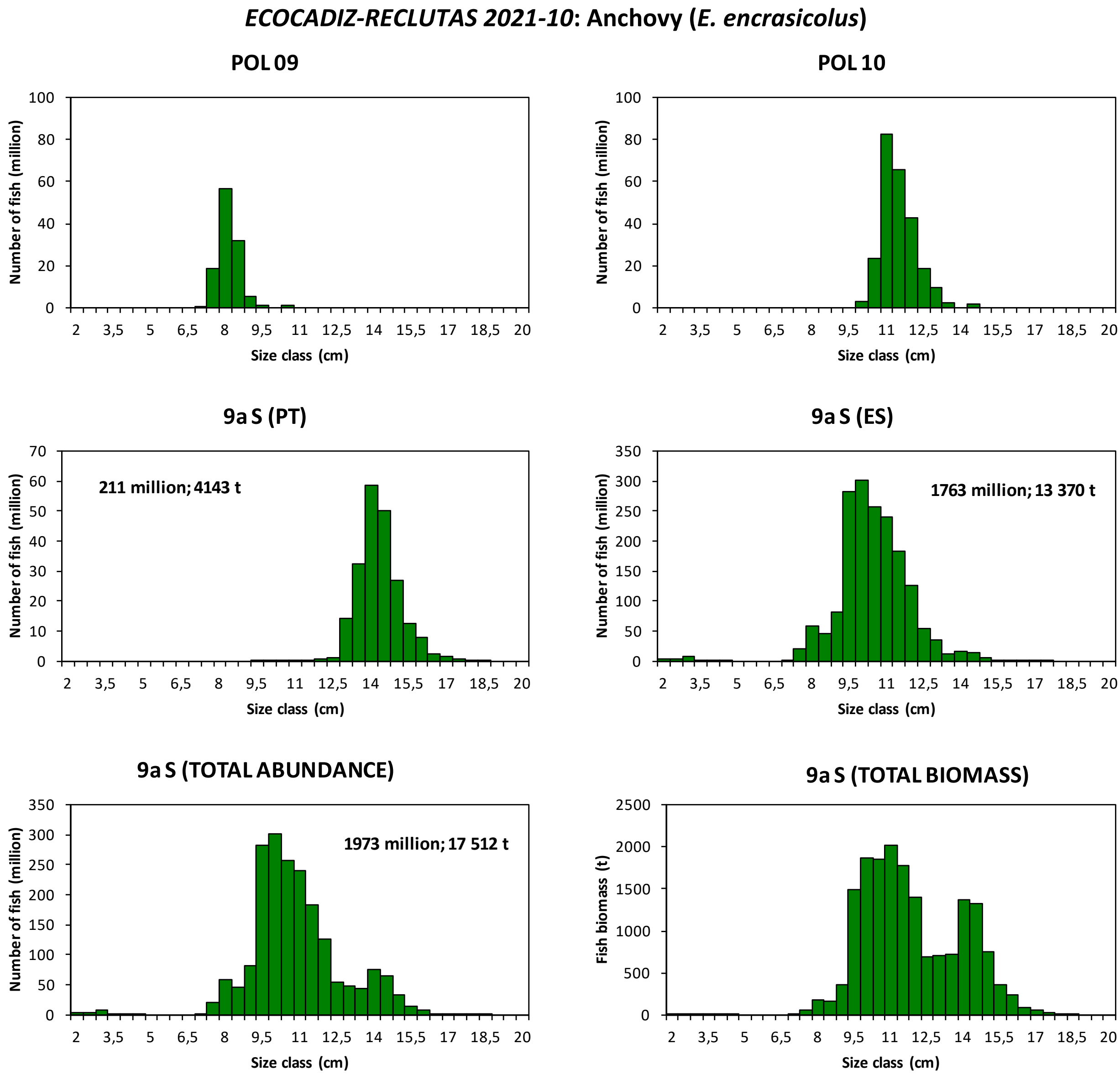


Figure 8. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Cont'd.

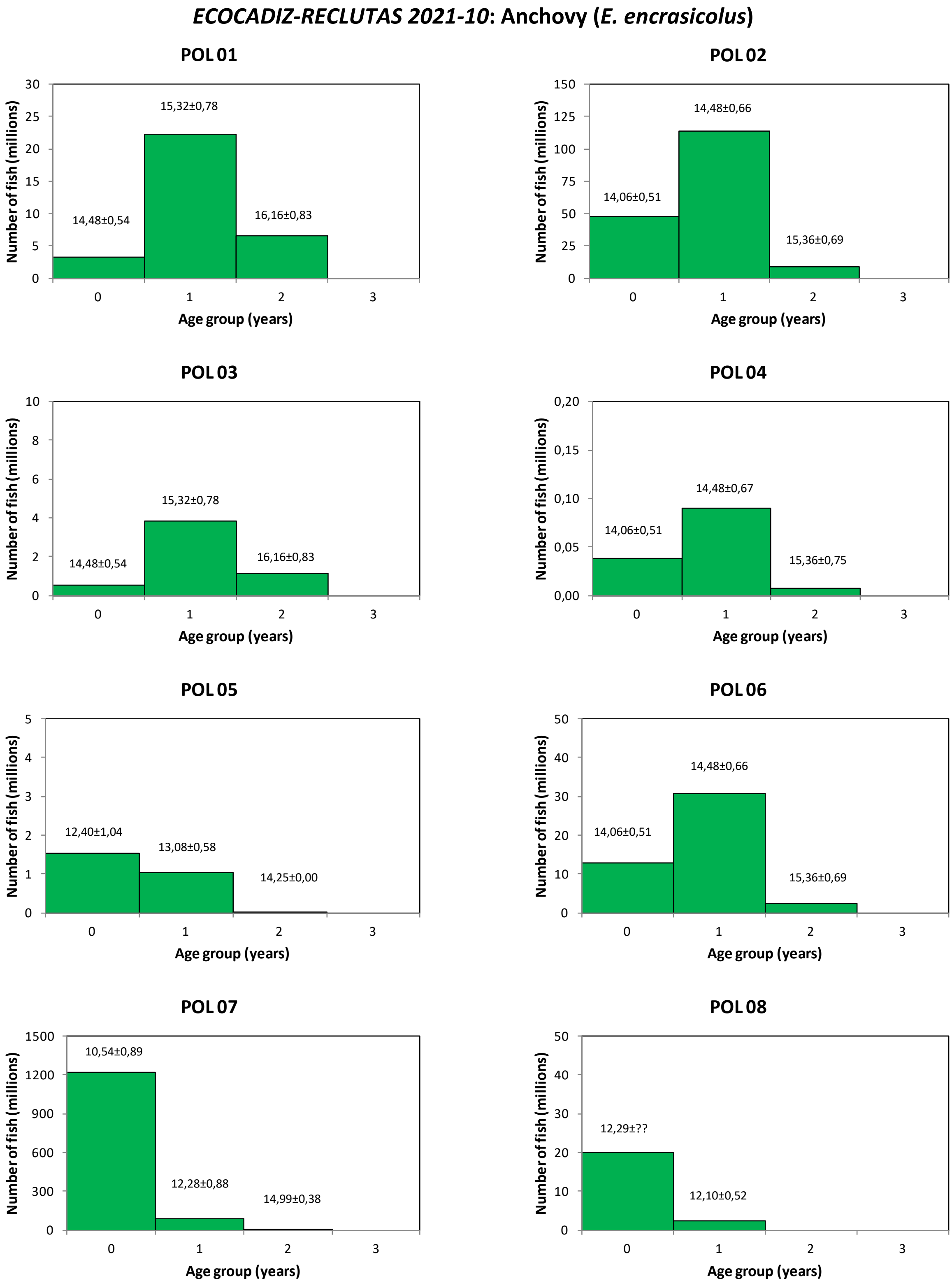


Figure 9. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 7**) and total sampled area. Post-strata ordered in the W-E direction. Mean (±SD) 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.

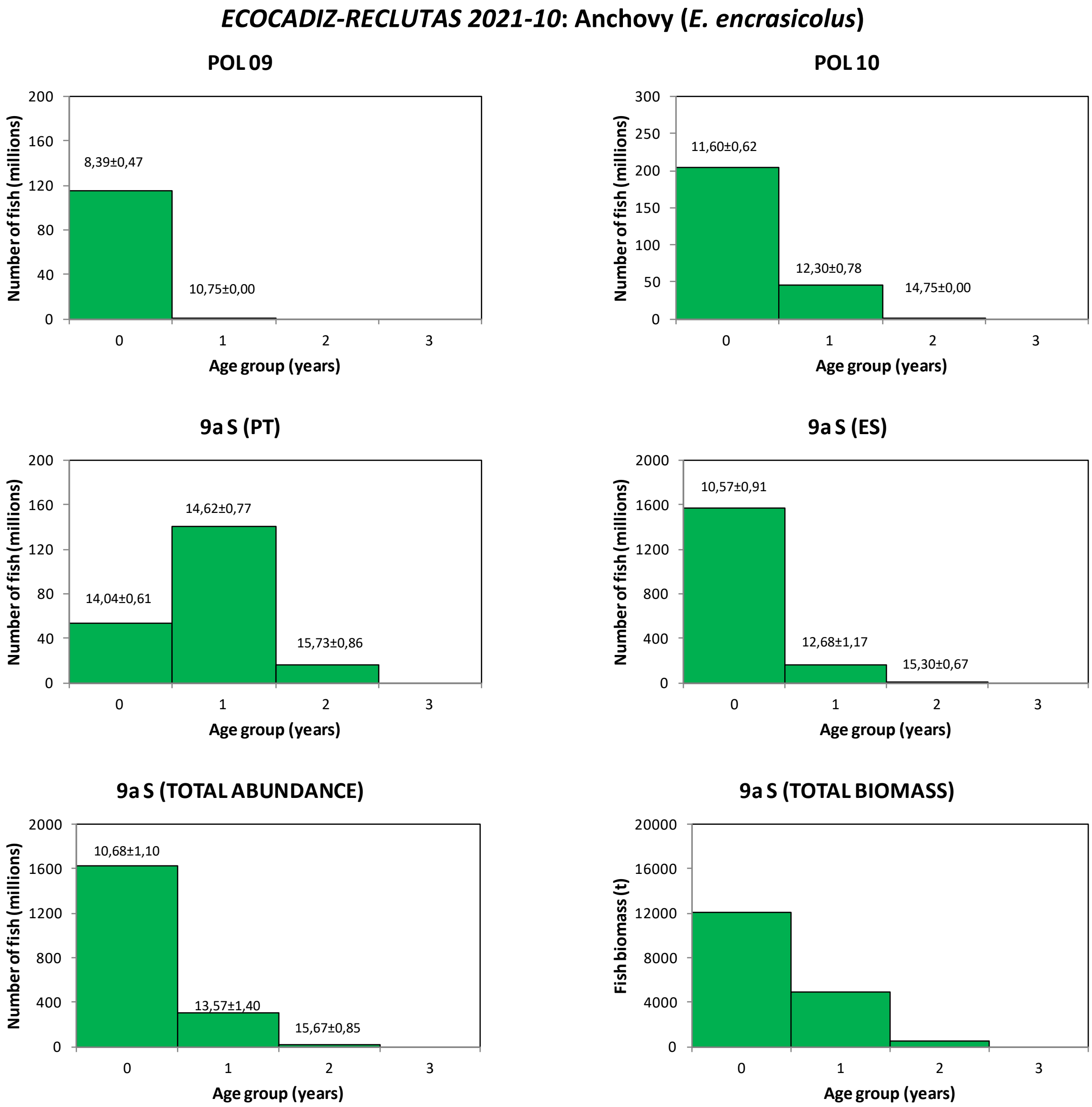


Figure 9. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Cont'd.

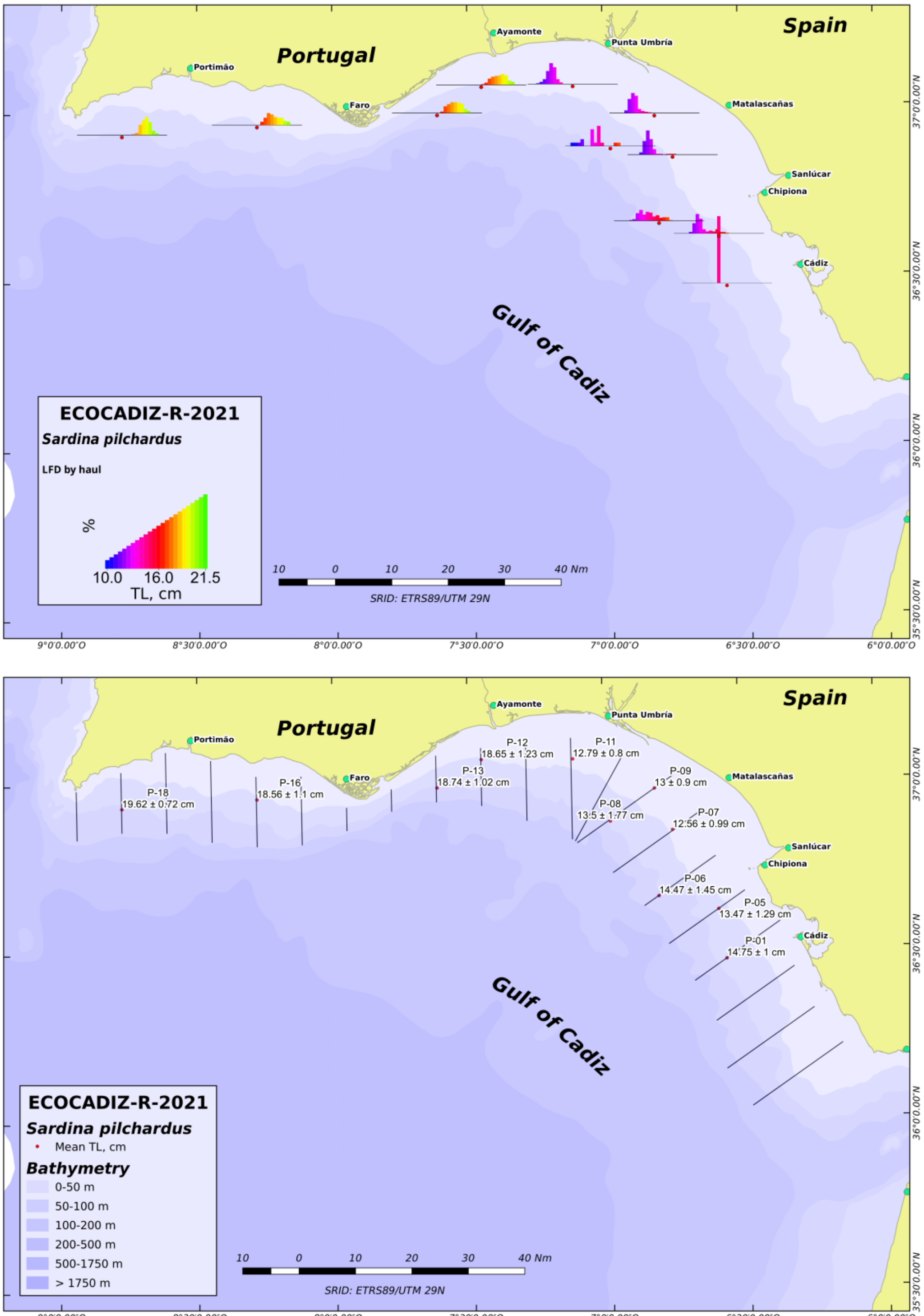
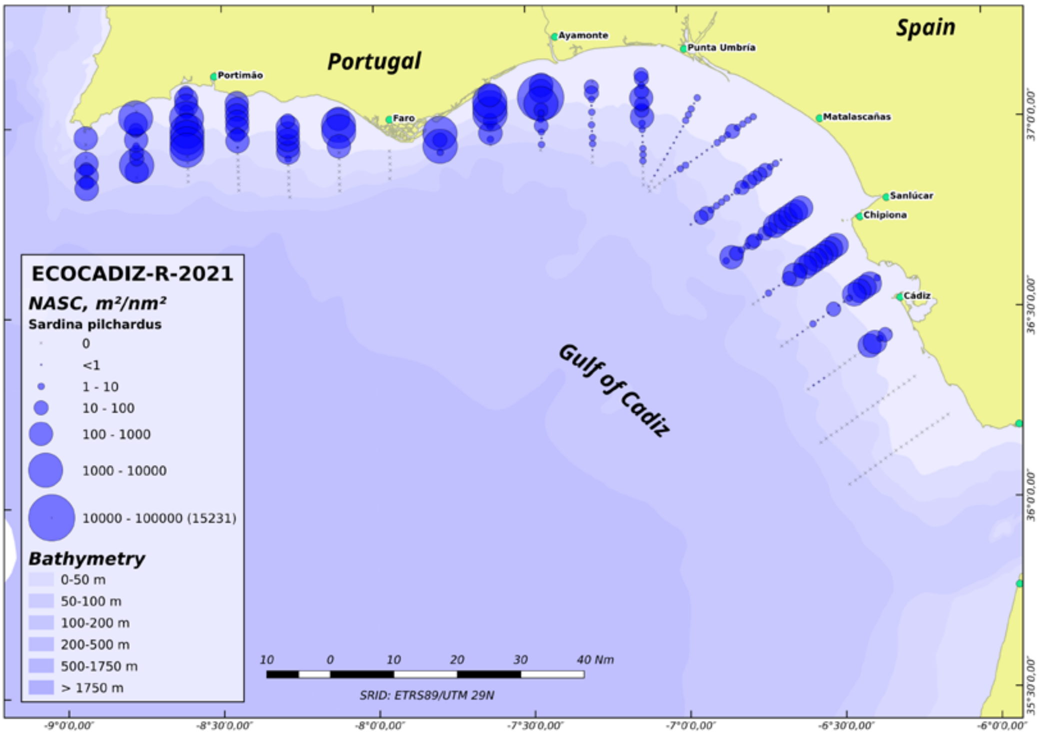


Figure 10. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.



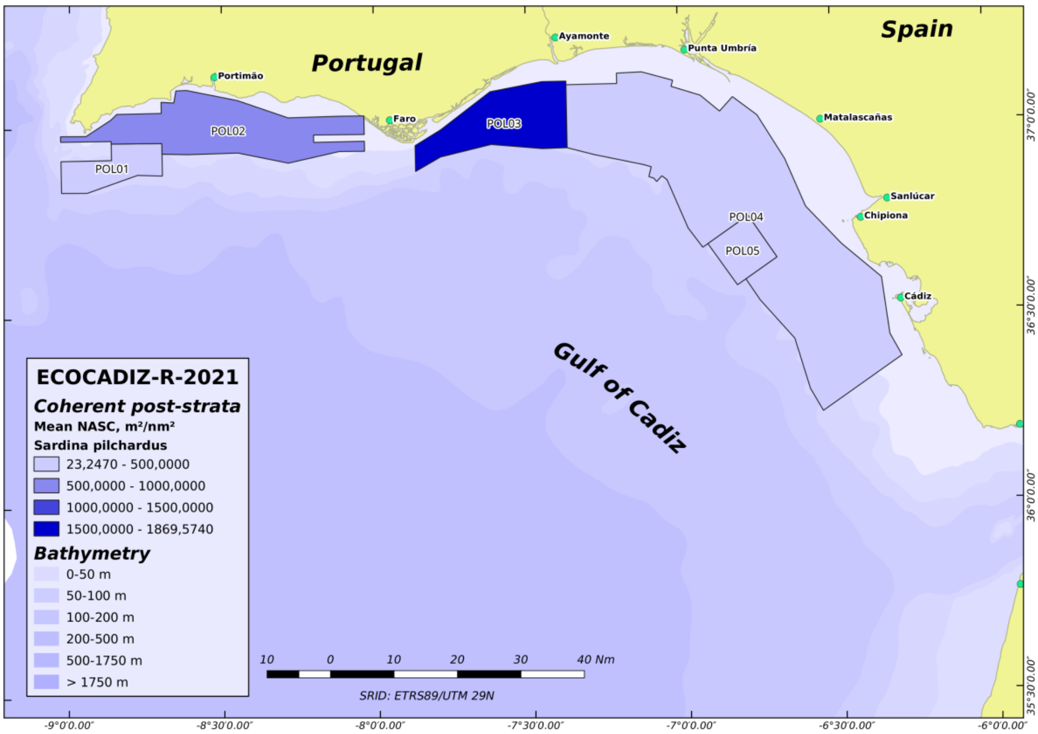


Figure 11. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

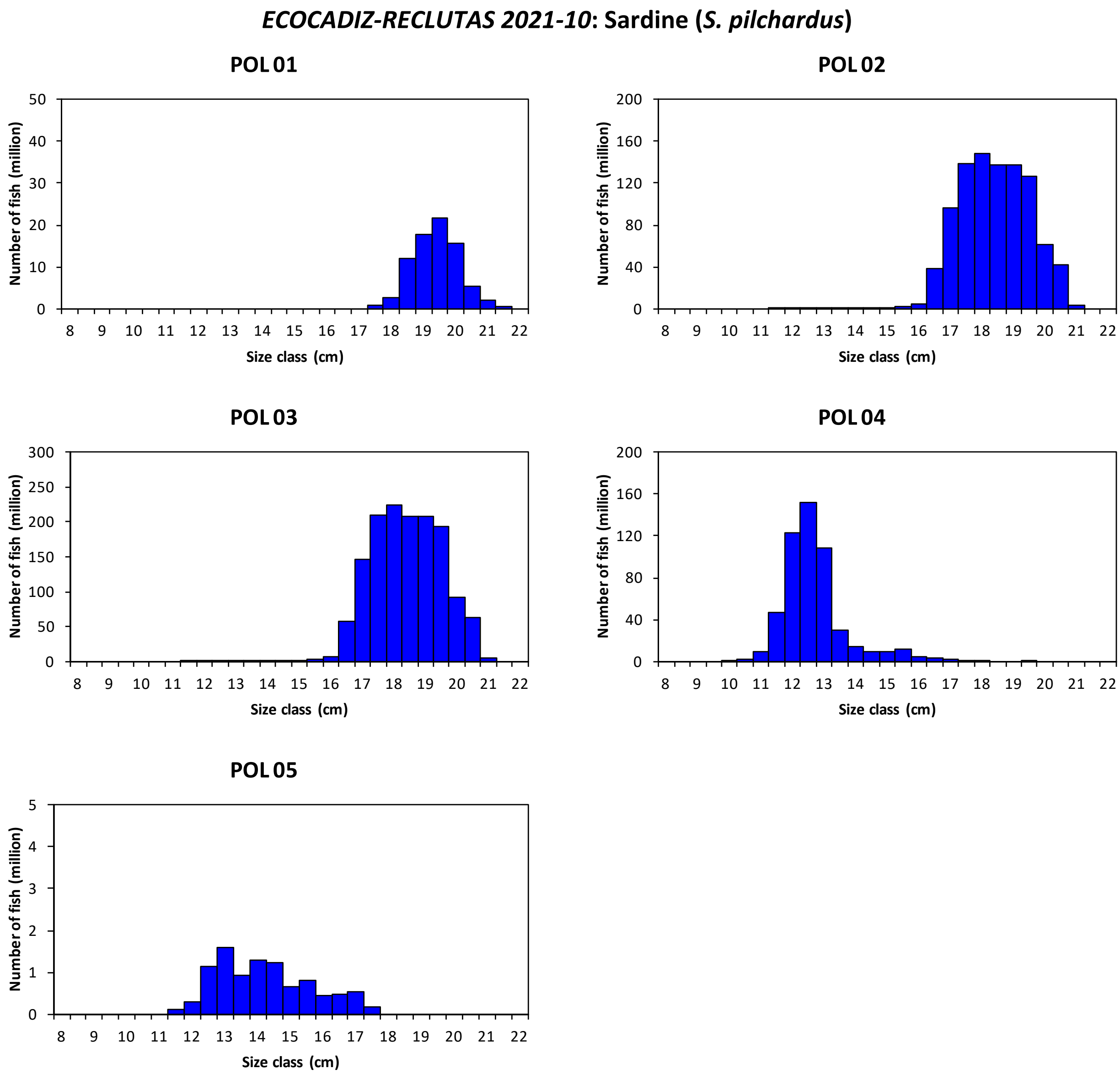


Figure 12. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 11**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

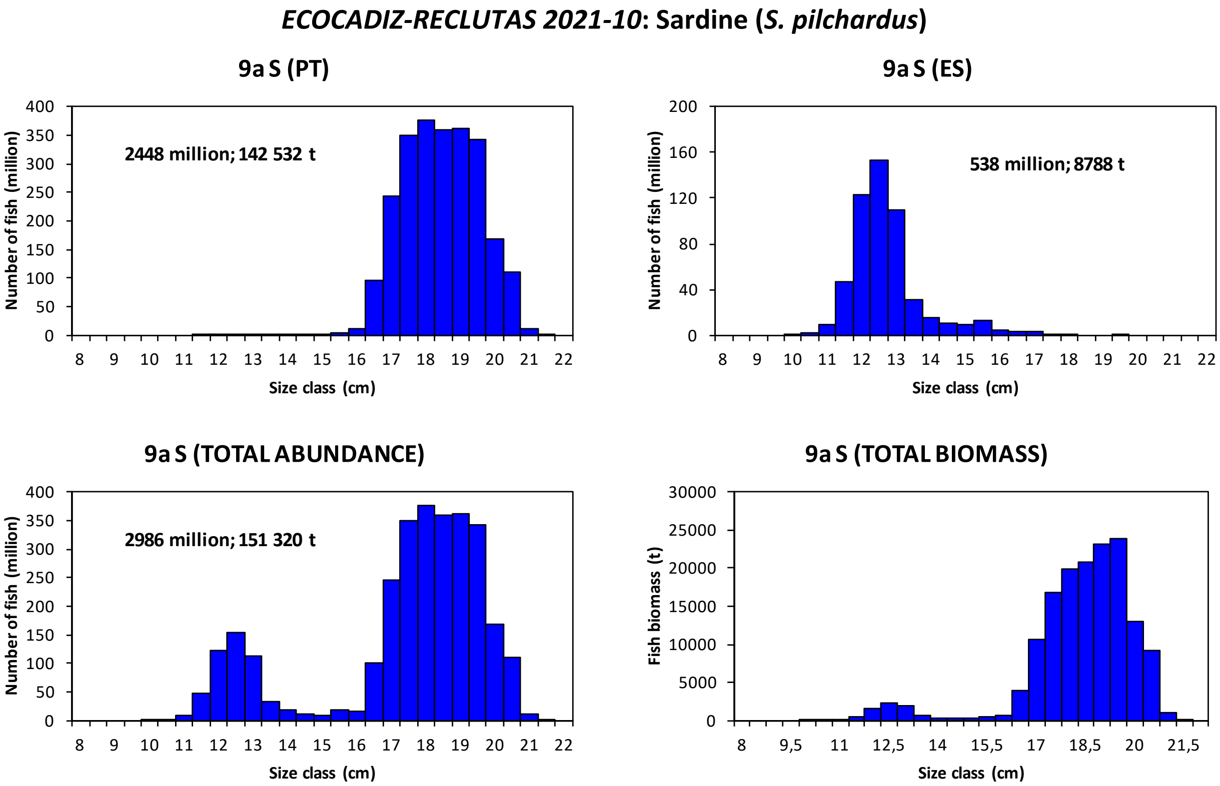


Figure 12. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Cont'd.

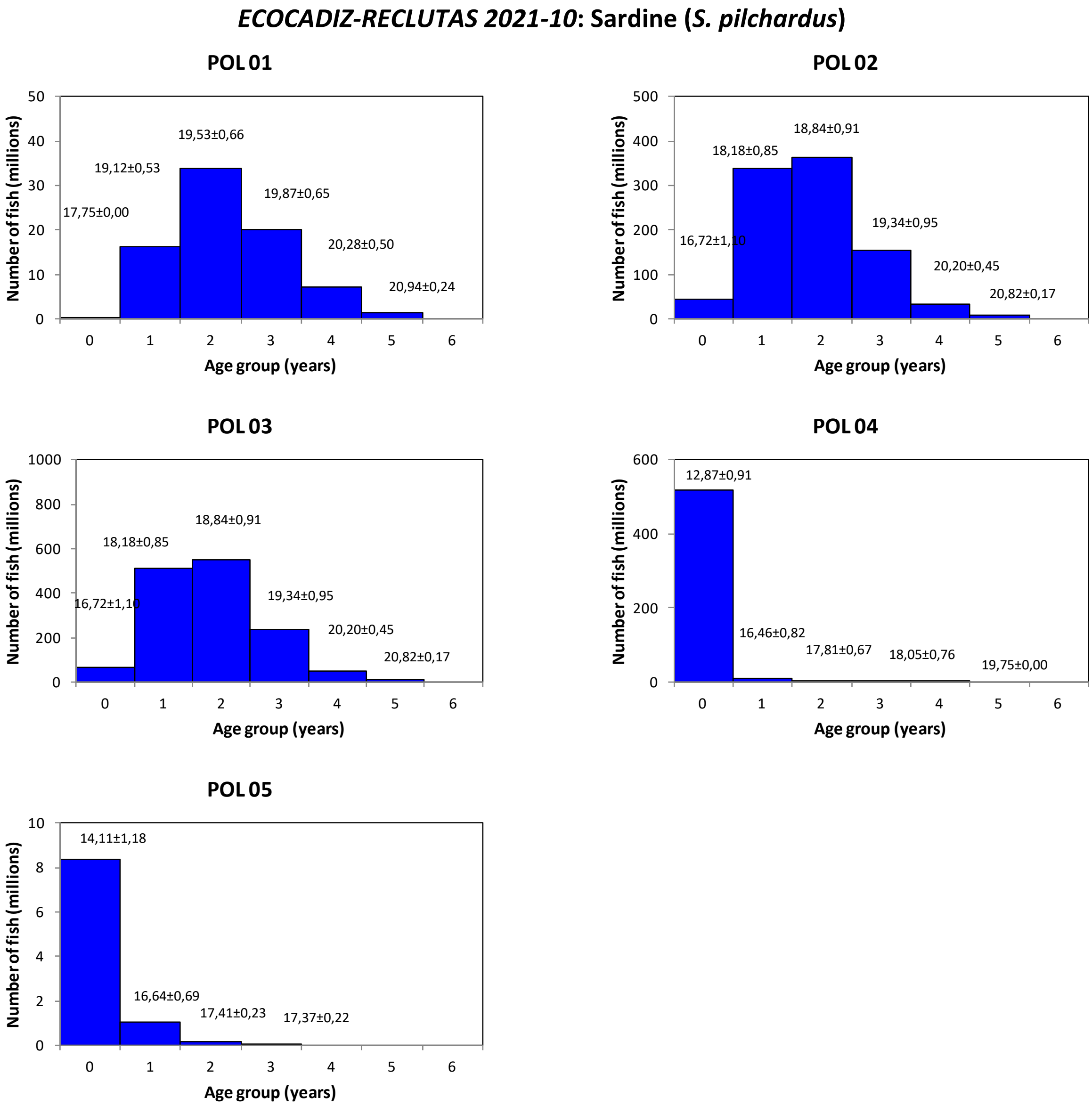


Figure 13. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 11**) and total sampled area. Post-strata ordered in the W-E direction. Mean (±SD) sizes 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.

