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Report of the Benchmark Workshop on Pelagic Stocks (WKPELA)

6–10 February 2017

Lisbon, Portugal

ICES CIEM

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Executive Summary

The Benchmark Workshop on Pelagic Stocks (WKPELA) meeting took place in Lisbon, Portugal, on 6–10 February 2017, hosted by IPMA (at its head quarter in Alges). It was chaired by Andrés Uriarte (ICES Chair), Spain, and by Dankert Skagen (External Chair), Norway, with the assistance of the invited external experts Yi-Jay Chang, Taiwan, and Martin Dorn, USA, (and ICES Professional secretary: David Miller/ Support secretary: Sarah Millar). The meeting was attended entirely or part time by 20 scientists from France, Spain and Portugal and 3 stake holders from the Netherlands, Spain and Portugal (Annex 1 list of participants). Three stocks passed the benchmarking process: Sardine (*Sardina pilchardus*) in Divisions 8c and 9a (Cantabrian Sea, Atlantic Iberian Waters); Sardine in Divisions 8a,b,d and Subarea 7 (Bay of Biscay, Southern Celtic Seas and English Channel) and Horse mackerel (*Trachurus trachurus*) in Division 9a (Atlantic Iberian waters) (Southern stock). Decisions on the assessments were undertaken after technical discussions and agreement among the ICES members and invited external experts for the Workshop.

For the southern Sardine (Divisions 8c and 9a), no need for a revision of the current stock boundaries was evidenced. Some immigration of sardines from the north (8abd, Bay of Biscay) to the Cantabrian sea (8c) may happen but this was perceived to be limited (SARDYN project 2002–2005) and recent studies on spatial cohort dynamics and growth patterns confirms the limited nature of such straying. Within the southern stock there are signs however of some regional sub structuring and potentially different population dynamics, especially concerning the Gulf of Cadiz area (9aSouth), as shown by analysis of otolith shape, morphometrics and recruitment dynamics. However, they were not considered enough as to change current stock definition.

For this southern sardine stock, detailed reviews of the data inputs were prepared in advance including, among others, revised estimates of the mean weights at age in the catches and the stock, small revision of the abundance of age 1 estimates in the acoustics surveys and major revisions of the SSB estimates from the DEPM surveys, the latter supported by ICES WGACEGG. Assessment was carried with Stock Synthesis 3 and starts in 1978. Regarding the fishery and population modelling in the assessment, the main adopted modifications refer to the methods to estimate the initial population (now starting at equilibrium since 1972), the stock-recruitment relationship (lognormal deviations from a Beverton-Holt stock recruitment model with steepness fixed at 0.71), the acoustic survey selectivity-at-age (fixed over the assessment period at 1 for all ages 1-6+) and the fishery selectivity-at-age (fixed for ages 3–5 for all the three periods considered: 1978–1987, 1988–2005 and 2006–2016). Furthermore, as a result of a systematic review of the fitting achieved for a combination of various scenarios of survey selectivity and fishery selectivity and for seven M scenarios, it was found that the assessment was optimised for a vector of natural mortality slightly higher than previously assumed. Accordingly, M at age was set equal the expected Gislason *et al*., values at age multiplied by a factor of 0.7. The Final adopted assessment model shows a better fit to the data available and provides more precise estimates of biomass, recruitment and fishing mortality than the last sardine assessment (WGHANSA 2016). The new assessment produces rather consistent estimates with former ICES assessments though some decrease of the biomass in 2016 (by about 25%) is obtained. Definition of Biological reference points could not be covered during the WKPELA meeting and were left for a posterior work

For the Northern sardine (Divisions 8a,b,d and Subarea 7), the basis for dealing together all these regions were reviewed. The workshop concluded that in the absence of firm evidences 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 – eggs, larval, juveniles and adults), it would be preferable to deal with the Bay of Biscay and subarea 7 separately as different stock units. The conclusion of WKPELA was that currently the limited and poor quality of the data available for the English Channel and Celtic sea region prevents producing an assessment of subarea 7. Furthermore, a joint assessment of Divisions 8abd and subarea 7 require the strong assumptions of similar population trends and age composition of catches in both areas, which is currently perceived as highly unlikely (according to the recent survey estimates and indications of different growth patterns). Therefore the conclusion, which the reviewers supported, was that it could be justified to explore assessing the Bay of Biscay part (Divisions 8a,b,d) as a separate stock unit.

An isolated assessment for the sardine in the Bay of Biscay (8abd) was prepared based on Stock Synthesis 3 and starting in 2000. Assessments with a4a were also tried in parallel, mainly for verification of results. Input data were: catches at age, acoustic estimates of population biomass and age structured information, a series of Egg Abundance as indicator of spawning biomass and two SSB estimates of DEPM surveys in 2011 and 2014. A complete systematic review of the fitting achieved for a combination of various scenarios of survey and fishery selectivity and for different patterns at age of natural mortality led to optimise the assessment for a vector of natural mortality as proposed by Gislason *et. al*, but multiplied by factor of 0.9., together with assuming a fixed fishery survey catchability for ages 35 and flat survey catchability for ages 2–5 over the entire assessment period. Such setting of the assessment was accepted as the best model for providing scientific advice. This assessment supposes an improvement over the previous survey trend-based assessment applied by ICES. However biomass estimates from SS3 are lower than the biomass indices derived from the surveys which intend to be provide absolute estimates of biomass (estimated catchability for Pelgas biomass index, 2.4, and for DEPM 1.8, and these values are perceived to be too high). The WK recommended to use the results of the assessment as indicative of trends only (category 2 stocks). Lack of time left the definition of biological reference points for a later stage after the workshop.

For southern Horse mackerel (in Division 9a), recent studies support the current assumption of stock identity. Little review of the data input was required, this only affected to horse mackerel bottom trawl survey data from the Portuguese and Spanish IBTS, which was analysed from 1983–2015. The expert group decided that the “standard” stratified mean was an acceptable method to deal with the non-normal abundance distribution of horse mackerel and with the variability in the survey data. Therefore, this estimator replaced the simple average method used before as the abundance index for tuning the assessment. The stock assessment was performed with the AMISH (Assessment Method for the Ibero-Atlantic Southern Horse mackerel), as in the last benchmark of the stock. Major Model assumptions were: Initial recruitment (age 0) is governed by the Beverton and Holt S-R relationship, assuming a steepness of h=0.8; One selectivity block for the survey abundance index, and three fishery selectivity blocks for the fitting of catch-at-age (1992–1997, 1998–2011, 2012 onwards) with Selectivity-at-age constant for ages 7+. The three time-blocks for the catch selectivity accommodates the recent changes in the fishery due to the strong year-classes of 2011 and 2012 and the increase of horse mackerel catches by purse-seiners. The outputs from the adopted assessment were very consistent with the former ICES assessment and so were the associated biological reference points (which did not require to be changed).

External experts endorsed the decisions made for setting up the assessments for the provision of advice, as reflected in the stock annexes and justified along the main text of the report. Finalising the work to address ToRs f) and g) outlined above, on the Evaluation of the compliance of the southern Sardine management plan with the precautionary approach, was delayed to a second WKPELA meeting foreseen on 29–31 May 2017.

1 Introduction

The Benchmark Workshop on Pelagic Stocks (WKPELA) meeting took place in Lisbon, Portugal, on 6–10 February 2017, hosted by IPMA (at its head quarter in Alges). It was chaired by Andrés Uriarte (ICES Chair), Spain, and by Dankert Skagen (ICES Chair), Norway, with the assistance of the invited external experts Yi-Jay Chang, Taiwan, and Martin Dorn, USA, (and ICES Professional secretary: David Miller/ Support secretary: Sarah Millar). The meeting was attended entirely or part time by 20 scientists from France, Spain and Portugal and 3 stake holders from the Netherlands, Spain and Portugal (Annex 1 list of participants).

The stocks undertaking benchmarking were the following (with corresponding stock assessment leaders):

Stocks	**Stock leader**
Sardine (*Sardina pilchardus*) in Divisions 8a,b,d and Subarea 7 (Bay of Biscay, Southern Celtic Seas and English Channel)	Lionel Pawlowski
Sardine (*Sardina pilchardus*) in Divisions 8c and 9a (Cantabrian Sea, Atlantic Iberian Waters)	Alexandra Silva
Horse mackerel (*Trachurus trachurus*) in Division 9a (Atlantic Iberian waters) (Southern stock)	Gersom Costas

<u>The terms of reference for WKPELA were:</u>

a. Evaluate the appropriateness of data and methods to determine stock status and investigate methods for short term outlook taking agreed or proposed management plans into account for the stocks listed in the text table below. The evaluation shall include consideration of:

- Stock identity and migration issues;
- Life-history data;
- Fishery-dependent and fishery-independent data;
- Further inclusion of environmental drivers, multi-species information, and ecosystem impacts for stock dynamic in the assessments and outlook

b. Agree and document the preferred method for evaluating stock status and (where applicable) short term forecast and update the stock annex as appropriate. Knowledge about environmental drivers, including multispecies interactions, and ecosystem impacts should be integrated in the methodology. If no analytical assessment method can be agreed, then an alternative method (the former method, or following the ICES data-limited stock approach) should be put forward;

c. Re-examine and update (if necessary) MSY and PA reference points according to ICES guidelines (see Technical document on reference points);

d. Develop recommendations for future improving of the assessment methodology and data collection;

e. As part of the evaluation:

- Conduct a 3 day data evaluation workshop (DEWK). Stakeholders are invited to contribute data (including data from non-traditional sources) and to contribute to data preparation and evaluation of data quality. As part of the data compilation workshop consider the quality of data including discard and estimates of misreporting of landings;

- Following the DEWK, produce working documents to be reviewed during the Benchmark meeting at least 7 days prior to the meeting

f. For the stock sar-soth re-evaluate whether the Portuguese-Spanish sardine fishery management plan remains precautionary taking into account the new agreed analytical assessment method and potential new biological reference points. In addition, it should be evaluated whether the plan remains precautionary when adding the following condition to the original plan: "*In cases where applying the plan results in catches of less than 50% of catches in the previous year, then ICES catch advice on a precautionary basis should apply.*" To the largest extent possible, the evaluation should follow the guidelines provided by the "Workshop on Guidelines for Management Strategy Evaluations" (WKGMSE, ICES CM 2013 ACOM 39), including the guidelines for reporting provided in Section 6 of the WKGMSE report. The agreed ACOM criteria for considering management plans as precautionary should also be taken into account in the evaluation.

g. Prepare the first draft of the advice to address the EU request on whether the Portuguese–Spanish sardine fishery management plan remains precautionary by introducing the condition *"In cases where applying the plan results in catches of less than 50% of catches in the previous year, then ICES catch advice on a precautionary basis should apply"*.

Preparatory work:

To prepare this meeting data evaluation and compilation workshops (DEWKPELA) for the stocks of sardine and southern horse mackerel took place in 2016 (accounting for ToR e):

- The Workshop on Atlantic Sardine (WKSAR), chaired by Alexandra Silva (Portugal) and Lionel Pawlowski (France), met in Lisbon, 26–30 September 2016.
- The data evaluation workshop for southern horse mackerel met in Lisbon, 21–24 November 2016, chaired by Andrés Uriarte (DEWKPELA).

Respective reports of these meetings were produced and are available in the backgrownd documents of the SharePoint of WKPELA. The two meetings aimed at reviewing information on stock structure, reviewing existing information from surveys/commercial vessels and to identify candidate datasets/model approach for the stocks.

Stakeholders invited to attend and contribute with any inputs by invitations to attend these DEWKPELA meetings, which were delivered to them by ICES (or directly by scientists).

In addition a Webex with ICES secretary and external experts took place on the December 05 2016, to update external experts on main issues and progress achieved during data compilation WK.

As requested working documents, summarising the prior work and the latest advances achieved just before the meeting, were made available mostly before the meeting but a few in the first day of the meeting (see the complete list of working documents in Annex 8).

<u>Purpose of the February meeting:</u>

The WKPELA meeting in February 2017 addressed ToRs a) to e) outlined above for the stocks under benchmarking.

Finalising the work to address ToRs f) and g) outlined above, on the evaluation of the sardine management plan compliance with the precautionary approach, was delayed to a second WKPELA meeting foreseen on 29–31 May 2017.

2 Organization of the work during the Benchmark and structure of report

Development of the work during the benchmark process

The meeting started, according to the draft agenda sent in advance (Annex 2), with introductory presentations and general issues, followed by a general presentation on stakeholders answers to questionnaires (see below) and a discussion on sardine stock identity. Subsequently presentations on the status of the assessment on stock by stock basis followed. Natural deviations from the initial agenda occurred throughout the meeting. The actual agenda can also be seen in Annex 2.

Stakeholders inputs were assured by invitations delivered to them by ICES and scientists members of this workshop to directly attend this WKPELA or any of the former DEWKPELA meetings. In addition a questionnaire on sardine biology, data input, and management issues were circulated during 2016 to main stakeholders of the South-western Advisory Council (including England UK ports). A working document summarising the answers received is attached in Annex 7 of this report.

During the benchmark the work was structured on topics by stocks with presentations and discussions (see list of Presentation in Annex 9), as follows:

- The first two days were devoted to introductory presentations and examination and decisions on stock identity issues; and next to the presentations on the status of the assessments on stock by stock basis.
- The following two days were devoted to address all technical issues about inputs, model setting and tuning through an iterative process of examination of prior results, definition of alternative approaches and examination of the new results to adopt or reject the suggested new model settings. This was achieved by splitting in subgroups respective to the stocks under benchmarking and with frequent interaction with ICES external experts to address the technical problems which might be arising during the process and to examine results.

Addressing of the definition of Biological Reference points was only achieved for the southern horse mackerel, but not for the other two species because the assessments for them took too much time as to start addressing that issue as it deserves. Therefore this will have to be addressed at a later stage. For sardine this will take place prior to the end of May to allow evaluation of compliance with PA of the current management plan for sardine (ToRs f & g).

During the last day of the meeting assessments were consolidated for southern horse mackerel and Iberian sardine, but nor for northern sardine because some not well understood issues remained unsolved. As a result of this a shopping list of home works to conclude the work for northern sardine in a week was agreed to culminate the work (through and a Webex meeting). Furthermore the follow up actions to address the evaluation of the Management Plan in May (ToRs f & g) were agreed. And finally the meeting was closed including a brief planning of the follow up actions for the reporting to be achieved during February.

During the two weeks after the meeting pending issues on northern and southern sardine were addressed and the texts on the stock annexes and main report were completed by the members of the group. As such, webex meeting were carried out on

February 22 and April 10 to address the pending issues on northern and southern sardine respectively (including in both cases re-evaluation of the M pattern at age and final revisions of the assessments), with participation of most WKPELA members and external reviewers.

Structuring of the report

The report is structured according to the Guidelines for Benchmark and Data Compilation Workshops as followed:

The main report contain the general introductory sections (chapters 1 and 2) and chapters by stocks, which describe the benchmarking work, e.g. explanation for arriving to a conclusion and how the external experts input was addressed (Chapters 3, 4 and 5 for Ibero Atlantic sardine, northern sardine and southern horse mackerel respectively).

Annexes addressed separately all additional issues:

- Stock annexes: Southern Sardine stock Annex (Annex.3), Northern Sardine stock Annex (Annex.4), Southern Horse mackerel stock Annex (Annex.5).
- External Reviewers Comments on WKPELA (Annex.6).
- Stakeholders' inputs (questionnaires) on sardine (Annex.7).

And the remaining annexes cover the list of attendees (Annex 1), agenda (Annex 2), working documents and presentations (Annexes 7 & 8), followed by a selection of relevant working documents which deserved forming part of the report as corroborative documentation of the basis for the decisions taken (from Annexes 10 and onwards+). The Report of the Data Evaluation Workshop for southern horse mackerel (DEWKPELA2017-WKSHOM) was included in Annex 10 and the report of the WKPELA Workshop to evaluate the management plan for Iberian sardine is included in Annex 11. Annex 12 includes a list of other relevant working documents to WKPELA 2017.

3 Ibero atlantic Sardine (Sar south)

3.1 Stock ID and sub-stock structure

No definite evidence has shown to support change of current stock boundaries. Locally there are signs of regional substructure and potentially different population dynamics (especially for areas in the limits, as the Gulf of Cadiz), revealed through multidisciplinary studies (ICES, 2016a):

- Genetic studies, using different molecular markers are not fully consistent; earlier studies using allozymes and studies using mtDNA indicated a higher degree of differentiation than recent studies using allozymes and studies using microsatellite DNA. In general, no genetic structure is evident in most of the distribution range for neutral markers and genetic differentiation among individuals increases as geographical distance increases.
- Data on cohort dynamics in recent years do not indicate massive straying of cohorts from the Bay of Biscay to the Cantabrian Sea. Furthermore, the recent review of growth by regions suggest some heterogeneity among the northern regions, with larger homogeneity in the periods 2000–2010 than in the years 2011–2016, whereby in Biscay smaller sardine mean growth than in the Cantabrian regions are seen.
- The continuity of the spawning area, overlap in spawning seasons, and similarity of genetic, morphometric and life-history properties studied in SARDYN project (2002–2005) support mixing between the stocks. Trial area-based assessments with different models indicated that migrations, most likely involving a net immigration from Biscay to Cantabria, were plausible. Further work after SARDYN with the Bayesian state–space model estimated likely emigration from south Biscay (8.b) to east Cantabria (8.c-east) for one-year-olds and also estimated likely immigration (at a smaller rate) into east Cantabria for 2+ adults. However, the total–stock biomass in Iberia resulting from immigration from Biscay was estimated to be low (1–4%).
- There is there evidence of connectivity between Cantabrian/North Galicia and western Portugal, both at the larval and adult stages. Marked geographical differences in adult growth patterns places south Galicia in an intermediate region between the high growth levels of sardine in the northern regions (North Galicia and Cantabria) and the smaller growth levels observed in the western Portuguese areas. In a recent study, using a biophysical model for simulating early life stages of sardine, an alongshore transport of larvae spawned in Portugal to the Cantabrian sea and viceversa was observed. They argue that the transport from Cantabria to north Portugal may be more important as a connectivity process because while larvae transported to the Cantabrian Sea end up in a cold area with limited food, sometimes larvae transported to the northern Portuguese shelf from the Cantabrian Sea end up in a favourable environment.
- Data on otolith microchemistry and cohort dynamics support the hypothesis that sardine cohorts stray from western Iberian to North Galicia and the Cantabrian Sea during their first 2–3 years of life.
- Growth patterns suggest some partially independent dynamics between the northern areas and the western areas. But higher lengths-at-age in northern areas might also suggest straying of larger fish to the north.

- However, sardine body and otolith shape, life-history properties and cohort dynamics, all point to some differentiation between the western and the southern areas, mainly with respect to the Gulf of Cadiz. In terms of otolith shape, growth and maturation sardine distributed in the Gulf of Cadiz appear to be closer to sardine in southwestern Mediterranean than to those in western Portugal.
- Areas in the limits, Gulf of Cadiz and Channel/North Sea, show differentiation in some approaches (Gulf of Cadiz: otolith shape, morphometrics, recruitment dynamics / English Channel: otolith shape, growth) but further information from the area (in the case of Channel/Celtic Sea/ North Sea) or from adjacent areas (southwestern Mediterranean and northern Morocco) is needed.

3.2 Issue list

Stock	Sardine in VIIIc and IXa……………………			
Issue	Problem/Aim	Work needed / Possible direction of solution	Data needed to be able to do this: are these available / where should these come from?	External expertise needed at benchmark Type of expertise / Proposed names
Stock identity	Following the outcome from project SARDYN, sardine in VIIIc and IXa is considered to be a separate stock from sardine in VIIIb+a and northwest Africa. However, there is indication of some exchange between VIIIc and Biscay North (VIIIb+a).	Review literature on genetic, morphometric, other stock identification methods. Analyse abundance-at-age and catch-at-age data disaggregated by area to follow cohorts in space/time. Perform stage-specific analysis of otolith elemental composition (LA-ICPMS) Perform a new genetic analysis in order to explore migration rates.	Data available from IPMA, IEO and IFREMER. Samples of otoliths and material for genetic analysis are available. The performance of the studies depend on getting funding for the analyses.	Steve Cadrin

Stock	Sardine in VIIIc and IXa......................			
Issue	Problem/Aim	Work needed / Possible direction of solution	Data needed to be able to do this: are these available / where should these come from?	External expertise needed at benchmark Type of expertise / Proposed names
Tuning series	Portuguese and Spanish spring acoustic surveys are combined in a single index of abundance in the assessment. The survey relative catchability and implications for their joint or separate use in tuning the assessment need to be investigated. There are conflicting signals between the acoustic and the DEPM survey in some years. Exploratory analyses indicate that P0 may be a good proxy of SSB. Investigate the possibility to estimate sardine P0 from horse mackerel AEPM surveys to complement interim years in sardine DEPM.	Revisit data from previous intercalibration experiments . Investigate the causes of conflicting signals between DEPM and acoustic surveys Sort and stage sardine eggs collected in horse mackerel surveys.	Dedicated session to discuss the results in WGACEGG if needed. Depends on work to be carried out within WGACEGG. Samples of sardine eggs from horse mackerel egg surveys are available from IPIMAR and IEO databases.	Miguel Bernal

Stock	Sardine in VIIIc and IXa........................			
Issue	Problem/Aim	Work needed / Possible direction of solution	Data needed to be able to do this: are these available / where should these come from?	External expertise needed at benchmark Type of expertise / Proposed names
Biological Parameters	Ogive and weights-at-are fixed in 1978–1985 at values far from long term average at some ages; obtain estimates by year. Weights-at-age are derived from spring acoustic surveys whereas the maturity ogive is derived from DEPM surveys. Tuning of the model to the DEPM survey should be based on weight-at-age consistent with the DEPM survey dates.	Compile data to review weights and maturity-at-age for as many years as possible prior to1985. Estimate weights-at-age from DEPM surveys.	Data available from the databases of commercial samples from IPIMAR and IEO since the early 1980s, from AZTI since the early 1990s. Availability of earlier data to be explored. Data available from the databases of IPIMAR and IEO.	

Stock	Sardine in VIIIc and IXa……………………			
Issue	Problem/Aim	Work needed / Possible direction of solution	Data needed to be able to do this: are these available / where should these come from?	External expertise needed at benchmark Type of expertise / Proposed names
Assessment method	Investigate assumptions about fishery and survey selectivity (over time and age); explore alternative temporal and spatial disaggregation of assessment data. Investigate stock-recruitment relationships within the assessment model. Depending on the results from stock identity and biological work (above), investigate different stock structure hypothesis Explore the use of environmental variables in the assessment and short term projection of the stock, namely to help explain recruitment, growth and maturity-at-age.	Explore survey and catch data to get guidelines for modelling fishery and survey selectivity. Analyse stock recruitment data. Apply sensitivity and simulation analyses to investigate selectivity and stock-recruitment assumptions. Review literature, select appropriate environmental variables, test within Stock Synthesis model.	Data from WGHANSA. Data from WGHANSA, environmental data from ??.	Richard Methot Carryn de Moor Chris Francis
Biological Reference Points	Reference points are not defined for this stock and might be considered.	Revisit limit and target reference points, together with proposals of harvest control rules.	Data from WGANSA.	

Stock	Sardine in VIIIc and IXa........................			
Issue	Problem/Aim	Work needed / Possible direction of solution	Data needed to be able to do this: are these available / where should these come from?	External expertise needed at benchmark Type of expertise / Proposed names
Other issues	Compile information on the role of sardine as a forage fish in the pelagic ecosystem	Review results from studies on the diet of sardine predators, including interannual, seasonal and geographic variation in sardine importance in their diets.	Published and unpublished information.	

3.3 Multispecies and mixed fisheries issues and Ecosystem drivers.

No additional considerations to the Stock Annex.

3.4 Stock assessment inputs

3.4.1 Catch

Catch or catch-at-age data were not revised. Minor differences in the benchmark catches-at-age compared to those used in the 2016 assessment, all below 2.5%, are due to the change of measurement units from millions to thousands of individuals and rounding criteria. Information on catches, discards and assumed input errors are described in the Stock Annex.

3.4.2 Weights at age in catches

In previous assessments catch mean weights-at-age were fixed from 1978 to 1989 and variable by year afterwards. In addition, the mean weight-at-age of the 6+ group was assumed to be 0.1 Kg and fixed over the whole assessment period. For some of the younger ages, the mean weights in the fixed period were low in comparison with those observed in the first years that mean weights were calculated by year. To the contrary, the 6+ mean weight was too high. Following discussions in the benchmark preparatory Webex meeting, the group agreed to revise the catch mean weights-at-age. It is not possible to revise mean weights-at-age for the earlier fixed period because part of the data are not available. The mean weights-at-age were re-calculated from 1991 to 2015 using data reported to the assessment WGs every year by Spain and Portugal (see Stock Annex) (and Table 3.6.3 below). Mean weights-at-age by quarter and area were aggregated to the quarter and then to the year using the corresponding catch numbers-at-age as weighting factors. The mean weights-at-age from 1978 to 1990 were assumed to be fixed at the mean values of the period 1991–1995. For the earlier period, the revised mean weights-at-age at younger ages (0–3 years) are slightly higher than in previous assessments (Figure 3.4.2). For the 6+ group, a downward revision occurred in the whole period with major differences in the second half of the 1990s.

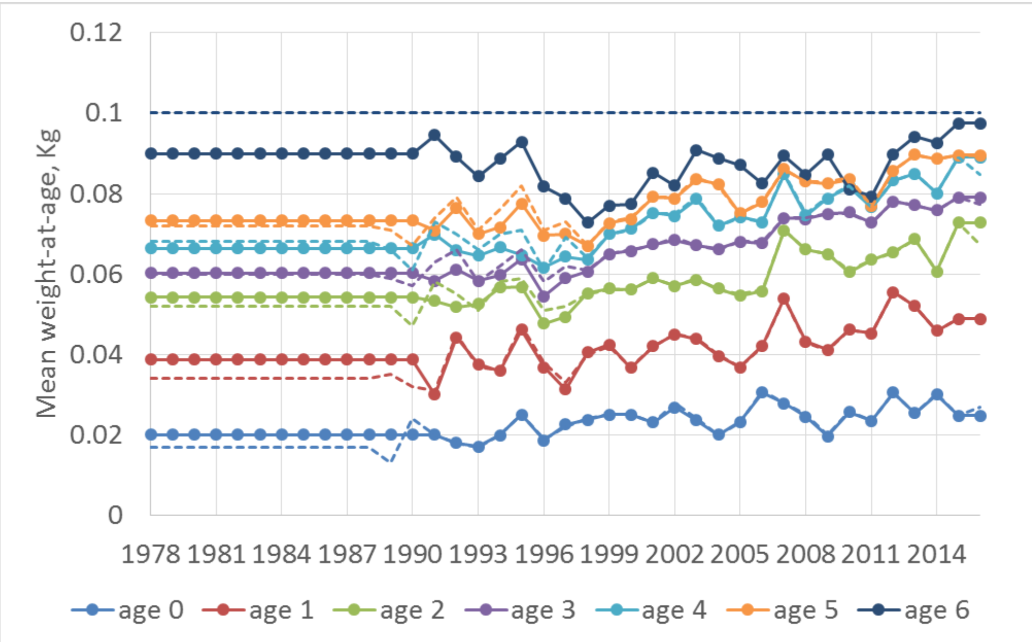


Figure 3.4.2. Mean weights-at-age in the catch for the sardine stock in 1978–2015. Values revised in the present benchmark (solid lines) and used in previous assessments (dashed lines) are shown for comparison.

3.4.3 Surveys

At present, the surveys used in the sardine assessment are the Spanish and Portuguese DEPM surveys and the spring acoustic surveys (described below), which jointly provide a full coverage of the stock area.

Description of both acoustic and DEPM surveys are included in the sardine stock annex. Both surveys are used in the assessment as relative indices of abundance. CVs of input estimates and effective sampling sizes are described in the Stock Annex.

It is noted that both the acoustic survey data and the DEPM data used in the present benchmark are pending revision related to the separation of data of age 0 from age 1 small individuals (Section 3.4.3.2). Although only minor changes are expected, the data used in the present benchmark should be considered provisional.

3.4.3.1 Revision of DEPM SSB estimates

During WGACEGG (November 2016), SSB estimates for the time series were revised and discussed (see WD Diaz et al. 2017 and WD Angélico *et al*. 2017 for further information). In order to allow egg mortality estimation in some years, and to have more biological plausible results, a new methodology, (Bernal *et al*., 2011) for the egg mortality estimation was applied for the survey series. The revision of the P0 and SSB estimates for the DEPM data series here presented is considered statistically consistent and the results less influenced by biased and imprecise, single survey, mortality estimates, while at the same time allows P0 and mortality results per stratum (Figure 3.4.3.1). In addition, the current SSB estimates are more in line with the tendencies observed in the biomass calculations obtained along the series of annual acoustics surveys.

The revision of age readings of small individuals (Section 3.4.3.2) was not carried out in DEPM samples and it is likely to affect data for some of the surveys (mean weights-at-age and to a less extent total biomass).

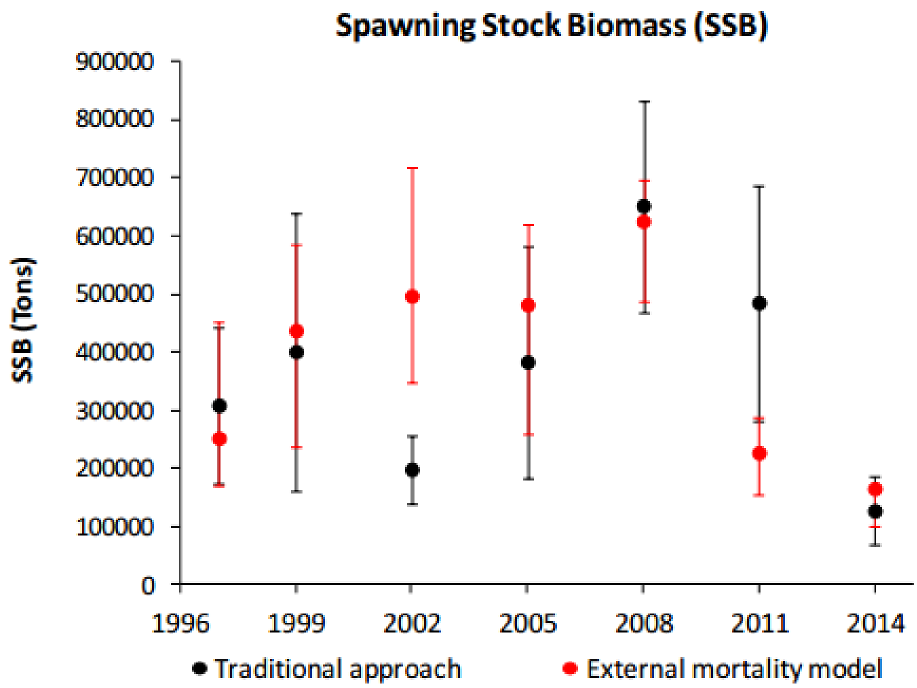


Figure 3.4.3.1. DEPM Spawning stock biomass (Tons) for the Atlanto-Iberian Peninsula (South+West+North strata) obtained by the traditional method (black dots) and using the mortalities obtained by the external model (red dots). The bars represent the confidence intervals for the estimates.

3.4.3.2 Revision of Portuguese acoustic data (PELAGO)-age classification of sardine small individuals

In the 2016 WGHANSA meeting (ICES, 2016b, Section 7.3.2.1), the WG group discussed the need to review the age classification of very small individuals in spring acoustic surveys for the southern stock. The issue is not new but became more relevant due to the occurrence of a large number of < 10 cm individuals in the Gulf of Cadiz in the PELAGO16 survey (56.4% of total abundance in the whole survey area). According to the age reading protocol for the stock these small individuals are classified as age 1 and are likely to be classified again as age 1 in the survey of the following year. This leads to mixing between the abundance of year-classes and bias in weight and maturity of 0 and 1 year-old fish.

The revision of a small set of otoliths of sardines (n=42) indicated that it was possible to discriminate between "false" and "true" age 1 individuals by examining the macrostructure of the otoliths (WD Moreno *et al.* 2016, ICES 2016b) (and see WD Silva *et al.*, 2017 for further information). In brief, the otoliths of "false" age 1 sardines had totally opaque otoliths (viewed in reflected light in a binocular microscope) whereas those of "true" age 1 sardines had an opaque centre and a hyaline edge, and in some cases an opaque centre, a hyaline ring and a thin opaque edge. All sardines below 7.5 cm were classified as "false" age 1 while length classes above 9 cm (and up to 14 cm) had increasing proportions of "true" age 1. Since the problem is likely to affect areas where recruits usually concentrate such as South Galicia, west Portugal and the Gulf of Cadiz, IPMA and IEO agreed to review age classifications of small sardines collected in their respective surveys, PELAGO and PELACUS. In the Data Compilation workshop, WKSAR (ICES, 2016a) IEO informed the problem didn't occur in South Galicia in PELACUS surveys. To the contrary, it occurred in several areas covered by PELAGO surveys (1996–2016). The revision of small sardines' age indicated that all individuals below 9 cm and a variable proportion of those between 9 and 14 cm should be classified as age 0 in spring PELAGO surveys. Overall, the revision did not change the internal consistency of the age composition whereas some improvement is noted in the estimation of recruitment strength.

Due to the limited time and manpower available for the work only a subset of the small sardines' otoliths was reviewed. In addition, a few discrepancies appeared between revised and original ALKs for other ages than age 1 which need to be clarified.

The group recommended continuing the revision of otoliths for the separation of age 0 and 1 individuals. A fully revised data set should be provided for the next assessment WG (WGHANSA 2017). Although major changes are not expected, it is noted that the acoustic survey data used in the present benchmark assessments is provisional.

3.4.3.3 Other surveys

Data from other acoustic surveys covering part of the stock area in other times of the year, such as ECOCADIZ-SUMMER, ECOCADIZ-RECLUTAS and JUVESAR, the latter two aiming to estimate recruitment of pelagic fish, were presented and discussed at the Data Compilation Workshop (ICES, 2016a). WKSAR considered that data from these surveys could be used as complimentary information in the sardine assessment outside the assessment model. It also recommended that WGACEGG examines the consistency of methods used in the two recruitment surveys and evaluate the possibility of, in the future, adding the regional estimates of recruitment to provide an index of recruitment for the stock.

Although this topic was not revisited in WKPELA, the group supports the recommendations of WKSAR.

3.4.4 Weights at age in the Population

Until now, weights-at-age were derived from spring acoustic surveys, whereas the maturity ogive is derived from DEPM surveys. This implies, mainly for the Portuguese spring surveys, a lag of time of several weeks, with potential implications in the biological performance of the fishes. In addition, maturity ogives and weights-at-age were fixed in the period 1978–1985 at values far from long term average at some ages.

The group agreed that the model should be tuning with weight-at-age consistent with the DEPM survey (Table 3.6.4). Therefore, mean weights-at-age in the stock in the new assessment comes from DEPM surveys (Figure 3.4.4) (see WD. Nunes *et al*., 2017 for further information):

For years with no DEPM survey between 1998 and 2014 (last DEPM survey at the moment), a linear interpolation was carried out to obtain the intermediate estimates of mean weight at age.

For the period 1978–1998 (before 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. The reasoning behind it is the apparent increasing trend in mean weights shown by several age classes (see ages 2 to 4) throughout the time series.

For the years 2015 and 2016 (years after the last DEPM survey), after the observation that the age composition of sardine population was similar between 2014 and 2016, the same estimates were assumed for the period 2014–2016.

It is noticeable the higher mean weight at age 1 obtained by this review for the early period of the fishery 1978–1991, which is more consistent with mean values in the first DEPM surveys.

For age 0 mean weight is just set to 0.

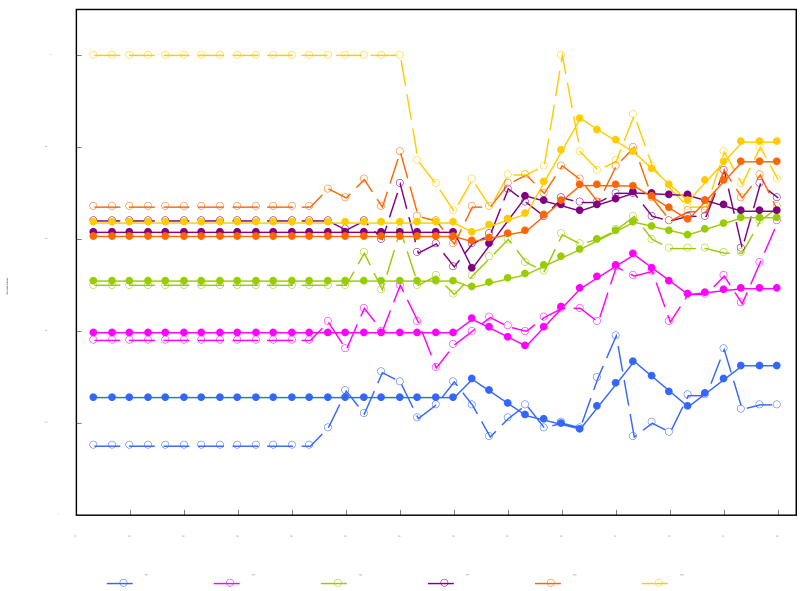


Figure 3.4.4. Mean weights-at-age in the stock, obtained from the revision based on the DEPM surveys (continuous line and full circles), and those used up to now in the assessment based on the acoustic surveys (dashed lines and open circles)

3.4.5 Maturity at age

In the former assessments maturity ogive came from DEPM surveys, whilst for the years without DEPM surveys, a constant value of 80% full maturity at age 1 (a median of former DEPM estimates) and a 100% for ages 2 and older was adopted in 2012.

The group agreed that the maturity ogive from the stock should come from DEPM surveys in the new assessment, with some assumptions for the years without survey (Figure 3.4.5) (see WD. Nunes *et al.*, 2017 for further information):

- For years with no DEPM survey between 1998 and 2014 (last DEPM survey at the moment), a linear interpolation was carried out to obtain the intermediate estimates of maturity at age.
- For the period 1978–1998 (years before starting DEPM series), constant proportions of mature at age were assumed, based on the average of the estimates obtained from the 6 DEPM surveys of the 1999–2014 period, thus including both years of strong year classes and years of low recruitment.
- For the years 2015 and 2016 (years after the last DEPM survey), after the observation that the age composition of sardine population was similar between 2014 and 2016, the same estimates were assumed for the period 2014–2016.

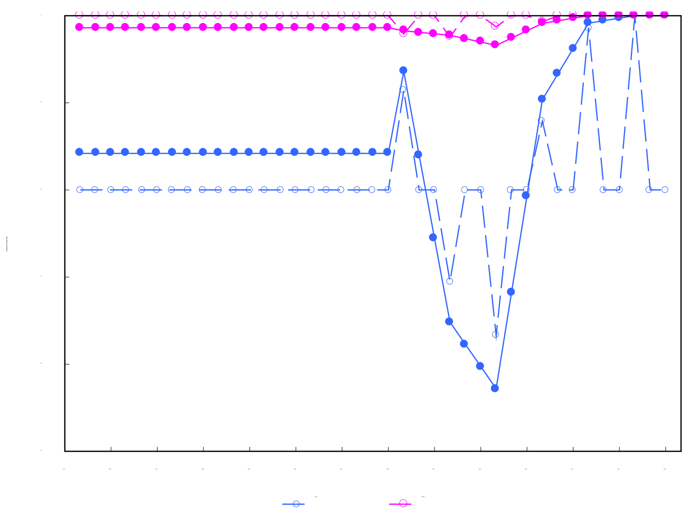


Figure 3.4.5. Proportion of mature fish, obtained from the revision based solely on the DEPM surveys (continous line and full circles), and those used up to now in the assessment (dashed lines and open circles)

3.4.6 Natural mortality

The group adopted new natural mortality values at age following a re-evaluation of M (see Section 3.5.2.5 below) (and see also Presentation Silva, 2017 for further information).

Age	M
0	0.98
1	0.61
2	0.47
3	0.40
4	0.36
5	0.35
6+	0.32
Mean (2-5)	0.39

3.4.7 Environmental covariates

Not included in previous assessments. Not considered in the present benchmark.

3.5 Assessment model

3.5.1 Assessment tool

The tool used is Stock Synthesis 3, version 3.24f (Methot, 2012; Methot and Wetzel (2013). The group considered there was no need to change the assessment tool. In this benchmark, the aim was to review and improve model settings and assumptions according to the issues identified in the last benchmark and additional ones raised since then.

3.5.2 Settings and assumptions

In previous assessments, biomass units were thousand tons and abundance units were million individuals. Units of measurement were changed to: biomasses in tons, numbers in thousands and mean body weight in kilograms. Compared to the 2016 assessment (ICES, 2016b), differences in the assessment outputs due to the change of units of measurement were minor (see also WD Silva and Riveiro, 2017b).

The separate impact of the revision of each dataset on the assessment is described in detail in WD Silva and Riveiro, 2017a. In section 3.6 the joint effect of all data revisions on the stock biomass, fishing mortality and recruitment is presented.

3.5.2.1 Initial population

In the 2016 assessment, the initial population was assumed to be a population in equilibrium subject to a fishing mortality rate estimated using an input initial equilibrium catch. Exploratory work showed the assessment results were very sensitive to the value of the initial catch. The higher the initial catch the higher was the early vs. recent fishing mortality and the lower was the early vs. recent biomass. In addition, the initial catch was set at 100 000 tons a value well below the average level of catches in the beginning of the assessment period.

In SS3, there are several approaches to estimate the population at the initial year of the assessment. When there is good age composition data in the first years of the assessment, the initial equilibrium age composition may be adjusted by projecting the year-classes backwards and estimating recruitment deviations (termed early recruitment deviations). This approach avoids the assumption of an equilibrium catch and reduces the influence of equilibrium conditions on the initial population. However, the assumption of an equilibrium catch may be needed in addition. In that case, the equilibrium year may be moved further back in time by adding catch biomass for some years before the first assessment year to reduce the influence of the initial catch value on the assessment.

We explored the approaches above setting two model configurations (WD Silva and Riveiro, 2017b):

- No equilibrium catch/F, equilibrium population modified by early recruitment deviations for 1974–1978 corresponding to the four cohorts represented in the catch-at-age data of the first year of the assessment (1978). Ages are grouped in a 6+ group, thus age 0 and the 6+ retain their equilibrium values.
- In addition to a) settings, the initial equilibrium catch was set at 135 000 tons, corresponding to the average catch of 1974–1978; the equilibrium year was moved back to 1972 by adding catch data for 1972–1977.

The two configurations were compared to the 2016 assessment model (with updated data). Configuration b) provided a better fit to the data (AIC=546.9) while configuration a) provided a worse fit to the data (AIC=558.6) compared to the 2016 assessment model (AIC=550.0). The improved fit of configuration b) was mainly due to a better fit to the fishery age composition, especially in the earlier period of the assessment (Table 3.5.2.1, Figure 3.5.2.1).

Given the better fit to the data, configuration b) the model with catch data starting in 1972, an assumed initial equilibrium catch of 135 000 tons and four early recruitment deviations was selected as the base case for further analysis.

Table 3.5.2.1. Log-likelihood, SSB, Recruitment and F in 2015 and final gradient for the different runs. Changes in likelihood are absolute, changes in SSB, R and F are relative and in %.

	Configuration b)				
	2016 assessment+ all revised data, equilibrium catch = 100 000		Equilibrium catch =135 000, catch start year=1972, 4 early R dev		Change
Log-likelihood components					
TOTAL	172.0		166.5		-5.5
Catch	2.3E-08		1.41E-08		0.0
Equil_catch	0.2		0.5		0.2
Survey TOTAL	-18.4		-17.4		-1.0
- Acoustic	-15.6		-14.7		-0.9
- DEPM	-2.8		-2.7		-0.1
Age_comp TOTAL	153.18		147.0		-6.2
- Purse seine	94.61		88.5		-6.1
- Acoustic	58.57		58.5		-0.1
Recruitment	34.95		34.8		-0.1
Parm_softbounds	4.3E-04		5.3E-04		0.0
Parm_devs	2.0		1.57		-0.5
Number Parameters	103.0		107.00		
Output quantities	Value	StdDev	Value	StdDev	
SSB 2015	153951	23410	170982	26458	11.1
R 2015	4520610	939271	4871720	1008930	7.8
apical F 2015	0.17	0.03	0.16	0.03	-11.2
AIC	549.99		546.90		
Final gradient	6.97E-07		6.31E-05		

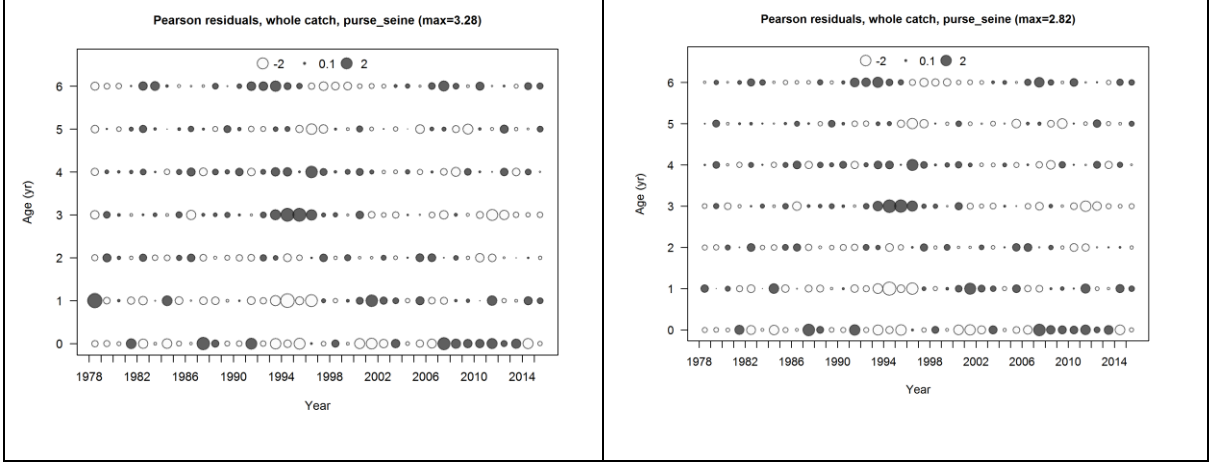
2016 assessment	Configuration b)
	

Figure 3.5.2.1. Catch-at-age residuals for the 2016 assessment and for model configuration b).

3.5.2.2 Recruitment

In the 2016 assessment, recruitment was assumed to be independent of biomass at all biomass levels. Equilibrium recruitment was estimated as a geometric mean with yearly deviations assuming a standard deviation of 0.55. Since 2006, the stock has shown historically low levels of biomass and only low recruitments have been observed. Thus, a stock-recruitment relationship which accounts for density-dependent recruitment at low levels of biomass appears to be more appropriate to describe the stock dynamics.

We explored models assuming the three most common SR models, Ricker, Beverton-Holt and Hockey-stick. In a first step, log-likelihood profiles of steepness or of the inflection point in the case of the Hockey-stick model were calculated for each of the models. The log-likelihood profiles pointed to a low steepness for all three SR models and therefore a strong dependency of recruitment on stock biomass up to high biomass levels. The three SR models were fitted with steepness values corresponding to the minimum total log likelihood. In all cases, assessment models were better fitted to the data and the differences in the negative log-likelihood were minor between the different SR forms. However, low steepness values appear to be too low in a small pelagic fish for which recruitment is primarily affected by environmental factors (Katara, 2014). In the case of sardine, the literature exploring drivers of recruitment variability indicate that recruitment is affected by a variety of environmental factors and only weakly related to spawning biomass (e.g. Santos *et al.* 2012).

Since the exploratory analysis did not point clearly to a best SR form and the estimated steepnesses were considered far too low for this type of stock, the group decided to assume a Berverton-Holt stock recruitment model with steepness fixed at 0.71, the median steepness for family Clupeidae from Myers *et al.* (1999) meta-analysis. The input standard deviation of log number of recruits was initially set to 0.55, as in the 2016 assessment model, and thereafter set to 0.70 to be consistent with the residual mean standard error of the recruitments estimated by the model.

The configuration including the Beverton-Holt model (configuration c) provided a better fit to the data (AIC=509.2) compared to the base case (configuration b) (AIC= 546.9) due mainly to an improved estimation of recruitment deviations and to a less extent to a better fit to the acoustic index and to the age composition data (Table 3.5.2.2, Figure 3.5.2.1). Similarly to previous model runs, recruitment deviations show a negative trend and high negative deviations are seen since 2006. The group discussed this issue and considered this to be an expected result taking into account that recruitment of this stock is likely to be driven by environmental factors. The group recognised that the SR relationship for this stock is uncertain but at the same time considered that it is more consistent with the recent stock history and more precautionary to assume some degree of density dependency in recruitment at low biomass levels.

Configuration c) assuming a Beverton-Holt stock-recruitment model with input steepness of 0.71 and input sigma R of 0.70 was selected as the base case for further analysis (Figure 3.5.2.2).

Table 3.5.2.2. Log-likelihood, SSB, Recruitment and F in 2015 and final gradient for the different runs. Changes in likelihood are absolute, changes in SSB, R and F are relative and in %.

	Configuration b)		Configuration c)		
	Equilibrium catch =135 000, catch start year=1972, 4 early R dev		Configuration b) + BH model, steepness 0.71, sigmaR 0.70		Change
Log-likelihood components					
TOTAL	166.5		147.6		-18.8
Catch	1.41E-08		4.33E-08		0.0
Equil_catch	0.5		0.1		-0.3
Survey TOTAL	-17.4		-20.0		2.6
- Acoustic	-14.7		-18.0		-3.3
- DEPM	-2.7		-2.0		0.7
Age_comp TOTAL	147.0		145.6		-1.4
- Purse seine	88.5		87.3		-1.2
- Acoustic	58.5		58.3		-0.1
Recruitment	34.8		20.3		-14.6
Parm_softbounds	5.3E-04		4.4E-04		0.0
Parm_devs	1.57		1.59		0.0
Number Parameters	107		107		
Output quantities	Value	StdDev	Value	StdDev	
SSB 2015	170982	26458	129951	20379	-24.0
R 2015	4871720	1008930	3787150	820536	-22.3
apical F 2015	0.16	0.03	0.21	0.04	35.2
AIC	546.9		509.2		
Final gradient	6.3E-05		9.4E-07		

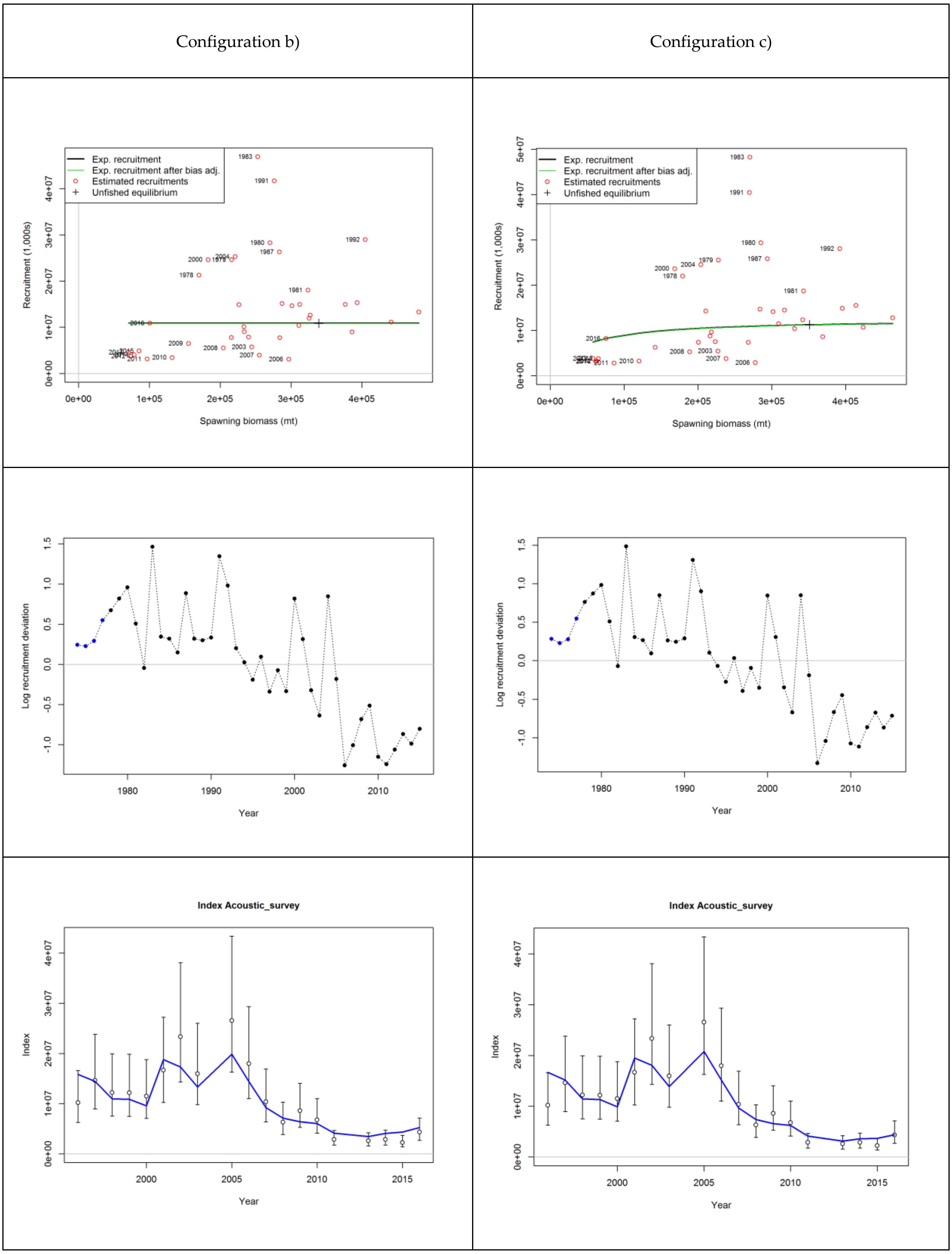


Figure 3.5.2.2. Stock-recruitment model, recruitment deviations and fit to the acoustic survey index for model configurations b) and c).

3.5.2.3 Survey catchability and selectivity-at-age

In the 2016 assessment the selectivity pattern estimated for the acoustic survey indicates slightly higher selectivity at age 1 (S=1) and substantially lower at the 6+ group compared to the ages in between (assumed to have equal selectivity, S= 0.68). In the last benchmark (ICES, 2012), it was recognised that equal selectivity at intermediate ages may be justified by the similar size and spatial distribution of fish. On the other hand, higher age 1 and lower age 6+ selectivity are harder to understand.

In this benchmark we explored the assumption of constant selectivity-at-age in the acoustic survey. In addition, catchability was estimated as a parameter instead of a scaling factor. The fit of the resulting model (Configuration d) is comparable to the model with variable survey selectivity-at-age (Table 3.5.2.3). The estimated catchability parameter is 1.67 (C.V=0.16) being similar to the scaling factor estimated in the 2016 assessment model (1.88). The group considered there is no clear justification to assume the survey does not measure all age groups according to their local availability. Assuming equal selectivity for age 1 and ages 2–5 years is also consistent with the fact that age 1 individuals are now identified with higher precision in acoustic surveys (Section 3.4.3.2). In addition, the survey covers the whole area and depth distribution of the stock so there are no strong reasons to suspect that old individuals are being underestimated by the survey. Finally, the assumption of flat selectivity is parsimonious and facilitates modelling and interpretation of fishery selectivity. However, the group recognised that other biological factors, such as senescence, which might increase natural mortality of older individuals could lead to an apparent decrease of selectivity in the 6+ group.

Configuration d), assuming flat selectivity in the acoustic survey was selected as the base case for further analysis.

Table 3.5.2.3. Log-likelihood, SSB, Recruitment and F in 2015 and final gradient for the different runs. Changes in likelihood are absolute, changes in SSB, R and F are relative and in %.

			Configuration d)		
	Configuration c)		Configuration c) + flat acoustic selectivity		Change
Log-likelihood components					
TOTAL	147.6		148.3		0.7
Catch	4.33E-08		2.78E-08		0.0
Equil_catch	0.1		0.1		0.0
Survey TOTAL	-20.0		-20.0		0.0
- Acoustic	-18.0		-18.1		-0.1
- DEPM	-2.0		-1.9		0.1
Age_comp TOTAL	145.6		146.1		0.5
- Purse seine	87.3		87.5		0.3
- Acoustic	58.3		58.6		0.3
Recruitment	20.3		20.5		0.3
Parm_softbounds	4.4E-04		4.1E-04		0.0
Parm_devs	1.59		1.58		0.0
Number Parameters	107		106		
Output quantities	Value	StdDev	Value	StdDev	
SSB 2015	129951	20379	133979	20533	3.1
R 2015	3787150	820536	3687600	795147	-2.6
apical F 2015	0.21	0.04	0.20	0.03	-3.3
AIC	509.2		508.7		
Final gradient	9.4E-07		2.5E-05		

3.5.2.4 Fishery selectivity

In the case of the fishery, the estimated selectivity pattern in the 2016 assessment model is dome-shaped in the most recent period (1991 onwards) while in the earlier period (1978–1990) it increases with age (ages 3–5 assumed to have equal selectivity). The change in time is abrupt and the difference between the two selectivity patterns is substantial, especially in the 6+ group. The causes for the change in fishery selectivity over time are not fully clear as well (ICES, 2012). In addition, an earlier analysis of catch/abundance ratios suggested that selectivity may have changed again in the most recent period, approximately since the mid-2000s (ICES, 2016b). Therefore the assumption of fixed selectivity since 1991 up to the present may be too rigid.

To explore alternative assumptions of variations in selectivity over time we considered that (i) time-varying fishery selectivity may result from time variations in the distribution of fishing when there are regional subpopulations with different age compositions and (ii) if subpopulations differ in their age compositions and gear selection is asymptotic and uniform across the region then population selection must be dome-shaped. The above reasoning may apply to sardine given (i) the age composition of the stock varies regionally due to the existence of localised persistent recruitment areas ICES, 2016a) and (ii) there have been marked variations in regional catches over time, namely from recruitment and non-recruitment areas. The percentage of catches coming from recruitment areas was examined revealing that it is comparable in the early (except 1978) and recent years of the assessment period and clearly lower in the late 1990s (Figure 3.5.2.4). The decrease from the late 1980s to the late 1990s appears to be gradual.

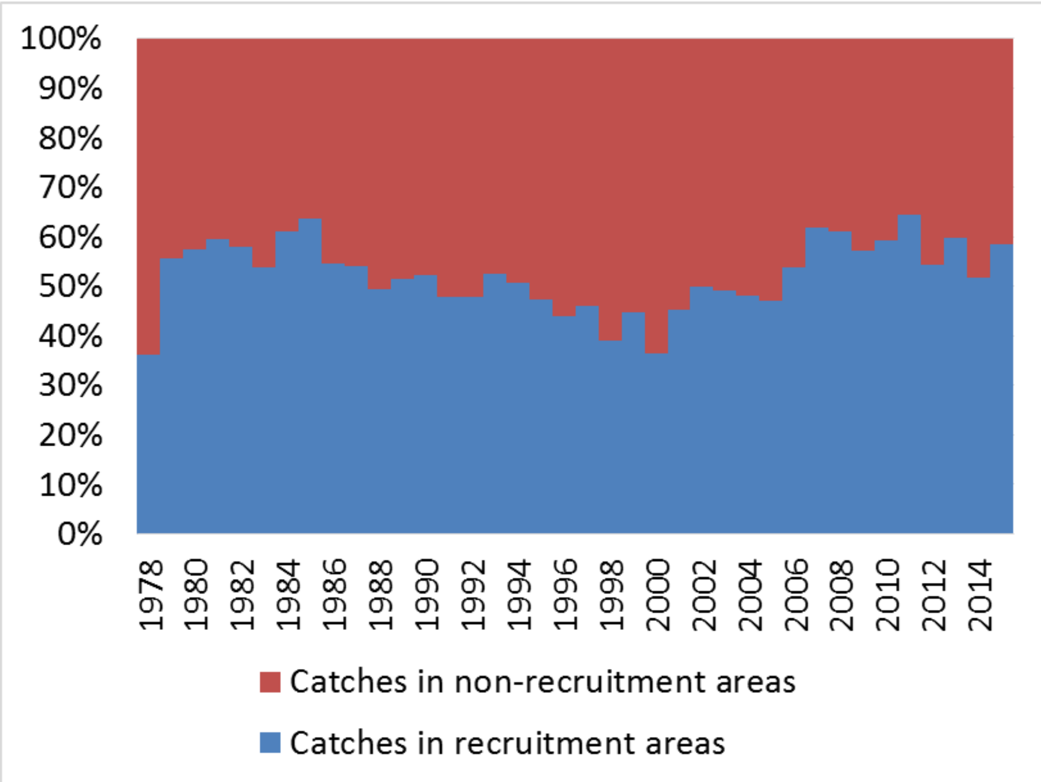


Figure 3.5.2.4. Percentage of sardine catches (in biomass) from recruitment areas (south Galicia+ north Portugal+Gulf of Cadiz) and non-recruitment areas (Cantabrian+North Galicia+southwest Portugal+south Portugal).

Based on the above, three periods were identified, 1978–1987, 1988–2005, 2006–2015, and various alternative options were explored:

i. selectivity assumed to be equal in the first and third period and fixed over time within each period, time-varying selectivity as a random-walk (S.D.=0.1) in the middle period; age selectivity as in the 2016 assessment
ii. the three periods may have different selectivity patterns, in all cases selectivity assumed to be fixed over time; age selectivity as in the 2016 assessment (fixed 3–5)
iii. the three periods may have different selectivity patterns , in all cases selectivity assumed to be fixed over time; selectivity-at-age 5 is estimated

We also considered an option assuming four selectivity periods (iv), in all cases with fixed selectivity over time, to account for a slightly lower percentage of catches coming from recruit areas from the mid–1990s to the mid–2000s (age selectivity as in the 2016 assessment).

In all cases the initial values were set to mimic dome-shaped patterns in all periods. However, the range of initial values is wide and almost any pattern can be estimated.

Option (iii) resulted in a model with substantially higher AIC than the base case while age 5 selectivity was estimated to be similar to age 3–4 selectivity. Option (iv) indicated a change in the 6+ selectivity over time similar to the base case model which was considered to be unrealistic. Options (i) and (ii) both lead to models showing a better fit to the data than the base case (Table 3.5.2.4). Option (ii) requires about half the number of parameters and has a comparable fit to option (i).

Configuration e), assuming three selectivity periods, 1978–1987, 1988–2005, 2006–2015, was selected (Table 3.5.2.4). Finally, the input sample size of the acoustic survey age compositions was decreased from 50 to 25 (equal in all surveys), in order to be consistent with the harmonic mean of expected sample sizes provided by the model.

Table 3.5.2.4. Log-likelihood, SSB, Recruitment and F in 2015 and final gradient for the different runs. Changes in likelihood are absolute, changes in SSB, R and F are relative and in %.

	Configuration d)		Configuration e) Configuration d) + 3 selectivity periods, fixed over time		Change
Log-likelihood components					
TOTAL	148.3		109.6		-38.8
Catch	2.78E-08		9.44E-09		0.0
Equil_catch	0.1		1.0		0.9
Survey TOTAL	-20.0		-22.0		2.1
- Acoustic	-18.1		-17.8		0.4
- DEPM	-1.9		-4.3		-2.4
Age_comp TOTAL	146.1		110.6		-35.5
- Purse seine	87.5		76.5		-11.0
- Acoustic	58.6		34.1		-24.5
Recruitment	20.5		20.0		-0.6
Parm_softbounds	4.1E-04		3.0E-04		0.0
Parm_devs	1.58		0.00		-1.6
Number Parameters	106		58		
Output quantities	Value	StdDev	Value	StdDev	
SSB 2015	133979	20533	108152	16211	-19.3
R 2015	3687600	795147	3313440	764864	-10.1
apical F 2015	0.20	0.03	0.20	0.03	-0.8
AIC	508.7		335.1		
Final gradient	2.5E-05		7.8E-05		

3.5.2.5 Exploration of natural mortality assumptions

(See Presentation Silva, 2017 for further information)

The model configuration e) was the best assessment in the WKPELA meeting (6–10 February 2017). The natural mortality used in that model (adopted in WKPELA, 2012) was M=0.8, 0.5, 0.4, 0.3, 0.3, 0.3, 0.3 for ages 0, 1, …, to 6+, derived from scaling the M vector calculated with the Gislason formula by 0.6 (Gislason *et al.*, 2010; growth parameters k= 0.44 and Linf=23.2 cm) (Table 3.5.2.5.1).

The group agreed to perform a re-evaluation of natural mortality for this model because (i) assumptions about survey and fishery selectivity were changed in the benchmark model therefore the M values that provide the best model fit with the new assumptions might change as well; (ii) Work done on the northern sardine stock suggested that M might be higher than assumed previously for the south stock.

Work to re-evaluate M and revise the assessment was carried out after the February benchmark meeting and discussed in a Webex held the 10 of April, with participation of most WKPELA members and external reviewers.

The work consisted in the combination of various scenarios of survey selectivity and fishery selectivity previously explored (sections 3.5.2.3-4) with seven M scenarios, corresponding to values of M= 0.4* to 1.0*Gislason M (0.1 steps, Table 3.5.2.5.1).

Three blocks of runs, a, b, and c, were carried out (explanatory diagram in Silva, 2017, see also sections 3.5.2.3.4) and runs in each block were combined with the M scenarios.

Table 3.5.2.5.1. M-at-age values corresponding to scaling the Gislason M for southern sardine from 0.6 to 0.8. Mean (StdDev) and median values of a broad index of Z-at-age derived from log-catch-ratios by cohort in the acoustic survey. The M value assumed for the Northern sardine stock is also presented.

Southern sardine	**Z-at-age**			**Southern sardine**	**M-at-age**		**Northern sardine**
Age	Mean	StDev	Median	0.8*Gislason	0.7*Gislason	0.6*Gislason	0.9 * Gislason
0				1.12	0.98	0.84	1.07
1	0.88	0.86	0.93	0.70	0.61	0.52	0.69
2	0.62	0.57	0.79	0.53	0.47	0.40	0.55
3	0.44	0.52	0.45	0.46	0.40	0.34	0.48
4	0.46	0.59	0.56	0.42	0.36	0.31	0.44
5				0.39	0.35	0.30	0.41
6+				0.37	0.32	0.28	0.40
Mean (2-5)				0.45	0.39	0.34	0.47
Mean(1-5)				0.50	0.44	0.37	0.51
Mean(1-4)	0.60		0.68	0.53	0.46	0.39	0.54

The main results of the analysis are as follow:

i. Playing with survey selectivity conditional to the modelling of the fishery selectivity as in the 2016 assessment: 3 survey selectivity scenarios (flat S all ages, flat S ages 2–6+, flat S ages 2–5): fishery selectivity as in the 2016 assessment (i.e. two periods the first one, 1978–1990, with random walk and the second one, 1991+, fixed over time, in both periods flat selectivity on ages 3–5). For the first scenario, log-likelihood profiles indicated that total logL decreased with decreasing M. Both survey indices and age composition data pointed to lower M values. Not unexpectedly, the catchabilities for the acoustic and DEPM surveys increased with decreasing M reflecting the decrease of the stock level. Despite some variation between runs, the general tendencies were similar for models with flat selectivity at ages 2–5 and 2-6+ years. Changing the acoustic sample size from 50 to 25 did not affect the results. The configuration with flat S at all ages for the acoustic survey has the lowest AIC at M values <=0.6*Gislason M, whereas at higher M values, relative lower AICs were observed with flat S ages 2–6 or 2–5 than with flat S for all ages. In absolute terms the results conditioned to the fishery selectivity adopted in WKPELA2012 pointed out to preferred M values below the former ones (<=0.6*Gislason M).

ii. Playing with fishery selectivity conditional to the modelling of the survey selectivity as flat for all ages (1-6+): 3 fishery selectivity scenarios (3 periods each fixed in time, 3 periods, mid-period with random walk, 4 periods each fixed; in all cases with flat on ages 3–5): survey selectivity flat all ages.

For the first scenario, total -logL was minimum at M=0.8* Gislason M with all data sets pointing to M values higher than 0.6* Gislason M. Profiles for the acoustic index, acoustic and fishery age composition point to a clear minimum in the range 0.7–0.9* Gislason M (Figure 3.5.2.5.1). Within that range of M, differences in model fit are small. LogL profiles for the other two fishery selectivity scenarios show some minor differences, but mostly pointing to a higher M than used in previous assessments (around 0.7* or 0.8* Gislason M). The model with 4 periods has the lowest AICs at all M values compared to the 3 fishery selectivity period fittings. However, the modelling with four selectivity periods leads to unrealistic change in selectivity between the two earlier and two later periods and was not considered further (see also section 3.5.2.4). Therefore, conditioned on having a flat survey selectivity, the preferred modelling was that for a 3 fishery periods of fixed selectivity with M optimums around 0.7* or 0.8* Gislason M.

