Preliminary analysis to include data from autumn acoustic surveys in the assessment of the Iberian sardine stock

Laura Wise, Isabel Riveiro, Alexandra Silva, Pablo Carrera,
Ana Moreno, Leire Ibaibarriaga, Susana Garrido, Manuela Azevedo, Fernando Ramos

October 2021

1 Introduction

The Iberian sardine stock distribution ranges from the west Cantabrian Sea (Division 8c) to western and southern Iberian Peninsula, including the Gulf of Cadiz (Division 9a) (Figure 1).

Sardine distribution off the Iberian Peninsula shows three core habitats: coastal areas in northern and southern Biscay (outside the distributional range of the Iberian sardine stock), the Gulf of Cadiz and the central Portuguese shelf (where mean abundance is the highest and constitutes juvenile core area of the Iberian sardine stock) (Figure 2).

In 2012 the model used to assess the Iberian sardine stock (Divisions 8c and 9a) changed from AMCI [11] to Stock Synthesis (SS, [9]). Since 2019, the version of SS used is version 3.30. The last benchmark was in February 2017 [1]. The main modifications were related to methods to estimate the initial population, the stock-recruitment relationship, the acoustic survey selectivity-at-age and the fishery selectivity-at-age [1]. Information on stock delimitation and the description of the fisheries was updated but did not translate into changes on stock boundaries.

Currently, the Iberian sardine stock SS model is age-based and assumes 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 and spawning–stock biomass (SSB) from a triennial DEPM survey. The assessment includes fishery data up to year y (final year of the assessment) and acoustic data up to year $y+1$ (interim year). Advice is given for the next year $y+2$. Information on recruitment (at Age 0) is given up to the final year of the assessment (y). This recruitment estimate is supported by the acoustic survey that takes places in the first quarter of the interim year and by the catch-at-age zero data in the final year of the assessment. The short-term forecast assumes that recruitment for the interim year and the subsequent two forecast years is the geometric mean

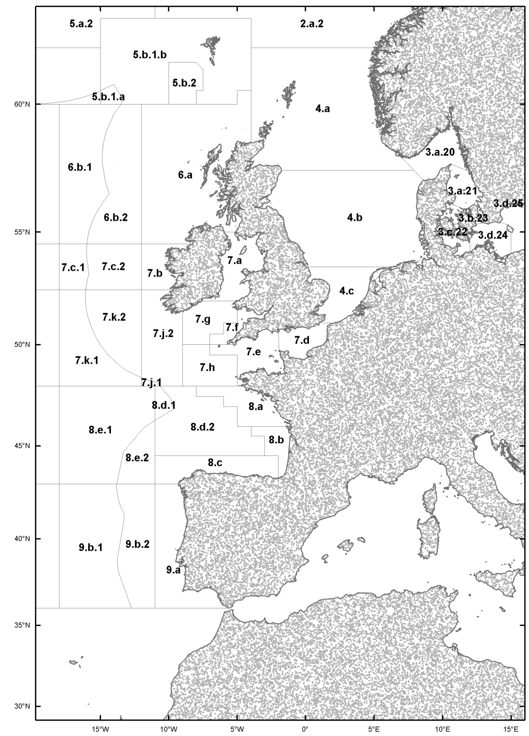


Figure 1: ICES Statistical Divisions and Subdivisions. The Iberian sardine stock is distributed in Divisions 8c and 9a.

of recruitment of the last five years in the assessment $(y-4, ..., y)$. Since small pelagic species such as sardine individuals mature early in life (individuals are mature at age 1) the impact in the stock biomass is fast and high.

2 Inclusion of a new index-recruitment index

Up until 2019, the assessment of the state of the stock (in year $y+1$) and advice for the following year $(y+2)$ would take place in June during WGHANSA-1. The current assessment model has information on recruitment up to the final year of the assessment (year y). Recruitment information in year y is provided by the catch-at-age zero data in year y and by the spring acoustic survey that takes places in the interim year (year $y+1$, age 1 individuals). The spring acoustic survey takes place in April/May.

The inclusion of another source of information on recruitment is thought to improve the advice that is provided since small pelagic species such as sardine have highly inter-annual recruitment variability that have major impacts in the stock biomass. In the case of the Iberian sardine there is a time series of autumn

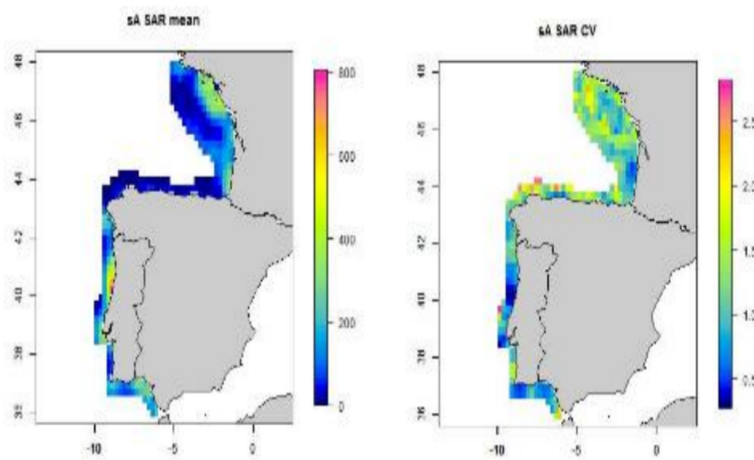


Figure 2: Sardine spring distribution (gravity centres) , time average (left) and CV (right). From the CRR 332 document.

acoustic surveys that can provide data on recruitment in the interim year and is not yet included in the assessment model. The inclusion of a recruitment index would provide an estimate of recruitment in the interim year that is not provided by any other source of information entering the model. This could be crucial to improve the short term catch advice but it is also expected to improve the estimates of past recruitment in general. This potential inclusion was one of the reasons for changing the advice calendar back in 2019, when the assessment was moved from June to November.

2.1 Time-series of autumn acoustic surveys

Over the last decades, several autumn acoustic surveys have been carried out in the Iberian sardine stock area with the objective of assessing the incoming recruitment to the fishery in year $y+1$. These surveys have had a different spatial coverage and seasonality, but have always covered the main area of juvenile concentration of the stock (subdivision 9a Central North).

In Table 1 we present the timing of each one of the autumn surveys carried out so far. Figure 3 shows the contribution of each subdivision to the recruitment index (Age Zero).

Table 1: Autumn acoustic surveys providing direct estimates for sardine juveniles in subdivision 9a.

Year	Month	Surveys	Subdivisions
1984	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS-Algarve
1985	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS-Algarve
1986	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS-Algarve
1987	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS-Algarve
1992	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
1997	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
1998	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
2000	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
2001	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
2003	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
2005	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
2006	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
2007	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
2008	Nov	SAR-PT-AUT	9aCN, 9aCS, 9aS
2012	Nov	ECOCADIZ-RECLUTAS	9aS
2013	Nov	JUVESAR[1]	9aCN and 9aCS
2014	Oct	ECOCADIZ-RECLUTAS	9aS
	Nov	JUVESAR	9aCN and 9aCS
2015	Oct	ECOCADIZ-RECLUTAS	9aS
	Dec	JUVESAR	9aCN and 9aCS
2016	Oct	ECOCADIZ-RECLUTAS	9aS
	Dec	JUVESAR	9aCN and 9aCS
2017	Oct	ECOCADIZ-RECLUTAS[2]	9aS
	Dec	JUVESAR	9aCN and 9aCS
2018	Oct	ECOCADIZ-RECLUTAS[3]	9aS
	Nov	IBERAS	9aCN and 9aCS
2019	Oct	ECOCADIZ-RECLUTAS	9aS
	Sep	IBERAS	9aCN and 9aCS
2020	Oct	ECOCADIZ-RECLUTAS	9aS
	Sep	IBERAS	9aCN and 9aCS

[1] JUVESAR only covers 9aCS partially.

[2] No acoustic estimate due to methodologic problems.

[3] Take care with acoustic estimate due to methodological problems.

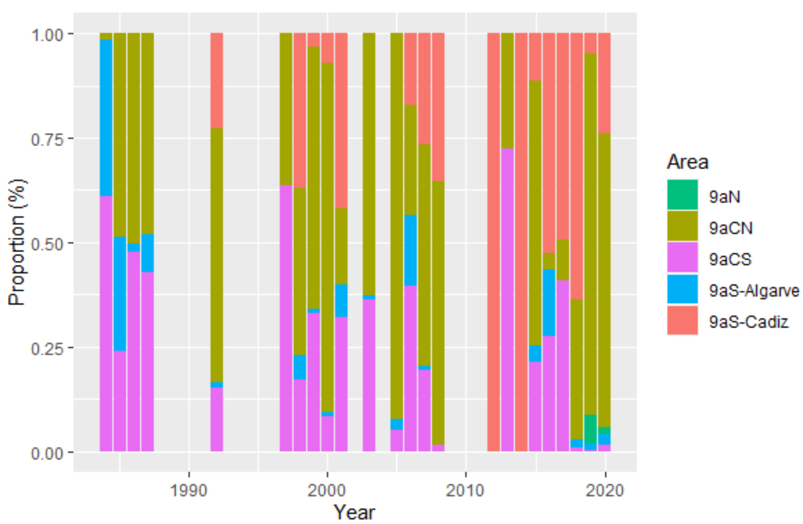


Figure 3: Contribution of each subdivision to the recruitment index (age zero).

2.1.1 SAR-PT-AUT

The SAR-PT-AUT survey time-series started in 1984 covering the Portuguese continental shelf, was interrupted in 1988 and resumed with a systematic periodicity between 1997 and 2008 that extended the coverage to the Gulf of Cadiz. A one time survey was carried out in 1992 covering also the Spanish Gulf of Cadiz. The acoustic methodology was the echo integration of the acoustic targets and fish schools, surveyed along transects. The earlier surveys design until the 1992 survey, varied between "zig-zag" and parallel transects 10 nautical miles (nm) apart. In 1997 the survey design changed to acoustic transects perpendicular to the coast line spaced ca. 8 nm. Surveys were conducted both day and night. For acoustic data collection several ecosounder models were used through this timeseries: Simrad EKS38 between 1984 and 1988, Simrad EK400 in 1992 and Simrad EK500 since 1997. For species identification and biological sampling, trawl hauls were performed with a pelagic or bottom trawl net.

2.1.2 JUVESAR

The JUVESAR autumn survey series started in 2013, ended in 2017 and only covered subdivisions 9aCN and part of 9aCS. In 2014, due to bad weather, only a small area was covered. The work area ranged from Póvoa do Varzim in the subdivision 9aCN and Cape Espichel in subdivision 9aCS, from shoreline (12 m) to the 60-100 m isobath over an adaptive grid with tracks spaced 4 or 8 nm (4nm in the main sardine recruitment areas). The methodology was similar to that of the spring acoustic surveys PELAGO. Acoustic equipment consisted of a Simrad EK-500 scientific echosounder, operating at 38 and 120 kHz. The backscattering acoustic energy from marine organisms was measured continuously during daylight. Pelagic or bottom trawls were carried out whenever possible to help identify the species (and size classes) that reflect the acoustic energy. This series provides the size composition (Length Frequency Data) and estimates of numbers and biomass for age 0 sardine and anchovy.