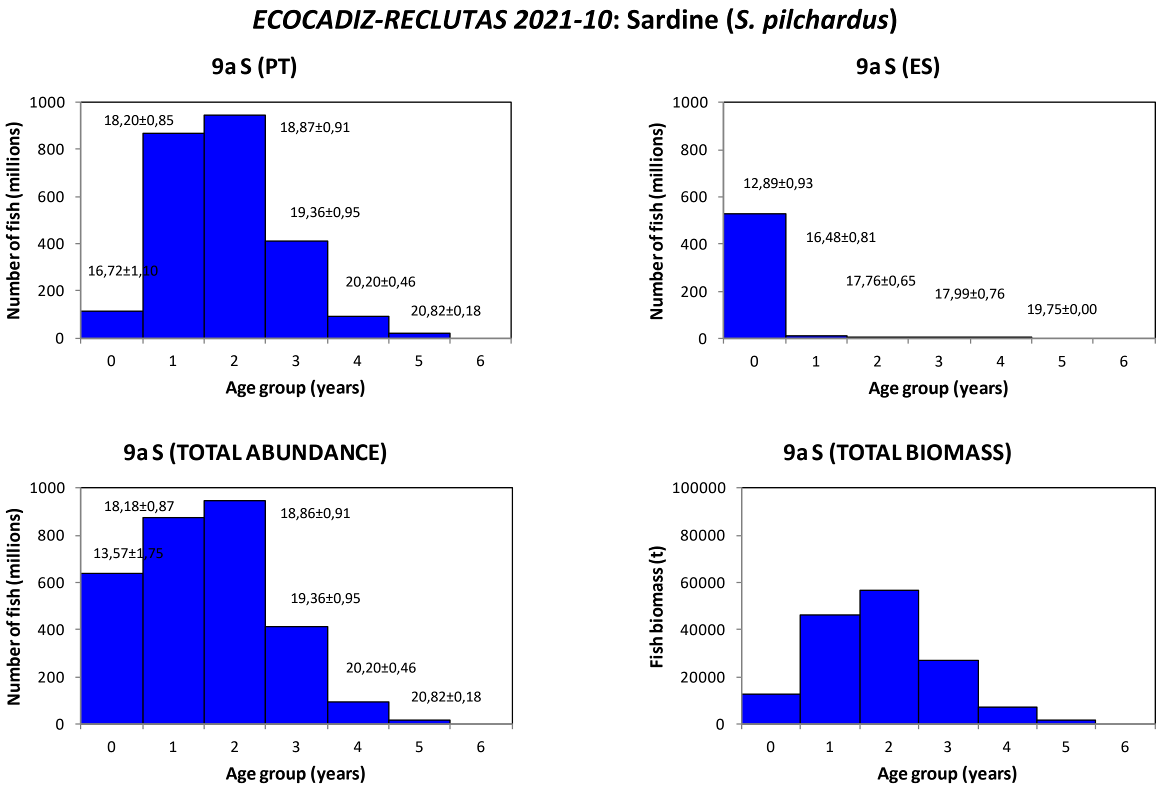


Figure 13. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Cont'd.

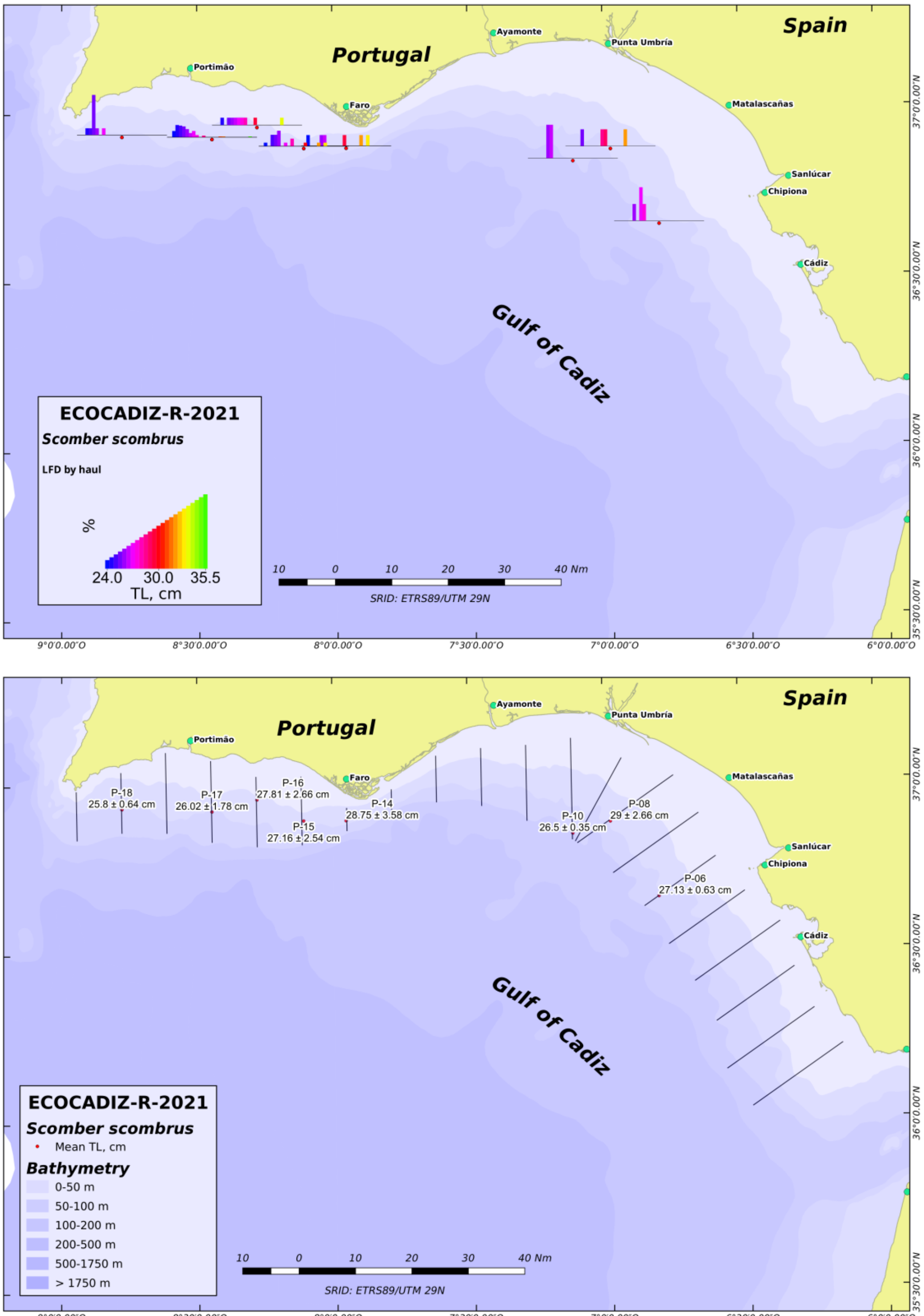


Figure 14. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

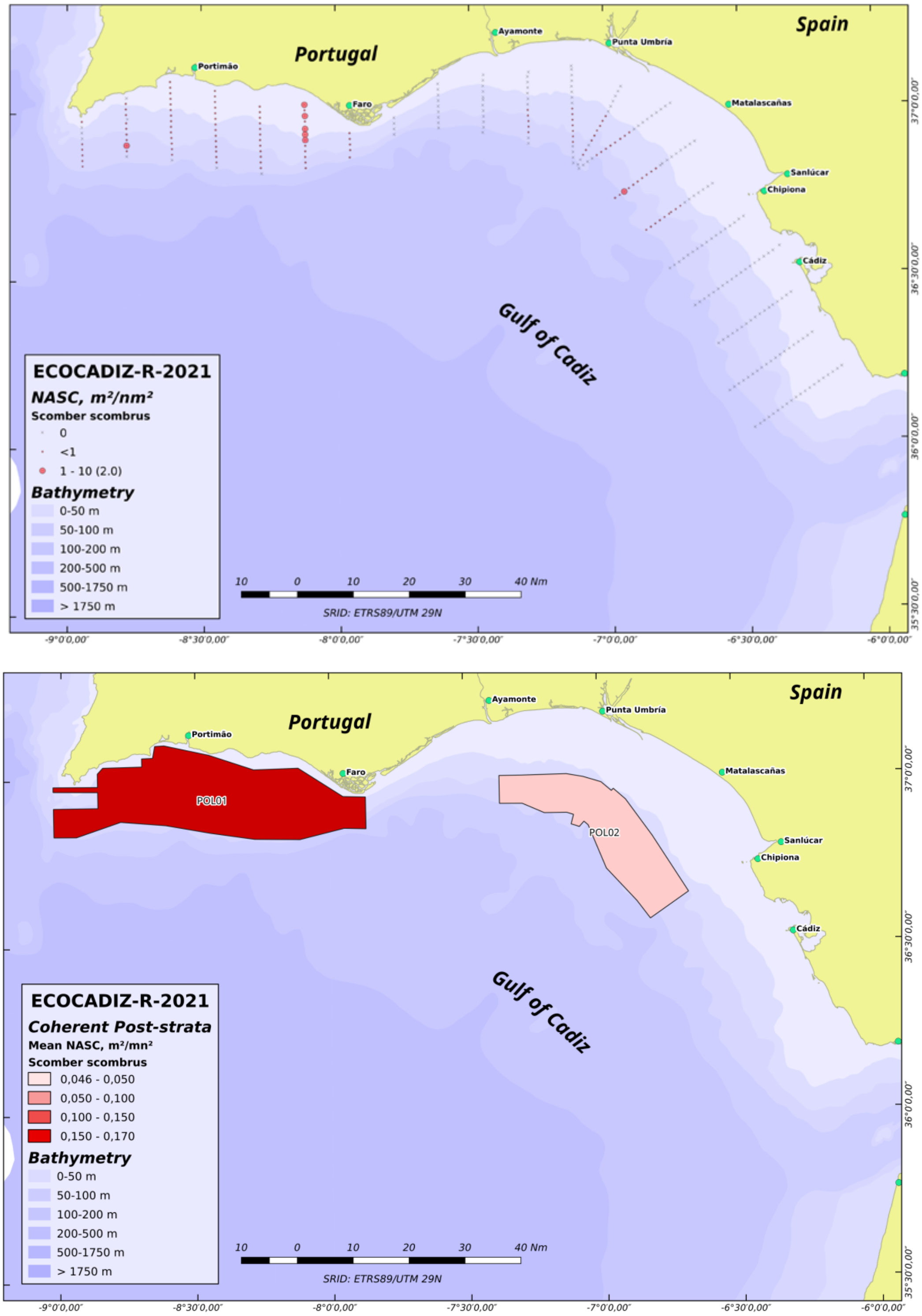


Figure 15. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

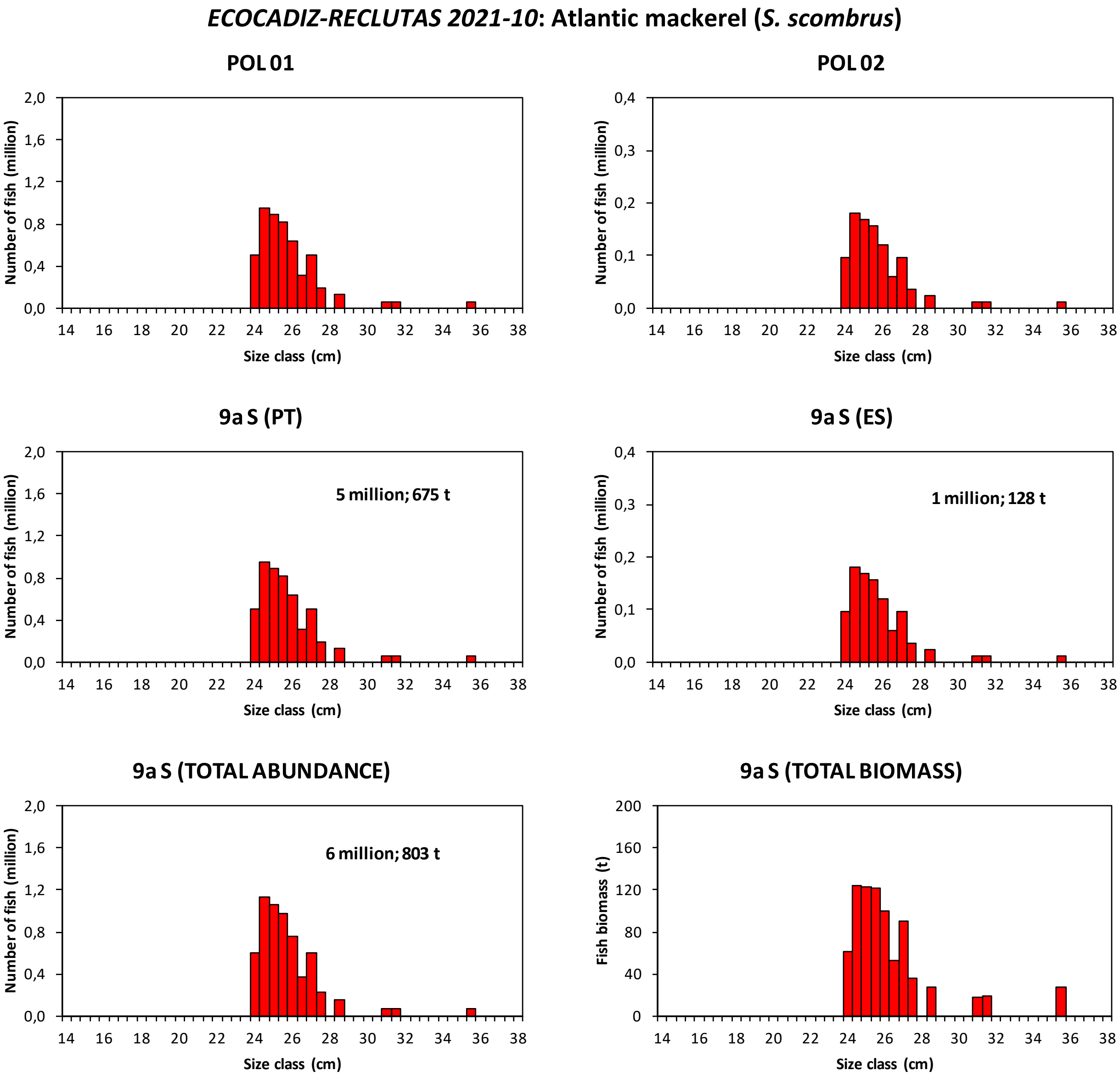


Figure 16. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 15**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

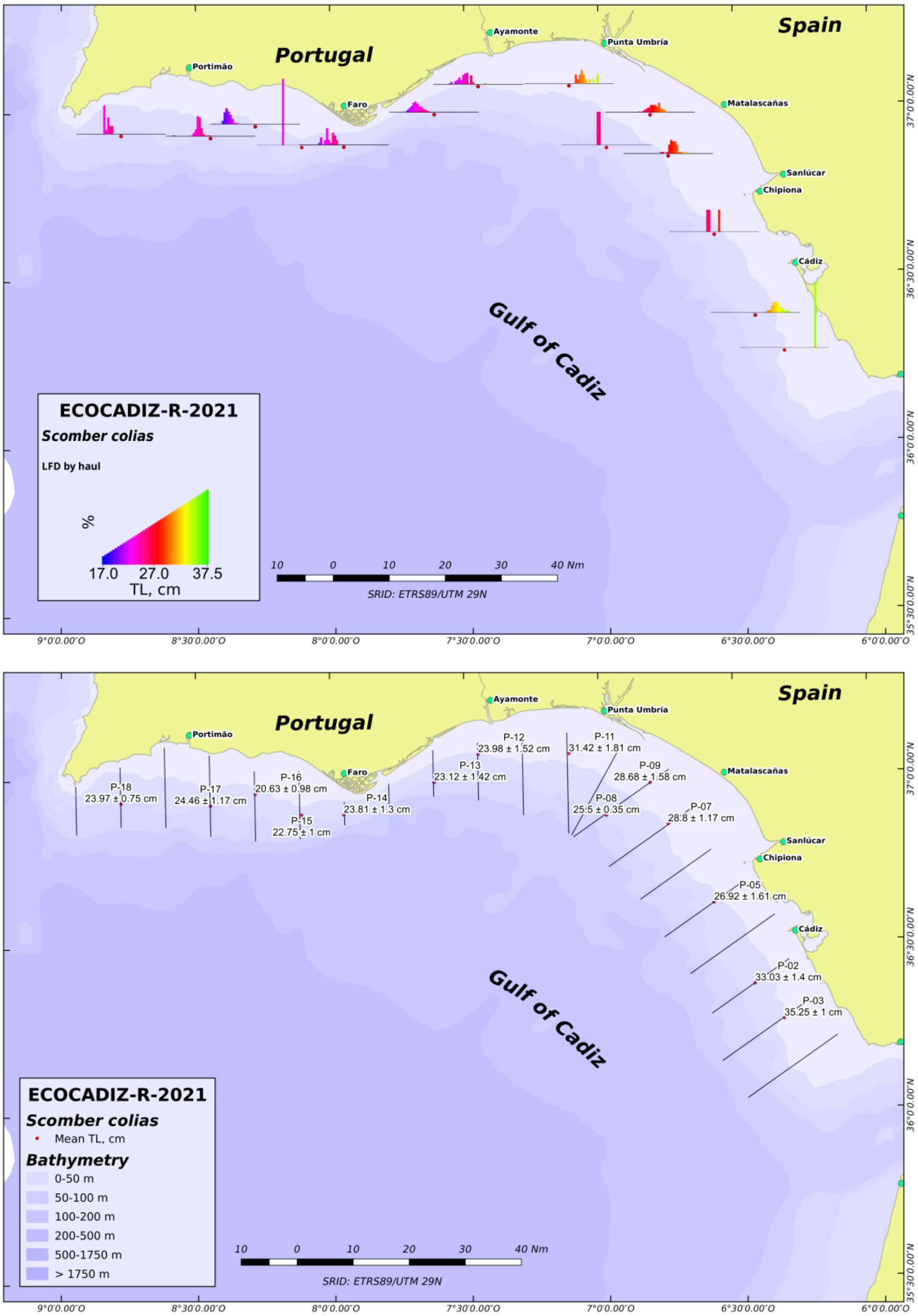


Figure 17. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

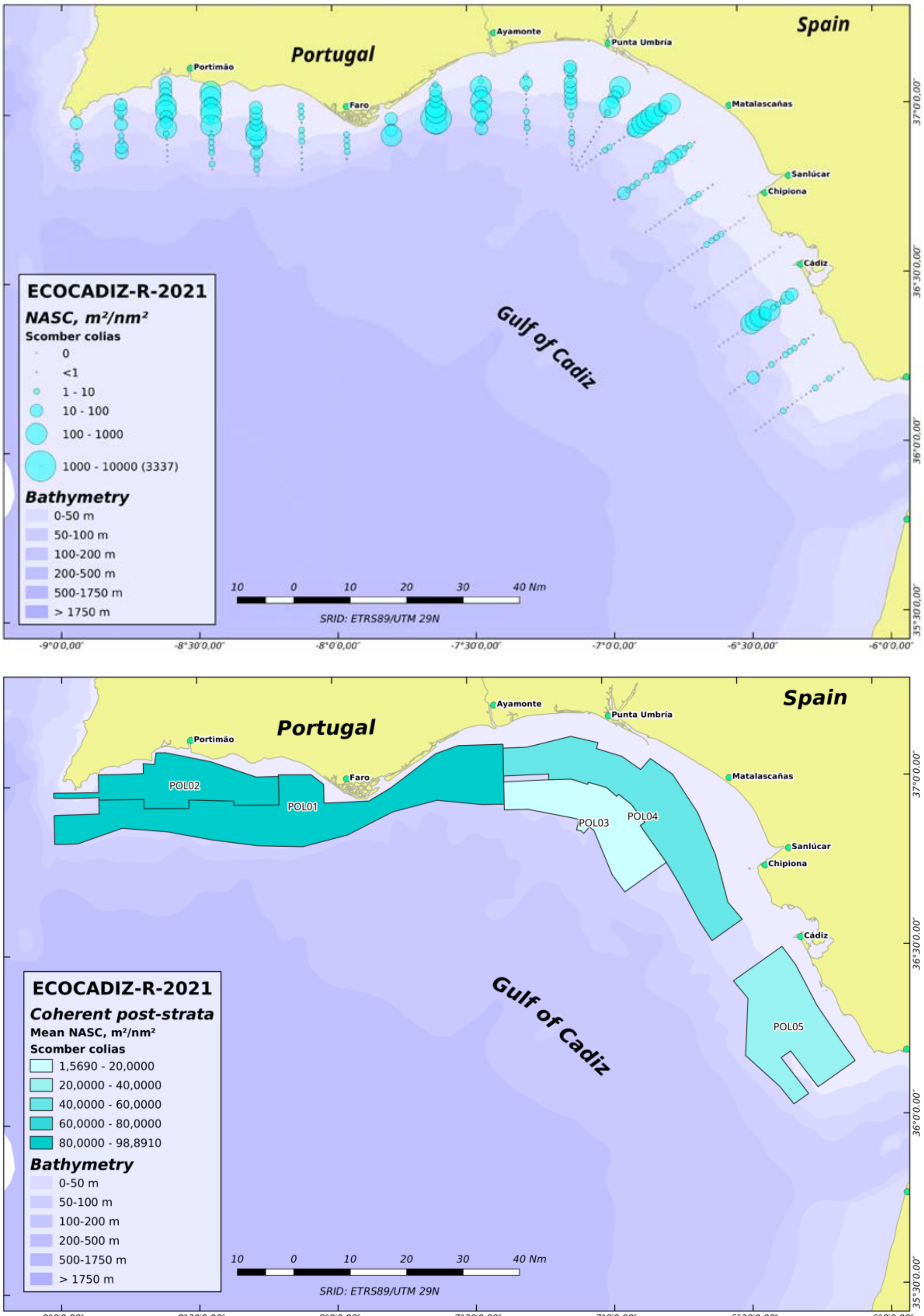


Figure 18. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

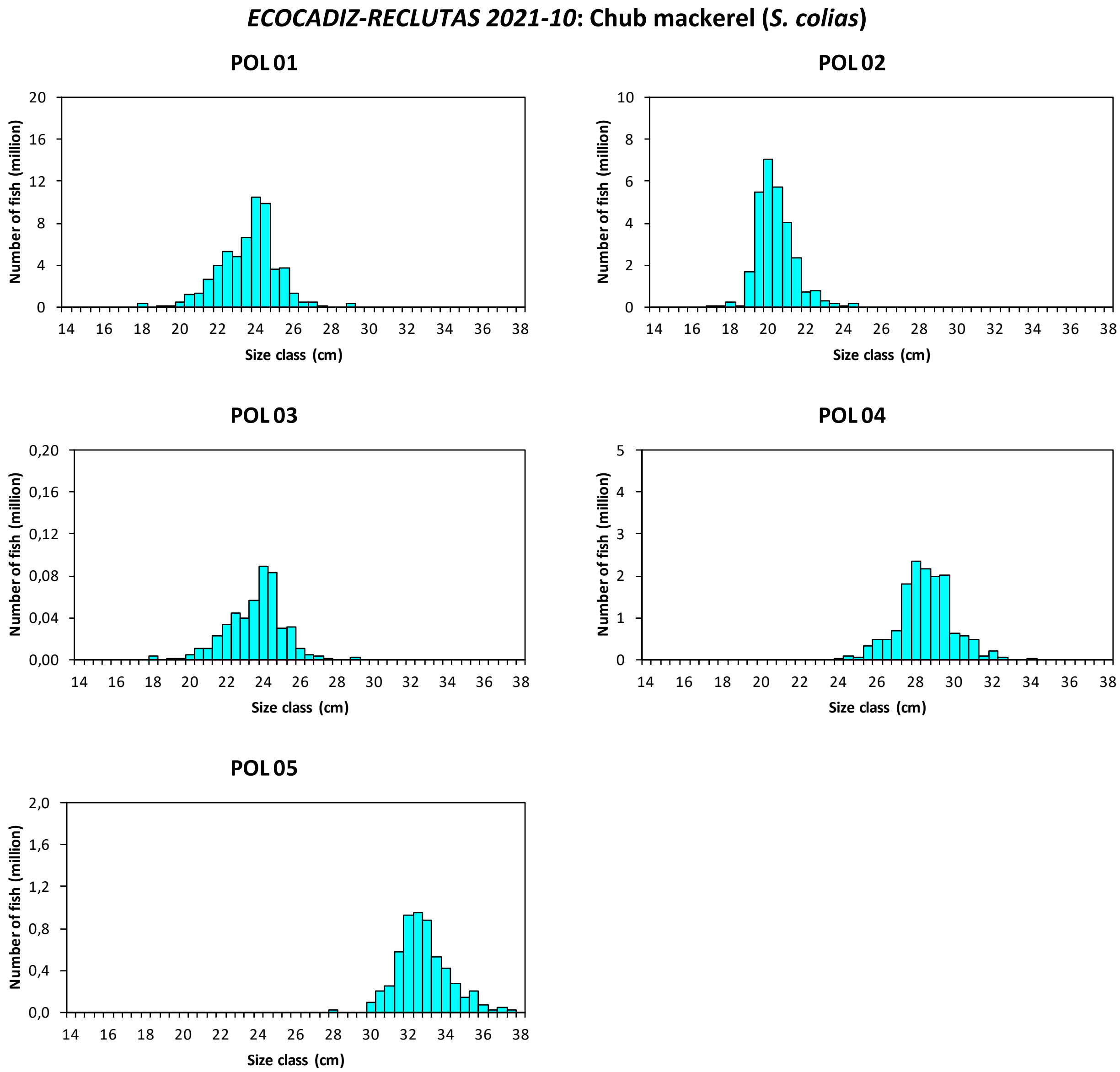


Figure 19. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 18**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

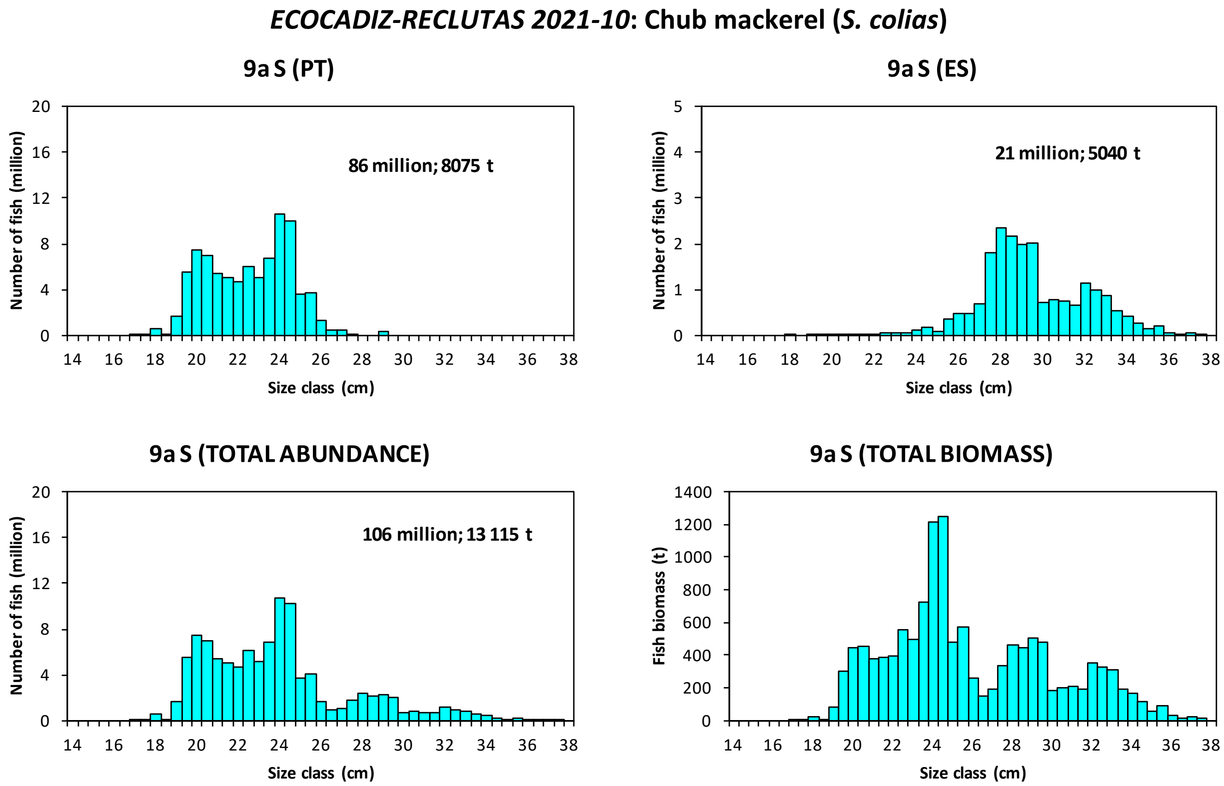


Figure 19. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Cont'd.

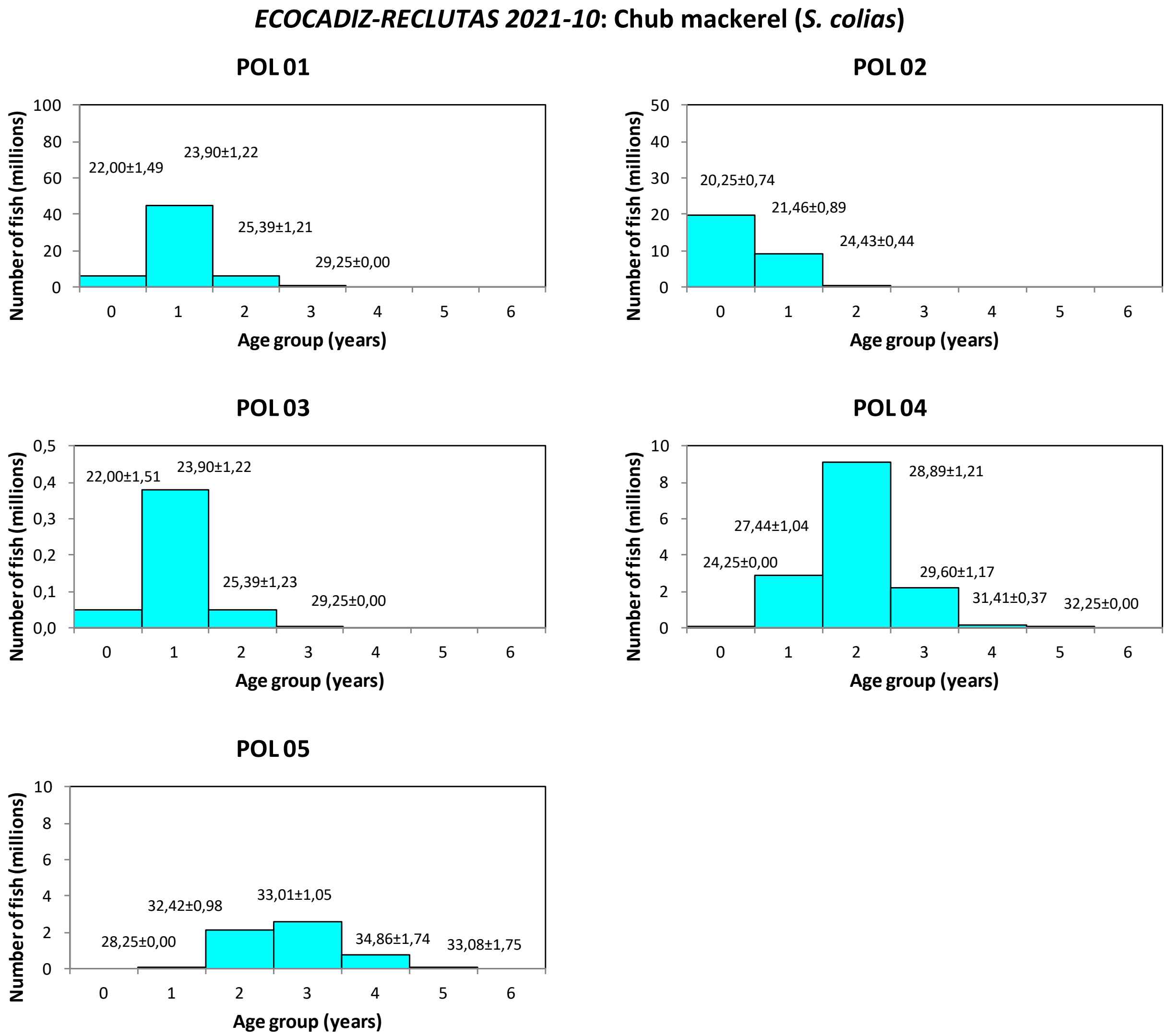


Figure 20. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 18**) and total sampled area. Post-strata ordered in the W-E direction. Mean (±SD) 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.