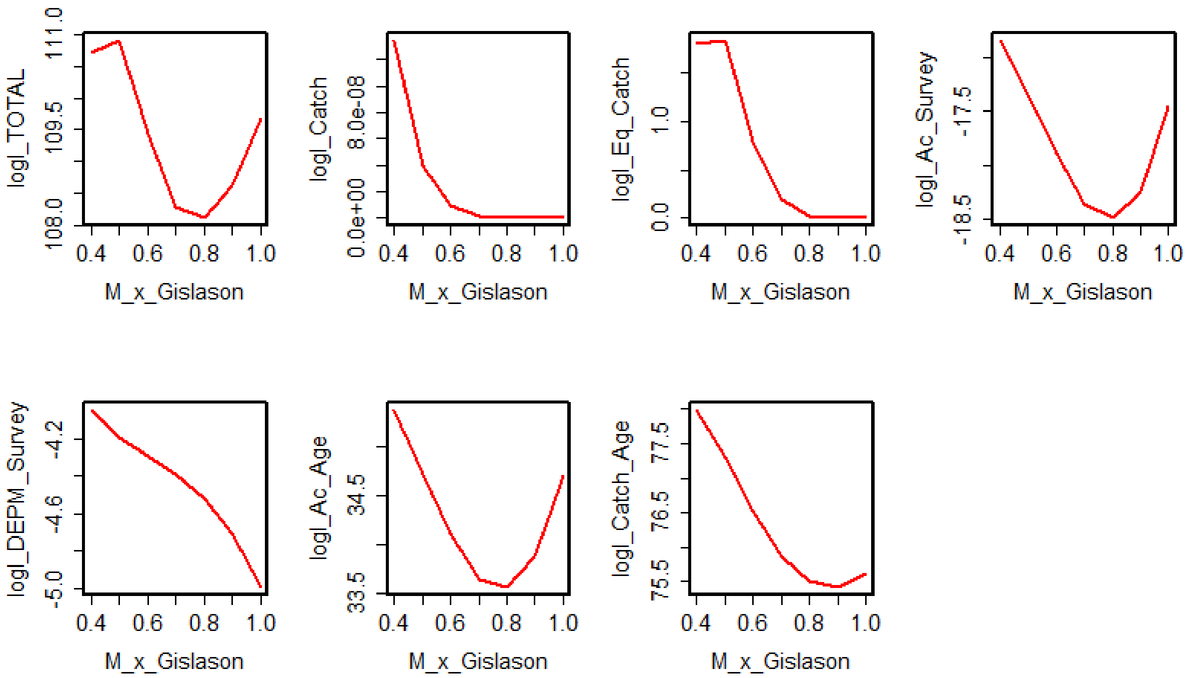


Figure 3.5.2.5.1. Log-likelihood (negative) profiles across M values for model runs assuming 3 fishery selectivity periods each fixed over time (as in configuration e) and flat selectivity at all ages in the acoustic survey.

iii. Playing with survey selectivity conditional to the modelling of the fishery selectivity as three periods of fixed selectivity: 1 fishery selectivity scenario (3 periods fixed, model configuration e) combined with 3 survey selectivity scenarios.

AIC profiles indicated that the best model has 3 periods of fishery selectivity, flat survey selectivity at all ages and M=0.8* Gislason M (Figure 3.5.2.5.2). A positive feature of this model is that estimated catchability coefficients are nearly 1 for the two surveys in the assessment. A negative aspect is that M values are very close to a broad index of total mortality calculated from the average acoustic survey log-catch ratios, particularly at older age groups. Compared to the 2016 assessment, F is on average scaled downwards 16.4% and biomass 1+ is scaled upwards on average 12.8%. The second best model has similar fishery and survey selectivity options but M=0.7* Gislason M. This model shows nearly the same fit to the data as the previous one (0.2 units higher AIC) and survey q's are still close to 1 (Table 3.5.2.5.2, Figure 3.5.2.5.2). Compared to the 2016 assessment, F is scaled upwards 21% with differences increasing to the past and biomass 1+ is scaled downwards on average 8.7%.

Table 3.5.2.5.2. Results for models with various M scalings

	Benchmark: M=0.6*Gis_flat_S	M=0.7*Gis_flat_S	M=0.8*Gis_flat_S	Input values
Acoustic Q	1.61	1.34	1.08	
Acoustic r.m.s.e.	0.24	0.23	0.23	0.25
DEPM Q	1.34	1.12	0.90	
DEPM r.m.s.e.	0.31	0.31	0.30	0.25
Purse seine EffN (HarmMean)	74.45	72.95	71.50	66.60
Acoustic EffN (HarmMean)	21.20	21.44	21.30	25.00
Recruitment RSME	0.70	0.72	0.74	0.70
- LogLikelihood	109.44	108.27	108.11	
N param	58	58	58	
AIC	334.88	332.54	332.22	

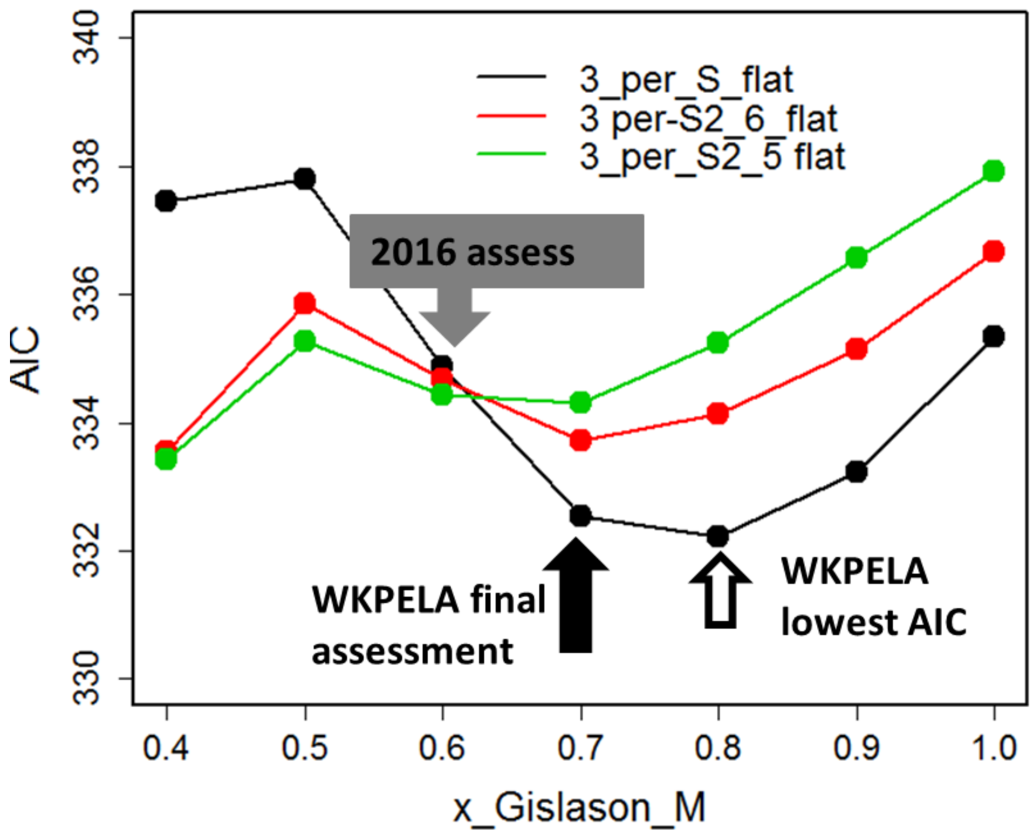


Figure 3.5.2.5.2. AIC profiles across M values for model runs assuming 3 fishery selectivity periods each fixed over time and 3 different scenarios of survey selectivity. The arrows show AIC values for the model selected in WKPELA February meeting (configuration e), the model with the lowest AIC obtained with M=0.8* Gislason M and the WKPELA 2017 final assessment obtained with M=0.7* Gislason M.

In summary:

The re-evaluation of M showed that the fit of the assessment model to the data improved with M values higher than those used in the 2016 assessment (M=0.6 * Gislason M). Specifically M values corresponding to scaling of 0.8* Gislason M and 0.7* Gislason M provided the best fits. The difference between these two M options is minor in terms of AIC (0.2 units). The various models explored indicated that the best M is very much dependent on the settings for survey and fishery selectivity. Other scenarios of fishery and survey selectivity which might be also be credible pointed to optimum fittings at M=0.7* Gislason M (e.g. mid-period random walk in fishery sel, survey sel flat ages 2–6 or flat ages 2–5). Therefore the natural mortality pattern which seemed to be robust to most model uncertainties, providing in general absolute or quasi optimum fittings was that of M=0.7* Gislason M. In addition, the model with M=0.7* Gislason M corresponds to a small change in M and therefore in the scale of the assessment in relation to the 2016 assessment. For these reasons, the group decided to adopt M=0.7* Gislason in the final assessment model.

3.6 Final assessment (Results, comments, comparison with previous assessments)

The tables below list the input data, assumptions and other model options of the WKPELA 2017 assessment and a comparison with the last sardine assessment (WGANSA 2016). Further details are provided in the Stock Annex.

Input data:	**WGHANSA 2016**	**WKPELA 2017**
Catch	Catch biomass 1978-2015 (thousand tons) Catch-at-age 1978-2015 (millions of individuals)	Catch biomass 1978-2015 (tons) Catch-at-age 1978-2015 (thousands of individuals)
Acoustic survey (Joint SP+PT)	Total numbers 1996-2016 (millions of individuals) Numbers-at-age 1996-2016 (millions of individuals)	* Total numbers 1996-2016 (thousands of individuals) * Numbers-at-age 1996-2016 (thousands of individuals)
DEPM survey (Joint SP+PT)	SSB 1997, 1999,2002,2005,2008,2011, 2014 (thousand tons)	* SSB 1997, 1999,2002,2005,2008,2011, 2014 (tons)
Weight-at-age in the catch	Yearly averages 1978-2015 (constant up to 1989), Kg	* Yearly averages 1978-2015 (constant up to 1989), Kg
Weight-at-age in the stock	Yearly averages from acoustic surveys 1996-2016 (constant up to 1990), Kg	* From DEPM surveys in DEPM years, linear interpolation for years in-between (constant 1978-1998, 2015-2016), Kg
Maturity-at-age	From DEPM surveys in DEPM years; 0%, 80% and 100% at ages 0,1,2+ in non-DEPM years, proportions	* From DEPM surveys in DEPM years, linear interpolation for years in-between (constant 1978-1998, 2015-2016), proportions

Model structure and assumptions:	**WGHANSA 2016**	**WKPELA 2017**
M	M-at-age 0=0.8, M-at-age 1=0.5, M-at-age 2=0.4, M-at-age 3+=0.3, all years	* 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-independent R model; annual recruitments are parameters, defined as lognormal deviations from a constant mean value penalized by a sigma of 0.55 (the standard deviation of log(recruits) estimated in WGANSA 2011)	* Density-dependent R model; annual recruitments are parameters, defined as lognormal deviations from Beverton-Holt stock recruitment model, penalized by a sigma of 0.70, and na input steepness of 0.71.
Initial population	N-at-age in the first year are parameters, derived from an input initial equilibrium catch, the geometric mean recruitment and the selectivity in the first year.	* 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.	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	Two periods: 1978-1990 with selectivity-at-age varying as a random walk and 1991-2010 for which selectivity-at-age is fixed over time	* Three periods: 1978-1987, 1988-2005 and 2006-2016. Selectivity-at-age is estimated for each period and within each period assumed to be fixed over time.
Survey selectivity-at-age	S-at age are parameters, each estimated as a random walk from the previous age; S-at-age 1 used as the reference; S-at-ages 3 to 5 assumed to be equal to S-at-age 2; fixed over time	* Selectivity assumed to be equal at all ages.
Fishery catchability	Scaling factor, median unbiased	Scaling factor, median unbiased
Acoustic survey catchability	Scaling factor, mean unbiased	* Parameter, mean unbiased
DEPM catchability	Parameter, mean unbiased	Parameter, mean unbiased

Log-likelihood function:	**WGHANSA 2016**	**WKPELA 2017**
Weights of components	All components have equal weight.	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, 50 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.	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.

Changes with respect to the 2016 assessment.

Tables 3.6.1 to 3.6.5 show the input data that were revised in this benchmark. The remaining data is presented in ICES (2016b).

Table 3.6.1. Numbers-at-age (thousands of individuals) estimated in the spring acoustic survey (PELACUS+PELAGO).

Year	1	2	3	4	5	6	Total (age 1-6+)
1996	1622593	2108992	2782962	2817046	794531	44913	10171036
1997	4373691	5388159	1714975	1360231	1461374	303499	14601927
1998	2152220	4140572	2222517	1488898	1230046	979892	12214145
1999	5789140	2617796	1552189	934033	640656	625539	12159353
2000	4942926	2366856	1575403	1126352	726783	751531	11489852
2001	13835299	1037016	702016	476215	370599	257994	16679138
2002	13039065	6979281	1190304	1127990	566829	437827	23341295
2003	5918333	4525169	3578814	1030659	573086	326893	15952954
2005	22769507	1333696	689413	759794	649425	368658	26570493
2006	7454560	8309213	577248	451829	578912	597002	17968764
2007	1615942	3120910	3993441	638458	284628	701618	10354997
2008	1542375	1081032	985435	1972356	216892	499897	6297987
2009	5550231	667139	418749	691478	772710	496546	8596852
2010	4666776	698477	536869	187723	268695	365542	6724083
2011	838225	1249226	202249	140467	89758	328420	2848345
2013	1824237	207875	192844	70141	123907	154603	2573607
2014	2001454	427454	148818	120774	48246	114350	2861097
2015	1644991	186212	155652	81948	85919	86940	2241662
2016	2376740	627658	473115	263478	300328	308035	4349353

Table 3.6.2. Spawning biomass (tons) estimated in the DEPM survey.

Year	2016 Assessment	Revised DEPM index	Change, %: revised-assess16
1997	308178	251387	-18
1999	382700	436919	14
2002	194800	496379	155
2005	382682	481447	26
2008	651500	625026	-4
2011	484750	226372	-53
2014	126584	164613	30

Table 3.6.3. Mean weights-at-age (Kg) in the catches. Weights-at-age in 1978–1990 are fixed.

Year	age 0	age 1	age 2	age 3	age 4	age 5	age 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	0.025	0.049	0.073	0.079	0.089	0.09	0.097

Table 3.6.4. Mean weights-at-age (Kg) in the stock. Weights-at-age in 1978-1998 are fixed.

Year	age 0	age 1	age 2	age 3	age 4	age 5	age 6
1998	0	0.027	0.041	0.05	0.059	0.06	0.063
1999	0	0.03	0.043	0.05	0.054	0.059	0.062
2000	0	0.027	0.041	0.05	0.059	0.06	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	0.02	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	0.06	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	0.07	0.072	0.079
2009	0	0.03	0.054	0.063	0.07	0.069	0.075
2010	0	0.027	0.051	0.062	0.07	0.067	0.072
2011	0	0.024	0.048	0.061	0.07	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	0.032	0.049	0.065	0.066	0.077	0.081
2016	0	0.032	0.049	0.065	0.066	0.077	0.081

Table 3.6.5. Maturity-at-age (proportions) in the stock. Maturity-at-age in 1978-1998 is fixed.

Year	age 0	age 1	age 2	age 3+
1998	0	0.84	0.99	1
1999	0	0.94	0.98	1
2000	0	0.84	0.98	1
2001	0	0.74	0.98	1
2002	0	0.65	0.98	1
2003	0	0.62	0.97	1
2004	0	0.60	0.97	1
2005	0	0.57	0.97	1
2006	0	0.68	0.97	1
2007	0	0.79	0.98	1
2008	0	0.90	0.99	1
2009	0	0.93	0.99	1
2010	0	0.96	1.00	1
2011	0	0.99	1.00	1
2012	0	0.99	1.00	1
2013	0	1.00	1.00	1
2014	0	1.00	1.00	1
2015	0	1.00	1.00	1
2016	0	1.00	1.00	1

Assessment diagnostics and results

Table 3.6.6 shows the parameters estimated by the benchmark assessment model. The total number of input observations of catch, abundance and age compositions is 220. There are 30 observations of weights-at-age in the stock, 30 observations of maturity-at-age and 189 observations of weights-at-age in the catch. The model estimates 58 parameters, 45 parameters less than the 2016 assessment model. The parameters estimated in the benchmark assessment are comparable to those from the 2016 assessment, apart from virgin recruitment (R0=15625270, CV=3%) and the initial F (0.68 year-1, CV=11.0%) which are 46.0% and 23.5% higher, respectively. The catchability parameters are closer to 1 for both the acoustic (Q=1.34, CV=8%) and the DEPM (Q=1.1, CV=11%) surveys.

The coefficients of variation of parameters indicate that the initial F is estimated with higher precision in the present assessment than in the 2016 assessment model. The correlations between the assessments parameters range from -0.98 to 0.76 although the majority are very close to zero. Negative correlations below -0.5 are observed between R0 and Q_acoustic survey and between selectivity parameters from the first period (5 cases).

The assumed CVs for both surveys, all years=0.25, are consistent with the residual mean square errors estimated by the model, 0.23 for the acoustic index and 0.31 for the DEPM index. The harmonic mean of the fishery age composition sample size, 72.9, suggests that the data is slightly more precise than assumed (mean initial sample size=66.7 for the whole period). In the case of the survey, the sample size was decreased to 25 to be consistent with the precision indicated by the model (the harmonic mean for the acoustic survey is estimated to be 21.4).

Table 3.6.6. Parameters and asymptotic standard deviations estimated in the final assessment model

Number	Label	Param_value	Parm_StDev	Phase	Min	Max	Init
1	SR_LN(R0)	16.17	0.022	1	1	20	16
2	Early_InitAge_4	0.52	0.594	_	_	_	_
3	Early_InitAge_3	0.53	0.473	_	_	_	_
4	Early_InitAge_2	0.49	0.279	_	_	_	_
5	Early_InitAge_1	0.73	0.177	_	_	_	_
6	Main_RecrDev_1978	0.89	0.148	_	_	_	_
7	Main_RecrDev_1979	1.00	0.145	_	_	_	_
8	Main_RecrDev_1980	1.10	0.137	_	_	_	_
9	Main_RecrDev_1981	0.60	0.164	_	_	_	_
10	Main_RecrDev_1982	-0.01	0.225	_	_	_	_
11	Main_RecrDev_1983	1.48	0.104	_	_	_	_
12	Main_RecrDev_1984	0.25	0.178	_	_	_	_
13	Main_RecrDev_1985	0.14	0.172	_	_	_	_
14	Main_RecrDev_1986	-0.01	0.183	_	_	_	_
15	Main_RecrDev_1987	0.77	0.119	_	_	_	_
16	Main_RecrDev_1988	0.15	0.154	_	_	_	_
17	Main_RecrDev_1989	0.11	0.152	_	_	_	_
18	Main_RecrDev_1990	0.16	0.149	_	_	_	_
19	Main_RecrDev_1991	1.23	0.084	_	_	_	_
20	Main_RecrDev_1992	0.79	0.096	_	_	_	_
21	Main_RecrDev_1993	-0.04	0.138	_	_	_	_
22	Main_RecrDev_1994	-0.15	0.132	_	_	_	_
23	Main_RecrDev_1995	-0.35	0.133	_	_	_	_
24	Main_RecrDev_1996	0.03	0.106	_	_	_	_
25	Main_RecrDev_1997	-0.35	0.128	_	_	_	_
26	Main_RecrDev_1998	-0.08	0.113	_	_	_	_
27	Main_RecrDev_1999	-0.34	0.133	_	_	_	_
28	Main_RecrDev_2000	0.81	0.084	_	_	_	_
29	Main_RecrDev_2001	0.27	0.106	_	_	_	_
30	Main_RecrDev_2002	-0.32	0.138	_	_	_	_
31	Main_RecrDev_2003	-0.57	0.163	_	_	_	_
32	Main_RecrDev_2004	0.90	0.073	_	_	_	_
33	Main_RecrDev_2005	-0.14	0.111	_	_	_	_
34	Main_RecrDev_2006	-1.29	0.173	_	_	_	_
35	Main_RecrDev_2007	-0.92	0.135	_	_	_	_
36	Main_RecrDev_2008	-0.62	0.113	_	_	_	_
37	Main_RecrDev_2009	-0.41	0.097	_	_	_	_
38	Main_RecrDev_2010	-0.92	0.120	_	_	_	_
39	Main_RecrDev_2011	-1.02	0.128	_	_	_	_
40	Main_RecrDev_2012	-0.81	0.118	_	_	_	_
41	Main_RecrDev_2013	-0.64	0.124	_	_	_	_
42	Main_RecrDev_2014	-0.96	0.161	_	_	_	_
43	Main_RecrDev_2015	-0.74	0.205	_	_	_	_
44	InitF_1purse_seine	0.84	0.150	1	-1	2	0.3
45	Q_base_2_Acoustic_survey	0.51	0.076	1	-3	3	0
46	Q_base_3_DEPM_survey	0.32	0.107	1	-3	3	0
47	AgeSel_1P_2_purse_seine	1.52	0.152	2	-4	4	0.9
48	AgeSel_1P_3_purse_seine	0.72	0.136	2	-4	4	0.4
49	AgeSel_1P_4_purse_seine	-0.22	0.167	2	-4	4	0.1
50	AgeSel_1P_7_purse_seine	-0.27	0.525	2	-4	4	-0.5
51	AgeSel_1P_2_purse_seine_BLK1delta_1988	-0.35	0.182	2	-4	4	0.9
52	AgeSel_1P_2_purse_seine_BLK1delta_2006	-0.20	0.158	2	-4	4	0.9
53	AgeSel_1P_3_purse_seine_BLK1delta_1988	-0.05	0.167	2	-4	4	0.4
54	AgeSel_1P_3_purse_seine_BLK1delta_2006	-0.15	0.155	2	-4	4	0.4
55	AgeSel_1P_4_purse_seine_BLK1delta_1988	0.82	0.190	2	-4	4	0.1
56	AgeSel_1P_4_purse_seine_BLK1delta_2006	-0.46	0.154	2	-4	4	0.1
57	AgeSel_1P_7_purse_seine_BLK1delta_1988	-0.44	0.531	2	-4	4	-0.5
58	AgeSel_1P_7_purse_seine_BLK1delta_2006	0.58	0.416	2	-4	4	-0.5

The benchmark assessment shows a substantial better fit to the data (AIC=332.5) than the 2016 assessment model (AIC=580.6) and this applies also to each set of data (Table 3.6.8). Figure 3.6.1 shows the fit of the model to the acoustic survey and DEPM indices of abundance. Compared to the 2016 assessment model, the present model shows an overall better fit to both survey indices, especially in the case of the DEPM. On the other hand, the present model fits poorly to the highest acoustic observations in 2002 and 2005.

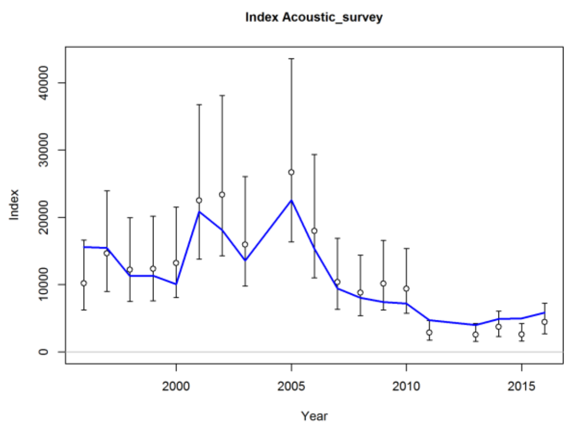
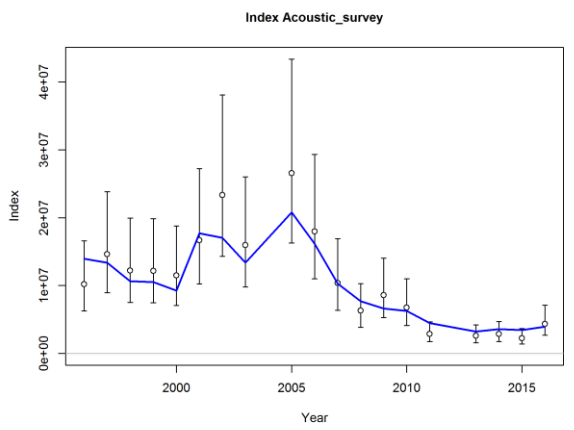
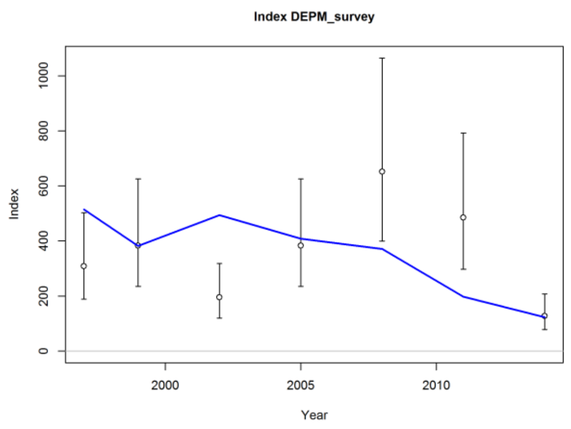
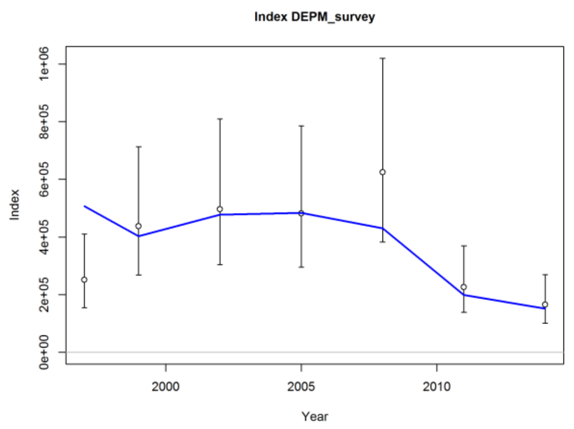
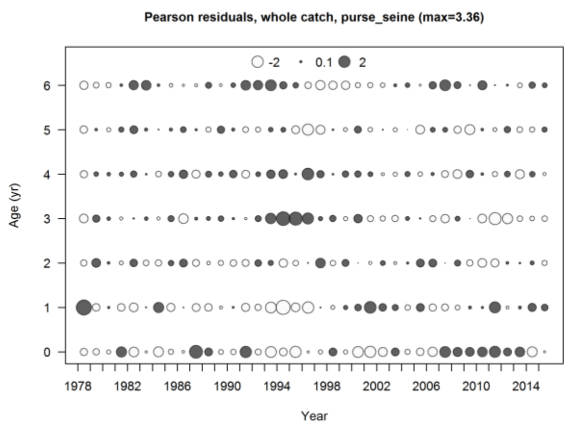
WGHANSA 2016 assessment	WKPELA 2017 assessment
	
	

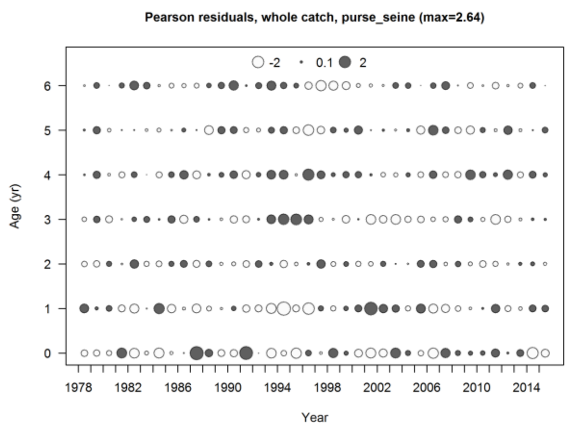
Figure 3.6.1. Fit of the WKPELA 2017 assessment model and of the 2016 assessment model to DEPM and to the acoustic survey-series. Bars are standard errors re-transformed from the log scale. Note that the units of measurement changed from millions to thousands of individuals for the total acoustic survey abundance and from thousand tons to tons for the DEPM SSB. In addition, both survey series were revised for this benchmark.

Figure 3.6.2 shows the model residuals from the fit to the catch-at-age composition (a) and the acoustic survey age composition (b). In both cases the residuals from the present assessment are lower than those from the 2016 assessment model, suggesting the current assumptions about survey and catch selectivity are more consistent with the age composition data. In particular, catch-at-age residuals show a more random distribution in recent years.

WGHANSA 2016 assessment	WKPELA 2017 assessment

(a)





(b)

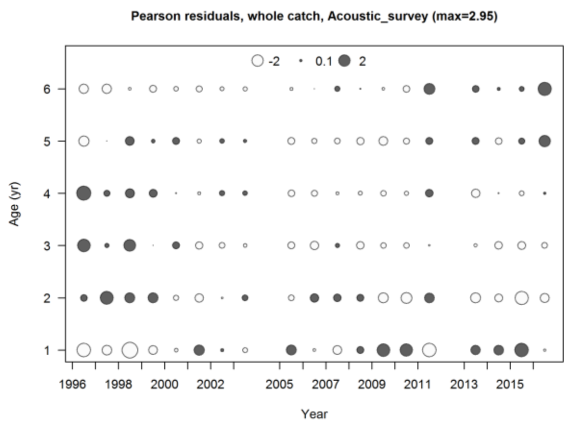


Figure 3.6.2. Model residuals from the fit to the catch-at-age composition (a) and the acoustic survey age composition (b).

The fishery selectivity patterns estimated in the present assessment show less abrupt changes over time and through ages (particularly at the 6+ group) and therefore seem to be more realistic than the patterns estimated in the 2016 assessment model (Figure 3.6.3). The patterns over age are dome-shaped in the three periods with the early (1978–1987) and recent periods (2006–2015) showing higher selectivity at ages 1–2 than the middle period (1988–2005), in agreement with the higher fraction of the catches coming from recruitment areas in those periods. The increase of age 0 selectivity estimated in the most recent period is consistent with large catches of this age group in a period that recruitment is at a very low level.

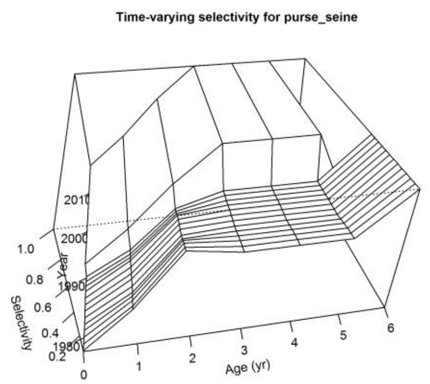
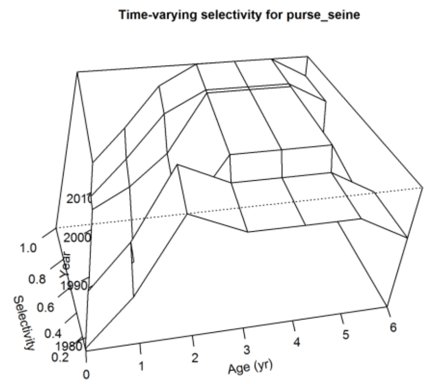
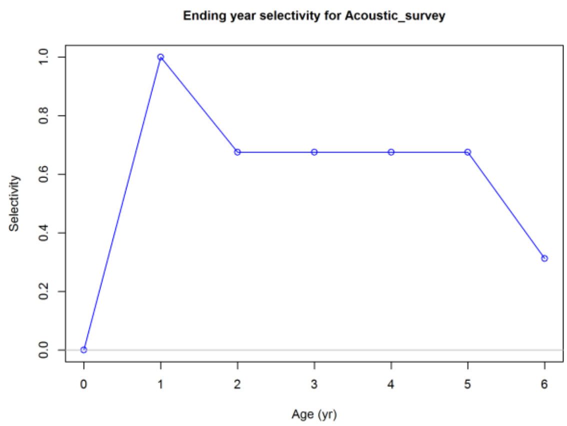
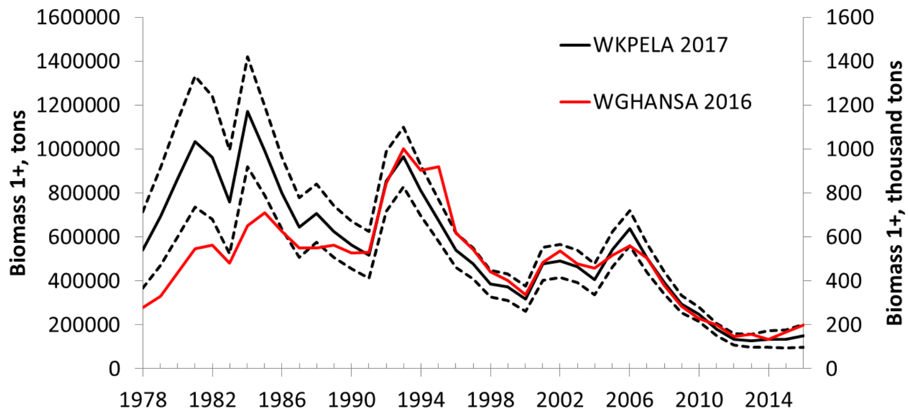
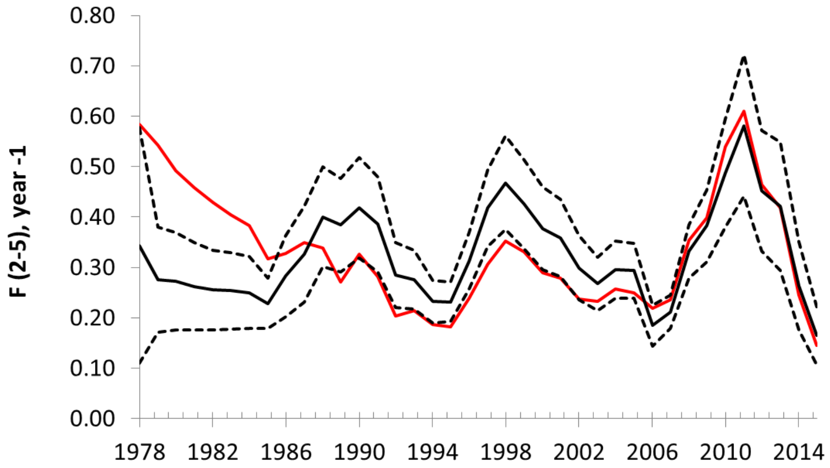
<table>
<tr><th>WGHANSA 2016 assessment</th><th>WKPELA 2017 assessment</th></tr>
<tr><td>(a)

</td><td>
</td></tr>
<tr><td>(b)

</td><td>Flat selectivity all ages</td></tr>
</table>

Figure 3.6.3. Selectivity-at-age in the fishery (a) and in the acoustic survey (b) for the 2016 assessment and the 2017 benchmark models.

The summary of the benchmark assessment results is shown in Table 3.6.7 and Figure 3.6.4 (in the figure compared also to the 2016 WGHANSA results).

Biomass, fishing mortality and recruitment estimates are generally more precise in this benchmark assessment than in the 2016 assessment model (Figures 3.6.6 and 3.6.7). The patterns of biomass and fishing mortality CVs are consistent with the abundance of data available to the assessment over time: precision decreases from the early 1990s towards the beginning of the assessment period, due to the lack of survey data; precision also decreases in the later years of the assessment that cohorts are incomplete. Finally, the retrospective plots of SSB and recruitment indicate the model is robust (Figure 3.6.8).





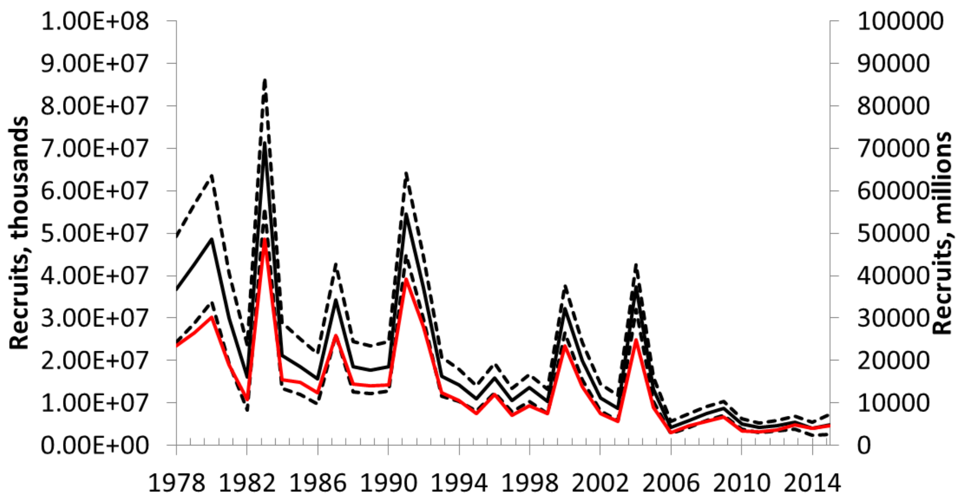


Figure 3.6.4. Sardine 8.c and 9.1: Biomass 1+ (top), F (middle) and recruitment (bottom) trajectories in the period 1978–2016 from the sardine final benchmark assessment (WKPELA 2017). The 2016 assessment (WGHANSA 2016) is shown for comparison.

Table 3.6.7. Results of the WKPELA 2017 assessment. R2016=R0.

Year	Biomass 1+	SSB	CV_{SSB}	Recruits	CV_R	F (2-5)	Apical F	$CV_{apicalF}$	Landings
1978	539443	489784	0.16	36686800	0.17	0.34	0.39	0.20	145609
1979	693677	635264	0.16	42693900	0.16	0.28	0.31	0.05	157241
1980	866610	798048	0.15	48651400	0.15	0.27	0.31	0.06	194802
1981	1034860	956508	0.14	29994300	0.18	0.26	0.30	0.08	216517
1982	960806	908576	0.15	16018500	0.24	0.26	0.29	0.11	206946
1983	758559	729930	0.16	71302900	0.11	0.25	0.29	0.13	183837
1984	1170940	1063850	0.11	21147200	0.18	0.25	0.29	0.20	206005
1985	991443	948092	0.10	18486200	0.18	0.23	0.26	0.19	208439
1986	799227	768392	0.10	15708900	0.19	0.28	0.32	0.18	187363
1987	643296	617216	0.11	34313300	0.12	0.33	0.37	0.17	177696
1988	707437	654995	0.09	18611200	0.16	0.40	0.45	0.16	161531
1989	625850	592733	0.09	17768300	0.16	0.38	0.44	0.15	140961
1990	563165	533980	0.10	18600600	0.16	0.42	0.47	0.14	149429
1991	517771	487621	0.10	54518200	0.09	0.39	0.44	0.11	132587
1992	852924	770210	0.08	37101900	0.10	0.28	0.32	0.14	130250
1993	964025	899605	0.07	16246100	0.14	0.28	0.31	0.15	142495
1994	812521	781810	0.07	14136300	0.13	0.23	0.26	0.12	136582
1995	673639	649763	0.07	11056300	0.14	0.23	0.26	0.12	125280
1996	539618	520667	0.07	15823600	0.11	0.31	0.35	0.12	116736
1997	478787	453579	0.07	10611500	0.13	0.42	0.47	0.12	115814
1998	387488	369274	0.08	13541100	0.12	0.47	0.53	0.11	108924
1999	371628	359995	0.08	10399300	0.14	0.43	0.48	0.11	94091
2000	318042	300581	0.09	32197500	0.09	0.38	0.43	0.09	85786
2001	477965	405718	0.08	19919800	0.11	0.36	0.41	0.08	101957
2002	491342	427425	0.08	11192800	0.14	0.30	0.34	0.09	99673
2003	466147	429690	0.08	8786360	0.17	0.27	0.30	0.09	97831
2004	406741	378837	0.09	37367800	0.07	0.29	0.33	0.10	98020
2005	544131	432867	0.07	13203900	0.11	0.29	0.33	0.10	97345
2006	639258	586815	0.06	4226590	0.18	0.18	0.19	0.11	87023
2007	504428	492803	0.06	5851780	0.14	0.21	0.22	0.11	96469
2008	391591	384484	0.07	7518430	0.11	0.33	0.35	0.11	101464
2009	295050	288740	0.07	8617730	0.09	0.38	0.40	0.10	87740
2010	248617	245586	0.07	4955130	0.12	0.49	0.51	0.10	89571
2011	179534	177822	0.08	4158150	0.13	0.58	0.61	0.09	80403
2012	134452	133038	0.10	4599990	0.13	0.45	0.47	0.11	54857
2013	126365	124766	0.12	5366530	0.15	0.42	0.44	0.08	45818
2014	135661	135661	0.14	3994300	0.19	0.26	0.27	0.08	27937
2015	135344	135344	0.15	4902360	0.23	0.16	0.17	0.09	20595
2016	151785	151785	0.17	11717100					

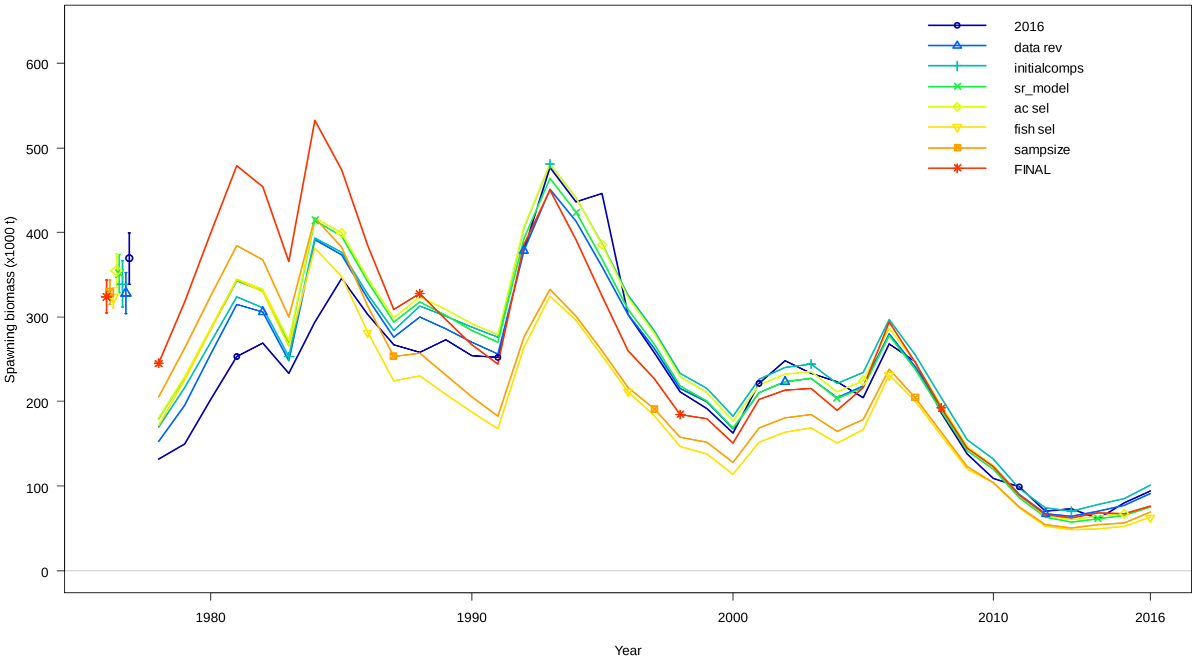


Figure 3.6.5. SSB from the exploratory runs carried out in the benchmark and comparison with SSB estimated in the 2016 assessment model. Note that SSB is generally lower than B1+, the reference stock biomass used for this stock.

Table 3.6.8. Negative log-likelihoods for the WKPELA 2017 assessment, the WGHANSA 2016 assessment (units of measurement changed) and the WGHANSA 2016 assessment including the data revised for the present benchmark.

	FINAL WKPELA 2017 ASSESSMENT	WGHANSA 2016 ASSESSMENT	WGHANSA 2016 ASSESSMENT + DATA REVISIONS	Change WKPELA 2017- WGHANSA 2016	Change DATA REVISIONS - WGHANSA 2016
Log-likelihood components					
TOTAL	108.3	187.3	172.0	-79.0	-15.3
Catch	1.65E-09	3.23E-08	2.28E-08	0.0	0.0
Equil_catch	0.2	0.1	0.2	0.1	0.1
Survey TOTAL	-22.7	-5.0	-18.4	-17.8	-13.4
- Acoustic	-18.3	-13.3	-15.6	-5.0	-2.3
- DEPM	-4.4	8.3	-2.8	-12.7	-11.1
Age_comp TOTAL	109.5	155.8	153.2	-46.2	-2.6
- Purse seine	75.9	96.5	94.6	-20.6	-1.9
- Acoustic	33.6	59.2	58.6	-25.6	-0.7
Recruitment	34.4	34.4	35.0	0.0	0.5
Parm_softbounds	5.6E-04	5.6E-04	4.3E-04	0.0	0.0
Parm_devs	1.98	1.98	2.02	0.0	0.0
Number Parameters	58	103	103	-45.0	0.0
AIC	332.5	580.6	550.0	-248.0	-30.6
Final gradient	8.6E-05	3.8E-06	7.0E-07		

Perception of the stock

The historical perception of the sardine stock provided by the benchmark assessment (Table 3.6.7) is comparable to the ICES WGHANSA 2016 assessment except in the early part of the time series (Figure 3.6.4). Until 1990, B1+ is scaled upwards and F scaled downwards in the benchmark assessment. Thereafter, B1+ and F from the 2016 assessment are generally inside the asymptotic confidence intervals of B1+ and F estimated in the benchmark assessment. Recruitment estimates in the benchmark assessment are scaled upwards across the assessment period, except in 2014 and 2015. The scaling of recruitment results from the increase of the assumed natural mortality.

The benchmark assessment indicates a continuous decrease of the stock since the mid–1980s and a lower recent biomass (24% in 2015) and higher F (14% in 2015) than estimated in the 2016 assessment.

The differences are mainly explained by the revision of the model assumptions, especially, those related to selectivity-at-age in the fishery (Figure 3.6.5 and Figure 3.6.6). The joint effect of data revisions was mainly an upward scaling of the biomass in the earlier years but also lower fishing mortality in the earlier years and higher in recent years compared to the 2016 assessment. The scaling of old versus recent biomass was probably caused by higher mean weight-at-age 1 in the stock up to the mid–1990s although other revisions may have contributed, as for instance the different fishing selectivity patterns at age by periods–see below–and in a lesser extent the different starting condition for the Initial population and associated recruitment.

The assumptions about selectivity-at-age in the fishery had the most pronounced effect on the results of assessment. The relative scale of the early vs recent stock biomass was extensively discussed by the group. Data compiled from a few acoustic surveys carried out in the 1980s were examined however the group considered they were not comparable to recent surveys due to major differences in methodology. Catches and age compositions in the 1980s suggest that recruitments and stock abundance were much higher at that time than ever seen afterwards. However, survey data is not available until 1996 (providing some backwards information until the early 1990s) making the relative scale of the early vs recent stock abundance/fishing uncertain. However, the benchmark model fits better to the data available for the early period than did the WGHANSA 2016 model as shown by the reasonable confidence intervals for fishing mortality and a more precise estimation of the initial population. In addition, the precision of biomass and fishing mortality estimates from the WKPELA 2017 model are more consistent with the abundance of data along the historical period (Figure 3.6.7). However, the group notes that the assessment results for the period 1978 to the early 1990s (1992 has already some information from the 1996 acoustic surveys) should be viewed with care namely to calculate reference points for management advice.

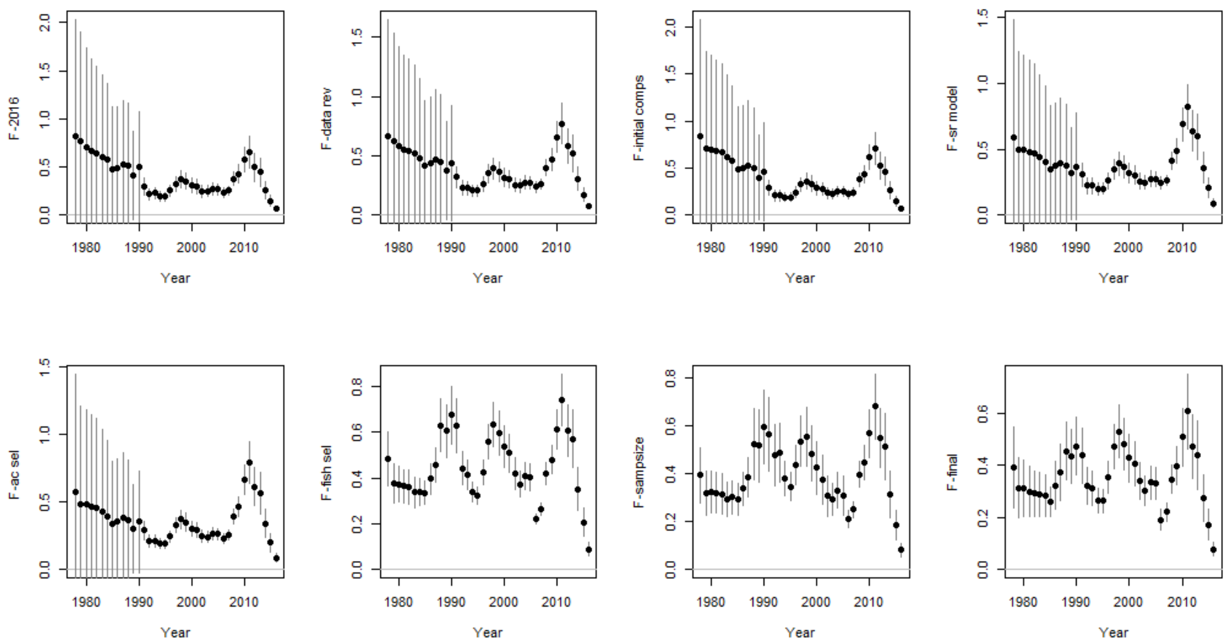
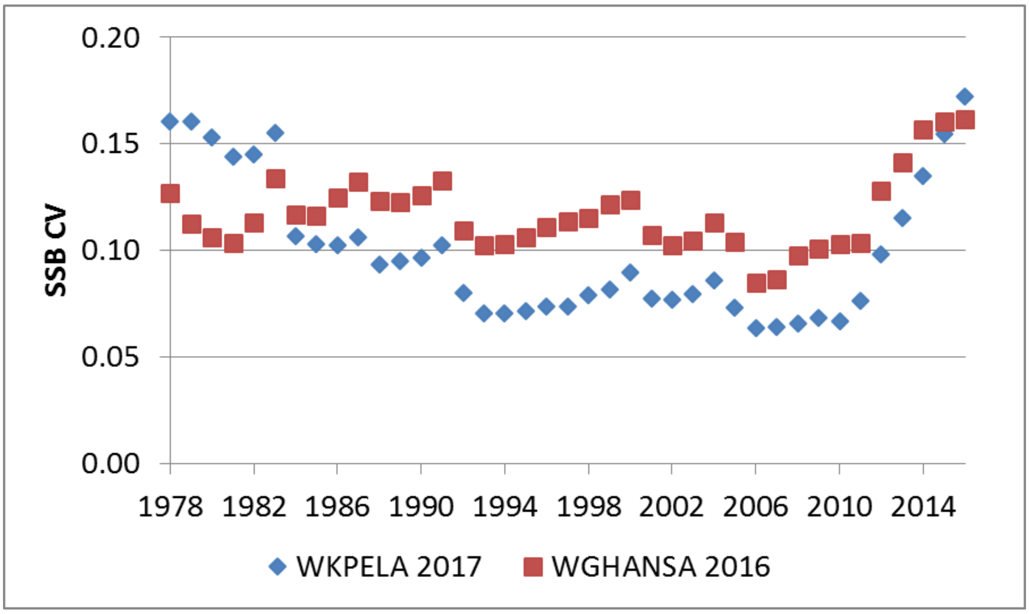


Figure 3.6.6. Apical fishing mortality from the exploratory runs carried out in the benchmark and comparison with SSB estimated in the 2016 assessment model. Note that Apical F is generally higher than the reference F=mean F at ages 2–5 years used for this stock.

(a)



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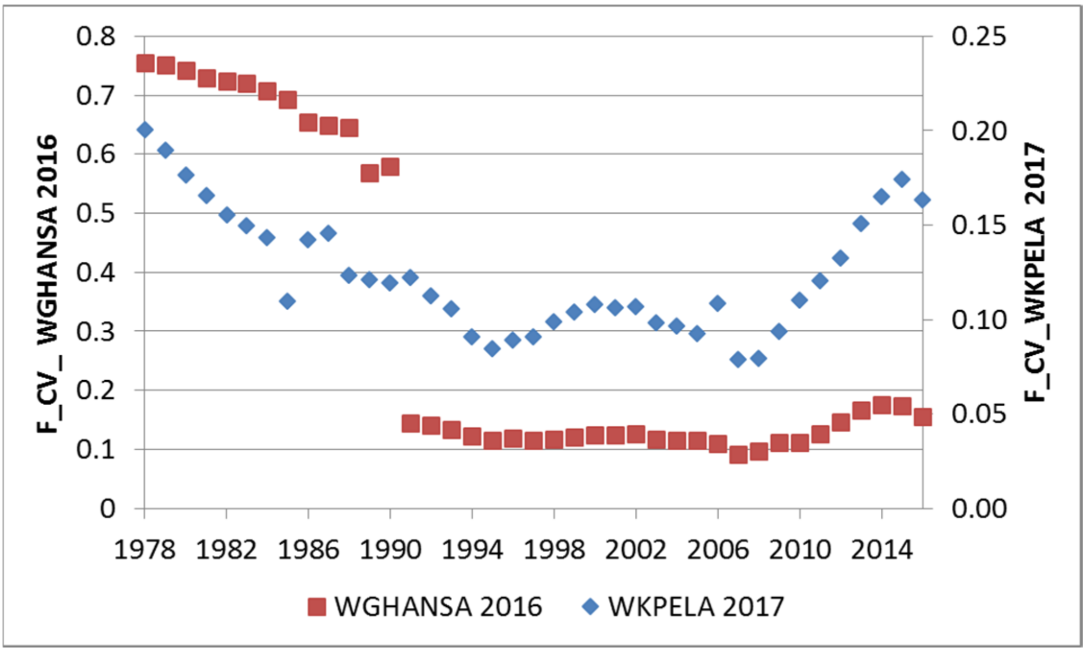
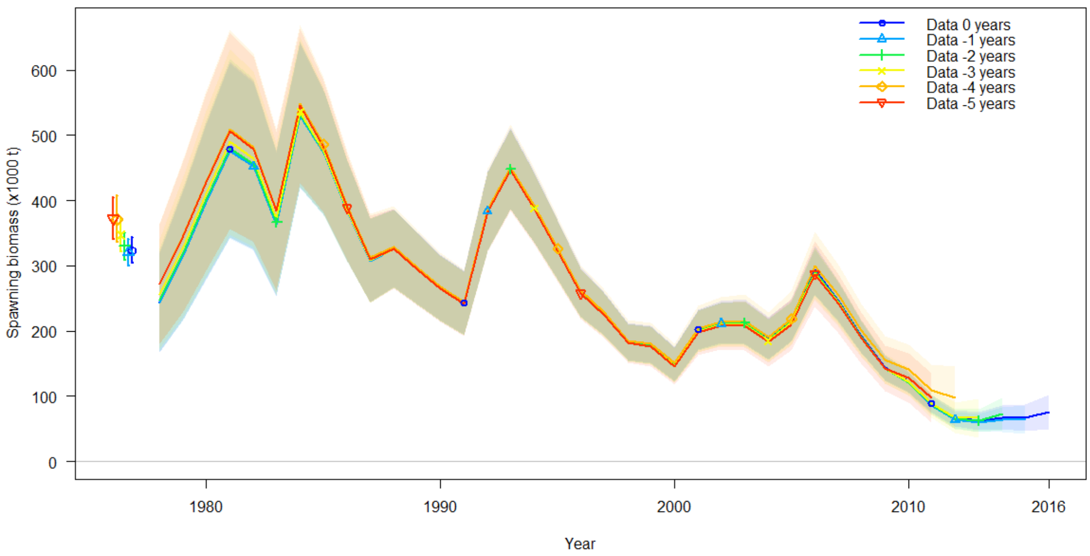


Figure 3.6.7. CVs of SSB and apical F in the WGHANSA 2016 and WKPELA 2017 assessments.



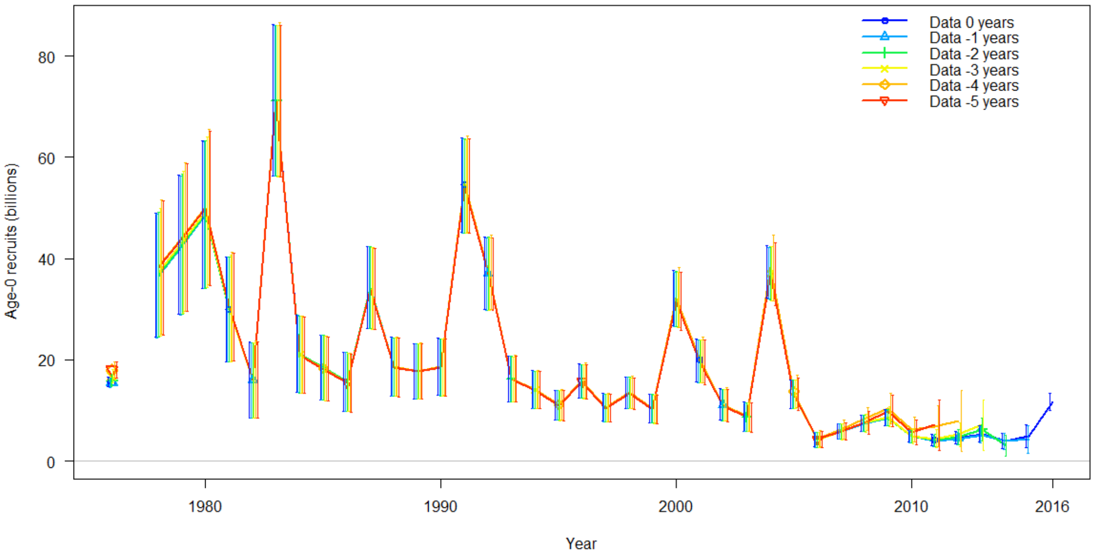


Figure 3.6.8. Retrospective error for the SSB (above) and Recruitment (below) in the assessment. Dashed lines represent asymptotic 95% confidence intervals for the estimates.

3.7 Short term forecast

The methodology agreed to carry out the short term forecast is detailed in the Stock Annex.

The main differences to the methodology used in the 2016 assessment respect the assumptions for the maturity ogive and the mean weights-at-age in the stock and for the recruitment in the interim year and forecast years.

Maturity-at-age and stock weights-at-age assumed in the forecast are now calculated as arithmetic mean values of the last six years of the assessment to include data from two DEPM surveys, as well as interpolated values for the years in between.

Given that recruitment is at a historically low level since 2006, the possibility that low recruitments continue in the near future should be taken into account in the short term predictions. Therefore, the assumed recruitment for the interim year and the forecast years is the geometric mean recruitment of the last five years in the assessment. Recruitment in the last year of the assessment is supported by the acoustic survey in the interim year and is therefore included in the calculation of the mean.

3.8 Conclusion with statement of what is recommended for the future

The final assessment model of this benchmark shows a better fit to the data available and provides more precise estimates of biomass, recruitment and fishing mortality than the last sardine assessment (WGHANSA 2016) (Table 3.6.8). Therefore, the group recommends this model for the assessment of the sardine stock.

The revision of data in general and of the DEPM in particular lead to a better consistency between the data used in the assessment and decreased the uncertainty of the results. Likewise, the revision of model assumptions resulted in a substantial improve of model fit and higher precision of the outputs.

Assuming flat survey selectivity was an option for a simple model that is in agreement with the perception of experts and the lack of support to adopt a more elaborate pattern.

The fishery selectivity model is more parsimonious as well and appears to reflect the major apparent changes in fishery selectivity. There was no basis to consider the fleet has changed their fishing pattern. On the other hand, it is possible that changes in population selectivity result from changes in the spatial distribution of the fishery jointly with the heterogeneous spatial distribution of young and old fish. Nevertheless, the definition of the selectivity periods is possibly an over-simplification as it is more likely that changes are gradual. In addition the boundaries of periods are ad-hoc and could probably be set slightly differently. It should also be mentioned that selectivity assumptions have a major impact on the scale of the assessment.

3.9 Biological Reference Points

Prior to the benchmark in 2017, there were no defined reference points for the southern sardine stock and the basis of ICES advice is the Sardine Fishery Management Plan agreed by Spanish and Portuguese governments and evaluated by ICES to be provisionally precautionary (ICES, 2013a).

An estimation of biological reference points (BRP) for this stock was performed based on data from the final benchmark assessment from WKPELA. The methodology used followed the framework proposed in ICES (2017c) guidelines for fisheries management reference points. All statistical analyses were carried out in R environment (R core team 2015). Sardine's latest stock information was converted to an 'FLStock' object using the 'FLCore' package (version 2.6.0.20170130). Simulations analyses were conducted with the package "msy" using the EqSim routines (https://github.com/ices-tools-prod/msy; ICES 2016c), a stochastic equilibrium reference point software that provides MSY reference points based on the equilibrium distribution of stochastic projections.

3.9.1 Exploration of time period used in stock recruitment models

During the initial WKPELA meetig, preliminary assessment model outputs were used to examine the sensitivity of biological reference points to the time period used in the stock recruitment models. The final reference point values may no match those calculated using the final assessment model. However, the model outputs were similar enough to allow for a recruitment sensitivity analysis to be conducted.

The available time series of SSB and recruitment was used to fit stock recruitment models for two different periods; i)1978–2015 and ii)1993–2015 (see section 3.6). Option ii) uses the same period used to explore BRPs and in the evaluation of the sardine MP (ICES, 2013). The stock recruitment fits, using the three models (Ricker, Beverton–Holt and Hockey-stick) estimated a much higher productivity when using the full time series. All tested models had a reasonable fit for both periods with slightly better results from the Hockey model.

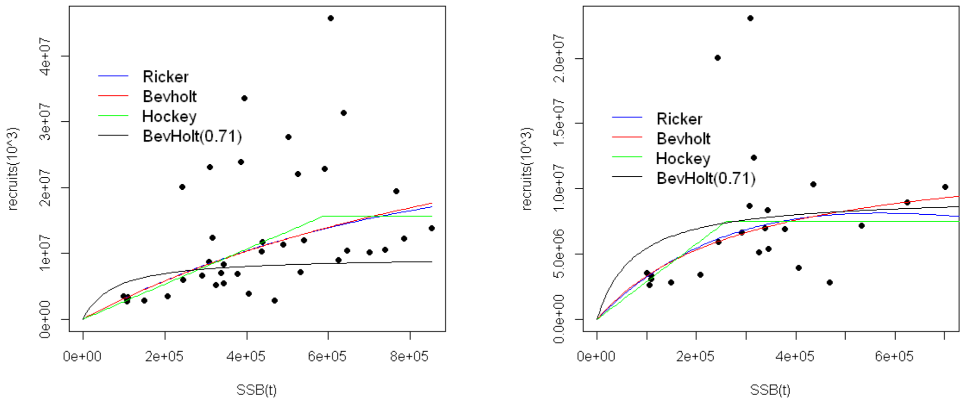


Figure 3.9.1. Sensitivity of BRPs to the time period **used in the stock recruit models.** S-R fits from hockey-stick (green), Ricker (blue), Beverton-holt (red) and Beverton-holt with forced h=0.71 (black) of the full time series 1979–2015 (left panel) and 1993–2015 (right panel).

As no preferable S-R relationship is determined, stochastic simulations were performed with a combination of the three S-R models fitted from bootstrap samples of the SSB and recruit pairs and the stock–recruitment model is weighted by applying model averaging (ICES, 2016c). Again, the Hockey-stick gave better results than the Ricker and Beverton-Holt with weights estimated to be 76%, 14%, 10% respectively for the full time series and 90%, 3% and 7% for the more recent period. 1000 simulated populations were tested over a range of F values (0–2) using historical variation in biological/productivity parameters of the last five years without assessment errors and recruitment autocorrelation. The technical basis and the estimated BRP for southern sardine are show in Table 3.9.1. A detailed description of the results is available in Mendes *et al*., WD2017.

Table 3.9.1. Sensitivity of BRPs to the time period used in the stock recruit models. Preliminary Biological Reference Points estimated during WKPELA 2017.

BRP	1978–2015	1993–2015	Technical basis
Blim	590936 t.	260060 t.	Blim = Hockey-stick break point
Bpa	821152 t.	361374 t.	Bpa = Blim * exp(1.645 * σ), σ = 0.2 (default ICES, 2017)
Flim	0.38	0.43	Stochastic long-term simulations (50% probability SSB < Blim)
Fpa	0.27	0.31	Fpa = Flim * exp(-1.645 σ), σ = 0.2 (default ICES, 2017) If Fpa < FMSY then FMSY = Fpa
Btrigger	821152 t.	361374 t.	Btrigger = Bpa
Fp0.5	0.15	0.25	Stochastic long-term simulations with ICES MSY AR (≤ 5% probability SSB > Blim); Constraint to Fmsy if Fp0.5<Fmsy
FMSY	0.36	0.36	If Fp0.5 < FMSY then FMSY = Fp0.5

There are indications of different S–R parameters for the two periods, with implications on the BRP results, the most adequate estimates should be based on the most reliable and recent state of the stock. It was proposed that given the low biomass condition of the stock (e.g. below B_{lim} estimates), that BRP estimation and implementation of a MSY management approach may only be expected to be applicable and operational after recruitment recovery or short-term management action that allows the stock to recover.

Recruitment for this stock has some very high values, these extreme observations can lead to different BRP's estimations (e.g. F_{MSY}, $F_{p0.5}$), and further analysis should be made to investigate the sensitivity of the results to the occasional high recruitments. The sensitivity of the model to the inclusion of additional and/or different periods of stochastic variability in biological/productivity parameters should also be further tested. As the WKPELA 2017 assessment, these BRPs are provisional pending on the re-evaluation of M.

A WD with a review of the proposals for Biological Reference points for southern sardine according to the latest updated stock annex (incorporating the re-evaluation of M) is included, among other WDs, in the Appendix 11+ to this report (Wise *et al.*, WD).

3.9.2 Final biological refernce points (1993–2015)

Several scenarios were explored (whole time series with and without auto-correlation in recruitment; period 1993-2015 with B_{lim} equal to the change point of the Hockey-stick S-R relationship and with B_{lim} equal to B_{2000}). Here we summarize the results for the base scenario (1993-2015 with B_{lim} equal to the change point of the Hockey-stick S-R relationship), for further details on the other scenarios please see Wise et al. (WD to this report in Annex 11).

In relation to stock productivity the group decided to use as the base scenario the period 1993-2015 similarly to the evaluation of the sardine MP (ICES, 2013a). There is evidence that sardine productivity has declined over time despite little or no unequivocal evidence of a clear regime shift. In approximately the last 20 years, recruitment is at a lower level and biomass range is narrower than in the previous 15 years. Following the analysis performed in ICES (2013a) a productivity break was identified in 1992-1993 in the time series. The group agreed to maintain the same break as in the historical series and assume that the stock productivity in the period 1993-2015 is a plausible scenario for future stock dynamics. However, the group acknowledged that recruitments since 2006 are well below the average of the period 1993-2015 and recommends a close monitoring of the stock productivity and a re-evaluation of reference points in case there are signs that the current very low productivity continues in the future.

Simulations were performed with stochasticity in population biology parameters using the observed historical stock variation from the last six years (2010-2015). This period was chosen due to trends (positive) in stock and catches weight-at-age. Stock weight-at-age is calculated from DEPM surveys, which are carried out on a triennial basis. For years in between DEPM surveys, weight-at-age is linearly interpolated from adjacent surveys. A period of six years was chosen to include two survey estimates. This procedure is similar to the one adopted for the short term forecast.

Several S-R relationships (Ricker, Beverton-Holt and Hockey-stick) were fit to the 1993-2015 data. The models showed comparable maximum likelihood estimates but the Hockey-stick achieved slightly better fits. The automatic weighting method implemented in EqSim (ICES, 2016c) was used to weight the combination of the three S-R models fitted from bootstrap samples of the SSB and recruit pairs. Again, the Hockey-stick had better results than the Ricker and Beverton-Holt with weights estimated to be 84%, 5% and 11%. The WG recognised the weighted S-R model had the advantage to acknowledge model uncertainty. However, the difference is small in this case as the Hockey-stick dominates the S-R combination by far (84% weight) and reference points from the two approaches were similar. The WG also considered that using a single S-R facilitates Management Strategy Evaluation (MSE) analyses in practical terms. In conclusion, the Hockey-stick S-R was adopted for the calculation of reference points.

Following ICES guidelines (ICES, 2017c), the S-R data of this stock is consistent with a Type 2 pattern given the wide dynamic range of SSB and evidence that recruitment is impaired. In this case, B_{lim} is equal to the change point of a Hockey-stick model fitted to S-R data. The B_{lim} candidate calculated as the change point of the Hockey-stick model was 337448 t. B_{pa} was derived as $B_{pa} = B_{lim} * \exp(1.645 * \sigma)$, with $\sigma = 0.17$, the coefficient of variation of SSB_{2016} from the WKPELA 2017 assessment.

Reference points were estimated based on the Hockey-stick S-R relationship with B_{lim} and B_{pa} as defined above and no MSY $B_{trigger}$ (i.e., without applying the ICES MSY AR). An initial simulation was performed over a range of F values (0-2) using historical variation in population and productivity parameters, re-sampled at random from the specified range of years but with no assessment/advice error.

The technical basis and the estimated BRP are shown in Table 2. F_{lim}, the equilibrium F that gives a 50% probability of SSB>B_{lim} was estimated at 0.25. F_{pa} was estimated as $F_{pa} = F_{lim} * \exp(-1.645 * \sigma)$, with σ = 0.17, the coefficient of variation of apical F_{2015} from the WKPELA 2017 assessment. F_{pa} was estimated at 0.19. Follow-up simulations with the same settings as well as assessment/advice error in fishing mortality and in spawning stock biomass, estimated the median F_{MSY} at 0.20.

Following ICES guidelines, and the fact that the stock has not been fished at/around F_{MSY} for 5 years, MSY $B_{trigger} = B_{pa}$. With the ICES MSY AR (Advice Rule) and setting MSY $B_{trigger} = B_{pa}$ the precautionary criterion for F_{MSY} level was also tested, i.e. fishing at F_{MSY} is precautionary in the sense that the probability of SSB falling below B_{lim} in a year in long term simulations with fixed F is ≤ 5% ($F_{p.05}$). The $F_{p.05}$ was estimated at 0.12.

$F_{p.05}$ is well below F_{MSY}. Although the reasons for this fact were not fully explored, a possible cause is that MSY Btrigger (= B_{pa}) is close to the mean stock biomass. It is also noted that $F_{p.05}$ estimates have a wide range with a highly right skewed distribution.

3.10 Future Research and data requirements

- Carry on research on stock identity, stock sub-structure and spatial dynamics;
- Complete the revision of the age of small sardines in both the acoustic and DEPM surveys and provide final datasets to the next annual assessment;
- Carry on research on the growth of sardine juveniles to help clarify the age determination of small sardines;
- Carry on research that may lead to improve the assumptions of natural mortality and survey catchability
- Improve the estimation of uncertainty for the different data sources, especially for age composition data and acoustic and DEPM surveys;
- Studies proving further insight on causes of changes in selectivity over time are still required.

4 Northern Sardine (Sar north)

4.1 Stock ID and sub-stock structure.

European sardine (*Sardine pilchardus*; Walbaum, 1792) has a wide distribution extending in the Northeast Atlantic from the Celtic Sea and North Sea in the north to Mauritania in the south. Populations of Madeira, the Azores and the Canary Islands are at the western limit of the distribution (Parrish *et al.*, 1989). Sardine is also found in the Mediterranean and the Black Seas. Changing environmental conditions affect sardine distribution, with fish having been found as far south as Senegal during episodes of low water temperature (Corten and van Kamp, 1996; Binet *et al.*, 1998). Because of its continuous distribution in the Northeast Atlantic, it is likely that there is movement of fish between areas.