2.1.3 IBERAS

The IBERAS time series started in 2018 and extended the JUVESAR surveyed area south. IBERAS main objective is to get a recruitment index for both sardine and anchovy in Atlantic waters of the Iberian Peninsula, aiming to improve the estimation of the strength of the recruitment of the Iberoatlantic sardine and the western component of the southern anchovy population. In the first year the survey was undertaken in November but due to bad weather conditions, the aggregation and distribution patterns of the fish were anomalous and to improve the precision of the biomass estimates, the timing of the survey was changed. From 2019 onwards the survey was shifted to September which also allows a synoptic coverage of the Iberian Peninsula at the end of summer, beginning of fall, since this is also the time period when the JUVENA acoustic survey takes place and still close to the ECOCADIZ-reclutas survey date in october. The work area ranged from Finisterra cape (in 2020 from Estaca de Bares cape) until São Vicente cape, from shoreline (20 m) to 100 m isobath over an adaptive grid (tracks were enlarged or shortened accordingly) with tracks distanced between 4-8 nm on account the potential recruitment distribution area of sardine. This series provides the size composition (LFD) and age-structure of the estimated population in numbers and biomass for anchovy and sardine, in particular of age 0 individuals. The methodology is similar to that of the previous surveys and is summarised in [2]. Acoustic equipment consisted of a Simrad EK-80 scientific echosounder, operating at 18, 38, 70, 120 and 200 kHz. The backscattering acoustic energy from marine organisms was measured continuously during daylight except in the northern area where some tracks were steamed at night. Pelagic trawls were carried out whenever possible to help identify the species (and size classes) that reflect the acoustic energy.

2.1.4 ECOCADIZ-RECLUTAS

ECOCADIZ-RECLUTAS is a survey restricted to Subdivision 9aS (20 – 200 m depth). The survey is conducted during the second fortnight of October, started in 2012 (only Spanish waters sampled) and continued in 2014. A serious breakdown in the RV's propeller system prevented from deriving an acoustic estimate from the 2017 survey. In 2018 ECOCADIZ-RECLUTAS has also experienced methodological problems related with the acoustic sampling coverage (ping rate), meaning that it should be carefully taken into account when dealing with the final acoustic estimates and interpreting their trends. This series provides the size composition (LFD) and age-structure of the estimated population in numbers and biomass for anchovy and sardine.

2.2 Survey suitability

WGACEGG believes that the combined (autumn) IBERAS and JUVESAR surveys could provide a suitable recruitment index for the Iberian sardine stock as they cover its northern recruitment area (located off north Portugal) during the relevant period. Both surveys specifically target the young of the year sardine in autumn (recruitment at age 0), and appear to capture this cohort well, both acoustically (they are found on the shelf in waters ¡50m and are aggregated) and in the trawl (very limited avoidance of these young age classes). While IBERAS is still a relatively short time-series (starting in 2018), the combined survey data (IBERAS/JUVESAR) show a significant positive correlation with the recruitment at age 1 estimated in the following spring by the combined PELAGO/PELACUS surveys.

The autumn survey ECOCADIZ-RECLUTAS covers the second known recruitment area of this stock further south, although the correlation between the recruitment signal at age 0 and the age 1 in the following year is much noisier than that from the combined JUVESAR/IBERAS surveys. This could be because most of the recruitment is occurring in the northern part. Another reason could be that the timing of ECOCADIZ-RECLUTAS is slightly offset relative to the other two surveys and, while potentially still relevant to sardine spawning, the 0-group sardine could be more dispersed and present in the shallow coastal waters and therefore less accessible to the survey. In summary, WGACEGG is of the opinion that a sardine recruitment index from IBERAS/JUVESAR could be used in the assessment model for the Iberian sardine stock.

2.3 Agreement between autumn and spring survey-based estimates

Numbers at age 0 in the autumn recruitment surveys (SAR-PT-AUT, JUVESAR, IBERAS and ECOCADIZ-RECLUTAS) were compared to numbers at age 1 estimated in the spring surveys (PELACUS and PELAGO) of the following year (Table 2) to check if there is a significant positive correlation (Pearson correlation) between estimates in log scale. The current assessment model uses the spring acoustic surveys PELAGO and PELACUS (covering all the stock area) as a joint index of abundance (from Age 1 to Age 6+). We tested for correlation of recruitment estimates from all autumn acoustic surveys (SAR-PT-AUT, JUVESAR, IBERAS and ECOCADIZ-RECLUTAS), all autumn acoustic surveys with the exception of ECOCADIZ-RECLUTAS, from common areas in the western continental area of the stock (9aCN and partially 9aCS), and only from the main recruitment area of the stock (9aCN), with the Age 1 estimates from the spring acoustic surveys (PELAGO and PELACUS) in the following year. We also tested for these areas groups but with shorter time series. One time series starting in 1997, the year from which it is believed that acoustic estimates are more robust due to the use of a Simrad EK500 equipment, and only starting from 2013, the year when JUVESAR time series started.

Table 2: Pearson correlation between numbers at age 0 in the autumn recruitment surveys and numbers at age 1 in the spring acoustic surveys of the following year (in log scale).

Autumn Acoustic Surveys	Years	Correlation	df	p-value
All surveys	1984 to 2020	0.432	20	0.045
All surveys	1997 to 2020	0.651	16	0.003
All surveys	2013 to 2020	0.399	6	0.327
Without ECOCADIZ-RECLUTAS	1984 to 2020	0.564	18	0.0096
Without ECOCADIZ-RECLUTAS	1997 to 2020	0.851	14	2.927e-05
Without ECOCADIZ-RECLUTAS	2013 to 2020	0.769	5	0.043
9aCN and 9aCS[1]	1984 to 2020	0.559	18	0.010
9aCN and 9aCS	1997 to 2020	0.843	14	4.053e-05
9aCN and 9aCS	2013 to 2020	0.758	5	0.048
9aCN	1984 to 2020	0.561	18	0.0099
9aCN	1997 to 2020	0.859	14	1.98e-05
9aCN	2013 to 2020	0.864	5	0.012

[1] JUVESAR only covers 9aCS partially.

Only in one case there was no significant positive correlation between Age 0 and Age 1 estimates (when we used Age 0 estimates from all surveys since 2013). When we use all areas for the whole time series, since 1984, or even when we use data since 1997, there is still a significant positive correlation. In this cases we include 9aS whenever the SAR-PT-AUT survey is carried out. In some years it covers the Gulf of Cadiz, in others it does not. The difference with the time series only since 2013 is that the information for 9aS comes from the ECOCADIZ-RECLUTAS survey. This survey usually takes place in Oct while the other was usually in November. The highest difference (in terms of correlation) is when the ECOCADIZ-RECLUTAS survey is included. Differences between the other options are very small. Correlation is greater when we only consider the time series starting in 1997 or 2013 (Figures 4 and 5) but the number of observations is smaller.

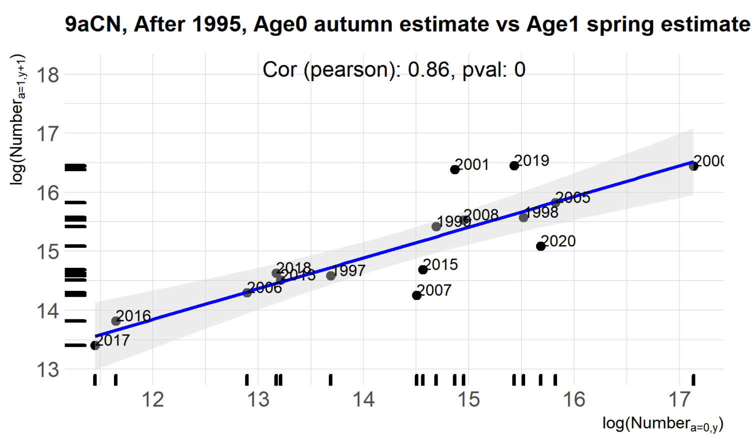


Figure 4: Pearson correlation (0.859, t = 6.2925, df = 14, p-value = 1.98e-05) between recruits estimated in year y for the 9aCN area with the number of individuals estimated in spring acoustic surveys of the following year (PELACUS + PELAGO). Time series restricted to 1997 onward. 2014 survey data not included since JUVESAR covered only a small area

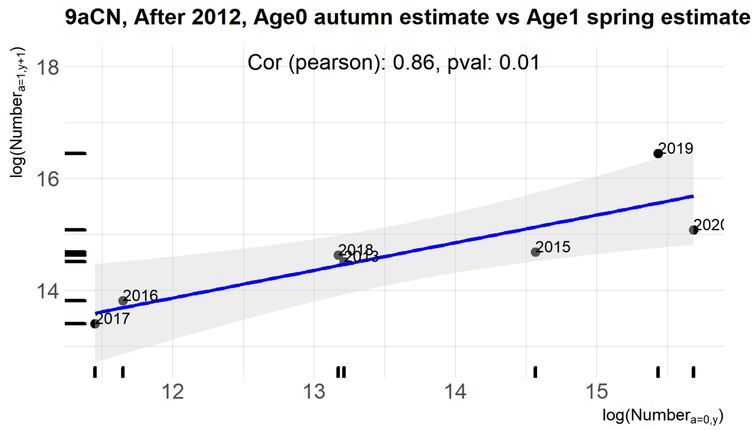


Figure 5: Pearson correlation (0.864, t = 3.8449, df = 5, p-value = 0.01206) between recruits estimated in year y for the 9aCN area with the number of individuals estimated in spring acoustic surveys of the following year (PELACUS + PELAGO). Time series restricted to 2013 onward. 2014 survey data not included since JUVESAR covered only a small area

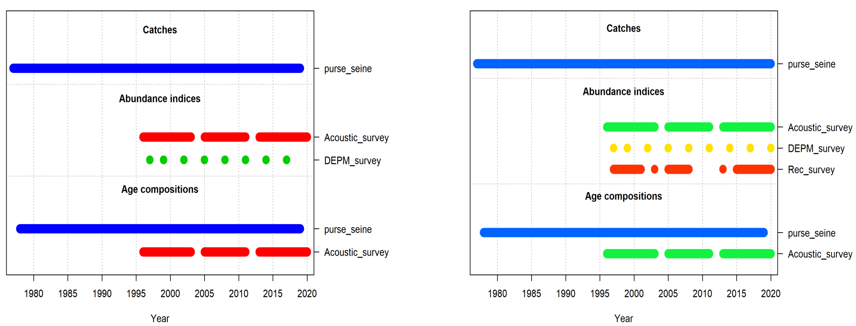
This high correlation supports the progress of this work to test the inclusion of the recruitment survey series in the Iberian sardine assessment. Although the highest correlations are found when only the 9aCN area is consider, they are very similar to when 9aCN and 9aCS are included, or all areas are included without ECOCADIZ-RECLUTAS.