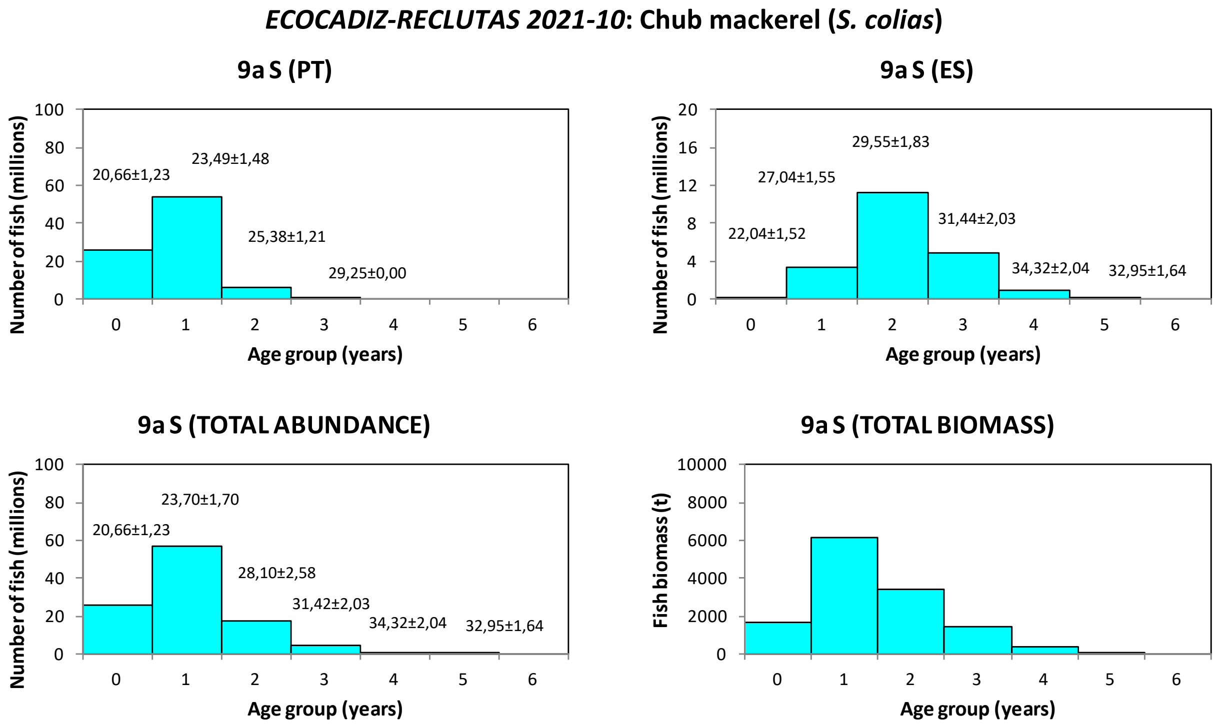


Figure 20. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Cont'd.

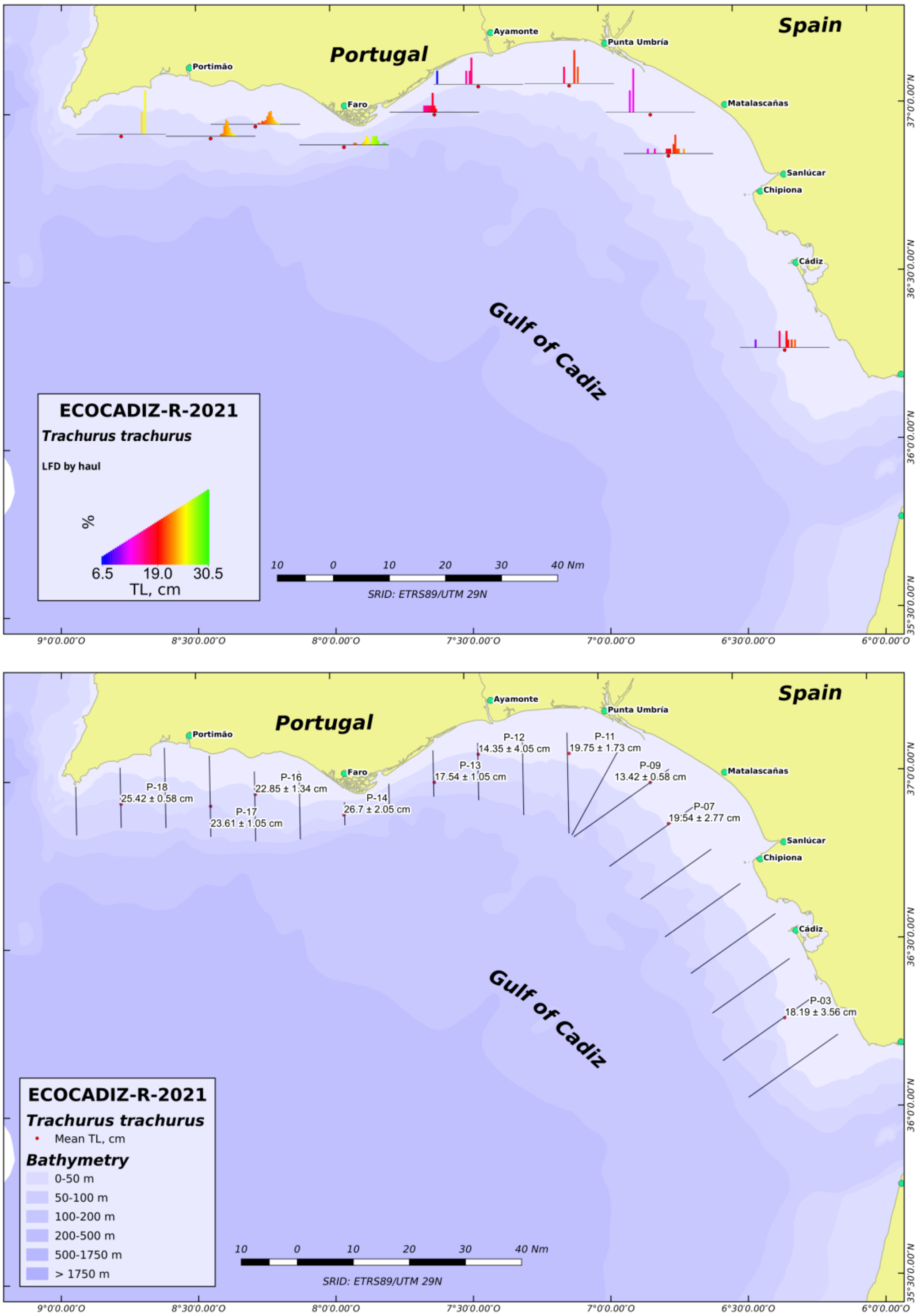


Figure 21. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

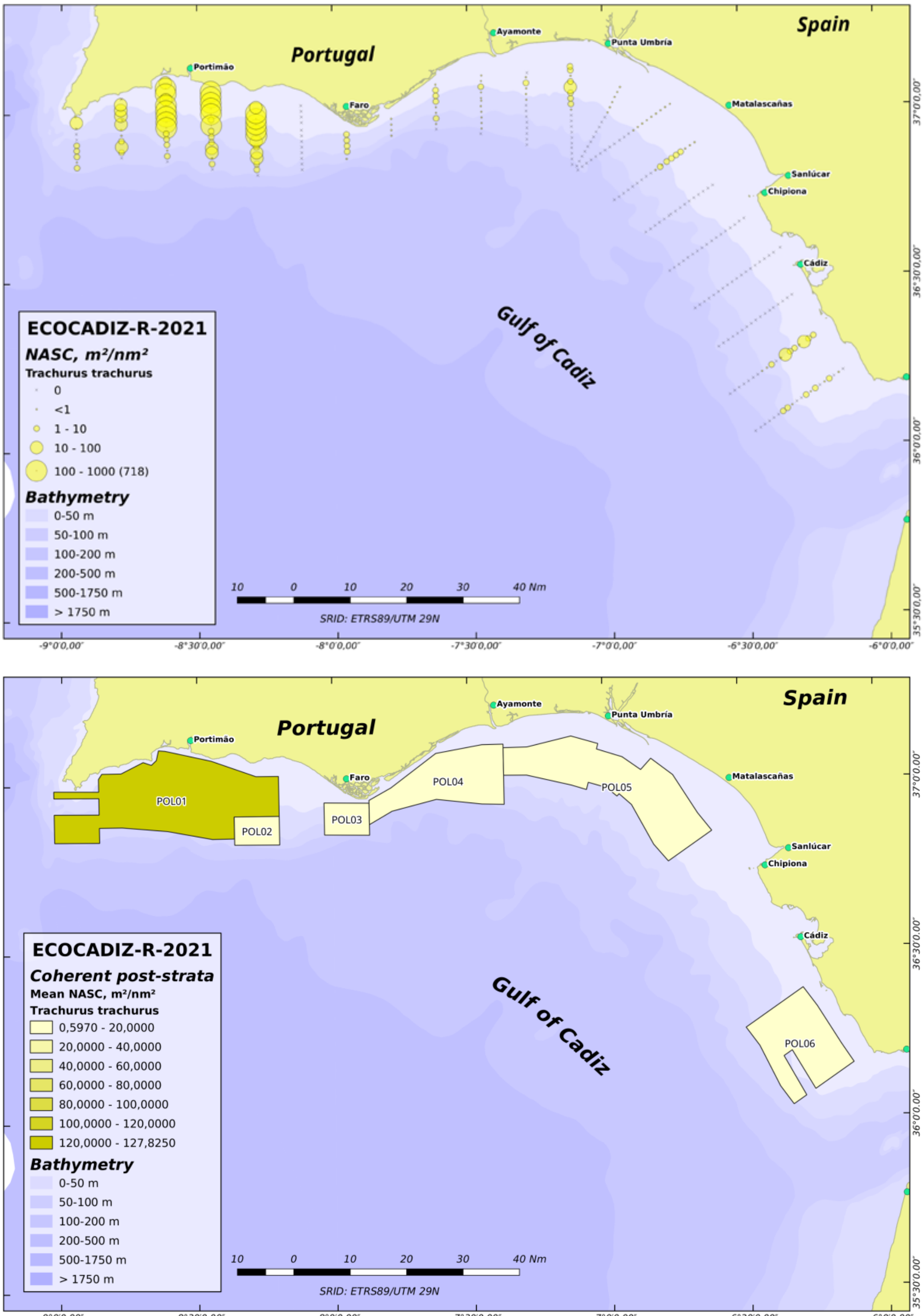


Figure 22. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

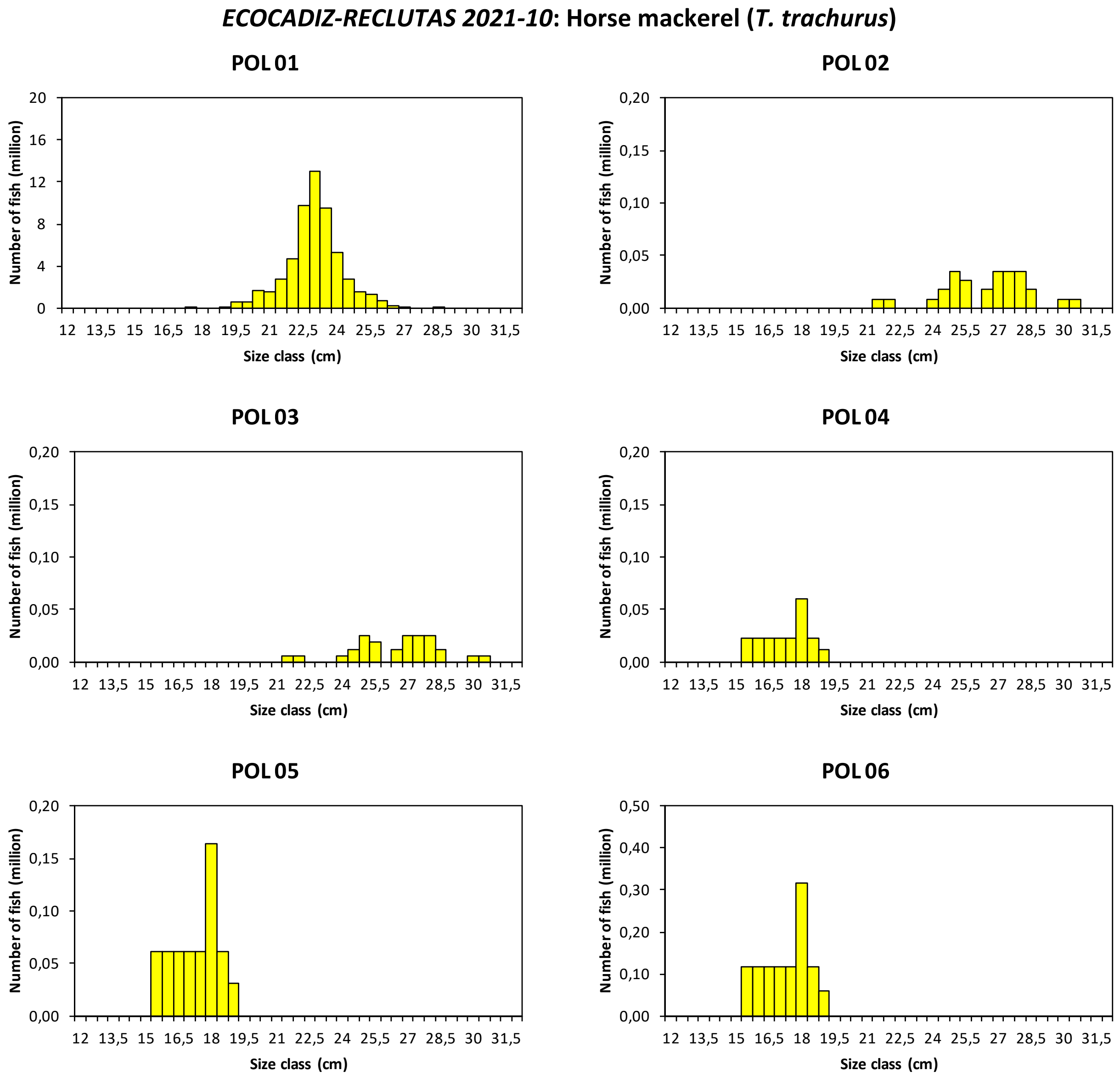


Figure 23. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 22**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

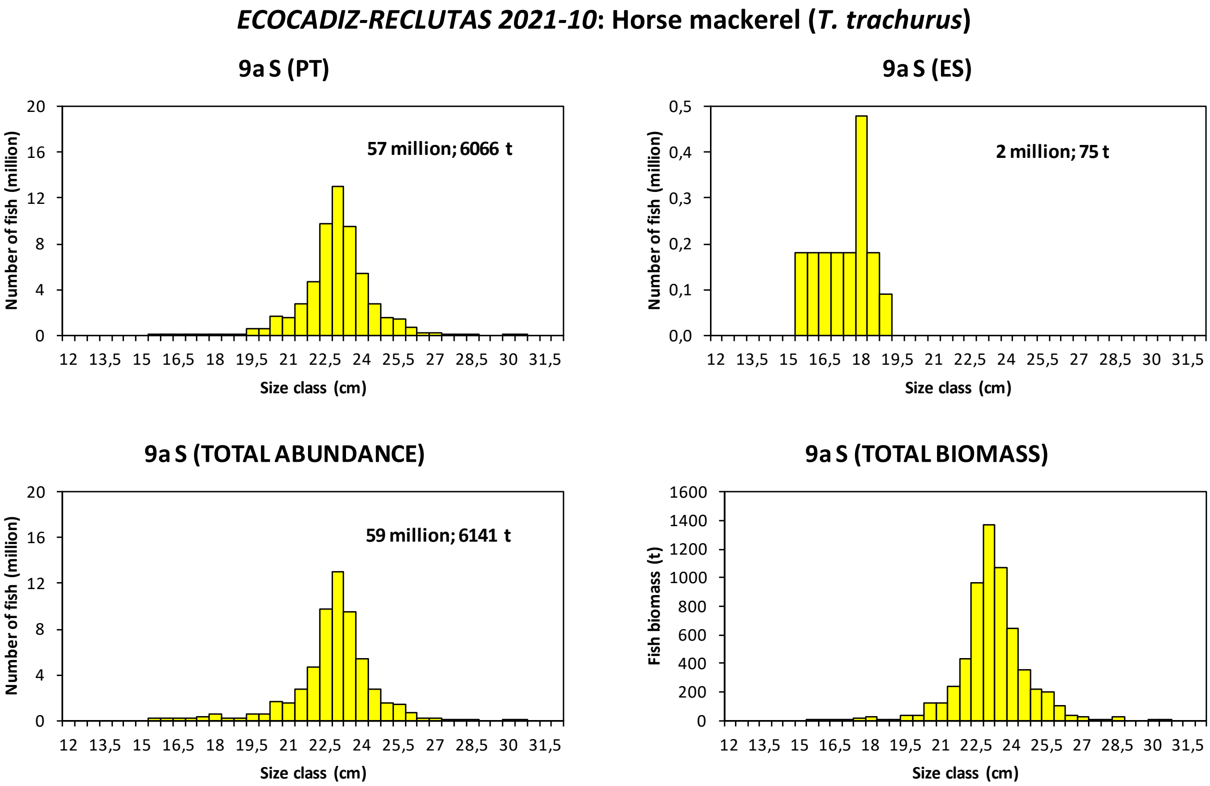


Figure 23. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Cont'd.

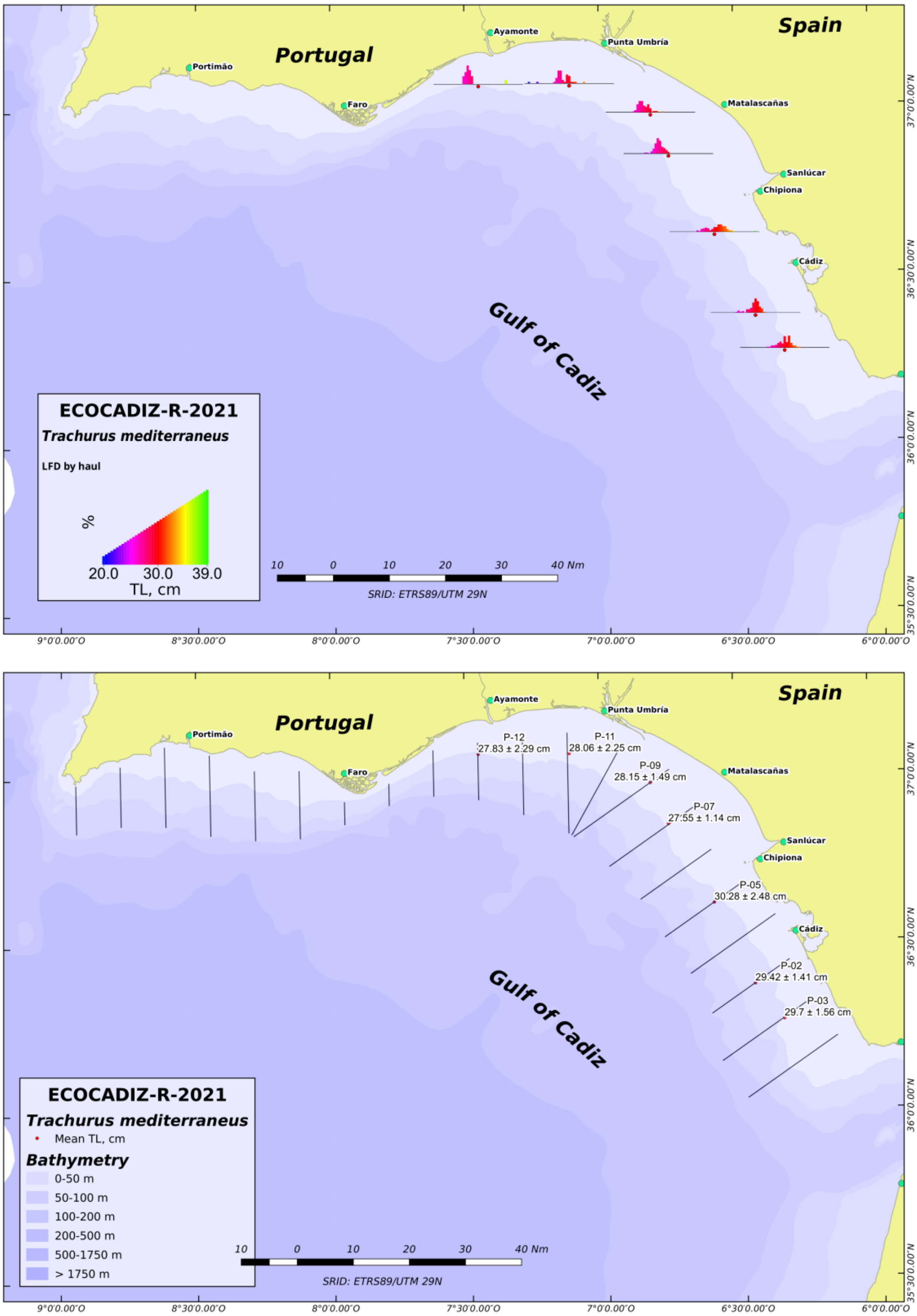


Figure 24. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

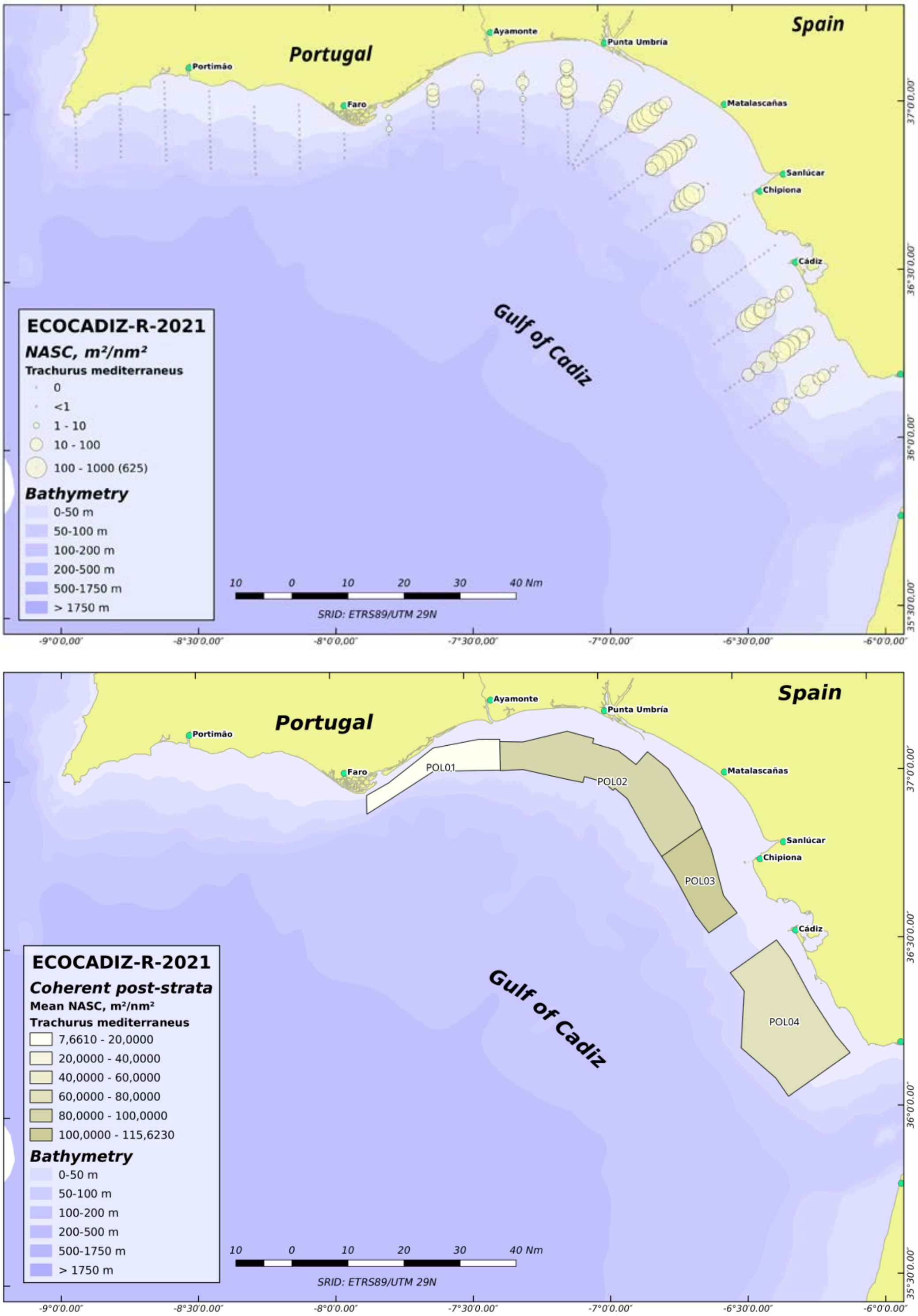


Figure 25. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

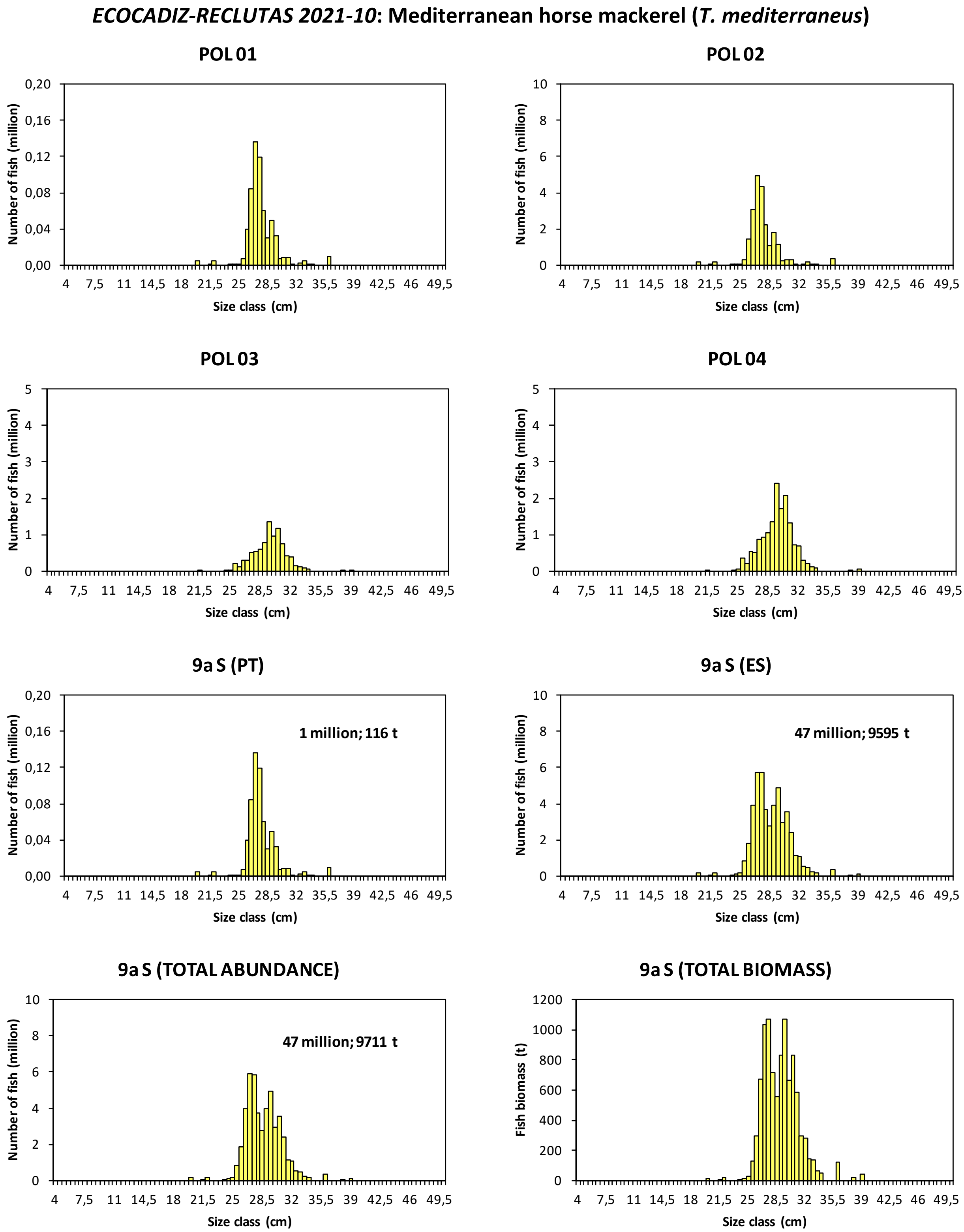


Figure 26. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 25**) and total sampled area. Post-strata ordered in the W-E 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.