Microsatellite analyses revealed no significant genetic differentiation among sardines in Subareas 7 and 8 (Shaw *et al.*, 2012). Recent genetic analyses conducted in the Celtic Seas and Western Channel show that no genetic differentiation has been detected between the Bay of Biscay and Cornwall for the sardine stock (ICES, 2013). For this reason, sardine in Celtic Seas (7.a,b,c,f,g,j,k), English Channel (7.d, 7.e, 7.h) and in Bay of Biscay (8.a,b,d) used to be considered to belong to the same stock from a genetic point of view. Therefore, it has been previously considered that the sardine stock in 8.a, b, d and 7. as a single stock unit. The assessment of this stock as a single unit has assumed that the trends derived from the observations made in the Bay of Biscay through the scientific surveys (PELGAS, BIOMAN) could be indicative of changes in area 7 as well.

Recent information suggest that the actual structuring of the sardine populations in these two areas (8 and 7) may be more complicate that formerly assumed. Information from the ICES WKSAR workshop (ICES, 2016) suggests a higher growth rates for the populations of the English Channel and Celtic sea than for the Bay of Biscay, though it is unknown if this results from different oceanographic conditions or from population characteristics. Sardine maturity-at-length has declined substantially in northern France while growth seems to be higher in the English Channel. Young sardine were not usually observed in this northern area suggesting that at least a portion of the older (2+) spawning individuals from the English Channel might originate in the French coast. However, in a recent acoustic surveys in this area relevant concentrations of juveniles have been found. Therefore older individuals might simply originate from this area as well. Furthermore, there is no information on connectivity between the Bay of Biscay and English Channel/Celtic Sea. Besides this, 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. At this point, it is unknown if mixing occurs between Bay of Biscay and English Channel populations.

The review of information during the WKSAR workshop led to conclude that the English Channel sardine is not simply an immigrant component of the Biscay sardine. 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 evidences (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 juveniles have been found (van der Kooij *et al.*, Presentation to WKSAR report ICES CM 2016/ACOM:41). Therefore, there are evidences that all life stages occur in subarea 7 in significant quantities as to sustain and justify a shelf contained population in the subarea 7. Furthermore, the Cornish fisheries has been operating there for more than a century. All this suggests that there can be a shelf contained population in the subarea 7.

In terms of stock assessment, the availability of data strongly differs between the subareas 7 (Celtic Seas, English Channel) and 8 (Bay of Biscay). Additionally, each area presents different historical exploitation patterns. Therefore analysis and management advice between the areas may differ.

The previous benchmark on this stock (WKPELA, ICES 2013) led to a trend based assessment from the combination of the Bay of Biscay indices from the local surveys. A review of the available datasets still has not showed any improvement in terms of data for the Celtic sea and English Channel as no biological sampling is routinely performed and absolute catches levels are even uncertain as numerous countries are operating there. More work and a robust sampling program is needed in order to derive any trend based assessment for these northern areas.

On the opposite, the various time series of fishery data in the Bay of Biscay monitored from commercial vessels and surveys are now long enough to provide some tentative assessment for the Bay of Biscay.

The workshop concluded that in the absence of evidences 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. Even in the case some connectivity would occur, dealing separately with them in a sustainable manner would be probably risk averse, as the potential northward emigrants from the Bay of Biscay to subarea 7 would be comprised in the natural mortality parameter estimated for the Bay of Biscay population.

4.2 Issue list

Issue	Problem/Aim	Work needed / possible direction of solution	Data needed to be able to do this: are these available / where should these come from?	External expertise needed at benchmark
Tuning series	- Short times series during last benchmark (2013). Relatively bad cohort tracking - no coverage of area VII. Few information available from sampling	Alternate indices (combined information from the different surveys ?)	Data are already collected	Experts on tuning indices
Discards	Not a problem			
Biological Parameters	Not a problem			
Ecosystem/mixed fisheries considerations		Alternate solution to provide an assessment might be to look at more closely to the hydrographic conditions in the relevant areas	Survey/Hydrographic data	Ecosystem/environmental modelling experts
Assessment method	Trends based assessment for the time being.	Development on a surplus production model in progress. Preliminary runs in line with previous approaches.		Experts in DLS for short-lived species or integrated assessment

Forecast method	No STF other than the DLS approaches	Dependant on the assessment method.		Experts in DLS for short-lived species or integrated assessment
Biological Reference Points	Not defined	Review of existing information and appropriate tools to estimates ref. points		Experts in DLS for short-lived species or integrated assessment

4.3 English Channel and Celtic sea sardine fisheries.

4.3.1 Some history

A complete revision of the series of catches was done during the meeting. Sardine catches in the English Channel in the past were very variable, and several countries (England, France, Netherlands...) declared sardine catches in this area.

Due to the closure of the fishery in the seine bay in 2010 due to PCB contamination, catches decreased during 2010 and 2014 but seem to increase again in recent years.

Catches in Celtic Sea seem to be very low.

As described in WGHANSA report every year, French catches in statistical rectangles 25E4 and 25E5 have been reallocated to area 8 (Bay of Biscay) because of the continuity with the Biscay purse seine fishery occurring next to these rectangles).

In opposition to the Bay of Biscay where the catches are mainly done by small purse seiners, landings of sardine in the Channel are due to artisanal and industrial pelagic trawlers.

4.3.2 Data available

4.3.2.1 Catch data and sampling

Catch data are the only information routinely available through the ICES datacall and other databases (FAO, ICES Statland, STECF Fishery dependant information database). Landings are mainly taken by France, UK and Netherlands while other countries also contributed to substantial amounts in the past.

Biological sampling on commercial catch has been close to inexistent so far. Length distribution data are scarcely available in 1994, 1996 and then every year since 2000 from the Dutch pelagic freezer trawler operating in the English Channel. Those vessels, while capturing substantial amounts of sardine are structurally different from the fishing vessels of the other main countries (United Kingdom, France) and therefore those length structures may not reflect the actual length distribution of the population. Other countries do not provide length or age information due to the lack of national biological sampling scheme and no DCF requirement regarding that species in 7.

4.3.2.2 Surveys

A summary of the sardine data from the PELTIC survey was presented to the WKSAR workshop (ICES CM 2016/ACOM: 41). The PELTIC survey (2012–2016) is a new, annual integrated survey conducted in Q4 which focuses on the distribution, abundance and size and age structure of small pelagic fish species in ICES Divisions 7.e–f, predominantly sprat, sardine, mackerel and anchovy. In addition, it aims to improve the understanding of the role of these mid-trophic species in the pelagic ecosystem by simultaneously sampling the multiple trophic levels and the physical oceanography. The survey is carried out over ~19 days in October on board the RV 'Cefas Endeavour' (ICES, 2015a).

Data from 2013–2015 were presented at the WKSAR workshop and included the acoustically derived sardine biomass estimates, the numbers-at-length, age–length relationship and sardine spawning activity measured in numbers of eggs. Although the time-series is too short now to be used in a stock assessment, the results showed some general patterns and a largely new insight into sardine dynamics at the northern boundary of its main distribution area. The results suggested that particularly the western Channel holds significant sardine biomass in autumn from 56 kt in 2013 to around 100 kt in 2014–2015. Increasing numbers of sardine were found to reside in the eastern Celtic Sea, peaking at 55 kt in 2015.

In 2015, sardine data from PELTIC were combined with those extracted from the JUVENA survey conducted a month earlier in the Bay of Biscay, and showed that of the two areas, most sardine biomass in autumn is found in Subarea 7. This may suggest a northwards migration of sardine in autumn. Significant sardine spawning activity was observed in the western Channel, and in 2015 sardine eggs were also found in some of the eastern Celtic Sea stations. While a large range of sardine lengths were found in the western Channel (from 7–25 cm), the eastern Celtic Sea appears to be an important recruitment area as a large component of the acoustically derived sardine biomass consisted of specimens under 9 cm.

4.3.3 Possible assessment approaches

4.3.3.1 Stand-alone assessment

There is currently no sufficient information to derive any analytical or trend-based assessment in the English Channel and Celtic Sea. One promising source of information may come from the PELTIC survey. However this survey has currently only four points and covers only a part of the area. Therefore, it still requires more year and continued fundings to develop an abundance or biomass index series.

In the past (WGHANSA, 2012), some data limited approach have been tested such as DCAC. However required assumptions for some parameters and the lack of trends in the landings for the Celtic sea and English Channel have not permitted to derive a robust indicator for the stock status in those regions.

A length distribution time series is available from the Dutch pelagic trawlers. The use of those measurements has not been investigated yet but may be considered in a further implementation of a length based model for area 7 when sufficient additional data will be available. However, as mentioned before, it is suspected that those length structures may not reflect the actual length distribution of the population in subarea 7.

4.3.3.2 Combined assessment with subarea 8 (8abd)

Combined assessments in a4a and SS3 for subareas 7 and 8 together have been presented at the beginning of the workshop. Those runs relied on the assumption that the dynamics and structure of the stock in 7 are the same than in 8abd. Therefore, they must be seen as preliminary exercises to see if the lack of information in subarea 7 can be somehow compensated by the available data in the Bay of Biscay.

4.3.3.2.1 A4a approach

In addition to the application of the a4a model (Jardim *et al.*, 2014) to the Bay of Biscay (section 4.4.4.2), an extension to include data from English Channel and Southern Celtic Sea was proposed in the working document (Citores *et al.*, WD).

The selected model for 8abd (model 2 in Table 4.4.4.2.5.5) was applied to data on the whole stock distribution. Since only total catch was available for English Channel and Southern Celtic Sea, the same age structure as in the French catches in the Bay of Biscay was assumed. Thus, the catch-at-age matrix of the Bay of Biscay was raised to the total catch. In addition, the PELTIC aggregated index from 2013 to 2015 was included in the model fit as a new independent biomass aggregated indicator on ages 0+.

In order to test the sensitivity to the assumed age structure in Subarea 7, the model fit was repeated assuming the age structure of the English Channel and Southern Celtic Sea was equal not only to the French catches, but to the age structure of the international catches in 8abd.

Generalizing the assessment from the Bay of Biscay to the whole stock distribution area (8ab+7), either assuming the age structure in subarea 7 was equal to only the French catches or to the international catches in Biscay (8ab), leads to an upward correction in the population abundance and a change in fishing mortality in the last four years (Figure 4.3.3.2.1). Certainly the assessment relies basically on PELGAS survey, as the additional data coming from egg abundance and from the PELTIC contains a lesser amount of information (the former is an aggregated index and the later is available just for the most recent years). In line with conclusions in section 4.4.4.2, when catchability is to estimate (without any indication of the absolute level of biomass), the assessment of the population biomass is scaled by the absolute level of the catches and by the assumed natural mortality rates. Therefore, additional information on the catchability of the surveys or the absolute level of the population would be necessary to scale properly the assessments for this wider geographical range.

In general, the lack of information in Subarea 7 makes difficult to generalise the assessment in 8abd to the whole area. Currently, any attempt to provide an overall assessment, rely on some strong assumptions that are difficult to test.

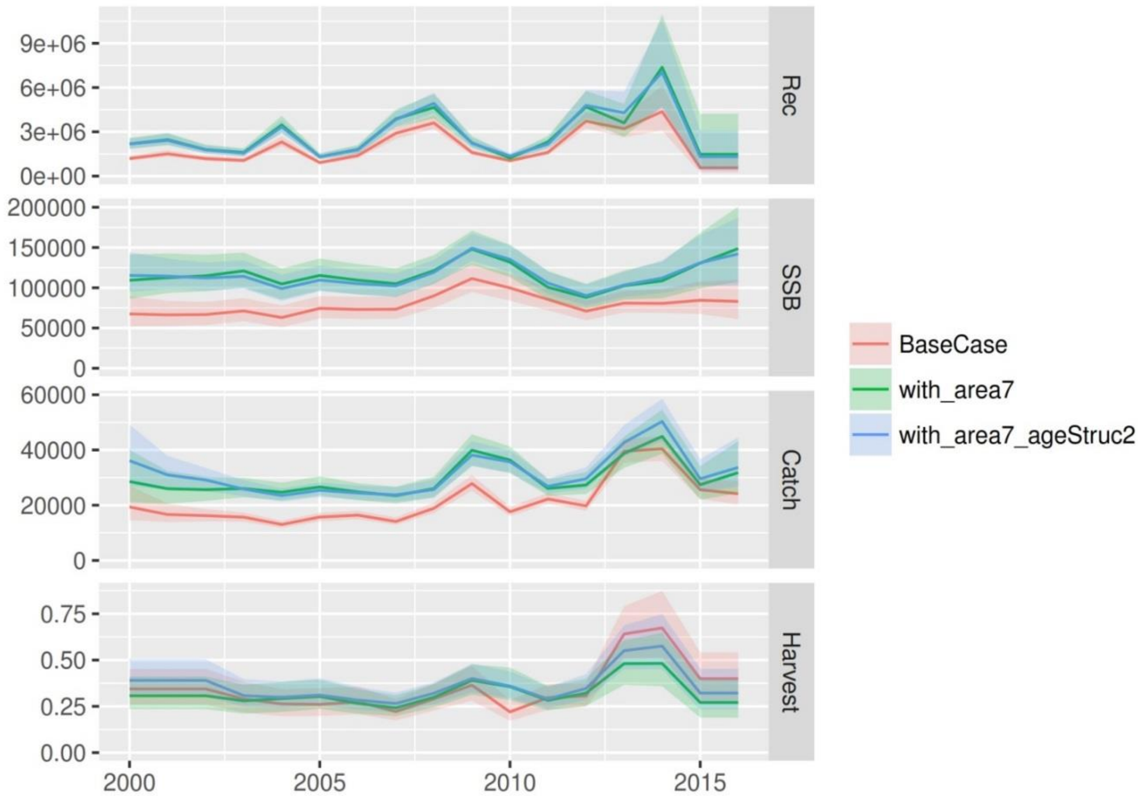


Figure 4.3.3.2.2. Summary of results for the assessment in the Bay of Biscay and in the whole distribution area with the two alternative age structure assumptions. The red color represents results from VIII area only (Base case), green is for raised catches using French catch age structure (with-area7) and blue for raised catches using international catch age structure (with_area7_ageStruc2).

4.3.3.2.2 SS3 approach

As for the a4a run, the initial run made for the Bay of Biscay using SS3 was applied to the data on the whole stock distribution. Due to the lack of data on stock structure for the English Channel and Celtic

Sea, it assumed the same age structure as in the French catches in the Bay of Biscay was prevalent in the English Channel and Celtic Sea. French catch at age data from the Bay of Biscay were topped up to reflect the increase of catches for the whole 7 and 8 a.b.d area. PELTIC aggregated index was included from 2013 to 2016.

The biomass estimates have an order of magnitude which is below the estimates from PELGAS and show increasing trends in the recent years despite no indication of a sharp increase of the biomass in the English Channel. The influence of Bay of Biscay trends is very strong especially in regards of the PELGAS survey data. The short time series for PELTIC does not bring at the moment much information. Therefore, the outcome from this run is highly dominated by the trends in the Bay of Biscay. Given the difference of the fisheries and the vessels between the Bay of Biscay and subarea 7, this exercise emphasizes that the lack of information in subarea 7 cannot simply be replaced by assumption from the fisheries in the Bay of Biscay. As for A4A, assuming the same stock structure between the two regions is a strong assumption that cannot be validated at the moment because of the lack of biological sampling and is probably highly doubtful given the difference in terms of fisheries and growth rates.

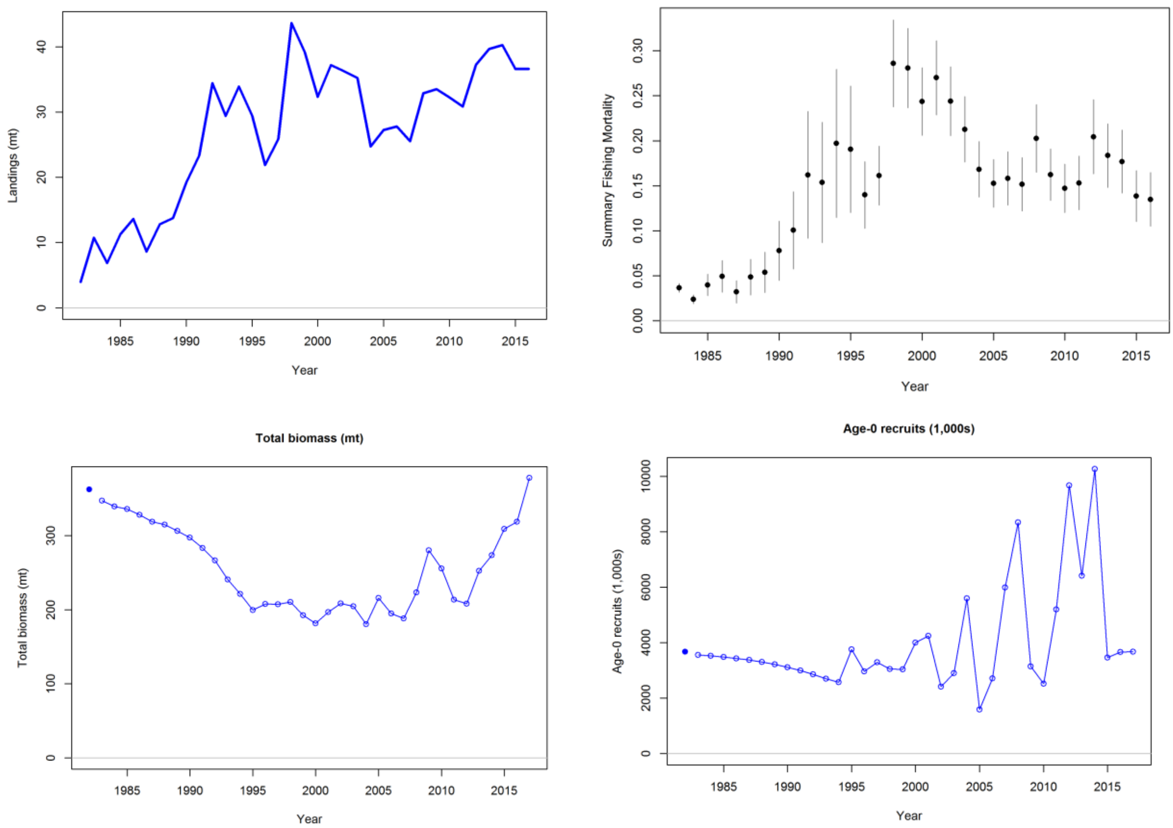


Figure 4.3.3.2.2. Summary of results for the assessment in the Bay of Biscay and in the whole distribution area using SS3.

4.3.4 Conclusions and Recommendations for further work.

Further work should be carried out to develop an assessment specific for the English Channel and Celtic sea region or a global assessment for the whole stock area (including Bay of Biscay).

An important effort is recommended regarding the availability of data. Basic data such as landings are still uncertain for many reasons related to the diversity of countries and type of vessels catching sardines. One way would be to use information from the canning industry to confirm the magnitude of landings. The lack of TAC for sardine, the overall good shape of the stock has so far not been an incentive to initiate some data collection as part of the DCF program or national effort. Therefore no age data, maturity information or length distribution are routinely available. If such program was implemented, it would still take probably a decade to start to be informative. One interesting and promising source of information is the PELTIC survey which should be continued as long as possible. In the medium term, this survey could provide indications on the trends of the population in the area.

In terms of assessment, SS3 may be set up for this area using length rather than ages once a comprehensive series would be available. However this configuration still requires a good estimate of growth parameters. Research projects such as CAPTAIN are useful to increase the knowledge on biological parameters for this area and derive information that may serve as the basis for some stock assessment model.

The conclusion of WKPELA was that currently the limited and poor quality of the data available for the English Channel and Celtic sea region prevents producing an assessment of subarea 7. Furthermore, a joint assessment of Divisions 8abd and subarea 7 require the strong assumptions of similar population trends and age composition of catches in both areas, which is currently perceived as highly unlikely (according to the recent survey estimates, indications of different growth patterns and different fishing gears). Therefore, the WK concluded that the sardine populations inhabiting area 7 cannot be analytically assessed currently. A proper assessment should wait until a consolidate series of biomass and age structured survey index is available and a length composition series, but preferably age composition series, of catches is available at least for about 5 years. Meanwhile the only indication of the current exploitation level could be obtained from the ratio of catches to the acoustic survey biomass indicators (under the assumption of catchability equal to 1 or for some range of acoustic catchability values, from 1 to 3) but the workshop could not explore such approach and therefore this is left for interim work until the next benchmark.

4.4 Divisions 8 a,b,d

4.4.1 Present assumption maintained. Any new information, plans for further studies, decisions with justification.

Several conclusions from WKSAR (ICES, 2016) were related to connectivity between the southern stock, Bay of Biscay, English Channel and Celtic sea. The data on cohort dynamics in recent years do not indicate massive straying of cohorts from the Bay of Biscay to the Cantabrian Sea (or south of it). In other terms, the Bay of Biscay sardine biomass does not provide substantial amount of biomass to the Iberian Peninsula. On the northern limit, it appeared that the English Channel sardine is not simply an immigrant component of the Biscay sardine as the fishes in the Channel/Celtic Sea region can be part of a self-sustained population with some uncertain mixing perhaps occurring between Bay of Biscay, English Channel and Celtic Sea.

There is no information on connectivity between the Bay of Biscay and English Channel/Celtic Sea. Bordering catches in 7 (statistical rectangles 25E4, 25E5) close to the Bay of Biscay area are generally considered to be taken from the sardine populations in the Bay of Biscay. Currently, it is unknown if mixing occurs between Bay of Biscay and English Channel populations.

Those points do not differ totally from the previous assumptions we made. Unanswered questions are still about a stock definition that would consider subarea 7 and Bay of Biscay as distinct stocks or as whole single stock. Previous assessments, because of the lack of proper biological information in subarea 7, were solely based on the Bay of Biscay survey data as the basis for the advice which was delivered for the whole area including Bay of Biscay, English Channel and Celtic sea.

For the purposes of assessment and management, the WK concluded that given the absence of evidences of connectivity between the Bay of Biscay and subarea 7 sardine populations, and the limited connectivity with southern sardine, the population in Divisions 8abd could be considered a shelf sustained population. Even in the case some connectivity would occur, dealing separately with the sardine in 8abd and 7, in a sustainable manner, would be probably risk averse, as the potential northward emigrants from the Bay of Biscay to subarea 7 would be comprised (assimilated) in the natural mortality parameter estimated for the Bay of Biscay population.

4.4.2 Multispecies and mixed fisheries issues and Ecosystem drivers.

The sardine fishery is not considered as being part of a mixed fisheries. When vessels are targeting sardine, landings are composed exclusively by sardine except for some small trawlers but their sardine catches are very low compared to normal pelagic trawlers and purse seiners really targeting sardine all over the year. Discards are considered negligible.

While work has been and is being done to understand and manage the Bay of Biscay, Celtic Sea and English Channel fisheries through integrated assessments, multispecies modelling, at the moment it is unknown which environmental factors drives the sardine dynamics.

4.4.3 Stock Assessment inputs

4.4.3.1 Catch-quality

Spain and France report catches in tonnes, by length and by age on quarter basis, usually up to age 9, though for assessment purposes an age plus group is created for ages 6 and older (6+ group).

The sampling intensity on catches is acceptable: in 2013, CV of the total length structure have been calculated about 14 %, and age structure about 18 % (Ifremer, CREDO-internal fishery Data Compilation group). Discards are assumed to be negligible.

4.4.3.2 Weights at age in Catches

According to a good level of sampling, the procedures to obtain these relevant data were not revised in recent years. Parallel to the weights at age observed during the PELGAS survey, mean weights at age in the catches show a clear decreasing trend year after year (figure 4.4.3.2.1).

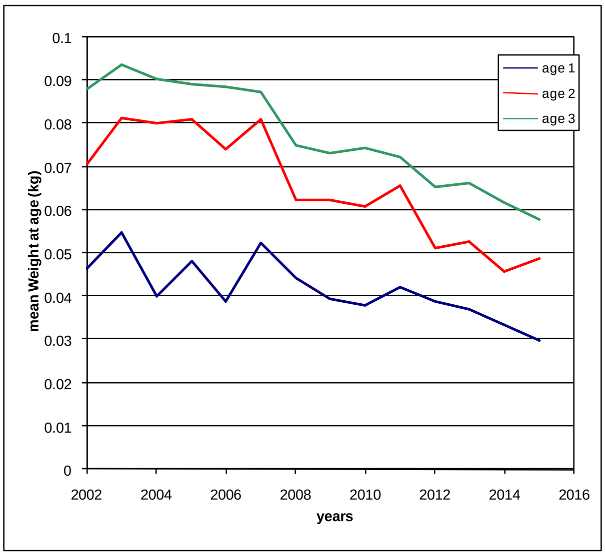


Figure 4.4.3.2.1. Series of mean weight at age of sardines in the catches.

4.4.3.3 Weights at age in the Population; Former input; Revised; Justification (Erwan, Andres)

The series of Weights at age in the stock from the acoustic survey (PELGAS) show a clear decreasing trend (figure 4.4.3.3.1). For instance, for the population assessed by the PELGAS acoustic survey in the Bay of Biscay, mean weight at age 1 declined from 40 to 25 grams over the series, started in 2000.

Preliminary results from some scientific projects on sardine in the Channel show a different growth pattern compared with the Bay of Biscay, showing higher values for 3 growth parameters in the former area: mean growth in length, weight and flesh energy density for each age class. These results must be confirmed with a higher number of samples.

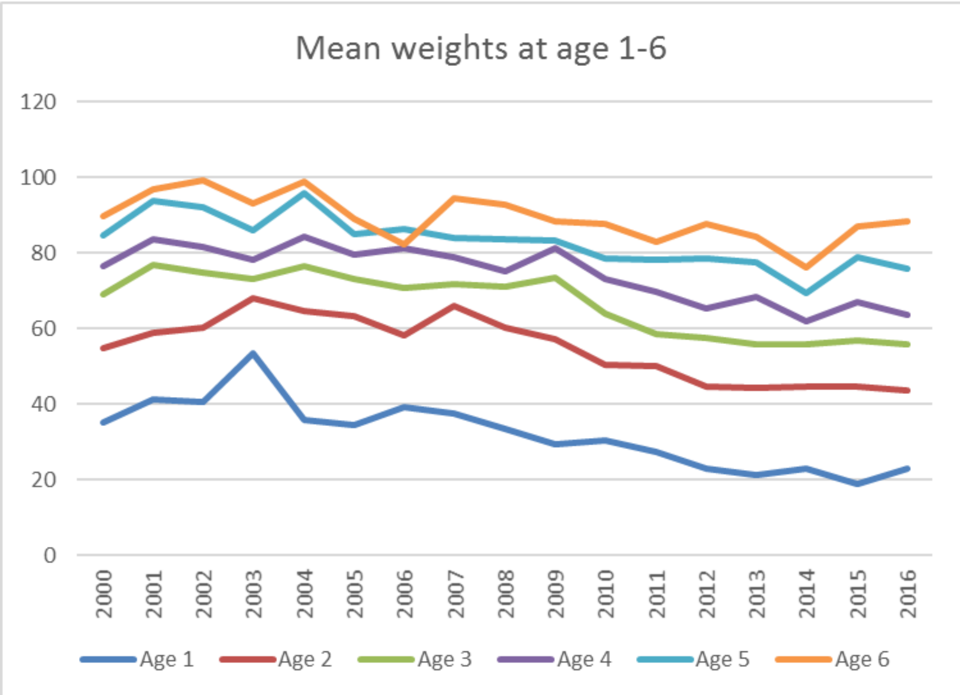


Figure 4.4.3.3.1. Series of mean weight at age of sardines in the population estimates of PELGAS acoustic survey

4.4.3.4 Maturity at age

Maturity ogive have not been used in the trend based assessment carried out by WGHANSA previously on sardine for Division 8abd. Maturity at age (based on semester 1 data from Pelgas and sampling onboard commercial vessels) has been compiled from 2000 to 2016 covering the whole time series.

The bulk of the samples is collected during semester 1 and amounts for about two thirds of the annual samples. Between 1000 to 2000 samples are collected each year. Data were only available for the Bay of Biscay.

Sardine maturity are divided into six stages. Stage 1 is made of immature fish. Stage 2 is a maturation stage. 50% of the fish belonging to that stage were considered immature and the other half mature. Stages 3, 4, 5 are the spawning stages. Stage 6 is post-spawning. This stage is rarely observed during semester 1 but more commonly seen during semester 2. The proportion of individuals belonging to those stages was considered by year and age (figure 4.4.3.4.1).

The proportion of mature individuals has been decreasing for age 1 (figure 4.4.3.4.2). This phenomenon could be likely related with the decrease of the mean individual size-at-age. With fish of a given age being smaller and smaller, the youngest fish are likely to have their metabolism and physiology impaired to some extent. The cause of the size decrease is currently unknown.

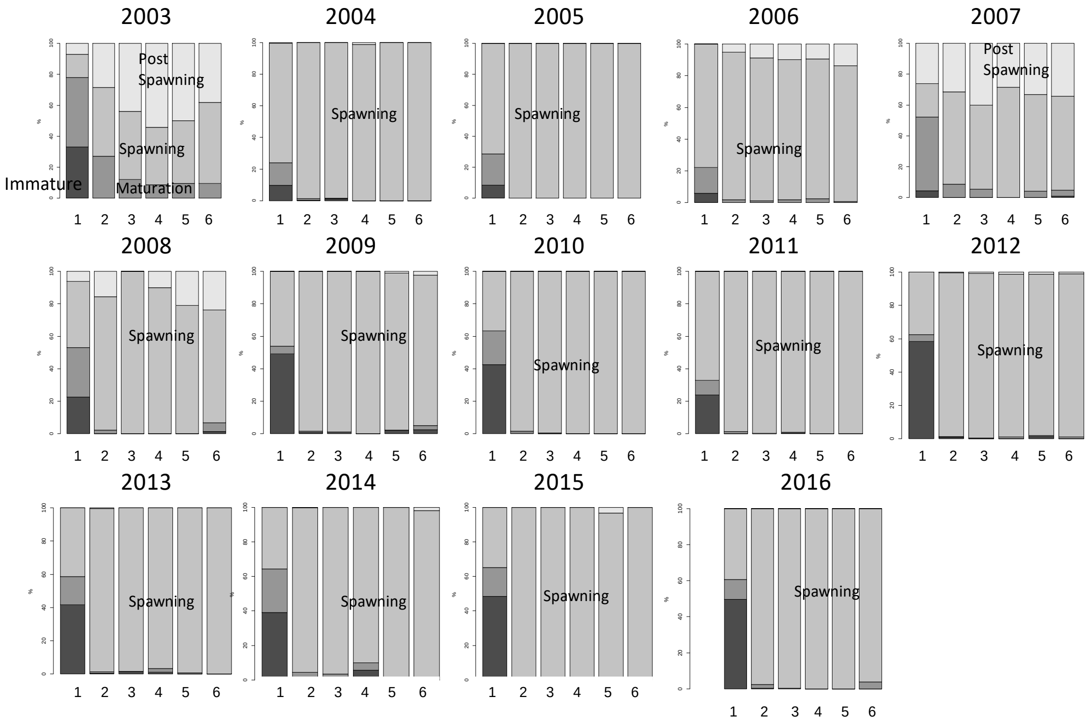


Figure 4.4.3.4.1. Proportion of mature individuals by age and year for semester 1 in the Bay of Biscay (years 2003–2016 from left to right columns and from upper to bottom lines).

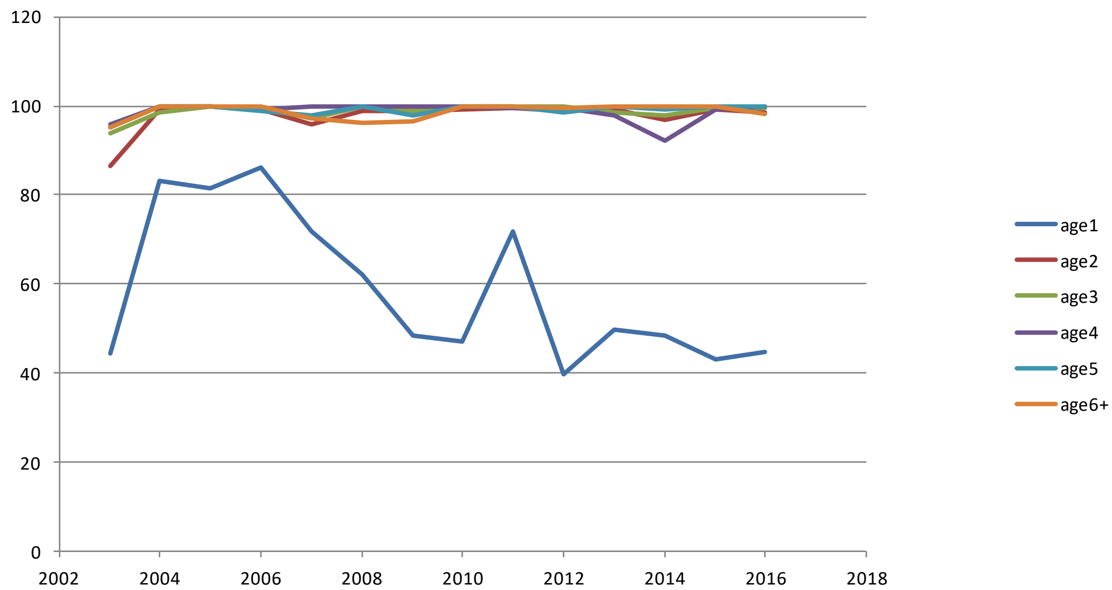


Figure 4.4.3.4.2. Proportion of mature individuals by age and year for semester 1 in the Bay of Biscay.

The consequence of this decrease of maturity for management has not been explored however it may numerically affect the spawning biomass estimates. Most stock assessment model use a constant maturity ogive. Setting a constant ogive may lead to substantial bias in spawning biomass. The bias will be proportional to the difference of proportion of mature at a given age between constant and variable ogive multiplied for each year by the number and weight-at-age. Therefore, it might be useful to consider here a variable ogive rather than a constant one. Maturity stage is currently unknown of the Celtic

Sea, English Channel. Given the potential differences of growth, it may be difficult to extend the ogive from the Bay of Biscay to these areas.

4.4.3.5 Natural mortality

Natural mortality at age values were previously considered to be the same than for the Iberian stock but were not used in the trend-based assessment. Cohort tracking was however previously performed to derive total mortality estimates.

SS3 and A4A use natural mortality parameters. Those parameters have been investigated through several approaches which further led to a set of different assessments (see section 4.4.4.1).

Four approaches were tested to derive new values for M at age:

In *Brodziak et al., (2011),* age-specific M is given by

$$\mathbf{M(a)} = \begin{cases} \mathbf{M_c \frac{L_{mat}}{L(a)}} & \mathbf{for\ a < a_{mat}} \\ \mathbf{M_c} & \mathbf{for\ a \geq a_{mat},} \end{cases}$$

$$M(a) = \begin{cases} M_c \frac{L_{mat}}{L(a)} & for\ a < a_{mat} \\ M_c & for\ a \geq a_{mat}\,, \end{cases}$$

$$\mathbf{M(a)} = \begin{cases} \mathbf{M_c \frac{L_{mat}}{L(a)}} & \mathbf{for\ a < a_{mat}} \\ \mathbf{M_c} & \mathbf{for\ a \geq a_{mat},} \end{cases}$$

whereL_{mat} is the length at maturity, M_c = 0.30 is the natural mortality at L_{mat}, L(a) is mean length at age for the PELGAS survey for the whole time series.

In *Lorenzen (1996)*, age-specific M for ocean ecosystems is derived by

$$M(a) = 3.69\ \overline{W}_a^{-0.305},$$

$$\mathbf{M(a) = 3.69\ \overline{W}_a^{-0.305},}$$

where$\overline{\mathbf{W}}_a$ $\overline{W}_a$ is the mean weight at age from the Pelgas Survey for the whole time series.

Gislason et al., (2010) provide age-specific M based on Von Bertalanffy parameters. This implies using the available length-age keys to derive those parameters for the full time series

$$\ln(M) = 0.55 - 1.61\ln(L) + 1.44\ln(L_\infty) + \ln(K),$$

An exponential decay shape for M.age is estimated. Assuming that the PELGAS survey provides absolute numbers at age, the methodology implies computing an overall total mortality rate Z derived for PELGAS and derive F (2009–2015) from the catch at age matrix conditioned to the number at age matrix available from PELGAS. M and F are expected to fit Z by adjusting the rate of decay using the following formula: M.age = 0.7 * exp (-(1-age)*rate).

The following parameters were estimated using the Brodziak, Gislason and Lorenzen approaches.

Table 4.4.3.5.1. Summary of natural mortality estimates derived respectively from the Brodziak, Gislason and Lorenzen approaches.Some of those values were then rescaled for some of scenarios explored with SS3.

Basis				Current Model Settings	Brodziak *et al.*, 2011 Mc=0.6 Lmat=16	Lorenzen *et al.*, 1996 "Ocean settings" 3.69 -0.305	Gislason *et al.*, 2010 linf=24 K= 0.4 t=-1.8
Age	Mean Length	Mean weight	N	M(Iberian settings)	M(Brodziak)	M(Lorenzen)	M(2003-2016)
0	12.41	16.65	498	0.8	0.77	1.54	1.190
1	16.29	32.16	5341	0.5	0.60	1.25	0.768
2	18.86	54.96	5035	0.4	0.60	1.06	0.607
3	20.57	66.83	2947	0.3	0.60	1.00	0.528
4	21.71	74.73	1916	0.3	0.60	0.96	0.484
5	22.47	83.04	1193	0.3	0.60	0.94	0.458
6	22.97	89.4	793	0.3	0.60	0.91	0.442
7	23.30	94.1	468	0.3	0.60	0.90	0.432
8	23.53	101.8	263	0.3	0.60	0.89	0.425
9	23.67	102.8	135	0.3	0.60	0.89	0.421
10	23.77	107.8	47	0.3	0.60	0.88	0.418
11	23.84	105.6	16	0.3	0.60	0.85	0.416
12			2	0.3	0.60	0.79	
14			1	0.3	0.60	0.91	

The following natural mortality scenarios were used for the SS3 runs. The mortality rates used into the model were those estimated by the previous approaches with or without a rescaling factor.

- The previous estimates from Iberian Sardine assessment from Age 0 to Age 6+ : 0.8, 0.5, 0.4, 0.3, 0.3, 0.3,0.3
- Constant value of M acrossages equal to 0.4, 0.5 and 0.6. This is close to the Brodziak, approach as in this one, for sardine, only age 0 is different from the rest of the age groups.
- Rescaled Gislason M at age multiplied by rates from 0.8 to 1.1 (by increment factor of 0.1).
- Rescaled Lorenzen M at age with the base parameter ranging from 0.8 to 2.8 (0.8, 1.2, 1.6, 1.8, 2, 2.4, 2.8).
- Exponential curves with M1 set 0.7 and a range of rates parameter from 0.12 to 0.24 (7 options).
- Lorenzen shapes: The best fit M at age dataset from rescaled Lorenzen runs with M for 6+ group fixed from 0.2 to 1. (6 options).

4.4.3.6 Surveys data input quality

Acoustic and DEPM pelagic surveys are designed to deliver biomass and age structure estimates of small pelagic fish. For sardine in 8abd the following indices are available: biomass and age structure estimates from Acoustic surveys since 2000 (PELGAS), spawning stock biomass from some DEPM applications (in 2011 and 2014) and a series of Total Sardine Egg abundance estimates from the DEPM survey series for anchovy (BIOMAN).

a. Acoustic PELGAS survey takes place in spring (around May) in the Bay of Biscay onboard the French research vessel Thalassa. The objective of PELGAS survey is to study the abundance and distribution of pelagic fish in the Bay of Biscay. The main target species are anchovy and sardine but they are considered in a multi-specific context and within an ecosystem approach as they are located in the centre of pelagic ecosystem.

   All the acoustic data along the transects are processed and scrutinised onboard. Acoustic energies (Sa) are cleaned by sorting only fish energies (excluding bottom echoes, parasites, plankton, etc.) and classified into 5 categories of echo-traces. Fish are sorted and sardine and anchovies are aged with otolith reading, also processed onboard.

   The strategy is identical year after year. The survey protocols are described in Doray M., Badts V., Masse J., Duhamel E., Huret M., Doremus G., Petitgas P. (2014). Manual of fisheries survey protocols. PELGAS surveys (PELagiques GAScogne). http://dx.doi.org/10.13155/30259:

- Age and size global distribution are calculated with spatial weighting.
- No data were revised in recent years.
- The CV of the sardine biomass calculated each year is regularly about 8%.

b. BDEPM surveys on sardine have been carried out by IEO and AZTI institutes in April and May in years 2011 and 2014 (Díaz *et al.*, 2011 and 2014–see WD to the respective WGACEGG reports–ICES 2011 and 2014) (see also the Santos *et al.* presentation). The surveys cover first the southern part of the Bay of Biscay (in April during SAREVA survey) and secondly the northern part from 45ºN northwards (in May during Bioman survey, Santos *et al.* in press). The respective estimates of Sardine spawning biomass in 2011 and 2014 were 136 kt (CV=0.43) and 410 kt (CV=0.3). This series has just started. They were considered in the WK just because of the presumed absolute nature of the DEPM estimates (i.e. biomass in tonnes).

c. Total sardine egg abundance during Bioman survey in May (Santos *et al*., in press) (based on Pairovet hauls for the regular implementation of the DEPM to anchovy in the Bay of Biscay) have been reported since 2000 (see the data in ICES 2016 WGHANSA report–ICES CM 2016/ACOM: 17). The estimates are just the addition across the whole surveyed standard area in 8abd of the egg counts per surface unit of every Pairovet sample multiplied by the area each sample represents. This series was already included as an auxiliary relative indicator of spawning biomass series in the trend based assessment carried out WGHANSA formerly on this sardine population. The correlation with the acoustic survey in May is significant (r=0.554, n= 17 & Prob Correl=0.021) (figure 4.4.3.6.1).

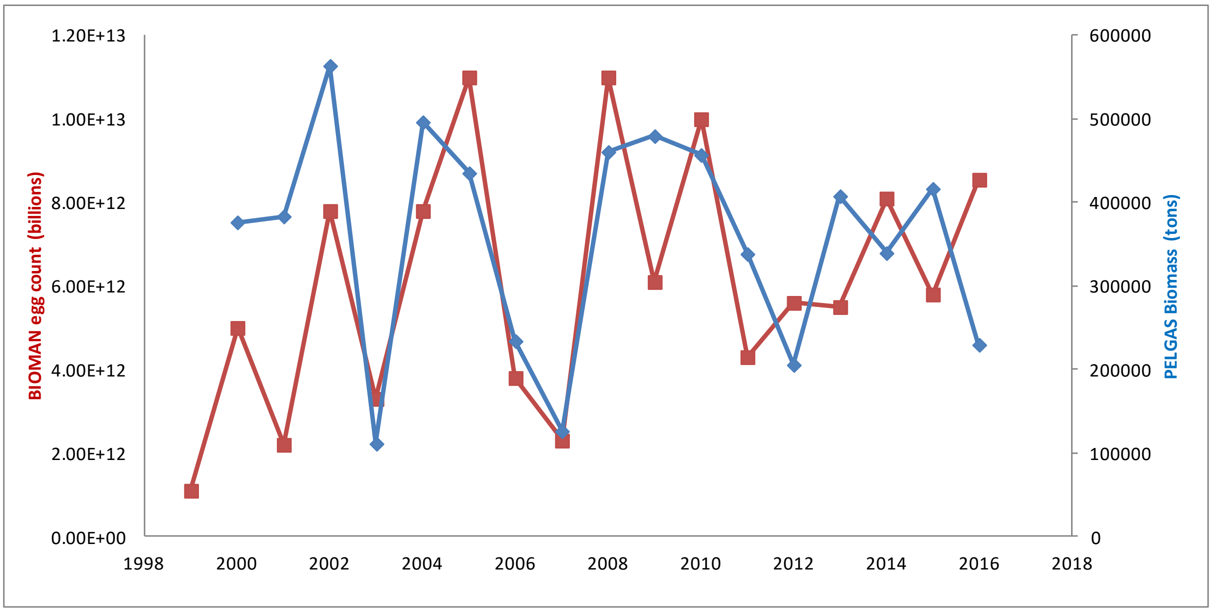


Figure 4.4.3.6.1. Survey indices from Pelgas (acoustic) and Bioman (DEPM) surveys in 8a,b,d (1999–2016).

4.4.3.7 Environmental covariates

No environmental covariates were included into the assessment.

The potential relationship between the year effects on the catchability of the PELGAS and BIOMAN surveys and the sea surface temperature was explored in the working document presented by Citores et al (2017). Larger temperatures could imply lower catchability. However, the temperature was not enough to explain some of the strong year effects of the survey (such as 2003, 2006 and 2007).

4.4.4 Assessment model

4.4.4.1 Stock synthesis Assessment (SS3)

Stock synthesis (Methot and Wetzel, 2013) was identified as the potential assessment model for sardine in the Bay of Biscay. An initial run was presented and discussed at the start of the meeting. Afterwards, during the benchmark a set of new runs were done in order to better understand the results obtained and choose the best model settings.

4.4.4.1.1 Settings and assumptions.

In general, the stock assessment model considered was similar to the model used for the Iberian sardine stock. The model was age-structured and it assumed a single area, a single fishery, a yearly season and both genders combined. The model was fitted to total biomass and age composition of the catch, total biomass (age 1+) and age composition from the PELGAS acoustic survey, an abundance index based on the total egg counts from the BIOMAN survey and a triennial SSB index from the DEPM (in 2011 and 2014). Most of the exercises were run with initial sample sizes for annual age composition of the fishery and the acoustic survey of 50 and 75 respectively. Standard errors of the total biomass of the acoustic survey were taken as estimated by the survey, whereas standard errors of the aggregated abundance index from the egg count and the SSB estimates from the DEPM were taken equal to 0.25. The assessment included data from the surveys of the interim year, whereas the fishery data finished the year before. Annual recruitments were estimated as deviations from an average value in log scale, with a standard deviation of 0.8. The initial population was calculated by estimating an initial equilibrium population modified by age composition data in the first year of the assessment. This was derived by assuming an initial catch of 13 000 tons corresponding to the average of catches for the period 1990-

1999. Weights at age and maturity at age were taken from the PELGAS surveys. All the aggregated indices were taken as relative, so that catchability parameters were estimated. Alternative options were tested for the selection pattern of the fishery and the PELGAS survey. In addition, various natural mortality vectors were considered (see below). For each case, the model parameters were estimated by minimisation of the likelihood in phases using standard ADMB process. Variance estimates for all parameters were calculated from the Hessian matrix. The best option for natural mortality and selectivity of the fishery and the acoustic survey was selected based on the smallest AIC (Akaike's Information Criteria).

For the selected model, initial estimates of data precision were modified to obtain the final model estimates. All these values were changed iteratively until approximate convergence of the harmonic mean of expected sample size and the root mean squared error of the aggregated indices according to the model results.

The full list of runs conducted are summarised below:

	Selection pattern PELGAS	Sel pattern fishery	M@age	Prior on q for PELGAS	Eff. Sample size
Case0	Flat 2-5	Free	Iberian sardine	Yes	50 -75
Case1	Flat 1-6+	Free	Exponential, Gislason, Lorenzen, constant and Iberian sardine	No	50 -75
Case2	Flat 2-5	Free	Exponential, Gislason, Lorenzen, constant and Iberian sardine	No	50 -75
Case2b	Flat 2-5	Free	Gislason	Yes	50 -75
Case3	Flat 2-5	Flat 2-5	Gislason	No	50 -75
Case4	Flat 2-5	Flat 3-5	Gislason	No	50 -75
Case4b	Flat 2-5	Flat 3-5	Gislason	Yes	50 -75
Case5	Flat 2-5	Flat 3-5	Gislason	No	45 – 45

The study was completed with the likelihood profile of the catchability of the acoustic survey and a retrospective analysis of the spawning stock biomass, recruitment and fishing mortality for ages 2-5.

4.4.4.1.2 Diagnostics, with interpretation and discussion

Case 1 and Case 2

A range of different natural mortality (M) vectors were considered to fit the model under different selection patterns for Pelgas, which cover two cases:a fixed flat pattern for ages 1 to 6+ (Case 1) and a fixed flat pattern for ages 2 to 5 with selectivity for ages 1 and 6+ estimated (Case 2). The selectivity for the fishery was not fixed at any age. Considered M vectors were classified in 6 different blocks:

1. Exponential shapes: for M1=0.7 and a range of decreasing rates from 0.12 to 0.24 (7 options) (according to the formula M.age = 0.7 * exp(-(1-age)*rate)).

2. Gislason shapes: rescaled Gislason M at age multiplied by rates from 0.8 to 1.1 (4 options).

3. Lorenzen shapes: rescaled Lorenzen M at age with the base parameter ranging from 0.8 to 2.8 (7 options).

4. The best M at age from Lorenzen shapes with M for 6+ group fixed from 0.2 to 1. (6 options).

5. Constant M: 0.4, 0.5 and 0.6 (3 options).

6. M from the Iberian Sardine (0.8, 0.5, 0.4, 0.3, 0.3, 0.3, 0.3) (1 option).

For each block (depending on the shape of the natural mortality vector) and each case (flat selection pattern for Pelgas for ages 2-5 or to ages 1-6+), the best natural mortality vector was selected based on the negative log likelihood of the SS3 runs (Table 4.4.4.1.2.2.1).

Table 4.4.4.1.2.2. Best natural mortality at age option in each block in terms of negative log likelihood.

Block	Case 1: Selection pattern PELGAS Flat 1-6+	Case 2: Selection pattern PELGAS Flat 2-5
1	M1=0.7 & expo rate 0.12 (0.789,0.7,0.621,0.551,0.488,0.433,0.384)	M1=0.7 & expo rate 0.14 (0.805,0.7,0.609,0.529,0.46,0.4,0.348)
2	Gislason*0.9 (1.071,0.691,0.546,0.475,0.436,0.412,0.398)	Gislason*0.9 (1.071,0.691,0.546,0.475,0.436,0.412,0.398)
3	Lorenzen (1.2) (0.534,0.442,0.378,0.358,0.346,0.336,0.329	Lorenzen (1.6) (0.712,0.589,0.505,0.477,0.462,0.448,0.439)
4	Best Lorenzen & M6+=0.8 (0.534,0.442,0.378,0.358,0.346,0.336,0.8)	Best Lorenzen & M6+=0.4 (0.712,0.589,0.505,0.477,0.462,0.448,0.4)
5	Constant M=0.4	Constant M=0.4
6	Iberian M (0.8,0.5,0.4,0.3,0.3 0.3,0.3)	Iberian M (0.8,0.5,0.4,0.3,0.3,0.3,0.3)

Selectivity patterns, catchabilities, estimated biomasses and residuals were explored for these selected options. Model fits were compared in terms of the negative log likelihood. The vector or natural mortalities that provided the best fit in terms of the negative log likelihood were Gislason (2) and Lorenzen (3) in Case 2 (flat selection pattern for Pelgas for ages 2–5) and the modified Lorenzen (4) and the constant M (5) in Case 1 (flat selection pattern for Pelgas for ages 1-6+).

When looking at the residuals a clear pattern was detected for ages 1 and 2 in Case 1 for all M vectors, which was corrected in Case 2 (see **Error! Reference source not found.**), where selectivity for ages 1 is not fixed. Thus, Case 1 was discarded and a flat selectivity pattern for ages 2 to 5 for Pelgas index, Case 2, was selected.

With this selectivity pattern, Gislason*0.9 and Lorenzen (1.6) were the options giving the minimum negative log likelihood with similar estimates on catchability for Pelgas (around 2.8), biomass (around 110–190 kt). Gislason*0.9 showed a better retrospective pattern and was selected as a preferable option for next steps.

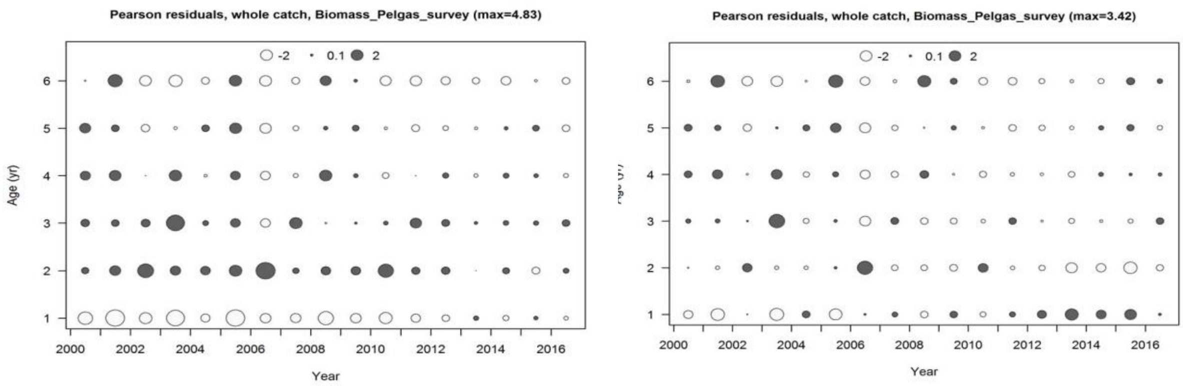


Figure 4.4.4.1.2.3. Residuals for Pelgas survey using Gislason M vector for Case 1 (left) and Case 2 (right)

<u>Case3, Case4 and Case0</u>

At this stage, maintaining settings from selected Case2, two different alternatives were proposed to model selectivity for the fishery, which was estimated freely in previous cases: a fixed flat pattern for ages 2 to 5 (Case 3) and a fixed flat pattern for ages 3 to 5 (Case 4). A likelihood profile was carried out using Gislason shaped Ms from block 2 for both Case 3 and 4. As the number of estimated parameters is not the same in each case, different options were compared in terms of AIC (Table 4.4.4.1.3.2). For the flat fishery selectivities either 2–5 or 3–5, the best model is for Gislason x 0.8 (named M3 and M4), whereas for the free selectivity the best model is for Gislason x 0.9 (named M2). The lowest AIC was reached with the flat selectivity 3-5 for the fishery selecting this selectivity pattern for the fishery (M4). Figure 4.4.4.1.2.2 shows selectivity patterns derived from each option. In M2, where selectivity for fishery is estimated freely an increasing pattern across ages is observed which is not expected. The selectivity pattern obtained when fixing a flat shape for ages 3-5 for the fishery was considered more appropriate, and along with a lower AIC it was selected as the best option (M4). Total biomasses derived from these models are shown in Figure 4.4.4.1.2.3.

Due to high values of estimated catchabilities for acoustic survey, which is designed to measure absolute abundance, the introduction of prior probability distributions on this parameter was considered. Case 2 with Gislason*0.9 M and Case4 with Gislason*0.8 M were modified to include priors (Case2b and Case4b) and were compared with the cases without priors. Lognormal distributions centred at 0 and with sd=0.5 were set as priors for DEPM and Pelgas survey catchabilities. The introduction of these non very informative priors showed no mayor differences in results. Hence, and considering that it was not found enough evidence to propose a more informative prior, it was decided not to incorporate priors in the model.

Table 4.4.4.1.3.2. AIC values and configuration for Case 2, 3, 4 and 5

Case	PELGAS Selectivity	Fishery Selectivity	Nb param.	Effective samplesize	Gislason x 0.8	Gislason x 0.9	Gislason x1	Gislason x 1.1
2	Flat 2-5	Free	36	50 - 75	236.7428	236.5226 (M2)	238.0476	240.9714
3	Flat 2-5	Flat 2-5	33	50 - 75	236.4118 (M3)	237.6436	240.2552	243.8008
4	Flat 2-5	Flat 3-5	34	50 - 75	235.6926 (M4)	236.2024	238.1668	241.075
5	Flat 2-5	Flat 3-5	34	45 - 45	183.7688	183.5674 (M5)	184.5592	186.3096

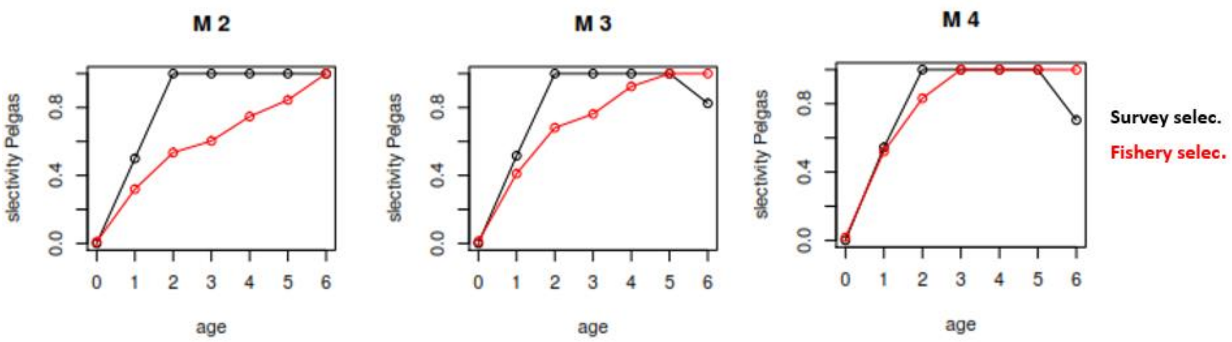


Figure 4.4.4.1.2.2. Estimated selectivity patterns for M2, M3 and M4 (defined in table 4.4.4.1.2.2). Red lines represent Fishery selectivity across ages and black represents selectivity for Pelgas survey.

<u>Case 4 and case 5:</u>

In Case5, effective sample sizes for age structured catch and Pelgas survey were changed to get an approximate convergence to the harmonic mean output reported in the fitting of the SS3 runs. Reported harmonic means suggested effective sample sizes, both for catches and suvery, between 40 and 50. Thus, they were set equal to 45. The analysis for rescaled Gislason shaped Ms was repeated, with the preferred flat 2-5 selectivity for the survey and the flat 3-5 selectivity for the fishery without priors. Results were compared with Case 4, where old effective sample sizes had been used. It turned out that the best option now, in terms of AIC, was the one with M=Gislason*0.9 (instead Gislason*0.8 as before) (Table 4.4.4.1.3.2). In addition, the same analysis was done setting the selectivity for the fishery as flat from ages 2 to 5, obtaining higher AICs for all M vectors.

This new weighting was considered more appropriate and therefore it was recommended to adopt this last model, Case 5 with M=Gislason*0.9, as the base model from the benchmark.

Results final run

Table 4.4.4.1.2.4. Final selected model configuration and AIC

	Selection pattern PELGAS	Sel pattern fishery	M@age	Prior on q for PELGAS	Eff. Sample size	AIC
Final run (M5)	Flat 2-5	Flat 3-5	Gislason*0.9	No	45	183.57

As summarized in Table 4.4.4.1.2.4, in the final selected model, selectivity for Pelgas survey was set to be flat between ages 2 and 5, with a value of 1 while selectivity for age 1 was estimated around 0.52 and for 6+ group around 0.74. For the fishery selectivity, a flat shape was fixed for ages 3 to 5, with a value of 1, while for ages 1 and 2 the estimated selectivities were 0.5 and 0.82 respectively and 0.99 for the plus group (see Figure 4.4.4.1.2.4).

Catchabilities for aggregated indices were estimated without any prior. Estimated catchability for Pelgas biomass index was 2.4, 1.8 for the DEPM and 39 for the egg count index. A likelihood profile for catchability for Pelgas is shown in Figure 4.4.4.1.2.5. The highest contribution to the total likelihood come from age structured data (first panel), with a higher contribution of the survey in comparison to catch data. However, with the new effective sample sizes these contributions became closer.

Total estimated biomass for the adopted final run was above 150 kt for most of the years. The time series is shown in Figure 4.4.4.1.2.3 together with lower biomass estimates from previous runs. Fishing mortality is estimated around 0.15 in the first period until 2011 with an increase in the last years to around 0.3. In

Figure 4.4.4.1.2.6 fishing mortality point estimates are shown with the respective confidence intervals. Yearly recruitment estimates oscillate between 2000 and 12000 thousand with its maximum in 2014 (Figure 4.4.4.1.2.7).

Retrospective patterns for SSB, fishing mortality and recruitment are shown in Figure 4.4.4.1.2.8. Residuals for this final model M5 do not show any strong pattern (Figure 4.4.4.1.2.9).

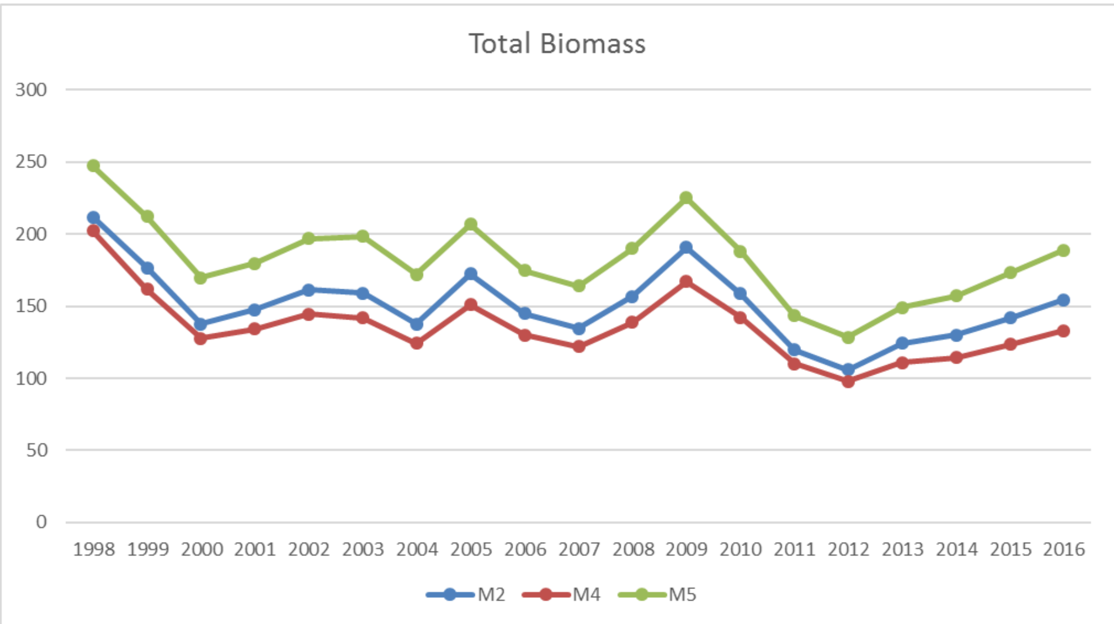


Figure 4.4.4.1.2.3. Total estimated biomasses in kt for M2, M4 and M5.

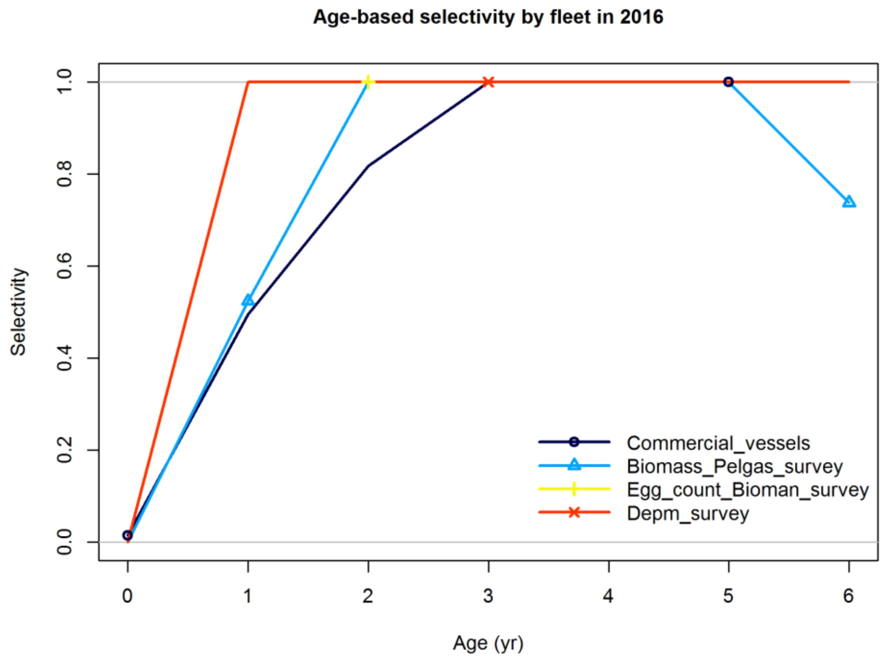


Figure 4.4.4.1.2.4. Selectivity patterns for final selected model (M5) for the fishery (dark blue) and Pelgas survey (light blue).

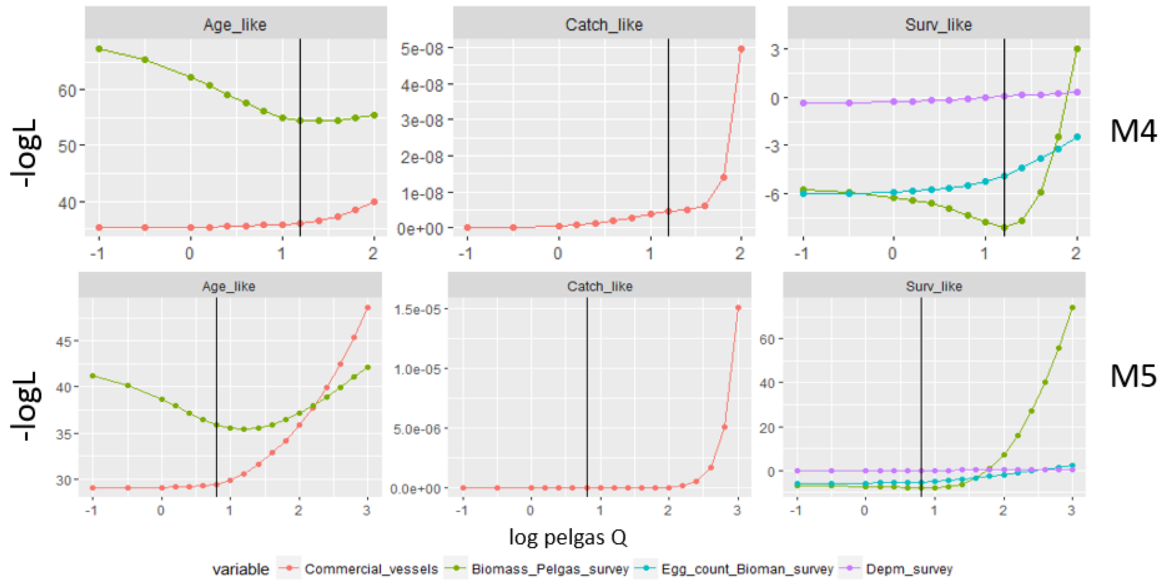


Figure 4.4.4.1.2.5. Likelihood profiles for catchability parameter for Pelgas survey for M4 (top) and M5 (bottom). Values in the x axes represent catchability values in log scale and in the y axes negative log likelihoods are shown. First panel shows age structured data contribution, second panel total catch contribution and last panel aggregated indices contributions.

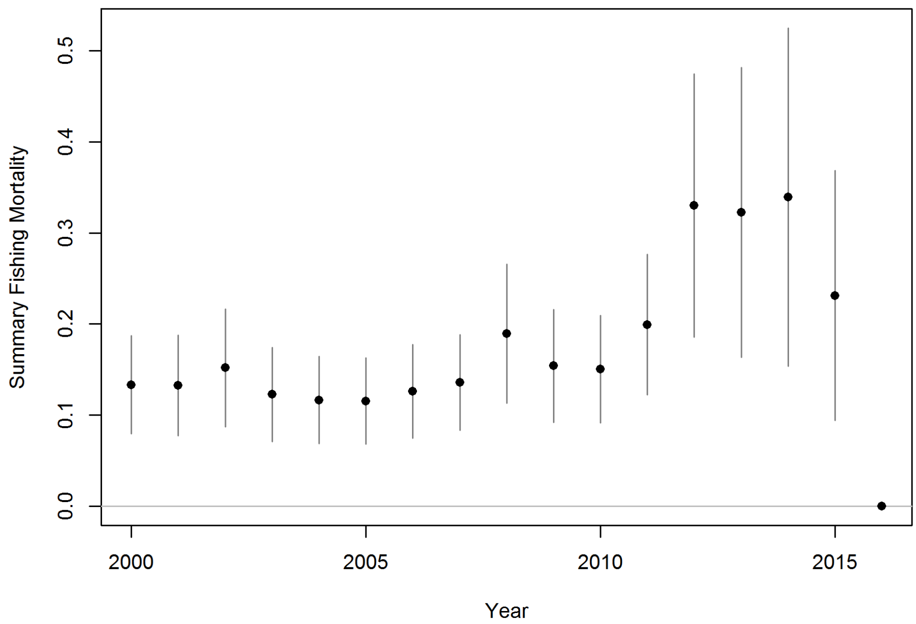


Figure 4.4.4.1.2.6. Fishing mortality estimates for M5 with 95% asymptotic intervals.

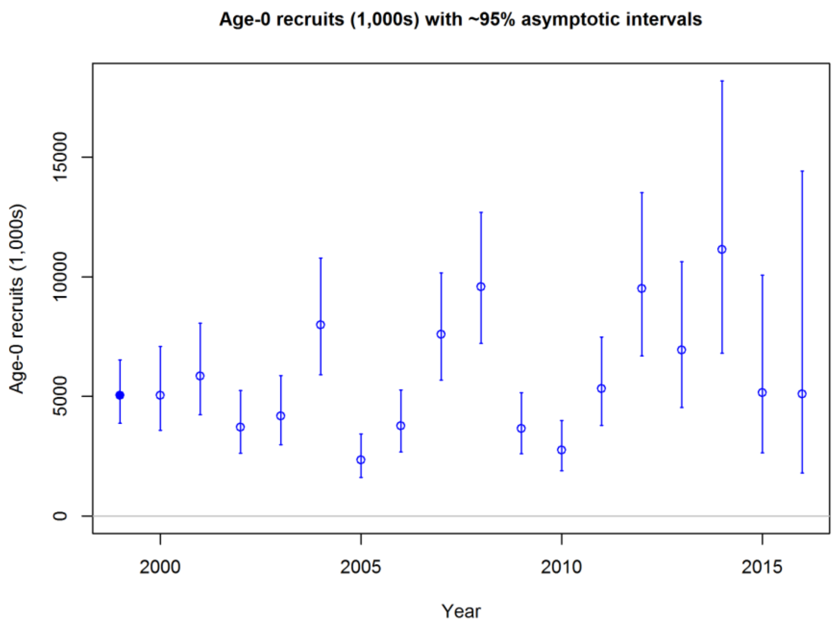


Figure 4.4.4.1.2.7. Recruitment estimates for M5 with 95% asymptotic intervals.