3 Model development

Although there is a more recent assessment of the stock (June 2021), the models tested in this study were compared with the 2020 Iberian sardine stock assessment model (current model), fitted to data from 1978-2020 [3]. This exercise mimics the future assessment process where in the interim year we have information from both the spring and the autumn acoustic surveys. The assessment takes place in November, during WGHANSA-2 and information from catches is provisional (only total catches, age composition in the interim year $y + 1$ is not known).

Acoustic autumn survey data were used as additional data to the already existing Iberian sardine model (current model; Figure 6). The parameters set in the input files were left the same as for the existing assessment, with the exception of additional parameters required to incorporate the autumn acoustic surveys. This new index was included as an index of abundance with a selectivity tailored to young fish, where age selectivity options were used to choose a single age, age 0.

Settings for recruitment deviation were modified to accommodate for the new index series (last year of main recruitment deviations in now the interim year as opposed to the last year of catch data) and the least squares estimate of alternative bias adjustment relationship for recruitment deviations settings follow the recommendations automatically estimated by SS (for more information, see [8]). We will name this setting as Setup a.



(a) **Current model** (b) Setup a

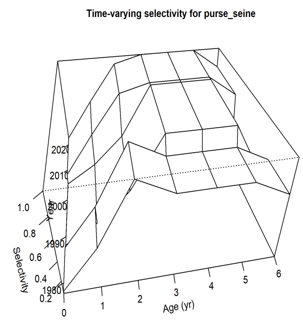
Figure 6: Data presence by year for each fleet and data type.

3.1 Testing area and time-series

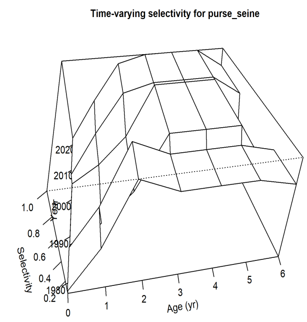
Several runs were made to test the performance of the model with the new recruitment index. In this subsection we present the outputs from 12 different runs and compare them with the current model (2020 assessment model).
Differences between these runs are the time series considered for the recruitment index: (i) long - the whole time series, from 1984 up to 2020; (ii) medium - from 1997, when surveys start using the EK500, up to 2020; and (iii) short - from 2013 up to 2020. Another difference is the areas considered to estimate recruitment: (i) all autumn acoustic surveys (SAR-PT-AUT, JUVESAR, IBERAS and ECOCADIZ-RECLUTAS), (ii) all autumn acoustic surveys with the exception of ECOCADIZ-RECLUTAS, (iii) from common areas in the western continental area of the stock (9aCN and partially 9aCS), (iv) and only from the main recruitment area of the stock (9aCN).

3.2 Testing other selectivity setting

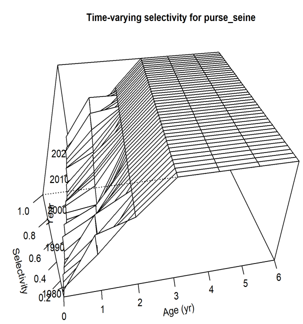
Table 3 summarises the current model assumptions for fishery selectivity and catchability (Setup a also has the same assumptions). During ICES workshop WKTaDSA [5] it was suggested to test other assumptions for both the purse seine fleet and the acoustic survey. Table 3 summarises the differences between the other two setting tested (named Setup b and Setup c). Figures 7 and 8 show the differences in time and at age for the 3 Setups tested.



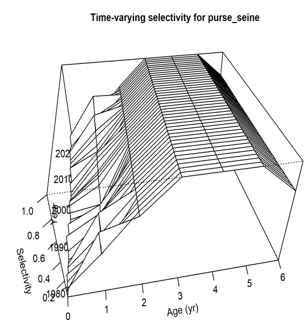
(a) **Current model**



(b) Setup a



(c) Setup b

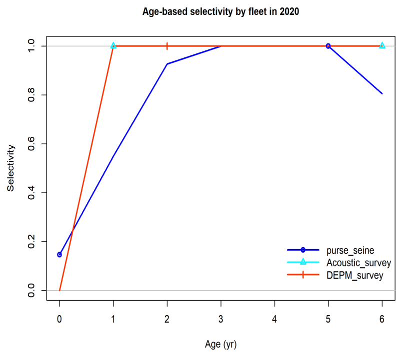


(d) Setup c

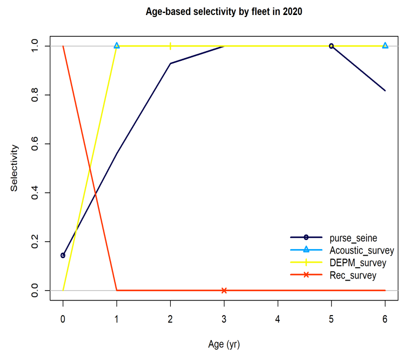
Figure 7: Time-varying selectivity surface for the purse seine fleet in the different runs.

Table 3: Model assumptions for fishery selectivity and catchability.

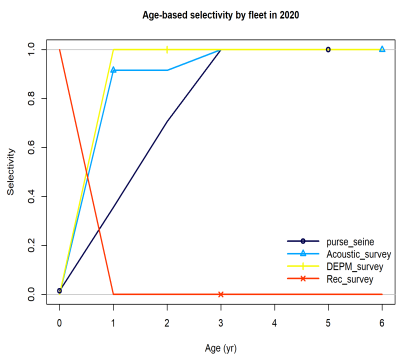
Model assumptions	Description
Fishery selectivity-at-age	
Setup a and c	S-at-age are parameters, each estimated as a random walk from the previous age; S-at-age 0 used as the reference; S-at-ages 4 and 5 assumed to be equal to S-at-age 3.
Setup b	S-at-age are parameters, each estimated as a random walk from the previous age; S-at-age 0 used as the reference; S-at-ages 4, 5 and 6 assumed to be equal to S-at-age 3.
Fishery selectivity over time	
Setup a	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.
Setup b and c	Selectivity-at-age is estimated every years (1978-2020) for ages up to 2
Fishery catchability	
All models	Scaling factor, median unbiased
Acoustic selectivity-at-age	
Setup a and c	S-at-age are parameters, each estimated as a random walk from the previous age; S-at-age 0 is set to be zero. S-at-age 1 used as reference.
Setup b	S-at-age are parameters, each estimated as a random walk from the previous age; S-at-age 0 is set to be zero. S-at-age 1 used as reference. Min and Max values differ from Setups a and b.
DEPM selectivity-at-age	
Setup a	Zero parameters, Selectivity = 1.0 for all ages beginning at age 1.
Setup b and c	Two parameters, Selectivity = 1.0 for a specified age range (from 1 to plus group)
Acoustic and DEPM survey catchability	
Setup a	Parameter, mean unbiased
Setup b and c	An extra parameter is estimated that will contain an additive constant to be added to the input standard deviation of the survey variability.



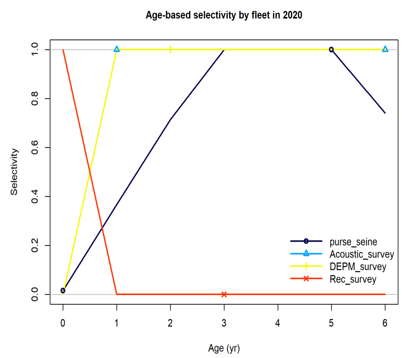
(a) **Current model**



(b) Setup a



(c) Setup b



(d) Setup c

Figure 8: Selectivity at age for the multiple fleets in 2020.

3.3 Diagnostics

Model diagnostics were explored using standard graphs created using ss3diag [12].

4 Results

4.1 Testing area and time-series

Table 4 summarizes the log-likelihood, SSB, Recruitment and F and final gradient for the different runs. Table 4 show values for the different runs with configuration model with Setup a. All models have the same number of parameters but differ in the input data for the recruitment index fleet. Within equal time-series, models that only include data from 9aCN and 9aCS are comparable, in terms of AIC, with models that only include data from 9aCN.

Within subgroups of time series used, the runs that have the lower AIC are the ones that consider only the subdivisions 9aCN and 9aCS (partially covered by JUVESAR).

Table 4: Log-likelihood, number of parameters, SSB, Recruitment, F, AIC and final gradient for the different runs with configuration Setup a

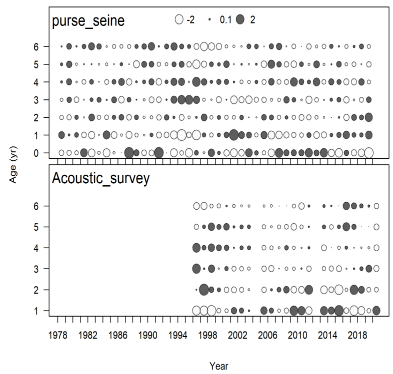
Label	All areas	All areas[1]	9aCN,9aCS	9aCN	All areas	All areas[1]	9aCN,9aCS	9aCN	All areas	All areas[1]	9aCN,9aCS	9aCN
Year	1984-2020	1984-2020	1984-2020	1984-2020	1997-2020	1997-2020	1997-2020	1997-2020	2013-2020	2013-2020	2013-2020	2013-2020
Total	258.06	187.41	176.86	301.31	242.19	165.88	153.31	228.17	204.3	145.26	144.95	180.16
Catch	1.88e-09	1.39e-09	1.17e-09	1.53e-09	3.06e-09	2.22e-09	1.91e-09	2.79e-09	1.73e-09	1.14e-09	1.12e-09	1.44e-09
Equil_catch	0.58	0.67	0.53	1.52	0.71	0.91	0.74	0.85	0.24	0.32	0.33	0.23
Survey	59.42	11.76	2.63	62.08	47.89	-3.04	-12.98	44.11	25.07	-16.13	-16.08	7.84
Age_comp	168.64	147.68	147.08	195.26	163.71	139.9	138.12	152.45	152.14	136.02	135.72	144.55
Recruitment	29.41	27.30	26.62	42.45	29.88	28.11	27.42	30.75	26.85	25.04	24.98	27.54
Parm_softbounds	0	0	0	0	0	0	0	0	0	0	0	0
Parm_devs	4.77e-04	4.82e-04	4.85e-04	4.73e-04	4.97e-04	5.04e-04	5.05e-04	5.03e-04	5.09e-04	5.12e-04	5.12e-04	5.11e-04
N parm	64	64	64	64	64	64	64	64	64	64	64	64
N catch data	43	43	43	43	43	43	43	43	43	43	43	43
N cpue data	56	54	54	54	51	49	49	49	40	39	39	39
N age comp data	66	66	66	66	66	66	66	66	66	66	66	66
AIC	644.12	502.83	481.72	730.62	612.38	459.76	434.62	584.34	536.59	418.52	417.89	488.32
Max Grad	2.16e-05	7.33e-05	8.09e-05	1.92e-05	2.16e-05	6.27e-05	1.94e-05	2.26e-05	7.96e-06	5.23e-05	5.42e-05	4.26e-05
SSB_2020	316.47	270.46	298.37	302.57	270.13	221.2	241.41	245.87	398.24	332.48	328.82	393.38
Recr_2020	29.03	20.53	24.18	39.2	23.55	15.81	18.4	29.72	42.73	30.58	30.31	64.64
F_2019	0.07	0.08	0.07	0.08	0.08	0.09	0.08	0.1	0.05	0.06	0.06	0.06

[1] without ECOCADIZ-RECLUTAS survey

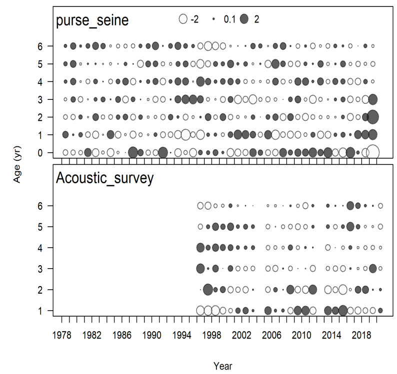
4.2 Testing other selectivity setting

For this analysis we used the recruitment index series starting in 1997 and only for area 9aCN. Model diagnostics for each of the new models were similar between them and also in comparison with the current model. An additional run with the 2020 assessment settings (no recruitment index) and input data for the exception of the inclusion of the 2020 DEPM point estimate is also presented. This additional run serves the purpose of checking if the differences between Setups a, b and c, when compared to the current model, are only due to the recruitment index or also caused by the additional DEPM year input data.