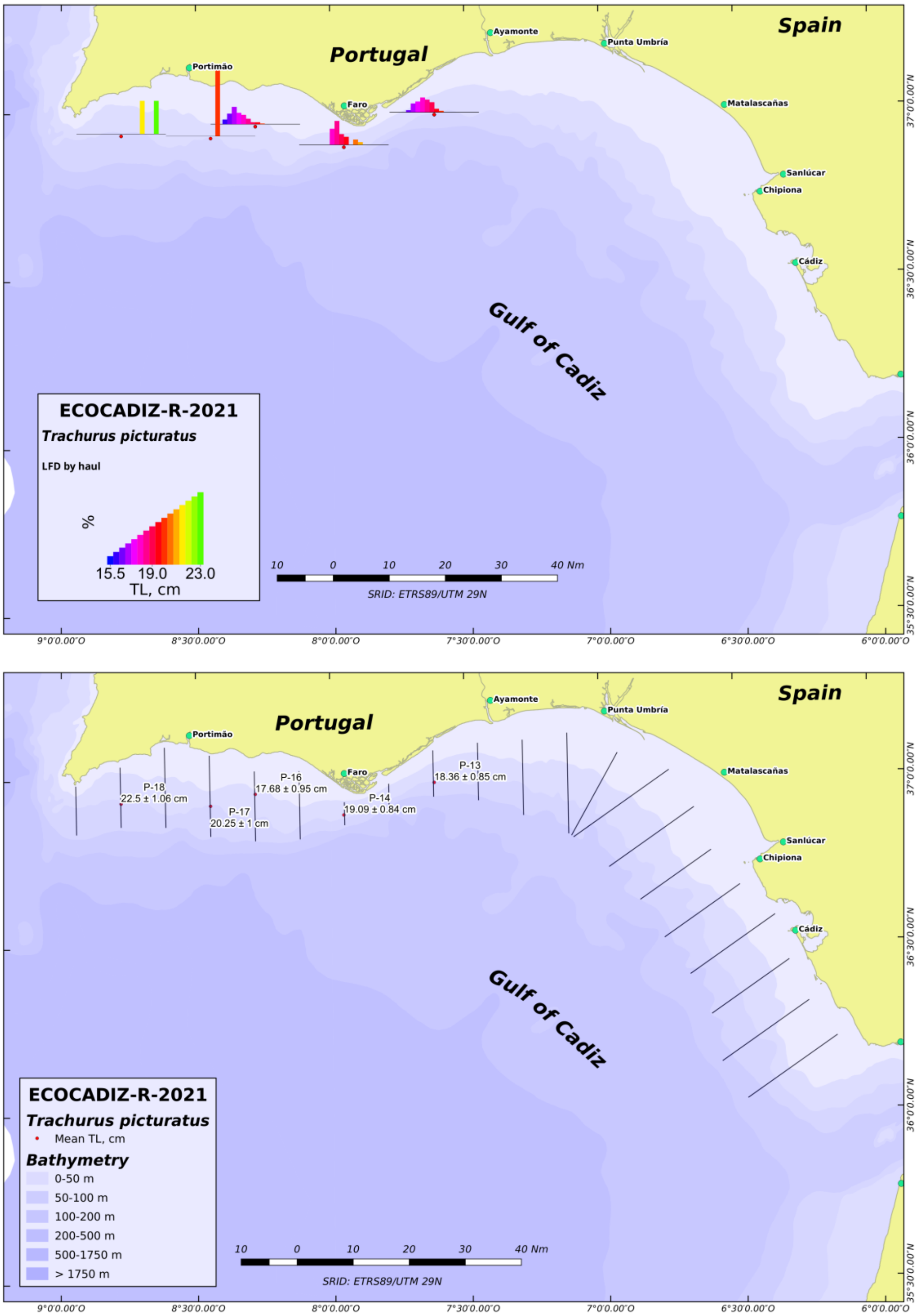


Figure 27. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue jack mackerel (*Trachurus picturatus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

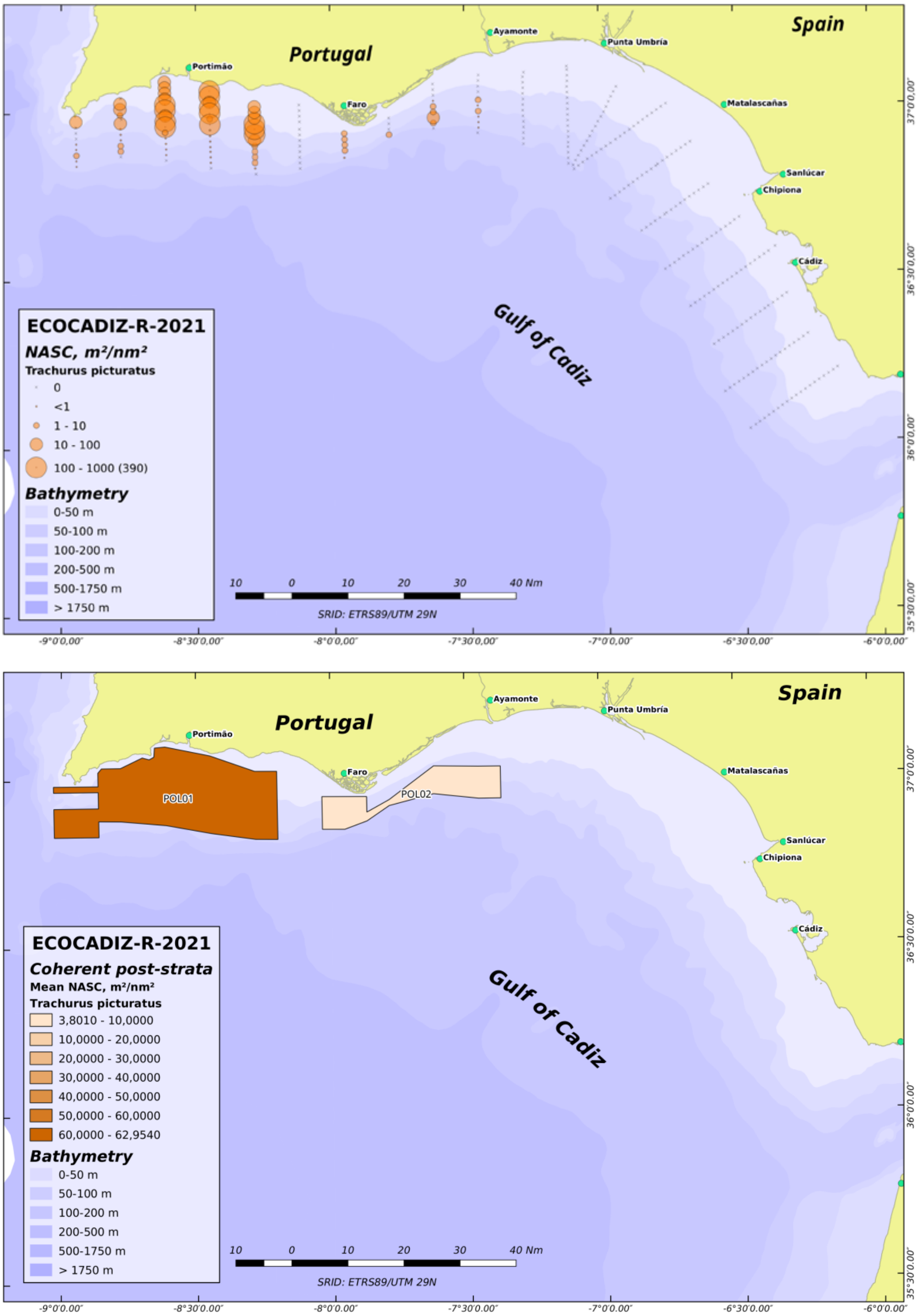


Figure 28. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue jack mackerel (*Trachurus picturatus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

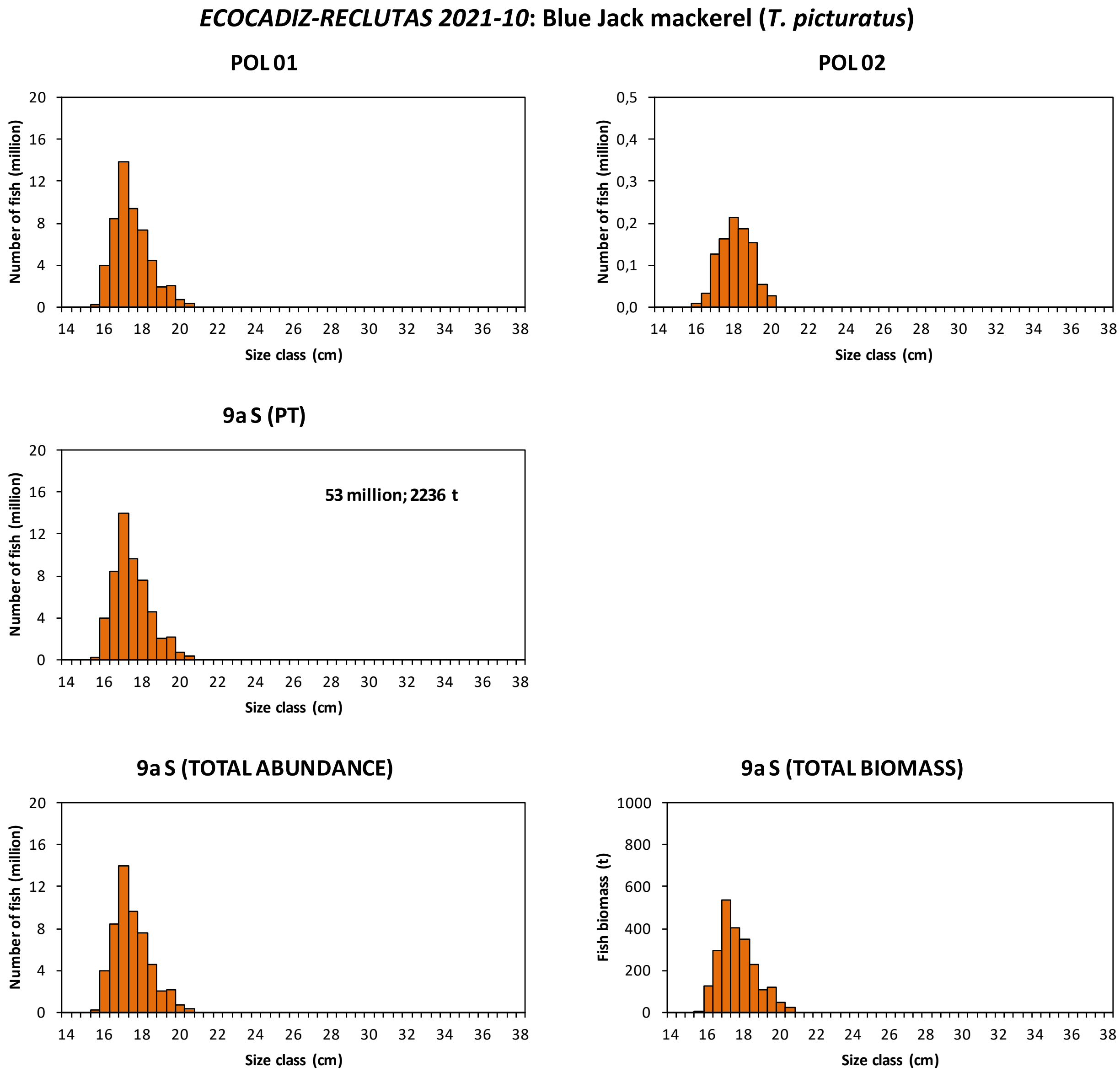


Figure 29. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue jack mackerel (*Trachurus picturatus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 28**) and total sampled area. Post-strata ordered in the W-E direction. 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.

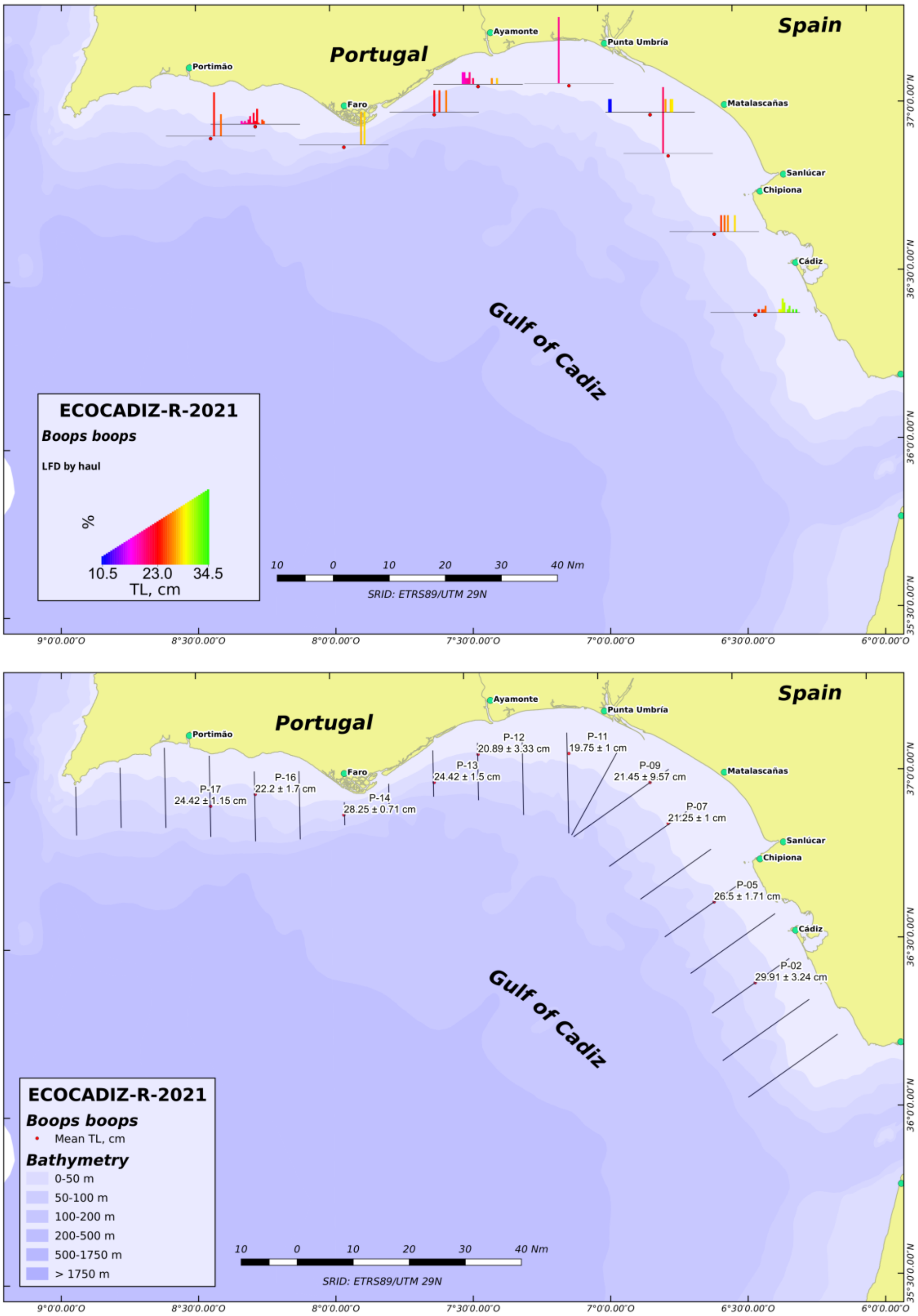


Figure 30. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

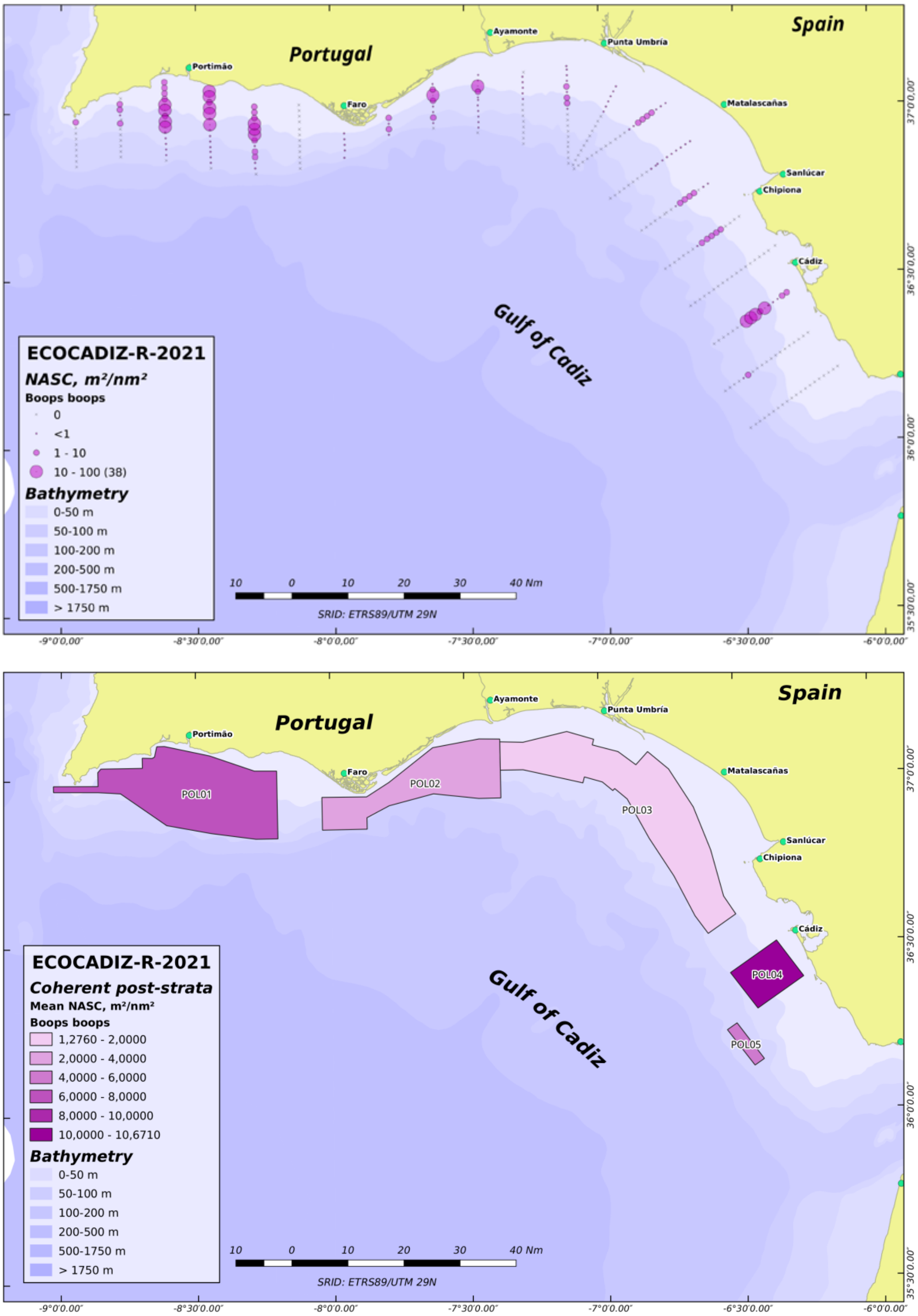


Figure 31. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

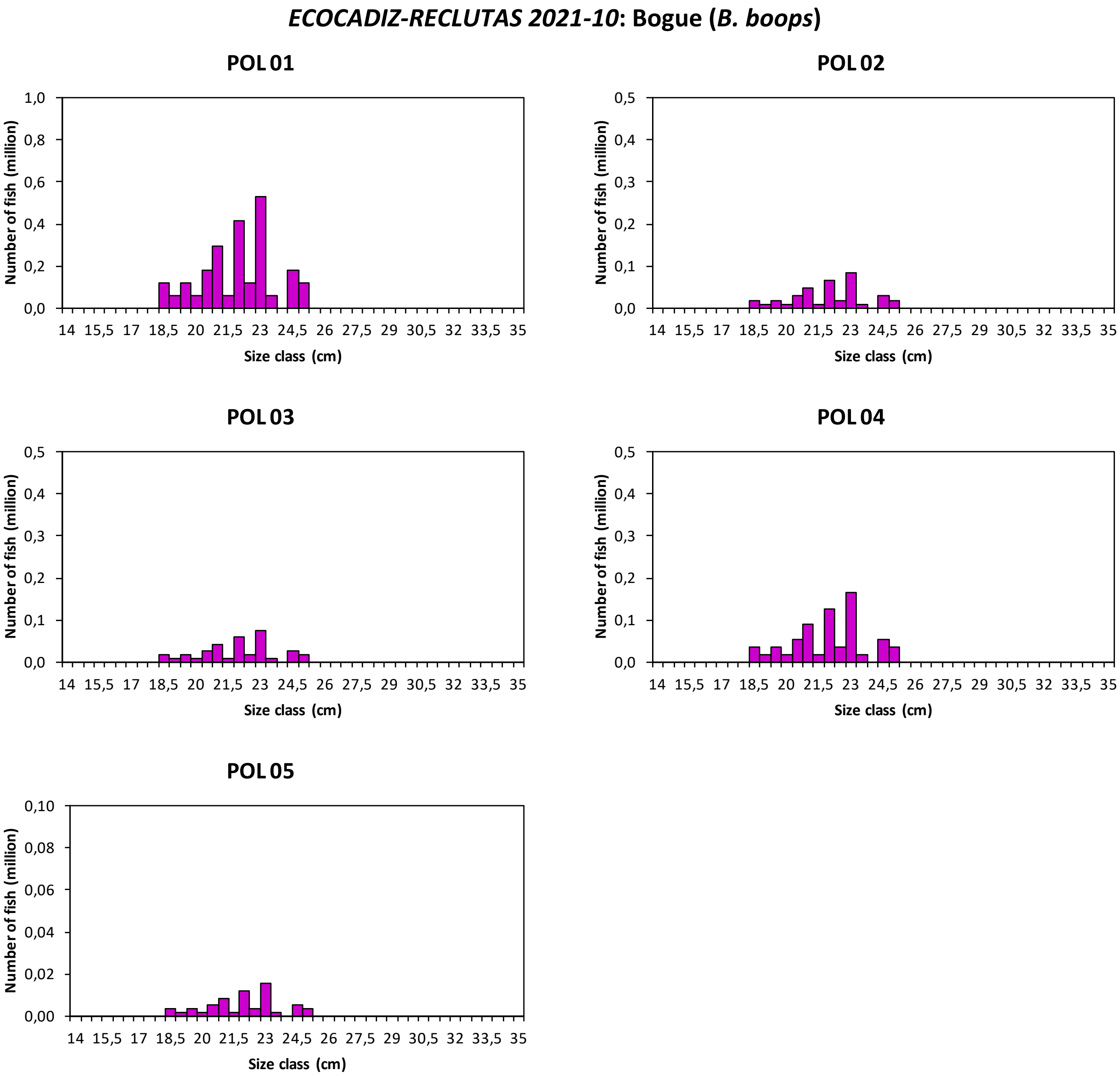


Figure 32. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 31**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

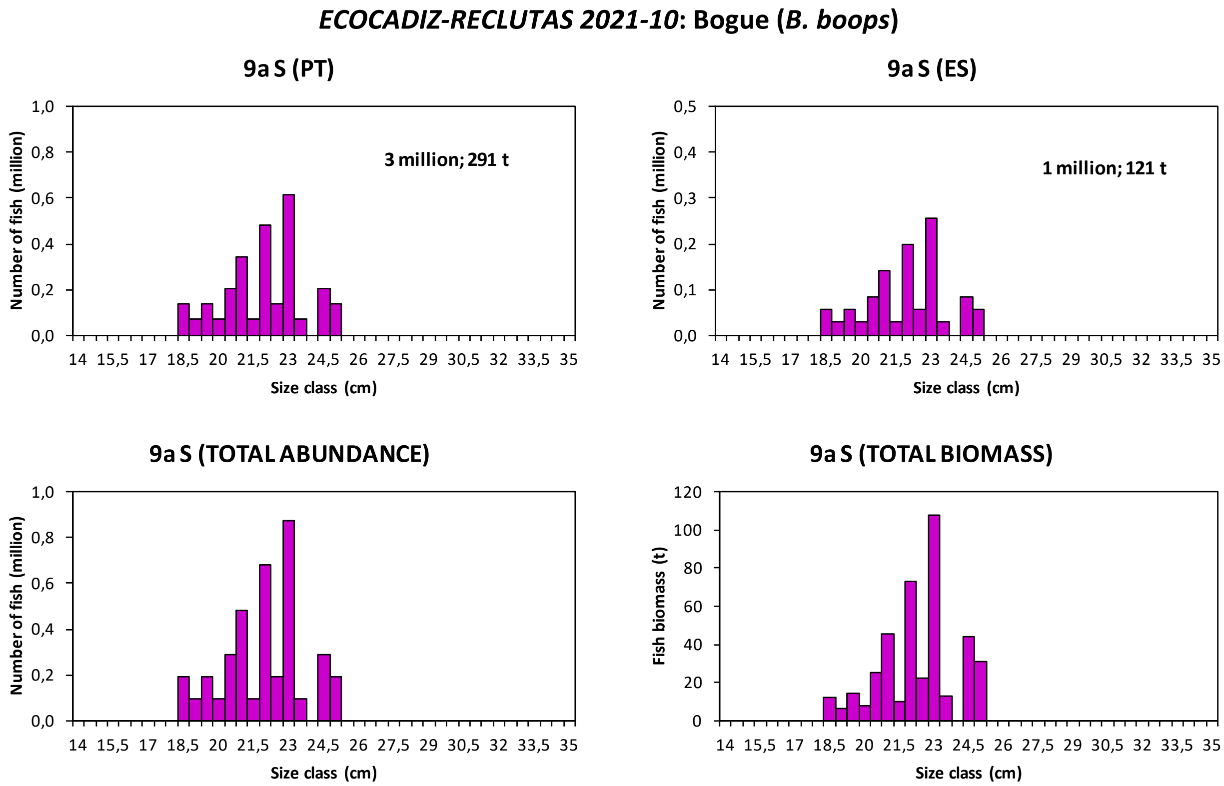


Figure 32. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Cont'd.

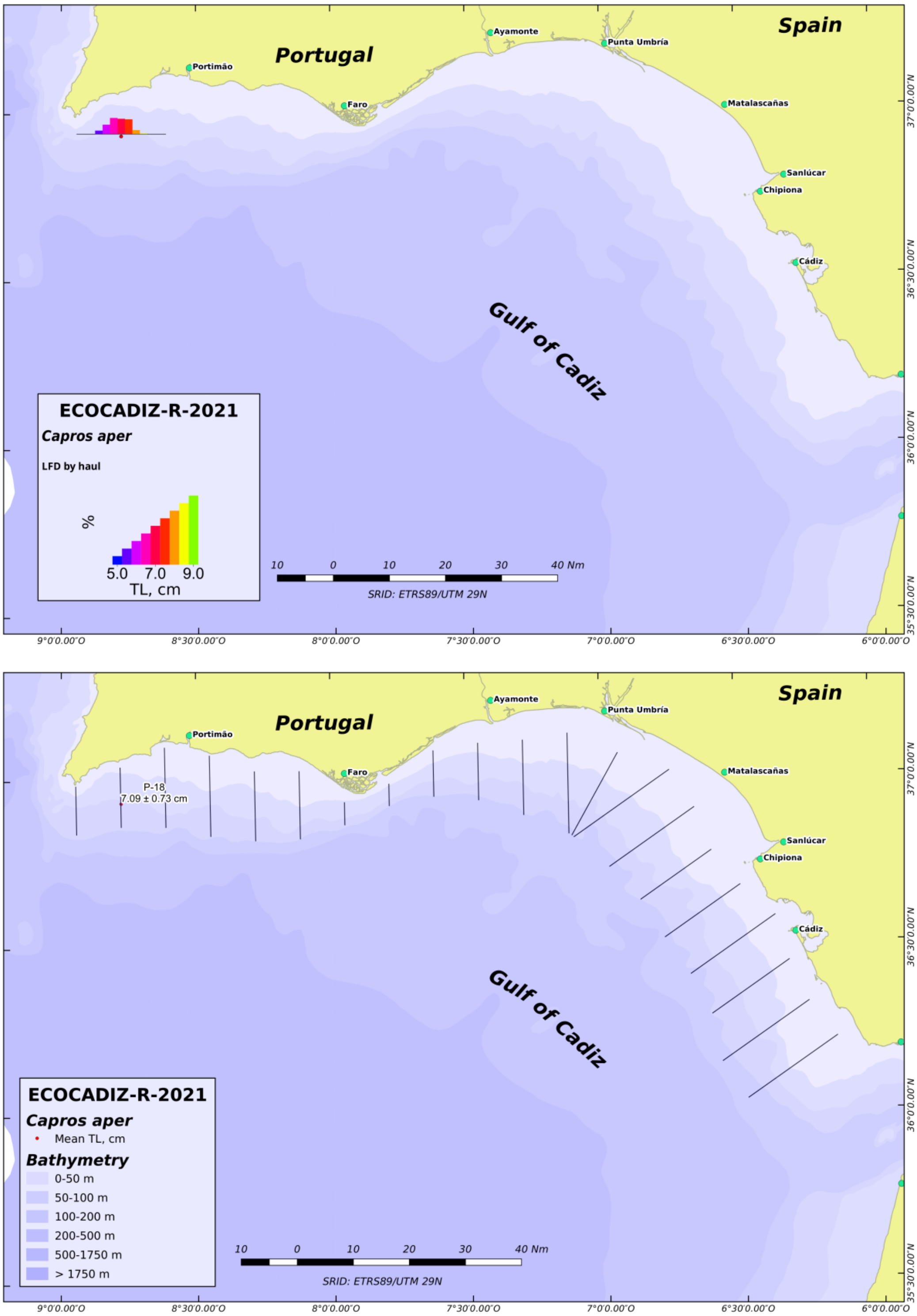


Figure 33. *ECOCADIZ-RECLUTAS 2021-10* survey. Boarfish (*Capros aper*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

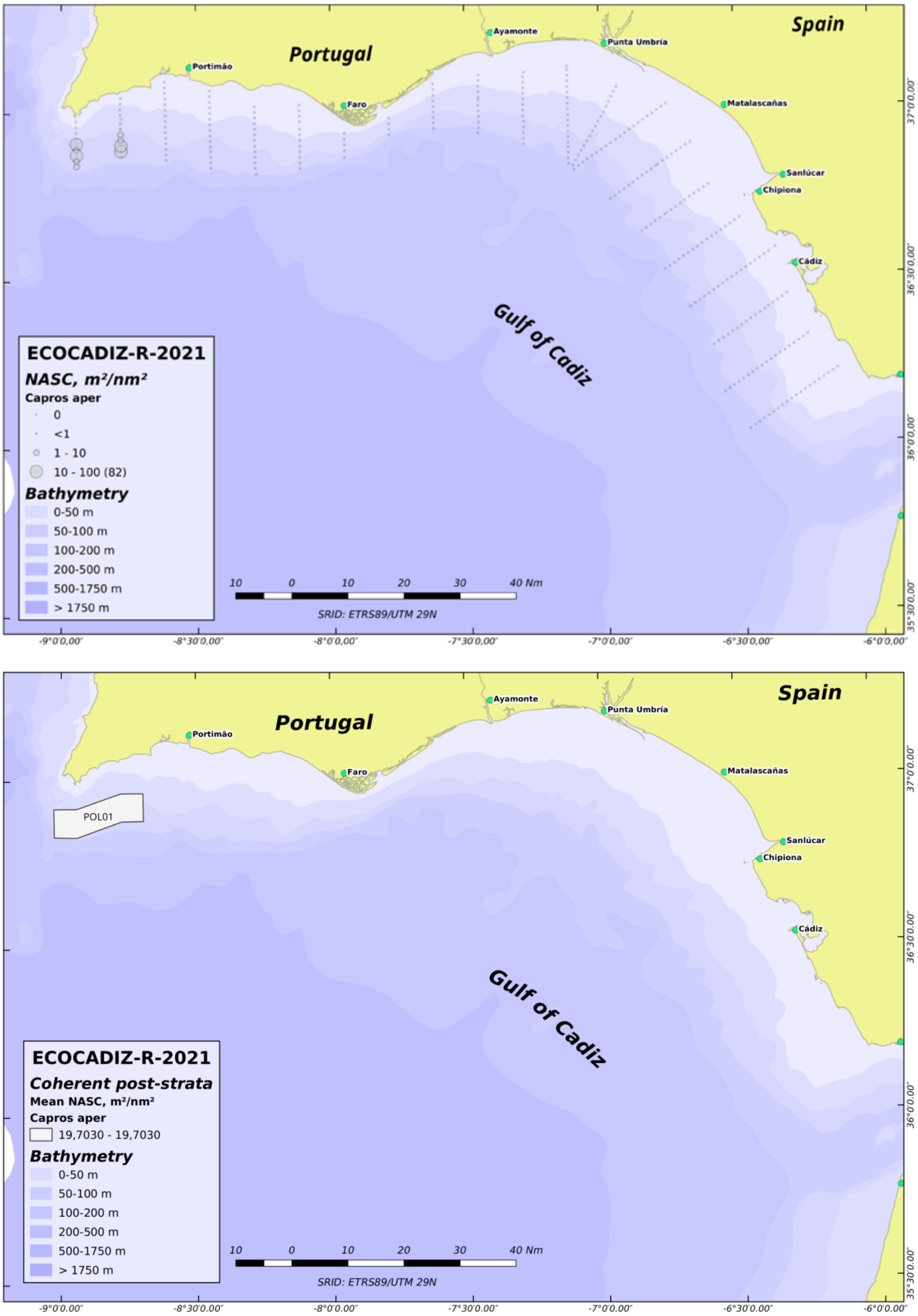


Figure 34. *ECOCADIZ-RECLUTAS 2021-10* survey. Boarfish (*Capros aper*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