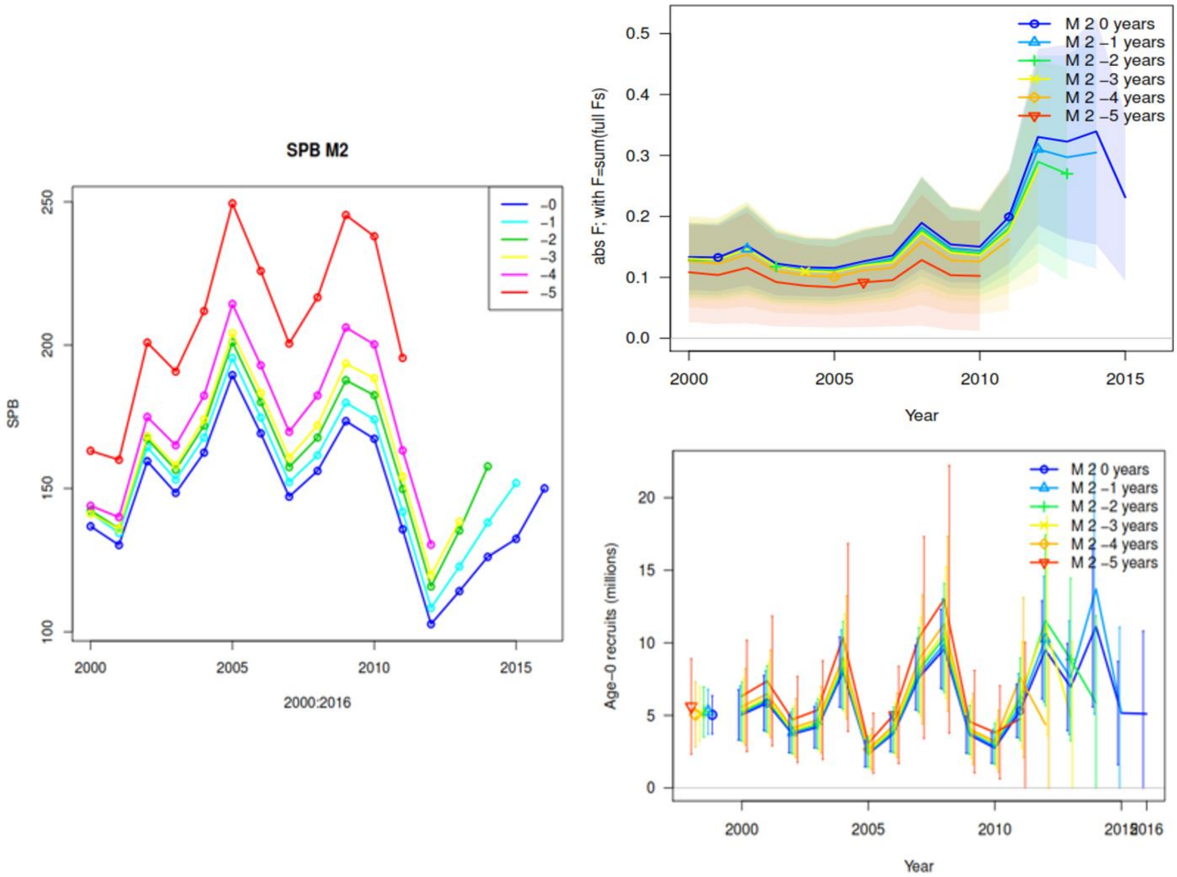


Figure 4.4.4.1.2.8. Retrospective patterns for M5. SPB (left), fishing mortality (top right) and recruitment (bottom right).

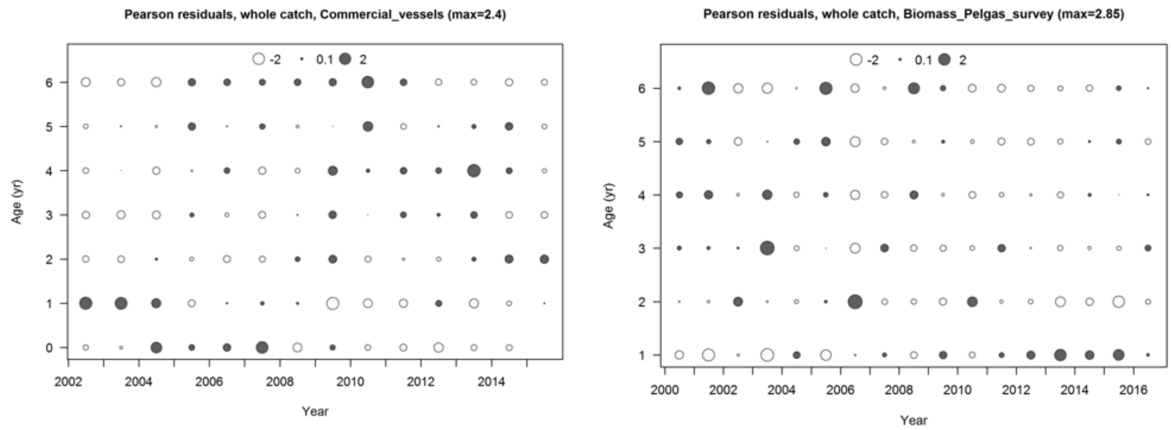


Figure 4.4.4.1.2.9. Residuals from final selected model M5. For age structured catch (left) and for age structured Pelgas survey (right).

4.4.4.1.3 Comparison with previous assessments.

While biomass estimates from SS3 are lower than the biomass indices derived from the surveys, this assessment can be seen as an improvement over the previous survey trend-based assessment which was the basis for the previous ICES advices (Category 3 stocks). The new assessment fully uses the available information from the surveys and commercial fleets for the Bay of Biscay analytically. However current estimated catchability for Pelgas biomass index (2.4), and for DEPM (1.8) are still perceived to be too high, because the acoustic and DEPM surveys are designed to estimate absolute biomass and because these catchabilities are quite different from those estimated for the southern sardine stock. It must be admitted that a revision of the acoustic survey estimates is being carried (by revisiting the target strength values) which will probably reduce the acoustic estimates, but overall the current assessment was considered to produce too uncertain scaling of the assessment. As diagnostics are consistent with the quality of available datasets, this assessment, while not reaching the full analytical stage, provide trends for biomass, recruitment and fishing pressure. Therefore the WK recommended to use the results of the assessment as indicative of trends only (laying it in category 2 stocks).

4.4.4.2 Assessment for all (a4a) Model

As an alternative to stock synthesis, a working document that applied the a4a model (Jardim *et al*, 2014) for the assessment of sardine in Bay of Biscay, English Channel and Southern Celtic Sea was presented (Citores *et al*., WDXX). This model provides a flexible framework that allows comparing alternative models easily. The a4a model was fitted under various model settings. The sensitivity of the results to the absolute level of catches and to the prior distribution of the catchability of the surveys was evaluated.

4.4.4.2.1 Input data

The model was fitted to catch-at-age from 2002 to 2015 and ages from 0 to 6+, PELGAS numbers-at-age estimates from 2000 to 2016 and ages 1 to 6+ and BIOMAN aggregated abundance index from 2000 to 2016. This is the situation in June at the ICES working group, where the catches are available up to the previous year, but the research survey indices have been already conducted and processed.

Natural mortality was fixed and equal to the values assumed for the Iberian sardine, whereas weights at age in the stock were taken from the PELGAS survey.

4.4.4.2.2 Model settings

The a4a assessment model needs to define the structure of five different submodels: recruitment, fishing mortality, indices catchabilities, initial population numbers at age and variances of the observation equations.

Initial population numbers at age (in 2000) were modelled as a cubic spline on age with k=3 and recruitment was considered a yearly factor assuming recruitment in 2016 to be equal to 2015.

Two alternative options were considered for the fishing mortality (Fmodel). On the one hand a typical separable model on age and year and on the other hand, a separable model of smooth functions of age and year (i.e. the product of a spline for age k= 4 and a spline for years with k=8). The later submodel would allow saving some degrees of freedom in the context of a smooth changes of F by ages and among successive years.

The catchability for the PELGAS survey (Qmodel) was assumed to be separable on age and year with the following models: Q1 with a spline on age with k=3 (i.e. constant along years), Q2: a product of a spline on age with k=3 and a spline on year with k=8 or Q3 product of a spline on age with k=3 and a spline on temperature with k=4.

Two alternative options were considered for the variance of PELGAS (Vmodels): Constant variance across ages or a spline on age with k=3. Variance of the catch-at-age and BIOMAN aggregated index observation equations were always set at the default options: spline on age with k=3 and constant along time, respectively.

The factorial design resulted in 12 alternative model settings (2 Fmodels x 3 Qmodels x 2 Vmodels;(*Table 4.4.4.2.5.5*). AIC (Akaike's Information Criteria) was evaluated but the best model was selected based on BIC (Bayesian Information Criteria) statistic.

Results were compared with an additional model, based on the work conducted in Workshop on Spatial effects on stock dynamics of European Atlantic sardine (held at JRC, Ispra, 14-18 December 2015). This model addressed problem of the apparent yearly variability in Q by setting a two level factor model for the yearly effect on Q, one level for the years 2003, 2006 and 2007 and the another fixed level for the remaining years.

4.4.4.2.3 Sensitivity to absolute level of catches

One of the issues in the Bay of Biscay assessment is the difference in the absolute level of the catches with respect to the biomass estimate from PELGAS. Total catches are around 30–40 000 t, whereas the direct biomass estimates produced by PELGAS have ranged between 100 (2003) and 550 (2002) thousand tons. DEPM applications in 2011 and 2014 were also within those limits.

In order to understand how much the absolute level of catches drive the absolute biomass levels estimated by the assessment, a sensitivity analysis was carried out. The model was fitted decreasing and increasing the absolute level of catches, namely, multiplying the catch-at-age by 0.05 and by 3 respectively and the resulting population estimates were compared.

4.4.4.2.4 Bayesian counterpart

A Bayesian counterpart of the selected model was constructed in JAGS, the only difference being that constant catchability across ages and years was considered for the Pelgas index. This allowed comparing the uncertainty estimates and studying the influence of the prior distribution of the catchability of the PELGAS survey in order to address the difference between the absolute levels between the catches and survey indices. Two different priors were compared: a tight and a loose prior distribution. Both were log normally distributed with mean at 1 and the coefficients of variation were 10% and 130% respectively.

4.4.4.2.5 Diagnostics and results

Summary statistics of all the models for sardine in the Bay of Biscay are shown in Table 4.4.4.2.5.5. The model with lowest BIC, model 2, was selected as the best model and was used as base case for the rest of the analysis. It consists on an annual recruitment, separable fishing mortality, catchability for the PELGAS age-structured index depending on age but constant along time and variance for the PELGAS observation equations as a spline function of age. On average, the biomass levels were lower than 100 000 tons. Besides some year effects of the PELGAS surveys, there are no other clear patterns in the model residuals in log scale (see the WD for detailed results and plots). Thorough comparisons between the base case and the rest of the configurations are available in the WD.

The base case model here is different from the model selected in the a4a workshop for North East Atlantic sardine. That model was constructed to improve the year effects of PELGAS observed in the residuals patterns. The BIC is lower than the models considered in this working document. However, it is difficult to decide whether new years would correspond to catchability according to the 2003, 2006 and 2007 years or to rest of years.

When increasing and decreasing catches, the levels of biomass, numbers at age and catchabilities are rescaled while the fishing mortality remains equal (figures in the WD). Given that natural mortality is known, the total mortality (and hence the fishing mortality) is derived from the age structure of the PELGAS survey. Then, the catch-at-age matrix determines the numbers at age and the survey catchabilities if these are to be estimated by the model (see discussion).

The Bayesian counterpart of the base case model gave almost equal summary plots with loose priors on q. So, again the absolute level of the assessments is set by the catch levels. However, if a tight prior is set on the catchability of PELGAS, the assessment is rescaled and the catchability of PELGAS is kept close to 1. So that any information on the catchability parameter of PELGAS could be incorporated to scale the assessment to the appropriate level (related figures available in the WD).

Table 4.4.4.2.5.5. Summary of models in a4a for sardine in 8abd

Model	R	F	Q	Variance	AIC	BIC	Df
1	Factor (2016=2015)	Separable factors	Age spline	Age Spline for catch Age invariant for survey	377	546	50
2	Factor (2016=2015)	Separable factors	Age spline	Age Spline for catch and pelgas	367	543	52
3	Factor (2016=2015)	Separable factors	Age spline + year spline	Age Spline for catch Age invariant for survey	371	563	57
4	Factor (2016=2015)	Separable factors	Age spline + year spline	Age Spline for catch and pelgas	351	551	59
5	Factor (2016=2015)	Separable factors	Age spline + temp spline	Age Spline for catch Age invariant for survey	374	553	53
6	Factor (2016=2015)	Separable factors	Age spline + temp spline	Age Spline for catch and pelgas	365	551	55
7	Factor (2016=2015)	Separable splines	Age spline	Age Spline for catch Age invariant for survey	420	562	42
8	Factor (2016=2015)	Separable splines	Age spline	Age Spline for catch and pelgas	409	558	44
9	Factor (2016=2015)	Separable splines	Age spline + year spline	Age Spline for catch Age invariant for survey	413	578	49
10	Factor (2016=2015)	Separable splines	Age spline + year spline	Age Spline for catch and pelgas	394	567	51
11	Factor (2016=2015)	Separable splines	Age spline + temp spline	Age Spline for catch Age invariant for survey	417	569	45
12	Factor (2016=2015)	Separable splines	Age spline + temp spline	Age Spline for catch and pelgas	406	565	47
13	Factor (2016=2015)	Separable factors	Age spline + factor splitting abnormal years (proposed in Ispra) (two factor levels)	Age Spline for catch and pelgas	290	470	53

4.4.4.2.6 Conclusions

The assessment of population biomass is scaled by the absolute level of the catches. When that catchability parameter is left entirely to be estimated as free parameter, the major information that can be obtained from the surveys is total Z (relative changes in abundance) by ages and globally. As the M vector is fixed, averaging over ages, F all ages will be approximately Z–M, hence Catch/F scales the population abundance obtained in the assessment and leads to the estimation of survey catchabilities. This highlights the importance of any information allowing some judgement on the actual absolute levels of sardine biomass inhabiting the Bay of Biscay.

Information from the surveys points to levels of sardine SSB well above 100 000 t in the Bay of Biscay (8abd). This could be translated in a prior distribution for the catchability of the acoustic survey that could help to determine the absolute level of the assessment. An example is provided in the Bayesian framework of how a more informative prior on the survey catchability would rescale the average biomass level in the assessment.

It is visually evident the occurrence of year factors affecting the catchability of the acoustic survey and the DEPM egg abundance index. Several essays have been tried to model such variability: the optimal assessment is obtained allowing two different levels of survey catchability to be estimated comprising two different set of years: a low value in 2003, 2006–2007 years and a higher value affecting all other years. The major problem of this approach is that the election of the subset of years where catchability is presumed to be reduced is somehow guided a posteriori from the actual pattern of residuals. This makes a priory very difficult to guess what the catchability of the most recent survey will be. So that, in terms of operationalization of the working group it was decided not to consider further this model.

4.4.4.3 Comparison of methods and discussion of choice.(All)

Both A4A and SS3 provide similar results and could potentially serve as assessments for the portion of the stock in the Bay of Biscay. A4A has the advantage of being rather simple to set up in comparison to extensive set of parameters of SS3. However, SS3 has the advantage also to be already used for the southern sardine stock, also assessed routinely in WGHANSA therefore any new development in one of these stocks may be beneficial to the other. Another criteria in favor of SS3 is the possibility to use lengths rather than age based data which might prove useful to start modelling development in the Celtic sea and English Channel portions of the stock where no age data are available while small time series exist for the PELTIC survey and Dutch pelagic trawler fishery.

4.4.5 Short term forecast.

Short term forecasts have not been implemented during the benchmark. However, ICES category 2 stocks require relative short term forecast. The FLSTF (FLR, Kell *et al.*, 2007) is a potential candidate as it is also used for the southern sardine stock.

Parameters for the short term projections will be discussed and updated into the Stock Annex during next WGHANSA (June 2017).

4.4.6 Conclusion

In the Bay of Biscay, both A4A and SS3 have shown similar results notably a lower than expected biomag ss in regards to observations from surveys. The group has investigated this issue by tuning and discussing parameters. It is currently assumed that model parameters are properly tuned in regards to available datasets but the issue persists. There is no evidence of issues with the sardine stock present in the Bay of Biscay. As the modelling exercice provide lower biomass estimates than actually observed during the survey, there is some doubts about the true extent of the stock in regards to the coverage of the surveys and fisheries as the differences between modelling and observations. One hypothesis would be some substantial transfer of sardines towards the English Channel and Bay of Biscay. Those two points are elements to investigate for a further benchmark.

The question of putting priors on the catchability of surveys was raised due to the apparent mismatch between the absolute levels of the biomass estimated by the assessment and the levels of biomass reported by the acoustic and DEPM surveys. However there not a clear consensus that such a prior was required, as it was not clear that the analytical assessment could not properly estimate the absolute levels of biomass without the help of priors. Furthermore it was known that target strength for sardines were under revision and it is expected that final revision would drop down the final acoustic estimates. In addition, the two DEPM estimates suppose a too short series for a reliable assessment of the average biomass levels. Therefore, improvements in direct survey estimates of the absolute levels of biomass would be very valuable for a better judgement of the position adopted by the WK in future benchmarks.

In terms of data precision and accuracy, there is a lack of contrast in data for the Bay of Biscay, leading to a magnitude of signal similar to the noise in the information therefore while trends can be derived, it is considered misleading to use the values (biomass, fishing mortality, recruits) from the assessment as absolute values for the time being. Therefore the methodology set up and carried out during the working group can not be classified as ICES category 1 assessment. This work is an improvement in comparison to the previous category 3 survey trend-based assessment as it fully uses all the available information and provides biomass and fishing pressure estimates. Relative short term forecast can be derived from the assessment therefore this methodology should probably be classified as category 2.

The imbalance in data availability between Celtic sea/English Channel and Bay of Biscay is a recurrent issue to be solved as a prerequisite for any management measure in VII or for the whole area. Due to the uncertainty or lack of information in 7, it would be advisable to treat 7 and Bay of Biscay separately in terms of advice, i.e. running the current benchmark assessment for Bay of Biscay and advising for Bay of Biscay in a separate way than from the Celtic sea and English Channel. For this region the lack of information may not lead to an advice other than following the precautionary approach. The PELTIC survey time series is actually too short to provide a category 3 assessment and the actual level of catches is actually uncertain.

4.4.7 Reference Points (MSY) Status

Attempt to derive reference points for this stock will be carried prior to the next WGHANSA meeting (June 2017). So far, no reference points have been set for this stock.

4.5 Future Research and data requirements

Further research should try to estimate the proper spatial extension of this stock and the magnitude of biomass fluxes between Bay of Biscay and English Channel/Celtic Sea as these information may provide explanation for the low biomass estimates from the assessment in the Bay of Biscay and about the connectivity with subarea 7.

In Subarea 7, data are highly needed. Each country should provide accurate estimates of landings. It is recommended that the PELTIC survey is carried out every year. Additional years in the time series from this survey will be helpful to derive a trend-based assessment over the next 5 years. In parallel, length distribution from the survey and commercial vessels will be used in SS3 to develop an exploration assessment for these regions, combined or not with information from the Bay of Biscay. In order to do so, a proper biological sampling should be implemented as it will provide the necessary information on maturity, growth and mortality. When a sufficient amount of biological information is available, it will be possible to derive input parameters (e.g growth, maturity ogive) that will start to allow some analytical exploratory assessment even in the absence of long time series of age distribution of the catches.

In terms of surveys, it is recommended to work on improving sardine target strength estimates used to convert backscatter to biomass for acoustic surveys. Survey coverage is currently limited to the Bay of Biscay and occuring only in a part of Subarea 7 at different periods of the year. Some valuable information on stock structure would probably be gained from a coordinated acoustic surveys in Bay of Biscay (ICES Divisions 8.a, 8.b, and 8.d) and in ICES Subarea 7, at the same time of the year and encompassing the known distribution of sardine in these areas.

There are uncertainty in the catches and unexplained factors regarding some large year-to-year variations in areas 7 and 8abd. The reason (stock dynamics? market?) should be investigated.

Environmental factors should be investigated to determine how they impact the availability of sardine to acoustic and egg surveys in the Bay of Biscay and the reasons for the high inter-annual variability of those indices.

In terms of modelling, SS3 could be set to consider separate French and Spanish fisheries to account for the greater participation by Spanish vessels in the southern part of the area since 2011. An alternative approach would be to model a selectivity break in 2011.

5 Southern horse mackerel (hom 9.a)

5.1 Stock ID

Horse mackerel in the north-east Atlantic is considered to be separated into three stocks: the North Sea, the Southern and the Western stocks. In 2004 as a consequence of results from de HOMSIR EU project the current boundaries of these stocks were established (ICES, 2004). The HOMSIR was a project on the stock structures of horse mackerel from the North-eastern Atlantic to Mediterranean Sea using a holistic approach from 2000 to 2003. The techniques used were: Genetics, parasites (biological Tags), morphological, molecular, otolith shape analysis, tagging and life history traits (Growth, reproduction and distribution). One of the consequences of this project was to move the former boundary of the "Southern" and "Western" stocks from the Capbreton canyon (southeast of Bay of Biscay) to the Northwest of Iberian Peninsula (Galician coasts).

Hence the current boundaries of these stocks are:

Western stock: northeast continental shelf of Europe, from Norway to the northwest of Iberian Peninsula (Galician coasts: Cape Finisterre at 43º N latitude).

North Sea stock: in North Sea area

Southern stock: The Iberian coast from the Strait of Gibraltar to Cape Finisterre in Galician waters (ICES division 9.a)

Recent studies were presented during the Southern Horse Mackerel Data Preparation Workshop (Uriarte *et al.*, 2016), supporting the current assumption of stock ID for Southern horse mackerel. These studies comprised the analysis of growth patterns by Subdivision since 2004 (Dinis *et al.*, 2016 in Uriarte *et al.*, 2016) and of the spatial distribution by age from the IBTS survey time series (Mendes *et al.*, 2017) and by size from the fishery (Azevedo and Silva, 2016 in Uriarte *et al.*, 2016). The results showed similar growth patterns of horse mackerel and that all ages are found within Division 9.a indicating that migration outside the area, if it occurs, is negligible.

5.2 Issues list

The issues list, compiled in 2015, is presented in the text table below:

Issue	Problem/Aim	Work needed / Possible direction of solution	Data needed to be able to do this: are these available / Where should these come from?
Survey data	Portuguese and Spanish IBTS bottom trawl surveys are combined in a single index of abundance in the assessment, based on simple mean abundance. Combined index is noisy, with strong year-effects. Explore SSB estimates from DEPM as a tuning index in the assessment model	Smooth data, explore alternative approaches to estimate abundance-at-age Obtain reliable SSB estimates from the DEPM	Data available from IBTS bottom-trawl surveys Data from triennial DEPM surveys

Issue	Problem/Aim	Work needed / Possible direction of solution	Data needed to be able to do this: are these available / Where should these come from?
Catch data	Short times series of catch-at-age. The data series available for the stock starts in 1992.	Compile catch data prior to 1992	Part of the Spanish catch data is available only in paper, should be compiled and saved electronically
Biological Reference Points	Not defined	Estimate BRPs	

Issues related to the catch data are addressed in section 5.4.1, to the survey in section 5.4.3 and to the biological reference points in section 5.6.

5.3 Multispecies and mixed fisheries issues

Horse mackerel is caught in both single species and mixed fisheries throughout division 9.a waters. The southern stock is primarily exploited by Portuguese and Spanish fleets in a mixed fishery that uses trawls, purse seiners, gillnets and long lines.

Horse mackerel is a schooling species and often close to the sea floor. Preference for a continental shelf habitat is a predominant distributional pattern for this stock. Therefore, horse mackerel shares the same habitat with other fish and invertebrate species that are usually caught during the bottom trawl surveys. These species are mainly: snipefish, boarfish, blue whiting, European hake, sardine, blue jack mackerel, squids and pelagic crabs (Sousa *et al*., 2006 andCardoso *et al*., 2015) also showed that horse mackerel (among other species) was part of closely linked trophic communities, mainly as a prey of other target species of the polyvalent and bottom trawl fleet. The occurrence of complex trophic communities between different gear-specific target species, points to both technical and biological interactions in fisheries management; as a management measure for a specific fleet/species might have unexpected consequences to other fleets/species through ecological pathways. Currently no multispecies or mixed fisheries issues are considered for the assessment. An ecosystem approach to mixed fisheries requires deeper studies and quality data to better characterize their fishing activities.

A management plan for the southern horse mackerel is being developed by initiative of the Pelagic Advisory Council (PELAC), in a collaborative work between scientists and stakeholders. The harvest control rule adopted by the stakeholders considers a minimum fishing mortality if SSB falls below B_{lim} ($F_{by\text{-}catch}$) to allow for some by-catch of southern horse mackerel due to the mixed fisheries nature of the trawl and artisanal fleets exploiting the stock in ICES Division 9.a. (Azevedo *et al*., 2016).

5.4 Stock Assessment inputs

5.4.1 Catch data

The annual age sampling data and intensity of the commercial catches is believed to achieve a good coverage of the fishery (above 95% of the total catch). Catch in numbers at age have been obtained by applying a quarterly ALK to each of the catch length distribution estimated from the samples of each Portuguese Subdivisions (9.a.c.n to 9.a.s) or a semester ALK to each of the catch length distribution estimated in the case of Subdivision 9.a.n (Spain–Galicia). Data is obtained from at-market sampling based on sound sampling scheme carried out under the EU Data Collection Framework (DCF).

Discards are estimated by both countries from national at-sea sampling (DCF) on board commercial vessels operating in ICES Division 9.a. Discards of southern horse mackerel are considered negligible

(ICES 2016a). Landings data are considered of good quality since black landings and discards are insignificant for horse mackerel in ICES Division 9.a.

The catch in numbers-at-age used in the assessment (age range 0–11+) is the total international catch-at-age starting in 1992.

5.4.2 Weights at age in the catch

Both mean length at age and mean weight at age values are calculated by applying the mean weighted by the catch over the mean weights or mean lengths at age obtained by Subdivision. Figure 5.4.2.1 show the mean weight-at-age in the catch (age range 0–11+) used in the assessment. The variations of mean length-at-age are of a similar scale along the time series (ICES 2016a).

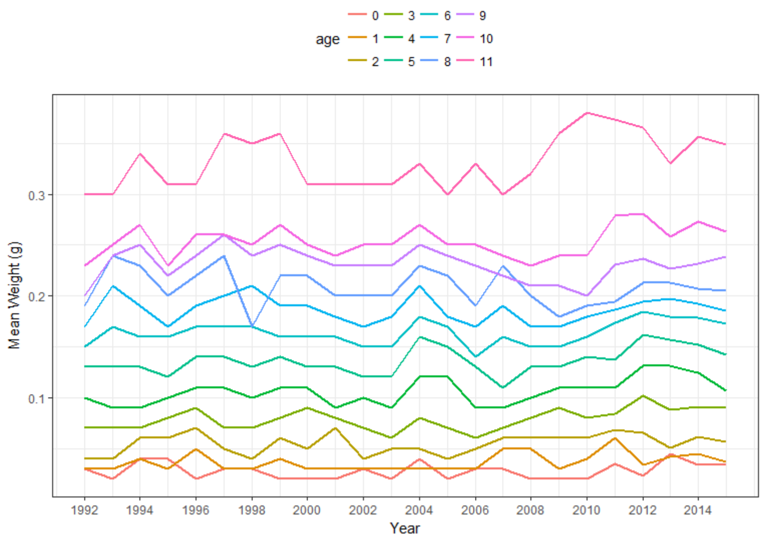


Figure 5.4.2.1. Southern horse mackerel mean weight-at-age (Kg) in the catch in the period 1992–2015.

5.4.3 Surveys

Historical horse mackerel bottom trawl survey data from the Portuguese and Spanish IBTS was analyzed from 1983–2015. The IBTS data provided 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 (Mendes *et al.*, 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 (section 5.5) as well as to evaluate the stock trends.

Horse mackerel abundance does not have a normal distribution with strong variability, especially in younger ages. Figure 5.4.3.1 shows the survey abundance (all ages combined) time series for the assessment period (1992–2015; in 2012 there was no Portuguese IBTS survey) of the alternative methods explored during the meeting. There were conflicting evidences, of which estimator to use to determine abundance from surveys. From the different methods of obtaining an abundance index by age and year, the expert group decided that the “standard” stratified mean following the methodology by Cochran (1960) was an acceptable method to deal with the non-normal abundance distribution and the variability in the survey data. This estimator was found adequate to deal with the data from the current classical stratified survey methodology applied in IBTS surveys, thus replacing the current simple average method as the abundance index for tuning the assessment (Figure 5.4.3.1 and Table 5.4.3.2).

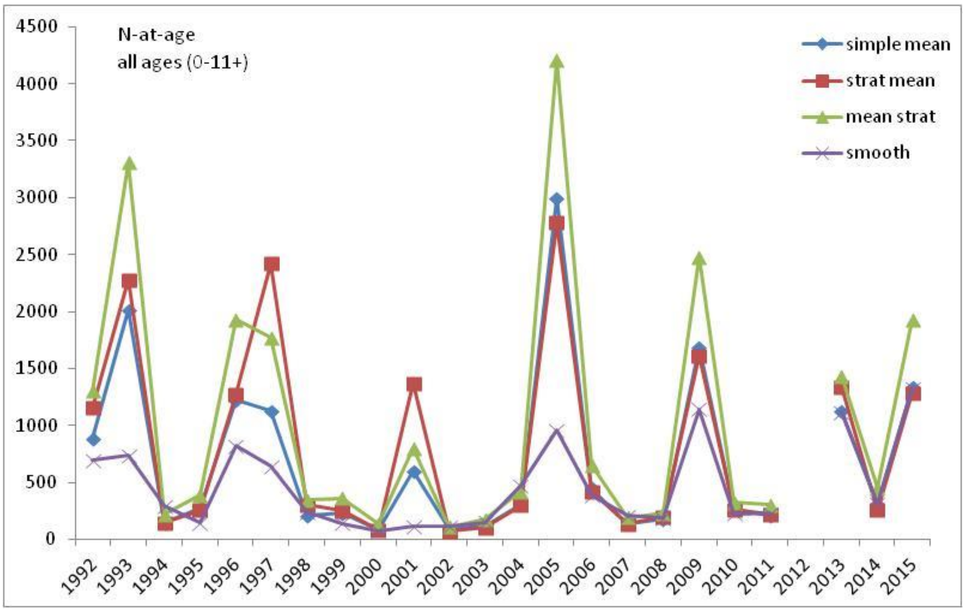


Figure 5.4.3.1. Estimated abundance (combined number/hour in ages 0–11+) from the alternative methods for calculating indices of abundance-at-age: simple mean, stratified mean, mean with post-stratification and smoothed cohorts (see details in Mendes *et al.*, 2017).

From each haul the total number of individuals is estimated and survey abundance data is standardized to number per hour (including zeros). From each haul, a length frequency distribution is estimated for the total catch. These length distributions are then transformed into age composition, using the age-length keys obtained from otoliths reading of the fish sampled in each area (Portuguese and Spanish) during the 4th quarter of the year. The frequency of age class a in a given haul is then given by $n_a = \sum_l n_l \times p_{a|l}$, where n_l is the frequency of length class l in that haul and $p_{a|l}$ is the proportion of fish in age class a within length class l. The survey abundance index is then based on a stratified mean abundance-at-age, y_{st}, by taking the mean catch (excluding age 0) per strata, including a combination of 3 depth strata, from 20 to 500m and 13 sectors, from Cape Finisterra to Guadiana River (Table 5.4.3.1) over the total strata in the surveyed area, following the methodology presented by Cochran (1960):

$$\bar{y}_{st} = \sum_{h=1}^{L} N_h \bar{y}_h \Big/ N$$

Where, N is the total number of units in all strata, Nh is the total number of units in stratum h and ȳh is the age sample mean of abundance in number in stratum h. The description of the number of sampling units per strata and the estimated abundance-at-age are shown in Tables 5.4.3.1 and 5.4.3.2.

Table 5.4.3.1. Portuguese and Spanish IBTS strata description. Sampling units: rectangles of 5x5 nautical miles; zone: North (N), Northwest (NW), SW (Southwest) and South (S); and depths: d1 (70–120m), d2 (121–200), d3 (200–500) in the N zone and d1 (20–100m), d2 (101–200), d3 (201–500m) for the remaining zones.

Strata	sampling units	zone	depth	Strata	sampling units	zone	depth
1A	14	N	1	SIN1	7	SW	1
1B	26	N	2	SIN2	14	SW	2
1C	11	N	3	SIN3	8	SW	3
CAM1	17	NW	1	MIL1	3	SW	1
CAM2	11	NW	2	MIL2	5	SW	2
CAM3	2	NW	3	MIL3	7	SW	3
MAT1	16	NW	1	ARR1	6	SW	1
MAT2	12	NW	2	ARR2	6	SW	2
MAT3	2	NW	3	ARR3	6	SW	3
AVE1	17	NW	1	SAG1	2	S	1
AVE2	15	NW	2	SAG2	3	S	2
AVE3	3	NW	3	SAG3	3	S	3
FIG1	14	NW	1	POR1	12	S	1
FIG2	23	NW	2	POR2	6	S	2
FIG3	5	NW	3	POR3	4	S	3
BER1	10	NW	1	VSA1	6	S	1
BER2	13	NW	2	VSA2	2	S	2
BER3	3	NW	3	VSA3	3	S	3
LIS1	18	SW	1				
LIS2	21	SW	2				
LIS3	12	SW	3				

Table 5.4.3.2. Stratified mean abundance-at-age (number/hour) by year.

year/age	0	1	2	3	4	5	6	7	8	9	10	11+
1992	454.53	488.16	145.83	26.84	13.21	5.89	4.05	4.39	2.44	2.29	4.02	3.42
1993	1678.91	184.25	213.34	148.82	32.63	1.99	2.14	3.20	3.07	4.30	2.63	7.27
1994	3.79	8.01	63.04	36.14	15.20	4.17	2.02	1.72	0.90	0.78	0.93	8.70
1995	15.82	61.24	89.70	49.70	23.86	6.51	1.42	1.24	0.62	0.27	0.41	6.23
1996	1222.48	6.29	8.73	13.47	14.03	3.65	1.73	0.65	0.40	0.77	0.19	2.80
1997	2095.29	97.43	68.96	20.40	45.02	55.43	15.00	11.20	4.82	5.77	2.05	1.71
1998	86.63	33.22	161.72	17.36	2.21	1.44	0.98	1.19	0.28	0.09	0.05	0.14
1999	159.52	20.18	31.79	34.79	2.85	0.96	0.58	0.23	0.22	0.69	0.87	3.03
2000	2.50	13.69	17.11	19.77	11.92	6.57	4.07	2.09	1.70	1.02	0.30	0.85
2001	1296.13	1.84	8.76	3.87	6.89	13.80	12.33	11.86	7.81	3.67	2.09	1.58
2002	21.23	1.51	11.40	10.00	5.50	2.76	1.15	1.10	2.58	2.31	3.10	6.57
2003	58.87	9.09	8.23	10.16	8.80	3.26	2.35	1.26	0.71	0.60	0.36	0.48
2004	82.70	37.42	112.43	42.35	8.13	4.24	1.86	3.83	5.15	0.97	0.40	0.18
2005	1289.99	1188.57	162.24	45.20	21.82	10.50	13.79	14.49	11.79	6.72	4.10	11.26
2006	72.63	84.60	181.81	46.63	3.40	10.36	7.39	6.65	2.71	1.41	0.49	0.30
2007	36.58	1.98	22.59	31.52	25.08	9.22	2.74	1.57	0.57	0.65	1.42	2.88
2008	52.57	28.24	39.69	20.64	26.75	17.34	2.22	0.81	1.30	1.90	1.42	4.98
2009	1268.32	79.50	147.03	52.39	44.70	11.61	2.82	1.69	1.38	0.91	0.72	4.63
2010	83.42	36.81	32.82	25.64	38.27	14.12	5.23	6.97	4.68	4.58	1.76	11.58
2011	133.20	33.09	24.54	16.23	4.71	1.20	0.42	0.55	0.36	0.68	0.81	1.59
2012	-	-	-	-	-	-	-	-	-	-	-	-
2013	12.62	363.78	820.02	105.41	18.92	3.02	2.47	2.73	2.17	2.23	1.45	2.87
2014	53.92	40.83	25.38	77.70	33.62	7.83	2.07	1.73	1.15	1.44	2.36	10.48
2015	906.80	160.33	112.58	48.47	40.85	5.51	2.37	1.18	0.89	0.95	0.85	2.59

5.4.4 Weights at age in the stock

Taking in consideration that the spawning season is very long, spawning is almost from September to June, and that the whole length range of the species has commercial interest in the Iberian Peninsula, with probably very scarce discards, there is no special reason to consider that the mean-weight in the stock is significantly different from the mean weight in the catch (section 5.4.2).

5.4.5 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). Therefore, microscopical analysis of the gonads collected during the triennial AEPM/DEPM surveys for horse mackerel carried out in 2004, 2007 and 2010 (1st quarter of the year) were used to estimate the proportion of mature females at length. The proportion of mature females-at-age in 2004, 2007 and 2010 was obtained by applying to the length composition the quarterly catch age-length-key (ALK) of the same year. A logistic model was fitted to the proportion mature-at-age by pooling together the data from the three surveys (Murta *et al.*, 2011). Table 5.4.5.1 presents the predicted proportion-at-age adopted by WKPELA for the assessment period (1992–2015).

Table 5.4.5.1. Southern horse mackerel proportion mature-at-age used in the assessment (7+: age 7 and older fish).

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

The maturity ogive could not be updated with the 2013 DEPM survey since, due to logistic problems, the adult samples were obtained by the commercial fleet and smaller/younger fish (likely corresponding to the immature/maturing individuals) could not be collected (Costa *et al.*, 2017). The sampling strategy during future DEPM surveys will be adapted to allow accurate estimation of maturity ogives. The maturity ogive will be updated every three years if the proportion-at-age from data collected during the trienial DEPM surveys fell outside the confidence bounds (95%CI) of the current predicted values.

5.4.6 Natural mortality

The fixed value of the natural mortality of 0.15 for all ages and adopted for all horse mackerel stocks since 1992 was considered an underestimation for this particular horse mackerel stock in the last benchmark. The assumption that natural mortality was the same for all ages was highly unrealistic. There are evidences that larger horse mackerel becomes much less targeted by predators and from observed diet composition it is obvious a progression in the mean trophic level from the younger planktophagic to the older ichthyophagic individuals. The adopted maturity-at-age is consistent with estimates using the Gislason *et al*., (2010) with the growth parameters estimated for Southern horse mackerel from sampling in the stock area. Moreover, the adopted values from the previous benchmark based in estimates for other similar pelagic species, observed diet composition of fish predators in the area and taking into account the observed mean life span and growth rate in southern horse mackerel were found adequate to reflect the age dependent natural mortality for this species. The adopted values are presented in Table 5.4.6.1.

Table 5.4.6.1. Southern horse mackerel natural mortality-at-age used in the assessment (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

5.4.7 Environmental covariates

No environmental covariates are used in the assessment for this stock. There is past and recent evidence in the literature that horse mackerel can be simultaneously influenced by a combination of different environmental factors (e.g. Santos *et al.*, 2001, Teixeira *et al.*, 2016). While statistical broad trends are evident, the mechanisms by which the environment affects stock productivity are poorly understood and should be further explored before taken into account in stock assessment.

5.5 Stock Assessment

5.5.1 Stock Assessment model

The stock assessment of the Southern horse mackerel is performed with the AMISH (Assessment Method for the Ibero-Atlantic Southern Horse mackerel), a statistical catch-at-age model adopted since the last benchmark of the stock (WKBENCH, ICES, 2011). The model uses ADMB translation and it is very flexible with regards to the functional forms that can be used for the biological processes (e.g stock-recruitment relationship) and the fishery (e.g selectivity-at-age) as well as to the number of parameters that can be estimated (e.g. Lowe, 2012). A similar model is adopted for the assessment of other Trachurus species such as, for example, the *Trachurus murphyi* carried out within the South Pacific Regional Fishery Management Organization (SPRFMO, 2016).

AMISH model was accepted by the benchmark as the assessment model for the Southern horse mackerel stock. The updated Stock Annex (hom 9a) provides details on the method, including model equations, model assumptions, estimated parameters, objective function and minimization process. In short, the stock dynamic is governed by the Beverton and Holt S-R relationship (Hilborn and Walters, 1992) with recruitment occurring at 1st January and spawning occurring instantaneously at mid January (corresponding to the time when main spawning is assumed to occur). The survivors follow the age-specific mortality (F-at-age plus natural M-at-age, the latter constant over time). Fishing mortality is separable into an age component (selectivity-at-age) and a year component (F multiplier). The observed survey (IBTS–Portuguese and Spanish) biomass is scaled to population through the catchability coefficient. The expected catch biomass is computed according to the usual catch equation (Hilborn and Walters, 1992).

5.5.2 Input data, model settings and assumptions

Input data and assumptions for the AMISH runs are summarized in Table 5.5.2.1.

The discussions and analysis conducted during the benchmark focused on the revision of the survey abundance-at-age obtained from several estimation approaches (simple mean, stratified mean, mean with post-stratification and smoothed cohorts), the age range in the survey (0–11+ vs 1–11+) and on assumptions regarding the number and time periods for selectivity blocks in the catch-at-age and survey abundance-at-age matrices. Exploratory assessment trial runs were performed only for the survey abundance-at-age computed as the stratified mean, considered to be the most appropriate method according to the IBTS survey design as well as to deal with the variability in the data (see section 5.4.3). The model configuration for the set of exploratory assessment trial runs and the base-run (ICES, 2016a) is presented in Table 5.5.2.2.

Table 5.5.2.1. Input data, assumptions and settings for the AMISH base-run. Base-run corresponds to the last assessment (ICES, 2016a).

Name	Year range	Age range	Assumptions/settings
Catch in weight	1992–2015		Variable in time
Catch-at-age	1992–2015	0-11+	Variable by age and time
IBTS (Spanish-Portuguese) mean abundance-at-age	1992–2015	1-11+	Variable by age and time
Mean weight-at-age (catch & stock)	1992–2015	0-11+	Variable by age and time
Proportion of F and M before spawning	1992–2015	0-11+	Fixed at 0.04 (mid January)
Natural Mortality	1992–2015	0-11+	Age-dependent; time invariant
Catch-at-age selectivity	1992–2015	0-11+	Dome-shaped; Two time-blocks: 1992-1997; 1998-2015
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	1992–2015	1-11+	Dome-shaped; Five time-blocks: 1992-1999; 2000-2001; 2002-2004; 2005-2007; 2008-2015
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	1992–2015	1-11+	Multinomial distribution; log-normal with a constant CV of 5%
Proportion-at-age in the survey	1992–2015	0-11+	Multinomial distribution; log-normal with a constant CV of 30%
Effective sample size catch			100
Effective sample size survey			10

Table 5.5.2.2. Code and model configuration for the assessment trial runs with survey abundance-at-age computed as the stratified mean abundance (for other input data see Table 5.5.2.1). Base-run corresponds to the last assessment (ICES, 2016a; survey abundance-at-age computed as simple mean).

Code	Model configuration		
	Age range in the survey	Survey selectivity time-blocks	Catch selectivity time-blocks
Base-run	1–11+	Five time-blocks: 1992–1999; 2000–2001; 2002–2004; 2005–2007; 2008–2015	Two time-blocks: 1992–1997; 1998–2015
Run1	1–11+	Five time-blocks: 1992–1999; 2000–2001; 2002–2004; 2005–2007; 2008–2015	Two time-blocks: 1992–1997; 1998–2015
Run1a	1–11+	One time-block: 1992–2015	Two time-blocks: 1992–1997; 1998–2015
Run1b	1–11+	One time-block: 1992–2015	Three time-blocks: 1992–1997; 1998–2001; 2012–2015
Run2	0–11+	Five time-blocks: 1992–1999; 2000–2001; 2002–2004; 2005–2007; 2008–2015	Two time-blocks: 1992–1997; 1998–2015
Run2a	0–11+	One time-block: 1992–2015	Two time-blocks: 1992–1997; 1998-2015

5.5.3 Diagnostics and results

Results were evaluated using the following set of criteria: parsimony, model fit to the catch biomass, to the biomass index and to the proportion-at-age in the catch and survey, residual patterns in the catch-at-age and abundance-at-age and uncertainty and retrospective patterns (5 year´s removal) in the stock key-parameter estimates: Fbar(2–10), R and SSB (Table 5.5.3.1).

Table 5.5.3.1. Summary table for criteria used to evaluate assessment trial runs: negative log-likelihood (-L), number of estimated parameters (# par), Akaike Information Criteria (AIC) and range of the coefficient of variance (%) for the stock key-parameters Fbar(2–10), SSB and Recruitment (age 0). See Table 5.5.2.2 for model configuration.

Code	L_catch	L_survey	L_total	# par	AIC	Fbar(2-10)	SSB	R
base-run	3.53e-02	53.8	380.1	128	1016	24-34	24–36	19–40
Run1	3.41e-02	52.9	379.0	128	1014	24-34	24–36	19–40
Run1a	3.33e-02	59.4	378.3	96	949	25-34	26–36	20–39
Run1b	3.37e-02	58.2	369.7	104	947	23-34	24–36	19–47
Run2	1.74e-02	51.6	381.1	128	1018	36-48	37–51	30–47
Run2a	2.47e-02	63.6	389.2	96	870	30-39	31–43	25–38

All runs showed equally good fit to the catch biomass and to the biomass index, as shown in Figure 5.5.3.1 for the assessment trial run 1b.

Figure 5.5.3.2 presents the observed and fitted proportion-at-age of the abundance indices and Figure 5.5.3.3 the abundance indices residuals for the assessment trial runs. Assessment trial runs 2–2a explored the effect of including age 0 in the survey abundance-at-age and of considering different number of time-blocks for the survey selectivity. Although the fit to proportion-at-age 0 was reasonably good and no age effect was observed (residuals at age 0) with these runs, residuals were slightly higher than with comparable assessment trial runs 1–1a. Comparing run 2a (age range in the abundance-at-age: 0–11+) to run 1a (age range in the abundance-at-age: 1–11+) it is shown that although the former has lower

AIC (870 from run 2a compared to 949 from run 1a), Fbar(2–10), SSB and R are estimated with higher uncertainty (Table 5.5.3.1).

Benchmark discussions concluded that the use of several time-blocks for the survey index (Table 5.4.2.2), adopted previously to remove age/year effects, was no longer justified. The survey characteristics (e.g. survey design, surveyed area, Research vessels and fishing gear) were unchanged along the assessment period (1992–2015) further supporting the use of one time-block for the selectivity.

Evaluation then focused on the assessment trial runs 1a and 1b (options differing in the number of time-blocks in the catch selectivity) which showed comparable AIC values (947–949) and uncertainty levels, among the lowest (Table 5.5.3.1), as well as good model fit to proportions-at-age and acceptable residual patterns (Figures 5.5.3.2 and 5.5.3.3). These runs were further evaluated against the base-run. The estimated selectivity-at-age (catch and survey) is compared in Figure 5.5.3.4. Figure 5.5.3.5 presents the retrospective patterns and Table 5.5.3.2 the relative differences for Fbar(2–10), SSB and R of each trial run with the base-run, showing small relative differences (below 4% in all parameters).

The retrospective pattern is similar among runs, showing overestimation of Fbar(2–10) and underestimation of SSB over the assessment period (1992–2015). There was no survey in 2012 which forces Fbar and SSB to deviate in years 2010–2012 (Figure 5.5.3.5). The main difference between run 1a and run 1b is in the number of the time-blocks for the catch selectivity-at-age, run 1b considering one extra time-block after 2012 to accommodate the observed increase in the purse-seine catches of horse-mackerel (due to the lower opportunities in the catch of the Iberian sardine stock) that exploits mainly juvenile horse-mackerel (ages 0–2). Although it was difficult to evaluate objectively the outcomes from these two runs, it was agreed to adopt run 1b, noting that despite the slightly increase in the number of parameters between runs, from 94 (run 1a) to 104 (run 1b), the AIC is slightly lower in run 1b (Table 5.5.3.1).

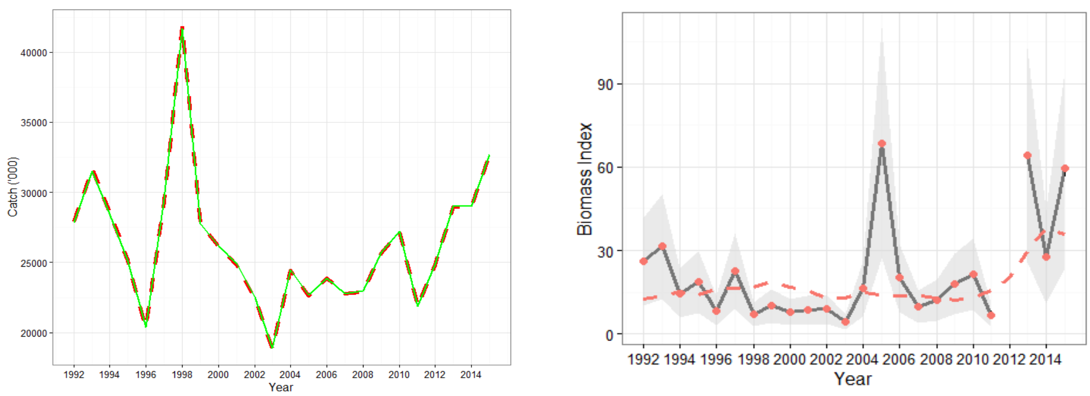
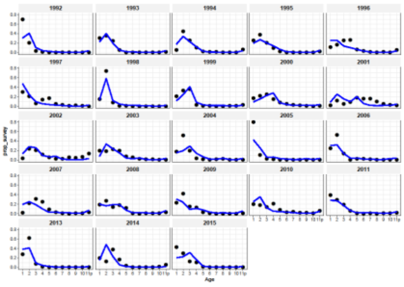
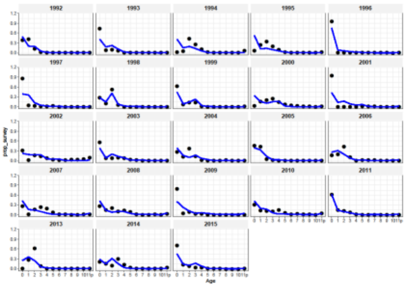


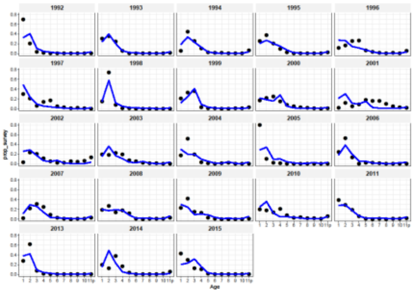
Figure 5.5.3.1. Catch biomass (left) and survey biomass index (right) for the assessment trial run1b: observed (solid black line) and estimated values (dashed red line).

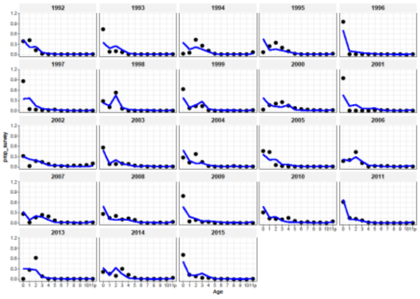
AGE RANGE: 1-11+	**AGE RANGE: 0-11+**
RUN 1	**RUN 2**





Run 1a	Run 2a





Run 1b

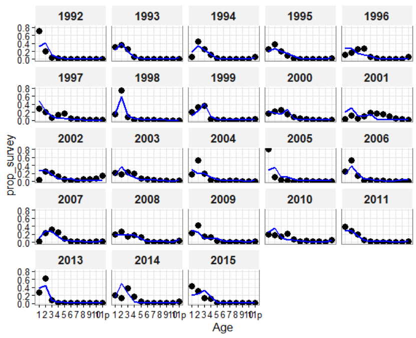
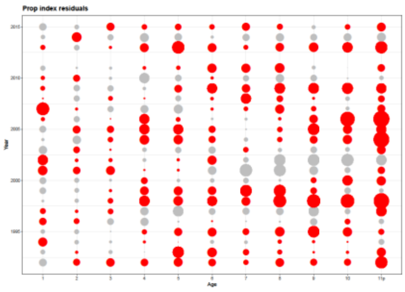
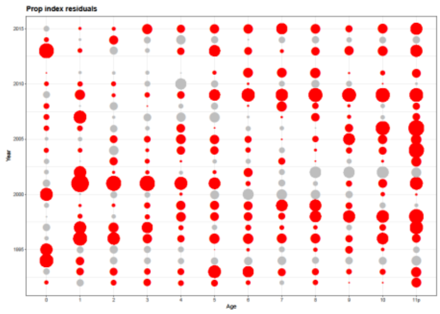


Figure 5.5.3.2. Proportion-at-age of the abundance indices by assessment trial run (observed values =dots; fitted values = solid lines).

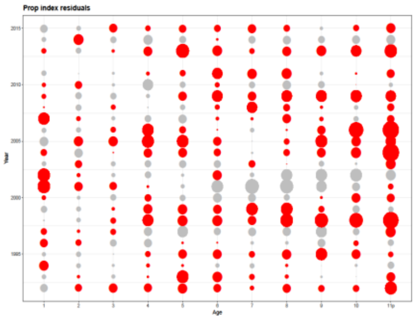
RUN 1



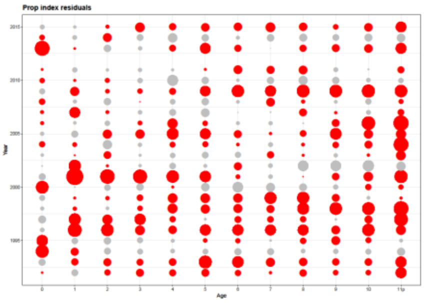
RUN 2



Run 1a



Run 2a



Run 1b

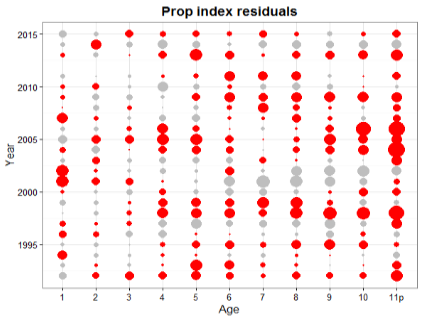


Figure 5.5.3.3. Bubble plot of abundance indices residuals by assessment run (negative residuals-red bubbles).

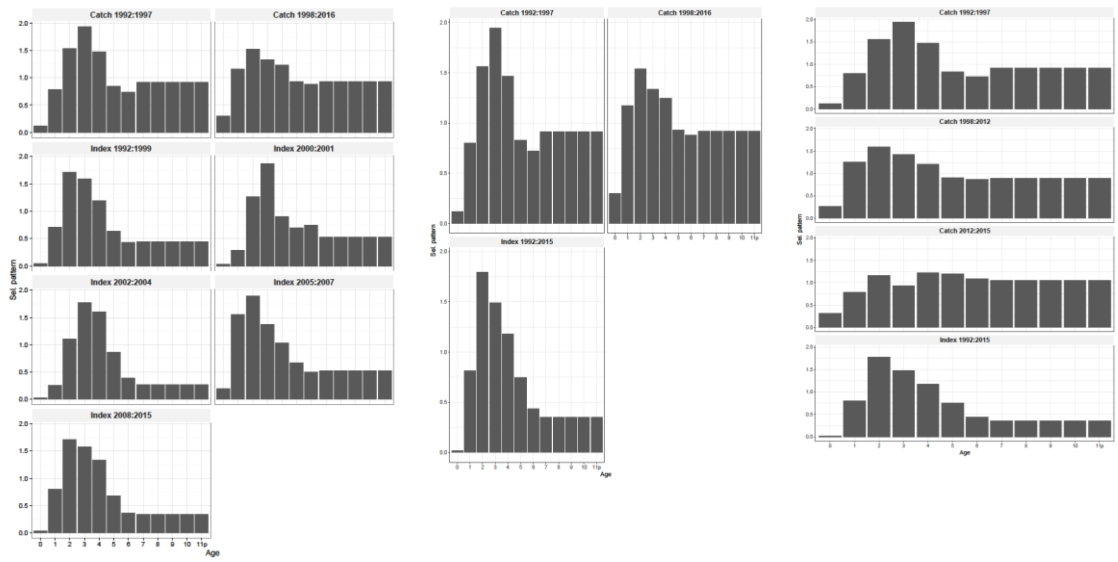


Figure 5.5.3.4. Estimated selectivity-at-age for the catch and survey index for the base-run (left: 2 blocks for the catch; 5 blocks for the survey), run 1a (middle: 2 blocks for the catch; 1 block for the survey) and run 1b (right: 3 blocks for the catch; 1 block for the survey).

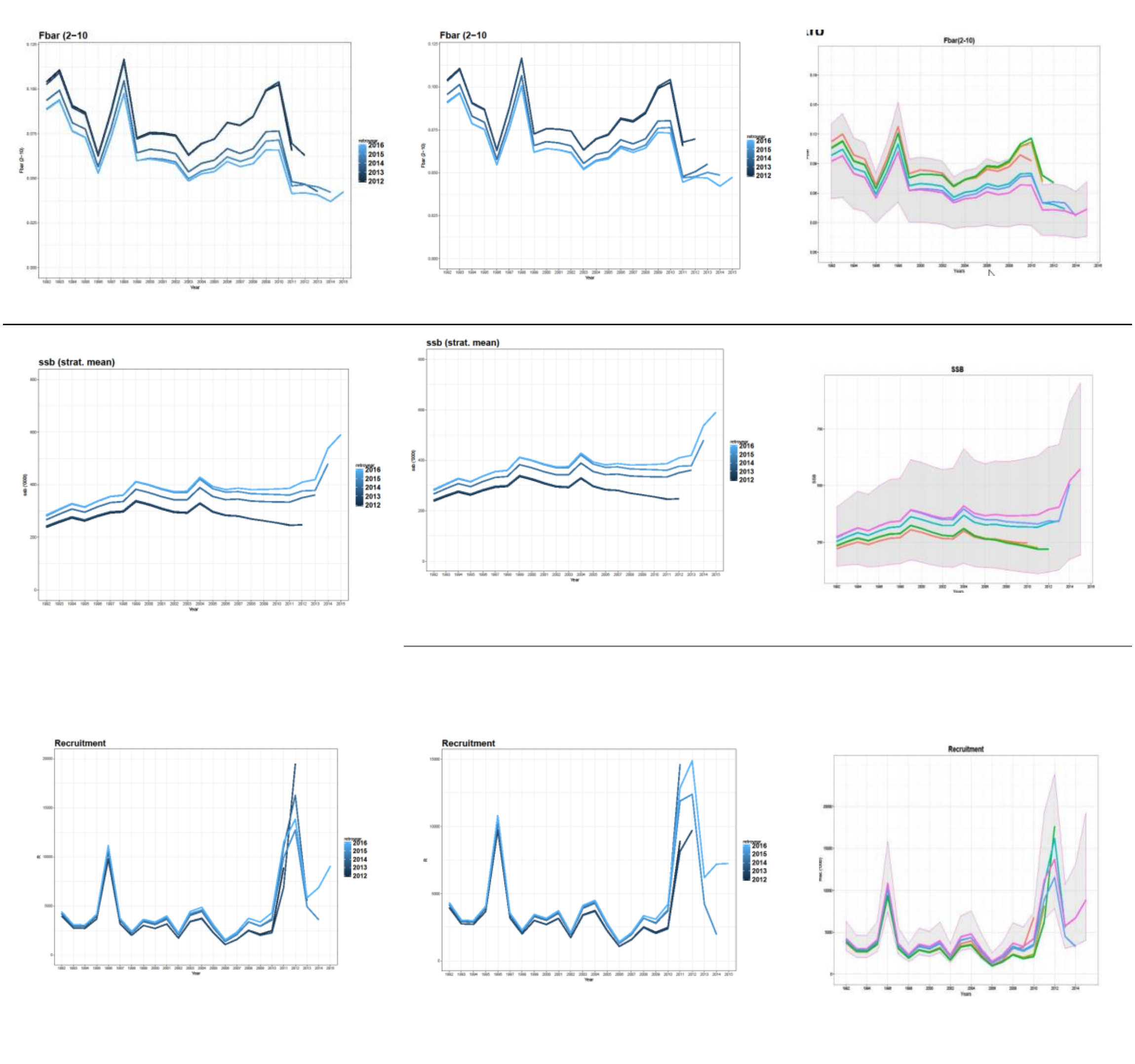


Figure 5.5.3.5. Retrospective pattern in Fbar(2–10), SSB and Recruitment for the assessment trial runs 1a (left) and 1b (middle) and the base-run (right), the latter with 95% confidence intervals.

Table 5.5.3.2. Relative differences (%) to the base-run in the parameter estimates of Fbar(2–10), SSB and R over the assessment period (1992–2015) for trial runs 1a (left) and 1b (right).

Year	Fbar	SSB	R
1992	-4.36	3.83	4.02
1993	-4.72	4.39	1.40
1994	-4.73	4.81	0.52
1995	-4.46	5.08	1.24
1996	-4.06	5.12	2.90
1997	-4.22	5.10	2.08
1998	-4.28	4.95	3.08
1999	-4.36	4.93	2.21
2000	-4.37	4.88	2.21
2001	-4.24	4.94	-0.05
2002	-3.99	5.01	0.21
2003	-3.51	4.84	-0.34
2004	-3.29	4.48	1.62
2005	-3.23	4.16	3.88
2006	-3.38	4.05	4.40
2007	-3.49	3.89	3.00
2008	-3.49	3.97	1.75
2009	-3.56	4.18	2.51
2010	-3.50	4.22	2.07
2011	-3.48	4.16	2.44
2012	-3.33	3.94	1.11
2013	-3.15	3.72	1.66
2014	-3.08	3.32	2.74
2015	-3.12	3.05	2.44
min	-4.7	3.1	-0.3
max	-3.1	5.1	4.4

Year	Fbar	SSB	R
1992	-1.90	1.17	1.77
1993	-2.12	1.61	-0.90
1994	-1.97	1.83	-1.77
1995	-1.56	1.94	-1.50
1996	-1.02	1.83	-0.56
1997	-0.95	1.68	-2.61
1998	-1.15	1.33	-1.68
1999	-1.09	0.84	-2.98
2000	0.84	0.35	-3.58
2001	1.31	0.06	-6.16
2002	1.62	-0.26	-6.46
2003	3.18	-0.88	-7.28
2004	4.20	-1.80	-6.02
2005	4.42	-2.66	-4.82
2006	4.57	-3.18	-5.42
2007	5.51	-4.10	-7.60
2008	6.67	-4.72	-8.64
2009	7.36	-5.17	-5.42
2010	7.25	-5.96	-0.49
2011	3.51	-6.78	14.78
2012	9.16	-7.01	8.84
2013	11.63	-4.74	8.12
2014	10.43	-0.29	7.52
2015	7.98	1.85	-18.14
min	-2.1	-7.0	-18.1
max	11.6	1.9	14.8

5.5.4 Conclusions on the assessment and model configuration

The assessment run with one time-block in the survey selectivity and three time-blocks in the catch selectivity (run 1b) was accepted as the assessment model configuration for southern horse mackerel. The three time-blocks for the catch selectivity accommodates the recent changes in the fishery due to the strong year-classes of 2011 and 2012 and the increase of horse mackerel catches by purse-seiners (both in Spain and Portugal). This pattern is likely to persist in the incoming years since the condition of the sardine stock does not show signs of improvement (see section 3). Figure 5.5.4.1 presents the estimates of Fbar(2–10), SSB and R with 95% confidence intervals and the stock–recruitment relationship for southern horse mackerel , adopted during the benchmark. The Stock Annex was updated accordingly. The outputs from the adopted assessment were used to re-estimate the BRPs for Southern horse mackerel (see section 5.6).

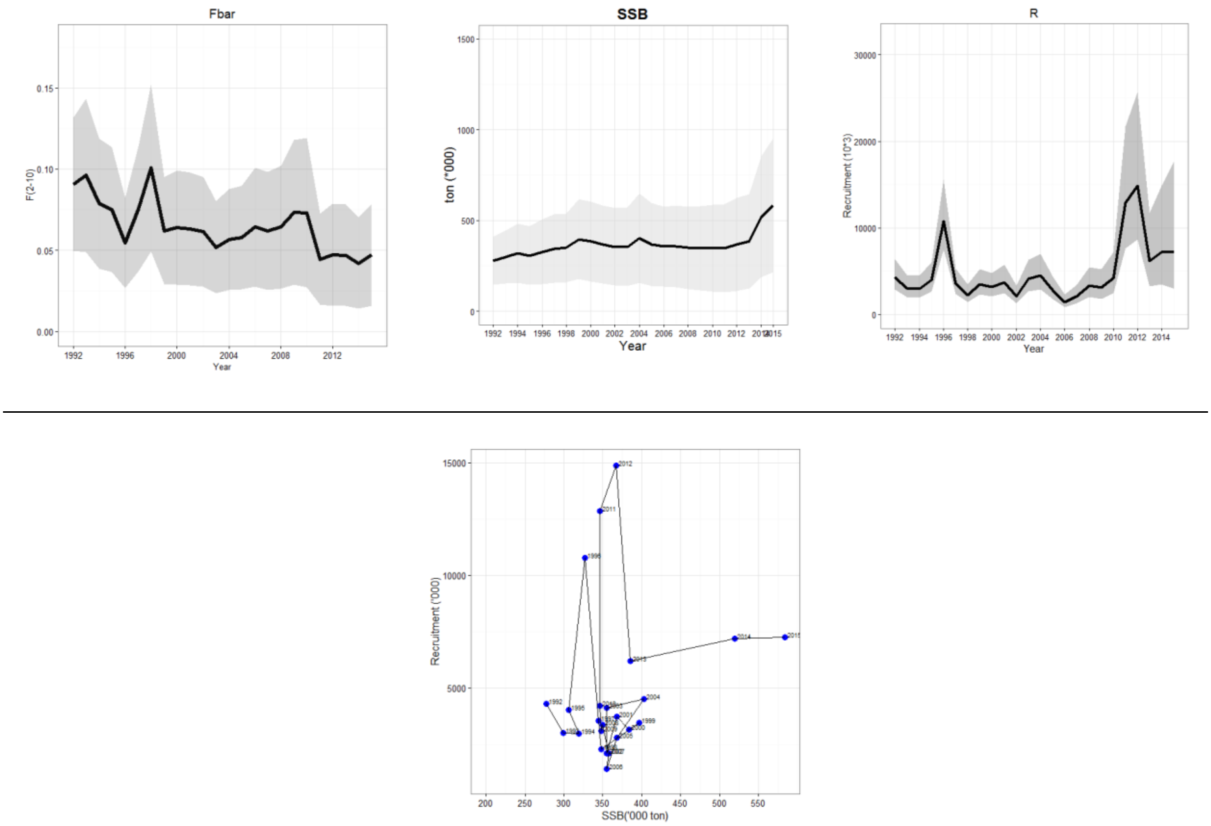


Figure 5.5.4.1. Estimates of Fbar(2 –10), SSB and R (age 0) with 95% confidence intervals and S–R plot.

5.6 Short term forecast

Short-term forecasts are deterministic. The initial stock size is the stock number-at-age 1–11+ estimated at the 1st of January in the final year of the assessment. For last assessment data year in 2015, the assessment provides the surviving stock numbers at 1st January of 2016 for ages 1–11+. Recruitment (age 0) at 1st January estimated in the final year of the assessment is usually very uncertain and is replaced by the geometric mean recruitment of the time series. The stock number-at-age 1 in the intermediate year (final year of the assessment +1) is the survivors of the geometric mean recruitment assumed in year-1. Natural mortality-at-age, mean weight-at-age in the catch and in the stock and maturity-at-age are the input values for the final year of the assessment. The spawning is assumed to take place at mid January and hence proportion of F and M before spawning is fixed at 0.04. As a standard approach, the exploitation pattern is the assessment estimates of F-at-age in the final year of the assessment (F status quo) and assumed also for the intermediate year. However, if a trend in F in recent years is depicted, it will be adopted the average F-at-age of the last 3 years.

Computations are carried out with R using the Fisheries Library in R (FLR) "FLAssess" and "Flash" (FLCore Version 2.6.0.20170123).

5.7 Biological Reference Points

Reference points were calculated using the accepted assessment and following the framework proposed in ICES (2017) guidelines for fisheries management reference point for category 1 stocks and evaluated with stochasticity using the observed historical stock variation in population, productivity parameters and assessment error as proposed in recent state-of-the-art workshops (e.g. ICES, 2016b). A full description of the methodology and biological/productivity parameters is available in Azevedo *et al.*, (2016). The Biological Reference points for southern horse mackerel stocks are show in Table 5.6.1.

Table 5.6.1. Summary table of Biological Reference Points estimated during WKPELA 2017 and in WGHANSA 2016 (in brackets).

BRP	Value	Technical basis
B_{lim}	102 (103)	$B_{lim} = B_{pa} * \exp(-1.645\ \sigma)$ $\sigma = 0.32\ (0.34)$
B_{pa}	182 (181)	$B_{pa} = B_{trigger}$
$B_{trigger}$	182 (181)	Lower bound (average) of 90%CI of $SSB_{1992\text{-}2015}$
F_{lim}	0.20 (0.19)	Stochastic long-term simulations (50% probability SSB > B_{lim})
F_{pa}	0.12 (0.11)	$F_{pa} = F_{lim} * \exp(-1.645\ \sigma)$ $\sigma = 0.32\ (0.32)$
F_{MSY}	0.11 (0.11)	Stochastic long-term simulations; constrained by F_{pa} (F_{MSY}=F_{pa})

5.8 Future Research and data requirements

The identified main aspects for future research and data requirements are the following ones:

- **Spanish landings data prior to 1992**

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. This is the case of the Galician coasts where the Subdivisions 8.c West and Subdivision 9.a North are located. Further work is necessary to recover the Spanish catches by port prior to 1992 and then distribute them by Subdivision (see Fishery section in the Stock Annex).