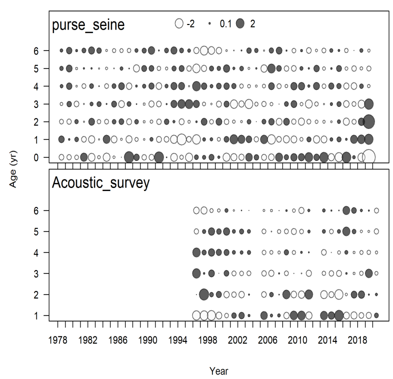
Pearson residuals for purse seine fishing fleet have small changes with apparently more positive residuals, specially in the final years of the assessment (Figures 9 and 10).



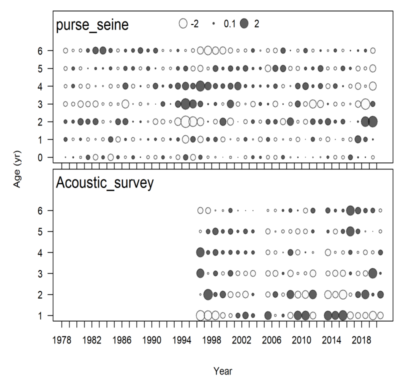
(a) **current model**



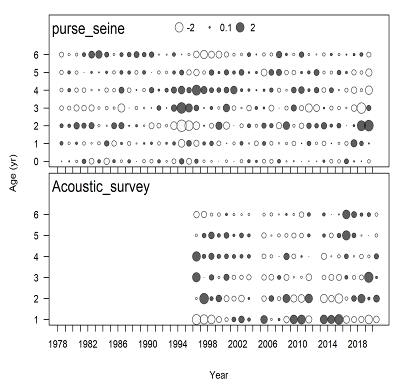
(b) **current model with 2020 point estimate**



(c) Setup a



(d) Setup b



(e) Setup c

Figure 9: Pearson residuals for age composition, comparing across fleets (purse seine and acoustic survey). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). New models versus current model (top left).

For the acoustic survey, Pearson residuals for age composition are similar between runs but change with the inclusion of the DEPM 2020 input data and the change of selectivity. For the purse seine fleet, changes in selectivity improve residuals specially for Ages 0 and 1.

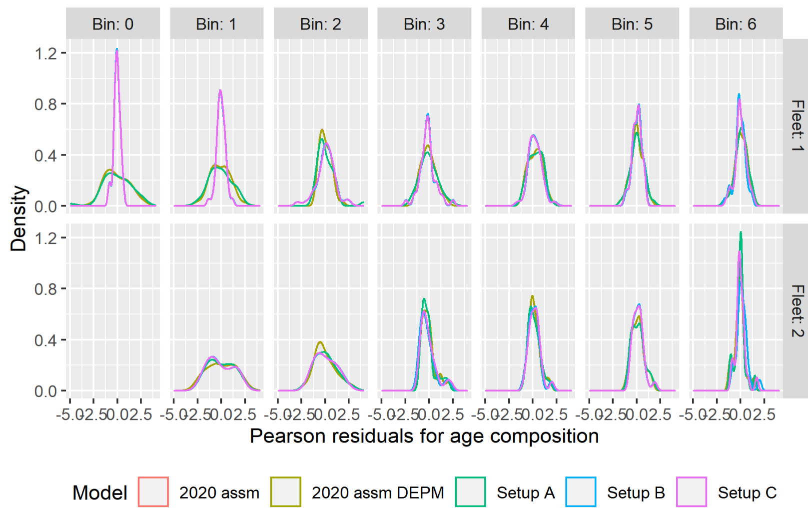
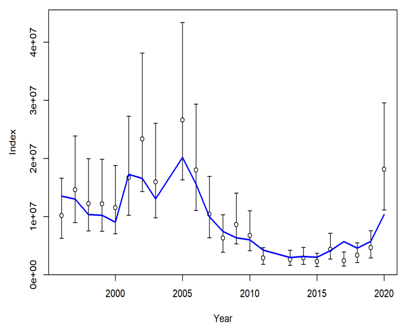
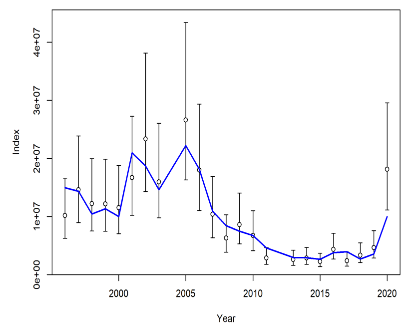


Figure 10: Density plot of Pearson residuals for age composition, comparing across fleets (purse seine is Fleet 1 and acoustic survey is Fleet 2) and runs (colors).

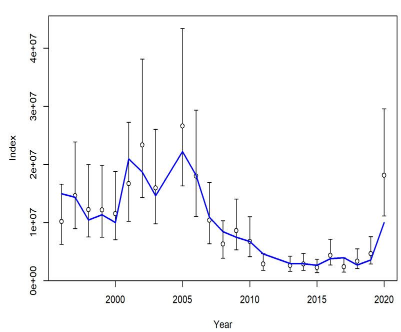
The fit to index data for the acoustic survey and for the DEPM survey are similar to those for the current model, with similar trends and peaks (Figures 11 and 12).



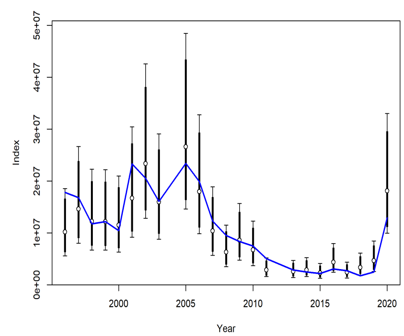
(a) **current model**



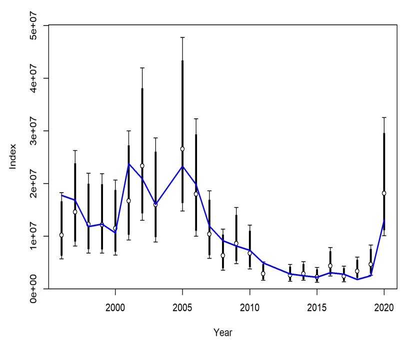
(b) **current model with 2020 DEPM model**



(c) Setup a

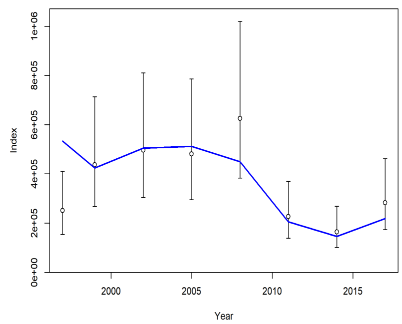


(d) Setup b

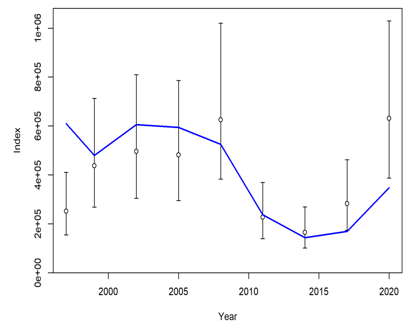


(e) Setup c

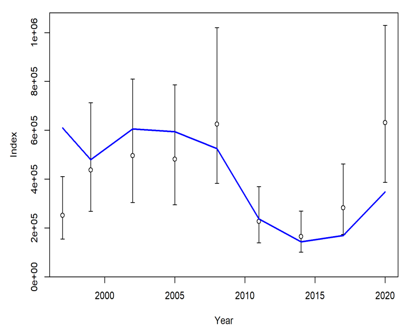
Figure 11: Fit to index data for the spring Acoustic survey. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines (if present) indicate input uncertainty before addition of estimated additional uncertainty parameter. current model (top left) versus new runs.



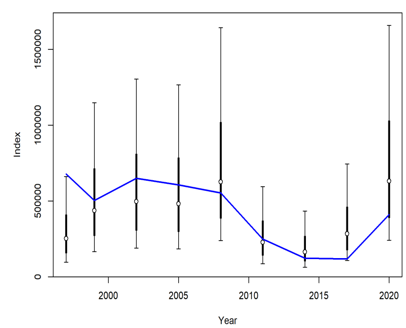
(a) **current model**



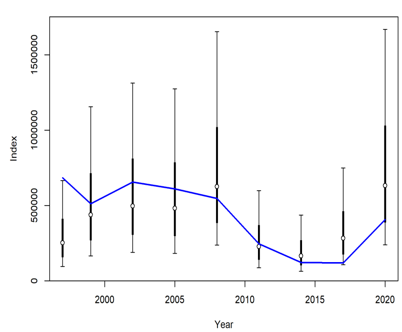
(b) **current model with 2020 DEPM point estimate**



(c) Setup a



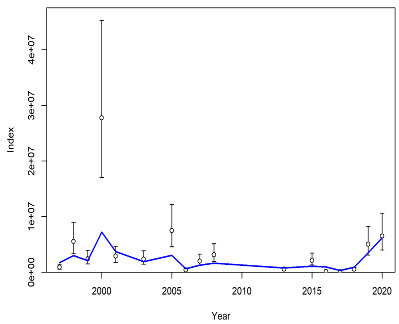
(d) Setup b



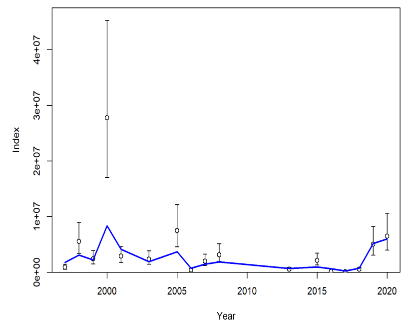
(e) Setup c

Figure 12: Fit to index data for the DEPM survey. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines (if present) indicate input uncertainty before addition of estimated additional uncertainty parameter.