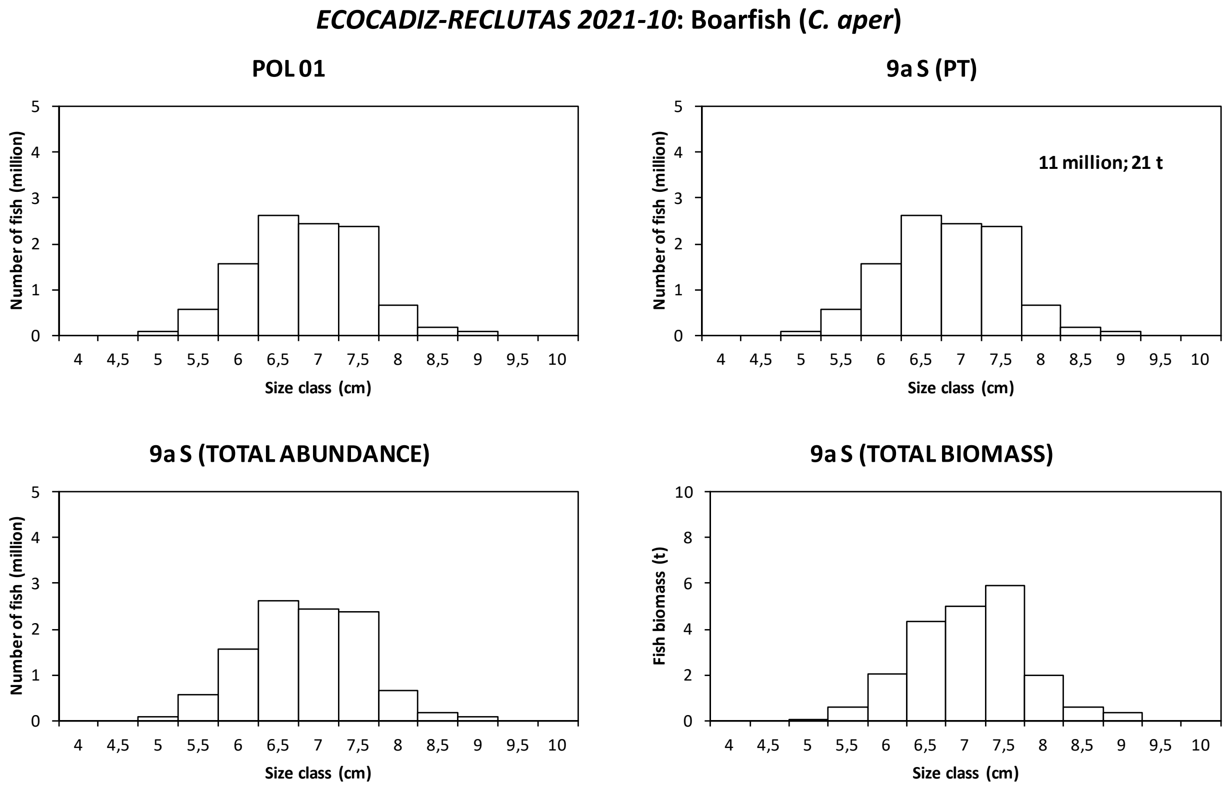
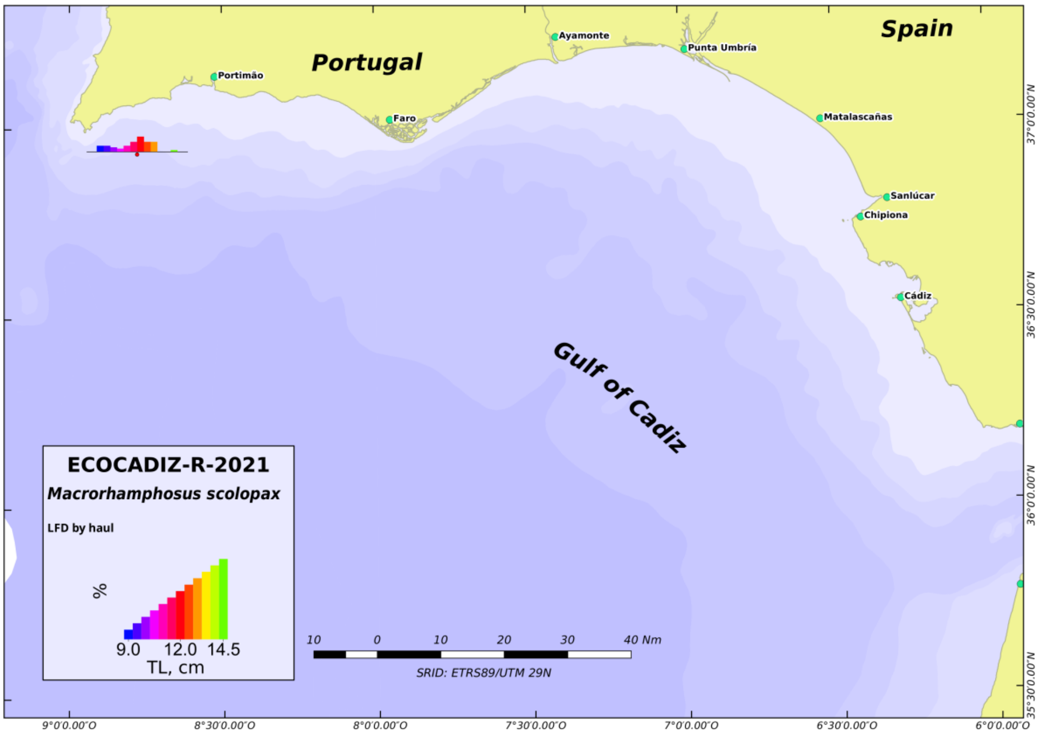


Figure 35. *ECOCADIZ-RECLUTAS 2021-10* survey. Boarfish (*Capros aper*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 34**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.



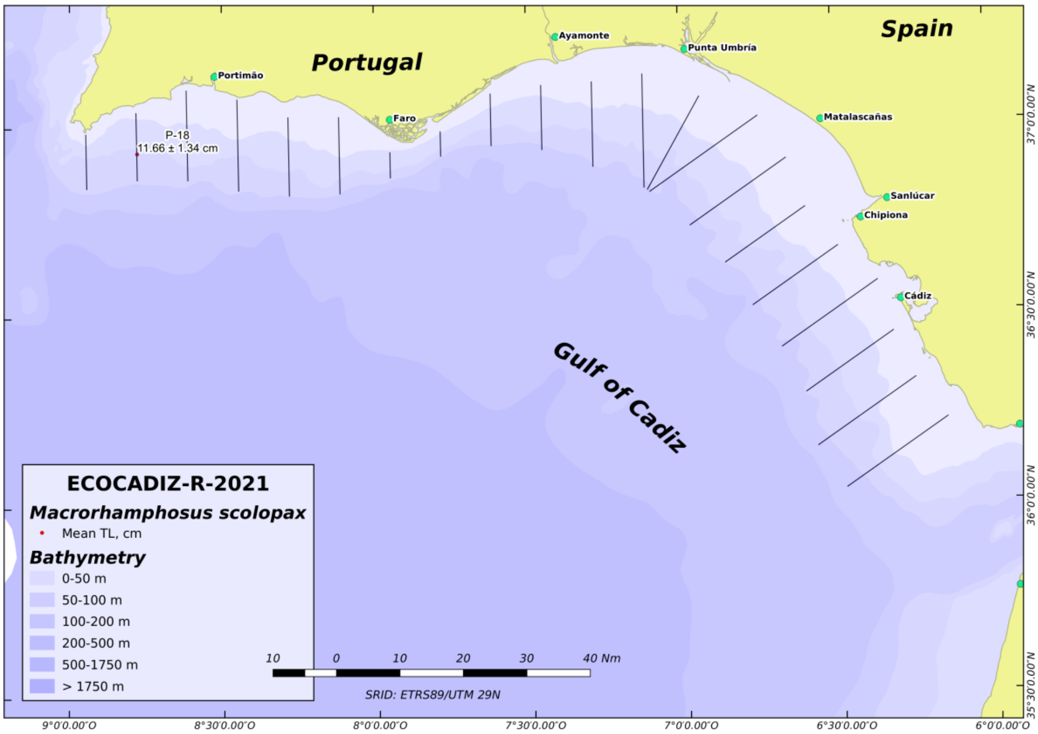


Figure 36. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

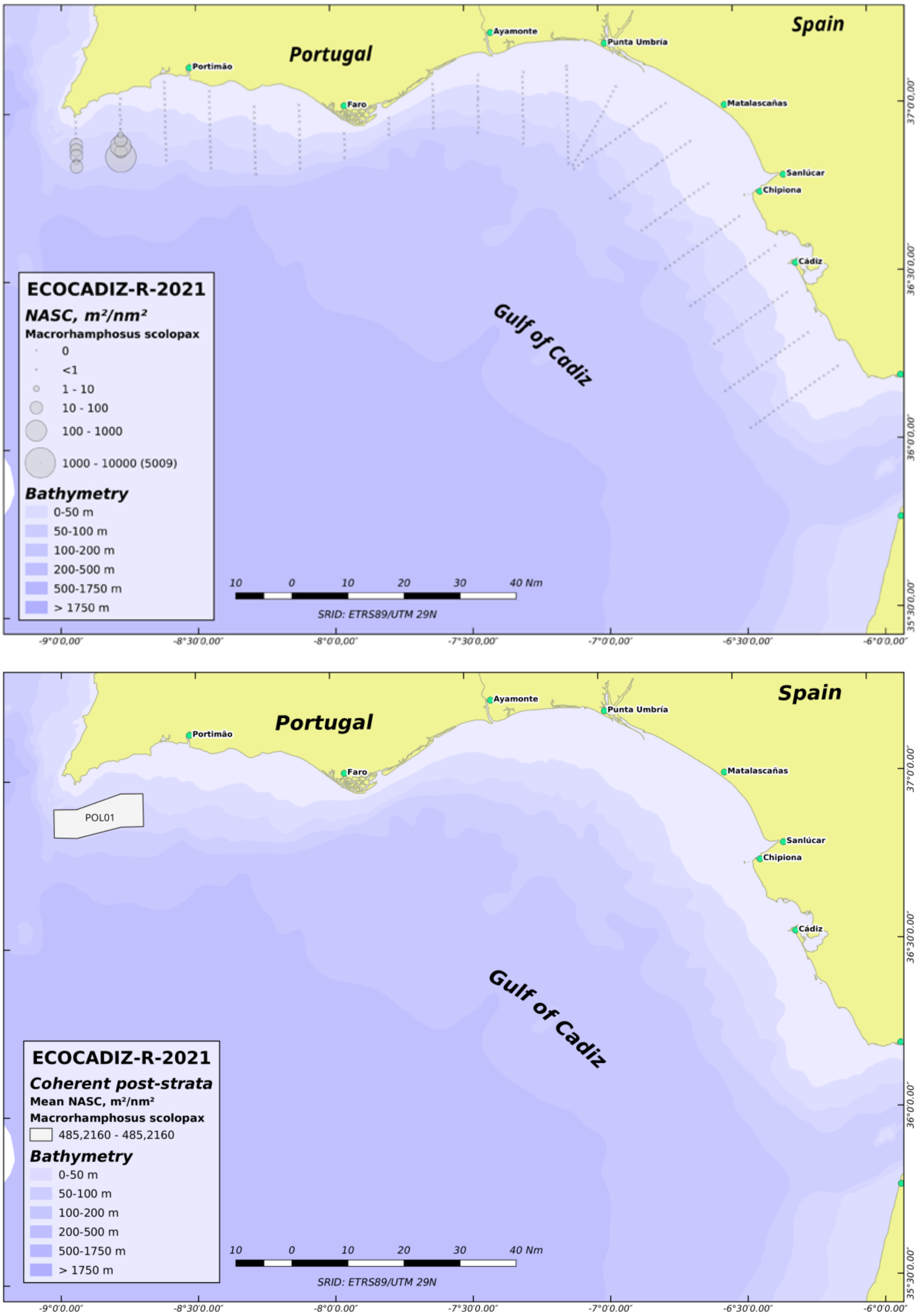


Figure 37. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

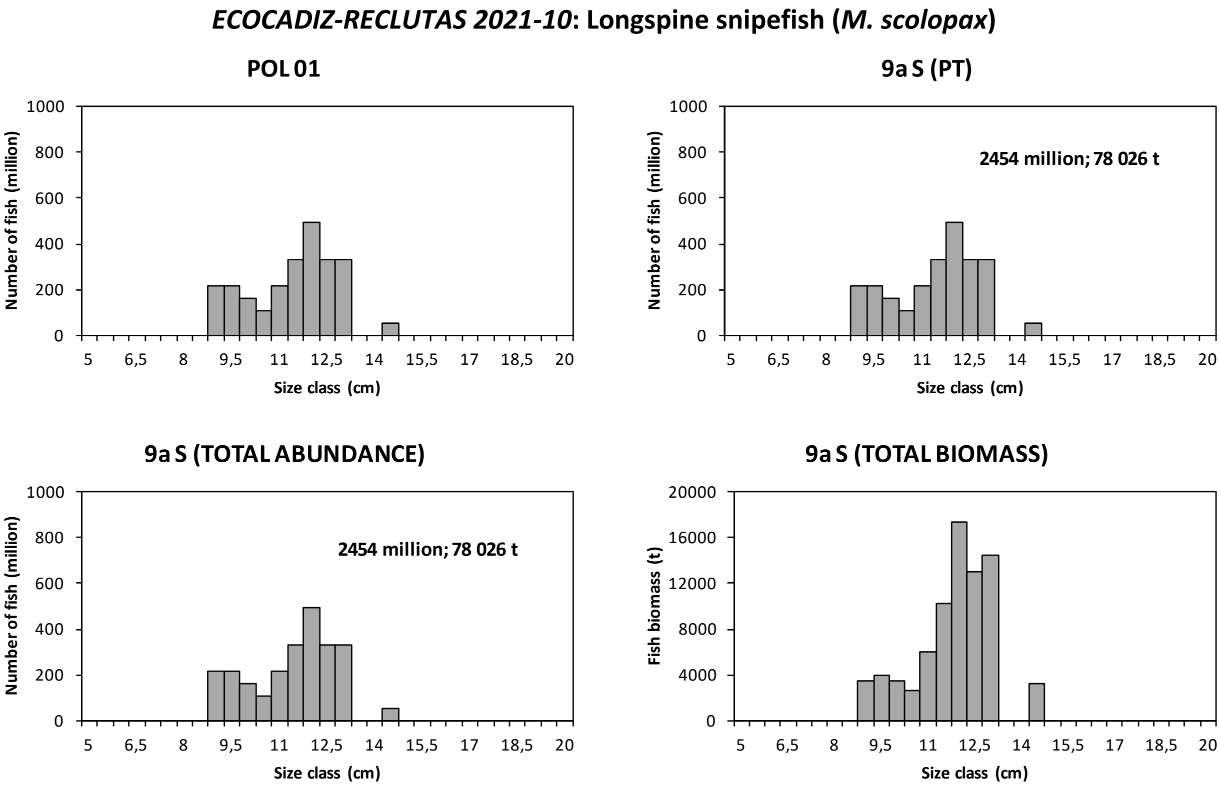


Figure 38. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 37**) and total sampled area. Post-strata ordered in the W-E direction. 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.

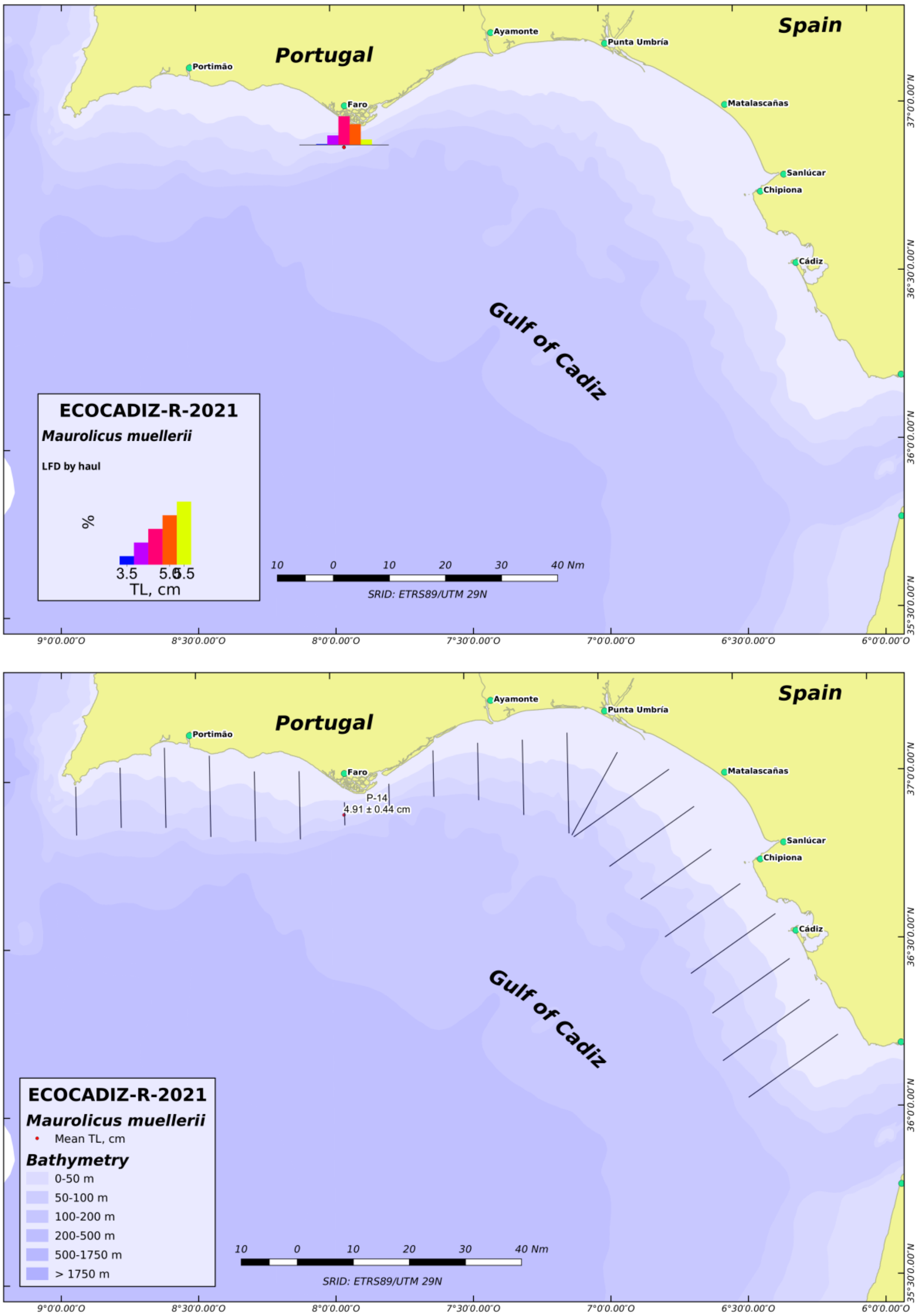


Figure 39. *ECOCADIZ-RECLUTAS 2021-10* survey. Pearlside (*Maurolicus muelleri*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

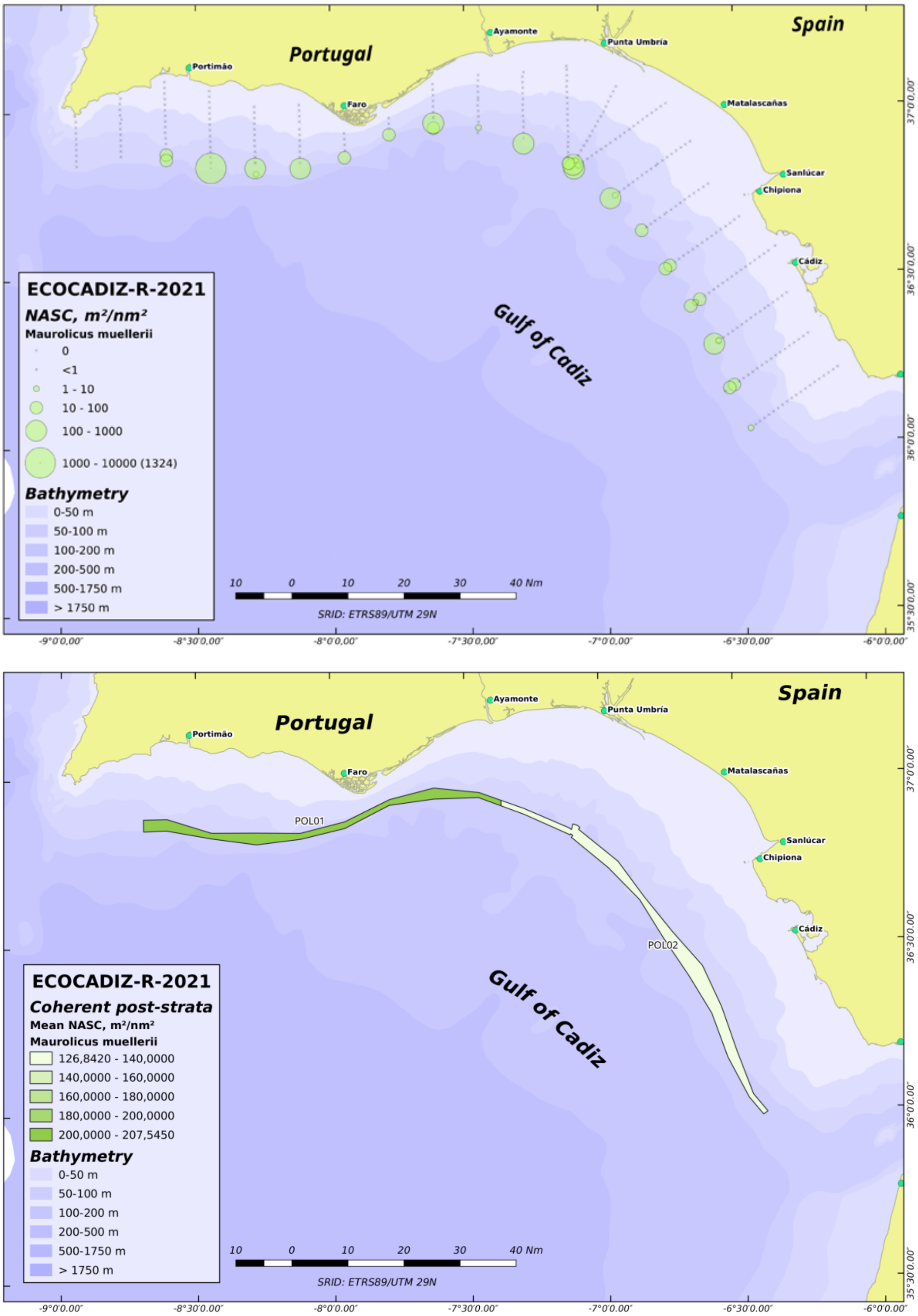


Figure 40. *ECOCADIZ-RECLUTAS 2021-10* survey. Pearlside (*Maurolicus muelleri*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

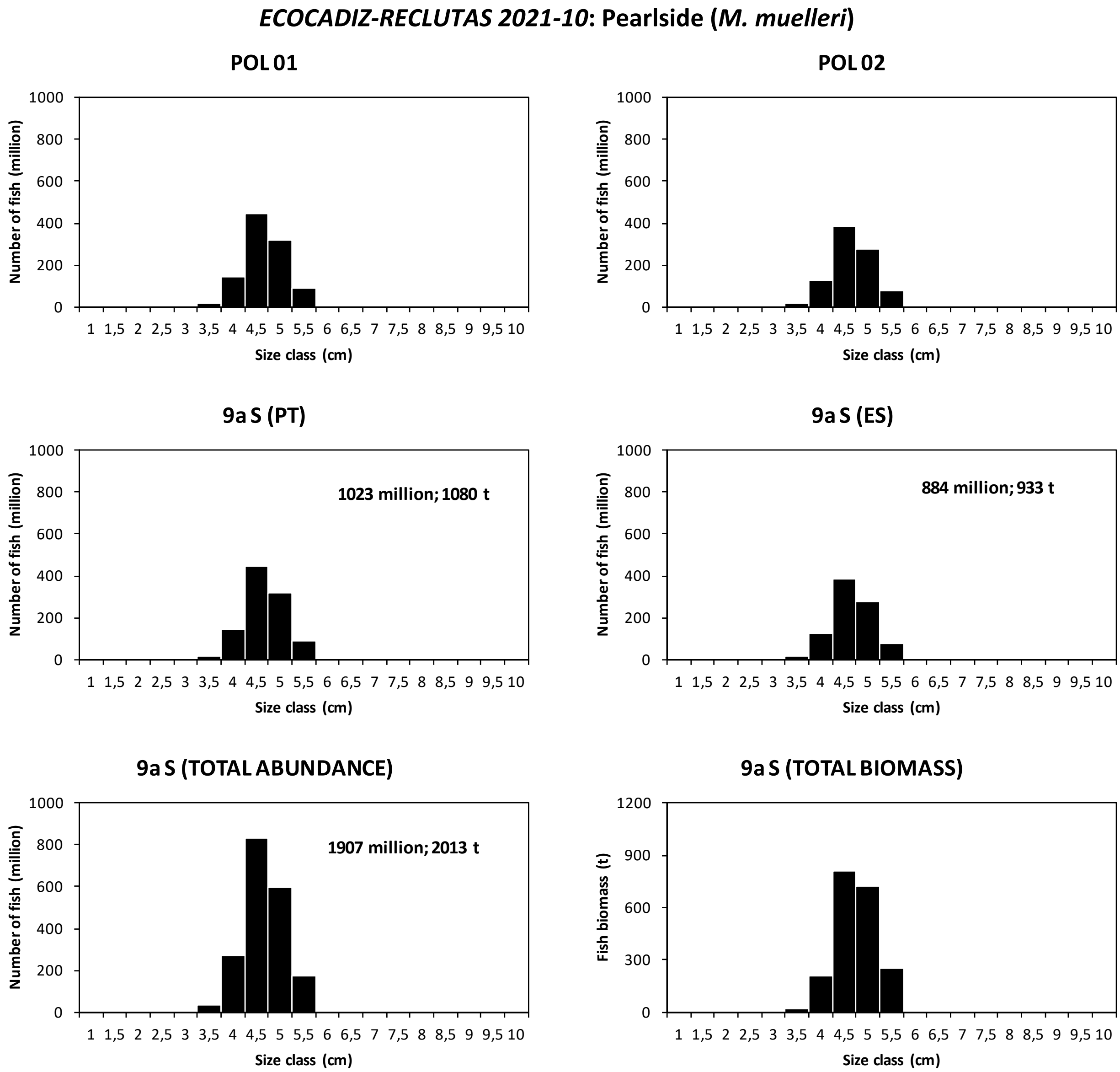


Figure 41. *ECOCADIZ-RECLUTAS 2021-10* survey. Pearlside (*Maurolicus muelleri*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 40**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

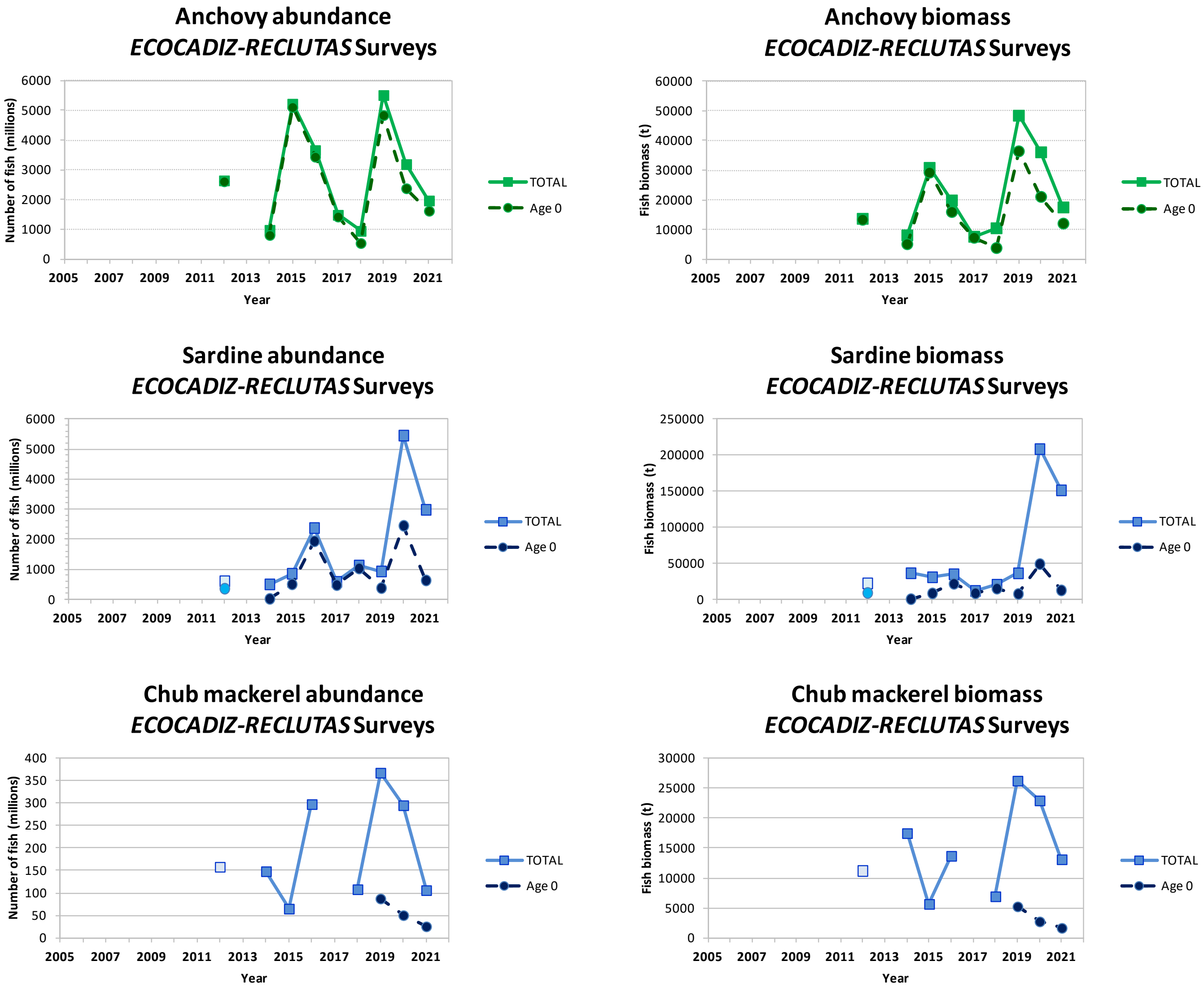


Figure 42. *ECOCADIZ-RECLUTAS* surveys series. Historical series of autumn acoustic estimates of anchovy, sardine and chub mackerel abundance (million) and biomass (t) in Sub-division 9.a South. The estimates correspond to the total population and age 0 fish. The 2012 survey only surveyed the Spanish 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.