- **Bottom trawl survey Cadiz**

In the Spanish part of the Gulf of Cadiz there is another bottom-trawl survey (Sp-GFS-caut-WIBTS-Q4) carried out usually in November. The time-series of this survey (starts in 1998) is shorter than the assessment period (starts in 1992) and the raw data were unavailable in time for WKPELA to investigate the effect of merging it with the data sets from the other areas. This work is expected to be completed in the future (see Stock Annex).

- **DEPM triennial estimates of SSB**

SSB estimates from DEPM surveys carried out in 2013 and 2016 will be discussed at WGMEGS in April 2017 as well as egg production for as many surveys as possible using the whole data series (including some AEPM and surveys directed at sardine for which the horse-mackerel eggs were processed) which can be used as external auxiliary information to the assessment of southern horse mackerel.

- **Model configuration**

Catch-at-age data is available for each fleet separately, and during the last benchmark of southern horse mackerel (WKBENCH -ICES, 2011) a fleet disaggregated assessment run was explored. However, probably due to over-parameterisation, the model seemed unstable and the catch-at-age of all fleets was added to make a single matrix and adopted for the assessment of hom9.a. Sample size of 100 is currently assumed for the proportion-at-age in the catch while a sample size of 10 is assumed for the proportion-at-age in the survey. In the preparation of the next benchmark of the stock the best sample sizes should be further explored.

6 References

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Annex 1: List of Attendees

Benchmark Workshop on Pelagic Stocks (WKPELA)

5–9 February 2017

LIST OF PARTICIPANTS

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Annex 2: Initial and actual agenda of work in WKPELA2017

The initial agenda proposed before the meeting was:

DAILY TARGET	Objectives/Organization/Inputs & Assessment Procedures	ASSESSMENTS SET UP (by Subgroups)	ASSESSMENTS & short term projections	MSY and PA reference points	SUMMARIZING / STOCK ANNEX / REPORTING / Pending TORs
Schedule of work	Monday 6	Tuesday 7	Wednesday 8	Thursday 9	Friday 10
9:00	Welcome & logistic set up...	Summing up from chair & Division of labour in subgroups with external experts	Summing Up by Stock coordinators on Assessments	Summing Up by Stock coordinators on Assessments & short term forecast	Summing up from chair for Reporting
9:30	Introduction to the meeting Goals; agenda of work and Reporting	Assessment subgroups	(summing up continuation & Plenary feedback approval or ammendments	(summing up continuation & Plenary feedback approval or ammendments	Going through stock annexes - Sardine North
10:00	Introduction to the meeting Goals; agenda of work and Reporting	Assessment subgroups	Assessment consolidations by subgroups	MSY and PA reference points by subgroups	Going through stock annexes - Sardine South
10:30	Coffe break (15 min)	Coffe break (15 min)	Coffe break (15 min)	Coffe break (15 min)	Coffe break (15 min)
10:45	**Sardine Presentation on stock ID & Questionnaires**	Assessment subgroups	Assessment consolidations by subgroups	MSY and PA reference points by subgroups	Going through stock annexes - SHOM
11:30	**Sardine South Presentation on stock ID & Data Inputs**	Assessment subgroups	Assessment consolidations by subgroups	MSY and PA reference points by subgroups	Going through the report sections
12:00	Sardine South presentation & Proposed assessment methods	Assessment subgroups	Assessment consolidations by subgroups	MSY and PA reference points by subgroups	External Expert overview and comments on the benchmarking
12:30	(continuation)	Assessment subgroups	Assessment consolidations by subgroups	MSY and PA reference points by subgroups	(continuation)
13:00	Lunch time	Lunch time	Lunch time	Lunch time	Lunch time
13:30	Lunch time	Lunch time	Lunch time	Lunch time	Lunch time
14:00	**Sardine North Presentation on stock ID & Data Inputs**	Assessment subgroups	Assessment consolidation & Short term forecasts	MSY and PA reference points by subgroups	Follow up on the Evaluation of conformity of Sardine South LTMP with PA (Pending TORs)
14:30	Sardine North presentation & Proposed assessment methods	Assessment subgroups	Assessment consolidation & Short term forecasts	MSY and PA reference points by subgroups	Recomendations
15:00	(continuation)	Assessment subgroups	Assessment consolidation & Short term forecasts	MSY and PA reference points by subgroups	Finalising the report
15:30	**Southern Horse mackerel update on Stock ID & data inputs**	Assessment subgroups	Assessment consolidation & Short term forecasts	MSY and PA reference points by subgroups	Finalising the report
16:00	Coffe break (15 min)	Coffe break (15 min)	Coffe break (15 min)	Coffe break (15 min)	Coffe break (15 min)
16:15	SHOM presentation & Proposed assessment methods	Assessment subgroups	buffer work time & stock annex writting	MSY and PA reference points reporting to plenary & feedback	List of pending issues to Finalize the report
17:00	(continuation)	Assessment subgroups	buffer work time & stock annex writting	MSY and PA reference points reporting to plenary & feedback	**END OF THE MEETING**
17:30	buffer work time	Assessment subgroups	buffer work time & stock annex writting	MSY and PA reference points reporting to plenary & feedback	
18:00	buffer work time	Assessment subgroups	buffer work time & stock annex writting	buffer work time & stock annex writting	
18:30	buffer work time	Assessment subgroups	buffer work time & stock annex writting	buffer work time & stock annex writting	
19:00	**End of daily meeting**	**End of daily meeting**	**End of daily meeting**	**End of daily meeting**	
Daily Milestones for the group	review of WD on data inputs and Biological issues (made available to the WK)		Define the stock annex contents	stock annex drafting	recommendations for future improving of the assessment methodology and data collection
	Decide on assessment methods either analytical		recommendations for future improvement of the assessment methodology		Follow up on the Evaluation of conformity of Sardine South LTMP with PA
	recommendations for future improving for data collection		short term projections accounting for management plans requirements		
Colours	= Subgroups	= Plenary			

Actual agenda of work during the benchmark follows:

(Every day started at 09:00 and finalise between 18 and 19:00 hh)

a) Monday, 6 Feb.:
   a. Introductory presentation and general issues were addressed in the morning of the first day.
   b. Overview of stakeholders answers to questionnaires and a discussion on Sardine stock identity
   c. Afternoon: Sardine South Review of data inputs and preliminary assessment
b) Tuesday, 7 Feb.:
   a. Southern horse mackerel Review of data inputs and preliminary assessment
   b. Afternoon: Northern sardine Review of data inputs and preliminary assessment

  c. Finalising by splitting in subgroups respective to the stocks under benchmarking.

c) Wednesday, 8 Feb.: working in subgroups respective to the stocks under benchmarking.
d) Thursday, 9 Feb.:
   a. working in subgroups respective to the stocks under benchmarking, and
   b. Consolidation of assessment and Reference Points for Southern Horse mackerel
   c. Consolidation of assessment for southern sardine
   d. Definition of further trials on northern sardine assessment
e) Friday, 10 Feb.:
   a. Consolidation of assessment and Reference Points for Southern Horse mackerel
   b. Consolidation of assessment for southern sardine and follow up actions to address the evaluation of the Management Plan in May (ToRs f & g).
   c. ICES external experts ad hoc meeting to clarify their reporting issues and concluding remarks
   d. Afternoon Last Runs for northern sardine assessment and shopping list of home works to conclude this work (through a Webex meeting in a week).
   e. 18:00 Conclusion of the meeting and planning of the follow up actions for reporting.

Annex 3: Stock Annexes

The table below provides an overview of the WGHANSA stock annexes updated at WKPELA 2017. 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
pil.27.8c9a	Sardine (*Sardina pilchardus*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)	March 2017	sar-soth
pil.27.78abd	Sardine (*Sardina pilchardus*) in divisions 8.a–b and 8.d and in Subarea 7 (Bay of Biscay, southern Celtic Seas, and the English Channel)	February 2017	sar-78
hom.27.9a	Horse Mackerel *(Trachurus trachurus)* in ICES Division 9a (Southern horse mackerel)	February 2017	hom-soth

Annex 6: External Reviewers Comments on WKPELA

Reviewers notes

Yi-Jay Chang, Martin Dorn and Dankert Skagen acted as the external experts for the WKPELA2017 benchmark of sardine and southern horse mackerel at a meeting from 6-10 February. We reviewed data compilation and assessment methods as presented to the benchmark meeting by the participating assessment analysts. This section of the report reflects solely the views of the external experts.

The external reviewers would like to commend all of the participants for their efforts during the benchmark process. Issues raised and the effects of data revisions were examined systematically and decisions were well justified. For the northern sardine stock, where an integrated assessment was attempted for the first time, a great effort from the analysts led to an acceptable assessment procedure.

The southern sardine stock and the southern horse mackerel stock both had well established data compilation and assessment procedures. For both, there were some data revisions and the assessment procedure was scrutinized and amended as appropriate. For the northern sardine, the process of establishing an integrated assessment and management advice started from the beginning.

The following sections covers what we considered the most important aspects of each stock assessment along with our recommendations. Some more general comments and suggestions are added at the end.

Sardine stock structure

At present, the southern sardine stock covers the areas between the Spanish-French border in the north and Gibraltar in the south. The bounds were confirmed in the SARDYN project (finalized in 2006). Subsequent studies support that, and there has not appeared any strong biological reasons for placing the breaks elsewhere. The common view is that both the Cantabrian coast and the Gulf of Cadiz are transition zones.

In the 'Northern area' (ICES Subarea VII and Divisions VIIIa,b,d), the critical issue is whether the sardine in the English channel and Celtic seas (Subarea VII) is separate from those in the Bay of Biscay (Divisions VIIIa,b,d). Genetics indicates no clear differences between sardines in European waters. It is not possible to be definitive with respect to any conclusion concerning separate treatment of the Subarea VII portion of the stock. The arguments in general are that:

- All sardine life history stages are present in Region 7. Hence, the conditions are in place for a self-sustained stock there.
- It is likely that eggs, larvae, and young of the year in the area represent in situ production, rather the transport from the primary Bay of Biscay larval retention area.
- There are too few surveys to track cohorts in the Bristol/English survey.
- Catches are probably reported correctly by area, previous misreporting by area has been corrected.
- Sardine apparently does not have major migrations, hence local occurrences may represent local stocks.

On a pragmatic basis, it appears that combining Subarea VII and Divisions VIIIa,b,d is limiting progress in developing an assessment of Divisions VIIIa,b,d. Fairly detailed information are available in Divisions VIIIa,b,d, while relevant data are almost nonexistent in Subarea VII, except for a survey that has been initiated only recently and is not coordinated with surveys further South. One may also argue that there is less potential for harm (i.e., it is more precautionary) if the stocks are managed separately rather than together.

The conclusion, which the reviewers supported, was that it could be justified to explore assessing the Bay of Biscay part (Divisions VIIIa,b,d) as a separate stock unit. Assessing a Subarea VII stock separately would be out of reach due to lack of data. Including the catch data from both areas in a common assessment tuned only to the survey data from Divisions VIIIa,b,d was also discussed briefly, but not followed up further since there is no justification for the necessary assumption that stock dynamics are the same in both areas.

Southern Sardine Stock

The assessment inputs were thoroughly revised. New weights at age for the survey time series, new weights at age for the population, a new maturity vector, revision of acoustic survey numbers at age to account for age-0s mis-identified as age 1 and revised DEPM estimates were introduced without leading to major changes in the stock estimate, only to an overall improvement in model fit. It was agreed that historic DEPM estimates normally would not need to be recalculated even if some parameters were revised.

The main issues dealt with were fishery and survey selectivity, model initialization, use of a stock recruit relationships in the assessment, survey catchability, and data-weighting checks for age composition and surveys. These issues were examined systematically and changes, also those that led to changes in the stock abundance estimates, were well justified and were accepted by the reviewers. In particular, the choice of stock recruit relationship mattered a good deal for the final outcome, and this could not be decided based on available data. As suggested by reviewers, a Beverton-Holt stock recruit relationship was included, with a fixed value of steepness at 0.71 based on the Myer's *et al*. (1999) meta-analysis.

There is still a modest retrospective inconsistency, with successive assessments indicating higher fishing mortality and lower stock abundance, in particular when the terminal year is 2012 when acoustic survey data were lacking. The pattern remained after the adjustments made at this benchmark, but the inconsistency in the most recent years is small.

Evaluation of alternative natural mortality schedules (multipliers applied to Gislason *et. al*) for the northern sardine stock motivated a similar analysis for the southern sardine stock. This occurred very late in the benchmark process and was completed in a Webex meeting in April. Likelihood profiles of M were very sensitive to assumptions about selectivity at age in survey and catch data and the near optimum range of M-values was rather broad. The combination of selectivity assumptions as decided earlier in the benchmark process and an M in the middle of the range (slightly higher than assumed until now) was adopted. The reviewers agreed on this conclusion.

The reviewers confirm that the outcomes of the benchmark in terms of data and method as described in the stock annex are appropriate to provide scientific advice on the Southern sardine stock.

Recommendations for future research

- A new method developed Bernal *et al*. (2011) was used to produce revised Daily Egg Production Method (DEPM) estimates for southern sardine. It may be beneficial to arrange for an external review of the revised estimates. The experts at the benchmark did not have the specialized expertise required to review the DEPM estimation procedures.

Southern Horse Mackerel

The current assessment method was introduced in 2011, and the benchmark now was for adjustments of data and method. The method has been considered acceptable, and there were no attempts to introduce new methods.

The most important issues were revision of the bottom trawl survey data, age range for the survey index and the choice of selectivity periods and assumptions for both catches and survey. In the survey, the final index used so far was just an average of abundance by station. The recommendation now, that was followed, was to derive a common index assuming a random stratified survey design, to account for variations in age composition by depth and latitude. Further refinement should be considered as future work, for example exploring spatial models to deal with zero tows and patchy distribution (see Thorson *et al*., reference below).

It was decided to split catch selectivity in three periods to accommodate minor changes in recent selectivity and likely changes in the near future during when the benchmark assessment is being used in update mode.

The retrospective pattern is relatively large but no worse than previous assessments. A large change occurs when the 2013 data are added. This may be a result of an influential 2013 survey datum.

The reviewers confirm that the outcomes of the benchmark in terms of data and method as described in the stock annex are appropriate to provide scientific advice on the southern horse mackerel stock.

Recommendations for future research

- The natural mortality schedule used for southern horse mackerel should be re-evaluated. There is some concern that the natural mortality for the older horse mackerel (0.15) may be too low, given the natural mortality values used in assessments of other horse mackerel stocks.
- The assessment method is not used for any other stocks in ICES. In a longer time perspective similar methods that are more familiar to the ICES community might be considered. The advantage would be to have a broader community that is familiar with the details of the method and to obtain greater ease in model evaluation using common R-software and similar tools. Stock synthesis would be one alternative, in particular since it is used for other pelagic stocks in the area and it is well established with a long experience using it in other areas.
- Consider analyzing trawl survey data using spatial generalized linear mixed models that are able to deal with zero tows and patchy distributions (see Thorson, J.T., Shelton, A.O., Ward, E.J., Skaug, H.J., 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES J. Mar. Sci. J. Cons. 72(5), 1297–1310. doi:10.1093/icesjms/fsu243.
- URL: http://icesjms.oxfordjournals.org/content/72/5/1297)

Northern Sardine Stock

Following the decision to attempt to treat the northern sardine stock within the Bay of Biscay (ICES Divisions VIIIa,b,d) as a separate entity, an age-structured stock assessment model was developed for that stock unit using the stock synthesis (SS) program. An initial model seemed reasonable in terms of model fits to the total egg production index, the acoustic survey, and the age composition data. However, acoustic survey catchability for this model was estimated in the 3-4 range, which was not considered plausible, both since this is an acoustic survey designed to estimate absolute biomass and because this catchability is quite different from that of the southern sardine stock. The high catchability was associated with a surprisingly low stock size estimate and a corresponding high fishing mortality. Much of review focused on understanding why the model behaved in this way, and evaluating alternative approaches to dealing with this problem.

An a4a application was also developed for the northern sardine stock. Comparison between the initial SS model and the a4a application indicated good consistency between the two models. Estimated abundances were on the same scale, and the times series of recruitment and fishing mortalities were similar. There were some fairly subtle differences between SS and a4a results that are likely due to the different ways that the initial age composition is estimated and how selectivity is modeled. It was concluded that both models were suitable for assessment of the northern anchovy stock, but that the effort should be focused on the stock synthesis model for consistency with the neighbouring sardine stock and because SS has a variety of options that could be valuable, like the ability to evaluate priors on parameters.

One major difficulty with assessing the northern sardine stock is that both survey time series, the acoustic survey and the total egg production index, are highly variable and lacking in strong trends in abundance. The variability in survey estimates is much greater than any plausible variability in population abundance based on the longevity of northern sardine. Input data consisting of stable but highly variable survey estimates are likely to make it difficult for the assessment to reliably estimate the scale of the population.

A likelihood profile on survey catchability indicated that both the acoustic survey age composition and biomass indices fit best when catchability is high. The acoustic survey age composition data was by far the most influential. Data sets that supported lower catchability included the egg count and the DEPM surveys. It was further realized that the results were quite sensitive to assumptions about the selectivity of the acoustic survey and to natural mortality. In particular, if the selectivity at age 1 was estimated freely, the estimate of catchability increased substantially, resulting in lower biomass estimate, while the fit of the model to the data improved considerably.

This led to an extensive exploration of various assumptions about catchability at age, natural mortality, use of a prior on survey catchability, and data weighting. This was a systematic process that was very well done. The end result, which was supported by the reviewers, was that a model with a natural mortality at age schedule as proposed by Gislason *et al*., but multiplied by factor of 0.9., together with assuming a fixed flat survey catchability for ages 2–5 and a fishery selectivity flat for ages 3–5 was accepted as the best model for providing scientific advice. Using a prior on the acoustic survey catchability was abandoned because it had minor effect on the catchability estimate and because it led to a worse retrospective inconsistency. The group was also concerned that use of a prior on catchability is an unfamiliar approach in ICES (but more common elsewhere) and would attract unnecessary controversy.

Due to the lack of time during the benchmark review, no reference points were estimated for the northern sardine stock. Therefore, we were therefore unable to review and endorse reference points for northern sardine.

Use of the final stock annex as basis for providing advice

The reviewers are satisfied that major progress has been made in establishing an analytic assessment for the stock, and that applying Stock Synthesis is a sound approach. The reviewers confirm that the outcomes of the benchmark in terms of data and method as described in the stock annex are appropriate to provide scientific advice. However, both reviewers and the group concluded that additional work is needed to improve the assessment. We note a large amount of uncertainty, particularly with respect to the overall of scaling of population size., and that there are plans to revise the acoustic survey estimates. We therefore recommend that until the sources of uncertainty are better understood and the assessment is adjusted accordingly, results of the assessment are treated as being indicative of trends only. We provide the list of recommendations below for the further development of the assessment.

Recommendations for future research

- Improve sardine target strength estimates used to convert backscatter to biomass for acoustic surveys.
- Explore possible reasons for the large year-to-year variations in relative catch from areas 7 and 8abd. Do for example catches in Subarea 7 include fish that migrates in from area 8abd?
- Evaluate environmental factors that may affect the availability of sardine to acoustic and egg surveys in the Bay of Biscay. What is causing the high inter-annual variability of the acoustic and egg count surveys for sardine?

In a longer time perspective:

- Consideration should be given to coordinated acoustic surveys in Bay of Biscay (ICES Divisions 8.a, 8.b, and 8.d) and in ICES Subarea 7. A coordinated survey effort at the same time of the year that encompasses the known distribution of sardine in these areas would provide valuable information on stock structure.
- Establish catch statistics and proper sampling of the catches in Subarea VII, and continue the newly established survey. This might be a formal recommendation from WKPELA if it so chooses.
- Evaluate a SS model with separate French and Spanish fisheries to account for the greater participation by Spanish vessels in the southern part of the area since 2011. An alternative approach would be to model a selectivity break in 2011.

General Comments and Recommendations

These are some more general suggestions that emerged from the discussions at WKPELA2017.

- It might be useful for ICES to consider the differences, similarities, pros and cons with the many closely related assessment tools of the forward projecting state space type now being used within ICES. Standardization may not be a goal in itself, and individually adapted methods for each stock may be advantageous. But the choice of assessment tool is probably person dependent to some extent, and a clear disadvantage is that the number of people who are really confident with each method becomes very small, and even fewer will be confident with all or most of them.
- We would suggest that ICES considers, on a broad scale, guidelines for what to assume for natural mortality. We note a transition in ICES towards revised assumptions for natural mortality, in particular age/size derived values as suggested for example by Lorenzen and by Gislason *et al*. For all the stocks at this benchmark, the assumed natural mortality would matter a good deal, since the fishing mortality probably is low compared to the natural mortality. In addition to size, which is a common factor, the role of the species as prey in the ecosystem and the increase in M towards old age might be considered. It adds to the problem that regarding acoustic and DEPM survey as absolute measures may be relevant, as discussed for the northern sardine stock. These issues are not unique to the stocks considered here, although these stocks demonstrate some important aspects of the problem.
- We suggest that ICES considers, on a broad basis, requirements for considering a survey measurement as an absolute measure of abundance. The use of acoustic and egg surveys as absolute measures of abundance is often debated. In ICES, surveys as absolute measures has only been implemented for species where ordinary assessment methods are not applicable (for example short lived species like anchovy and capelin). Yet clearly, assuming that a survey measures absolute biomass is tremendously helpful for stock assessment, since it determines the overall scale of the population, but this assumption may be difficult of justify given issues such as survey coverage, target strength etc. The Northern sardine stock case illustrates the problem, but the issue has broader implications for ICES assessments.

Annex 7: List of Working Documents

For all sardine stocks:

Laura Wise andAlexandra Silva; Pablo Carrera; Lionel Pawlowski and Andrés Uriarte: Analysis of the stakeholder inputs for population assessment of sardine.

For southern sardine (Atlanto-Iberian sardine):

Maria Manuel Angélico, Cristina Nunes, Jose Ramón Pérez and Paz Díaz: Summary of the revised DEPM data series estimations for the Atlanto-Iberian sardine (ICES 9a + 8c), 1988–2014, using the traditional methodology (in line with the 2012 revision).

Paz Díaz, Ana Lago de Lanzós, Isabel Riveiro, Pablo Carrera, Cristina Nunes, Vitor Marques, Elisabete Henriques, Maria Manuel Angélico: Atlanto-Iberian sardine (ICES 9a + 8c) spawning stock biomass reanalysis for the DEPM data series, 1988-2014, considering egg production estimation using a mortality model obtained from aggregated data and with temperature as covariate. Part I. SSB reanalysis for the DEPM data series, 1988-2014, considering egg production estimation using a mortality model obtained from aggregated data and with temperature as covariate. (With a Part II. - Comparison of trends in the sardine SSB estimates (ICES 9a + 8c) obtained from DEPM and acoustics surveys)

Maria Manuel Angélico, E. Henriques, A. Lago de Lanzós, Paz Díaz and Isabel Riveiro: Sardine Egg Production Estimation (ICES áreas 9a + 8c) using data from EPM surveys directed at mackerel and horse-mackerel.

Nunes C., Uriarte A., Diaz Conde P., Perez J.R., Soares E., Riveiro I., Angelico M.M., Silva A.: Revision of the life history parameters (proportion of mature and mean weights at age) for the Iberian (south) sardine stock (ICES 8c and 9a)

Alexandra Silva, Eduardo Soares and Delfina Morais: Revision of Portuguese acoustic data (PELAGO) – age classification of sardine small individuals.

Alexandra Silva and Isabel Riveiro: Revision of the assessment of the sardine south stock (sardine in ICES Divisions 8.c and 9.a) – Impact of revisions of input data on the 2016 assessment.

Alexandra Silva and Isabel Riveiro: Revision of the assessment of the sardine south stock (sardine in ICES Divisions 8.c and 9.a). Model configuration: initial population and stock-recruitment.

Hugo Mendes, Alexandra Silva, David Miller: Preliminary estimates of biological reference points for southern sardine stock (ICES Division 8.c and 9.a) (Draft Version 08032017).

For Northern Sardine

Paz Díaz, Maria Santos, Ana Lago de Lanzós, Concha Franco and Andrés Uriarte: Preliminary sardine spawning stock biomass estimates at ICES divisions VIIIab applying the DEPM in 2011 (Wd to WGACEGG 2011–ICES CM 2011/SSGESST:20).

Paz Díaz, Maria Santos, Ana Lago de Lanzós, Concha Franco, José Ramón Perez and Andrés Uriarte: Preliminary sardine spawning stock biomass estimates at ICES divisions VIIIab applying the DEPM in 2014 (Wd to WGACEGG 2014 –ICES CM 2014/SSGESST:21).

Leire Citores, Leire Ibaibarriaga, Andrés Uriarte and Lionel Pawlowski: Stock assessment for sardine in 8abd and 7 using a4a and its variants.

For Southern Horse Mackerel

Costa, A.M., Villamor, B., Silva, C., Nunes, C., Pinto, D., Perez, J.R., Inácio, M., Abreu, P., Azevedo, M.: Spawning season, maturity and fecundity: Southern horse mackerel, Trachurus trachurus, Life-history: Reproduction.

Hugo Mendes, Manuela Azevedo, Corina Chaves, Gersom Costas, and Francisco Velasco: Characterization of Southern horse mackerel survey indices and implications for stock assessment.

Andrés Uriarte, Manuela Azevedo, Gersom Costas, Hugo Mendes: Report of the Workshop on data evaluation for Southern Horse Mackerel (WKSHOM). Held at IPMA-Lisbon, on 21-23 November, 2016.

Posterior contribution on Southern Sardine:

Laura Wise, Alexandra Silva, Hugo Mendes, David Miller, and Manuela Azevedo: Estimates of biological reference points for southern sardine stock (ICES Division 8.c and 9.a). (First version issued on 10/05/2017 by email to members of WKPELA).

Annex 8: List of presentations

GENERAL

- Uriarte A.: Introduction to ICES benchmarking
- Laura Wise, Alexandra Silva; Pablo Carrera; Lionel Pawlowski and Andrés Uriarte: Analysis of the stakeholder inputs for population assessment of sardine.
- Silva *et al*., SARDINE STOCK ID. BRIEF SUMMARY

For southern sardine (Atlanto-Iberian sardine):

- Alexandra Silva, Eduardo Soares and Delfina Morais: Revision of Portuguese acoustic data (PELAGO)-age classification of sardine small individuals.
- Alexandra Silva and Isabel Riveiro: Revision of the assessment of the sardine south stock (sardine in ICES Divisions 8.c and 9.a)-Impact of revisions of input data on the 2016 assessment.
- Alexandra Silva and Isabel Riveiro: Revision of the assessment of the sardine south stock (sardine in ICES Divisions 8.c and 9.a). Model configuration: initial population and stock-recruitment.
- Alexandra Silva and Isabel Riveiro: Sardine South. Introduction.
- Alexandra Silva and Isabel Riveiro: Sardine South BH and Selectivity.
- Alexandra Silva: South sardine assessment model impact of data revision. Model exploration.
- Alexandra Silva. Work on natural mortality for southern sardine Follow-up from post-benchmark discussions. Presentation posterior to WKPELA 2017 by webex 10/04/2017.

For Northern Sardine

- Erwan Duhamel, Lionel Pawlowski, Martin Huret, Matthieu Doray: Northern Sardine stock (VIIIabd-VII).
- Erwan Duhamel: Pil North Maps 2010–2014: Egg Adults and Fishing Effort
- M. Santos, L. Ibaibarriaga & A. Uriarte: DEPM Spawning Biomass Sardine estimates in Bay of Biscay.
- Leire Citores, Leire Ibaibarriaga, Andrés Uriarte and Lionel Pawlowski: Stock assessment for sardine in 8abd and 7 using a4a and its variants.
- L. Pawlowski, E. Duhamel, L. Citores, L. and Ibaibarriaga: Exploratory assessment using SS3.
- L. Citores, A. Uriarte, L. Pawlowski, E. Duhamel and L. Ibaibarriaga: SS3 Sardine 8abd discussion.
- Dankert Skagen: Where does the high catchability estimate come from? Presentation posterior to WKPELA 2017 by webex 22/02/2017.
- L. Citores, A. Uriarte, L. Pawlowski, E. Duhamel and L. Ibaibarriaga: Additional work from WKPELA regarding sardine in Biscay. Presentation posterior to WKPELA 2017 by webex 22/02/2017 (Summary Biscay Sardine_v1 and v1 (plus).

For Southern Horse Mackerel

- Gersom Costas, Manuela Azevedo, Hugo Mendes: Southern Horse Mackerel
- Hugo Mendes, Manuela Azevedo, Corina Chaves, Gersom Costas, Francisco Velasco: Characterization of Southern horse mackerel survey indices and implications for stock assessment.
- Hugo Mendes, Manuela Azevedo, Gersom Costas: MSY reference points for southern horse mackerel (IXa) using 2016 stock assessment (Update WKPELA, 2017).
- Manuela Azevedo, Hugo Mendes, Gersom Costas: Input data, assumptions/model settings, results, discussion, conclusions, survey abundance: approaches (simple mean, stratified mean, mean with post-stratification, smoothed cohorts) (WPELA_Hom9a_Trial assessments).

Annex 9: Stakeholders inputs (questionnaires) on Sardine (Wd from Laura *et al.)*

Working document on the analysis of the stakeholder inputs for population assessment for sardine.

Authors:

Laura Wise (IPMA)

Alexandra Silva (IPMA)

Pablo Carrera (IEO)

Lionel Pawlowski (IFREMER)

Andreas Uriarte (AZTI)

Objectives

The purpose of this questionnaire was to get the perception of stakeholders on various aspects of the biology, fisheries and management of sardine.

Distribution

The questionnaires were distributed to stakeholders by a variety of techniques:

- Direct e-mail to stakeholders identified by the WG;
- Paper distribution at several public meetings;
- Indirect submission through the Public fisheries organisms or organizations.

Responses

Responses to the questionnaires were received by e-mail, postal mail, and fax and were entered into a small database (excel spreadsheet) for organization and primitive analysis. Stakeholders from the fishing activity sector and from NGO (Portuguese) filled a total of 28 questionnaires. From the fishing activity sector, some were individual fishermen, others owners of fishing companies and others by leaders/representatives of fishermen organizations. 16 of the questionnaires were from Spanish stakeholders (working from as north as the South of Biscay to as south as Cádiz), 7 from Portuguese stakeholders (all areas of Portugal), 3 from French stakeholders (from the North to South of Biscay) and 1 from the United Kingdom (area of activity is in the Western Channel).

In the case of Portugal, leaders of Producer Organizations (PO) filled six of the questionnaires and the owners of a fishing company filled one questionnaire. The six POs represent about 75% of the purse seine fleet. PO leaders (except one) signed in the name of their organizations but they likely transmitted a mix of their personal view/knowledge and their associates.

In the case of Spain all came from fishermen, either from individual fishermen or from representatives of the fishermen organization (Federation of Cofradías or OPS). Most of them came from the Galicia area (11 answers) several from individual fishermen of Pontevedra (4) and Lugo (4) provinces but others from ports and fishermen organization (3) and the rest from representatives of OPs covering all other provinces from the

Northern (8c) and southern (9a) coastal regions (with 3 and 1 answers respective to these regions).

Analysis

For each question, we first calculated how many stakeholders selected each response option and then used tables or graphs to display the data. All answers were subdivided by country (here the only NGO is treated as a country also). In the table format one can easily observe the percentage (%) and the number (n) for each possible answer (including those that were left blank) by country and for the group of all countries. The percentage per country adds to 100%. In the graph format one can easily observe the percentage of the number of answers per country and for the group of all countries. Several questions were conditional to a previous response in another question and this was taken into consideration when analysing the number of answers per questions. The number of stakeholders answering one question can easily be observed in the total N of the group ALL. Non-valid answers, i.e., that didn't correspond to the question asked or were incorrectly filled were removed from the analysis of that question. This is the case, for example, of question 5 where an order of importance of multiple factors was asked and stakeholders just selected factors with no order of importance or gave the same order of importance to two or more factors. Due to the limited number of questionnaires filled out and the different sample size for each country no analysis was performed to access whether there was any significant differences between countries or different types of stakeholders. Questions where stakeholders were asked to give suggestions or recommendations were either divided by 'main topic' (questions 14, 21 and 25) or every answer was transcribed (questions 18, 22 and 26). In this second type of tables we present the number of (non unique) answers (A) among the N questionnaires that provided replies to the question (A/N), so that occasionally the sum of A can exceed N.

Results

Stock identity and dynamic

Regarding question 1, on average all the countries agree that there is not a single population from Gulf of Cadiz to the North of France (Table 6).

Table 6. Do you believe the sardine inhabiting from Gulf of Cadiz to north France belongs to a single population? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Yes		No		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
Spain	5	31.2	11	68.8	0	0	16	100
Portugal	3	42.9	4	57.1	0	0	7	100
France	0	0	3	100	0	0	3	100
U.K.	0	0	1	100	0	0	1	100
NGO	0	0	1	100	0	0	1	100
All	8	28.6	20	71.7	0	0	28	100

However, there is no general agreement on how many populations (Table 7). Two to three different populations are the most plausible scenarios with only one stakeholder stating that there are six.

Table 7. How many populations do you believe are in this area? Values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	2		3		6		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
Spain	4	36.4	5	45.5	1	9.1	1	9.1	11	100
Portugal	3	75.0	0	0	0	0	1	25.0	4	100
France	0	0	2	66.7	0	0	1	33.3	3	100
U.K.	0	0	1	100	0	0	0	0	1	100
NGO	1	100	0	0	0	0	0	0	1	100
All	8	40.0	8	40.0	1	5.0	3	15.0	20	100

Even within the group of stakeholders that believe there are two or three different populations there is no general agreement on where these populations are and where they separate themselves. Notice that some answers make us believe that some stakeholders, when answering to question 3, where thinking about sardine populations in their main fishing activity areas. Considering that this is the main area of activity is only expected that they can refer to the populations of their knowledge and aren't considering the all area referenced in question 1. For example, one stakeholders reports that "from the Gulf of Cadiz to the North of France we can really say, but we have it very clear that there is one distinct population in the Gulf of Cadiz." Another stakeholder reports that there are three different populations in question 2 and the areas drawn in the map in question 3 are all in the Biscay areas.

Taking this consideration, we however report the different populations drawn by stakeholders in question 3. The group of stakeholders that believe there are two distinct populations can be subdivided in 4 subgroups. One subgroup (4 stakeholders) considers that one population ranges from the Western Channel to North Galicia and the other from South Galicia to the Gulf of Cadiz. Another subgroup (1 stakeholder) considers that the northern population ranges from South Galicia to the Western Channel and the Celtic Sea. Another subgroup (1 stakeholder) considers one population to be in France and another one in area VIII and reports that they don't know about the population in the Gulf of Cadiz. The last subgroup considers the northern population to be from North Galicia to Eastern Galicia and the other one in the Atlantic, from South Galicia to the South of Portugal.

The group of stakeholders that believe there are at least three distinct populations can almost be subdivided in as many groups as stakeholders. From one stakeholder that considers three different populations in the areas of Biscay, to subgroups that consider the northern population to start in North Biscay or South Biscay and coming as south as to East Cantabria. Another subgroup considers the northern population to be in

Cantabria. The 'middle' population is in most cases the North of the Atlantic (South Galicia and North of Portugal) but some stakeholders include the Western Cantabria area in this population or one different opinion says it's the all Cantabria without the Atlantic areas. Regarding the southerner population for the majority it's the Algarve and Cadiz area but others also include in this area the South of Portugal.

Finally, the stakeholder that considers there are 6 different populations considers the first to be Algarve and Gulf of Cadiz, the second South of Portugal, the third in North Portugal and South of Galicia, the forth in North Galicia and West Cantabria, the fifth in East Cantabria and the last one in South and North of Biscay.

Within those stakeholders that believe there is more than one population, the majority also believes that the boundaries aren't permanent along time (Table 8). But notice that among countries this belief is stronger for some than for others.

Table 8. Do you believe the boundaries are fixed (permanent) along time? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Yes		No		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
Spain	1	9.1	10	90.9	0	0	11	100
Portugal	2	50.0	2	50.0	0	0	4	100
France	1	33.3	1	33.3	1	33.3	3	100
U.K.	0	0	1	100	0	0	1	100
NGO	0	0	1	100	0	0	1	100
All	4	20.0	15	75.0	1	5.0	20	100

Regarding question 5, only 11 stakeholders out of 15 answered to it. The four stakeholders that for one reason or the other didn't answer to the questions belong to NGO (1), UK (1) and Spain (2). This either means that they left this answer blank or that they didn't give a valid answer. Overall, temperature stands out as the most important factor driving the changes in the populations' boundaries along time (Figure 10). This is followed by interactions with other species and wind.

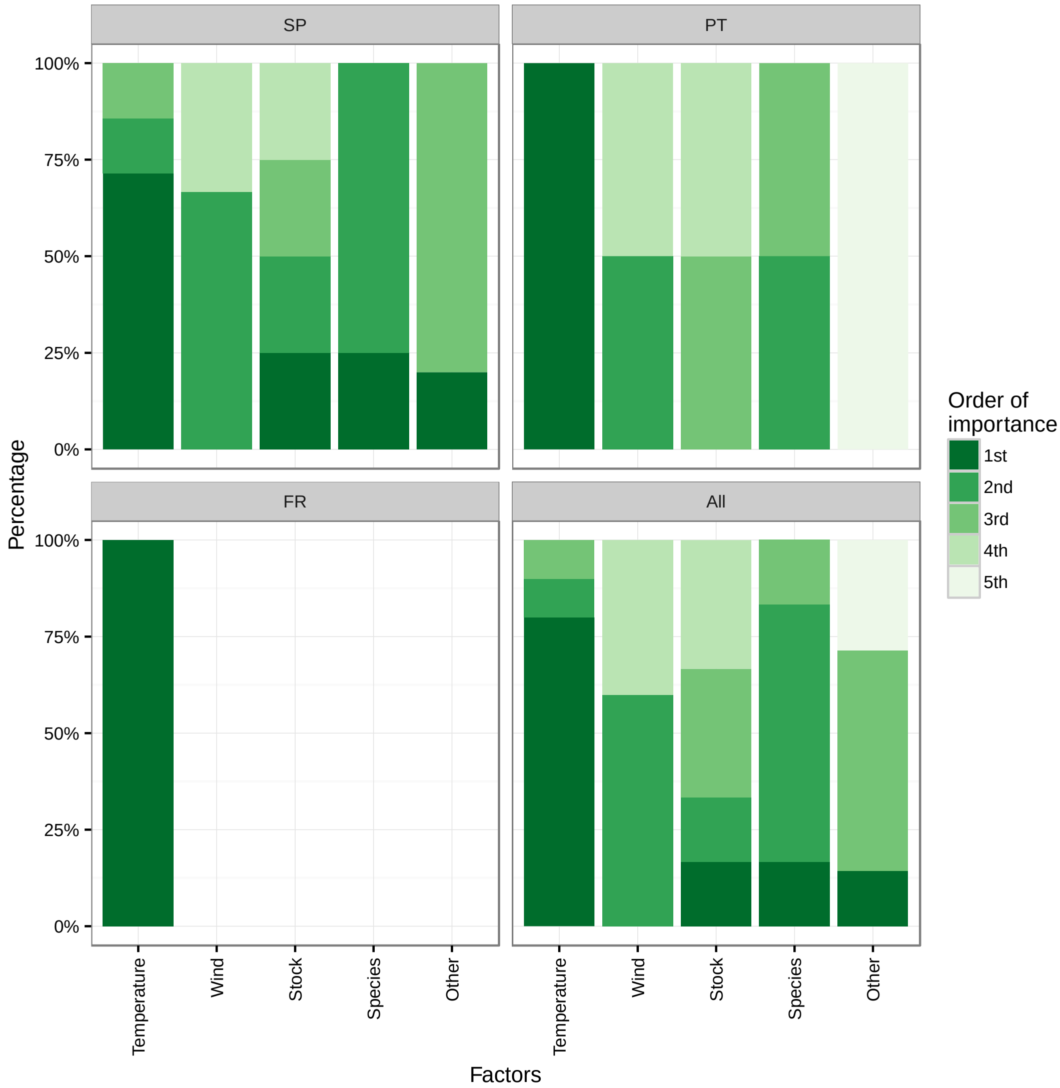

Figure 10. Which of the following processes/factors do you believe are driving such changes in boundaries? In case of more than one, please numbering in order of importance.

When asked about their belief on whether the populations are interconnected or not, the majority of all stakeholders believe that they are but this is not the case for the French stakeholders participating in the questionnaire (Table 9).

Table 9. Do you believe the populations are interconnected? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Yes		No		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
Spain	7	63.6	3	27.3	1	9.1	11	100
Portugal	2	50.0	2	50.0	0	0	4	100
France	1	33.3	2	66.7	0	0	3	100
U.K.	1	100	0	0	0	0	1	100
NGO	0	0	0	0	1	100	1	100
All	11	55.0	7	35.0	2	10.0	20	100

Those that believe that the populations are interconnected they feel that the degree of this interconnectivity is of a median degree (

Table 10).

Table 10. Could you quantify the degree of such inter-changes? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Few/rare		Median		High		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
Spain	2	28.6	4	57.1	1	14.3	0	0	7	100
Portugal	0	0	2	100	0	0	0	0	2	100
France	0	0	1	100	0	0	0	0	1	100
U.K.	0	0	1	100	0	0	0	0	1	100
NGO	-	-	-	-	-	-	-	-	-	-
All	2	18.2	8	72.7	1	9.1	0	0	11	100

Almost half of all stakeholders say that they aren't able to identify sardine's nursery areas (

Table 11). However and by country, the majority of the Portuguese stakeholders seem to know where these nursery areas are.

Table 11. Are you able to identify nursery areas? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Yes		No		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
Spain	9	56.2	7	43.8	0	0	16	100
Portugal	5	71.4	2	28.6	0	0	7	100
France	1	33.3	2	66.7	0	0	3	100
U.K.	0	0	1	100	0	0	1	100
NGO	0	0	0	0	1	100	1	100
All	15	53.6	12	42.9	1	3.6	28	100

Those stakeholders that reported they were able to identify sardine's nursery areas shared different views on how many areas there are and where they are located.

Table 12 summarizes information on how many sardine nursery areas where identified.

Table 12. Number of sardine nursery areas identified by stakeholders. Balues represent frequency of respondents.

Number of nursery areas	1	2	3	4
All	3	5	3	2

Figure 11 summarizes where these nursery areas where located. Area size was not taken into consideration.

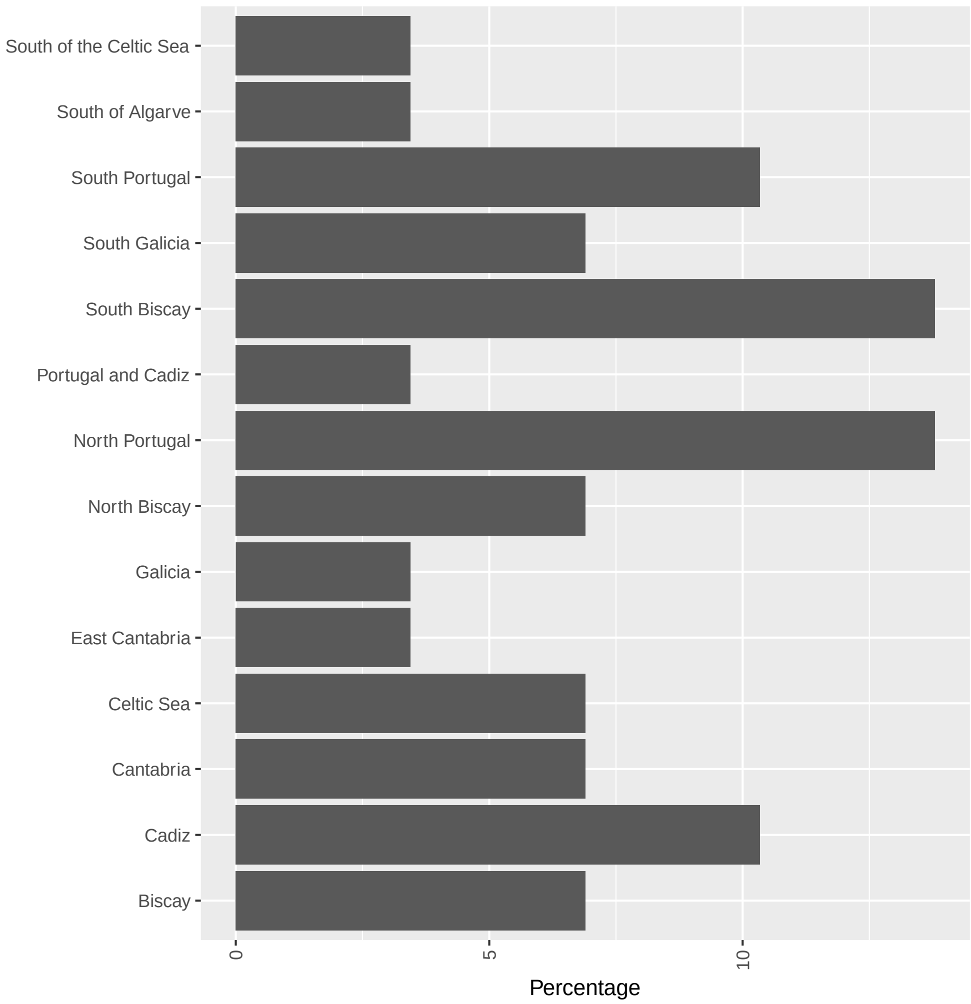

Figure 11. Areas where stakeholders located the nursery areas. Values represent percentage of times an area was reported.

Also, half of all the stakeholders say that they're not able to identify the main feeding areas of sardine (**Error! Reference source not found.**). However and by country, the majority of the French stakeholders seem to know where these feeding areas are.

Table 13.Are you able to identify the main feeding areas? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

	N	Percent	N	Percent	N	Percent	N	Percent
Spain	6	37.5	8	50.0	2	12.5	16	100
Portugal	3	42.9	4	57.1	0	0	7	100
France	2	66.7	1	33.3	0	0	3	100
U.K.	0	0	1	100	0	0	1	100
NGO	0	0	0	0	1	100	1	100
All	11	39.3	14	50.0	3	10.7	28	100

Those stakeholders that reported they were able to identify the main feeding areas of sardine either said they were on the beaches (1), in the platform (1) or divided the feeding areas in 2 different areas (4), 3 different areas (2) or four different areas (1). As previous we summarize in

Figure 12 where these main feeding areas were located according to stakeholders.

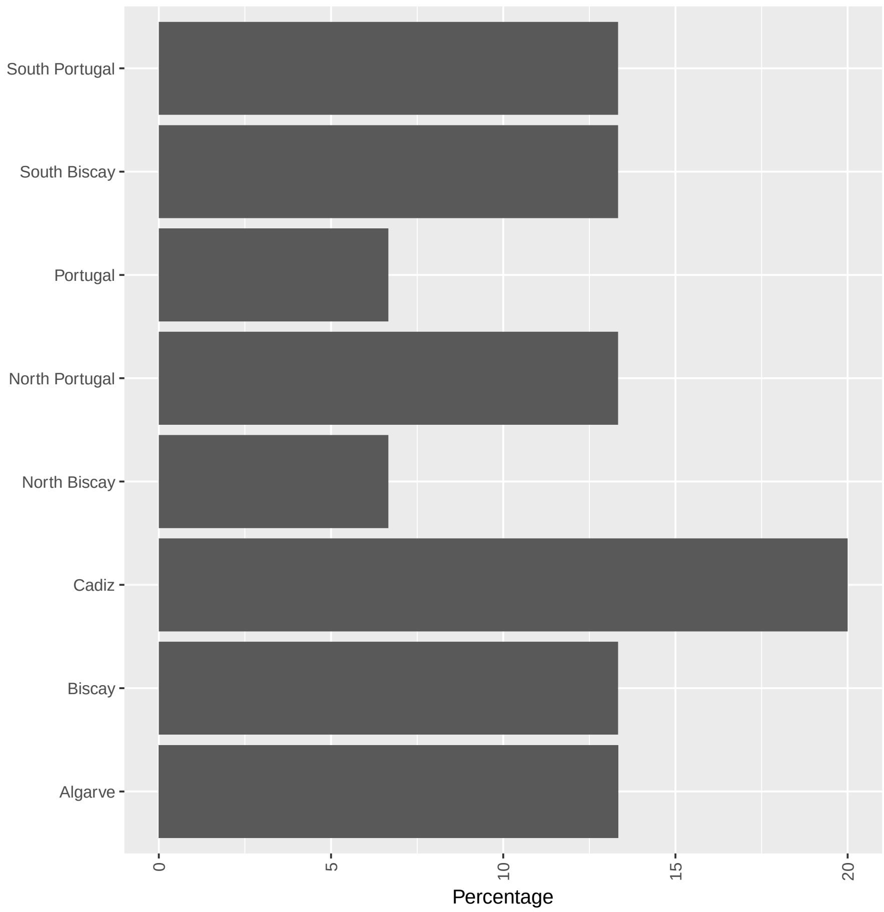

Figure 12. Areas where stakeholders located the feeding areas. Values represent percentage of times an area was reported.

When asked in which quarter(s) the stakeholders believe the feeding season takes place, all of the 21 stakeholders that answer to this question believes it takes place during spring and summer (Figure 13). Some Spanish and Portuguese stakeholders also believe that it takes place along autumn and winter. The seven stakeholders that didn't answer to this question were from Portugal (1), France (1), UK (1), NGO (1) and Spain (3).

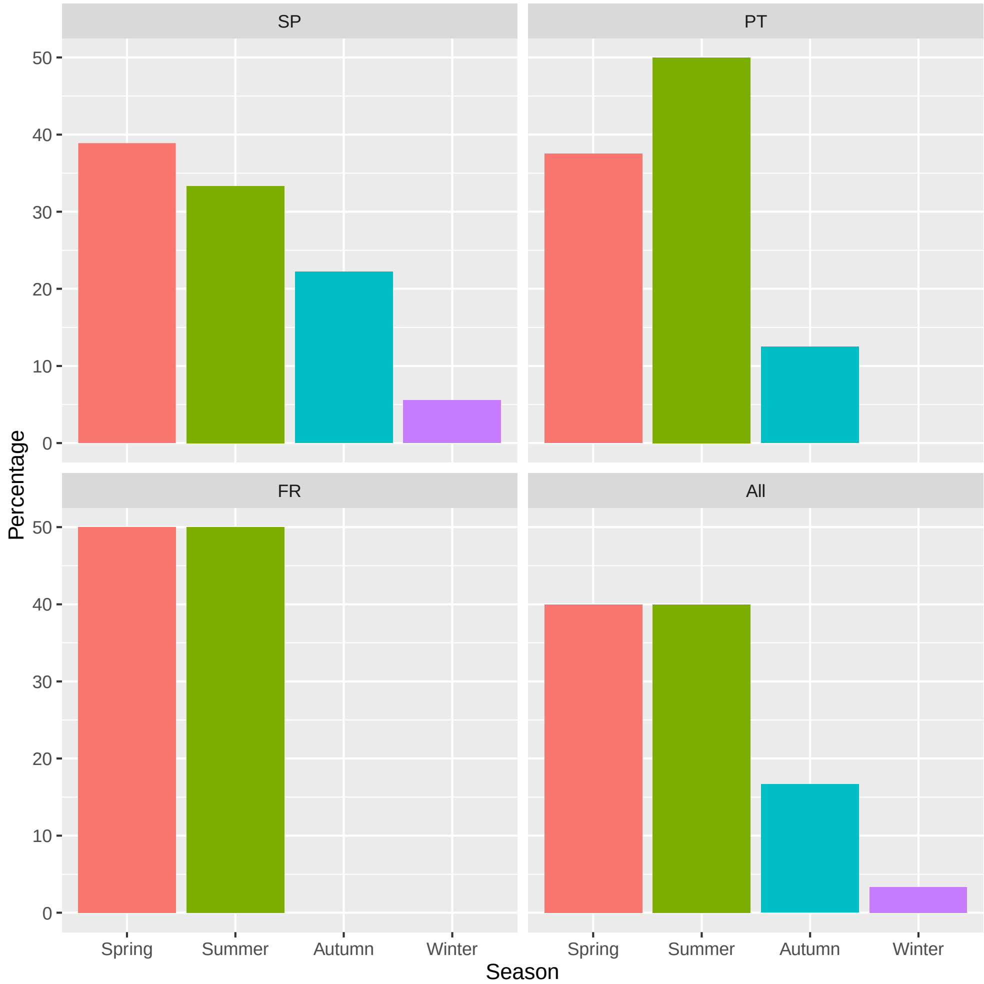

Figure 13. In what quarter(s) do you believe the feeding season takes place?

About the fishing activity

The main season of fishing activity for all the stakeholders is summer (almost 45%) followed by autumn (Figure 14). However, for UK stakeholders the main seasons are autumn and winter.

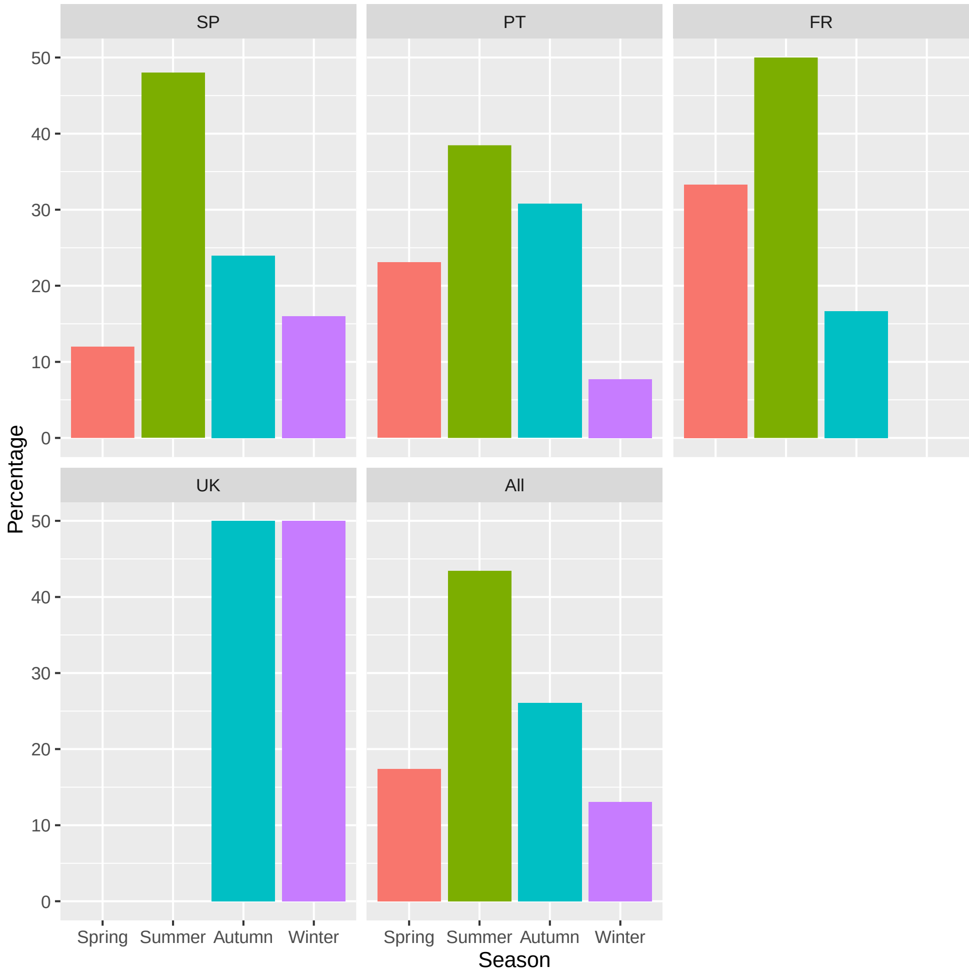

Figure 14. In which seasons does your main fishing activity take place?

Fishing activity takes places in all areas from as north as the Western Channel to as south as Cadiz (Figure 15). The Spanish stakeholders are the ones that operate in more different areas that range from the North of Biscay to Cadiz although the main areas are within Spanish waters. Portuguese stakeholders say they operate in Portugal and Cadiz. The French and UK stakeholders say that they only operate in their countries areas.

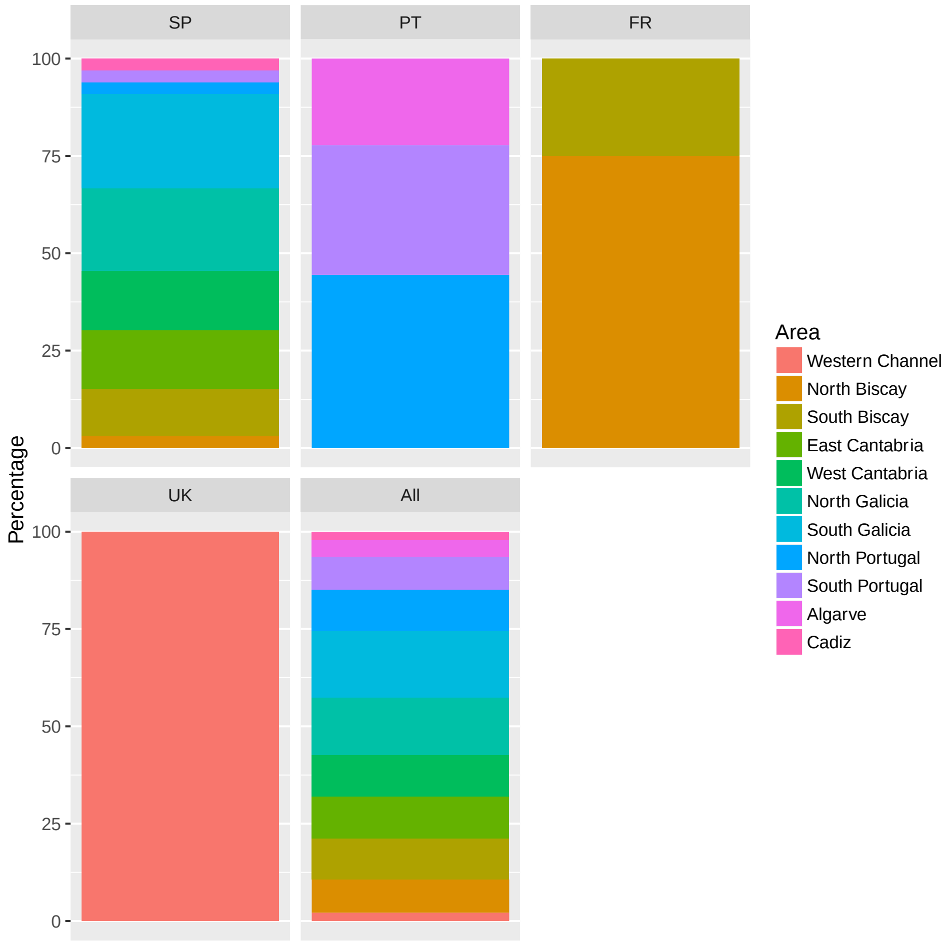

Figure 15 - In which area(s) does it take place?

Five Spanish stakeholders that operate in Galicia and Cantabria and 1 UK stakeholder that operates in the Western Channel answered that they move fishing areas seasonally. All Spanish stakeholders move to adjacent areas to where they normally fish going as far as South Biscay. The UK stakeholder says that he changes areas but they are all in the Western Channel area due to the necessity of proximity to fishing ports.

From all the stakeholders, 10 answered why they move. Reasons are described in Table 13 by order of importance. Importance in this case is related to higher number of stakeholders stating the same reason to move fishing area.

Table 13. Reasons on why stakeholders move from their main fishing activity area(s). Values represent the number of (non unique) answers (A) among the N questionnaires that provided replies to the question (A/N).

Reason	A/N
Fish movements/higher abundances	9/10
Better prices	4/10
Quality (size)	1/10
Proximity	1/10

The preferred size of sardine for market and selling differs among countries (Figure 16). French and Portuguese stakeholders seem to prefer the intermediate sardine sizes (T2 and T3) while the Spanish and the UK stakeholders seem to prefer the bigger size of sardine (T1). However, answers from Portuguese and Spanish stakeholders are very mixed and both stakeholders groups mention all categories, as they preferred size.

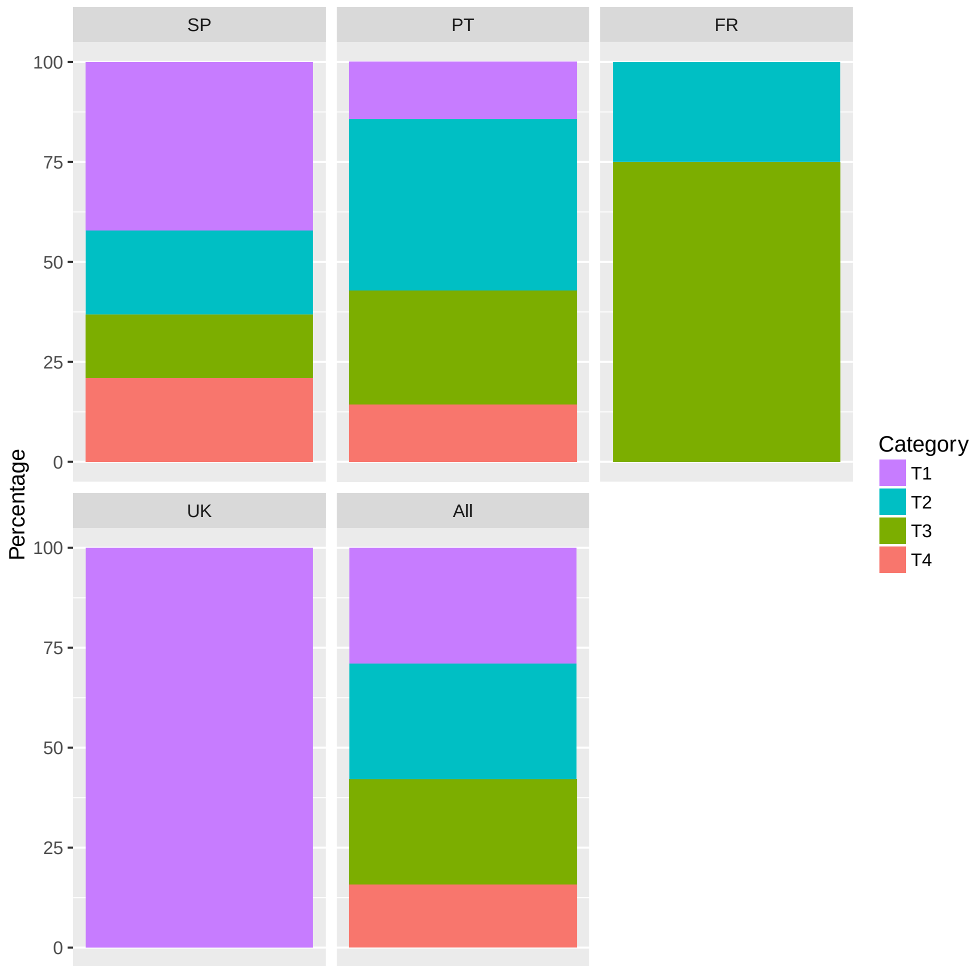

Figure 16. What is the preferred size of sardine for the market and selling?

Assessment and inputs:

When considering all stakeholders, the majority (53.6%) believes that the current state of the sardine stock is Bad with better perspectives in short term (

Table 14). However, the majority of French stakeholders believe that the current state of the stock is Normal. Few stakeholders believe that the stock is Good (3) or Bad with worse perspectives in the short time (1).

Table 14. What is your vision about the current status of the stock? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Good		Normal		Bad to better		Bad to worse		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
Spain	1	6.2	3	18.8	11	68.8	1	6.2	0	0	16	100
Portugal	0	0	3	42.9	3	42.9	0	0	1	0	7	100
France	1	33.3	2	66.7	0	0	0	0	0	0	3	100
U.K.	1	100	0	0	0	0	0	0	0	0	1	100
NGO	0	0	0	0	1	100	0	0	0	0	1	100
All	3	10.7	8	28.6	15	53.6	1	3.6	1	3.6	28	100

82% of all stakehlders believe that the official catch data is good enough (Table 16).

Table 16. Do you believe official catch data are good enough? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Yes		No		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
Spain	12	75.0	4	25.0	0	0	16	100
Portugal	7	100	0	0	0	0	7	100
France	3	100	0	0	0	0	3	100
U.K.	0	0	1	100	0	0	1	100
NGO	1	100	0	0	0	0	1	100
All	23	82.1	5	17.9	0	0	28	100

Those that believe that they aren't good enough think that the problem comes from different issues. In Table 15 we can see what the main problem for this is for these stakeholders.

Table 15. Reported reasons for why the survey indices aren't good enough. Values represent the number of (non unique) answers (A) among the N questionnaires that provided replies to the question (A/N).

Problem	A/N
The inexistence of TAC's.	1/5
Take into account information from professionals and combine them with scientific information.	1/5
The assessment of stocks is data poor. ICES assessment does not take account of information gathered from Area VII. To improve data I would suggest a self-sampling program for both vessels and processors (...). Stock surveys would also be a very useful addition to improve stock assessment.	1/5
Scientific data lack liability because there are an insufficient number of surveys. This resource should have a more potent and robust dedicated study with at least 4 surveys per year. New design of these studies should be done in collaboration with the fishing sector.	1/5

On the other hand, 64.3% of all stakeholders believe that the survey indices aren't good enough (Table 18).

For this majority of stakeholders survey indices information could be improved mostly by a better collaboration between fishermen and scientists (Figure 19) but also by combining vessels (fishing and research vessels).

Table 18. Do you believe surveys indices are good enough? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Yes		No		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
Spain	3	18.8	11	68.8	2	12.5	16	100
Portugal	2	28.6	5	71.4	0	0	7	100
France	3	100	0	0	0	0	3	100
U.K.	0	0	1	100	0	0	1	100
NGO	0	0	1	100	0	0	1	100
All	8	28.6	18	64.3	2	7.1	28	100

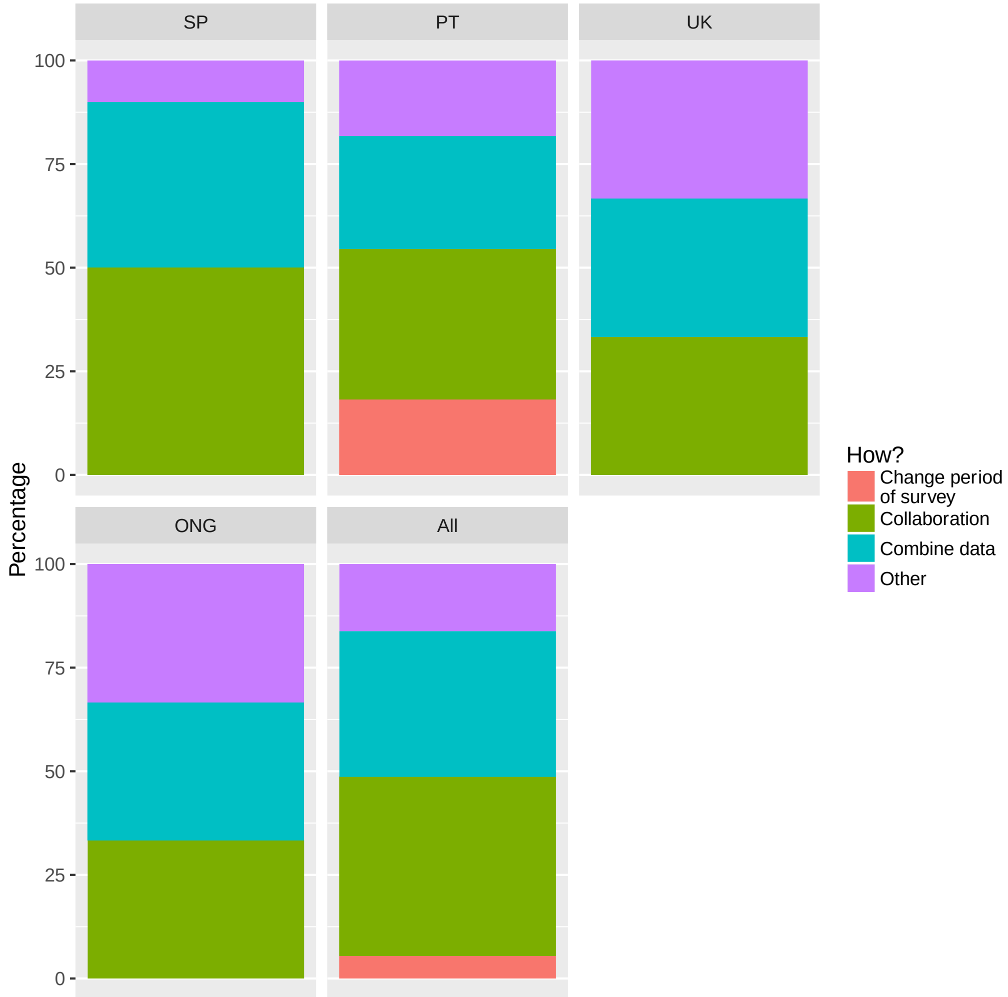

Figure 17. How would survey indices be improved?

From the 6 stakeholders that gave ‘Other’ as an answer, Table 16 summarizes the information they gave.

Table 16. Suggestions on how the survey indices could be improved. Values represent the number of (non unique) answers (A) among the N questionnaires that provided replies to the question (A/N).

Suggestions	A/N
Change assumptions	1/6
Create a specific cabinet of supervision with several entities	1/6
Two annual surveys instead of one	1/6
Surveys in all areas considering sardine as just one stock and baring in mind the migration route of displacement	1/6
Commitment to regular research cruises for stock assessment purposes	1/6
Make a survey by the end of summer	1/6

Stakeholders reported that they had input data that they would like to be considered in the assessment, such as those mentioned in Table 17.

Table 17. Input data that stakeholders would like to be considered in the stock assessment. Values represent the number of (non unique) answers (A) among the N questionnaires that provided replies to the question (A/N).