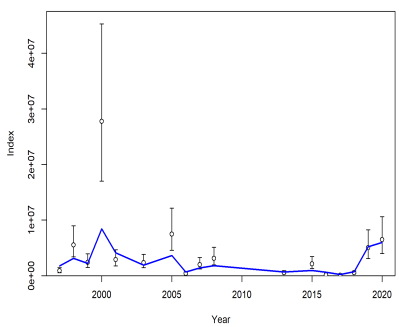
The fit to index data for the autumn/recruitment acoustic survey in Setup a, b and c are similar, following trends of the observed index and with a poor fit for higher index value points mainly in the early period of time series (Figure 13).



(a) Setup a



(b) Setup b

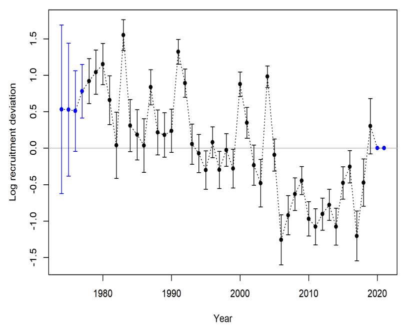


(c) Setup c

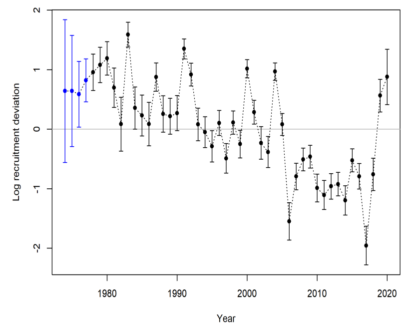
Figure 13: Fit to index data for the autumn acoustic survey. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. current model (top left) versus new runs.

Patterns for recruitment deviations are similar between models (Figure 14), the bigger changes occur at the beginning of the series and in the last two recruitment points.

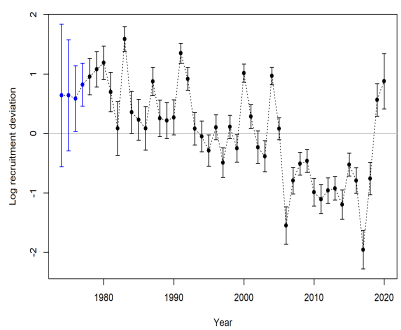
Overall, age composition fit is very good for all models (Figures 15 to 20).



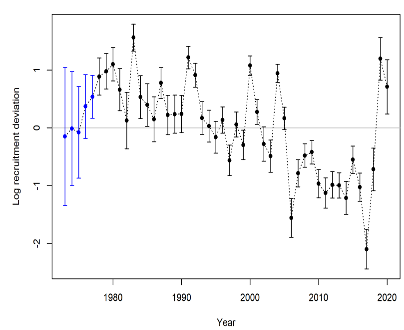
(a) **current model**



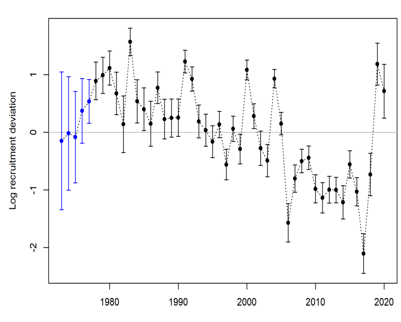
(b) **current model with 2020 DEPM point estimate**



(c) Setup a

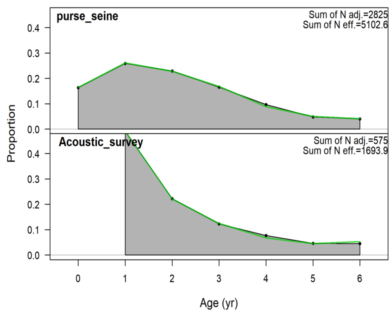


(d) Setup b

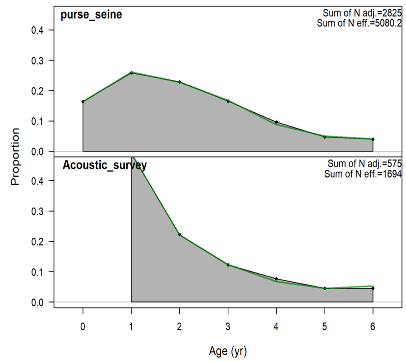


(e) Setup c

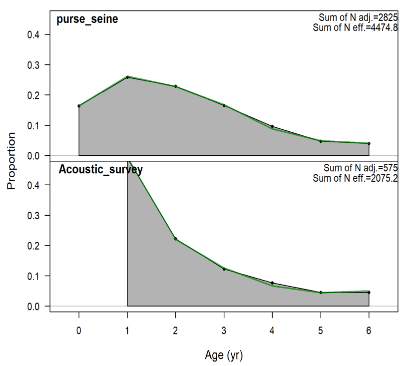
Figure 14: Recruitment deviations with 95% intervals. current model (top left) versus new runs.



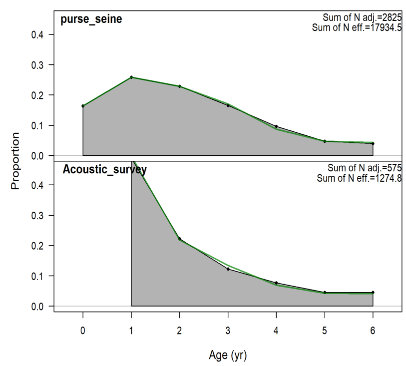
(a) **current model**



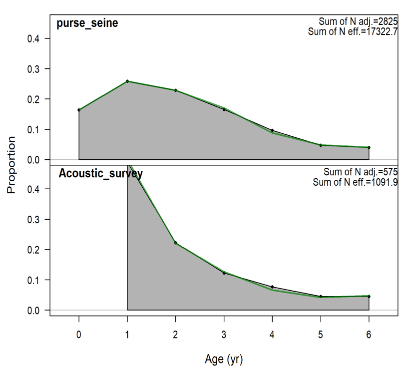
(b) **current model with 2020 DEPM point estimate**



(c) Setup a

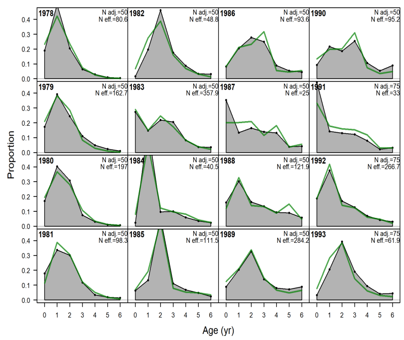


(d) Setup b

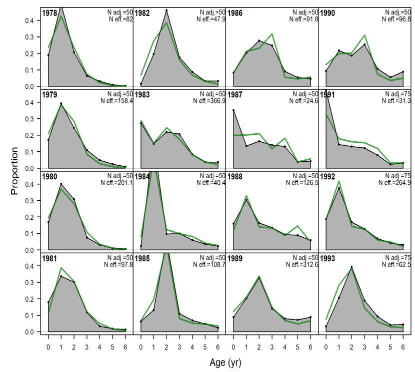


(e) Setup c

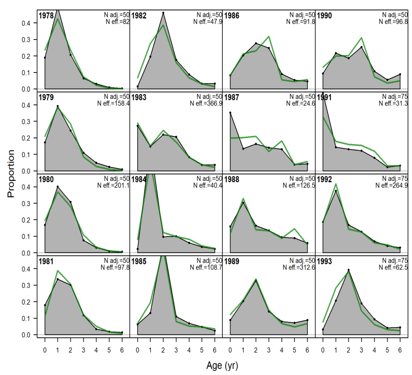
Figure 15: Age composition, aggregated across time by fleet. current model (top left) versus new runs.



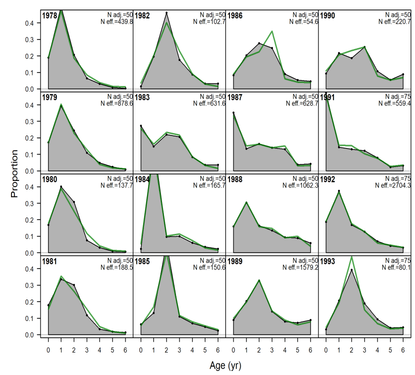
(a) **current model**



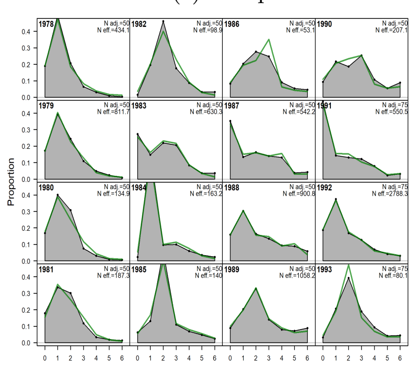
(b) **current model with 2020 DEPM point estimate**



(c) Setup a

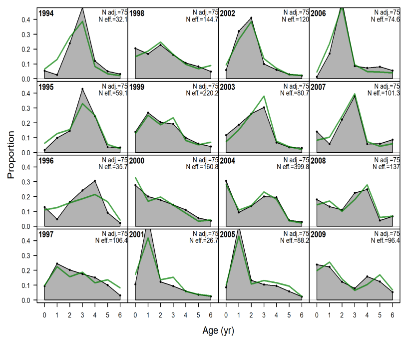


(d) Setup b

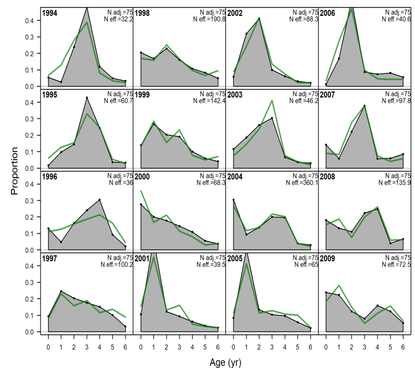


(e) Setup c

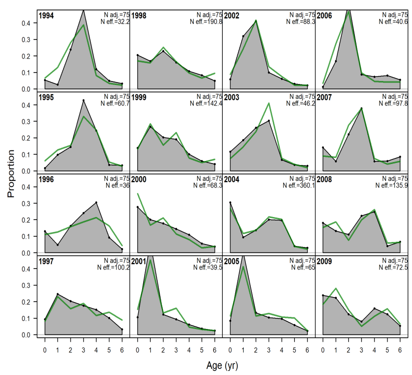
Figure 16: Age composition, whole catch, purse seine (plot 1 of 3). 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method. current model (top left) versus new runs.