Working Document to WGHANSA 2022 (23-27 May 2022)

Exploratory assessment of anchovy 27.9a-west using a surplus production model.

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Abstract

The aim of this WD was to explore surplus production models to assess the western component of the anchovy 27.9a stock. Models were fitted to catch per quarter or semester (1991 – 2021) and to one biomass index, the spring acoustic survey (1999 – 2021), or two biomass indices, the acoustic survey and the autumn groundfish survey (1991 – 2018) using SPiCT. Various assumptions regarding the shape of the production curve, the initial biomass depletion and the intrinsic growth rate of the population were combined such that models varied from nearly unconstrained (more complex) to increasingly constrained (less complex). Bi-annual catch data and two survey indices lead to a higher number of convergent models. Several models passed all ICES criteria to accept a SPiCT assessment, except for a higher level of uncertainty in F/F_{MSY} than the agreed one for long-lived stocks. A model assuming a Schaefer production curve, a prior on *r* from a meta-analysis and, an initial depletion rate of 80%, showed better retrospective analysis, survey hindcast cross-validation and convergence performance than other candidate models. The results indicated that F/F_{MSY} was below 1 across most of the period, B/B_{MSY} fluctuated well below 1 until 2010 and above 1 since 2016. The present results may be considered for further work in a benchmark workshop.

1. Introduction

The anchovy 27.9a stock spans the ICES Division 9a corresponding to the region between Cape Finisterre and the Strait of Gibraltar in the Gulf of Cadiz. Anchovy distributed off the western coast of the Iberian Peninsula, from Cape Finisterre to Cape Saint Vincent is the west component of the stock. The southern component ranges from Cape Saint Vincent to the Strait of Gibraltar, the southern waters of the Iberian Peninsula. ICES provides separate catch advice annually for each of the stock components using a common basis: the rule “one-over-two” constrained by an uncertainty cap of +/- 80% of the former catch advice (ICES 2018, 2020).

In the case of the southern component, the rule uses an SSB indicator estimated in a Gadget assessment model, using length-age based catches and, length-age based abundance indices from two acoustic surveys, ECOCADIZ and PELAGO. For the western component, the rule uses an indicator obtained by adding the biomasses estimated in the acoustic surveys PELAGO and PELACUS which together cover the area. The western component is data-poor. The limited data available before the 2000s is related to a near absence of the species in the area. Monitoring such small catches and very low abundance was practically impossible. Monitoring of the western component population started in the late 1990s as a “by-product” of acoustic surveys targeting sardines while catches started to be sampled systematically in the late 2010s (ICES, 2018).

The use of estimates from a stock assessment model may have advantages over the direct use of survey estimates in terms of catch advice. Models, as they integrate several sources of data and may take both observation and process error into account, become more robust to specific situations of bias or noise in the case of a single indicator, such as a research survey. The fact that anchovy is a short-lived species precludes the application of assessment and reference points methods developed by ICES for medium- and long-lived data-limited species, as they are often based on equilibrium assumptions (approximately constant recruitment over time) (ICES, 2018). This fact promoted the search for alternative methods, work that has been developed within the scope of the ICES WKDLSSLS. In 2021, the WKDLSSLS concluded that short-lived stocks that have sufficiently long time series (catch data and total biomass indicators) can be assessed with surplus production models (SPMs, also called biomass dynamic models) (ICES, 2021a), provided the data have enough contrast. Scientific advice can be formulated based on F_{MSY} and rules for achieving MSY should include biomass limits and uncertainty buffers (Mildenberger *et al*. 2021). The F_{MSY} rule will be most successful if applied to an assessment including an indicator of population biomass immediately before the management period and which includes most age classes of the exploitable population.

During the WKDLSSLS workshops, SPMs were applied to various short-lived stocks using SPiCT (SPiCT, Stochastic Surplus Production Model in Continuous Time; (Mildenberger *et al*. 2021; Pedersen & Berg, 2017), namely to the west and south components of the anchovy in division 9a, sprat on the west coast of Scotland and sardines in sub-area 7 (Celtic Sea). In the case of anchovy from the 9a south component, SPiCT showed a good performance and results comparable to those of the analytical model in use. Classical surplus production models were generally not applied to assess short/medium lived stocks, due to the high variability. The appearance of SPMs that allow observation and process error, such as SPiCT, increased the chances of good results with short-lived species (Zhou *et al*. 2009).

In this WD, we explored SPMs to assess the anchovy 9a-west stock component using SPiCT. Various combinations of catch data and survey indices and various model configurations were explored.

2. Material and methods

Data

- catch biomass, t, per quarter or semester from the beginning of the first quarter of 1991 to the end of the second quarter of 2021
- total biomass, t, in the spring acoustic surveys PELACUS+PELAGO 1999 – 2021 (gaps in 2000, 2004 and 2012) (Massé *et al.*, 2017; Doray *et al.*, 2021)
- mean biomass and corresponding standard deviation (SD), kg h^{-1}, in groundfish surveys October/December 1991 – 2018 (autumn, with gaps in 1994 and 2012). The computation of indices followed the methodology provided by Cochran (1977) for stratified random sampling and the survey methodology is described in ICES (2017).

Survey indices were corrected to reflect the exploitable biomass, assumed to correspond to the biomass of individuals > 10 cm total length, the minimum length present in the commercial catches. For both survey series, the differences between the corrected and uncorrected data were minor (see Figure 2.1 for the acoustic survey; in the groundfish survey, there were differences in 1997 and from 2014 to 2016, all below 3% except for 2015 where they were 23%).

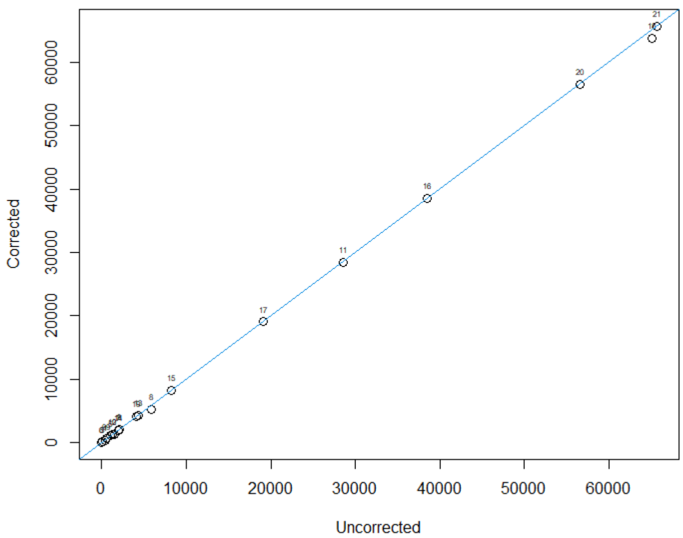


Figure 2.1 - Anchovy 9a-west: the relationship between uncorrected (all length classes) and corrected (biomass of length classes 10+) acoustic biomass.

Models were fitted to catch per quarter or semester and to one abundance index, the acoustic survey, or to both indices, with various assumptions regarding the shape of the production curve, the initial biomass depletion and the intrinsic growth rate of the population (see below). SPiCT fits surplus production models which incorporate dynamics in both biomass and fisheries and observation error of both catches and biomass indices. SPiCT uses a re-parametrization of the Pella and Tomlinson (1969) equation:

$dB_t = r/(n-1) * B_t*(1-(B_t/K)^{n-1}) - F_tB_t$

where B_t is the exploitable population biomass, F_t is the instantaneous fishing mortality rate, r is the intrinsic growth rate of the population, K is the carrying capacity and n is a unit-less parameter determining the shape of the production curve. The fraction B_1/K, where B_1 is the biomass in the first year of the assessment ($1-B_1/K$ is termed the initial depletion rate), is often difficult to estimate from the data. Data available on historical catches may be used to set priors for this parameter.

All models start in the middle of the calendar year (July 1st), following the ICES advice calendar for this stock. Assessment years go from 1 July of year *y* to 30 June of year *y+1*.

The time of catch (timeC) and survey (timeI) observations in the model is shown in Table 2.1.

Table 2.1 – Anchovy 9.a-west: Time of catch and survey observations. The forecast period is shown in bold.

Year	Time of catch observations				Time of survey observations	
	Quarterly data		Biannual data		Acoustic survey (spring)	Groundfish survey (autumn)
1991	1	1990.50	1	1990.5	1990.75	1991.25
1991	2	1990.75				
1991	3	1991.00	2	1991.0		
1991	4	1991.25				
1992	1	1991.50	1	1991.5	1991.75	1992.25
1992	2	1991.75				
1992	3	1992.00	2	1992.0		
1992	4	1992.25				
…	…	…	…	…	…	…
2021	1	2020.50	1	2020.5	2020.75	
2021	2	2020.75				
2021	**3**	**2021.00**	**2**	**2021.0**		
2021	**4**	**2021.25**				
2022	**1**	**2021.50**	**1**	**2021.5**		
2022	**2**	**2022.00**				

Coefficients of variation (CV) of groundfish indices were used as weighting factors of the data points to reflect differences in observation error. Acoustic surveys were given equal weight (=1) over time since estimates of observation error were not available. For better numerical stability all indices and weighing factors were scaled to have a mean = 1.

Priors for n, B_1/K, and r were combined such that models varied from nearly unconstrained (more complex) to increasingly constrained (less complex) (Table 2.2; Figure 2.2). The n.Thorson and r.Thorson priors were derived from n and r parameters for Clupeiforms and *Engraulis encrasicolus*, respectively, obtained in meta-analyses (Thorson *et al.* 2012; Thorson, 2020). Default priors (lognormal, mean = ln(1), SD = 2) were applied to the ratios of process error of fishing mortality/biomass to observation error in catches/abundance indices.

Table 2.2 – Anchovy 9.a-west: Prior means and standard deviations for n, B1/k and r parameters. In all cases prior probability distributions are lognormal. SD of n.Thorson and r.Thorson priors calculated as sqrt[mean(r)^2 /predictive error(r)^2].

	Prior		
Parameter	Name	exp(Mean)	Standard deviation
n	Default	2.00	2.00
	Schaefer	2.00	1.00E-03
	Fox	1.00	1.00E-03
	n.Thorson	0.60	0.57
B_1/K	20	0.20	0.50
	50	0.50	0.50
	80	0.80	0.80
r	r.Thorson	1.98	0.28

Figure 2.2 – Anchovy 9.a-west: Diagram of all possible prior combinations.

n		B_1/K		r
n.none		BKnone		r.none
Default	**X**	BK20	**X**	r.Thorson
Schaefer		BK50		
Fox		BK80		
n.Thorson				

To find one or a few final models, standard criteria of convergence, goodness-of-fit and consistency were checked according to ICES guidelines for the acceptance of a SPiCT assessment (2021b) and to recommendations of Pedersen and Berg (2017) and Carvalho *et al.* (2021). The following checklist was applied:

1) Convergence: successful completion of the fit, finite and reasonable confidence intervals; all absolute values of parameter correlations below 0.95; low sensitivity to initial values;
2) Goodness-of-fit: residuals normal (Shapiro-Wilk test; q-q plot), unbiased (t-test comparing the mean to zero; scatterplot of standardized residuals) and independent (Ljung and Box (1978) test on four lags; empirical auto-correlation plot);
3) Consistency: 5-year retrospective Mohn's Rho of B/BMSY and F/FMSY between -0.22 and 0.30; consistent retrospective trajectories across the historical period;
4) Prediction skill: mean absolute scaled error (MASE) of each abundance index of 7-year hindcast cross-validation, below 1 and, as low as possible.

The checklist was applied sequentially, apart from the sensitivity test to initial values, a time-consuming procedure, which was therefore applied only to models that passed the checklist. The sensitivity test consists of perturbing initial parameter values by random proportions between -2 and +2 and re-fitting the model. The recommended number of trials is 30. A vector of the distance between the estimates of the main model parameters of each trial and those of the base model is provided. The closest the distances are to zero the better although quantitative thresholds to accept a model have not been defined yet. Here, we calculated the 50^{th} and the 90^{th} percentiles of the distance vector and the proportion of vectors which failed to converge as ad-hoc indices to compare models.

3. Results

3.1. Overview of anchovy catches and abundance

The historical series of anchovy catches in Portugal from 1943 to 2020 showed fluctuations around a mean of 722 t (SD = 1075 t) apart from a period of consistently higher catches since 2017 (mean ± SD = 6944 ± 1705 t) and a single high value in 1943 (7476 t) (Figure 3.1). Although there were no data from Spanish catches far back in time, assuming Portuguese catches made the bulk of the catches of the stock component as seen in recent years, there were no signs of overexploitation of the resource at the beginning of the assessment period (1991). In the late 2010s the abundance "took off" reaching unprecedented levels in recent years (Figure 3.2). The index of abundance in the autumn groundfish survey in a given year *y* is significantly positively correlated with the index of abundance in the acoustic survey the following year, *y+1* (r = 0.91, p<0.001). Both indices presented marked fluctuations since 2015; the groundfish survey showed an increase to very high abundance in 2017, which resulted mainly from a single haul with a catch of 600 Kg of adult anchovy; abundance drops markedly the following autumn (2018). A similar, although less dramatic, variation was observed in the acoustic survey from 2017 to 2018.

Total catches showed a strong seasonal component, being the highest in the 3rd quarter of the year and decreasing from the 3rd quarter of a year to the second quarter of the next year (Figure 3.3). On average, 36% of the catches were obtained in the first semester.

Length frequency distributions (LFDs) of catches and surveys by semester available from the period 2015 – 2020 indicate that surveys observe smaller sized anchovy than caught in the fisheries (Figure 3.4). The difference is more pronounced in the second semester, with the autumn groundfish survey showing large proportions of individuals around 11 cm (possibly recruits) in some years.

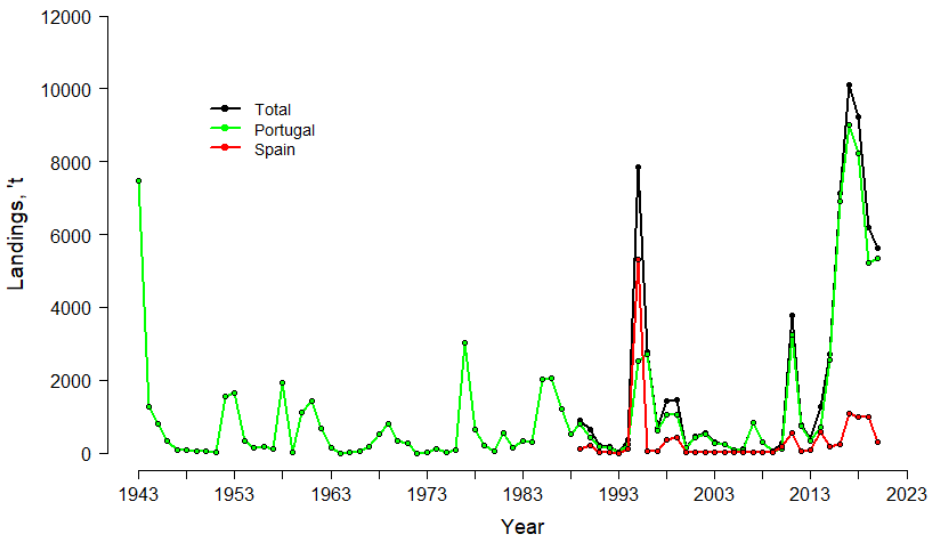


Figure 3.1 – Anchovy 9a-west: annual catch 1943 – 2021 by country and in total.

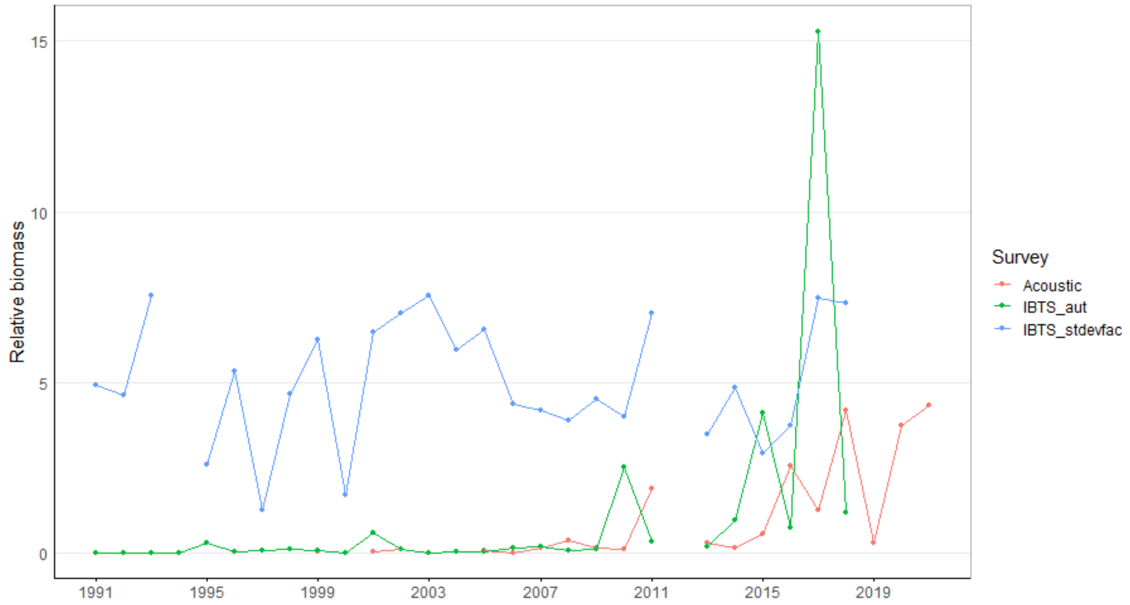


Figure 3.2 – Anchovy 9a-west: Index of the abundance of the spring acoustic survey 1999 – 2021 and index of abundance and coefficient of variation of the Portuguese autumn groundfish survey 1991 – 2018. Each survey and CV observation was divided by the mean of the corresponding series, therefore each series has a mean = 1 (the CV series was multiplied by 5 to improve the readability of the figure).

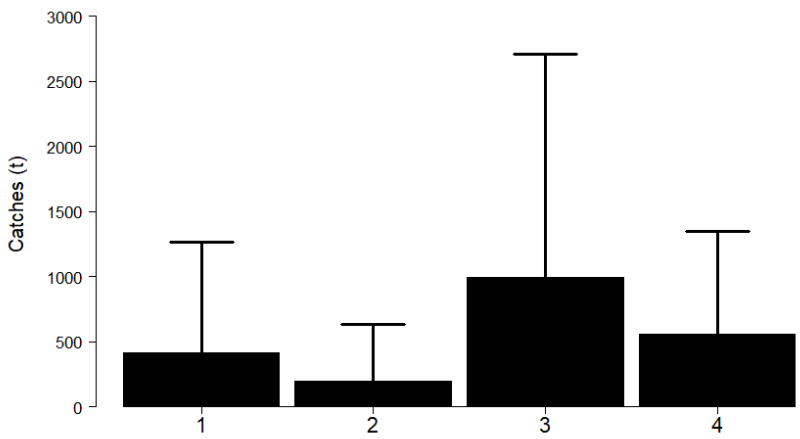


Figura 3.3 - Anchovy 9a-west: Mean catches by quarter in the period 1991 – 2021. Bars represent 1 standard deviation.

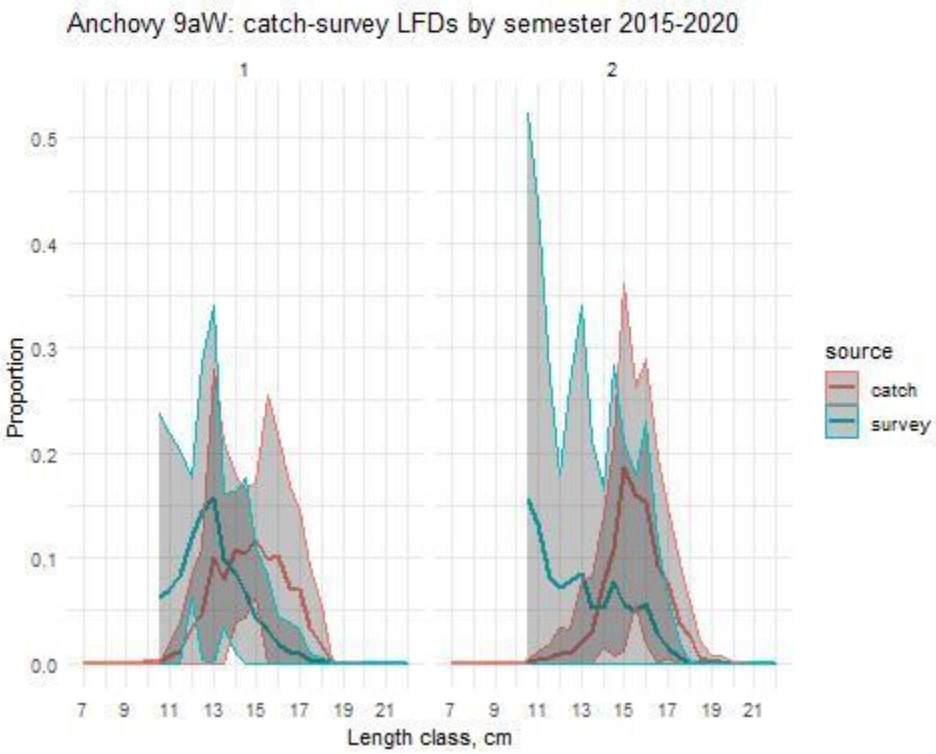


Figure 3.4 – Anchovy 9a-west: Mean proportion of individuals per ½ cm length class in the catches and the surveys by semester in the period 2015 – 2020.

3.2. Model diagnostics and results

Table 3.1 presents a summary of the main model diagnostics, parameters and derived quantities with corresponding estimates of uncertainty, for models which converged, had random, unbiased and independent residuals and, showed a minimum of four converged retrospective runs with consistent trajectories over time. Out of the initial 160 models, fourteen were retained on this step, 10 based on bi-annual catch data of which 4 used the acoustic survey and 6 used both the acoustic and the groundfish survey. All 14 models had, at least, one parameter with a prior from Table 2.2.

None of the models complied with the ICES guideline about the magnitude of B/B_{MSY} and F/F_{MSY} confidence intervals. Considering that larger uncertainty is expected for small pelagic fish due to their highly variable dynamics, this criterion was relaxed to admit models which estimated B/B_{MSY} and F/F_{MSY} confidence intervals spanning 2 orders of magnitude of the point estimates (T. Mildenberger, personal communication).

Models 11 to 14 showed the best performance in hindcast cross-validation of survey indices and overall good resistance to jittering of initial parameters (Table 3.1). Except for model 11, all showed MSY-K correlations above + 0.95; on the other hand, model 11 showed high sensitivity to the perturbation of initial values in a few trials. The four models had a similar performance regarding the checklist criteria and comparable point and uncertainty estimates of parameters (Table 3.1). The second retrospective trajectory, corresponding to the run with the 2019 acoustic survey and the 2018 groundfish survey as the last survey data points indicated considerably higher F/F_{MSY} and lower B/B_{MSY} in 2019 (with some backward effect) than the remaining retrospective runs (Figure 3.1). These surveys showed a 90% drop in biomass from the previous year’s surveys and were followed by an increase of biomass of more than 1000%.

While any of the four models could be considered for further analysis, model 12, assuming a Schaefer production curve (n = 2), a Thorson prior on r (lognormal, mean=0.68, SD=0.30) and a lognormal prior on B1/K with mean = 0.20 (CV=0.50), corresponding to an initial depletion of 80%, seemed to have a slightly better retrospective, hindcast and convergence performance than the other 3 models (Table 3.1; Figures 3.1 and 3.2). Residuals complied with the assumptions of normality, no bias and independence (Figure 3.3). The retrospective pattern of the period 2016 – 2021 was positive for both B/B_{MSY} and F/F_{MSY} and, according to Mohn’s Rho, substantially stronger for the latter while still below the threshold for short-lived species of 0.30. MASE scores were <1 for both surveys indicating the model had a superior prediction skill than the naïve baseline forecast (MASE=0.5 means twice as accurate as of the naïve forecast, i.e.; assuming the same abundance next year; Carvalho *et al.* 2021). The groundfish survey appears to have a better prediction skill than the acoustic survey; however, it is unclear if the fewer number of years used to calculate the MASE of the groundfish survey, 5 instead of 7 years, may have affected the result and prevented a fair comparison. Posterior distributions indicated that there is not much information on the data to estimate the intrinsic growth rate (Figure 3.4). Estimates of alpha ratios indicated that biomass process error was around double the observation error for both surveys (Table 3.1). On the other hand, the fishing mortality process error was about half the catch observation error. The estimate of B_{1991}/K (mean=0.11, CV=0.52) pointed to a depleted stock at the beginning of the assessment period.

Historical variations of B/B_{MSY} and F/F_{MSY} are shown in Figure 3.5. Point estimates of F/F_{MSY} were below 1 across most of the period. However, the huge confidence interval until the mid-2000s prevents any conclusion about the state of the stock. B/B_{MSY} fluctuated well below 1 until 2010. Since 2016, the stock has fluctuated slightly above B_{MSY}. On the 30 of June 2021, the end of the assessment period, the relative fishing mortality was estimated to be 0.06 and the relative total exploitable stock biomass was estimated to be 1.15, suggesting that the stock was healthy.

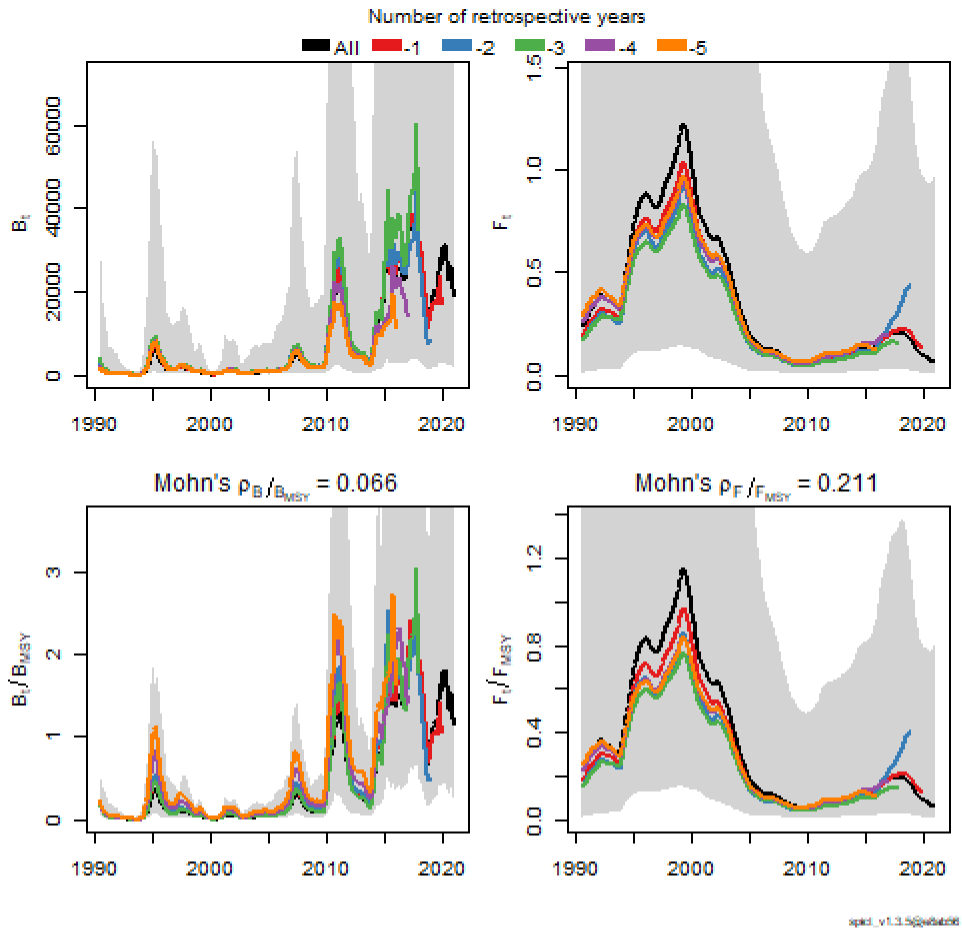


Figure 3.1 – Anchovy 9a-west: Retrospective error of B_{MSY} and F_{MSY} (top panel) and B/B_{MSY} and F/F_{MSY} (bottom panel) of model 12.

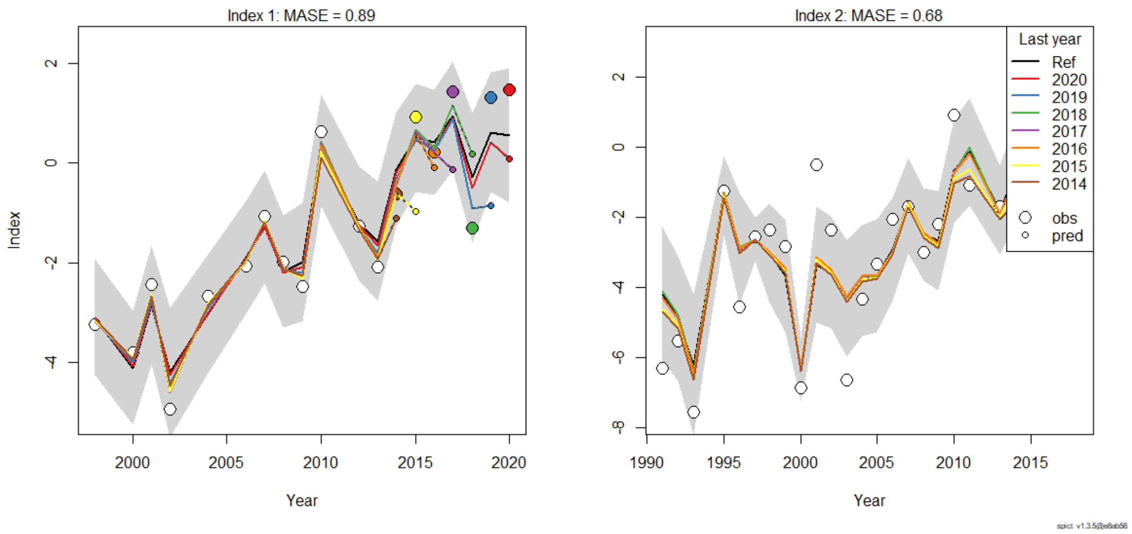


Figure 3.2 – Anchovy 9a-west: Hind-cast cross-validation results for the acoustic (left) and groundfish survey indices (right). The reference result corresponds to the result of Model 12; seven and five hindcast runs were carried out for the acoustic and the groundfish surveys, respectively (the last groundfish survey was in 2018).