Suggestions	A/N
Use information from the fishing sector	3/15
Studies should also be made in other areas	1/15
Catch size from other sources	1/15
(...) Historic records of fish processed levels, fish weight samples and oil content.	1/15
Self-sampling program	1/15
Yes	3/15
No	7/15

Also, they feel that ICES should consider other relevant information while making the assessment (Table 18).

Table 18. Other relevant information that should be taken into consideration in the assessment. Values represent the number of (non unique) answers (A) among the N questionnaires that provided replies to the question (A/N).

Suggestions	A/N
Information from the fishing sector	6/12
Consider the equation Revenues/Catch versus Fishing Effort	1/12
Evaluate different realities across the country and not just in some circumstantial zones	1/12
Sardine migration/change in distribution studies	2/12
Relation with other species in an ecosystem approach	1/12
Population genetics studies	
Climate change	1/12
Permanent dialogue for the analysis of CPUE's and assessment	2/12

Management

The majority of all stakeholders (64.3%) believe that there should be a long-term management plan for this species (Table 22). However, when considering only the French stakeholders this position is inverted, i.e., the majority feels there is no need for such a long-term management plan.

Table 19. Do you believe a long term management plan is needed for this specie? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Yes		No		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
Spain	10	62.5	6	37.5	0	0	16	100
Portugal	5	71.4	1	14.3	1	14.3	7	100
France	1	33.3	2	66.7	0	0	3	100
U.K.	1	100	0	0	0	0	1	100
NGO	1	100	0	0	0	0	1	100
All	18	64.3	9	32.1	1	3.6	28	100

Considering the 18 stakeholders that believe there should be a long-term management for this species, only 14 ranked the five management objectives proposed. There seems to be no general agreement on the order of importance of the management objectives (Figure 18). However, the two most important within all stakeholders is divided either by sustainability of the resource or maximum profitability. The second is stability of catch.

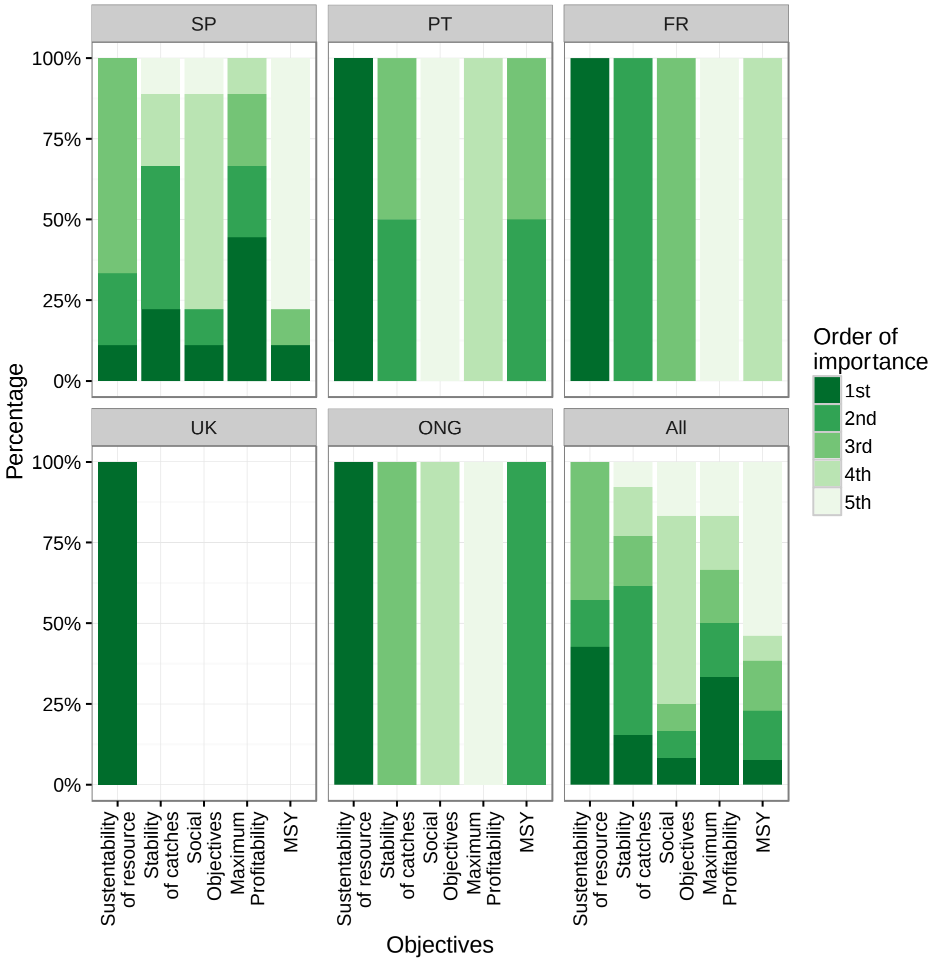

Figure 18. Rank your preferences for management objectives

Within the stakeholders that believe there should be a long-term management plan for this resource, the majority (83.3%) feels that the basis to establish a TAC or a maximum allowable level of catches should be based on the mean stock abundance in a period of years as opposed to what is in practice at the moment for the southern stock (Table 20).

Table 20. For a management plan, select the basis to establish a TAC or a Maximum allowable level of catches. The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	Last Year		Median of years		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
Spain	1	10.0	8	80.0	1	10.0	10	100
Portugal	1	20.0	4	80.0	0	0	5	100
France	0	0	1	100	0	0	1	100
U.K.	0	0	1	100	0	0	1	100
NGO	0	0	1	100	0	0	1	100
All	2	11.1	15	83.3	1	5.6	18	100

This group of stakeholders, however, seems to have no general agreement on how many years this should be based on (Table 21). From 3 to five or more than five, stakeholders are divided.

Table 21. If you chose the latter option, would you prefer the mean of the last 3 years, 5 years, or other. The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All).

Country	3 years		5 years		> 5 years		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
Spain	4	50.0	2	25.0	2	25.0	0	0	8	100
Portugal	0	0	1	25.0	1	25.0	2	50.0	4	100
France	0	0	2	100	0	0	0	0	1	100
U.K.	1	100	0	0	0	0	0	0	1	100
NGO	0	0	0	0	1	100	0	0	1	100
All	5	33.3	4	26.7	4	26.7	2	13.3	15	100

When asked to select or propose constraints for the definition of Harvest Control Rules, only 16 answered the question. Overall, restriction of variability in catches along years appears as the most selected constraint being followed by a proposed constraint (Figure 19). Proposed constraints can be seen in Table 22. Spanish and Portuguese stakeholders were the only that selected the other two proposed constraints.

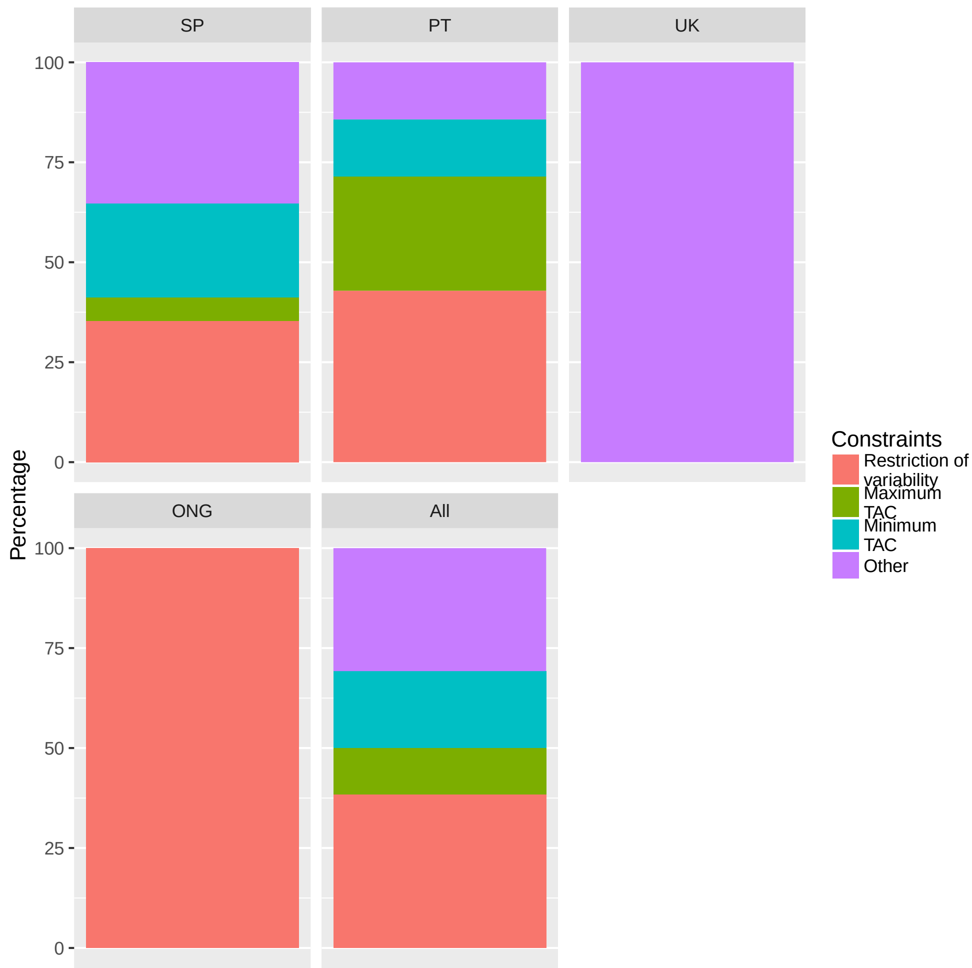

Figure 19. For a management plan, Select or propose constrains that you would ask for the definition of Harvest Control Rules.

Table 22. Suggestions reported by stakeholders that could be used for the definition of Harvest Control Rules. Values represent the number of (non unique) answers (A) among the N questionnaires that provided replies to the question (A/N).

Constraints	A/N
Flexibility in the agreed TAC	1/7
Controls dependent on stock size and recruitment – better definition of stocks required prior to long term management measures being introduced.	1/7
Restore management with control mechanisms and annual revisions to adjust TAC	1/7
TAC in function of stock and socio-economic circumstances	3/7

The majority of the 15 stakeholders that answered to question 27, believe that the technical measures suitable to achieve the goals established are a temporal ban during the main spawning period followed by the establishment of a daily quota per vessel (Figure 20). Both these measures are not considered the best suitable options by the NGO that participated; they feel that the two best options are a spatial and temporal ban in the main spawning and recruitment period. This is one of the situations where the NGO and the other type of stakeholders seem to be in disagreement.

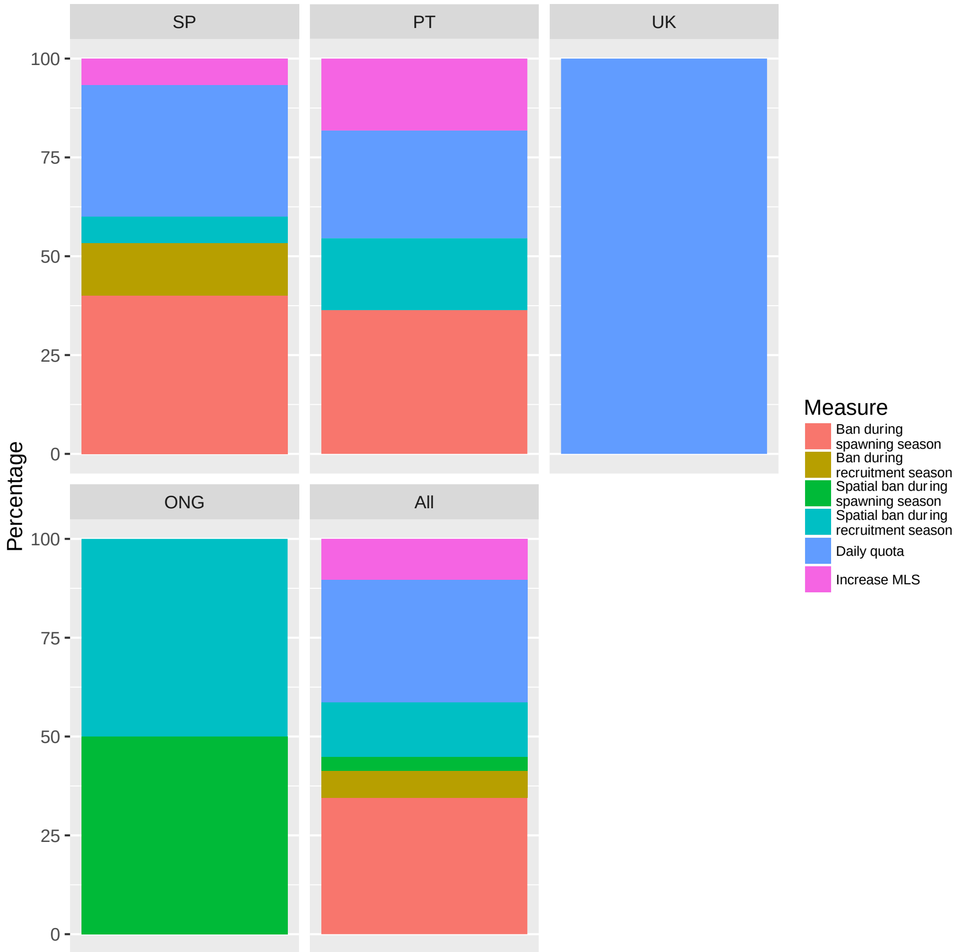

Figure 20. In order to achieve the goals established in the management plan, which technical measures to regulate the fishing effort, do you believe are suitable?

When asked they're opinion on whether they are in favour of any type of spatial explicit management, the Spanish and the UK stakeholders are not in favour, the Portuguese are and the others didn't answer. Considering all stakeholders, 61.1% is opposed to any spatial explicit management (**Error! Reference source not found.**).

Table 23. Would you be in favor of any spatial explicit management? The values presented correspond to frequency (N) and proportion (%) per country of respondents to each response option. Values are also shown for the entire group of stakeholders (All)

Country	Yes		No		NA		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
Spain	1	10.0	9	90.0	0	0	10	100
Portugal	2	40.0	1	20.0	2	40.0	5	100
France	0	0	0	0	1	100	1	100
U.K.	0	0	1	100	0	0	1	100
NGO	0	0	0	0	1	100	1	100
All	3	16.7	11	61.1	4	22.2	18	100

Only three stakeholders answered to question 29 either drawing on the map the geographical boundaries of a spatial explicit management or writing down these boundaries. One stakeholder reported that the boundaries should be from the north national frontier of Portugal down to Sagres, from the Algarve coast to the national frontier of Spain and the Spain (Gulf of Cadiz). Another one reported there should be only two areas, one from the South of Portugal and the Algarve, and the other one should be Gulf of Cadiz. The last stakeholder reported these areas with latitudes, from 36ºN to 37ºN and from there to 40ºN.

Discussion

Although the sample is relative small sample this is still an important feedback from stakeholders that can promote the ongoing dialogue. We now have their opinion on several aspects of the biology, management and dynamics of the species.

Regarding the French sample, all 3 questionnaires are from the small pelagic trawler stakeholders. The purse seiners (responsible for almost 95% of sardine catch), unfortunately, are not included in the sample. This might be an important issue when, for example, the French stakeholders don't choose maximum profitably as a management objective (question 24).

Stakeholders tend to have views on the area where they work, which is considered to be normal, and this may be one factor that contributes to the variety of answers and views described above.

From the responses, stakeholders don't seem to have a very good knowledge on the biology of the species. However, contributing to this maybe be the fact that the questionnaires where handed over to/sent to stakeholders and they didn't give sufficient dedication to it (e.g., too fast, no personal interactions, PO leaders and not really fishermen). This could probably be minimized if personal interviews would have taken place instead of a questionnaire.

However, stakeholders have knowledge on some important aspect of the biology of the species such as they seem to know that fish moves with upwelling because they selected as main factors influencing change in boundaries 'wind' and 'temperature'.

It should be mentioned that a great percentage of stakeholders believe that there should be more collaboration between fishermen and scientist. According to them this could benefit the quality of the official catch data and of the survey indices.

Regarding management of the fishery, and specifically selected measures for Harvest Control Rules, a discussion was raised on why stakeholders selected restriction of variability in catches along the years as their preferred measure. Is it related to the fact that when the stock is in a good state and the TAC is increased from year to year it is very difficult to adapt when there are slightly changes in the abundance (e.g., the fish moves somewhere, etc): the market is ruined, there are lots of landings. This could also be related to stakeholders belief that TAC should be based on the mean stock abundance in a period of years. They believe that this might restrict variability of catches.

Annex 10: Report of the Data Evaluation Workshop for Southern Horse mackerel (DEWKPELA2017–WKSHOM)

Within the ICES process to benchmark Pelagic Stocks (WKPELA 2017) two Data evaluation meetings were foreseen: the first one 26–30 September 2016 for the stocks of sardine (sar-soth & sar–78) and a second one 21–23 November 2016 for the southern horse mackerel stock (hom-soth), both taking place in Lisbon, hosted by IPMA and chaired by Andrés Uriarte.

The current report summarizes the issues addressed during the data evaluation workshop for southern horse mackerel.

The meeting was structured according to a set of presentations made following the agenda prepared for the Meeting (Annex 1)

Attendees are listed in Annex 2.

The following sections report on the presentations made and the issues on data compilations addressed by the Workshop. They all have first a summary of the information presented to group, followed by a summary of the main discussion and conclusion or recommendations passed to WKPELA.

Contents

10.1 Review information on Southern horse mackerel stock unit (HOMSIR) and on ongoing studies on Stock ID of North and Western horse-mackerel

By Gersom Costas.

Summary: The unit Stock is defined by FAO as a group of individuals in a species having same growth mortality parameters and occupying a particular geographic area. Currently, in the Northeast Atlantic waters there are three different stocks for Horse mackerel are used for assessment purposes: Southern, Western and North Sea stocks.

The current area of distribution of the Southern stock in ICES division 9.a was established from the EU-funded project HOMSIR (QLK5-CT1999-01438) on horse mackerel stock identification, in 2004. HOMSIR project defined the limits of horse mackerel stocks from North-eastern Atlantic to Mediterranean Sea through a holistic approach. Techniques they were used were: Genetics, parasites (biological Tags), morphological, molecular, otolith shape analysis, tagging, life history traits (Growth, reproduction and distribution). In the HHOMSIR project horse mackerel from the west Iberian Atlantic coast could be distinguished from the rest of the Atlantic areas. A genetic technique results showed significant differences between the west Iberian Atlantic coast and the rest of the Atlantic areas. The same result was obtained with the analysis of body morphometrics and partially with the otolith shape analysis. The parasite composition is also distinctive, although the results indicate the possibility of some relationship with the rest of the Atlantic areas. Therefore, it was to move the former boundary of the "Southern" and "Western" stocks from the Capbreton canyon (southeast of Bay of Biscay) to the Northwest of Iberian Peninsula (Galician coasts).

Currently there are a few new initiatives trying to better clarify on horse mackerel stock structure and stock boundaries. The project has been initiated by the Pelagic Freezer - trawler Association (PFA) and other pelagic industries, in collaboration with Wageningen Marine Research (formerly: IMARES) and University College Dublin. They make use of genetic, chemical analysis and information from commercial catch sampling. They have just started and they are looking for further funding. So far no concluding results are available. See Gersom Costas presentation and original papers of Abaunza et al. (2008), etc.

See for further information the presentation in WKPELA/09.DEWKPELA/Presentations.

Discussion/Conclusions: So far the prior definition of the southern stock holds on. The definition of the southern stock was well stablished from HOMSIR integrated project. There is currently no new information on this issue questioning such definition of stock unit.

In relation to stock ID: the analysis of spatial distribution of SHOM in terms of length and age from IBTS and catches shows that all ages are found within the current stock area definition… so migration outside the current geographic stock unit is not suggested from these analysis.

There are no major changes in the time series of Growth (section 4), nor across regions; they seem compatible and consistent in all places and years. This gives some support and assurance on the homogeneity of the stock structure.

10.2 Horse-mackerel spatial distribution in Portuguese waters

By Manuela Azevedo & Cristina Silva.

Summary: The length composition of the Portuguese bottom trawl catches of horse-mackerel was computed by trip, using a size-category approach (see item 10). The fish were grouped into three main fish sizes: i) small/juvenile (T5–T6), medium size (T3–T4) and large/old fish (T1–T2). Using bottom trawl VMS data, fishing effort (hours) was estimated by trip and grouped into three depth strata: i) shallower waters (0–100 m), intermediate (100–200 m) and deep (> 200m) waters. The presentation illustrates the catch size composition of horse-mackerel caught with bottom trawl along the Portuguese coast. It is shown that the size of the fish varies with depth strata. The deeper the fishing ground the bigger the sizes of horse mackerel caught. The pattern is very clear in the NW and SW Portugal. In the South zone, the fishing grounds are mainly at shallower and intermediate depths and hence the catch is dominated by small-medium size horse-mackerel. The purse-seiners operate along the coast at shallower waters (< 100 m depth), catching mainly small size fish which agrees with former observations on bathymetrical distribution of horse mackerel. It is shown an example of the catch length composition of a vessel from the polyvalent fleet segment which is licensed to operate with purse-seine and gill and trammel nets: the small fish are caught in trips at shallower grounds and using purse-seine gear while the medium-large fish are caught in fishing grounds in medium to deep waters and using nets.

See for further information the presentation in WKPELA/09.DEWKPELA/Presentations.

Discussion/Conclusions:

For future: Explore VMS data from Purse-seiners and Polyvalent-Nets trips to define horse- mackerel fishing ground by trip and to compute fishing effort; Model the trip time-series of the catch composition by size to investigate seasonal and spatial patterns and changes over time in distribution and abundance

Conclusion: the ontogenic migration of horse mackerel with age from shallow to deeper waters are clearly shown.

10.3 Horse mackerel distribution from IBTSurveys

By Hugo Mendes, Manuela Azevedo, Corina Chaves, Gersom Costas.

Summary: The Portuguese and Spanish IBTS survey are internationally coordinated bottom trawl survey that covers the Iberian Peninsula waters. These are surveys in autumn (October–November) that follow a stratified sampling scheme with a mixture of fixed and random fishing stations distributed across several sectors and depth strata. Survey data from 1992–2015 and from 1990-2015 were analyzed for the Spanish and Portuguese IBTS surveys, respectively. Fishing stations were grouped by areas N, NW, SW and S roughly corresponding to the subdivisions of the IXa. Moreover, the fishing stations were grouped by 3 depth strata: d1 (below 100m), d2 (100m–200m) and d3 (above 200 m). Total abundance (number/hour) of horse mackerel shows a patchiness in the distribution across the entire time series with occasional high values that seem to be consistent across all the areas; also showing significant correlations in some areas but with no clear relationship among contiguous areas. The bulk of the horse mackerel surveyed individuals are in the larger NW and SW areas and below 100m with some abundance in the intermediate layer. Age abundance data shows that the majorities of

surveyed individuals are from the younger ages (0–2) and are mostly distributed northward. Horse mackerel has clear and different occurrence distribution patterns across the three depth strata, showing a strong stratification of younger individuals onshore that gradually go offshore as they grow.

See for further information the presentation in WKPELA/09.DEWKPELA/Presentations.

Discussion/Conclusions:

The allocation to depth strata by haul will take into account the slight differences between the Portuguese and Spanish IBTS survey depth stratification at d1. Explore and track cohort abundance by zone and across zones from the surveys to help understand the spatial pattern of abundance and of occurrences by ages.

Age distribution changes by depth, this may ask for stratified estimates of CPUE. A suggestion to make the occurrence analysis also by length.

The seasonality analysis from CPUE data from the fishery may help understand the spatial pattern of spawning of big fishes.

In relation to stock ID: This analysis and the former one (section 2) shows that all ages are found within the current stock area definition. Thus, migration outside the current geographic stock unit is not suggested from these analyses.

In addition so many age classes suggest the stock is not heavily exploited. Those big fishes have a very high reproductive capacity and are the ones sustaining good spawning outputs. Perhaps those deep areas should be preserved from exploitation?!

10.4 Spatial and temporal patterns in length-at-age

By David Dinis, Hugo Mendes, Manuela Azevedo, Gersom Costas.

Summary: For stock assessment purposes, the catches at age are obtained quarterly by using quarter ALK. The main goal of this study was to investigate differences in the growth pattern seasonally, yearly and spatially across the ICES subdivision of southern horse mackerel distribution (9.a division). A Von Bertalanffy growth curve was fitted from 2004 to 2014, by season (quarter for Portuguese data and semester for Spanish data) and by area (N, NW, SW and S, see presentation 3). For comparative reasons, horse mackerel growth patterns from Division 8.c were also analyzed. The results showed no major differences in growth by season and year. However, the growth pattern in the south area, despite being similar until ages 8–10, shows a slight different growth on the older ages. We observed that the ranges in length distribution is very narrow for this area and most probably the growth difference is related to a poor sampling coverage of larger individuals in this area and not to a distinct growth pattern.

Other aspects such as differences in shape and deposition in the otholits could be further explored. This analysis showed that the growth is constant across years/seasons and in most of the southern horse mackerel distribution area. Moreover, the use of the 11+ group reduces most of the observed variability.

See for further information the presentation in WKPELA/09.DEWKPELA/Presentations.

Discussion/Conclusions:

The difference of the Growth in the southern area (after age 8+) is probably due to the limited length composition of catches, barely reaching very big lengths (because trawls operate over there in shallow waters at coastal or medium depth layers very rarely catching fishes of length overpassing 30 cm?)

Other aspects such as otolith miss interpretation might occur, but this is difficult to explain. In any case, these would imply little impact on the total age composition due to catches from the southern area representing around 10%. In addition as the plus group starts at age 11 the implications would be minimized.

Unique annual ALKs would be sufficient for age composition estimates? Growth curves do not change by quarters or semesters, but the question which should be answered by the analysis is if the ALK (i.e. the age composition by length or proportions by length) changes throughout the year (so further analysis is needed, perhaps by fitting logistic models). This is said because the aim of ALK is not estimating growth but age composition. And this is particularly relevant for the younger ages where growth is more intense.

In relation to stock ID: So there are no major changes in the time series in the Growth, nor across regions, as they seem compatible and consistent in all places. This gives some support and assurance on the homogeneity of the stock structure.

10.5 Spawning season, maturity and fecundity: Southern horse mackerel, Trachurus trachurus, Life-history: Reproduction

By A. M. Costa, Begona Villamor, Carmo Silva, Cristina Nunes, Daniel Pinto, José Ramón Perez, Mónica Inácio, Paula Abreu.

Summary/discussions: Information on the Southern horse mackerel (HOM) reproductive biology was compiled based on data from regular sampling of the commercial fleet, from AEPM/DEPM surveys, and from an annual cycle ad hoc monthly sampling undertaken in 2014. Results were presented for areas 9a C and S (and some for areas 9a N and 8c, too) on: sex ratio, proportion of maturity stages, comparison between macro and micro maturity stages, seasonal changes of ovarian histological (micro) characteristics in relation to the reproductive activity, gonadosomatic index (GSI), condition factor (K), length at first maturity (L50, macro and micro), and fecundity (total and batch). The analysis disregards lengths or ages (all ages and lengths were pooled together). Nevertheless a rather constant range of lengths appears in the series (with few exceptions as in the 2014 annual cycle and in some EPM surveys when smaller/younger fish were scarce).

There is some erroneous macroscopic assignation of maturity stages (e.g., in 2014, only 50% of macroscopic stageing were correctly done if microscopically examined), in particular between stages 1 and 2, which may disturb the actual percentage of maturity. The group questionned if the macro scale could be improved to better fit the micro analysis (or by using oocyte sizes and packing density methods), but this will be difficult.

Various indices (evolution of GSI, presence of POFs, vitellogenesis and NM oocytes, proportion of maturity stages) suggest that population spawning peak occurs during the first semester (max March–May), but HOM can spawn a bit all year around. Data from 2014 (data from fishes 20 cm onwards and for the NW of Portugal) show that vitellogenic and MN oocytes, and gonads with POFs, appear between March and May–June, whereas in summer and autumn time most of the females have non vitellogenic oocytes, and atresia becomes predominant.

GSI is maximum between January to May (1992/2015 & 2014), however, considering a shorter period of analysis (2010/2015), GSI appears much more constant throughout the year.

Condition factor shows an inverse pattern in relation to the GSI, but varies little with time. The group suggested that stakeholders could contribute with information about the fish condition and fat content, and spawning time.

For the maturity analysis, a logistic model was fitted to proportion of mature fish by length (with the separation for mature in stage 2+) during the main spawning season (Jan-May), and for females. In the catches, L50 estimates vary around 17cm (macro), whereas in DEPM surveys, L50 estimates were usually a bit lower micro than macroscopically, and in the 2014 annual cycle the L50 obtained microscopically was around 23.5 cm (larger than in any other year ??).

Fecundity (absolute or relative) is not relevant to assessment by the time being, though it is related with the reproductive potential by age classes, and thus to the S–R relationship and to stock resilience. Biologically it is of great interest assessing if the relative batch fecundity changes with age or not (if it is linear and crosses the X_axes at 0 or if it has a negative intercept).

See for further information the presentation in WKPELA/09.DEWKPELA/Presentations.

Conclusions: For management, the key issue on maturity is if a fish caught will spawn or has spawned in the current year, and evaluate the actual impact of such individual maturity determinations on the age maturity ogive.

Actually, maturity ogives by ages should be used. Maturity estimates from DEPM should be obtained, which make use of microscopical analysis (exercises shown from 2004, 2006, 2007 and 2010), for the DEPM years, and the historical mean of DEPM years, for the other years. Nevertheless, caution should be taken in regard to the sampling coverage of smaller fish (corresponding to the ages of first maturation), as in earlier EPM surveys, only females with macro stage 2 and above were collected for histology, stage 1 fish being undersampled.

- Required Exercise: Apply the ALKs (from catches of the 1st quarter) for the DEPM years to the maturity at length, evaluate the actual interannual variability in the maturity at age and how it compares with the currently applied maturity at age (in the stock annex, page 10).

  Result: work pending to be made after this meeting (in about 10 days).
- Required Task: Clarify the origin of the currently applied maturity at age, as inconsistency seem to exist in what is described in sections B.2 and D of the stock annex, in section 3.2.2. of the report of the 2011 benchmark assessment (WKBENCH 2011), and in later WGHANSA reports (e.g., section 8.3.3. of the WGHANSA 2016).

  Result: the currently applied maturity at age, which is in use since 2012 (included), is the result of the work undertaken by Murta *et al*. (WD 2011), who used microscopical information collected for females during the 2004, 2007 and 2010 AEPM/DEPM surveys carried out during the 1st quarter: ALKs obtained from catches (the 1st quarter of the same year) were applied to the proportion of mature females at length in the surveys; a logistic model was fitted to the resulting proportions of mature females at age from these 3 years of data; the stock ogive at age being the result of the estimates predicted by the model.

Remarks:

What was being presented for the western horse mackerel in the WGWIDE benchmarking???? They did not look at growth, nor for maturation.

10.6 IBTS: methodology to combine abundance-at-age from Pt-GFS-WIBTS-Q4 and Sp-GFS-WIBTS-Q4.

By Hugo Mendes, Manuela Azevedo, Corina Chaves, Gersom Costas.

Summary: The Spanish and Portuguese IBTS autumn are the only surveys used for tuning indices for assessment purposes and are currently treated as single survey. Raw data of the two datasets are merged and treated as a single dataset. In the past, data smoothing was tested using Generalized Additive models (GAM´s) with several distributions and age, year and year-classes as covariates but all tested strategies had a poor fit and undesirable patterns in the residuals. Consequently, a simple average of the number-per-hour by age (including zeros) is currently used as abundance index. The abundance data does not follow a normal distribution having a big proportion of zeros and a few extreme values if all the IBTS fishing stations are combined. Time series analysis of the probability of 0´s and P75%–defined as the probability of encountering hauls with abundance above the 75 percentile of the distribution (after removing the 0´s)–revealed a very significant negative correlation, suggesting that this stock expand his spatial distribution in high abundance years. Minor differences in these two statistics were found across areas (N, NW, SW, S, see presentation 3) but major differences across the three depth strata (d1, d2, d3, see presentation 3) revealed that this species is very often found in onshore areas. The estimates of abundance-at-age may be improved using GLM or GAM modelling/smoothing with depth as a covariate.

See for further information the presentation in WKPELA/09.DEWKPELA/Presentations.

Discussion/Conclusions:

This study shows that the probability of 0´values and the encountering of big shoals is closely related with the depth strata. So they will try a two stage modelling presence/absence and then probability of abundance given presence, including the depth as a covariate (compulsory). Several distributions will be tested (e.g. negative binomial, binomial) with GLMs, GAMs or GLMM. Also paying attention to the year and age effects.

There is already some work in modelling horse mackerel distribution that could be further explored (Sousa *et al.*, 2007; Murta *et al.*, 2008 see in WKPELA/09.DEWKPELA/References).

Looking at the analysis of surveys from the western horse mackerel stock (Gersom) there are lessons to be learnt about different modelling methods, e.g. including the correlation between probability of presence and abundance. These analyses will be carried out in the following weeks and they will be ready before the benchmark in February.

10.7 Southern horse-mackerel (*Trachurus trachurus*) information from Egg Production Method surveys. 90's to present - IPMA

By Maria Manuel Angélico, Elisabete Henriques, Ana Costa, Cristina Nunes.

The information from a series of Egg Production surveys, from 1998 to 2016, was summarized and maps with egg distribution of all available campaigns were presented. Following the redefinition of the southern horse-mackerel stock (HOMSIR project) and the mounting evidence for the species, in the southern region, to exhibit an indeterminate fecundity pattern, the DEPM was adopted after 2004. So far, four surveys using the DEPM methodology were conducted in the area of the southern stock (2007, 2010, 2013, 2016). In order to adopt the DEPM, several studies were carried out over the years. The presentation shows the progress undertaken in: (i) sampling design – increase in the grid spatial resolution and modification of the gear used for egg collection and also increase in the number of adult fish sampled making use of RV and commercial sampling; (ii) egg identification and stageing/ageing – development of artificial fertilization experiments under temperature controlled conditions, for egg description and morphometric analyses and egg development modelling with temperature; The rates of development were assessed using a multinomial modelling approach. The experiments showed that eggs of T. picturatus are very similar in appearance to those of T. trachurus but the former are slightly but significantly larger. Egg development until hatching occurred in 67 hours for T. trachurus while T. picturatus needed an extra 8 hours at a water temperature of 16.5ºC. (iii) egg identification/genetic analyses – primers were design which allow sorting apart the three species of the Trachurus genus which could potentially be misidentified in the plankton samples. Results of the morphometric and genetic analyses proved a very good agreement with the routine identification using binocular microscopy; (iv) daily spawning pattern/synchronicity – this issue was readdressed, based on the investigation of the (24h day) time distribution of the stage I eggs in the plankton and of the post-ovulatory follicles (POFs) size in the ovary, the evolutionary pattern of the diameter of the oocyte advanced batch in the ovary and of the relative batch fecundity of the hydrated individuals; all results argue strongly in favour of the existence of a daily spawning synchronicity for the southern stock horse-mackerel, spawning seeming to take place mostly towards the end of the day (18–19h from eggs data, after 16h from adults data); (v) fecundity type – revisiting of this issue, with results corroborating the indeterminate spawning strategy of the southern stock horse-mackerel (vi) spawning fraction determination – making use of a series of spawning markers, eg. migratory nucleus (MN) and hydrated oocytes (HO) and POFs), and for the latter, complemented with the development of a POFs stageing/ageing methodology and the spawning synchronicity results, estimates of spawning fraction can be achieved for some of the DEPM surveys.

The aggregated egg data distribution showed a spawning area for the species over the entire shelf with a higher occurrence of positive stations in the outer shelf. However there was a considerable inter-annual variability in the egg densities distribution and that analysis was not yet taken into account in the analyses of the egg depth distribution. Egg production estimation could be attempted for the majority of the surveys presented but there are some assumptions that should be considered owing to the different spatial coverage of the surveys in the series. An index of egg abundance can be available for the benchmark meeting considering egg densities and spawning area (sampled). Spawning stock biomass estimations for the more recent surveys are planned to be presented at the next WGMEGS meeting in April 2017.

Notes

Triennial surveys applying the DEPM to SHM since 2007/2010/2013/2016.

Methodological issues: Sampling grid (10 nm spaced transects). Calvet of 40 cm diameters with CTDs. Vertical hauls reaches 200 m. Spatial distribution of eggs are shown to be restricted to the continental shelf. Egg identification issues with T. picturatus. (Genetics proves that 87% of eggs were correctly classified by eye). Peak spawning time at 18-19 horas with sigma of 6 hh.

Indeterminate spawner; this being clearly established for this population (Ganias et al. 2016). For the western stock they only use currently the total Egg production. There isn't yet any S parameters available. They plan to do in a few weeks making use of POF (for almost 4 days) and perhaps MN oocytes.

Spawning seems (according to occurrence) to happen beyond the 100 m depth. They have to produce the P0 and Ptot estimates with the usual GLM model.

They are looking at the CUFES data to improve as well.

See for further information the presentation in WKPELA/09.DEWKPELA/Presentations.

Discussion/Conclusions:

It is questioned the validity of the P0 estimation procedure with the GLM. But this is the usual method for the DEPM.

Potential use of strata for P0 and Z estimates. Consider including the covariate with depth for the GAM modelling.

Good indicator should be based on Ptot, try to make parallel analysis to Sardine in modelling for P0 and Z. Alternatively Egg Abundance over the whole area could be a valid indicator.

Suggest to produce a series of indicators from this survey: Select the best years (an omit the Northern area, Galicia, to set an area of reference for the indicator – common and consistent area throughout the series).

Adult parameters can be based on the POFs and advanced MN oocytes occurrence. SHOM is shown to spawn all along the Portuguese coast.

What happens with the 2005 (earlier coverage and very cold temperature). If any environmental factor would be relevant then the use of Ptot or egg abundance indicators would be affected by those disturbances. IN addition it should be discarded any miss identification of eggs in that year (with jack mackerel for instance which is known to have been abundant in those year (something to be checked by Vitor – acoustics – Mmanuel – eggs). (Preliminary re-analysis of egg samplings suggests that there was no misidentification of eggs). It would be worth comparing the results from the IBTS surveys wich points out to high value in that year).

Work before WKPELA meeting (6–10 February). Make a brief presentation for day 5 December (seeking for expert feedback). IN addition a WD should be submitted during January to WLPELA (at the latest on January 23) for the people to check it in advance.

10.8 Spring Acoustic Survey: spatial distribution of juvenile fish and qualitative indicator of recruitment strength

By Eva García-Seoane, Pedro Amorim, Vítor Marques.

Summary:

The aims of this study were: (i) to investigate if the spring acoustic survey represents the spatial distribution of horse mackerel juveniles, and (ii) to investigate if this survey is a qualitative indicator of the recruitment strength of this species. The acoustics fishing are planned according to previous knowledge of sardine resources (transects cover from 20 to 150 m depth). However the horse mackerel distribution exceeds the 150 m depth. In 2009, 2013 and 2016, horse mackerel estimations (based in acoustic data) were conducted during the spring surveys. In 2013, these estimations were also made in the autumn acoustic survey. Higher values of acoustic estimations were associated to the higher proportions of horse mackerel in the hauls. We also analyze the horse mackerel data provided by the pelagic and the bottom trawls. In the northwest area, medians of length class distributions seem to be smaller than the medians in the south and southern areas. We found a positive relationship between fish length and bottom depth, i.e. size of the individuals increase with increasing bottom depth. Juvenile abundance estimations calculated from haul data were different from the recruitment estimation of the ICES. In conclusion, data from pelagic and bottom trawls is an indication of the spatial distribution of horse mackerel, inside the 100 m depth, but is not a good indicator of the recruitment strength.

See for further information the presentation in WKPELA/09.DEWKPELA/Presentations.

<u>Discussion/Conclusions:</u>

Not in all years they could produce acoustic estimates of SHM, because in some years there are few fishing hauls for horse mackerel.

The size of SHM fishes are mainly small corresponding to juveniles. That is why they looked for indicators of juvenile abundance. An indication of juvenile abundance would be useful for short-term forecast. However, so far, the few acoustic abundance estimates were not associated to recruitment estimates from assessment, not the occurrence of the juveniles in fishing hauls. The reasons might be related to: a design prioritising fishing for sardine // only small juveniles are catchable with the current fishing haul and over the coastal areas where most fishing hauls are launched. Fishing for horse mackerel was not a priority.

Suggestion for improvements: To increase the amount of fishing hauls for identification of horse mackerel. With a proper design this survey could be improved to provide an indicator of SHM juveniles. What matters to improve the survey design is the Ship (equipment and the ability to fish the big fishes as it depends on the engine power while trawling, the gear and the time for surveying.) However the surveys it is not ready to provide such an outcome. So it is promising for future (next benchmarking?). So the first priority for SHOM Juveniles should be to add some more time for making more identification fishing hauls (extended around 10 days. It will also be necessary a larger pelagic net (net of 20 m vertical opening) and trawl ship speed of at least 4.5 knots.

In addition work on the TS should be carefully examined (as for many other species).

An examination of possibilities to improve the survey to achieve the goal of providing an indicator of recruitment should be examined at IPMA.

Final Discussion and conclusions (all) on INPUTS (IBTS surveys / DEPM /Spring Acoustic surveys):

IBTS are the basic tuning survey for the assessment, but further standardization work by GLM/GAM modelling including depth is to be done.

DEPM could provide complementary information for stock assessment on an indication of SSB. However is not yet fully available and more work is being carried out. The final utility of DEPM will be pending on the construction of a series of an Indicator of spawning stock (e.g. Ptot or egg abundance or SSB series).

Acoustic series is not operative yet for providing an indicator of juvenile abundance.

In conclusion there is a need to finish the Work before WKPELA meeting (6–10 February). Both IBTS and DEPM surveys should make a brief presentation for day 5 December (seeking for expert feedback). In addition respective WDs should be submitted during January to WLPELA (at the latest on January 23) to allow the people to check this in advance.

10.9 Historical Spanish catch data in ICES 9.a north

By Gersom Costas.

Summary: There was a requirement on recovering Spanish horse mackerel catch data from Subdivision 9aN 1992 backward but that was not possible. Catch statistics were submitted by area backward 1992 since the definition of the ICES subdivisions were set in 1992 and some of the previous catch statistics came from an area that comprises more than one subdivision. This is the case of the Galician coasts where the Subdivisions 8.a West and Subdivision 9.a North are located. The separation of the catches of Subdivisions 9.a North from 8.c West has not been possible to do, the people who compiled that information are not any more working now, and it might have been done by just by hand. They cannot provide yet any recompilation of the catch at age prior to 1992 for the Benchmark.

The Spanish catches in Subdivision 9.a South (Gulf of Cadiz) are not included in the assessment data. This was a decision taken in the former WKBENCH 2011 due to the lack of catches prior 2002. In addition catches by length in this subdivision only are available since few years ago (since 2009) and there is not age reading. On the other hand, the total catches from the Gulf of Cádiz are scarce and represent less than the 5% of the total catch. By then the benchmark concluded that "they will not be included in the assessment data until they are available for all assessment years, to avoid a possible bias in the assessment results. Therefore, their exclusion should not affect the reliability of the assessment." For the time being the catches prior to 2002 have not recovered and hence the WG keep on the previous position.

We ask for a proper reporting on the actual knowledge available from cadiw before the benchmark.

10.10 Catch length composition estimated from modelled commercial size-categories

By Manuela Azevedo and Cristina Silva.

Summary: In Europe, there is a requirement for fishery products of several species to be graded on the basis of size categories (over 30 fish and crustacean species). In Portugal, several fish are landed and sold at auction in boxes with fish of uniform size and labelled with the fish commercial size category. The number of size-categories varies with species. Horse-mackerel has six size categories, labelled T1 to T6. The study shows the approach to model the length distribution by size category from onshore sampling data and how the modelled length composition by size category can be used to estimate the landings/catch length composition, designated "size category" approach. Using the grade in landings to estimate the catch length composition overcomes the limitations of the current "trip" raising approach (e.g. unbalanced sampling of some gears or too high raising of few samples). The size category approach was used to estimate the trip catch composition by size shown in presentation 2 (Azevedo and Silva: horse mackerel spatial distribution in Portuguese waters). There is a very low inter-annual variability of the mean length by size category. The approach is applied to the Portuguese annual catches of horse-mackerel in the period 2013–2015 to estimate the catch- at-length and catch-at-age by fleet segment which are compared to the catch-at-length and catch-at-age obtained with the "trip" approach. The main differences between approaches (size category vs trip approach) occur in the younger ages (0–2) both in Purse-seine and polyvalent catches.

The WG adopted the conclusions from the presentation:

- Size-category approach allows estimating the catch length composition at trip level: trip approach under/overestimating the catch length composition; e.g in 2013 few onshore samples from PS catch were collected in the NW-SW area, mainly in the 3rd quarter hence raising sampled trips to total catch resulted in overestimation of small size fish in PS catches // pos-stratification of trips by fleet segment; better characterization of PS and polyvalent catch length composition.
- Size-category approach requiring lower onshore sampling effort.

For the future: They plan to make a Pilot sampling plan during 2017: Test in the field (Portuguese onshore sampling) a size category sampling design and sampling effort to estimate horse-mackerel catch-at-length and catch-at-age composition

Discussion: there might be some mismatches between the vessel categories in the officials sampling and the one applied in the study (perhaps explaining some of the differences between the polyvalent fleet).

The current approach can be more precise and less subject to random errors than the official practice.

Conclusion: Globally in terms of catches at age new catches at length did not lead to major discrepancies compared to the former catch at age estimates based on the trip sampling for lengths. Therefore the authors are not planning to revisit the past series of length and catch at age composition. They propose to base the Portuguese inference on length composition on the new approach for future. By prudence they propose to make the pilot research in 2017.

Summary Discussion and conclusions (all): on the time-series of catch-at-age (all).

In principle no revision of the past catches at age are expected to be done for WKPELA 2017.

Natural Mortality (M)

Currently M Changes and reduces with age.

Age	0	1	2	3	4	5	6	7	8	9	10
Nat Mor	0.9	0.6	0.4	0.3	0.2	0.15	0.15	0.15	0.15	0.15	0.15

There is no new information that allows revising the current values. No information from tagging available. There is no new quantitative data from trophic interaction that allows changing the current values. Small horse mackerel is more targeted by predator species and have higher mortality than the bigger (older) fishes. Work undergoing by Hugo Mendes confirms that some species as horse mackerel move up the trophic level as they grow reducing their natural mortality by predation. So former assumption is going to be maintained.

10.11 Assessment models and data use as inputs for assessment and forecast

By Manuela Azevedo and Gersom Costas.

Summary: The current stock assessment is performed with a the statistical catch at age model (AMISH) adopted in the Benchmark 2011 (WKBENCH 2011) and describe in the stock annex (hom-soth_SA). Until 2011 the analytical stock assessment was performed with XSA and the implementation of AMISH model improved the residual and the retrospective pattern in F and SSB because it allowed greater flexibility in underlying assumptions for several parameters (e.g changes in the selectivity pattern). At present (WGHANSA, 2016) a good fit is obtained for the proportions-at-age of the catch in numbers as well as for the abundance indices in number/hour from the bottom-trawl survey. However, the retrospective analysis suggests an underestimation of SSB and an overestimation of F. There are also changes in SSB and F in recent years (compared to previous assessments). The retrospective pattern is mostly likely due to the addition of the strong recruitments in 2011 and 2012 and a change in the selection pattern to increased selectivity of young ages and decreased selectivity of older ages in recent years. The selectivity vectors (2 periods for catch-at-age and 5 for the survey index) defined during last benchmark have not been changed (update assessments). Therefore, these vectors should be re-evaluated during the benchmark. The IBTS survey is the independent source of stock abundance-at-age but the age range is 1–11+ due to the strong variability at age 0. This strong variability should be tackled with the modelling approach suggested for IBTS survey (see section 6). Smoothing the data for younger individuals may improve recruitment estimates.

Discussion: Selectivity patterns in the index: Before there was an XSA assessment with great residuals. A model allowing changing selectivity in time would be preferable. That was the reason for selecting AMISH. So the periods were selected to reduce the strong patterns of residuals. The selection of periods are relevant for the assessments, there should be a discussion on the selections made and on the basis to change them. Explanations for the subperiods selected should be documented in the benchmarking report. Any changes should lead to a better fit.

Maturity is fine but if there are changes in the matrix it will imply revisiting the Reference points. The use of microscopic histological analysis may lead to changes in that scale (pending to be solved).

Natural mortality (decreasing with age): we do not have indications requiring any changes here. Stock annex will be revisited to include any new overview or information available (along with the ecosystem considerations). It is clear that the trophic level of SHOM changes and increases with age, this can be an indicator of the lower M values with age.

There is little contrast in the data input (rather stable abundance) and catches, they all lead to uncertainty (confident intervals with CV around 30%), but that is not a problem in itself. It gives some assurance on the stability perspective, but puts uncertainty in the actual biomass values at sea.

Regarding very high values as the ones observed in the surveys in 2005. Provided the model assumes lognormal errors it could consider to allow for correlation errors in observations by ages.

The model allows for aggregated SSB indexes (in cases DEPM values would be ready) (to be verified).

Information available from stakeholders relevant for southern horse mackerel

Most of the information regarding the management plan and HCRs will be dealt in the meeting foreseen for the 24th of November. There is a warning remark about the potential for increasing fishing mortality on juveniles as result from the recent increase of the purse seine catches (to be confirmed?).

10.12 Southern horse mackerel management plan: First set of stochastic simulations to get feedback from stakeholders

By Manuela Azevedo, Hugo Mendes, Gersom Costas.

To inform and update the participants in the meeting on the development of a management plan (MP) for southern horse mackerel it was used the presentation at the Pelagic Advisory Council (PELAC) meeting on the 5th October 2016 (Southern Horse Mackerel (9.a) Management Plan – 1st set of stochastic simulations to get feedback from stakeholders). The development of a MP started in late 2014 by initiative of the PELAC that aims to set MP for as many stocks as possible. Several meetings have been carried out since 2014 involving IPMA and IEO scientists, stakeholders (from PELAC and SWWAC and ONGs) to discuss main features of the MP, such as objectives, biological reference points and harvest control rule. Biological Reference Points (BRPs) were adopted by ICES in current year, following the analysis carried out during the 2016 WGHANSA meeting. Preliminary simulations using a MSE "short-cut" approach were carried out for three options of management scenarios and considering two productivity scenarios.

The starting conditions were based on the latest assessment (WGHANSA 2016) and the simulated populations were projected from 2017 to 2070. Results were presented to stakeholders and several questions were raised to define key aspects for the starting conditions and for management options to be considered in the simulations. A questionnaire on these key aspects was sent to stakeholders.

Closure of the meeting and work plan for next WKPELA meeting

The current version of the report was reviewed in plenary at the end of the meeting.

Pending issues on any of the topics addressed above which should be finalised for the WKPELA meeting (Feb 2017) are listed within every section above.

Annex 1: Draft Agenda

WKSHOM – Workshop on data evaluation for Southern Horse Mackerel 21–23 November, IPMA-Lisbon.

Agenda (Draft)

Start 21 Nov, 09:30 & end 23 Nov, 18:00

Coffee-break: 1100–1130; 1600–1630; Lunch-break: 1300–1430 Social dinner: 22 Nov, 8 pm

Day 21

09:30–13:00 (Stock ID)

- Review information on Southern horse mackerel stock unit (HOMSIR) and on ongoing studies on Stock ID of North and Western horse-mackerel
- Horse-mackerel spatial distribution in Portuguese waters
- Discussion and conclusions (all): Stock unit 14:30-18:00 (Life-history traits: Growth/Reproduction)
- Spatial and temporal patterns in length-at-age
- Spawning season, maturity and fecundity
- Discussion and conclusions (all): Age-length-keys & Maturity-at-age

Day 22

09:00–13:00 (Fishery-independent data)

- IBTS: methodology to combine abundance-at-age from Pt-GFS-WIBTS-Q4 and Sp-GFS- WIBTS-Q4
- DEPM: reproductive potential, egg identification, time-series of egg distribution and abundance, spawning synchronicity and egg production (PO) estimation
- Spring Acoustic Survey: spatial distribution of juvenile fish and qualitative indicator of recruitment strength
- Discussion and conclusions (all): IBTS as the tuning survey and complementary information from DEPM and Spring Acoustic survey for stock assessment and short-term forecast

14:30–18:00 (Fishery-dependent data)

- Historical Spanish catch data in ICES 9.a North (some recovery of data available here)
- Catch length composition estimated from modelled commercial size-categories
- Discussion and conclusions (all): time-series of catch-at-age

Day 23

09:00–13:00

- Assessment models and data use as inputs for assessment and forecast
- Information available from stakeholders relevant for southern horse mackerel
- Horse mackerel management plan: Biological Reference Points, Harvest Control Rule and evaluation

14:30–18:00

Summary of main conclusions and work plan for WKPELA (6–10 Feb 2017)

Annex 2: Attendees

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Annex 3: Presentations (appended to this report)

Annex 3 Presentations DEWKPELA (WKSHOM)

Review information on Southern horse mackerel stock unit

Gersom Costas

Data evaluation Workshop for Southern Horse Mackerel (DEWPELA hom-soth).
Lisbon. 21–23 November 2016.

Introduction

Stock concept:

FAO defines stock as a "subset of one species having the same growth and mortality parameters, and inhabiting a particular geographic area"

Stock structure information

uncertainty in fisheries management

HOMSIR project

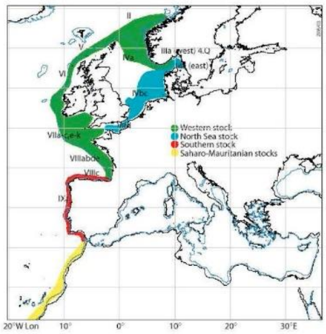
A MULTIDISCIPLINARY APPROACH USING GENETIC MARKERS AND BIOLOGICAL TAGS IN HORSE MACKEREL (*Trachurus trachurus) STOCK STRUCTURE ANALYSIS*

Objective: biological stock identification of the horse mackerel throughout its whole range, from North-eastern Atlantic to Mediterranean Sea.

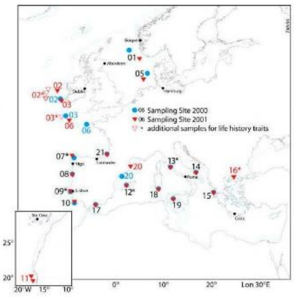
`holistic' stock identication approach

HOMSIR

Former distribution of stocks



Realised sampling



Range of stock identication techniques

•Genetics: multilocus allozyme electrophoresis (MAE), microsatellite DNA, mitochondrial DNA on control region and two enzymatic regions and (SSCP) on nuclear DNA.

•Parasites: The use of parasites as biological tags. identification of the species by morphological criteria and molecular

•Morphometry. body and otolith shape differences among areas or samples.

•Tagging: It was explored

•Life history traits: Growth, reproduction and distribution are the resultant in space and time of the population dynamic characteristics.

Genetics

4 genetics techniques

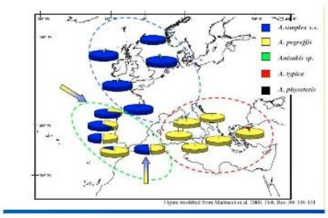
The SSCP technique on nuclear DNA, was succesful in finding a genetic marker.

Low levels of genetic differentiation, high genetic variability and a stable genetic structure over time

The Atlantic Iberian coast is separated from the rest of the Atlantic areas.

Significant differences between the horse mackerel from the Atlantic Ocean and the Mediterranean

Parasites



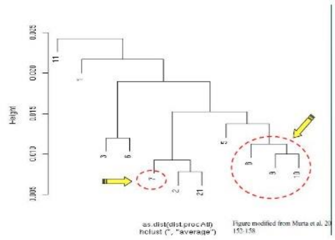
Distinguish the North Sea population from the rest of the Northeast Atlantic sites

Evidence of some migration from areas to the west of the British Isles into the North Sea, possibly restricted to older fish.

Morphometry

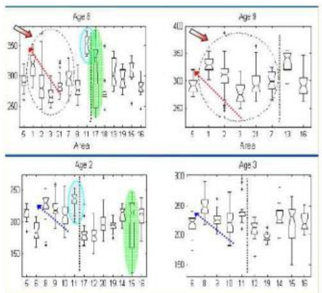
Body morphometrics. three well differentiated groups in the Atlantic Ocean: current t 3 stocks

Otolith shape separation of the Portuguese coast from the more northerly Atlantic areas



Life history traits: Growth

Great variability in growth along its distribution area



Clear pattern of increasing length with latitude:

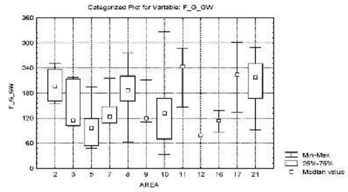
areas 3 2 1
areas 10 9 8 7

Mauritania shows the highest length at age values

Life history traits: Reproduction

Maturity ogives suggest thatfirst maturity seems to decrease with decreasing latitude

Batch fecundity: it seems to occur a decreasing trend in batch fecundity with decreasing latitude when batch fecundity is related with length; in terms of the number of eggs per gram of female gutted weight, no clear trend exists



Main results

There is certain homogeneity in the characteristics of the horse mackerel from the west European waters (from Galicia to Norway) based on:

- Otolith shape analysis
- Body morphometrics
- Anisakid species composition

There are clear signals of migratory movements throughout the Atlantic areas, based on:

- Distribution of commercial catches
- Parasite species composition
- Life history traits
- Distribution of indices of abundance by age.

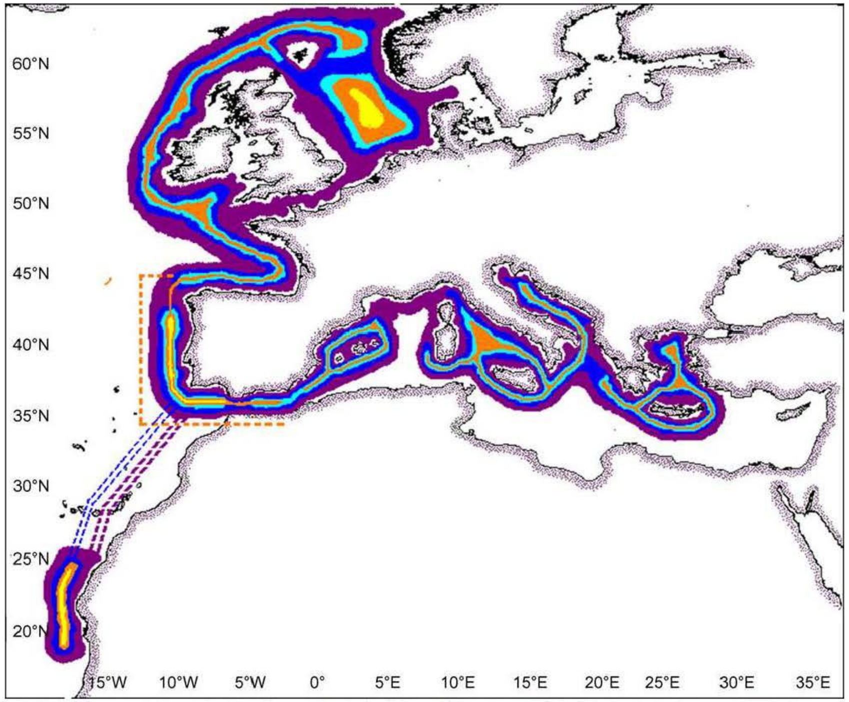
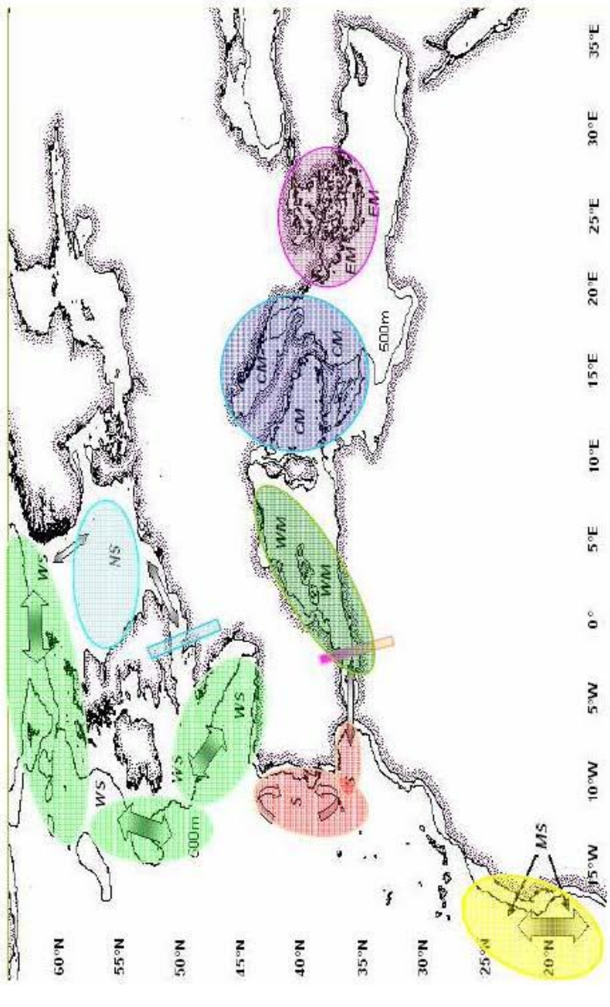
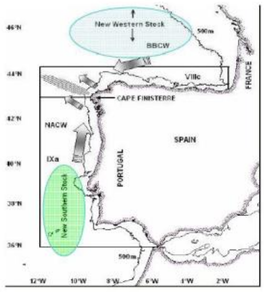


Fig. 2. Map of the study area showing the results obtained from different stock identification techniques applied in horse mackerel (*T. trachurus*). ( ) Genetic techniques (allozymes, mtDNA, msDNA); ( ) otolith shape analysis; ( ) body morphometrics; ( ) parasites as biological tags; ( ) life history traits (growth, reproduction, distribution). Dashed line in orange colour: detail of the results from anisakid species composition. Dashed lines in dark purple and dark blue indicate similar results in genetics and otolith shape analysis between the connected areas.