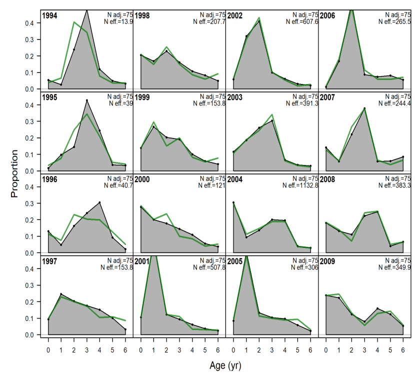
(a) **current model**



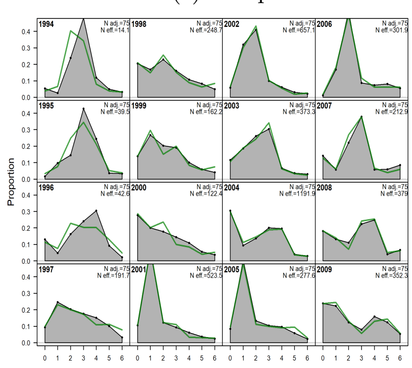
(b) **current model with 2020 DEPM point estimate**



(c) Setup a

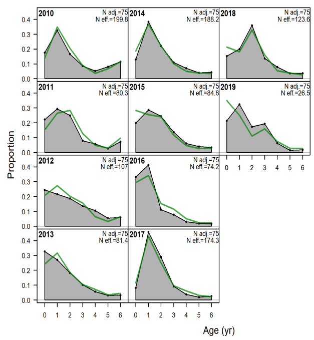


(d) Setup b

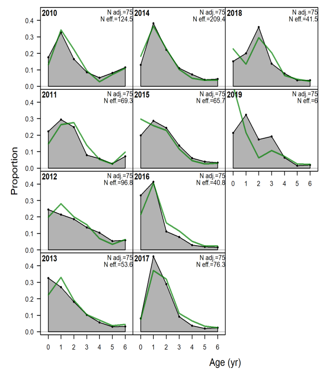


(e) Setup c

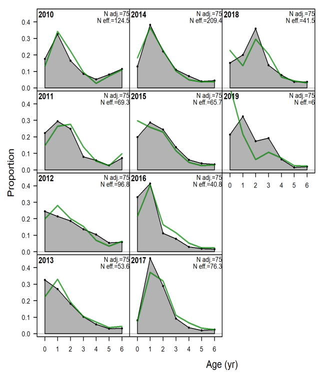
Figure 17: Age composition, whole catch, purse seine (plot 2 of 3). 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method. current model (top left) versus new runs.



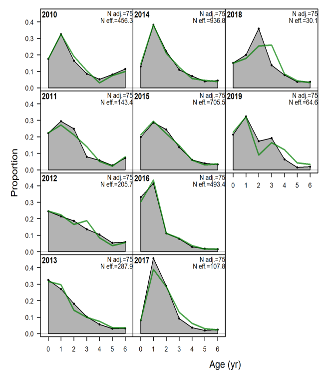
(a) **current model**



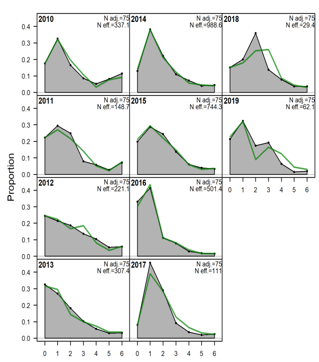
(b) **current model with 2020 DEPM point estimate**



(c) Setup a

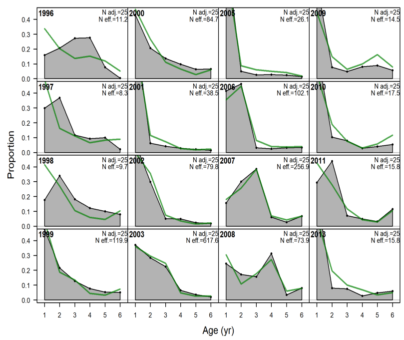


(d) Setup b

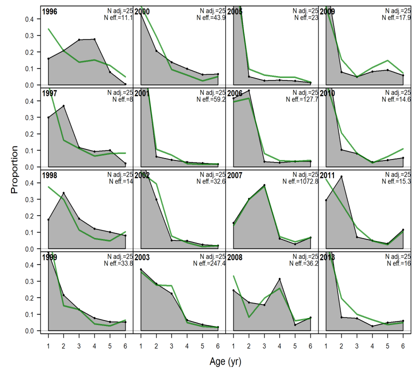


(e) Setup c

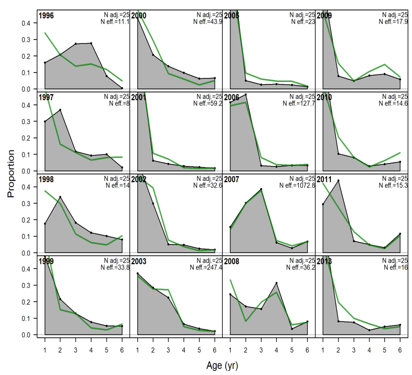
Figure 18: Age composition, whole catch, purse seine (plot 3 of 3). 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method. current model (top left) versus new runs.



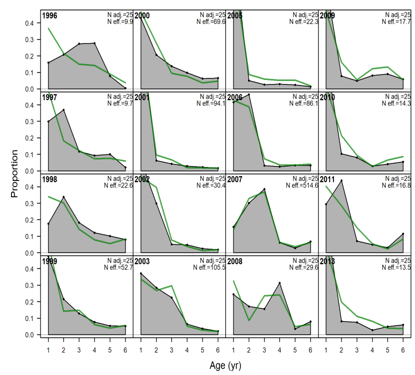
(a) **current model**



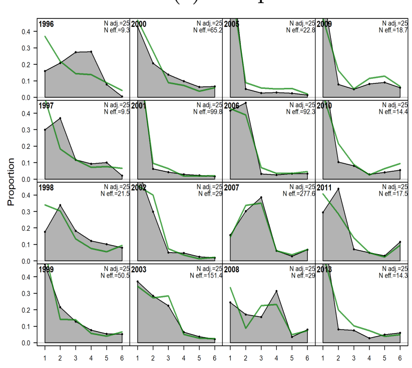
(b) **current model with 2020 DEPM point estimate**



(c) Setup a

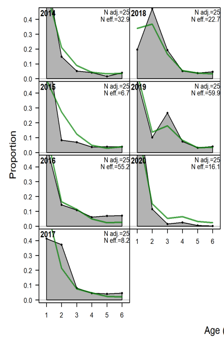


(d) Setup b

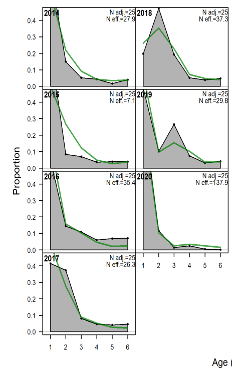


(e) Setup c

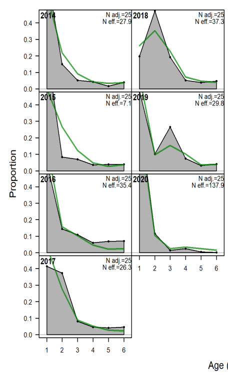
Figure 19: Age composition, whole catch, acoustic survey (plot 1 of 2). 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method. current model (top left) versus new runs.



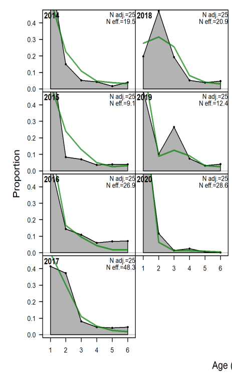
(a) **current model**



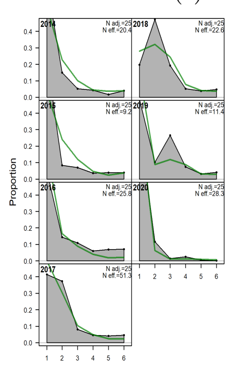
(b) **current model with 2020 DEPM point estimate**



(c) Setup a



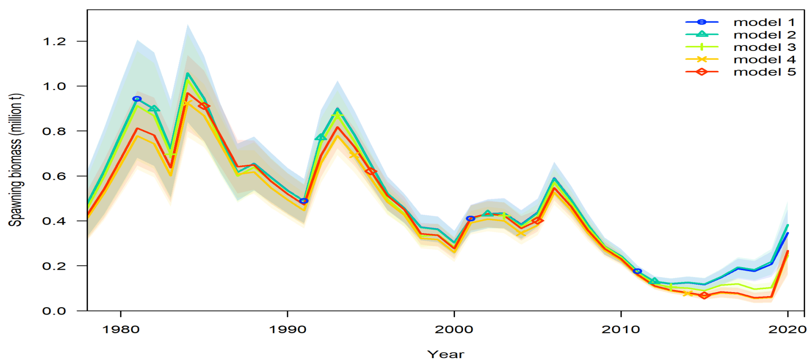
(d) Setup b



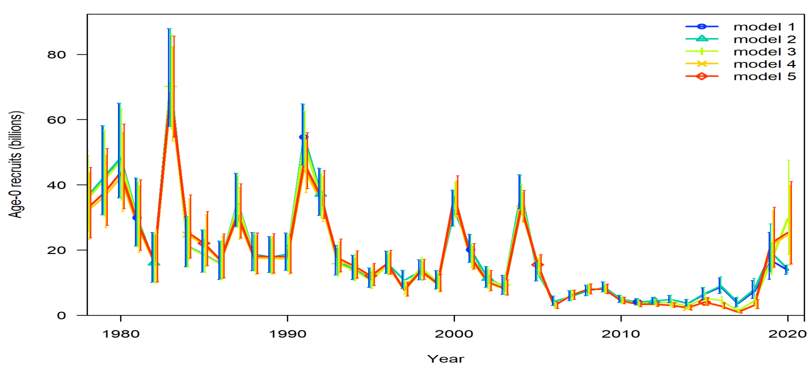
(e) Setup c

Figure 20: Age composition, whole catch, acoustic (plot 2 of 2). 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method. current model (top left) versus new runs.

Spawning stock biomass and recruitment time-series, as estimated by the models tested, follow the same trends as the current assessment model (Figure 21 and Table 6). For spawning stock biomass, the model with Setup a only seems to diverge from the current assessment model in the most recent 8 years while the other 2 models seem to diverges at the start and end of the time series. Model Setup b and c are very similar between them. Recruitment trends seem to follow the current model very well except at the start and the end of the time series. Differences between the 2020 assessment model and the new Setups don't seem to be related to the inclusion of the 2020 DEPM survey estimate. The new models show that the population in 2020 is smaller than what was estimated in the 2020 assessment, but recruitment is higher.



(a) Spawning stock biomass time series.



(b) Recruitment time series

Figure 21: Model comparison for SSB (a) and Recruitment (b). The blue line (model 1) is the current model, the green line (model 2) is the current model with the 2020 DEPM point estimate, the yellow line (model 3) is the model with Setup a, the orange line (model 4) is the model with Setup b and the red line (model 5) is the model with Setup c.

Table 5: Recruitment index values (numbers) for 9aCN area.