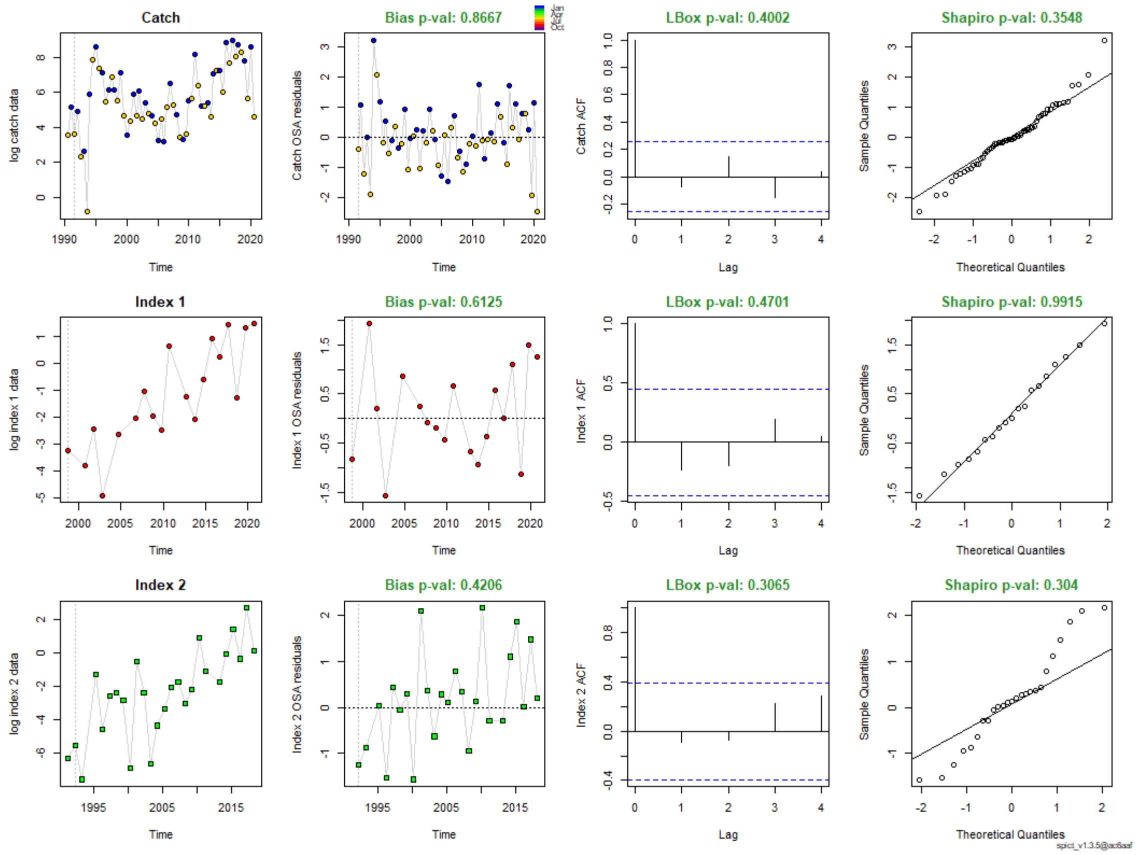


Figure 3.3 – Anchovy 9a-west: Plots of catch and survey residuals of Model 12.

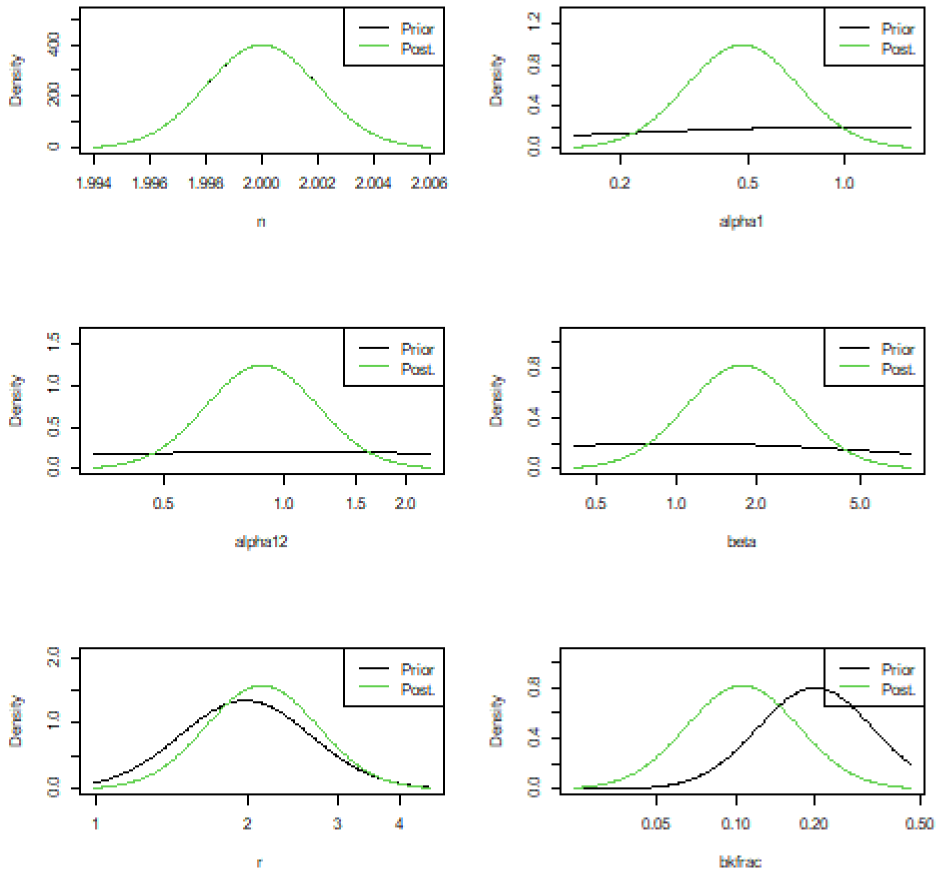


Figure 3.4 - Anchovy 9a-west: Prior and posterior distributions of n, alphas, beta, r and bk fraction of Model 12.

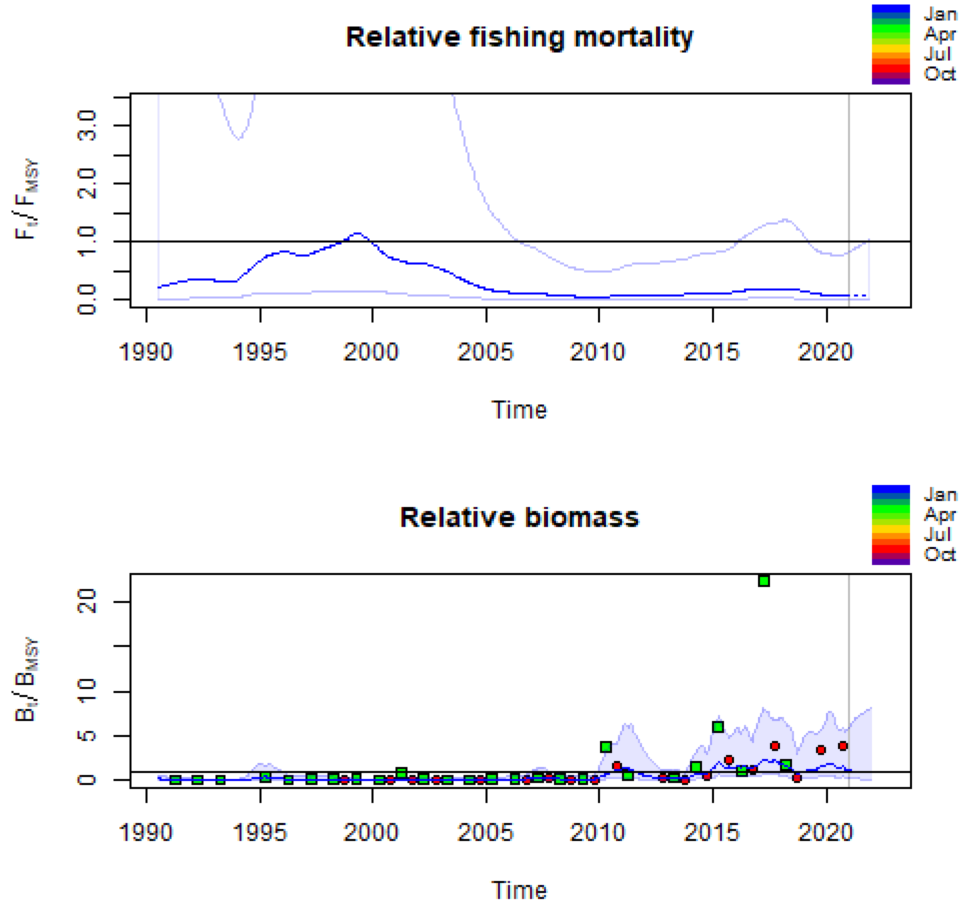


Figure 3.5 – Anchovy 9a-west: Historical F/F_{MSY} and B/B_{MSY} trajectories over the period 1991 – 2021. 95% CIs of relative biomass and fishing mortality are shown using shaded blue regions. The end of the data range is shown using a vertical grey line. Data are shown using points coloured by season.

3.3. Sensitivity of Model 12 to potentially biased survey data points

Three sensitivity tests of model 12 to down-weighting the following survey data points were carried out:

1) 2019 acoustic survey
2) 2019 acoustic survey and 2018 groundfish survey
3) 2017 groundfish survey

In all cases, the standard deviation of the data point was increased by a factor of 3, meaning an increase from 1 to 3 in the case of acoustic surveys and an increase from 1.44, to 4.32 in the case of 2018 groundfish survey.

Compared to Model 12, both models 1) and 2) showed a small decrease in the CV of B/B_{MSY} and the MASE of the acoustic survey (both around 8%) (Table 3.2). Changes in the CVs of the remaining parameters were negligible. The divergence of the second peel of the retrospective analysis decreased substantially in both runs compared with model 12 (Figures 3.1 and 3.6). Graphically, the fit of the model to the biomass in the two most recent years 2 improved (Figure 3.7). However, the Mohn's Rho of B/B_{MSY} and F/F_{MSY} increased 124% and 9% in comparison to model 12, respectively, something that was contrary to the expectation given the graphical pattern

Regarding test 3), down-weighting the 2017 groundfish data point decreased substantially the Mohn's Rho of F/F_{MSY} (67%) at the cost of cancelling the predictive power of the survey (MASE=1.1) (Table 3.2).

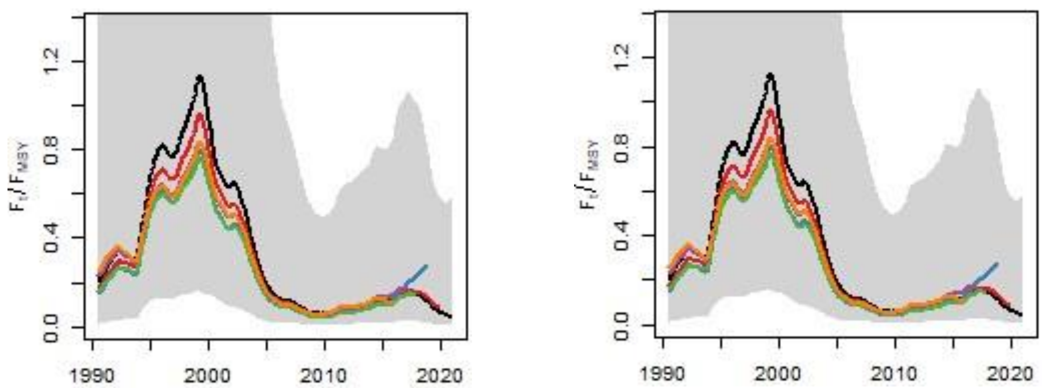


Figure 3.6 – Anchovy 9a-west: F/FMSY retrospective runs of models with down-weighted 2019 acoustic survey (left) and both the latter and the 2018 groundfish survey (right).

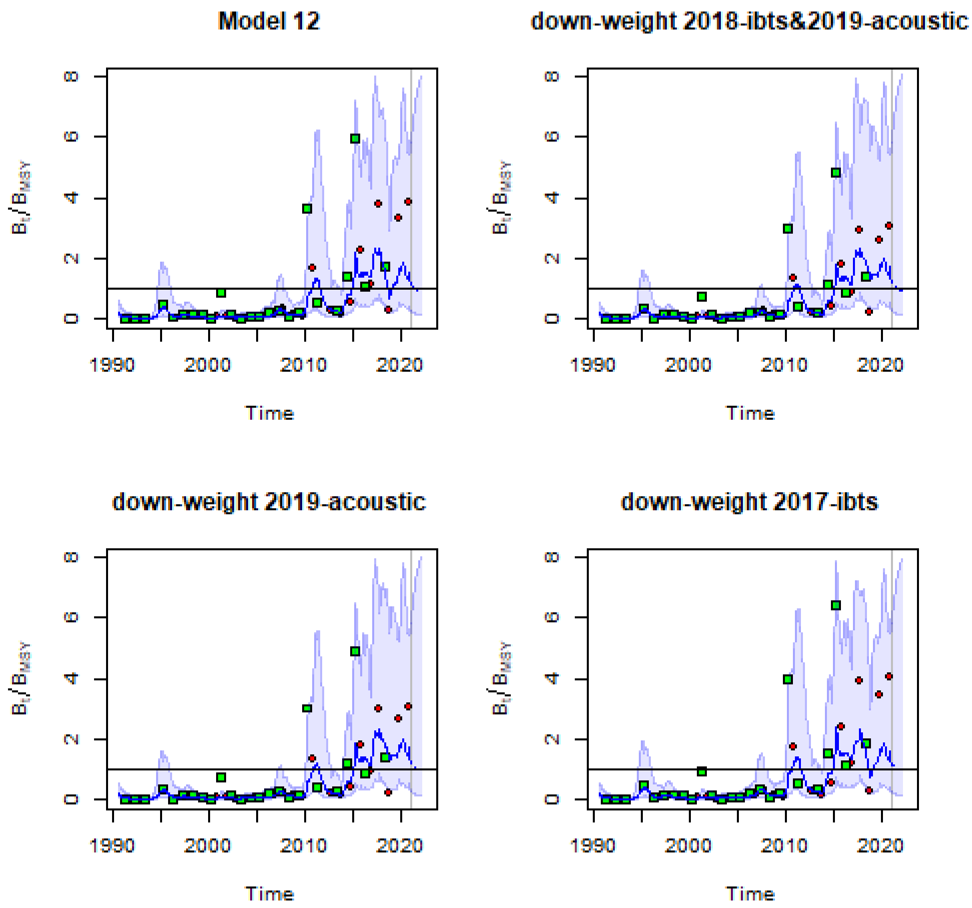


Figure 3.7 – Anchovy 9a-west: Plots of B/BMSY estimates of Model 12 and the models with down-weighted 2018 groundfish and 2019 acoustic surveys observations, down-weighted 2019 acoustic survey observation and down-weighted 2017 groundfish survey observation. The y-axis is truncated at 8 therefore the 2017 groundfish survey observation is not visible.

3.4. Sensitivity of Model 12 to the default prior assumptions on alpha and beta

Three additional sensitivity tests were:

4) Excluding the beta default prior
5) Excluding the alfa default prior
6) Excluding beta and alfa default priors

All tests had small effects on the CVs of parameters and derived quantities (Table 3.2). The main improvement when estimating alpha and beta parameters without priors was a decrease of 25-30% on F/F_{MSY} Mohn's Rho. Although at the same time the Mohn's Rho of B/B_{MSY} increased about 10%, the values were still well below the limits. Therefore, the free estimation of both alpha and beta parameters might be an option to consider in the final model.

4. Discussion

The following bullet points summarise the discussion in the group plenary:

- Surveys may not always represent the exploitable biomass, as they observe larger proportions of small individuals in years of good recruitment; small individuals may also be under-represented in the catches if there is slipping in those years; the fact that surveys are point observations in time may contribute to the differences observed in the LFDs; it may be sufficient that surveys cover the general length range caught in the fisheries; in future work, it may be worth to test the influence of a larger cut-off length (e.g. >13 cm) or corrected LFDs following Pedersen *et al.* (2017);
- The index of biomass of the autumn groundfish survey appears to be an acceptable index of abundance of anchovy since it showed a significantly positive correlation with that of the spring acoustic survey in the following year; both indices should continue to be explored for assessment purposes;
- PELACUS estimates are available since 2007 therefore this is the first year in the ICES assessment. In the present WD, the acoustic survey index starts in 1999, the first year with PELAGO survey estimates. Total abundance was assumed to be equal to the PELAGO estimates from 1999 to 2005 since abundance estimates of PELACUS in that period was assumed to be zero. The group considered this assumption to be acceptable since it was based on statements that PELACUS surveys were carried out although the estimation of anchovy was not possible due to its low abundance:
  "*Spanish acoustic surveys aimed at sardine have been conducted in Sub-division IXa North and Division VIIIc since 1983. Results from these surveys for the Sub-division IXa North have shown the scarce presence or even the absence of anchovy in this area (Carrera et al., 1999; Carrera, 1999, 2001). This situation still continues in the most recent years (surveys in the 2003-2007 period, see Porteiro et al., 2005; WD Iglesias et al., 2007)*". ICES, 2007, page 598)**.**

- The possibility of using PELACUS and PELAGO separately was not considered an option because PELACUS coverage is not representative of the stock since it is just a small part of the western component distribution area.

- The decision to down-weight the 2018/2019 survey data points should be discussed with survey experts;
- The group noted that in the best model (model 12), F/F_{MSY} was estimated to be near the lowest historical harvest rate level calculated in the ICES assessment and well below the average of the historical series (Figure 4.1); the wide confidence intervals, namely in the past, may partly result from some very high harvest rates in combination with gaps in the acoustic survey series;
- Finally, the seasonal F parameter was inadvertently fixed equal to 1 in the bi-annual models but should have been estimated; the correction of this issue (running: `inp$phases$logphi=1)` was found just before the meeting, there was no time to re-run the models. It is noted that correcting this issue may introduce changes to the results presented so far.
- The WG considered that the present approach may be considered for further work in a benchmark workshop.

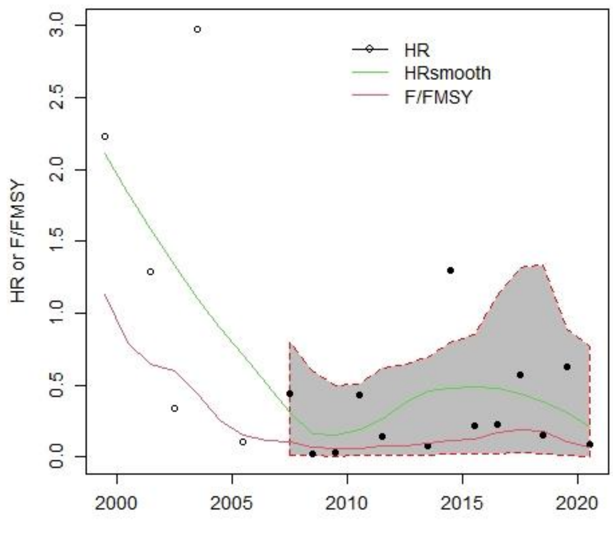


Figure 4.1 - Anchovy 9a-west: Estimates of F/F_{MSY} from the best SPiCT model (model 12) and harvest rates (ratio between annual catch and the PELAGO+PELACUS biomass) used in the ICES assessment (dots). The white dots show harvest rates before 2007 which are not used in the advice.

References

Carvalho, F., Winker, H., Courtney, D., Kapur, M., Kell, L., Cardinale, M., Schirripa, M. *et al*. 2021. A cookbook for using model diagnostics in integrated stock assessments. Fisheries Research, 240: 105959 .

Doray, M., Boyra, G., and van der Kooij, J. (Eds.). 2021. ICES Survey Protocols – Manual for acoustic surveys coordinated under 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.746

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. 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. 2021a. Workshop on Data-Limited Stocks of Short-Lived Species (WKDLSSLS3). ICES Scientific Reports. 3:86. 60 pp. https://doi.org/10.17895/ices.pub.8145.

ICES 2021b. Benchmark Workshop on the development of MSY advice for category 3 stocks using Surplus Production Model in Continuous Time; SPiCT (WKMSYSPiCT) (tech. rep.). ICES Scientific Reports. 3:20. 316 pp. https://doi.org/10.17895/ices.pub.7919

Kell, L. T., Sharma, R., Kitakado, T., Winker, H., Mosqueira, I., Cardinale, M., & Fu, D. (2021). Validation of stock assessment methods: Is it me or my model talking? ICES Journal of Marine Science, https://doi. org/10.1093/icesjms/fsab104

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.

Mildenberger, T. K., Berg, C. W., Kokkalis, A., Hordyk, A. R., Wetzel, C., Jacobsen, N. S., ... & Nielsen, J. R. (2022). Implementing the precautionary approach into fisheries management: Biomass reference points and uncertainty buffers. Fish and Fisheries, 23(1), 73-92.

Pedersen, M. W., & Berg, C. W. (2017). A stochastic surplus production model in continuous time. Fish and Fisheries, 18, 226–243.https://doi.org/10.1111/faf.12174

Zhou, A. E. Punt, R. Deng, C. M. Dichmont, Y. Ye and J. Bishop, "Modified Hierarchical Bayesian Biomass Dynamics Models for Assessment of Short-Lived Invertebrates: A Comparison for Tropical Tiger Prawns," Marine & Freshwater Research, Vol. 60, No. 12, 2009, pp. 1298-1308. doi:10.1071/MF09022

Table 3.1 - Anchovy 9a-west: Summary of data, assumptions, diagnostics and results of the models fitted to anchovy data which converged, had random, unbiased and independent residuals and, showed a minimum of four converged retrospective runs with consistent trajectories over time (14 out of 40 initial models).

						Model parameters and coefficient of variation																	
Model number	Catch aggregation	Indices of abundance	n prior	r prior	B1/K prior	n	n.cv	bkfrac	bkfrac.cv	r	r.cv	K	K.cv	alpha$_{ac}$.est	alpha$_{ac}$.cv	alpha$_{IBTS}$.est	alpha$_{IBTS}$.cv	beta	beta.cv	q$_{ac}$.est	q$_{ac}$.cv	q$_{IBTS}$.est	q.cv
1	quarter	1-acoustic	Schaefer	None	BK50	2	0	0.42	0.56	1.26	0.71	45837	1.20	0.79	0.55			1.17	0.36	4.4E-05	1.35		
2	quarter	1-acoustic and 2-groundfish	Thorson	None	BK20	1.05	0.26	0.13	0.54	0.68	0.88	24611	1.08	0.49	0.90	0.47	0.44	1.81	0.53	7.2E-05	4.8E-05	1.08	0.99
3	quarter	1-acoustic and 2-groundfish	Thorson	None	BK50	0.92	0.39	0.33	0.54	0.52	1.15	20525	0.98	0.53	1.10	0.53	0.52	1.48	0.49	7.4E-05	4.3E-05	0.83	0.78
4	quarter	1-acoustic and 2-groundfish	Thorson	None	BK80	0.87	0.36	0.53	0.53	0.48	0.99	18658	0.98	0.54	1.18	0.52	0.46	1.39	0.4	7.4E-05	4.2E-05	0.84	0.78
5	semester	1-acoustic	Schaefer	None	BK50	2	0	0.42	0.55	1.24	0.85	50828	1.35	0.79	0.63			1.07	0.46	3.9E-05	1.50		
6	semester	1-acoustic	Schaefer	Thorson	BK50	2	0	0.42	0.55	1.79	0.26	40789	1.19	0.61	0.41			1.07	0.47	5.5E-05	1.19		
7	semester	1-acoustic	Schaefer	None	BK80	2	0	0.68	0.55	1.24	0.73	47786	1.23	0.81	0.59			1.00	0.44	4.1E-05	1.37		
8	semester	1-acoustic	Schaefer	Thorson	BK80	2	0	0.69	0.55	1.78	0.26	38238	1.15	0.62	0.42			1.02	0.46	5.8E-05	1.14		
9	semester	1-acoustic and 2-groundfish	Schaefer	None	None	2.0	0.0	0.00	2.20	2.53	0.36	67843	1.82	0.43	0.67	0.48	0.36	1.70	0.49	4.7E-05	3.8E-05	1.56	1.41
10	semester	1-acoustic and 2-groundfish	Schaefer	Thorson	None	2.0	0.0	0.00	2.20	2.18	0.24	86715	1.99	0.47	0.73	0.44	0.33	1.72	0.5	3.7E-05	3.0E-05	1.65	1.51
11	semester	1-acoustic and 2-groundfish	Schaefer	None	BK20	2.0	0.0	0.10	0.53	2.58	0.48	25387	1.56	0.44	0.78	0.48	0.40	1.86	0.53	9.2E-05	5.7E-05	1.62	1.66
12	semester	1-acoustic and 2-groundfish	Schaefer	Thorson	BK20	2.0	0.0	0.11	0.52	2.13	0.26	34166	1.31	0.48	0.88	0.42	0.33	1.78	0.52	6.5E-05	4.0E-05	1.26	1.25
13	semester	1-acoustic and 2-groundfish	Schaefer	Thorson	BK50	2.0	0.0	0.26	0.54	2.09	0.26	37817	1.34	0.47	0.93	0.43	0.34	1.63	0.51	5.7E-05	3.2E-05	1.30	1.29
14	semester	1-acoustic and 2-groundfish	Schaefer	Thorson	BK80	2.0	0.0	0.42	0.55	2.07	0.26	38702	1.33	0.48	0.98	0.43	0.34	1.53	0.5	5.4E-05	2.9E-05	1.29	1.28

	Absolute reference points			Relative reference points		Coefficient of variation			Mohn's Rho			Sensitivity to initial values			Hindcast crossvalidation (MASE)			
Model number	BMSY	FMSY	MSY	B/BMSY	F/FMSY	B/BMSY	F/FMSY	Abs(param correlations) > 0.95	B/BMSY	F/FMSY	Comments on retro	P50 dist.	P90 dist.	Prop. fail	Acoustic survey (5 runs)	Groundfish survey (3 runs)	Number not converged (order)	other comments
1	NaN	0.37	NaN	1.52	0.02	0.82	2.35		0.06	0.13	retro-2 contrasts with the others; retrospective -5 not converged	0.47	193286.45	0.19	0.96	-	3 (5, 6, 7)	
2	NaN	0.62	NaN	1.88	0.04	1.58	1.91		-0.08	0.26	retrospective -5 not converged	0.12	0.49	0.16	1.00	0.47	2 (6, 7)	Odd shape of the production curve
3	7240	0.57	4113	2.59	0.04	2.01	1.98		-0.11	0.09		0.15	11327.14	0.26	1.13	0.68		
4	6401	0.56	3555	2.98	0.03	1.98	2.04		-0.16	0.15		0.13	11469.48	0.23	1.16	0.72		
5	NaN	0.36	NaN	1.4	0.04	0.86	3.11		0.11	0.18		0.13	72941.05	0.06	1.07	-	1 (7)	
6	NaN	0.74	NaN	1.28	0.04	0.89	3.01	MSY-K	0.18	0.24	retro-2 contrasts with the others	0.08	0.31	0.16	1.05	-	1 (7)	
7	NaN	0.37	NaN	1.44	0.04	0.83	2.94		0.12	0.17		0.29	136430.71	0.00	0.91	-	2 (6, 7)	
8	NaN	0.73	NaN	1.31	0.04	0.87	2.86	MSY-K	0.19	0.19		0.14	0.44	0.16	1.07	-	1 (7)	
9	NaN	2.64	NaN	0.96	0.03	1.03	2.16	MSY-K	0.08	0.12	Trajectories diverge to the past	0.25	16322.83	0.06	0.74	0.66		
10	NaN	1.37	NaN	0.97	0.03	1.03	2.39	MSY-K; q$_{ac}$-q$_{IBTS}$	0.08	-0.11		0.45	1.06	0.10	0.75	0.67		
11	NaN	2.94	NaN	1.11	0.07	0.96	2.16		0.05	0.24		2.72	108623.70	0.13	0.89	0.66		
12	NaN	1.25	NaN	1.15	0.06	0.95	2.18	MSY-K	0.07	0.21	retro-2 contrasts with the others	0.09	0.35	0.03	0.89	0.68		
13	NaN	1.16	NaN	1.18	0.05	0.96	2.33	MSY-K	0.07	0.25		0.12	0.49	0.03	0.93	0.71		
14	NaN	1.14	NaN	1.20	0.05	0.96	2.36	MSY-K	0.07	0.27		0.12	0.53	0.10	0.94	0.73		

Table 3.2 – Anchovy 9a-west: Percentage of change of point estimates and coefficients of variation between Model 12 and each of the sensitivity test models.

Sensitivity test	Model	BBMSY	BBMSY.CV	FFMSY	FFMSY.CV	B.MoR	F.MoR	bkfrac	bkfrac.cv	r	r.cv	K	K.cv	$alpha_{ac}$.est	$alpha_{ac}$.cv	$alpha_{IBTS}$.est	$alpha_{IBTS}$.cv	beta	beta.cv	q_{ac}.est	q_{ac}.cv	q_{IBTS}.est	q.cv	P50 dist.	P90 dist.	Prop. fail	MASE Acoustic survey (5 runs)	MASE Groundfish survey (3 runs)
13	Down-weight acoustic 2019	9.6	-8.4	-33.3	-1.8	123.9	19.3	-9.1	0.0	-1.4	0.0	22.9	0.8	-25.0	-1.1	11.9	-3.0	1.1	-1.9	3.4	-1.0	-0.8	-0.6	-52.9	1.4	400.0	-7.7	0.000
14	Down-weight groundfish 2018 & acoustic 2019	8.7	-7.4	-33.3	-1.4	127.0	28.4	-9.1	0.0	-0.9	0.0	24.7	2.3	-27.1	-2.3	11.9	0.0	1.7	-1.9	2.6	-0.7	-0.1	0.0	-52.9	-1.4	300.0	-7.7	0.000
15	Down-weight groundfish 2017	0.9	-1.1	0.0	-1.8	118.6	-67.1	-9.1	0.0	2.3	0.0	-8.5	-1.5	0.0	-8.0	0.0	6.1	0.0	0.0	4.9	1.5	-0.7	-0.2	17.6	71.6	0.0	0.3	1.1
16	No beta prior	0.0	0.0	0.0	0.5	-5.7	-4.3	0.0	0.0	0.5	0.0	-1.6	0.8	0.0	0.0	0.0	0.0	3.4	3.8	1.7	1.7	1.3	1.4	100.0	80.3	200.0	-0.1	-0.2
17	No alpha prior	0.9	-1.1	0.0	0.9	10.0	-25.7	0.0	0.0	0.9	0.0	1.6	0.8	-4.2	-1.1	7.1	0.0	0.0	0.0	-0.8	-0.5	0.9	0.9	41.2	84.1	300.0	-0.8	-0.2
18	No alpha&beta priors	0.9	0.0	0.0	1.4	11.4	-30.5	0.0	0.0	0.9	0.0	0.0	2.3	-4.2	-2.3	7.1	0.0	3.9	3.8	0.9	1.2	2.3	2.3	105.9	71.0	200.0	-0.9	-0.3

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 updated	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 2021	Sardine 8c and 9a

Annex 4: Review of ICES Scientific Report

Expert group Chair: Leire Ibaibarriaga

Secretariat representative: David Miller

WGHANSA I

1.1 Audit of Anchovy 9a (ane.27.9a)

Date: 30/05/2022
Auditor: Andrés Uriarte and Laura Wise

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 is based on the recently approved by ACOM, 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).