WS
NS
WM
CM
EM
S
MS
500m
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
20°N
15°W
10°W
5°W
0°
5°E
10°E
15°E
20°E
25°E
30°E
35°E

Iberian Peninsula

Horse mackerel from the west Iberian Atlantic coast can be distinguished from the rest of the Atlantic areas.
The northern boundary of the “southern stock” was revised, and accordingly, the shouthern boundary of the “western stock”



The southern boundary of the so called “southern stock” is more uncertain

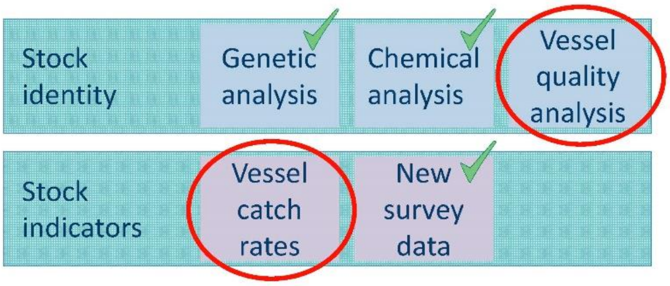
Current projects Horse mackerel stock ID

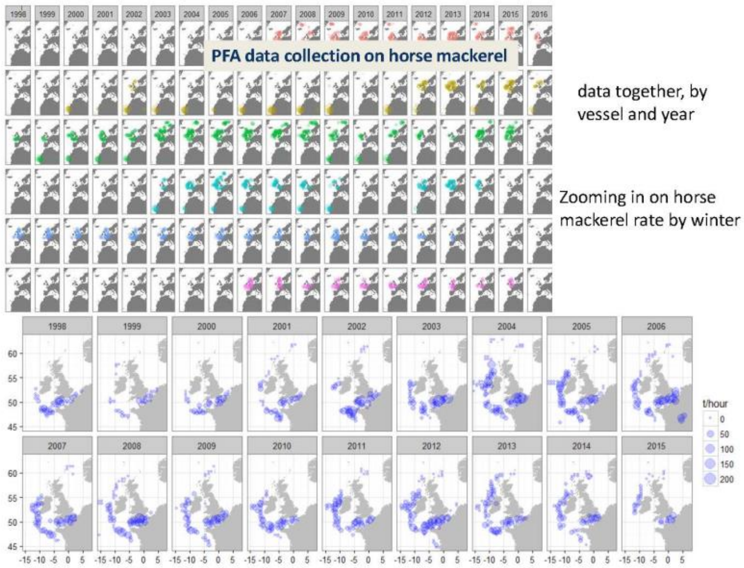
Aim: Developing new methods to get insight on stock boundaries and abundance on North Sea horse mackerel

UCD / Genetic Analysis: larger sample set (include southern stock or Med outgroup)

PFA : make use of fishermen’s knowledge and information. Use haul by haul catch information from personal logbooks to derive abundance indices quality records (fat content, pictures)

Focus areas




PFA data collection on horse mackerel
data together, by vessel and year
Zooming in on horse mackerel rate by winter
t/hour
0
50
100
150
200

DEWKshom, 21-23 November 2016, Lisbon

Horse mackerel size spatial distribution in Portuguese waters

Azevedo, M and Silva C (*in prep*). Using commercial size categories to model fish size seasonal and spatial distribution and to investigate changes over time

Manuela Azevedo & Cristina Silva

Data

- ✓ Year: 2013
- ✓ Catch (weight) by trip and commercial size category
- ✓ Onshore length sampling data by commercial size-category
- ✓ length-weight relationship
- ✓ Bottom trawl VMS data by trip

Method

✓ Catch (number) by trip and commercial size-category (T1-T6)

• Length distribution by commercial size-category
(Azevedo & Silva: Commercial size category approach to estimate horse mackerel catch length composition for stock assessment. DEWKShom)

• Raising factor by size-category
catch (weight) by size category / mean weight by size category

• Fish size groups
Small (T5-T6), Medium (T3-T4), Large (T1-T2)

✓ VMS (Bottom trawl)

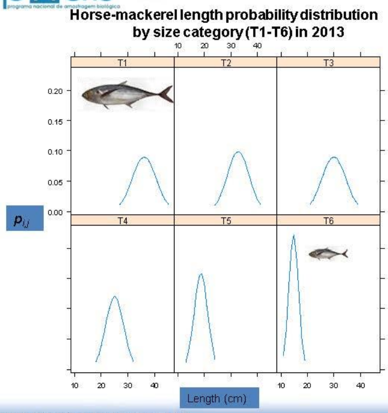
• Fishing effort (fishing trips) derived from VMS data
Fishing trips with information on port and time of departure and arrival, trip duration and fishing hours (assuming a speed profile for the fish trawl)

• Fishing grounds (only Portuguese fishing grounds were considered)
NW (north of Nazaré canyon: 39.6º – 41.5º N), SW (south of Nazaré canyon: 37º – 39.6º N), S (Algarve area: south of 37º N with the border with Spain as the eastern limit)

• Depth strata
[0,100[[100, 200[[200,1500]

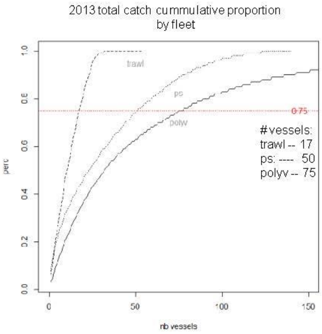
Trips were linked to landing records according to the port and date of arrival

Results



Size categ	Mean Length (cm)	Age
T1	38	11+
T2	35	11+
T3	30	9
T4	25	5
T5	19	2
T6	15	0

T1-T2: large, old fish
T3-T4: medium
T5-T6: small, juvenile fish

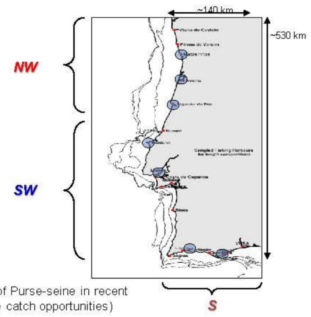


		2013		
Fleet-Metier	Vsize	# Vessels	# Trips	Landing (t)
Trawl	[12-18[	7	380	83
	[18-24[	7	171	9
	[24-40[	40	5017	7685
PSeine (include Polyv vessels)	[0-10[	277	3880	659
	[10-12[	53	1305	522
	[12-18[	86	2056	749
	[18-24[	65	2016	3124
	[24-40[	18	612	675
Nets (from polyv fleet)	[0-10[	516	6359	197
	[10-12[	52	862	227
	[12-18[	131	3111	533
	[18-24[	44	2075	736
	[24-40[	1	5	18

Catch in weight (2013, prop) by fleet segment & area (NW-SW-S)

Proportion by zone/fleet

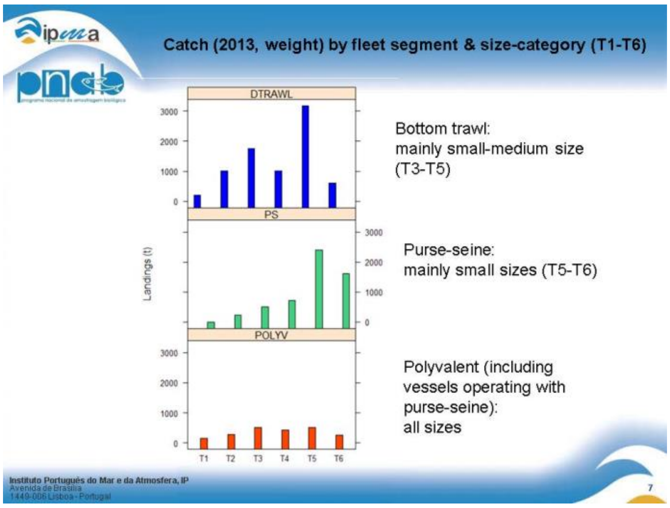
year	area	Fleet			
		Trawl	Purse-seine	Polyv	
	NW	0.53	0.31	0.16	0.47
2013	SW	0.49	0.39	0.12	0.38
	S	0.38	0.49	0.13	0.14
	NW	0.61	0.19	0.21	0.40
2014	SW	0.53	0.40	0.07	0.42
	S	0.40	0.52	0.08	0.17
	NW	0.41	0.43	0.15	0.45
2015	SW	0.59	0.30	0.10	0.40
	S	0.38	0.53	0.09	0.15



- Catch mainly from trawl fleet, though increasing importance of Purse-seine in recent years (effort shift to catch horse-mackerel due to lower sardine catch opportunities)

- Catch mainly from NW & SW area (40-47%)

- Trawl mainly NW-SW; Polyvalent mainly in NW & Purse-seine in the South



ipma
pnab
Catch (2013, weight) by fleet segment & size-category (T1-T6)
DTRAWL
PS
POLYV
Landings (t)
T1 T2 T3 T4 T5 T6
Bottom trawl:
mainly small-medium size
(T3-T5)
Purse-seine:
mainly small sizes (T5-T6)
Polyvalent (including
vessels operating with
purse-seine):
all sizes
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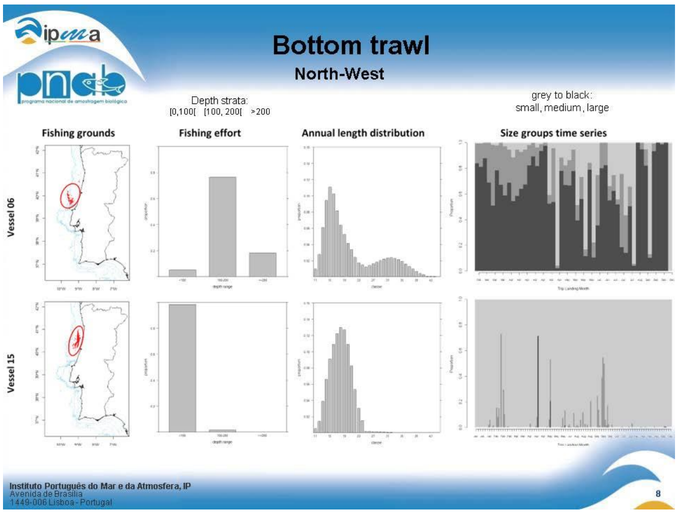

Bottom trawl
North-West
Depth strata:
[0,100[[100, 200[>200
grey to black:
small, medium, large
Fishing grounds
Fishing effort
Annual length distribution
Size groups time series
Vessel 06
Vessel 15
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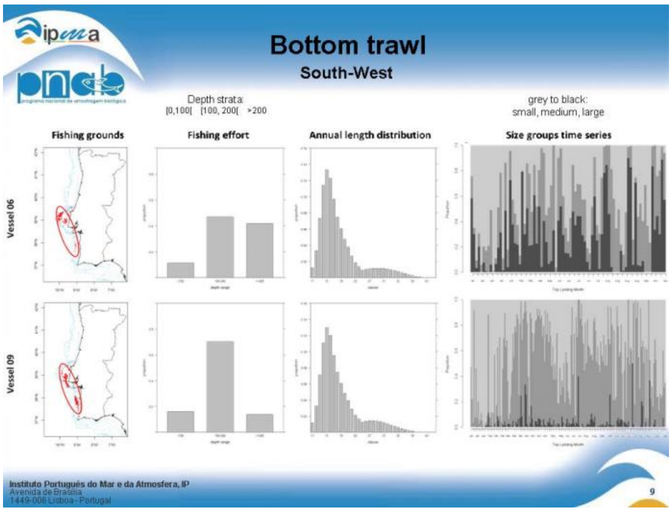

Bottom trawl
South-West
Depth strata:
[0,100[[100, 200[>200
grey to black:
small, medium, large
Fishing grounds
Fishing effort
Annual length distribution
Size groups time series
Vessel 06
Vessel 09
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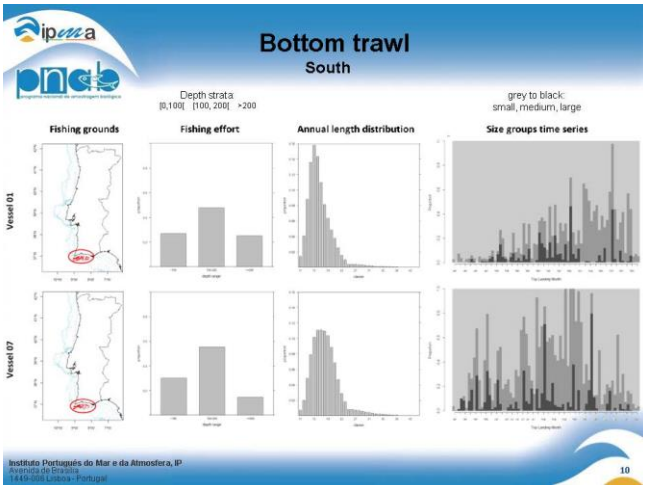

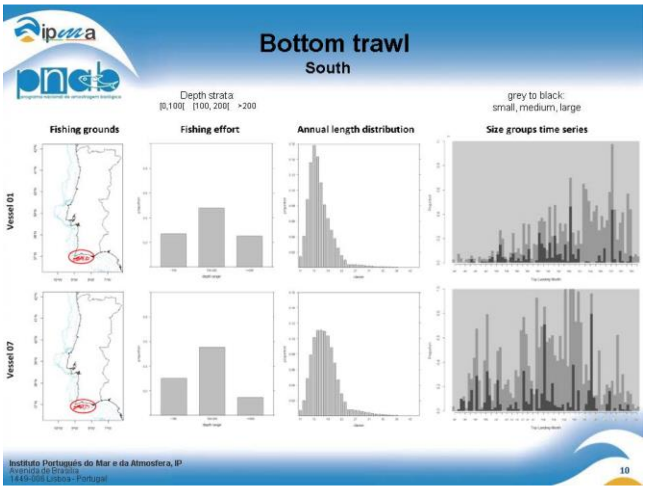
Bottom trawl
South
Depth strata:
[0,100[[100, 200[>200
grey to black:
small, medium, large
Fishing grounds
Fishing effort
Annual length distribution
Size groups time series
Vessel 01
Vessel 07
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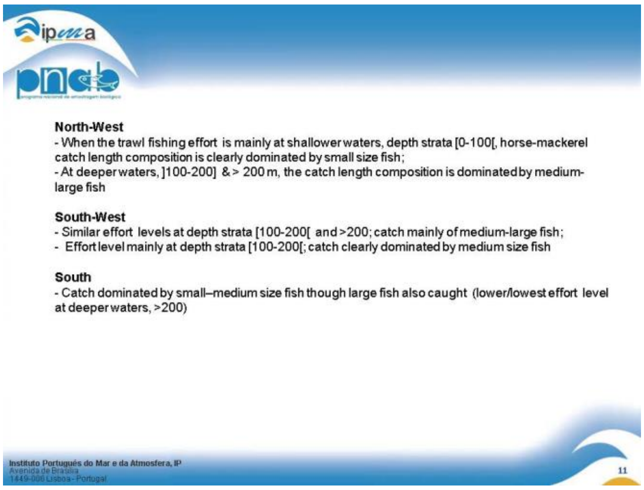

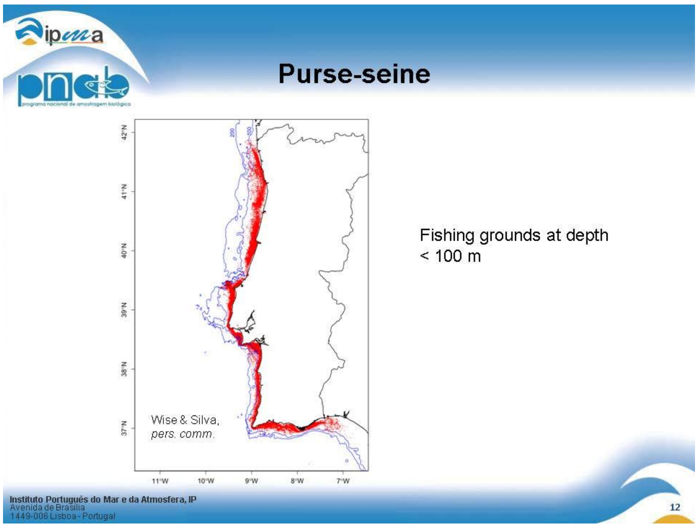
ipma
pnab
Purse-seine
Fishing grounds at depth
< 100 m
Wise & Silva,
pers. comm.
42°N
41°N
40°N
39°N
38°N
37°N
11°W
10°W
9°W
8°W
7°W
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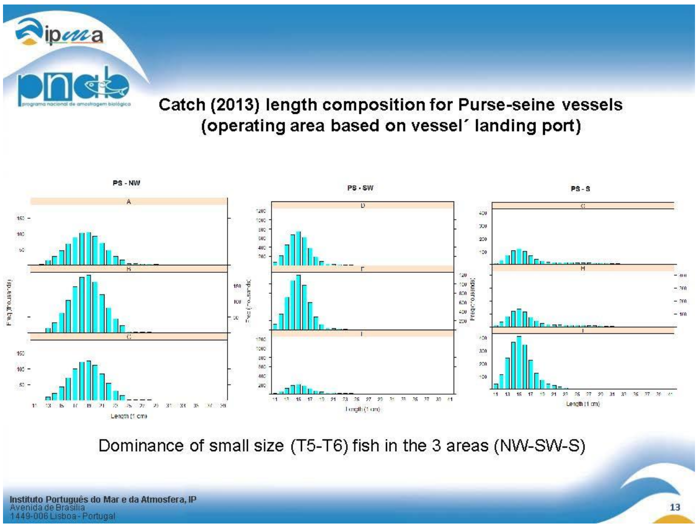
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Catch (2013) length composition for Purse-seine vessels
(operating area based on vessel´ landing port)
PS - NW
PS - SW
PS - S
Dominance of small size (T5-T6) fish in the 3 areas (NW-SW-S)
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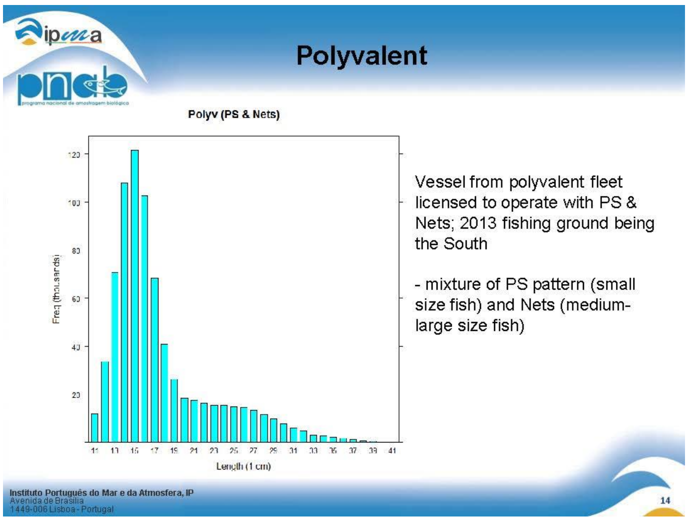
ipma
pnab
Polyvalent
Polyv (PS & Nets)
Freq (thousands)
120
100
80
60
40
20
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
Length (1 cm)
Vessel from polyvalent fleet
licensed to operate with PS &
Nets; 2013 fishing ground being
the South
- mixture of PS pattern (small
size fish) and Nets (medium-
large size fish)
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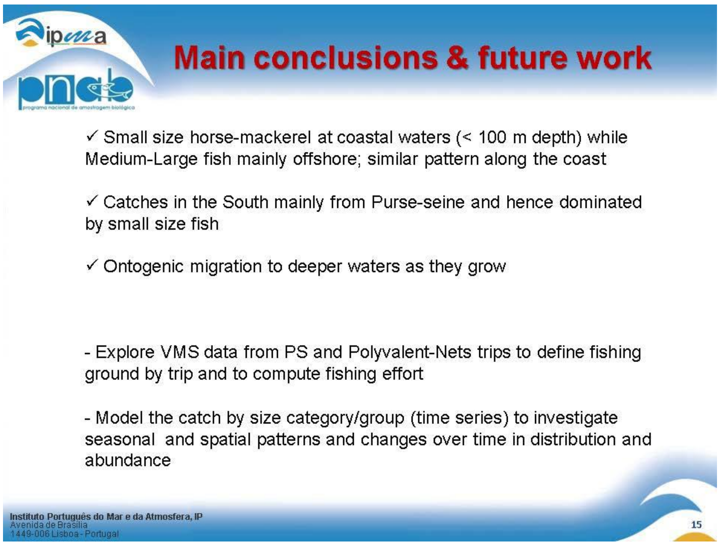
Main conclusions & future work
✓ Small size horse-mackerel at coastal waters (< 100 m depth) while Medium-Large fish mainly offshore; similar pattern along the coast
✓ Catches in the South mainly from Purse-seine and hence dominated by small size fish
✓ Ontogenic migration to deeper waters as they grow
- Explore VMS data from PS and Polyvalent-Nets trips to define fishing ground by trip and to compute fishing effort
- Model the catch by size category/group (time series) to investigate seasonal and spatial patterns and changes over time in distribution and abundance
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Horse-mackerel Distribution from IBTSurveys

Hugo Mendes, Manuela Azevedo, Corina Chaves, Gersom Costas

DEWKshom – Workshop on data evaluation for Southern Horse Mackerel

21-23 November, IPMA-Lisbon

Sampling

The Portuguese and Spanish IBTS survey data was stratified over:

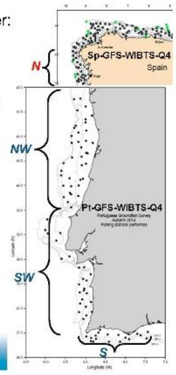
Four areas:

- **N** –> Cabo Finisterra –> (area: 4 139 km^2)
- **NW** –> Caminha –> (area: 13 241 km^2)
- **SW** –> Berlengas –> (area: 9 927 km^2)
- **S** –> Cabo S.Vicente -> VR Santo António (area: 3 713 km^2)

Three depth ranges:

- d1 <100m
- d2 100m-200m
- d3 >200m

Both surveys cover contiguous IXa areas at the same time (October – November)



Sampling (cont.)

Sp-GFS-WIBTS-Q4


RV´s

- 1992 – 2012 –> Cornide Saavedra
- 2013 – 2015 –> Miguel Oliver

(20 mm codend mesh size without groundrollers)

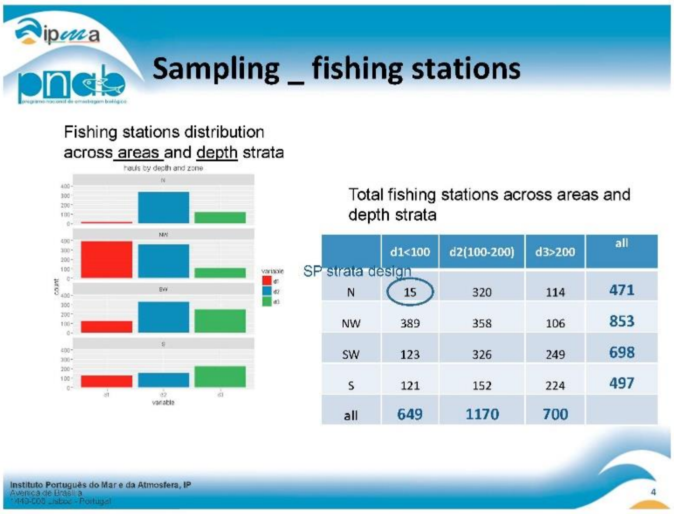
Pt-GFS-WIBTS-Q4


RV´s

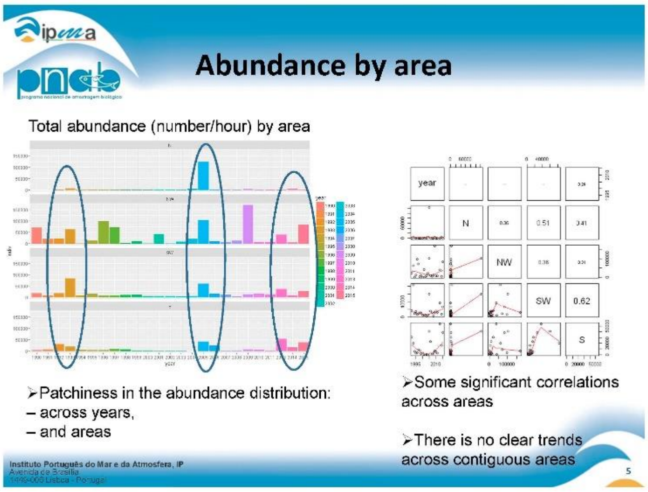
- 1990 – 2015 –> Noruega (20 mm codend mesh size with groundrollers)
- 1996,1999,2003,2004 Capricórnio (20 mm codend mesh size without groundrollers)

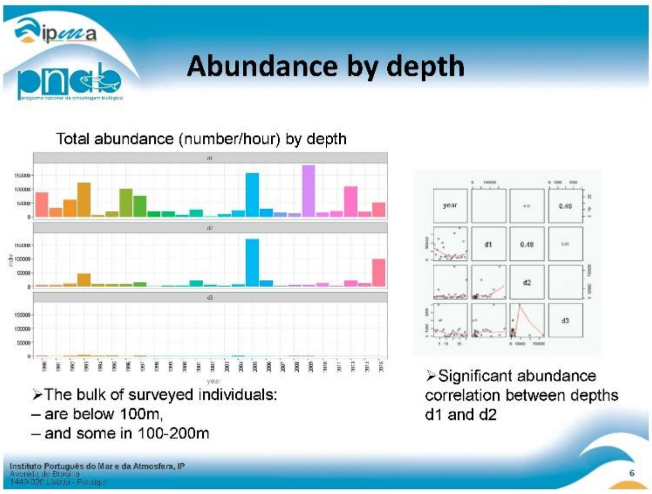
- No significant differences in horse mackerel catchability betweeen BO Cornide Saavedra and NI Noruega gears (Sánchez et al. - SESITS project)

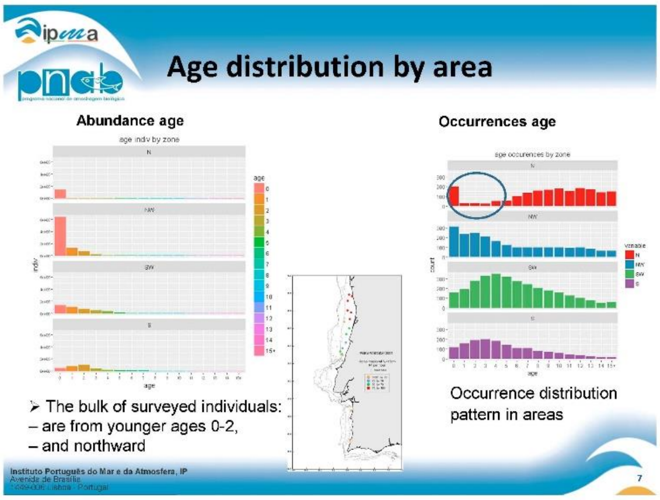
- Although they are carried out with different vessels and slightly different bottom-trawls there is no evidence to treat the datasets differently



	d1<100	d2(100-200)	d3>200	all
N	15	320	114	471
NW	389	358	106	853
SW	123	326	249	698
S	121	152	224	497
all	649	1170	700	






ipma
pnab
Age distribution by area
Abundance age
age indiv by zone
Occurrences age
age occurences by zone
➢ The bulk of surveyed individuals:
– are from younger ages 0-2,
– and northward
Occurrence distribution pattern in areas
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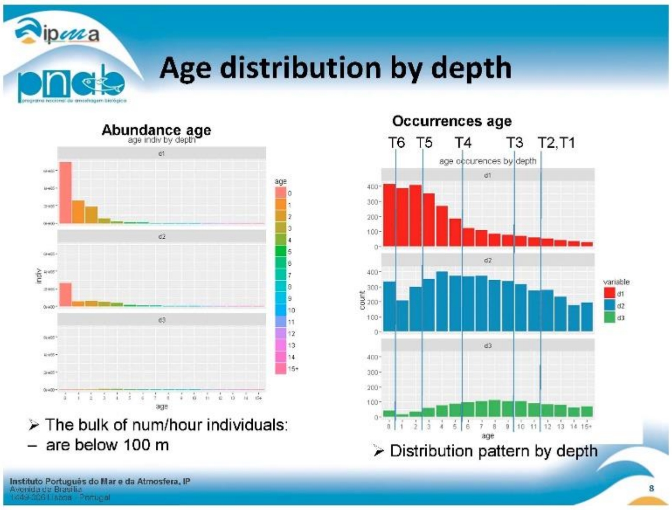
ipma
pnab
Age distribution by depth
Abundance age
age indiv by depth
Occurrences age
T6 T5 T4 T3 T2,T1
age occurences by depth
➢ The bulk of num/hour individuals:
– are below 100 m
➢ Distribution pattern by depth
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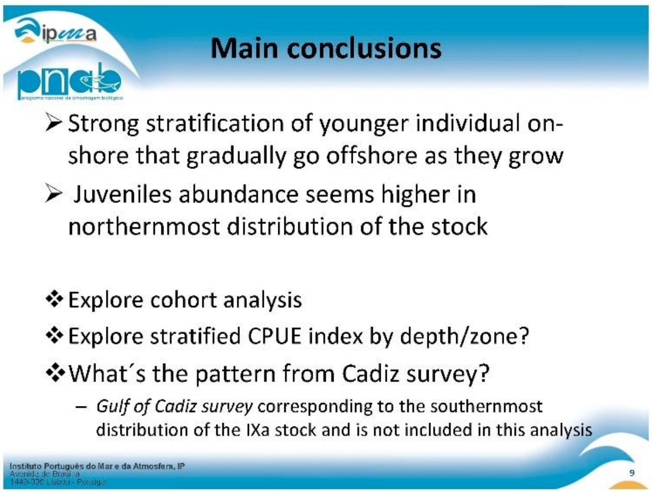
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Main conclusions
➢ Strong stratification of younger individual on-shore that gradually go offshore as they grow
➢ Juveniles abundance seems higher in northernmost distribution of the stock
❖ Explore cohort analysis
❖ Explore stratified CPUE index by depth/zone?
❖ What´s the pattern from Cadiz survey?
– *Gulf of Cadiz survey* corresponding to the southernmost distribution of the IXa stock and is not included in this analysis
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Spatial and temporal patterns in length-at-age

David Dinis, Hugo Mendes, Manuela Azevedo, Gersom Costas

DEWKshom – Workshop on data evaluation for Southern Horse Mackerel

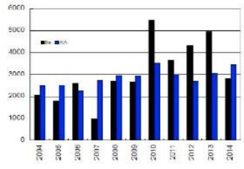
OBJECTIVES

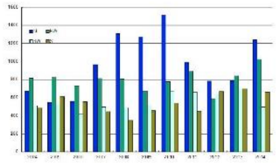
- Analyse the growth pattern of Southern horse mackerel stock (9a) and in area 8c by:
  - season (quarter/semester)
  - year (2004-2014)
  - Area (8c, 9a: N, NW, SW, S)

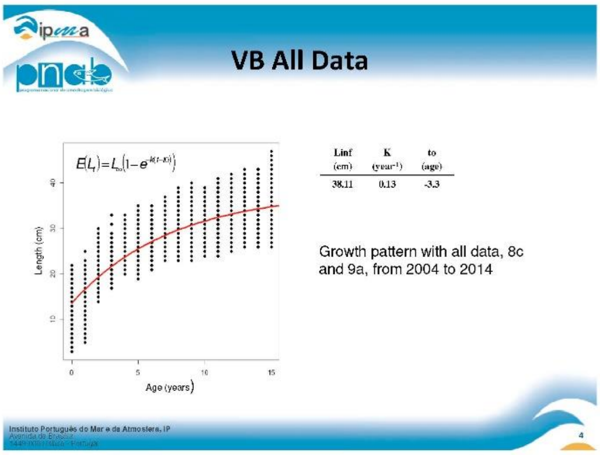
Data

observations

	8c	N	NW	SW	S
2004	2045	675	815	510	491
2005	1802	548	820	533	615
2006	2599	559	731	423	556
2007	972	965	811	499	448
2008	2688	1309	808	491	348
2009	2676	1272	676	519	455
2010	5463	1518	781	678	538
2011	3643	992	896	664	454
2012	4324	783	591	645	669
2013	4942	790	843	699	700
2014	2819	1239	1029	498	665






VB All Data
$E(L_t) = L_\infty(1 - e^{-k(t-t_0)})$
Length (cm)
Age (years)

Linf (cm)	K (year^{-1})	to (age)
38.11	0.13	-3.3

Growth pattern with all data, 8c and 9a, from 2004 to 2014
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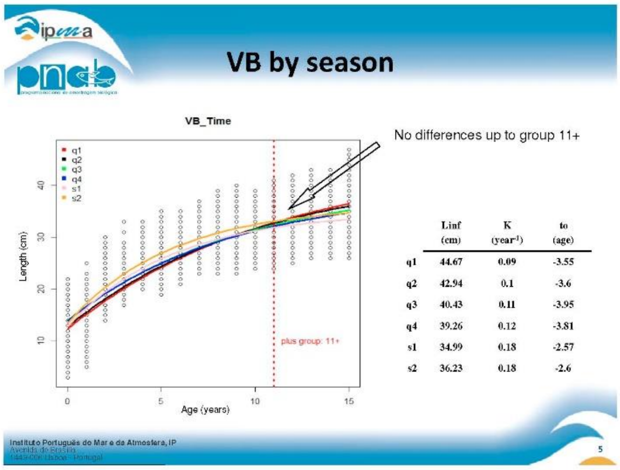
4


VB by season
VB_Time
q1
q2
q3
q4
s1
s2
Length (cm)
Age (years)
plus group: 11+
No differences up to group 11+

	Linf (cm)	K (year^{-1})	to (age)
q1	44.67	0.09	-3.55
q2	42.94	0.1	-3.6
q3	40.43	0.11	-3.95
q4	39.26	0.12	-3.81
s1	34.99	0.18	-2.57
s2	36.23	0.18	-2.6

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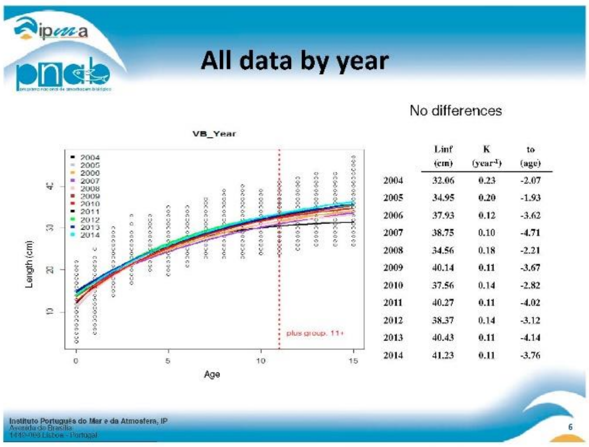
All data by year
No differences
VB_Year
Length (cm)
Age
plus group: 11+

	Linf (cm)	K (year^{-1})	to (age)
2004	32.06	0.23	-2.07
2005	34.95	0.20	-1.93
2006	37.93	0.12	-3.62
2007	38.75	0.10	-4.71
2008	34.56	0.18	-2.21
2009	40.14	0.11	-3.67
2010	37.56	0.14	-2.82
2011	40.27	0.11	-4.02
2012	38.37	0.14	-3.12
2013	40.43	0.11	-4.14
2014	41.23	0.11	-3.76

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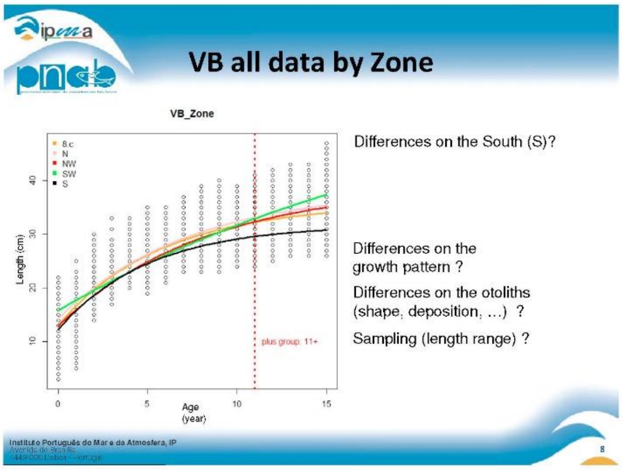
6


VB all data by Zone
VB_Zone
Differences on the South (S)?
Differences on the growth pattern ?
Differences on the otoliths (shape, deposition, ...) ?
Sampling (length range) ?
plus group: 11+
Length (cm)
Age (year)
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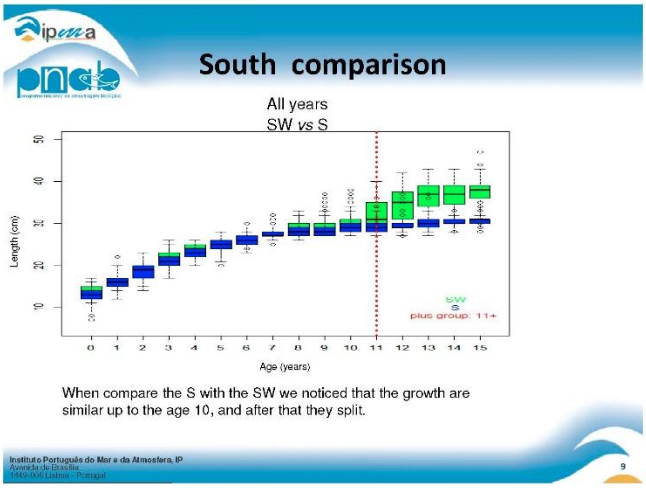
8


South comparison
All years
SW vs S
Length (cm)
Age (years)
SW
S
plus group: 11+
When compare the S with the SW we noticed that the growth are similar up to the age 10, and after that they split.
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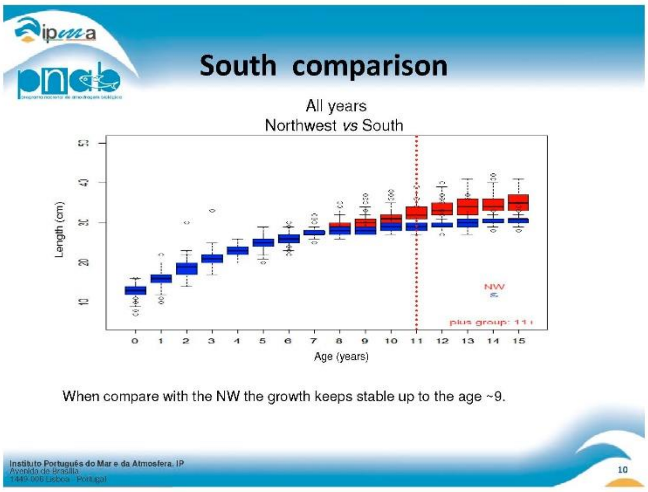
South comparison
All years
Northwest vs South
Length (cm)
Age (years)
NW
S
plus group: 11+
When compare with the NW the growth keeps stable up to the age ~9.
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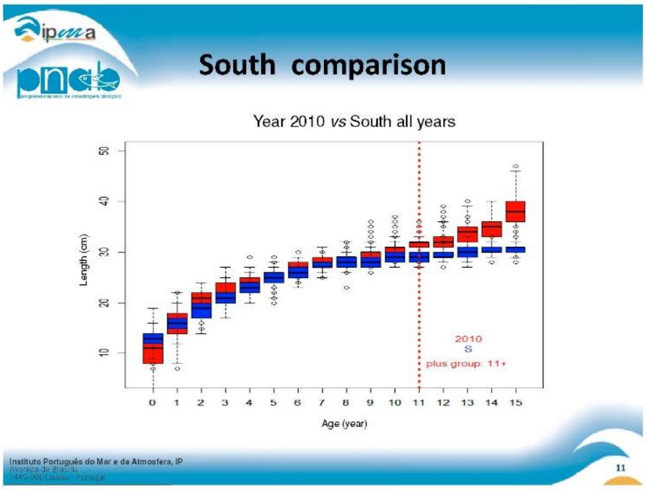
South comparison
Year 2010 vs South all years
Length (cm)
Age (year)
2010
S
plus group: 11+
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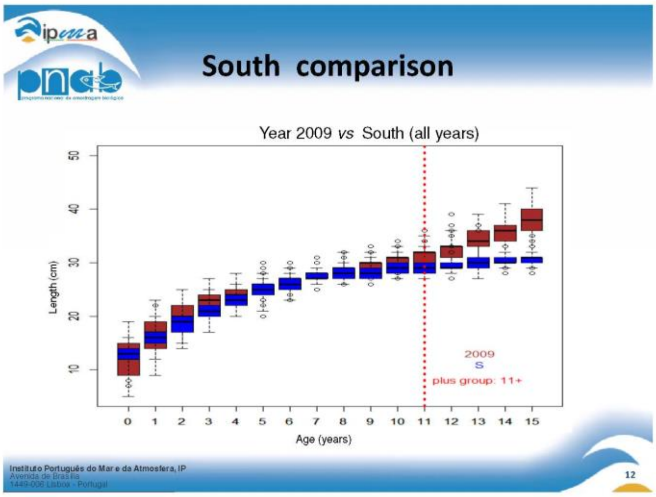
South comparison
Year 2009 vs South (all years)
Length (cm)
Age (years)
2009
S
plus group: 11+
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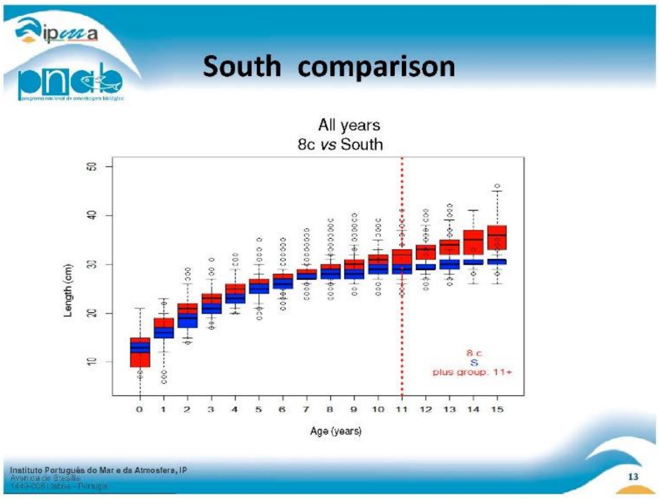
12


South comparison
All years
8c vs South
Length (cm)
Age (years)
8 c
S
plus group: 11+
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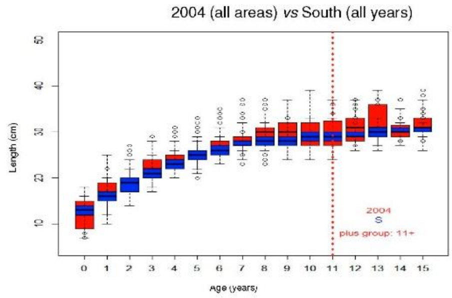
South comparison



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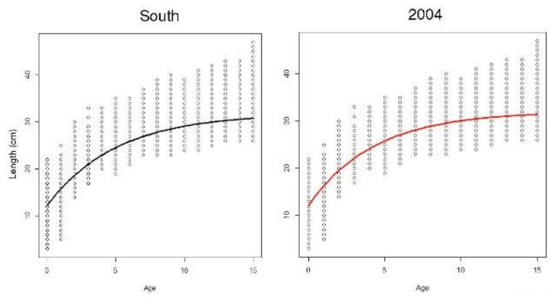
South (all years) *vs* year 2004 (all areas)



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Discussion

- Analysis by time / all year
  - There are no differences in growth when analyzed by year or season (quarter, semester)
- The observed difference in S is probably caused by scarce sampling of larger individuals in older ages (>11+)
- The results should be considered for the sampling design to estimate ALK´s for assessment purposes

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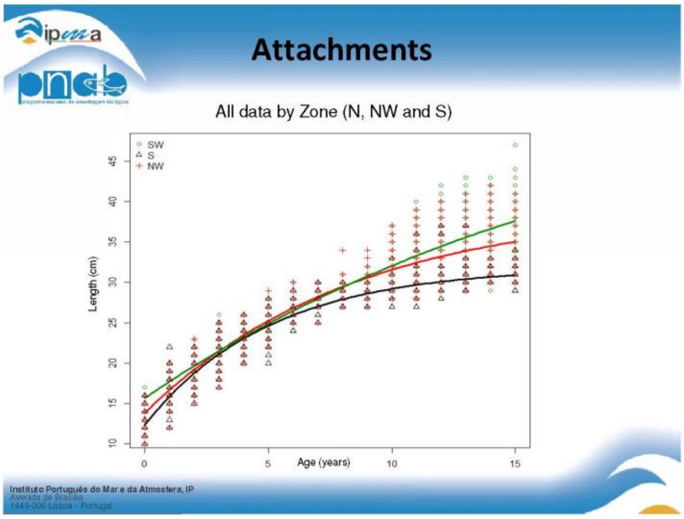
ipma
pnab
Attachments
All data by Zone (N, NW and S)
SW
S
NW
Length (cm)
Age (years)
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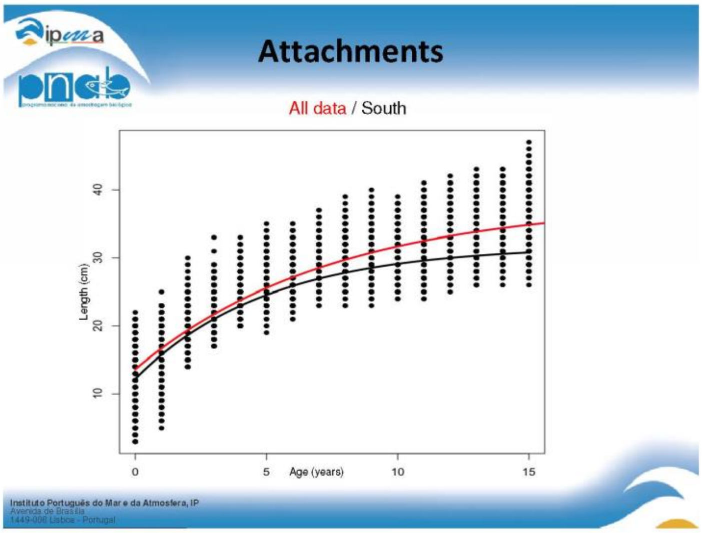
ipma
pnab
Attachments
All data / South
Length (cm)
Age (years)
Instituto Português do Mar e da Atmosfera, IP
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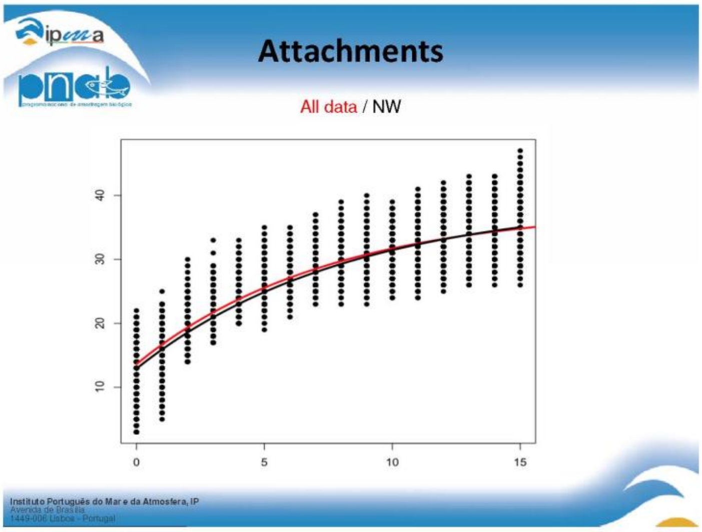
ipma
pnab
Attachments
All data / NW
Instituto Português do Mar e da Atmosfera, IP
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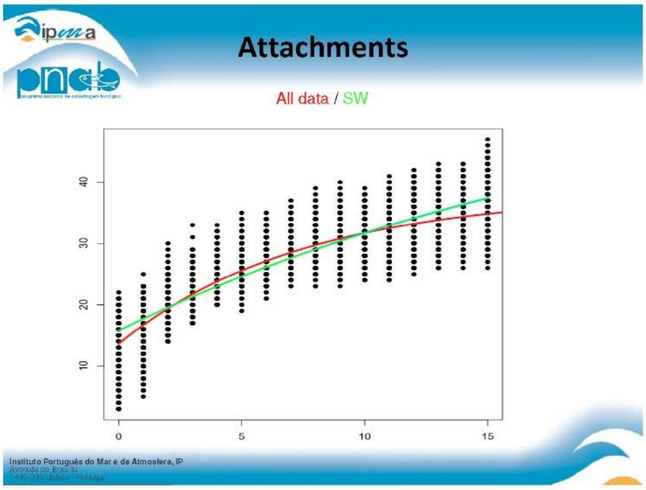
ipma
Attachments
All data / SW
40
30
20
10
0
5
10
15
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Avenida de Brasília

Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 – 23 November 2016

Southern horse mackerel, *Trachurus trachurus*
Life-history: Reproduction

Ana Costa, Begoña Villamor, Carmo Silva, Cristina Nunes, Daniel Pinto, José Ramón Perez, Mónica Inácio, Paula Abreu

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Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 – 23 November 2016

DATA

ICES Division IXa CS

- ✓ DCF - 1992-2015
- ✓ Egg Production Methods
  - ✓ DEPM - 1992, 2002, 2006 (NeoMAv), 2007, 2010, 2013
  - ✓ AEPM - 1995, 1998, 2001, 2004
  - ✓ IBTS - 2007
- ✓ Annual cycle - Jan. 2014 - Jan. 2015

ICES Divisions VIIIc and IXa N

- ✓ DCF - 2010-2015

RESULTS

- ✓ Sex ratio
- ✓ % maturity stages
- ✓ GSI
- ✓ K
- ✓ L_{50} (macro and micro)
- ✓ Fecundity

- ✓ Comparison of the values of GSI and K from Divisions VIIIc, IXa N and IXa CS

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Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 – 23 November 2016

DATA

ICES Division IXa CS

✓ DCF - 1992-2015

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	18	20		88	103	78	45	34	102	92	53	59	692
1993	68	92	42	72	143	142	71	78	86	88	111		993
1994	58	35	85	65	62	52	49	67	61	74	79	42	729
1995	33	187	69	93	71	182	173	52	27	47	73	33	1040
1996	113	59	79	134	188	31	63	146	172	81	97	35	1198
1997	237	273	150	334	365	314	223	89	67	128	137	97	2414
1998	247	291	324	150	189	145	233	210	139	277	186	161	2552
1999	201	118	168	186	207	183	225	211	244	199	184	107	2233
2000	273	260	190	199	209	224	214	152	210	165	224	152	2472
2001	273	240	223	282	261	367	188	191	232	268	245	139	2909
2002	314	298	231	327	436	304	248	214	142	239	286	197	3236
2003	108	152	257	245	212	269	148	202	209	268	179	71	2320
2004	207	251	246	274	220	322	248	97	202	160	307	11	2545
2005	135	192	204	214	312	400	308	182	364	324	298		2933
2006	137	212	413	366	145	258	318	246	223	282	156		2756
2007	129	199	233	208	323	311	213	258	180	277	226		2557
2008	176	160	113	214	427	287	295	164	216	196	184		2432
2009	1	258	159	197	285	254	277	196	231	246	211	119	2434
2010	260	360	427	240	353	294	249	260	182	247	218		3090
2011	248	199	144	181	181	249	222	204	244	221	265	229	2587
2012	290	184	132	146	190	320	312	92	112	180	312	271	2541
2013	305	1249	278	148	278	309	293	304	199	289	281	282	4215
2014	262	223	278	321	194	222	216	187	182	289	216	271	2861
2015	243	304	300	285	249	269	220	165	274	263	324	232	3128
Total	4336	5816	4745	4969	5603	5786	5051	4001	4300	4900	4852	2508	56867

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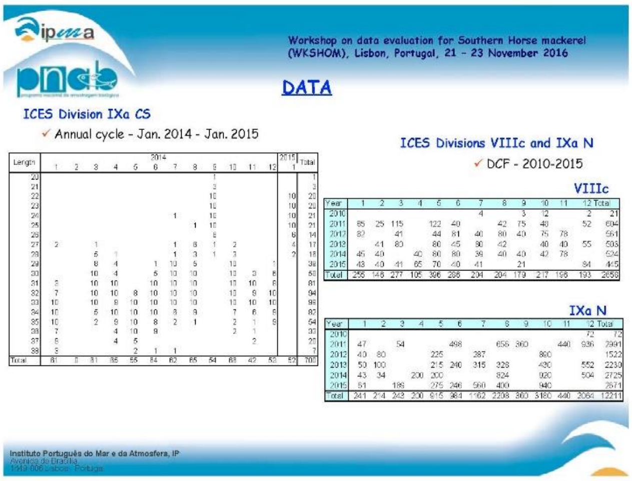
Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
DATA
ICES Division IXa CS
✓ Annual cycle - Jan. 2014 - Jan. 2015

Length	2014 1	2	3	4	5	6	7	8	9	10	11	12	2015 1	Total
20									1					1
21									3					3
22									10				10	20
23									10				10	20
24							1		10				10	21
25								1	10				10	21
26									8				6	14
27	2		1				1	6	1	2			4	17
28			5	1			1	3	1	3			2	16
29			8	4		1	10	5		10		1		39
30			10	4		5	10	10		10	3	6		58
31	3		10	10		10	10	10		10	10	8		81
32	7		10	10	8	10	10	10		10	9	10		94
33	10		10	9	10	10	10	10		10	10	10		99
34	10		5	10	10	10	8	9		7	6	9		82
35	10		2	9	10	8	2	1		2	1	9		54
36	7			4	10	9				2	1			33
37	5			4	5						2			20
38	3				2	1	1							7
Total	61	0	61	65	55	64	62	65	54	68	42	53	52	700

ICES Divisions VIIIc and IXa N
✓ DCF - 2010-2015
VIIIc

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
2010							4		3	12		2	21
2011	85	25	115		122	40		42	75	48		52	604
2012	82		41		44	81	40	80	40	75	78		561
2013		41	80		80	45	80	42		40	40	55	503
2014	45	40		40	80	80	39	40	40	42	78		524
2015	43	40	41	65	70	40	41		21			84	445
Total	255	146	277	105	396	286	204	204	179	217	196	193	2658

IXa N

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
2010												72	72
2011	47		54			498		656	360		440	936	2991
2012	40	80			225		287			890			1522
2013	50	100			215	240	315	328		430		552	2230
2014	43	34		200	200			824		920		504	2725
2015	61		189		275	246	560	400		940			2671
Total	241	214	243	200	915	984	1162	2208	360	3180	440	2064	12211

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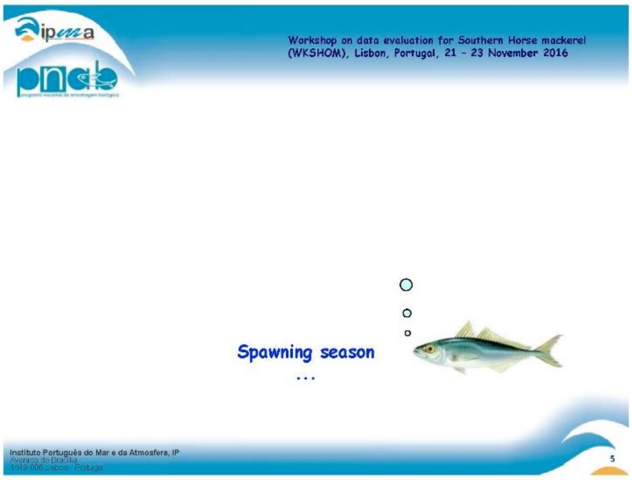
Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
Spawning season
...
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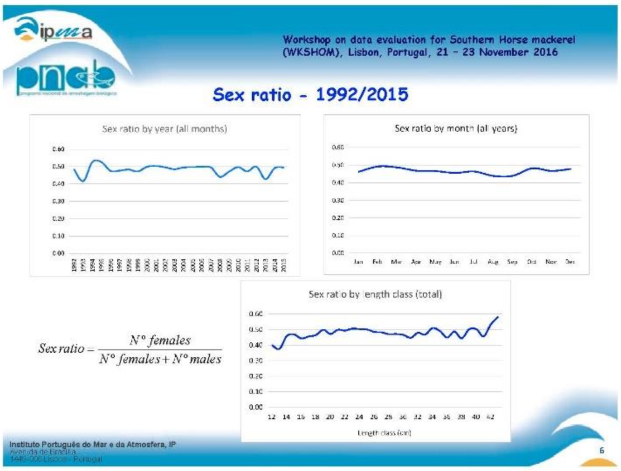
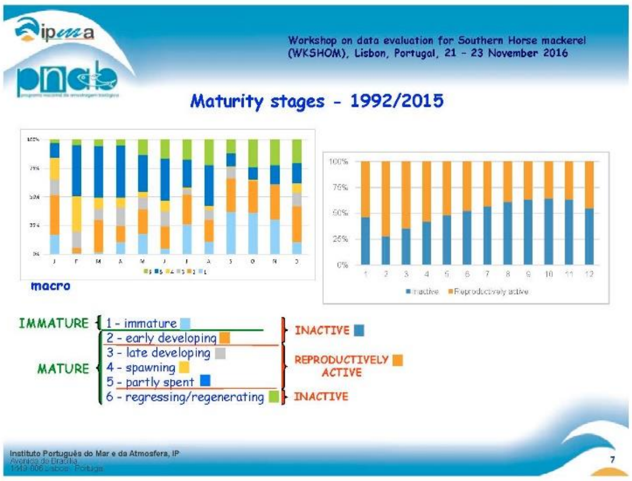
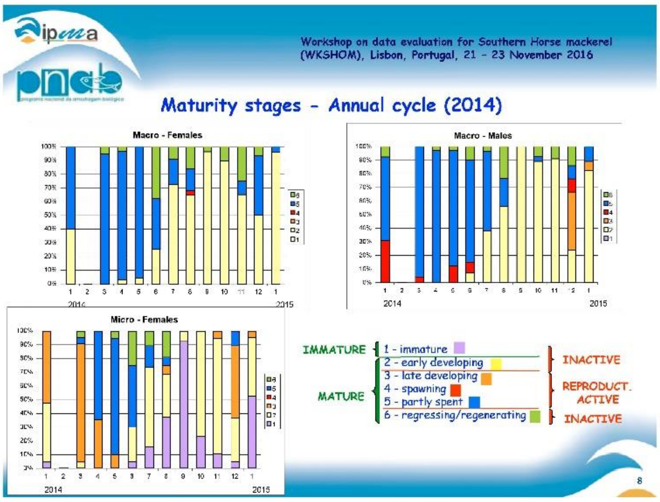
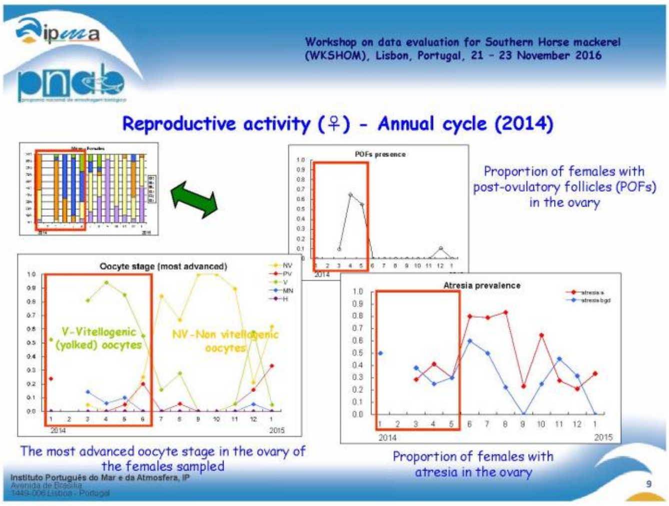
5


Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
Sex ratio - 1992/2015
Sex ratio by year (all months)
Sex ratio by month (all years)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Sex ratio by length class (total)
Length class (cm)
$$Sex\,ratio = \frac{N^{o}\,females}{N^{o}\,females + N^{o}\,males}$$
Instituto Português do Mar e da Atmosfera, IP
6


Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
Maturity stages - 1992/2015
macro
IMMATURE
1 - immature
2 - early developing
3 - late developing
4 - spawning
5 - partly spent
6 - regressing/regenerating
MATURE
INACTIVE
REPRODUCTIVELY ACTIVE
INACTIVE
Instituto Português do Mar e da Atmosfera, IP


Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
Maturity stages - Annual cycle (2014)
Macro - Females
Macro - Males
Micro - Females
IMMATURE
1 - immature
2 - early developing
3 - late developing
4 - spawning
5 - partly spent
6 - regressing/regenerating
MATURE
INACTIVE
REPRODUCT. ACTIVE
INACTIVE


Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
Reproductive activity (♀) - Annual cycle (2014)
POFs presence
Proportion of females with post-ovulatory follicles (POFs) in the ovary
Oocyte stage (most advanced)
V-Vitellogenic (yolked) oocytes
NV-Non vitellogenic oocytes
Atresia prevalence
The most advanced oocyte stage in the ovary of the females sampled
Proportion of females with atresia in the ovary
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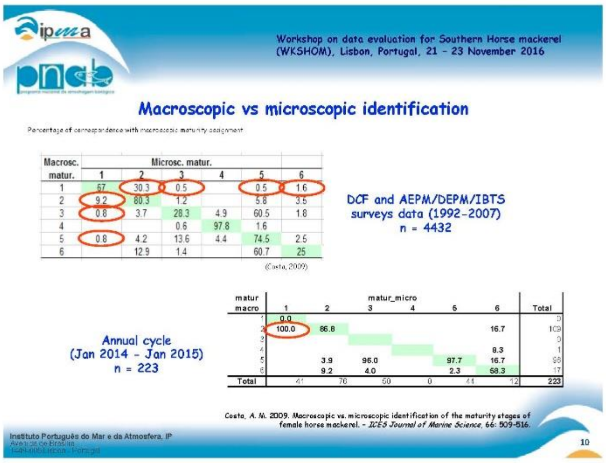
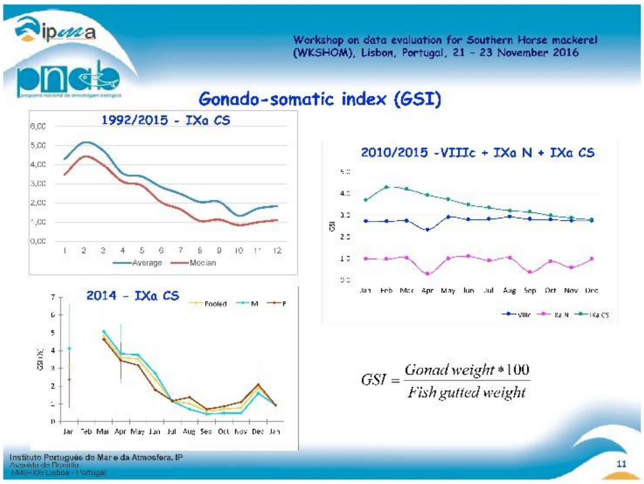

Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
Macroscopic vs microscopic identification
Percentage of correspondence with macroscopic maturity assignment

Macrosc. matur.	Microsc. matur. 1	2	3	4	5	6
1	67	30.3	0.5		0.5	1.6
2	9.2	80.3	1.2		5.8	3.5
3	0.8	3.7	28.3	4.9	60.5	1.8
4			0.6	97.8	1.6	
5	0.8	4.2	13.6	4.4	74.5	2.5
6		12.9	1.4		60.7	25

(Costa, 2009)
DCF and AEPM/DEPM/IBTS surveys data (1992-2007)
n = 4432
Annual cycle
(Jan 2014 - Jan 2015)
n = 223

matur macro	matur_micro 1	2	3	4	5	6	Total
1	0.0						0
2	100.0	86.8				16.7	109
3							0
4						8.3	1
5		3.9	96.0		97.7	16.7	98
6		9.2	4.0		2.3	58.3	17
Total	41	76	50	0	44	12	223

Costa, A. M. 2009. Macroscopic vs. microscopic identification of the maturity stages of female horse mackerel. - ICES Journal of Marine Science, 66: 509-516.
Instituto Português do Mar e da Atmosfera, IP
10


Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
Gonado-somatic index (GSI)
1992/2015 - IXa CS
Average
Median
2010/2015 -VIIIc + IXa N + IXa CS
GSI
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
VIIIc
IXa N
IXa CS
2014 - IXa CS
Pooled
M
F
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
$GSI = \frac{Gonad\,weight * 100}{Fish\,gutted\,weight}$
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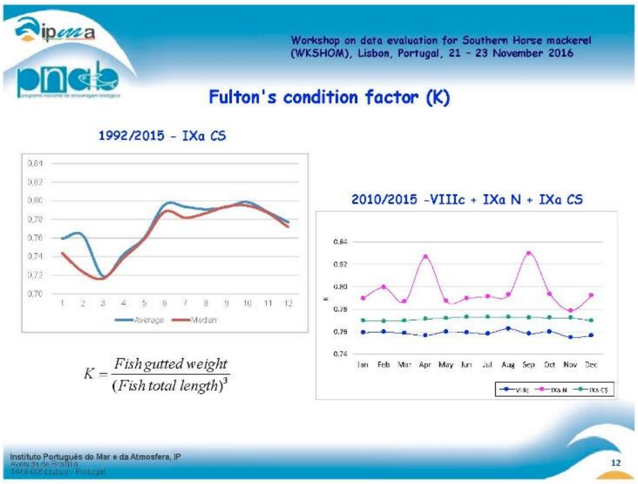
11


Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
Fulton's condition factor (K)
1992/2015 - IXa CS
Average
Median
2010/2015 -VIIIc + IXa N + IXa CS
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
VIIIc
IXa N
IXa CS
$K = \frac{Fish\,gutted\,weight}{(Fish\,total\,length)^3}$
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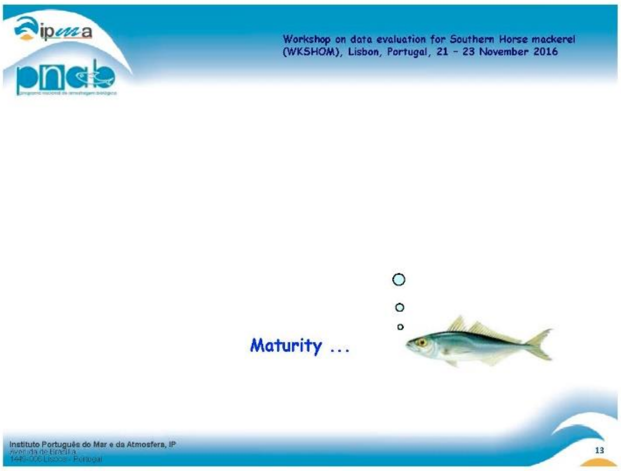
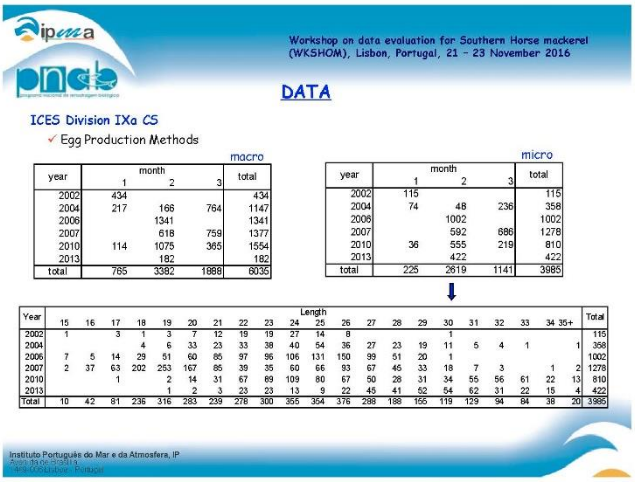
12





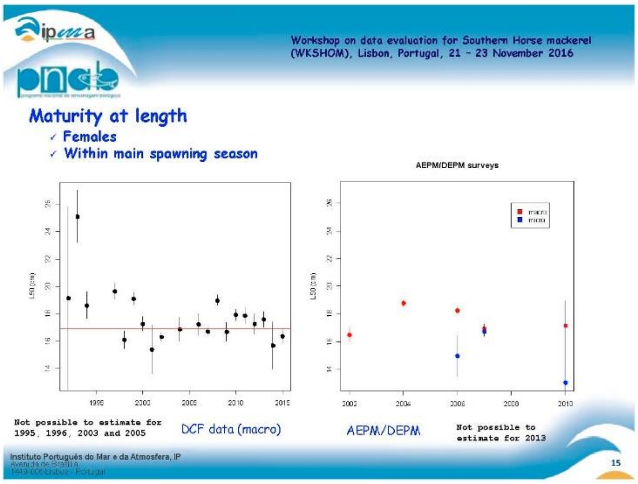
macro

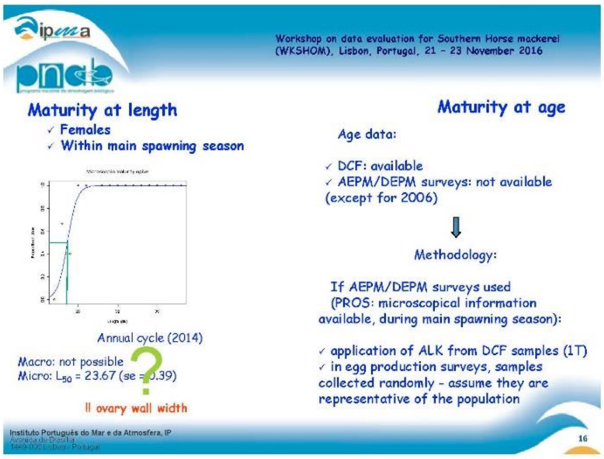
year	month 1	2	3	total
2002	434			434
2004	217	166	764	1147
2006		1341		1341
2007		618	759	1377
2010	114	1075	365	1554
2013		182		182
total	765	3382	1888	6035

micro

year	month 1	2	3	total
2002	115			115
2004	74	48	236	358
2006		1002		1002
2007		592	686	1278
2010	36	555	219	810
2013		422		422
total	225	2619	1141	3985

Year	Length 15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35+	Total
2002	1		3	1	3	7	12	19	19	27	14	8				1						115
2004				4	6	33	23	33	38	40	54	36	27	23	19	11	5	4	1		1	358
2006	7	5	14	29	51	60	85	97	96	106	131	150	99	51	20	1						1002
2007	2	37	63	202	253	167	85	39	35	60	66	93	67	45	33	18	7	3		1	2	1278
2010			1		2	14	31	67	89	109	80	67	50	28	31	34	55	56	61	22	13	810
2013					1	2	3	23	23	13	9	22	45	41	52	54	62	31	22	15	4	422
Total	10	42	81	236	316	283	239	278	300	355	354	376	288	188	155	119	129	94	84	38	20	3985




Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 – 23 November 2016
Maturity at length
✓ Females
✓ Within main spawning season
Annual cycle (2014)
Macro: not possible
Micro: L50 = 23.67 (se = 0.39)
!! ovary wall width
Maturity at age
Age data:
✓ DCF: available
✓ AEPM/DEPM surveys: not available (except for 2006)
Methodology:
If AEPM/DEPM surveys used (PROS: microscopical information available, during main spawning season):
✓ application of ALK from DCF samples (1T)
✓ in egg production surveys, samples collected randomly - assume they are representative of the population
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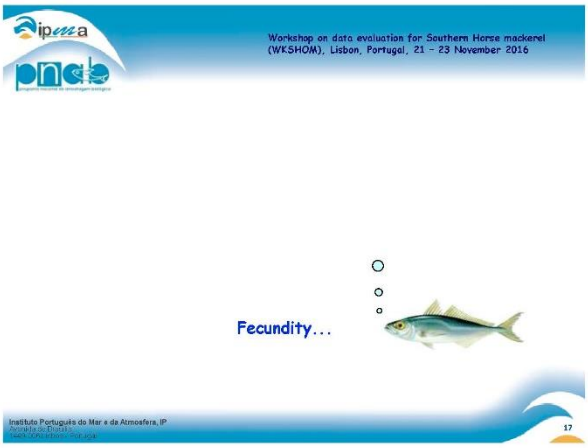
Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 – 23 November 2016
Fecundity...
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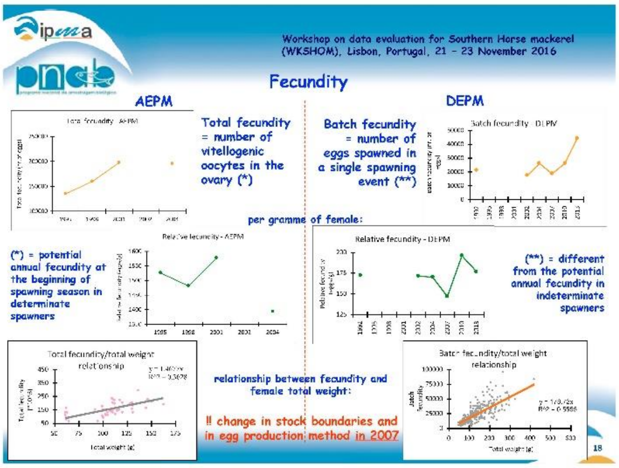
Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 – 23 November 2016
Fecundity
AEPM
DEPM
Total fecundity = number of vitellogenic oocytes in the ovary (*)
Batch fecundity = number of eggs spawned in a single spawning event (**)
Batch fecundity - DEPM
per gramme of female:
Relative fecundity - AEPM
Relative fecundity - DEPM
(*) = potential annual fecundity at the beginning of spawning season in determinate spawners
(**) = different from the potential annual fecundity in indeterminate spawners
Total fecundity/total weight relationship
Total weight (g)
relationship between fecundity and female total weight:
!! change in stock boundaries and in egg production method in 2007
Batch fecundity/total weight relationship
Batch fecundity
Total weight (g)
18


ipma
pnab
Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
"Take-home messages" ...
> HOM spawning season not fully clear: existence of a main spawning season (Dec-Jan to May-Jun?), but fish are observed to be reproductively active almost whole year (some population asynchronism?)
Needs further clarification?
> Problems in the macroscopical assignment of maturity stages - consequences in the delimitation of the spawning season? in the distinction between immature/mature/resting individuals?
Importance of using microscopical data
> Maturity at length showing some inter-annual variability, but...
Needs checking the consequence on the maturity at age
Decide on which data to use (requisites: micro, during spawning season): DEPM surveys?
Improve sampling (especially for the smaller individuals)
> Inter-annual changes in HOM relative (batch and total) fecundity, suggesting possible variations in HOM reproductive potential BUT time series still short to infer
Considering HOM reproductive strategy (indeterminate batch spawner), still difficult to estimate reproductive potential
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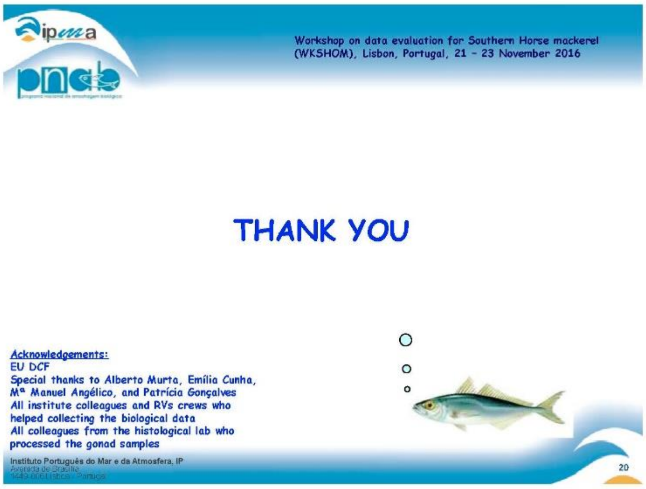
ipma
pnab
Workshop on data evaluation for Southern Horse mackerel (WKSHOM), Lisbon, Portugal, 21 - 23 November 2016
THANK YOU
Acknowledgements:
EU DCF
Special thanks to Alberto Murta, Emília Cunha, Mª Manuel Angélico, and Patrícia Gonçalves
All institute colleagues and RVs crews who helped collecting the biological data
All colleagues from the histological lab who processed the gonad samples
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Workshop on data evaluation for southern horse-mackerel - WKSHOM
21-23 November 2016, Lisboa, Portugal

Presentation 5

Southern Horse-Mackerel (*Trachurus trachurus*) Life history: Reproduction - Spawning season, Maturity and Fecundity

Ana Costa, Begoña Villamor, Carmo Silva, Cristina Nunes, Daniel Pinto, José Ramón Perez, Mónica Inácio, Paula Abreu

❖Compilation of information on the Southern horse mackerel (HOM) reproductive biology, based on data from regular sampling of the commercial fleet, from AEPM/DEPM surveys, and from an annual cycle ad hoc monthly sampling (2014).

❖Results presented for areas 9a C and S (and some for areas 9a N and 8c, too) on: sex ratio, proportion of maturity stages, comparison between macro and micro maturity stages, seasonal changes of ovarian histological (micro) characteristics in relation to the reproductive activity, gonadosomatic index (GSI), condition factor (K), length at first maturity (L_{50}, macro and micro), and fecundity (total and batch).

❖Main results obtained:

○ Spawning season: population spawning peak occurring during the first semester (max March-May), though HOM individuals can be observed reproductively active all year around

○ Macroscopic maturity stages: macroscopic assignation of gonads to maturity stages subjected to errors, in particular between stages 1 (immature) and 2 (mature), possibly disturbing the proportion of maturity, which strenghtens the requirement of using microscopical maturity information

○ Maturity: first maturity at length (L_{50}) estimates (from catches and DEPM surveys) for females during the main spawning season showing some inter-annual variability, but need to evaluate the impact on the maturity at age (applying ALKs from the 1st quarter catches), actually used in the assessment (pending work). It is recommended to obtain maturity estimates from DEPM surveys for the DEPM years, and the historical mean of DEPM years for the other years.

○ Fecundity (total and batch): showing some inter-annual variability; at present, fecundity not relevant to assessment (though related with stock's reproductive potential and resilience), but of biological interest (namely,need to investigate if relative batch fecundity changes with age or not).

❖Suggestion of work for the future: Carry out ad hoc HOM sampling for histology during the 1st semester, focusing on a good coverage ofthe smaller fish (at first maturation lengths/ages), and aiming at investigating the progression of proportion of mature fish along the main spawning season

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IBTS: methodology to combine abundance-at-age from Pt-GFS-WIBTS-Q4 and Sp-GFS-WIBTS-Q4

Hugo Mendes, Manuela Azevedo, Corina Chaves, Gersom Costas

DEWKshom – Workshop on data evaluation for Southern Horse Mackerel

21-23 November, IPMA-Lisbon

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Abundance index – CPUE

Survey CPUE index 1992 – 2015 (All ages)

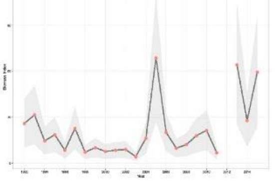

Figure 8.3.1.1. Southern horse mackerel. Historical series of biomass index estimates from the combined bottom-trawl survey (combined Spanish and Portuguese surveys).