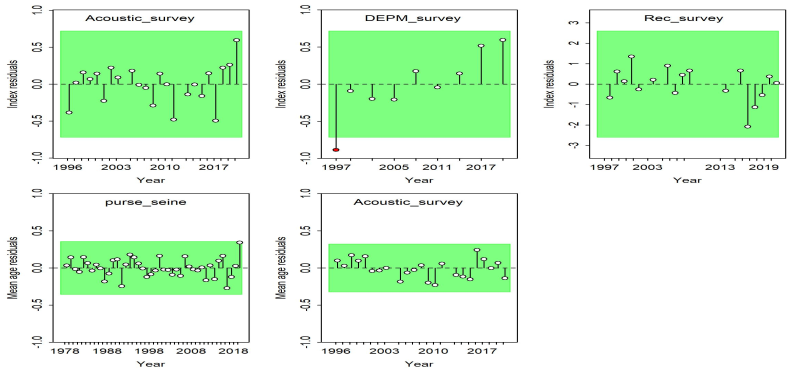
Year	Index value
1997	881535
1998	5496580
1999	2396691
2000	27739240
2001	2865167
2003	2355687
2005	7452078
2006	397637
2007	1993687
2008	3119792
2013	547673
2015	2115099
2016	114422
2017	93955
2018	524781
2019	5039175
2020	6491801

Table 6: Log-likelihood, SSB, Recruitment and F, AIC and final gradient for the different runs.

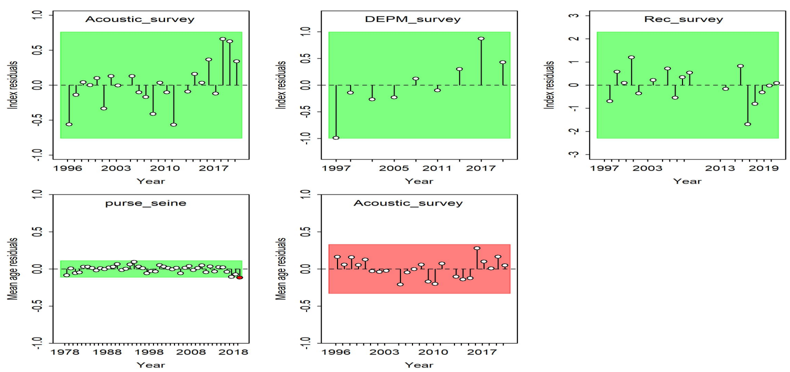
Label	Ass2020	Ass2020 with DEPM	Setup a	Setup b	Setup c
Log-likelihood components					
Total	135.14	134.84	228.17	139.5	138.66
Catch	1.20e-09	1.25e-09	2.79e-09	6.40e-15	5.88e-15
Equil_catch	0.41	0.36	0.86	0.02	0.02
Survey	-20.37	-20.9	44.11	22.68	22.5
Age_comp	131.36	131.94	152.45	93.87	92.79
Recruitment	23.74	23.44	30.75	14.91	15.32
Parm_softbounds	5.11e-04	5.11e-04	5.03e-04	7.32e-04	7.36e-04
Parm_devs	0	0	0	8.01	8.03
N parm	62	62	64	144	142
Output quantities					
SSB_2020	346.83	383.46	245.87	258.04	267.26
Recr_2020	13.8	14.13	29.72	24.72	25.38
F_2019	0.06	0.06	0.1	0.28	0.26
AIC	394.28	393.67	584.34	566.99	561.31
Max Grad	6.29e-05	3.65e-05	2.26e-05	3.00e-05	2.17e-05

4.3 Diagnostics

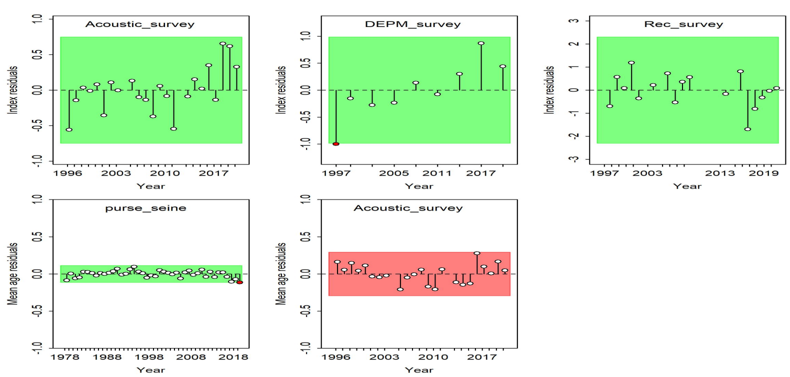
Diagnostics with ss3diag package for the three Setups can be seen in Figures 22 to 24. Mean age composition data 'pass the test' for Setup a but not for the Acoustic survey with Setups b and c (Figure 22). RSME for index and age composition are lower for Setups b and c.



(a) Setup a

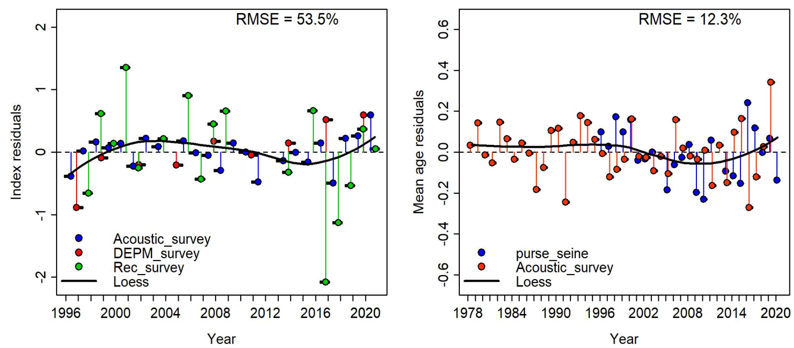


(b) Setup b

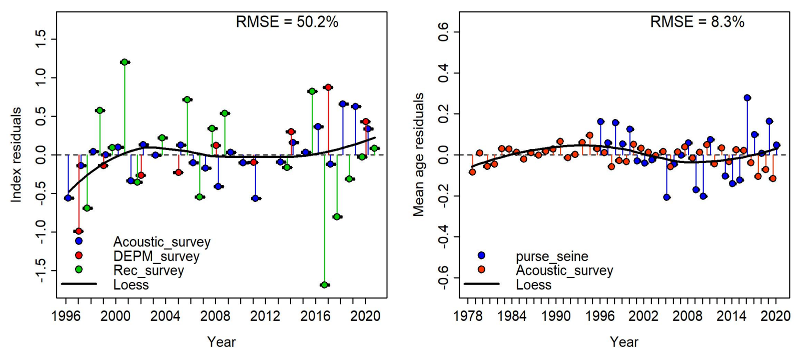


(c) Setup c

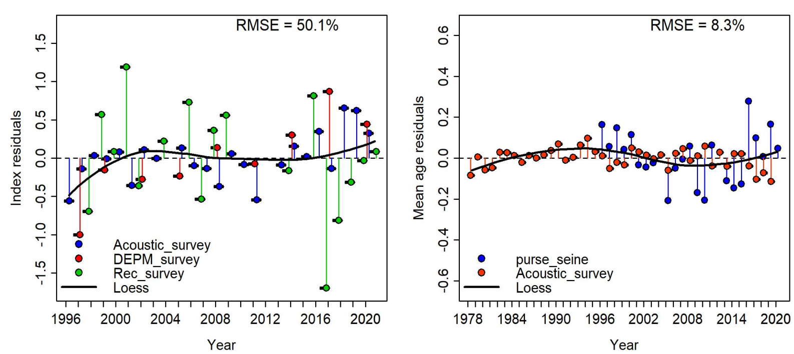
Figure 22: Runs Test residuals for mean composition data.



(a) Setup a

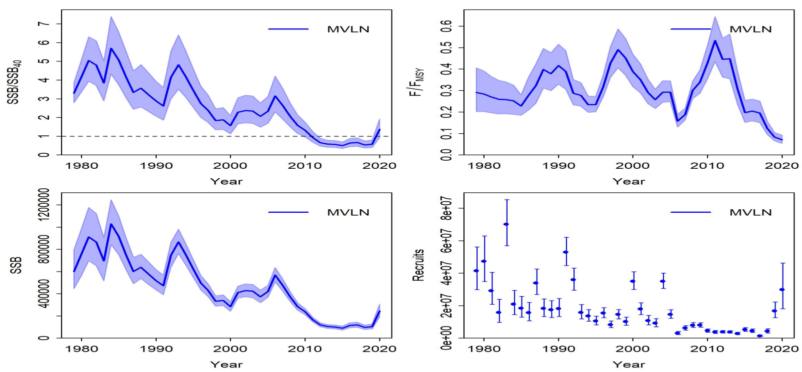


(b) Setup b

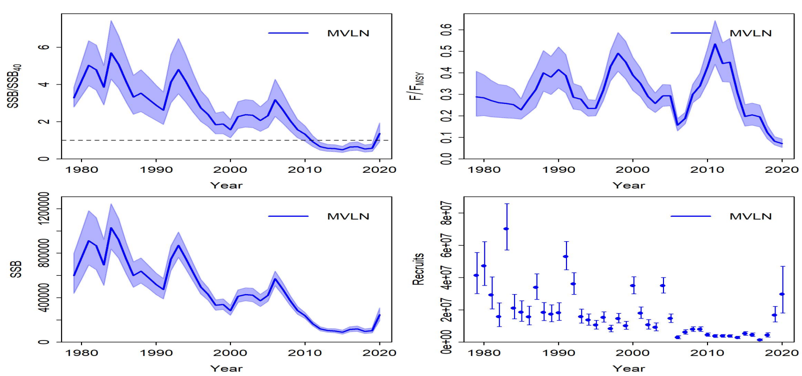


(c) Setup c

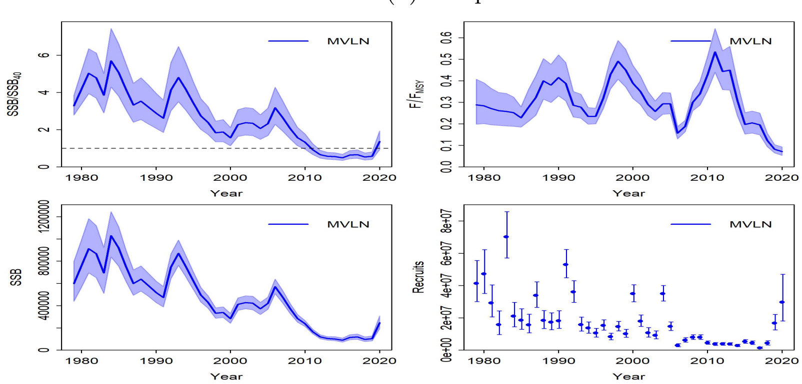
Figure 23: Joint residuals to check for conflicts in index residuals and mean age residuals.



(a) Setup a



(b) Setup b



(c) Setup c

Figure 24: Approximate uncertainty with MVLN (hessian).

5 Agreement of survey based estimate with recruitment model estimate

To assess the accuracy of the survey-based predictions of recruitment compared to assessment-based estimates, we computed the Pearson correlation coefficient (r) between the survey-based recruitment estimates and the stock assessment model-based abundance for age zero. The Pearson correlation coefficient was computed for the model with Setup a (r_1, model that uses the recruitment survey) and for the current model (r_2, assessment that does not use the recruitment survey). Another proxy (r_3) was computed: the geometric mean of the model-based abundances for the youngest year class during the previous 5 years was computed. $r1$ or $r2$ and $r3$ were then compared. According to [6], a higher value of r_1 or r_2 compared to r_3 indicates that survey estimates agree with assessment values better than average recruitment agrees with the assessment values. In this way, r_3 is an approximate proxy of the contribution of survey-based pre-recruit indices to estimate future recruitment over and above the use of a 5-year average.