- For both components the stock annex has been followed as much as possible, i.e. except the non inclusion of the missing survey ECOCADIZ 2021 in the assessment model of the 9a South component.program
- 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 9 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.
Recommendation: The evaluation of the potential utility of these surveys to improve the assessment and provision of advice deserves a full benchmark and a recommendation was put forward for consideration of ACOM.

For the western component the information on recruits coming from IBERAS acoustic survey in autumn is not used, though preliminary analysis of its consistency vs. the PELAGO age 1 estimates in the following year, shows it yet to be weak.

- This year no major damage on data input arising from the COVID19 disruption has been reported.

- The major weakness has come from the lack of the summer ECOCADIZ acoustic survey in 9aSouth in 2021 whose continuity is not guaranteed.

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 fifth year where advice following the precautionary approach will be provided and the fourth without the use of the 80% uncertainty cap.

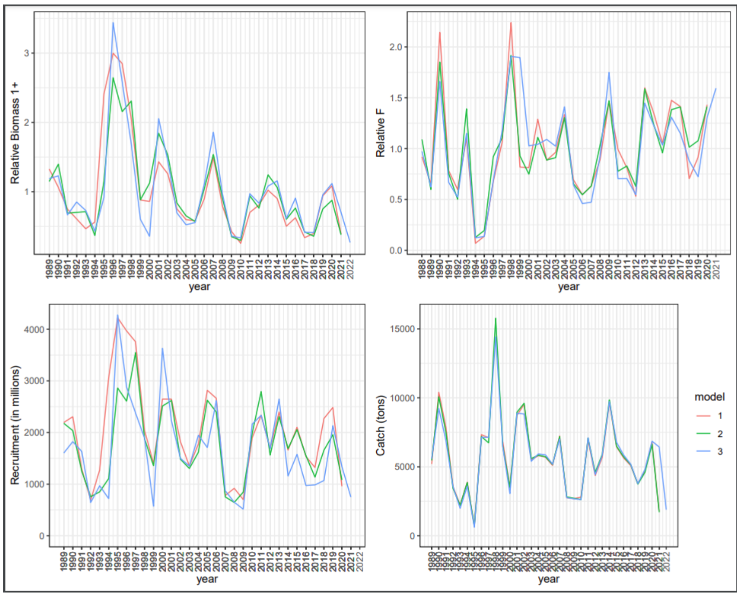
The assessment of Anchovy 9a South:

- It was carried out as expected, i.e. following the stock annex, by incorporating the new information from the acoustic survey PELAGO 2022, and commercial catch in the last year (2021) with their quarterly ALKs and finally the total catch for the first half of the year 2022 (assuming historical % of catches in June). However, the summer ECOCADIZ acoustic survey in 9a South in 2021 was not carried out due to technical problems and couldn't be used as input to the assessment. This survey will not be carried out in 2022 either and therefore its continuity is not guaranteed.

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). Outputs are rather consistent with past year.
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, 2022 index included) and ECOCADIZ (last index from Summer 2020 index already included in the assessment carried out in 2021).
5) **Consistency**: This new assessment was carried out accordingly to the stock annex but the ECOCADIZ survey estimate in 2021 was missing.

Compared to last year assessment, there is a global consistency, although there has been some revision of the series in absolute terms, whereby biomass has been rescaled globally slightly upward. These changes are somewhat expected with the addition of new data (catch and index information). In relative terms and from that point of view the assessment of the relative series of B1+ is not much changed compared to past assessment output year (blue line is the current assessment and the red line is the past assessment in the figure below). Nevertheless, the ratios between recent years of B1+ estimates have changed slightly and this affects the advice procedure which uses those ratios to correct the former catch advices (see technical comments at the end of this subsection on anchovy in 9a).



6) **Stock status**: Although the assessment of B1+ is not taken in absolute terms but as relative indicator of stock abundance, current B1+ is at the lowest level of the historical series, below B_{pa} and B_{lim}. 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**: A trend based advice, following the "one-over-two" ratio of B1+ series from the Gadget assessment model, with an uncertainty cap of +/- 80%, applied to the advised catch of the previous management season (from 1 July 2021 to 30 June 2022). This is 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 has been implemented with a biomass safe guard reducing factor, because the current B1+ is estimated to be below B_{lim}, which is taken as $B_{trigger}$ for this assessment. For this reason the 1-over-2 ratio (0.294) was also multiplied by a biomass safe guard ratio of 0.803 ($B_{current}/B_{lim}$), which produced a combined relative change from previous advice of 0.236. This implied a catch advice for the 2022/2023 management period 76% lower than in 2021/2022.

9) **Data issues:** The biomass estimates from the spring PELAGO survey arrived during the Working Group and there were some unresolved issues with the data that require revision in the next future. Though the estimates were considered precise enough for the provision of advice, the definitive revised estimates will only be available in November 2022 for examination of ICES WGACEGG.

The summer ECOCADIZ acoustic survey in 9a South in 2021 was not carried out and could not be used as input to the assessment. This survey will not be carried out in 2022 either and therefore its continuity is not guaranteed. A recommendation is passed endorsing its continuity.

All available and inferred catch data as well as survey inputs were fully used for the assessment.

Some additional surveys (ECOCADIZ-Reclutas and Bocadeva) are available but aren't used in the assessment. This was agreed in the 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.

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 can propagate to the following years.
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 like saying 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 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.

<u>On the basis of the advice</u>: ADVICE does not deviate from the standard ICES guidelines for category 3 short lived stocks

Conclusions
- The assessment has been performed correctly SALY.

- The southern component of the stock is assessed to be below the historical mean and below B_{lim} in 2022
- The revision of the estimates of B1+ in recent years, according to the updated assessment, would have induced some changes in the advice produced this year for 2022/2023.
- The advice does not deviates from the recently adopted standard ICES guidelines for category 3 stocks advice which allows a 80% uncertainty cap for short lived species and has by the first time included a biomass safe guard.

B. Anchovy 9a West:
For the western component of anchovy in 9a (distributed in 9a North, Central North and Central South) the stock size indicator is the combined acoustic biomass (B1+) estimated from PELAGO spring acoustic survey over the continental western shelf of Portugal (9a Central North + 9a Central South) and PELACUS in 9aN in spring as well. This is the fifth year where advice will be provided and the third subject to the 80% uncertainty cap (Advice of 2019, 2021 and the current 2022) .

The assessment of Anchovy 9a western:
- It was carried out as expected (SALY) incorporating the new information from PELAGO 2022 + PELACUS 2022, plus the commercial catch in the second half of year 2021 and the first half of the year 2022 catches (assuming catches in May and June). This is not an

analytical assessment and catches-at-age are not used for the assessment or provision of advice.

For single stock summary sheet advice (Western Component):

1) **Assessment type:** update (last benchmarked in 2018)
2) **Assessment**: Direct input from the combined spring acoustic survey covering subdivisions 9a North + 9a Central North + 9a Central South. Since this is a Category 3 stock, the analytical assessment is only used as a relative indicator of stock trends (not as absolute estimates).
3) **Forecast**: not required; The advice follows the catch advice Rule for category 3 short lived data-limited stocks.
4) **Assessment model**: Not applicable
5) **Consistency**: This new assessment was carried out according to the stock annex.

   This year of 2022 the PELAGO+PELACUS spring acoustic estimates represents the highest survey index of the time-series, almost double of the former maximum observed in 2021.
6) **Stock status**: Although the assessment is not taken as absolute but as relative, current B1+ is around 112 000 t , the highest of the historical series. No B_{lim} or $B_{trigger}$ have been defined for this western component.
7) **Management Plan**: There is no management plan
8) **Basis of the advice**: A trend based advice, following the "one-over-two" ratio of B1+ indexes from the combined acoustic estimate, with an uncertainty cap of +/- 80%, applied to the advised catch for the previous management season (from 1 July 2021 to 30 June 2022). This is like in-year advice as approved in the stock annex for this category 3 stock. The one-over-two ratio is 1.83 and therefore a maximum increase of up to 80% (the uncertainty cap) was applied. This implied a catch advice for the 2022/2023 management year of 14083 tonnes, corresponding to a Harvest rate of 0.126.
9) **Data issues:** The biomass estimates from the spring PELAGO survey arrived during the Working Group and there were some unresolved issues with the data that require revision in the next future. Though the estimates were considered precise enough for the provision of advice, the definitive revised estimates will only be available in November 2022 for examination of ICES WGACEGG.

Some additional surveys on recruits (Juvesar and/or IBERAS) are available but are not used in the assessment as agreed in the benchmark until proving a satisfactory performance in relation to the combined spring acoustic surveys.

General comments

In 2021, the acoustic index had reached its highest value (65683 t) very similar to the second highest (65096 tonnes record in 2018). The estimates in 2022 are again the highest in the series. In this period the harvest rate implied by the advice based on the 1 over 2 rule has been decreasing from 0.16 in 2020 to about 0.12 in 2021 and for the current 2022 advice.

Technical comments:

This year and in the previous year the expert group considered that the current advice procedure for short-lived species category 3 stocks, based on the 1-over-2 ratio with uncertainty cap of 80%, is still not flexible enough to adapt to the highly fluctuating nature of this stock component. The approach (1-over-2 with 80%UC) can only be taken as an interim approach while a better formulation for providing advice can be established, either by allowing greater uncertainty caps (such as being capable of restoring catch levels when sharp increases of the population occurs) or simply by applying harvest rates to the most recent biomass estimates from surveys.

Further work is planned to be carried out to manage these highly fluctuating populations.

Current comments do also apply to the Anchovy southern component.

On the basis of the advice: ADVICE does not deviate from the standard ICES guidelines for category 3 short lived stocks.

Conclusions

- The assessment has been performed correctly SALY.
- The western component of the anchovy stock in 2022 is assessed to be well above historical mean value (it is at the highest biomass levels).
- The advice does not deviate from the recently adopted standard ICES guidelines for category 3 stocks advice which allows a 80% uncertainty cap for short lived species, though the group considers this as an interim approach until finding a better way to manage these oscillating anchovy resources.

1.2 Audit of Southern Horse Mackerel (hom.27.9a)

Date: 31/05/2022
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 were reported in years 2012, 2019 and 2020 due to technical/legal issues or Covid disruption in 2020. For 2021 no missing data were reported, and the assessment model fitting was carried out following the stock annex. As survey data from 2021 provided information on previous years' recruitment, the usual procedure detailed in the stock annex for the short-term forecast was recovered (in 2019 and 2020 some deviations were needed).

For single-stock summary sheet advice

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 2020 remain basically the same as in the last assessment, no significant upward or downward revisions have been observed.
6) Stock status: SSB >> $MSYB_{trigger}$; F << F_{MSY} ; high uncertainty on last years' R.
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.

WGHANSA II

1.3 Audit of Bay of Biscay anchovy stock (ane.27.8)

Reviewer: Maxime Olmos
Date: 30/11/2022
Expert group Chair: Leire Ibaibarriaga
Secretariat representative: David Miller

General

The Bay of Biscay anchovy stock assessment was benchmarked in February 2013 (ICES, 2013).

Model structure
The assessment for the Bay of Biscay anchovy population is a Bayesian two-stage biomass-based model (CBBM; Ibaibarriaga et al., 2011). In this model, the population dynamics are described in terms of biomass with two distinct age groups: (i) recruits (or fish aged 1 year) and (ii) fish that are 2 or more years old. The biomass changes exponentially with time according to intrinsic growth, natural mortality and fishing mortality rates.
Growth and natural mortality are separated processes that are assumed constant along time but distinct across age groups (recruits and older individuals). Fishing mortality is treated as a continuous process in time and separable into age and year effects.

Inputs data

- *Likelihoods*
    - Biomass from DEPM (BIOMAN) and acoustic survey (PELGAS) are log-normally distributed. Observed biomass are scaled to the true population biomass by the catchability coefficient defined for each survey.
    - Age 1 biomass proportion from the acoustics and DEPM surveys follow a beta distribution
    - Juvenile abundance index from the JUVENA surveys are log-normally distributed; where the abundance index observed in year (y-1) is related to the true recruitment (age 1 biomass in January of year y) by a power model, and the observed recruitment is scaled to the true recruitment by a catchability coefficient
    - Total fisheries catch by semester are log-normally distributed
    - Age 1 biomass proportion in the catch by semester follow a beta distribution
    - Growth rates by ages are normally distributed (where observed growth is the logarithm of the weights-at-age ratio estimated from surveys in consecutive year (Ibaibarriaga et al., 2011).

- *Data from 2022 assessment and potential differences with 2021 assessment*
    - 2022 biomass from PELGAS, BIOMAN, JUVENA
    - 2022 age proportion from PELGAS and DEPM
    - Growth per age group from observed weights at age
    - Updated catch 2021 for France: no length sampling was available due to low total landings so the same age structure as AZTI catches in 8abd were used

- Preliminary catch 1st semester 2022 (total and age 1):
  - *Spanish catches preliminary (based on sales)*
  - *French catches in 1st sem same age structure as Basque catches in June*
- Preliminary total catch second semester 2022 under the assumption that:
  - *France and Spain: Nov-Dec catches are 2.4% of the total catch (average 2010-2021), i.e. Nov-Dec 612 tonnes.*
- Preliminary total catch Jan-Oct 2022: 24884 tons (264 Fr, 24619 Sp from which only 5340 landed in the Basque Country)

Parameters and inference

The unknown parameters are the initial biomass, the mean and the precision of the recruitment process in log scale, the acoustic and DEPM surveys catchabilities, the catchability and the power parameters of the JUVENA index, the precision of the survey and catch observation equations, the year and age components of the fishing mortality by semester, the annual intrinsic growth rates by age, the precision of the observation equations for growth. The natural mortality is fixed at the values agreed by the WG.

Bayesian posterior distributions were approximated using Monte Carlo Markov Chain (MCMC).

Deviation for the stock annex

For the 2021 assessment, biomass and age structure estimates in 2020 by the PELGAS survey were missing due to COVID.

For the 2022 assessment, there is no deviation in the assessment from the stock annex (no data missing), except how the age structure for French catch was defined due to low total landings and such a small deviation does not have a significant impact in the assessment estimates and in the catch advice for 2023 (French catches represent 0.02% of the total catch in 2021 ; totalCatch(2021) = 27982, frenchCatch (2021)=64 tons).

For single-stock summary sheet advice

8) Assessment type: update
9) Assessment: presented
10) Forecast: presented
11) Assessment model: Bayesian two-stage biomass dynamic model.
12) Consistency: The assessment is consistent with last year´s assessment. Recruitment (age 1) in 2021 was significantly revised upwards.
13) Stock status: SSB>B_{lim} (21000t) since 2009. SSB has decreased compared to 2021 but still shows a very high value (B_{pa}, MSY $B_{trigger}$ and F_{MSY} not defined for this stock).
14) Management plan: harvest control rule evaluated as precautionary by ICES and agreed in 2016. According to this HCR, TAC_{y+1}=0 if the estimated SSB_{y+1}≤24 000 tonnes, TAC_{y+1}=-2600+0.4*SSB_{y+1} if 24 000≤SSB_{y+1}≤89 000 tonnes and TAC_{y+1}=33 000 tonnes if SSB_{y+1}>89 000 tonnes.

    SSB for 2023 is defined as mid-May estimate, with 60% of the catch assumed to be taken in the first six months of the year. Because SSB(2023)= 120428, catches in 2023 should be no more than 33 000 tonnes

General comments

The assessment is well documented. The stock assessment input data and the assessment run code was available for the audit. Checking was performed by confronting the input data files for the assessment and for the short-term forecast.
In terms of outputs, historical trends in recruitment, SSB and harvest rate show consistent trends with previous assessments.

Potential typos

In the advice sheet, in Table 1, Recruitment = 82388 whereas in Table 9, Recruitment = 82389 (the advice sheet has been corrected changing the recruitment in Table 1 to 82389)

Technical comments

In Table 9 of the advice sheet, called "Assessment summary", I noticed that the catches column corresponds to the total catches and not the catches used in the assessment model (catches for age 1 and 2+). Because this Table 9 describe the summary of the assessment, may I suggest to provide the data (catches for age 1 and 2+) related to the assessment model and not the total catches.

Conclusions

The assessment and short-term forecast have been performed correctly, giving a valid basis for advice.

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

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.

1.4 Audit of Sardine (Sardina pilchardus) in divisions 8.a–b and 8.d (Bay of Biscay)

Reviewer: Hugo Mendes, 28/11/2022

Expert group Chair: Leire Ibaibarriaga

Secretariat representative: David Miller

General

The stock assessment is conducted using Stock Synthesis 3. The assessment is an age-based assessment assuming a single area, a single fishery, a yearly season and genders combined. Input data include catch (in biomass), age composition of the catch, total abundance (in numbers) and age composition from an annual acoustic survey (PELGAS), egg abundance (BIOMAN) and SSB from a triennial DEPM survey operating in the Bay of Biscay.

At the time of this audit the report section was not yet available but overall the available presentations in the sharepoint, advice sheet and documentation sent by the stock assessors was well explained and included the necessary generic information needed for an ICES category 1 assessment and advice sheet.

Data issues as the estimation of Q4 catches in the interim year are well explained and alternative hypothesis were also tested and discussed during the working group. In 2021, the majority of French catches originated from rectangles 25E5 and 25E4 in Subarea 7, catches from these areas are considered to be more closely associated with this stock and are included in this assessment.

The stock assessment and short term forecast followed the methodology described in the Stock annex. The stock annex was updated in 2019 following the interbenchmark, where the assessment was upgraded to ICES category 1. The changes made to the model settings included new assumptions on selectivity, maturity ogive and SR to reduce the previous retrospective pattern, but there is still a slight tendency to overestimate biomass (Mohn's rho = 0.350, value mostly driven by the difference in 2017) and underestimate fishing mortality (Mohn's rho = -0.287).

The spawning biomass shows a decreasing trend in the last years and was estimated to be the second lowest level of the time-series. 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 only slightly above Blim.

Fishing pressure on the stock is above F_{MSY} and below F_{lim}.

For single-stock summary sheet advice

Stock: Sardine in divisions 8.a–b and 8.d (Bay of Biscay)

1) **Assessment type**: Update
2) **Assessment**: Accepted
3) **Forecast**: Accepted
4) **Assessment model**: The model used is Stock Synthesis 3, version 3.24f. A description and discussion of the model can be found in Methot and Wetzel (2013). 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 biomass), 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 (last update in 2020).

5) **Consistency**: There is still a slight tendency to overestimate biomass with a Mohn's rho = 0.350, although the 5-yr retrospective pattern show that this somehow high value is mostly driven by the 2017 estimates and the recent values show a substantial improvement in the consistency. Concurrently, there is a tendency to underestimate fishing mortality (Mohn's rho = -0.287). There is a slight overestimation of recruitment (Mohn's rho = 0.094) that could be explained by large age 1 estimates in the PELGAS survey in 2018, 2019 and 2021 (no survey in 2020) that could not be tracked consistently in the age 2 estimates of the following year.
6) **Stock status**: Fishing mortality is above F_{MSY} and F_{pa} and below F_{lim}; The spawning biomass is below MSY $B_{trigger}$, B_{pa}, and only slightly above B_{lim}. As the stock is below MSY $B_{trigger}$ and according to the ICES HCR the advised catch for 2023 is based on the deterministic projection (*fwd* function from FLR) with F = F_{MSY} * SSB(2023)/ MSY $B_{trigger}$ = 0.40. The advice for 2023 is 24% lower than the advice for 2022.
7) **Management plan**: No official TAC is set for this stock. ICES advice is based on the MSY approach.

General comments

At the time of this audit the report section was not yet available but the available presentations in the sharepoint, advice sheet and documentation sent by the stock assessors was well explained and documented. The assessment follows the agreed methodology after the 2019 interbenchmark and only minor updates are needed in the stock annex regarding the time range for the recruitment assumption in the short term forecast section and include some reference to the use of the BIOMAN egg count in the general description of the "model used of basis for advice"

Technical comments

None

Conclusions

The assessment and short-term forecast have been performed correctly according to 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.

1.5 Audit of Sardine (Sardina pilchardus) in Subarea 7 (2021 ASSESSMENT)

Reviewers: Andrés Uriarte
Expert group Chair: Leire Ibaibarriaga
Secretariat representative: David Miller

General

The sardine stock in the southern Celtic Seas and the English Channel was benchmarked in 2021 (ICES, 2021) and was upgraded to category 3. A SPiCT model based on quarterly landing data and a biomass index derived from the acoustic survey PELTIC was developed, but as there is a high uncertainty of the MSY reference points of absolute biomass and fishing mortality the assessment was not considered reliable, and is not used for provision of advice. Therefore the advice is based on the ICES framework for category 3 short-lived stocks (ICES, 2020), making use of the 1-over-2 rule with an uncertainty cap of 80% and a biomass safeguard (ICES, 2020), taking as biomass indicator the estimates produced by the PELTIC acoustic survey, for which there used to be yearly estimates of sardine biomass for the total area since 2017 to present.

However in 2022 the PELTIC survey was severely reduced for technical reasons and the restricted covered area constitutes a bit less than 30% of the standard total area covered by this survey to produce the indictor for the assessment and advice. Thus an equivalent of the total are index of biomass was inferred from the proportions of biomass which in the past were observed within that restricted area covered in 2022, as explained below.

For single-stock summary sheet advice

1) Assessment type: benchmark 2021
2) Assessment: No assessment is carried out, other than taking the direct estimates from the autumn PELTIC acoustic survey as relative indicator of abundance trends. The equivalent of the total area index of biomass inferred from the restricted area covered in 2022 area suggest an increase of 20% over the mean of the previous two indexes.
3) Forecast: not presented (In-year advice using Catch Advice Rule for category 3 short lived data-limited stocks)
4) Assessment model: Direct estimates from the autumn PELTIC acoustic survey are used as stock indicator of trends, to apply the data-limited approach for small pelagic fishes, i.e.i.e. the 1 over two harvest control rule with 80% cap, based on survey trend
   A preliminary SPICT was set at the benchmark as it is updated every year, but its results are not considered reliable yet. Furthermore in this year the indirectly inferred indicator for the total area covered was not used as input for the SPICT update.
5) Consistency: This new assessment is carried out accordingly to stock annex.
6) Stock status: The equivalent of the total are index of biomass inferred from the restricted area covered in 2022 area suggest an increase of 20% over the mean of the previous two indexes. The SPICT (partially updated during the WG) suggests Fishing pressure is below FMSY and stock size is

above MSY Btrigger, but these indications are not considered reliable yet.

7) Management plan: No management plan.

General comments

The ICES framework for category 3 short-lived stocks (ICES, 2020) used for the advice of this stock consists of multiplying the most recent advised catches by the ratio between the last biomass index value (index A) and the average of the two preceding biomass values (index B). This is the second year of implementing the 1o2 rule and the advised catch for 2022 is used to provide the advice for 2023 according to the former ratio of Index A/Index B. All calculations have been checked twice and are correct as collected in the report and in the draft of the summary sheet for advice.

The current advice relies on the rescaling of the PELTIC 2022 abundance estimate for the restricted area covered in 2022 to the Total area should have been covered to produce the abundance estimate to be used for the advice according to the stock annex. The procedure made the most of the available information form the past series of PELTIC, and the raising was made in two steps: First the restricted area estimate was raised to the Core area coverage by using the ratios of the Core/restricted abundance ratios in the two former years (2020 and 2021). Next the Core area 2022 inferred abundance was raised to the Total area by using the ratios of the TotalArea/CoreArea abundance estimates in the period 2017-2021, as explained in the report. This procedures was discussed and endorsed by the WG.
The raised to total area index of biomass for 2022 (336 306 t) resulted to be 20% over the mean of the previous two indexes (2020 & 2021) (279 607 t).

To produce the advice based on the 1 over 2 rule, the former advice (6906 t for 2022) was multiplied by the 1.2 which resulted in an advice for 2023 of 8306 t.

Technical comments

The expert group considers that this rule for short-lived species category 3 stocks, based on the 1over2 ratio with uncertainty cap of 80% can only be taken as an interim approach while a better formulation for providing advice can be established.

Conclusions

The assessment has been performed correctly, accounting for the restricted area covered by the PELTIC survey in 2022, therefore giving a valid basis for advice. Everything is well justified and documented in the report.

References

ICES. 2020. 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. 2021c. 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

1.6 Audit of Sardine (Sardina pilchardus) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)

Date: 07/12/2022
Auditor: Alfonso Pérez Rodríguez
Expert group Chair: Leire Ibaibarriaga
Secretariat representative: David Miller

General

Assessment made according to the benchmarked assessment procedure agreed in 2017 (WKPELA2017) and updated in 2021 (ICES WKIBIS being currently pending final publication) which accounts for the inclusion of a recruitment index during the interim year to inform on the strength of the age 1 in the management year. This has supposed a neat improvement in the forecast capability of the managed population.

In 2019, the stock was considered by ICES (ICES 2019) to be a low productivity regime which had started in 2006 when a series of poor recruitment began. The reference points were accordingly then updated (ICES 2019).

The cancellation of Spanish spring DEPM survey in 2020, due to Covid-19, led to a lack of sardine data for estimating the total stock SSB in 2020, with impact on the 2021 assessment. In 2021 and 2022 no problem has arisen in survey coverages due to the Covid-19 disruption.

The assessment of 2022 shows a poor fit to the 2022 point estimate of the spring acoustic survey index (PELAGO and PELACUS) (ICES, 2022a). The model has a tendency to underestimate abundance in years when the survey index is large. Also, the 2022 spring acoustic survey index estimated an increase of Age 1 individuals (cohort of 2021) compared to 2021 which is in disagreement with the decrease of the recruitment index (IBERAS 2021 for subdivision 9aCN).

In 2022, the IBERAS survey showed thick schools of juvenile sardine near surface, partially outside the echosounder detection area. For this reason, the recruitment index in 2022 may be underestimated.

For single-stock summary sheet advice

1) Assessment type: update
2) Assessment: accepted
3) Forecast: accepted
4) Assessment model: Stock Synthesis (SS3) V3.30.11.00. A description and discussion of the model can be found in Methot and Wetzel (2013). The assessment is age-based, assuming a single area, a single fishery, a yearly season and genders combined. The model is tuned by input data updates from the triennial Portuguese and Spanish DEPM surveys (PT-DEPM and SP-DEPM) and total abundance (numbers) and age structure from the Portuguese and Spanish spring acoustic surveys (PELAGO and PELACUS). In addition, according to the Inter-benchmark IBIS in October 2021, the recruitment index provided by IBERAS survey from area 9aCN was included in the assessment to allow the estimate of recruitment-at-age

0 in the last assessment year, and age 1 in the management year. Total catch and age proportions in the catch are used, including provisional estimates of the total catch in tonnes for 2021.

5) Consistency: In recent years, coincident with the increase of the stock size, the model has a tendency to underestimate the stock biomass (Biomass at age1+, Mohn's rho of -0.333) and recruitment (Mohn's rho of -0.139).
6) Stock status: In 2022 B1+ > Blim and above Bpa reference points, while F is slightly above Fpa and Fmsy, but lower than Flim; The high recruitment in 2019 has restored the population to higher levels than Bpa for the last two years, which had not been observed since 2009. In 2022, estimated recruitment is above the average since 2005. However, since recruitment in 2020 and 2021 were low, the scenario of low productivity of this stock was not revised.
7) Management plan: Management plan for 2021–2026 evaluated and approved by ICES. It was concluded to be precautionary with maximum allowed catches between 30 000 and 50 000 tonnes (ICES, 2021a). For 2023, the European Commission requested ICES to provide advice based on the MSY approach and include the HCR in other catch scenarios.

General comments

The assessment is well documented. The stock assessment input data and the assessment run code was available for the audit. In terms of outputs, historical trends in recruitment, SSB and harvest rate show consistent trends with previous assessments.

Technical comments

None

Conclusions

The assessment and short-term forecast have been performed correctly according to 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.

1.7 Audit of Blue jack mackerel (Trachurus picturatus) in Subdivision 10.a.2 (Azores grounds)

Reviewer: Susana Garrido, 06/12/2022
Expert group Chair: Leire Ibaibarriaga
Secretariat representative: David Miller

General

This is a category 5 stock for which there is no index available reflecting the development of the stock. Data available are official landings and ICES estimates of total catches including 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 unavailable.

Purse-seine fishery represents the majority of catches for this stock (85%) and lands mostly juveniles. For this metier, the number of fishing days and vessels decreased in the last decade and fishing days per year have been below the maximum allowed number of days (5000) since 2010, being below 4000 days.

Data issues, besides the absence of an index reflecting the development of the stock is that recreational catches do not include catches by anglers from the shore.

Given that there is no information on abundance or exploitation for this stock, the PA buffer was applied this year (it was not applied in 2018).

ICES cannot assess the stock and exploitation status relative to MSY and precautionary approach (PA) reference points because information to define reference points is not available.

For single-stock summary sheet advice

Stock: Blue jack mackerel in Subdivision 10.a.2 (Azores grounds)

1) **Assessment type**: Update
2) **Assessment**: none
3) **Forecast**: none
4) **Assessment model**: No assessment model
5) **Consistency**: NA
6) **Stock status**: There is no information on abundance or exploitation.
7) **Management plan**: ICES advice is based on the precautionary approach.

General comments

Technical comments
None

Conclusions
The advice was in line with the framework of category 5 stocks for which there is no information of stock abundance and exploitation and the PA buffer was applied given that there were no strong evidences that the current level of exploitation is appropriate for the stock, although the

number of purse-seine vessels and number of fishing days per year have been reducing in the last decade. Further analysis of the available data to try to derive a CPUE for this stock is commended. The assessment has been performed correctly, giving a valid basis for advice. Everything is well justified and documented in the report.

Annex 5: Joint session WGACEGG-WGHANSA

On the first and third days of WGHANSA, 23th and 25th May, 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.

Apart from the WGHANSA participants, the joint session was attended by the following WGACEGG members:

Jeroen Van der Kooij (chair)

Maria Manuel Angelico (chair)

Pablo Carrera

Paz Díaz

Magdalena Iglesias

Ana Moreno

Silvia Rodrigues

Some participants (Fernando Ramos, Isabel Riveiro, Andrés Uriarte, Gersom Costas and Leire Ibaibarriaga) are members of both groups.

The following presentations were carried out:

- “PELAGO 22 Acoustic survey. Preliminary Results”
- “PELACUS 0322: Sardine and anchovy results”

The main results of these presentations are briefly summarised in the stock assessment input data sections of the WGHANSA report.

The estimates from PELAGO were not available on the first day of the meeting and a second session was planned. The WGs identified some unresolved issues in the PELAGO results that require further verifications, but overall, the estimates were considered sufficiently reliable. WGACEGG approved the abundance indices from PELAGO and PELACUS 2022 surveys for their inclusion in the stock assessment. These surveys will be discussed more extensively within WGACEGG in the meeting that will take place in November 2022 and a detailed description will be available in the corresponding WGACEGG report.