Survey-based pre-recruit abundance indices had higher correlations with the model-based recruitment estimates than the geometric means of the five previous years of model based abundances (Table 7).

Table 7: Pearson correlation coefficient (in log scale) between the survey-based recruitment estimates and the stock assessment model-based abundance for age zero (r_1 and r_2) and with the geometric mean (r_3).

Coefficient	Correlation	df	p-value
r_1	0.90	15	8.1e-07
r_2	0.77	15	2.9e-04
r_3	0.60	15	1.1e-02

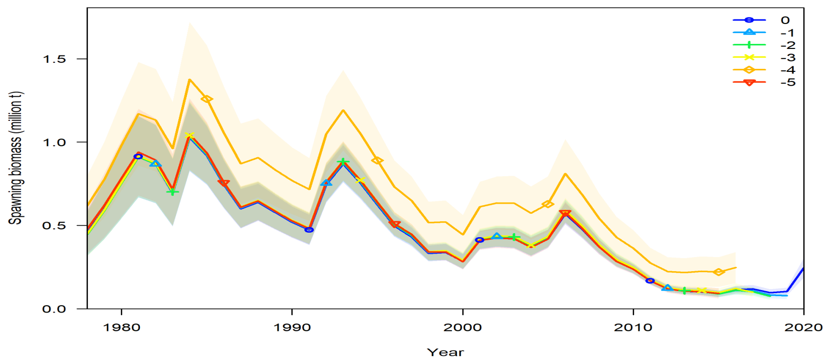
6 Retrospective

Retrospective patterns for SSB, F-values and recruitment were computed for years 2015–2020. 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. This range of runs include runs prior and after the benchmark (2017). The potential retrospective bias in the assessment was quantified using an approach based on the Mohn's rho [10], following ICES guidelines, and was computed using the function mohn() available in the R package called icesAdvice [7]. Results are shown in absolute terms (Figure 25). The model slightly underestimates F-values (Mohn's rho of -0.038) and recruitment (Mohn's rho of -0.153) while it overestimates SSB (Mohn's rho of 0.114). Comparing with the Mohn's rho values of the current model (2020 assessment), we see that Mohn's rho is now positive and the absolute increase is negligible (from -0.112 to 0.114) for SSB, Mohn'r rho value for recruitment decreased from -0.24 to -0.153. Mohn's rho for F-values changed signal from positive to negative and absolute value from 0.059 to 0.038. This seems to indicate that the retrospective pattern, already conforming to ICES standards, as improved and mainly for recruitment.

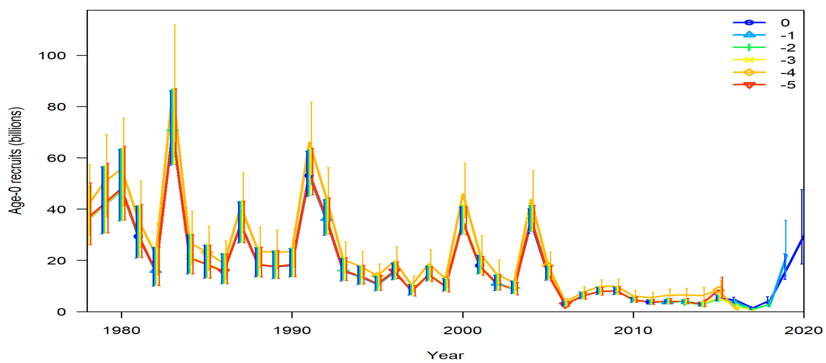
7 Short-term forecast

Catch predictions were carried out following the current stock annex with the exception of the assumption for recruitment in the interim year. Recruitment in the interim year (2020) is now the estimate from the assessment model. For the forecast year (2021) we tested 3 options: (i) set to the geometric mean of the last five years (2016–2020)[1], (ii) set to the geometric mean of the last ten years and (iii) set to the last year observation (2020).
Fishing mortality in the interim year is the fishing mortality that corresponds to a catch constrain. The catch assumption for 2020 was the official catches for 2020 that we already know and in the future it will correspond to a catch assumption based on preliminary official catch data. For 2021, predictions were carried out with an $F_{multiplier}$ assuming an $F_{sq} = 0.148$, the average estimate of the last three years known in the assessment (i.e. mean of $F_{ages2\text{–}5}$ for the years 2017 to 2019), as indicated in the Stock Annex. Table 8 shows input data for the short-term forecast. Figure 26 shows the results of the short-term forecast for the 3 options tested and the for the 2020 assessment.

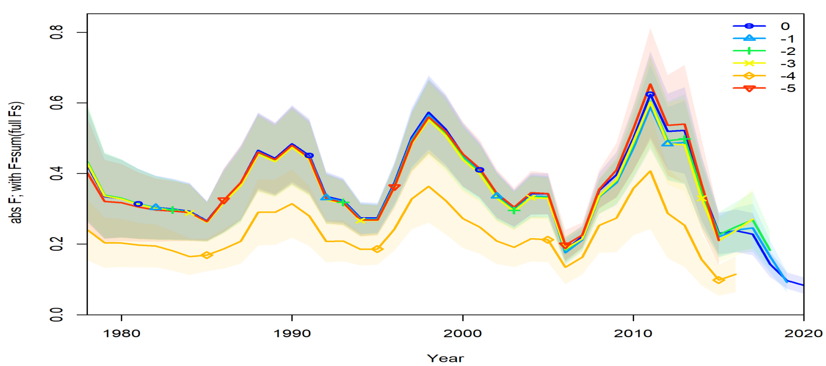
[1]Now it includes the interim year estimate for recruitment



(a) Spawning stock biomass time series.



(b) Recruitment time series



(c) F-value time series

Figure 25: Retrospective for SSB (a), Recruitment (b) and F value (c).

Table 8: Basis for the catch scenarios. Assumptions made for the interim year and in the forecast.

Variable	Values	Notes
$F_{ages2\text{–}5}$ (2020)	0.081	The F that corresponds to the assumed catch in 2020 (22143 t)
B1+ (2021)	351159	Tonnes; obtained from the short-term forecast
R_{age0} (2020)	29723200	Thousands; model recruitment estimate
R_{age0} (2021)	6734017 for option (i)	Thousands; geometric mean (2016–2020)
	29723200 for option (ii)	Thousands; 2020 model recruitment estimate
	5082699 for option (iii)	Thousands; geometric mean (2011–2020)
Total catch (2020)	22143	Tonnes; official catch (will be assumption based on preliminary official catch)
Discards (2020)	Negligible	

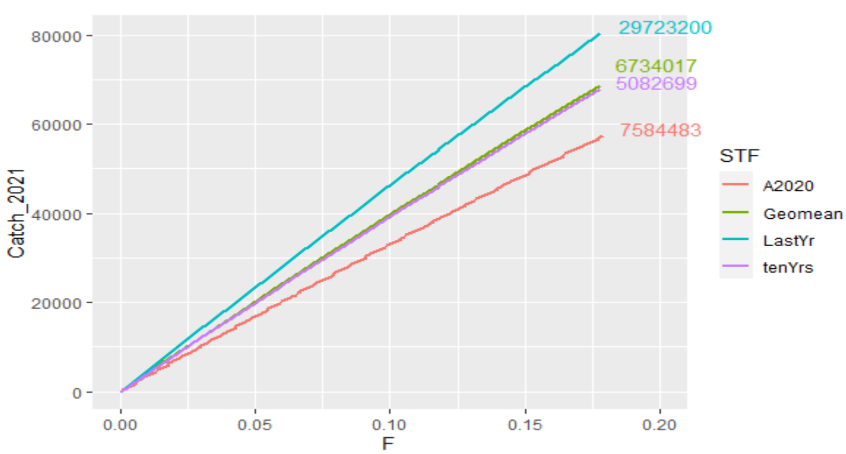


Figure 26: Short-term forecast for options (i) to (iii) and the 2020 assessment (current model). Values in the plot are labels for the 2021 recruitment assumption in each option. A2020 corresponds to the current model, Geomean corresponds to option (i) where recruitment is the geometric mean of the last five years, LastYr corresponds to option (ii) where recruitment is the model recruitment estimate in 2020, and tenYrs corresponds to option (iii) where recruitment is the geometric mean of the last ten years.

8 Implications for reference points

Depending on the model selected for the assessment of the IBERIAN sardine, it will be necessary to evaluate if reference points and the Long Term Management Plan recently evaluated in WKSARHCR [4] should be re-evaluated.

9 Discussion/To do?

References

[1] ICES. Report of the benchmark workshop on pelagic stocks. Technical Report DOE-SLC-6903-1, The International Council for the Exploration of the Sea, Copenhagen, Denmark, feb 2017.

[2] ICES. Pelagic survey series for sardine and anchovy in ices subareas 8 and 9. towards an ecosystem approach. *Cooperative Research Report*, No.332:268, 2018.

[3] ICES. Working group on southern horse mackerel, anchovy and sardine (wghansa). Technical report, ICES Scientific Reports, 2020.

[4] ICES. The workshop for the evaluation of the iberian sardine hcr (wksarhcr). Technical Report 3:49, The International Council for the Exploration of the Sea, Copenhagen, Denmark, 2021.

[5] ICES. Workshop on tools and development of stock assessment models using a4a and stock synthesis (wktadsa). Technical report, ICES Scientific Reports, 2021.

[6] Olivier Le Pape, Youen Vermard, Jérome Guitton, Elliot J Brown, Karen E van de Wolfshaar, Romuald N Lipcius, Josianne G Støttrup, and Kenneth A Rose. The use and performance of survey-based pre-recruit abundance indices for possible inclusion in stock assessments of coastal-dependent species. *ICES Journal of Marine Science*, 77(5):1953–1965, 06 2020.

[7] Arni Magnusson, Colin Millar, and Anne Cooper. *icesAdvice: Functions Related to ICES Advice*, 2018. R package version 2.0-0.

[8] Richard D. Methot and I. G. Taylor. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. *Can. J. Fish. Aquat. Sci.*, 68:1744–1760, 2011.

[9] Richard D. Methot and Chantell R. Wetzel. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research*, 142:86–99, 2013.

[10] R. Mohn. The retrospective problem in sequential population analysis; an investigation using cod fishery and simulated data. *ICES Journal of Marine Science*, 56:473–488, 1999.

[11] D.W. Skagen. Amci, version 2.4 assessment model combining information from various sources. Technical report, Available from the author (dankert@imr.no), Available from the author (dankert@imr.no) 2005.

[12] Henning Winker, Felipe Carvalho, Massimiliano Cardinale, and Laurence Kell. *ss3diags: What the Package Does (One Line, Title Case)*, 2020. R package version 1.0.4.