Current methodology

➢Spanish and Portuguese IBTS are treated as a single survey

- Number per hour at age, combined and treated as a single data set
- Simple average of the number-per-hour by age and year

Num. hauls	d1<100	d2(100-200)	d3>200	
N	15	320	114	471
NW	389	358	106	853
SW	123	326	249	698
S	121	152	224	497
	649	1170	700	

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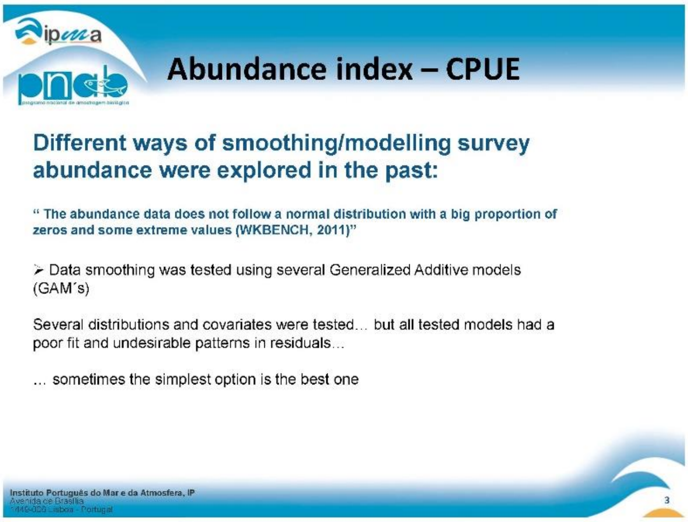
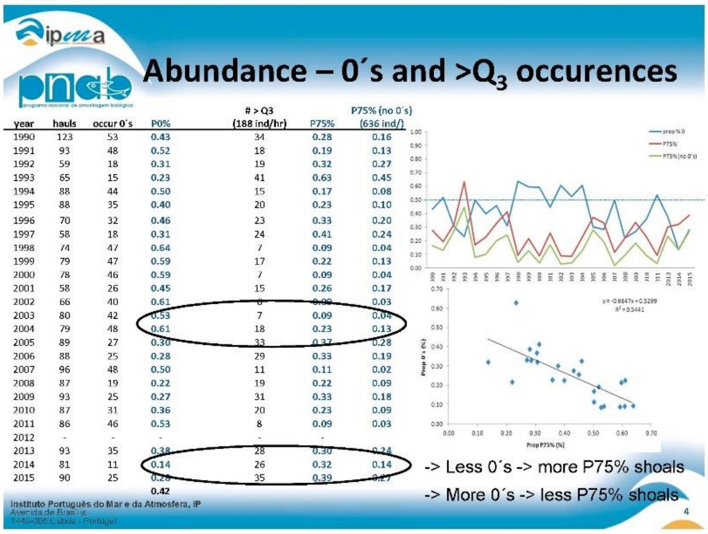
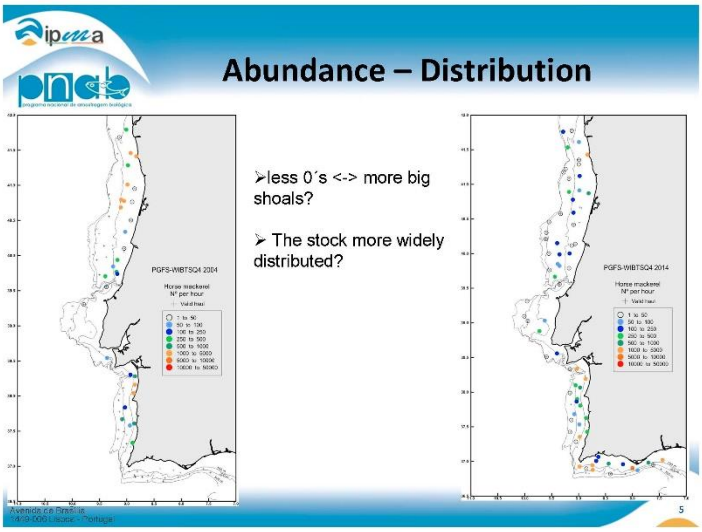




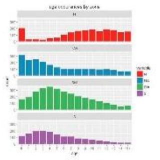
year	hauls	occur 0´s	P0%	# > Q3 (188 ind/hr)	P75%	P75% (no 0´s) (636 ind/)
1990	123	53	0.43	34	0.28	0.16
1991	93	48	0.52	18	0.19	0.13
1992	59	18	0.31	19	0.32	0.27
1993	65	15	0.23	41	0.63	0.45
1994	88	44	0.50	15	0.17	0.08
1995	88	35	0.40	20	0.23	0.10
1996	70	32	0.46	23	0.33	0.20
1997	58	18	0.31	24	0.41	0.24
1998	74	47	0.64	7	0.09	0.04
1999	79	47	0.59	17	0.22	0.13
2000	78	46	0.59	7	0.09	0.04
2001	58	26	0.45	15	0.26	0.17
2002	66	40	0.61	[illegible]	[illegible]	0.03
2003	80	42	0.53	7	0.09	0.04
2004	79	48	0.61	18	0.23	0.13
2005	89	27	0.30	33	0.37	0.28
2006	88	25	0.28	29	0.33	0.19
2007	96	48	0.50	11	0.11	0.02
2008	87	19	0.22	19	0.22	0.09
2009	93	25	0.27	31	0.33	0.18
2010	87	31	0.36	20	0.23	0.09
2011	86	46	0.53	8	0.09	0.03
2012	-	-	-	-	-	
2013	93	35	0.38	28	0.30	0.24
2014	81	11	0.14	26	0.32	0.14
2015	90	25	0.28	35	0.39	0.27
			0.42			



Distribution – Area and depth

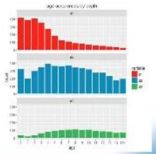
ALL surveys	zone	hauls	occur 0´s	prop % 0	# > Q3 (130 ind/hr)	P75%	P75% (no 0´s)
	N	449	134	0.30	52	0.12	0.04
	NW	853	373	0.44	214	0.25	0.17
	SW	698	232	0.33	222	0.32	0.12
	S	497	246	0.49	136	0.27	0.28

➢ Some differences in distributions across areas to be further explored (depth driven ?)



ALL surveys	strata	hauls	occur 0´s	prop % 0	extreme	P75%	P75% (no 0´s)
	d1	648	103	0.16	338	0.52	0.38
	d2	1156	388	0.34	255	0.22	0.11
	d3	693	494	0.71	31	0.04	0.01

➢ Clear different distributions by the 3 depth strata that should me modelled separately (e.g. as covariate)



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Abundance index – CPUE

Different ways of smoothing/modelling survey abundance were explored in the past:

➢ Data smoothing tested Generalized Additive models (GAM´s) by:
- age (GAM model by age - covariate year)
- year (GAM model by year - covariate age)
- year-class (GAM model by year-class - age as covariate)
- age & year (GAM with age & year as covariates)

Several distributions were tested – the less worst was negative binomial with a log link function – but all tested models had a poor fit, especially for younger ages and undesirable patterns in residuals…

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Future work
(…for Benchmark, 2017)

- Explore modelling approaches: GAM (with depth covariates) GLM, GLMM…
  - Stratified age CPUE index by depth/area

GLMs, GAMs and GLMMs: an overview of theory for applications in fisheries research

W.N. Venables*, C.M. Dichmont

Analysis of horse mackerel, blue whiting, and hake catch data from Portuguese surveys (1989–1999) using an integrated GLM approach

Pedro Sousa[1*], Ricardo T. Lemos[2], Manuel C. Gomes[3] and Manuela Azevedo[1]

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Workshop on data evaluation for southern horse-mackerel - WKSHOM
21-23 November 2016, Lisboa, Portugal

Southern horse-mackerel (*Trachurus trachurus*) information from Egg Production Method surveys 90's to present

IPMA

Maria Manuel Angélico, Elisabete Henriques, Ana Costa, Cristina Nunes

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Outline:

- Historic info - Data compilation
- Issues for DEPM application
- Egg distribution
- Egg production estimates

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1. Historic info - Data compilation

Available information

year	egg data 11 stages	fish samples	histology	fecundity	spawning markers
1992		√	√	√	√
1995		√	√	√	
1998	√	√	√	√	
1999	√				
2001	√	√	√	√	
2002	√	√	√	√	√
2004	√	√	√	√	√
2005	√	√	√	√	
2007	√	√	√	√	√
2008	√				
2010	√	√	√	√	√
2011	√				
2013	√	√	√	√	√
* 2014	√	√	√		
* 2016	√	√	√		

* with acoustics

AEPM 92-04

DEPM-PIL

HOM southern stock redefinition

together with mackerel egg survey – AEPM implementation within MEGS

DEPM-HOM since 2007
IPMA
develop/implementation

at present: triennially 1 HOM survey southern stock (IPMA), ICES 9a + MAC for MEGS South
triennially 1 PIL survey, Cape Trafalgar to Minho (IPMA) 9a + IEO 9a north

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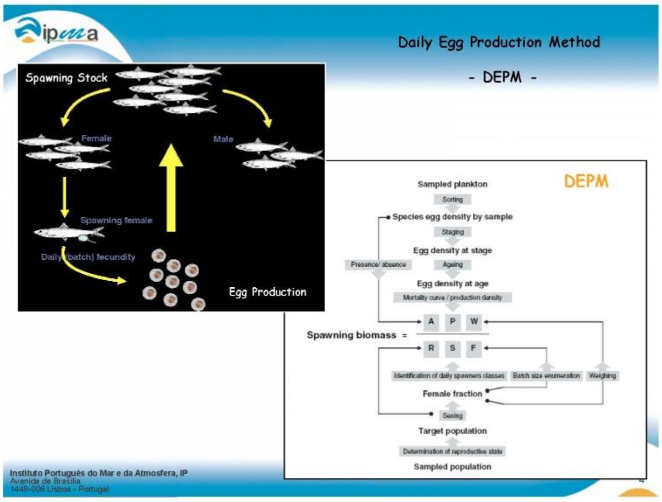
Daily Egg Production Method
- DEPM -
Spawning Stock
Female
Male
Spawning female
Daily (batch) fecundity
Egg Production
DEPM
Sampled plankton
Sorting
Species egg density by sample
Staging
Egg density at stage
Presence/ absence
Ageing
Egg density at age
Mortality curve / production density
Spawning biomass =
A P W
R S F
Identification of daily spawners classes
Batch size enumeration
Weighing
Female fraction
Sexing
Target population
Determination of reproductive state
Sampled population
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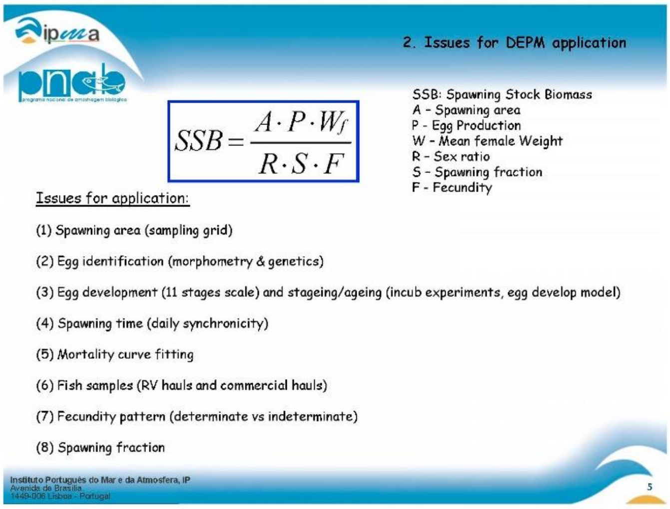
2. Issues for DEPM application
$$SSB = \frac{A \cdot P \cdot W_f}{R \cdot S \cdot F}$$
SSB: Spawning Stock Biomass
A - Spawning area
P - Egg Production
W - Mean female Weight
R - Sex ratio
S - Spawning fraction
F - Fecundity
Issues for application:
(1) Spawning area (sampling grid)
(2) Egg identification (morphometry & genetics)
(3) Egg development (11 stages scale) and stageing/ageing (incub experiments, egg develop model)
(4) Spawning time (daily synchronicity)
(5) Mortality curve fitting
(6) Fish samples (RV hauls and commercial hauls)
(7) Fecundity pattern (determinate vs indeterminate)
(8) Spawning fraction
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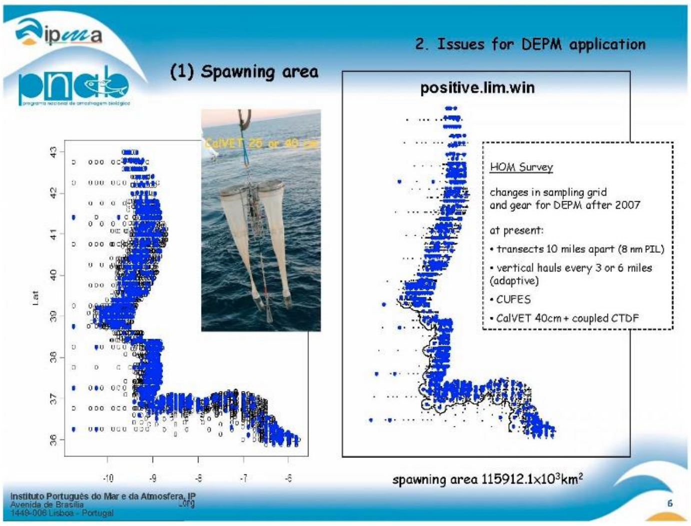
2. Issues for DEPM application
(1) Spawning area
positive.lim.win
CalVET 25 or 40 cm
HOM Survey
changes in sampling grid and gear for DEPM after 2007
at present:
• transects 10 miles apart (8 nm PIL)
• vertical hauls every 3 or 6 miles (adaptive)
• CUFES
• CalVET 40cm + coupled CTDF
Lat
spawning area 115912.1x10³km²
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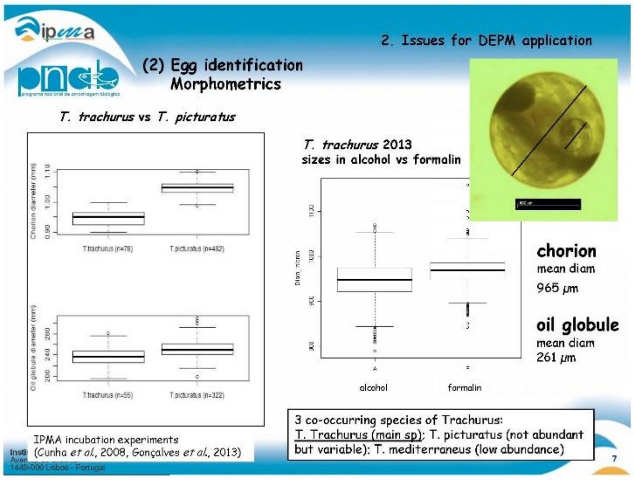
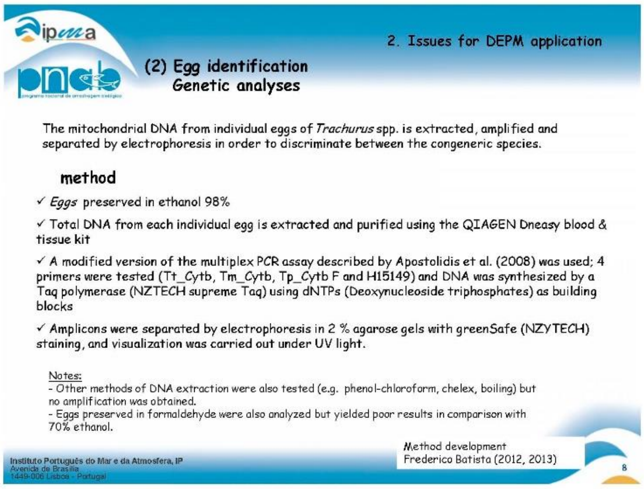


2. Issues for DEPM application
(2) Egg identification
Morphometrics
T. trachurus vs T. picturatus
T. trachurus 2013
sizes in alcohol vs formalin
alcohol
formalin
chorion
mean diam
965 µm
oil globule
mean diam
261 µm
IPMA incubation experiments
(Cunha et al., 2008, Gonçalves et al., 2013)
3 co-occurring species of Trachurus:
T. Trachurus (main sp); T. picturatus (not abundant but variable); T. mediterraneus (low abundance)
7



2. Issues for DEPM application
(2) Egg identification
Genetic analyses
The mitochondrial DNA from individual eggs of Trachurus spp. is extracted, amplified and separated by electrophoresis in order to discriminate between the congeneric species.
method
✓ Eggs preserved in ethanol 98%
✓ Total DNA from each individual egg is extracted and purified using the QIAGEN Dneasy blood & tissue kit
✓ A modified version of the multiplex PCR assay described by Apostolidis et al. (2008) was used; 4 primers were tested (Tt_Cytb, Tm_Cytb, Tp_Cytb F and H15149) and DNA was synthesized by a Taq polymerase (NZTECH supreme Taq) using dNTPs (Deoxynucleoside triphosphates) as building blocks
✓ Amplicons were separated by electrophoresis in 2 % agarose gels with greenSafe (NZYTECH) staining, and visualization was carried out under UV light.
Notes:
- Other methods of DNA extraction were also tested (e.g. phenol-chloroform, chelex, boiling) but no amplification was obtained.
- Eggs preserved in formaldehyde were also analyzed but yielded poor results in comparison with 70% ethanol.
Method development
Frederico Batista (2012, 2013)
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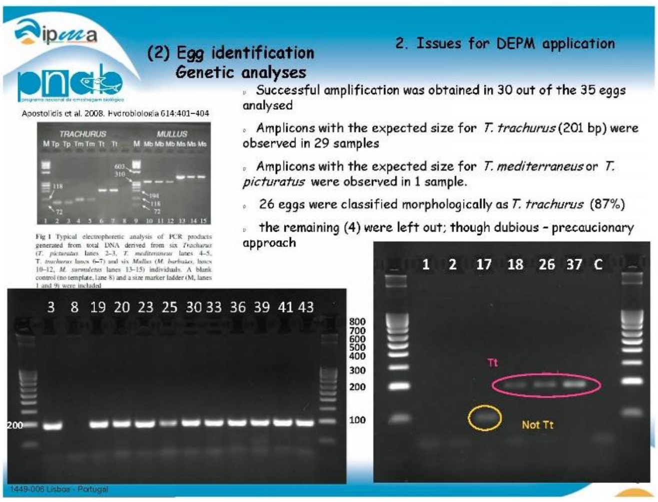

2. Issues for DEPM application
(2) Egg identification
Genetic analyses
Apostolidis et al. 2008. Hydrobiologia 614:401–404
TRACHURUS
MULLUS
Successful amplification was obtained in 30 out of the 35 eggs analysed
Amplicons with the expected size for T. trachurus (201 bp) were observed in 29 samples
Amplicons with the expected size for T. mediterraneus or T. picturatus were observed in 1 sample.
26 eggs were classified morphologically as T. trachurus (87%)
the remaining (4) were left out; though dubious – precaucionary approach
3 8 19 20 23 25 30 33 36 39 41 43
200
800
700
600
500
400
300
200
100
1 2 17 18 26 37 C
Tt
Not Tt
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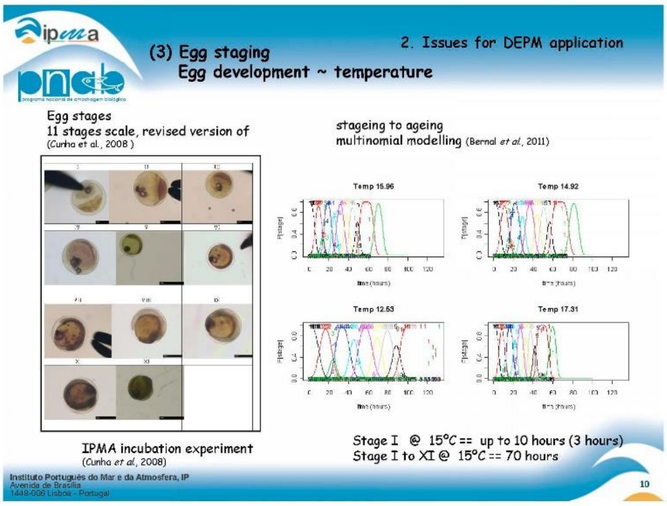
(3) Egg staging
Egg development ~ temperature
2. Issues for DEPM application
Egg stages
11 stages scale, revised version of
(Cunha et al., 2008)
stageing to ageing
multinomial modelling (Bernal et al, 2011)
Temp 15.96
Temp 14.92
Temp 12.53
Temp 17.31
Stage I @ 15°C == up to 10 hours (3 hours)
Stage I to XI @ 15°C == 70 hours
IPMA incubation experiment
(Cunha et al, 2008)
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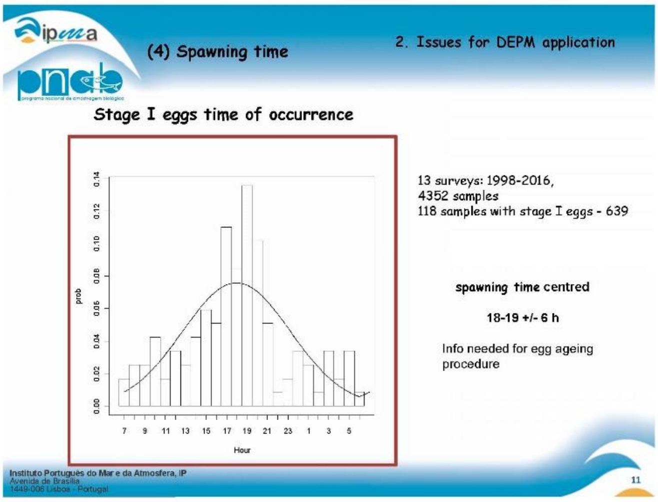
(4) Spawning time
2. Issues for DEPM application
Stage I eggs time of occurrence
prob
Hour
13 surveys: 1998-2016,
4352 samples
118 samples with stage I eggs - 639
spawning time centred
18-19 +/- 6 h
Info needed for egg ageing procedure
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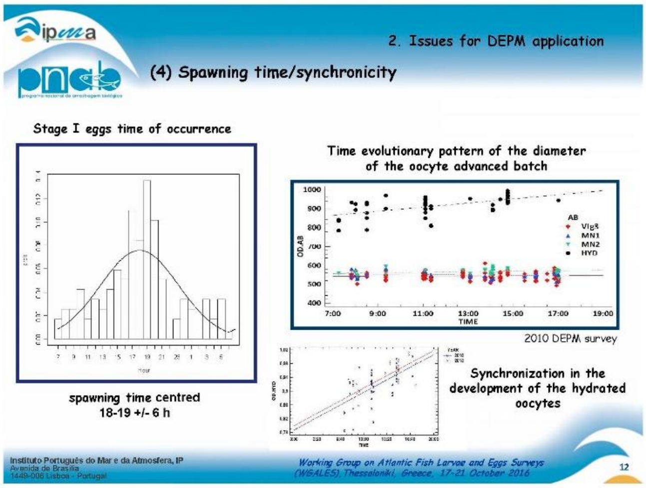
2. Issues for DEPM application
(4) Spawning time/synchronicity
Stage I eggs time of occurrence
spawning time centred
18-19 +/- 6 h
Time evolutionary pattern of the diameter of the oocyte advanced batch
2010 DEPM survey
Synchronization in the development of the hydrated oocytes
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Working Group on Atlantic Fish Larvae and Eggs Surveys (WGALES) Thessaloniki, Greece, 17-21 October 2016
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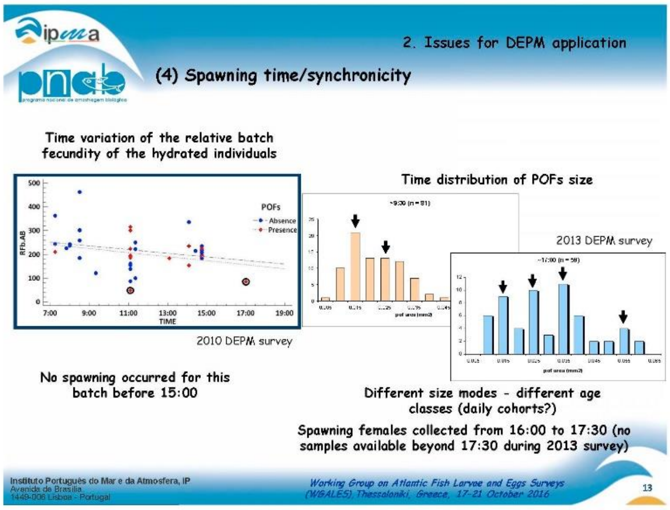
ipma
pnab
2. Issues for DEPM application
(4) Spawning time/synchronicity
Time variation of the relative batch fecundity of the hydrated individuals
POFs
Absence
Presence
TIME
2010 DEPM survey
Time distribution of POFs size
2013 DEPM survey
No spawning occurred for this batch before 15:00
Different size modes - different age classes (daily cohorts?)
Spawning females collected from 16:00 to 17:30 (no samples available beyond 17:30 during 2013 survey)
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Working Group on Atlantic Fish Larvae and Eggs Surveys (WGALES) Thessaloniki, Greece, 17-21 October 2016
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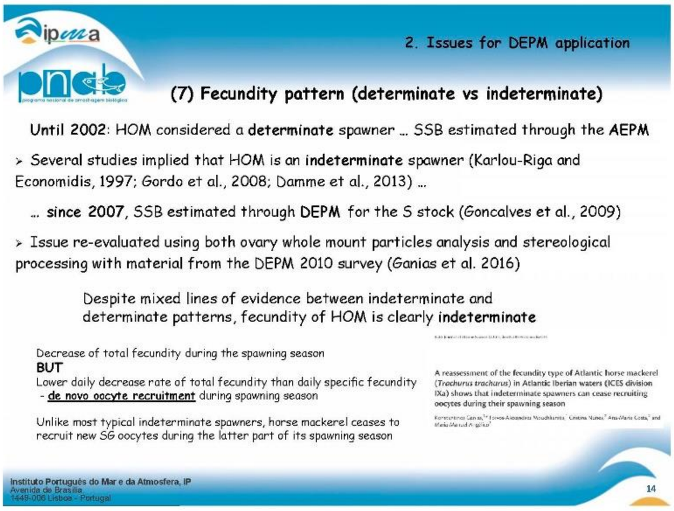
ipma
pnab
2. Issues for DEPM application
(7) Fecundity pattern (determinate vs indeterminate)
Until 2002: HOM considered a determinate spawner … SSB estimated through the AEPM
➢ Several studies implied that HOM is an indeterminate spawner (Karlou-Riga and Economidis, 1997; Gordo et al., 2008; Damme et al., 2013) …
… since 2007, SSB estimated through DEPM for the S stock (Goncalves et al., 2009)
➢ Issue re-evaluated using both ovary whole mount particles analysis and stereological processing with material from the DEPM 2010 survey (Ganias et al. 2016)
Despite mixed lines of evidence between indeterminate and determinate patterns, fecundity of HOM is clearly indeterminate
Decrease of total fecundity during the spawning season
BUT
Lower daily decrease rate of total fecundity than daily specific fecundity
- de novo oocyte recruitment during spawning season
Unlike most typical indeterminate spawners, horse mackerel ceases to recruit new SG oocytes during the latter part of its spawning season
A reassessment of the fecundity type of Atlantic horse mackerel (Trachurus trachurus) in Atlantic Iberian waters (ICES division IXa) shows that indeterminate spawners can cease recruiting oocytes during their spawning season
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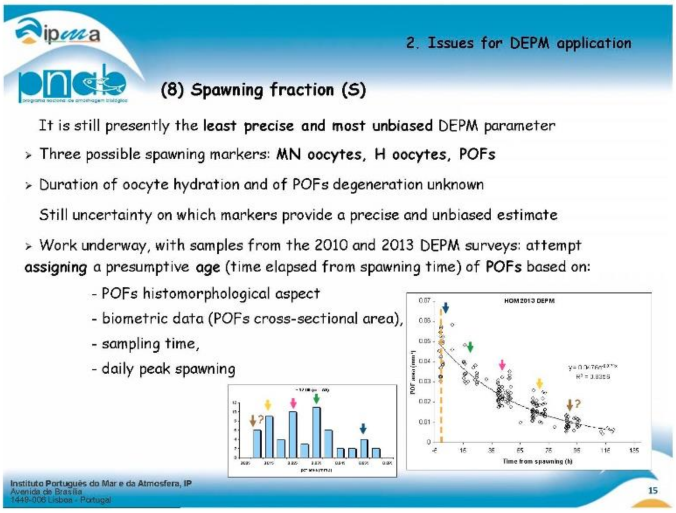
ipma
pnab
2. Issues for DEPM application
(8) Spawning fraction (S)
It is still presently the least precise and most unbiased DEPM parameter
➢ Three possible spawning markers: MN oocytes, H oocytes, POFs
➢ Duration of oocyte hydration and of POFs degeneration unknown
Still uncertainty on which markers provide a precise and unbiased estimate
➢ Work underway, with samples from the 2010 and 2013 DEPM surveys: attempt assigning a presumptive age (time elapsed from spawning time) of POFs based on:
- POFs histomorphological aspect
- biometric data (POFs cross-sectional area),
- sampling time,
- daily peak spawning
HOM 2013 DEPM
Time from spawning (h)
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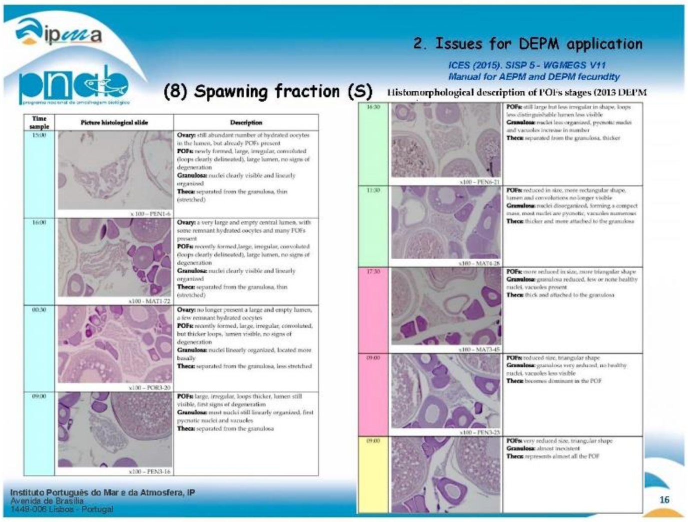

ipma
2. Issues for DEPM application
ICES (2015). SISP 5 - WGMEGS V11
Manual for AEPM and DEPM fecundity
(8) Spawning fraction (S)
Histomorphological description of POFs stages (2013 DEPM
Time sample
Picture histological slide
Description
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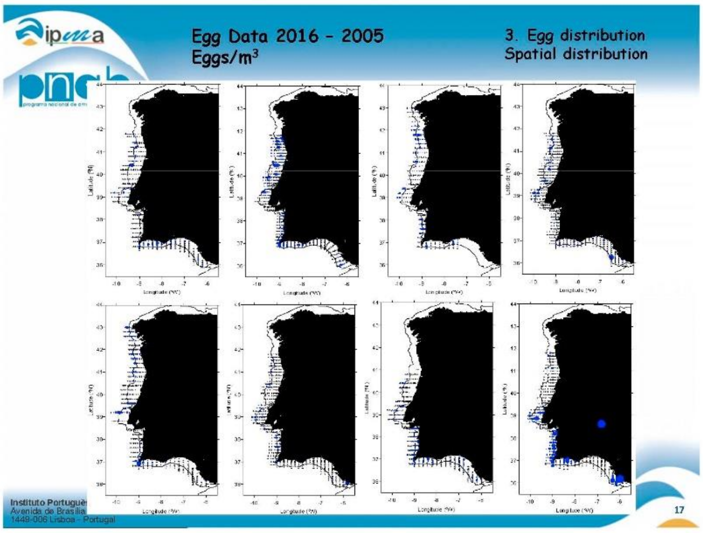
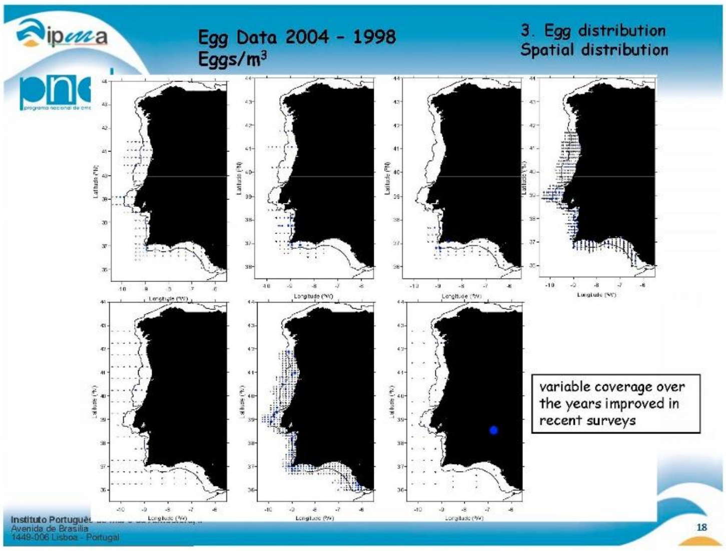


ipma
Egg Data 2016 - 2005
Eggs/m3
3. Egg distribution
Spatial distribution
17



ipma
Egg Data 2004 - 1998
Eggs/m3
3. Egg distribution
Spatial distribution
variable coverage over the years improved in recent surveys
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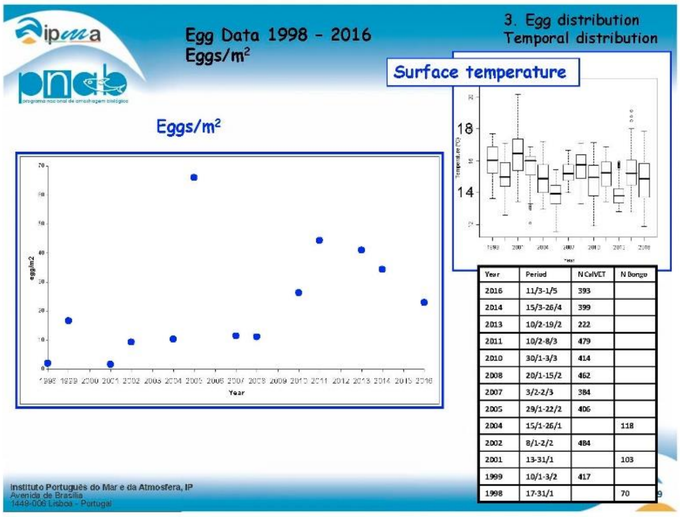
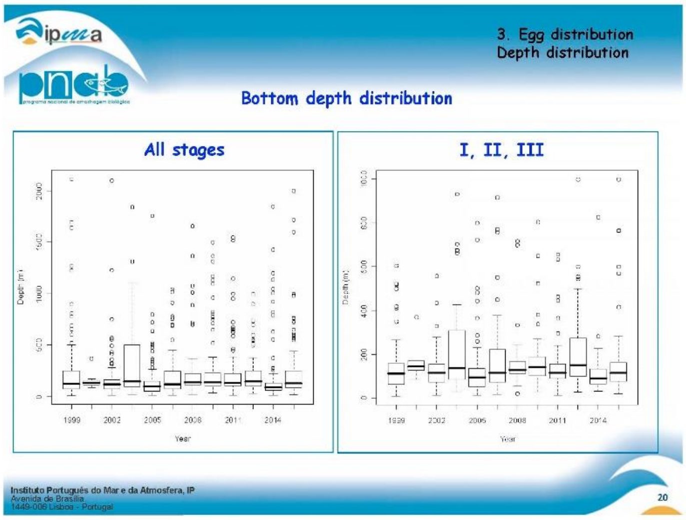
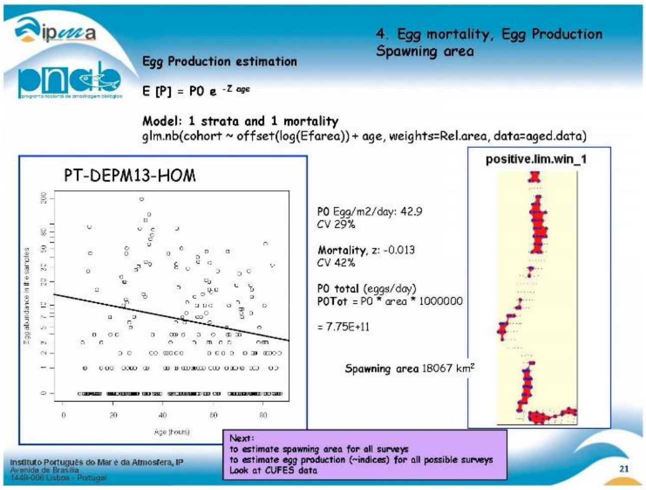
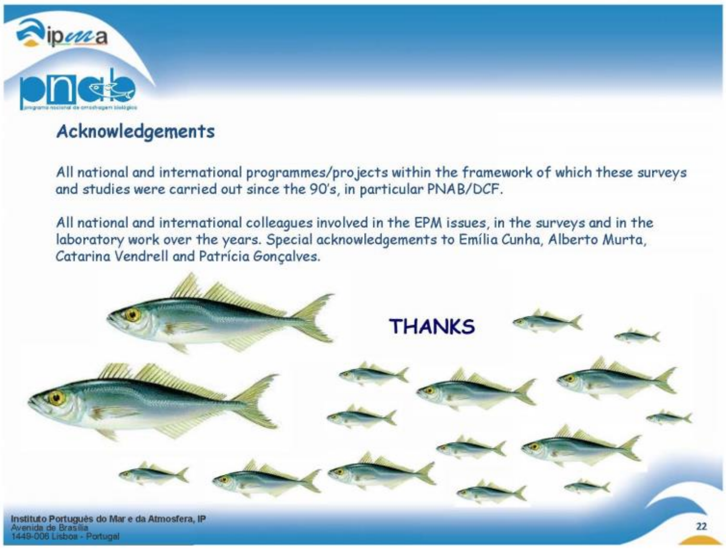


Year	Period	N CalVET	N Bongo
2016	11/3-1/5	393	
2014	15/3-26/4	399	
2013	10/2-19/2	222	
2011	10/2-8/3	479	
2010	30/1-3/3	414	
2008	20/1-15/2	462	
2007	3/2-2/3	384	
2005	29/1-22/2	406	
2004	15/1-26/1		118
2002	8/1-2/2	484	
2001	13-31/1		103
1999	10/1-3/2	417	
1998	17-31/1		70






ipma
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Acknowledgements
All national and international programmes/projects within the framework of which these surveys and studies were carried out since the 90's, in particular PNAB/DCF.
All national and international colleagues involved in the EPM issues, in the surveys and in the laboratory work over the years. Special acknowledgements to Emília Cunha, Alberto Murta, Catarina Vendrell and Patrícia Gonçalves.
THANKS
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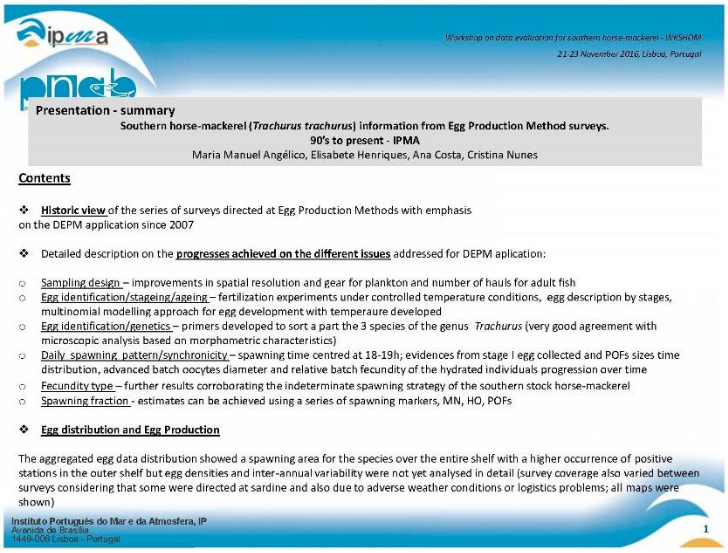
ipma
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Workshop on data evaluation for southern horse-mackerel - WKSHOM
21-23 November 2016, Lisboa, Portugal
Presentation - summary
Southern horse-mackerel (Trachurus trachurus) information from Egg Production Method surveys.
90's to present - IPMA
Maria Manuel Angélico, Elisabete Henriques, Ana Costa, Cristina Nunes
Contents
❖ Historic view of the series of surveys directed at Egg Production Methods with emphasis on the DEPM application since 2007
❖ Detailed description on the progresses achieved on the different issues addressed for DEPM aplication:
○ Sampling design – improvements in spatial resolution and gear for plankton and number of hauls for adult fish
○ Egg identification/stageing/ageing – fertilization experiments under controlled temperature conditions, egg description by stages, multinomial modelling approach for egg development with temperaure developed
○ Egg identification/genetics – primers developed to sort a part the 3 species of the genus Trachurus (very good agreement with microscopic analysis based on morphometric characteristics)
○ Daily spawning pattern/synchronicity – spawning time centred at 18-19h; evidences from stage I egg collected and POFs sizes time distribution, advanced batch oocytes diameter and relative batch fecundity of the hydrated individuals progression over time
○ Fecundity type – further results corroborating the indeterminate spawning strategy of the southern stock horse-mackerel
○ Spawning fraction - estimates can be achieved using a series of spawning markers, MN, HO, POFs
❖ Egg distribution and Egg Production
The aggregated egg data distribution showed a spawning area for the species over the entire shelf with a higher occurrence of positive stations in the outer shelf but egg densities and inter-annual variability were not yet analysed in detail (survey coverage also varied between surveys considering that some were directed at sardine and also due to adverse weather conditions or logistics problems; all maps were shown)
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Work plan:
✓ Egg production estimation could be attempted for the majority of the surveys presented but there are some assumptions that should be considered owing to the different spatial coverage of the surveys in the series.
✓ An index of egg abundance can be available for the benchmark meeting considering egg densities and spawning area (sampled).
✓ Spawning stock biomass estimations for the more recent surveys are planned to be presented at the next WGMEGS meeting in April 2017.
✓ (after - look for horse-mackerel eggs in CUFES samples (DEPM and acoustics surveys) in order to asess feasability of an index using this information)
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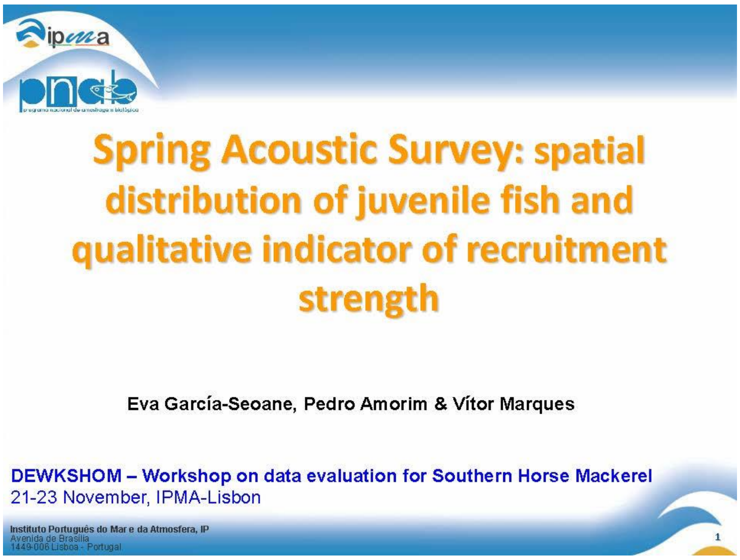
Spring Acoustic Survey: spatial distribution of juvenile fish and qualitative indicator of recruitment strength
Eva García-Seoane, Pedro Amorim & Vítor Marques
DEWKSHOM – Workshop on data evaluation for Southern Horse Mackerel
21-23 November, IPMA-Lisbon
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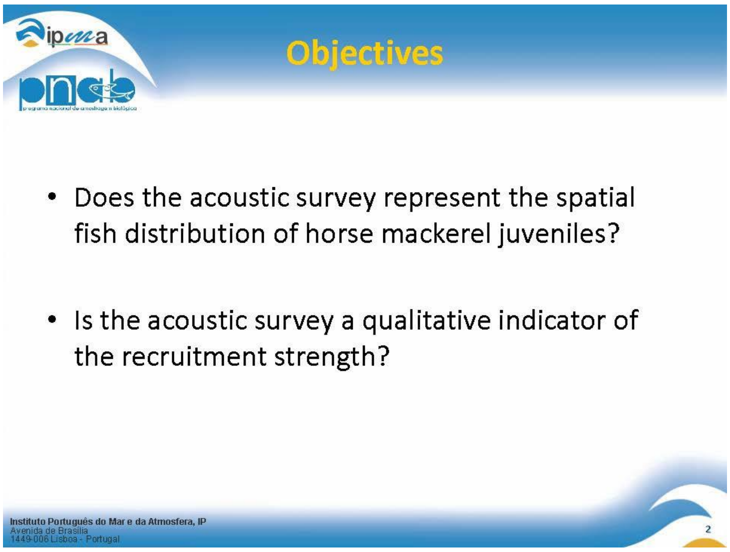
Objectives
• Does the acoustic survey represent the spatial fish distribution of horse mackerel juveniles?
• Is the acoustic survey a qualitative indicator of the recruitment strength?
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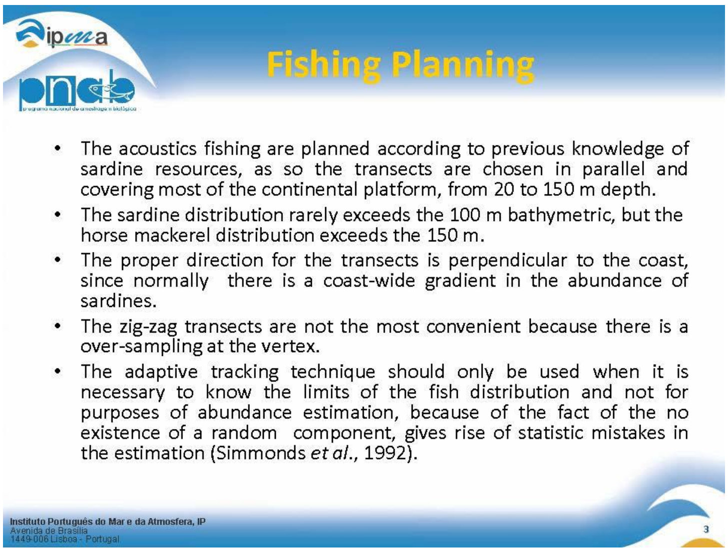
Fishing Planning
• The acoustics fishing are planned according to previous knowledge of sardine resources, as so the transects are chosen in parallel and covering most of the continental platform, from 20 to 150 m depth.
• The sardine distribution rarely exceeds the 100 m bathymetric, but the horse mackerel distribution exceeds the 150 m.
• The proper direction for the transects is perpendicular to the coast, since normally there is a coast-wide gradient in the abundance of sardines.
• The zig-zag transects are not the most convenient because there is a over-sampling at the vertex.
• The adaptive tracking technique should only be used when it is necessary to know the limits of the fish distribution and not for purposes of abundance estimation, because of the fact of the no existence of a random component, gives rise of statistic mistakes in the estimation (Simmonds et al., 1992).
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Spring Acoustic Survey

- Begining – 1982
- Systematic series from 1984
- Survey cordinated by ICES:
  - Until 2005 – "Planning Group for Acoustic Surveys in ICES Sub- areas VIII and IX"
  - From 2005 – "Working Group on Acoustic and Egg Surveys for sardine and anchovy"

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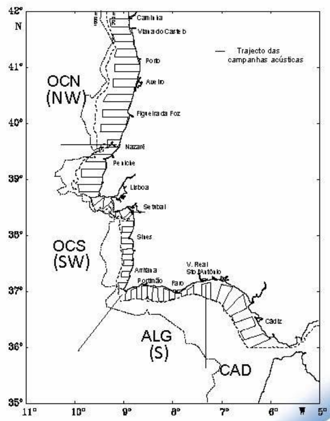
Coastal zone and Sectors

- Post-stratification in homogeneous sectors in terms of acoustic abundance and/or of the structure of the samples lenght;
- The abundance estimation is conducted by sector;
- The estimation in number is converted into biomass through the aplication of the length-weight relationship based on the samples.
- The abundance by age groups starting at the lenght-age key, through the otolith analysis.



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Echo-Tracking Trasects
Space between radials

Commitment between time and coefficient of variation

- A= area to track (8000 square nm)
- D= total lenght of the track (1200 nm)
- Spacing between transects of approximately: 8 nm
- Ship speed around 10 knots
- Time to navigation+tracking+fisheries+stops ≈ 1 month

Acoustic equipment
EK500 38Khz: 1 ms pulse length, split beam 7x 8 degrees
Processing software movies+ (IFREMER)

Sample nets:
Pelagic trawl, 10 m vertical opening
Bottom trawl
Trawl speed around 3.5 knots

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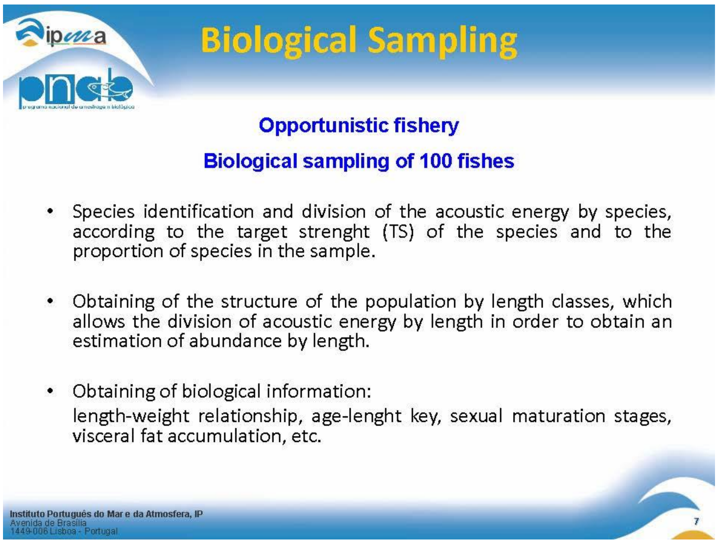
Biological Sampling
Opportunistic fishery
Biological sampling of 100 fishes
• Species identification and division of the acoustic energy by species, according to the target strenght (TS) of the species and to the proportion of species in the sample.
• Obtaining of the structure of the population by length classes, which allows the division of acoustic energy by length in order to obtain an estimation of abundance by length.
• Obtaining of biological information:
length-weight relationship, age-lenght key, sexual maturation stages, visceral fat accumulation, etc.
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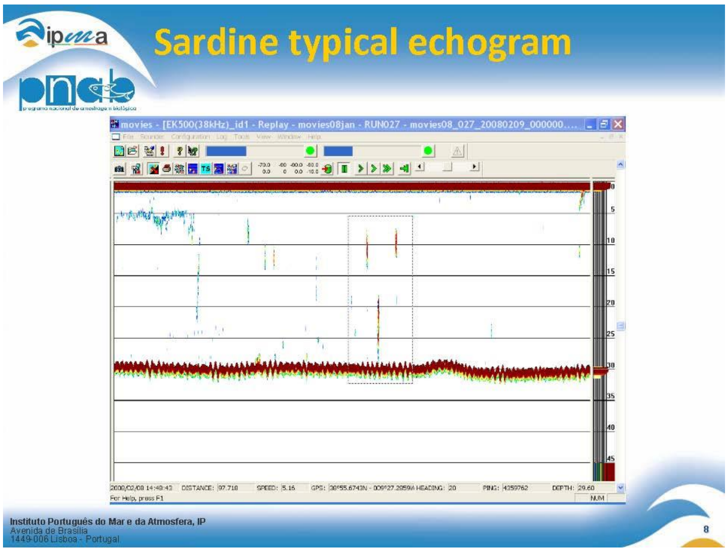
Sardine typical echogram
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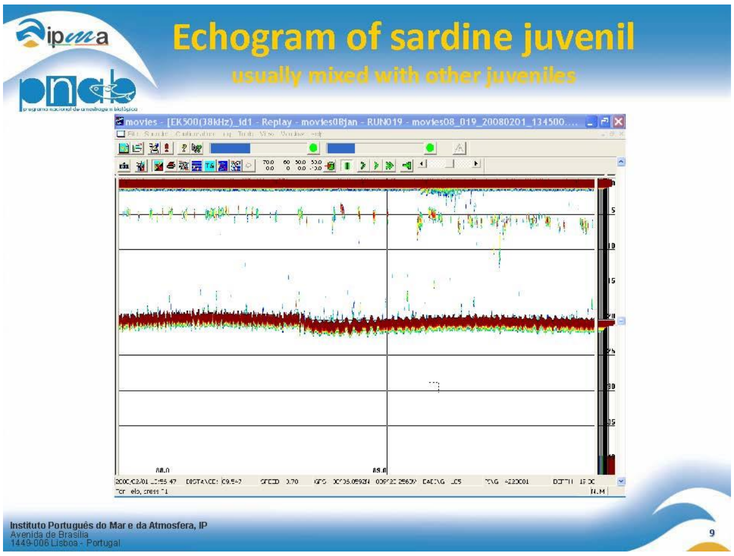
Echogram of sardine juvenil
usually mixed with other juveniles
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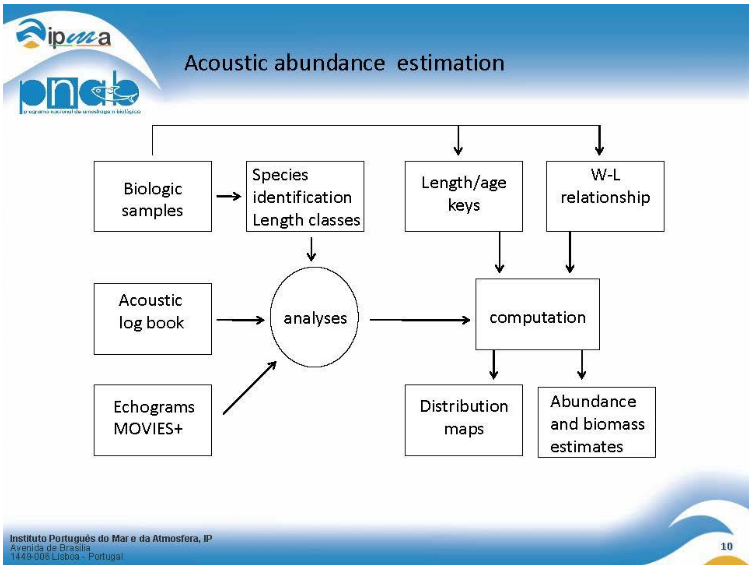
Acoustic abundance estimation
Biologic samples
Species identification Length classes
Length/age keys
W-L relationship
Acoustic log book
analyses
computation
Echograms MOVIES+
Distribution maps
Abundance and biomass estimates
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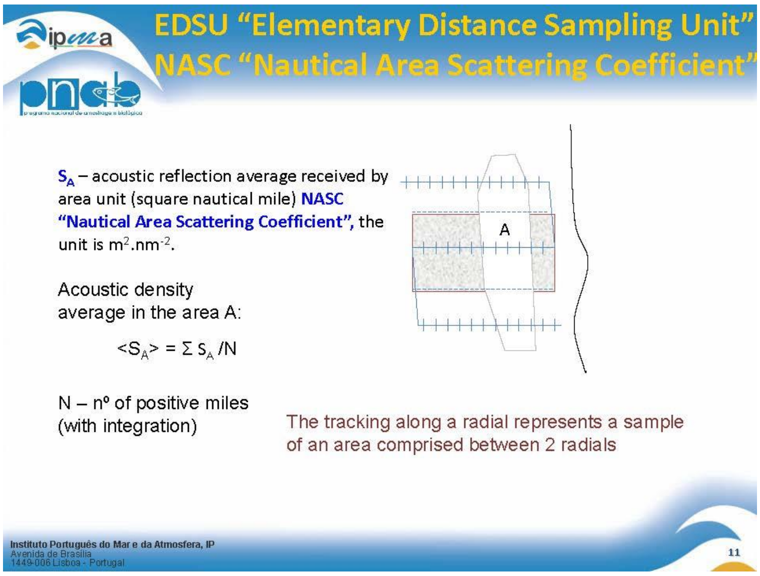
EDSU "Elementary Distance Sampling Unit"
NASC "Nautical Area Scattering Coefficient"
S_A – acoustic reflection average received by area unit (square nautical mile) NASC "Nautical Area Scattering Coefficient", the unit is $m^2.nm^{-2}$.
Acoustic density average in the area A:
$<S_A> = \Sigma S_A /N$
N – nº of positive miles (with integration)
A
The tracking along a radial represents a sample of an area comprised between 2 radials
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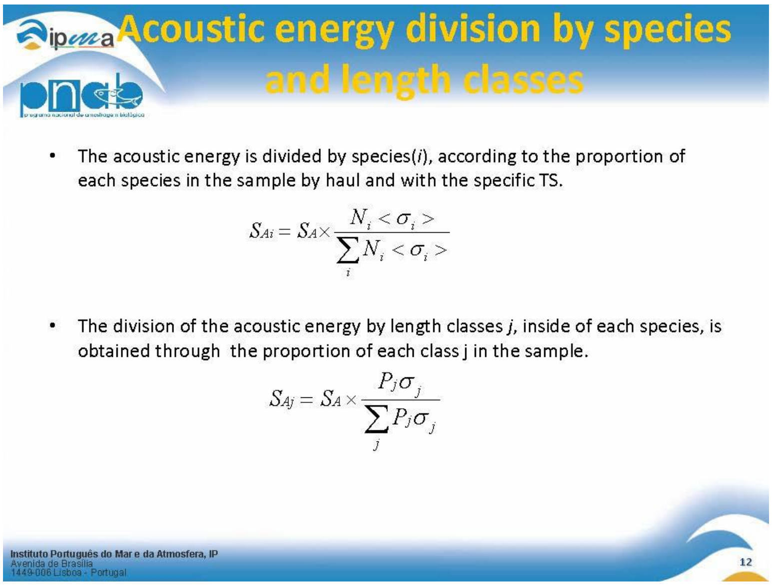
Acoustic energy division by species and length classes
• The acoustic energy is divided by species(*i*), according to the proportion of each species in the sample by haul and with the specific TS.
$$S_{Ai} = S_A \times \frac{N_i < \sigma_i >}{\sum_i N_i < \sigma_i >}$$
• The division of the acoustic energy by length classes *j*, inside of each species, is obtained through the proportion of each class j in the sample.
$$S_{Aj} = S_A \times \frac{P_j \sigma_j}{\sum_j P_j \sigma_j}$$
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Abundance estimates

- The number by length classes (N_j) is obtained dividing the total acoustic energy, atributed to the species, in the area, for the length classes *j*, by the acoustic energy reflected by one fish of that length (*j*).

  $S_{Aj} = \langle S_{Aj} \rangle A$ $$Nj = \frac{S_{Aj}}{\langle \sigma j \rangle}$$

  $\langle \sigma_j \rangle$ mean backscattering strength of the fish (*j*)

- $\langle \sigma_j \rangle$ is obtained transforming the TS "Target Strength" of the species to linear units, for length *j*:

$$C_j = \frac{1}{\langle \sigma_j \rangle} \qquad \langle \sigma_j \rangle = \frac{10^{TSj/10}}{4\pi}$$

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Horse mackerel estimations using acoustics

(2009, 2013, 2016)

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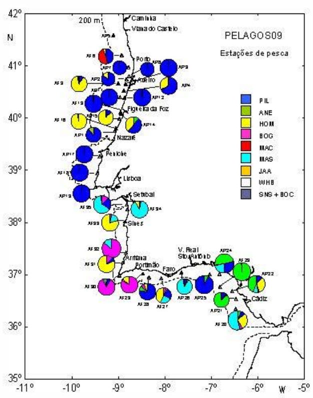
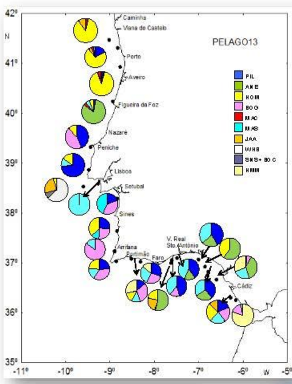
Hauls





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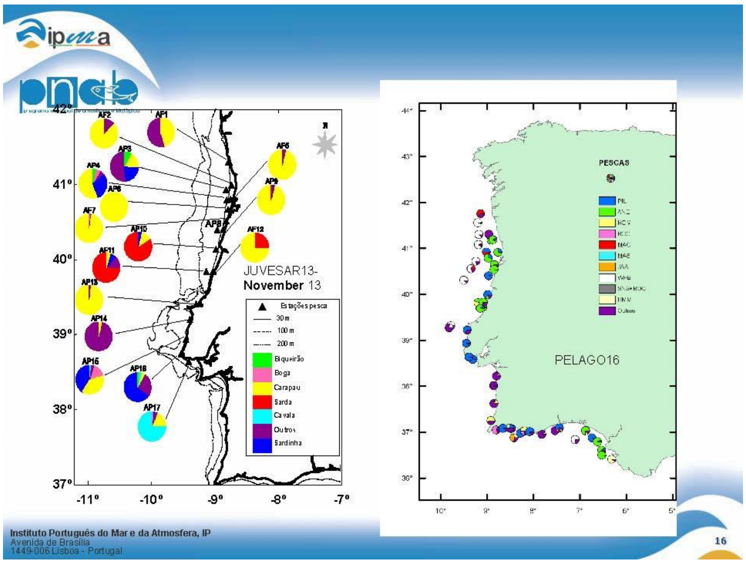
ipma
pnab
JUVESAR13-
November 13
Estações pesca
30 m
100 m
200 m
Biqueirão
Boga
Carapau
Sarda
Cavala
Outros
Sardinha
PESCAS
PELAGO16
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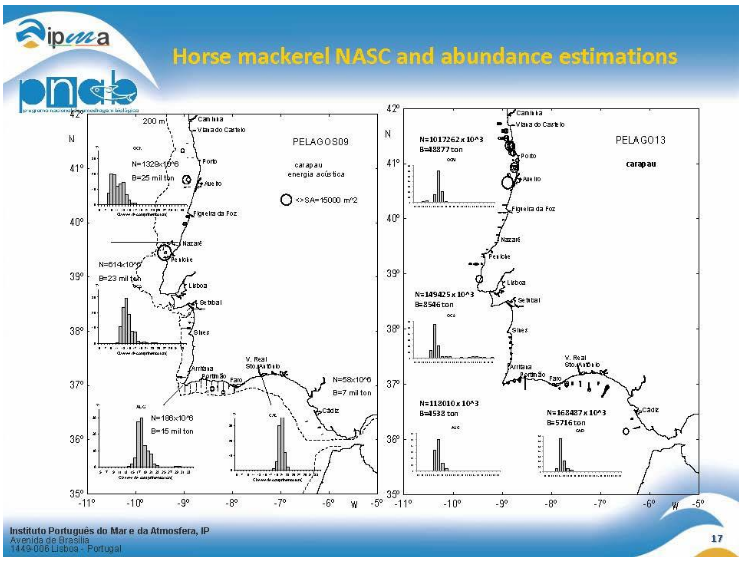
ipma
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Horse mackerel NASC and abundance estimations
PELAGOS09
carapau
energia acústica
<>SA=15000 m^2
N=1329x10^6
B=25 mil ton
N=614x10^6
B=23 mil ton
N=186x10^6
B=15 mil ton
N=58x10^6
B=7 mil ton
PELAGO13
carapau
N=1017262 x 10^3
B=48877 ton
N=149425 x 10^3
B=8546 ton
N=118010 x 10^3
B=4538 ton
N=163437 x 10^3
B=5716 ton
Caminha
Viana do Castelo
Porto
Aveiro
Figueira da Foz
Nazaré
Peniche
Lisboa
Setúbal
Sines
Arrifana
Portimão
Faro
V. Real
Sto António
Cadiz
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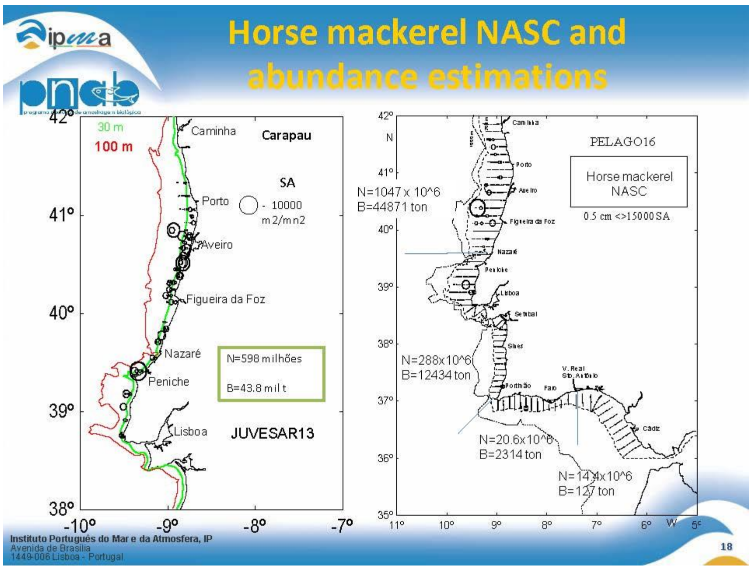
ipma
pnab
Horse mackerel NASC and abundance estimations
30 m
100 m
Carapau
SA
- 10000
m2/mn2
Caminha
Porto
Aveiro
Figueira da Foz
Nazaré
Peniche
Lisboa
N=598 milhões
B=43.8 mil t
JUVESAR13
PELAGO16
Horse mackerel
NASC
0.5 cm <>15000 SA
N=1047 x 10^6
B=44871 ton
N=288x10^6
B=12434 ton
N=20.6x10^6
B=2314 ton
N=14.4x10^6
B=127 ton
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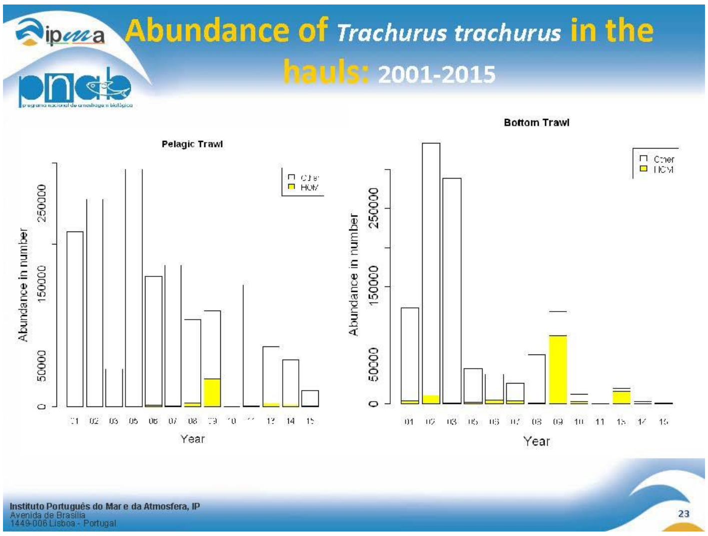

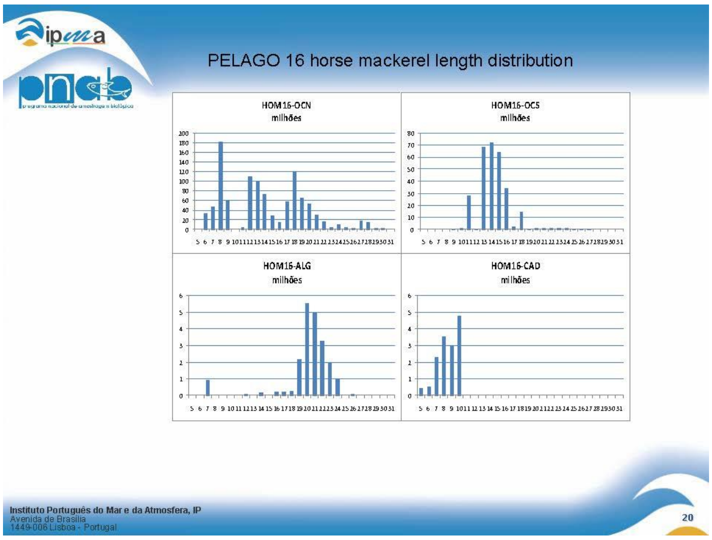

Estimated abundances for pelago9 (spring), pelago13 (spring), juvesar13 (autumn) and pelago16 (spring)

	OCN mil	OCN ton	OCS mil	OCS ton	ALG mil	ALG ton	CAD mil	CAD ton
HOM09	1329082	24886	614385	23198	186053	15017	57833	6641
HOM13	1017262	48877	149425	8546	118010	4538	168487	5716
JUV13	598000	43800	-	-	-	-	-	-
HOM16	1046991	44871	288303	12434	20645	2314	14409	127

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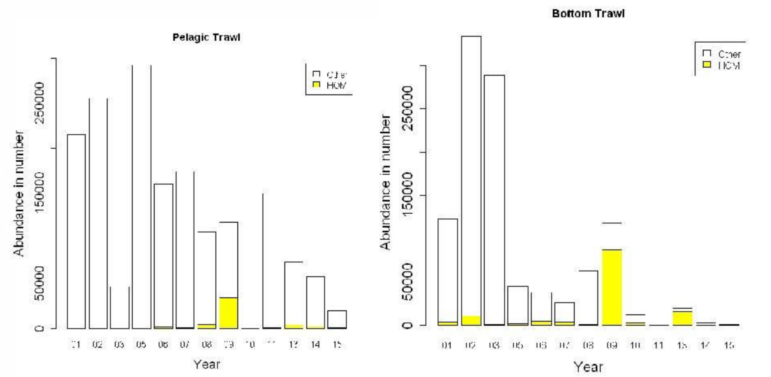
Data available for horse mackerel using the hauls

Pelagic and bottom trawl

Abundance of *Trachurus trachurus* in the hauls: 2001-2015



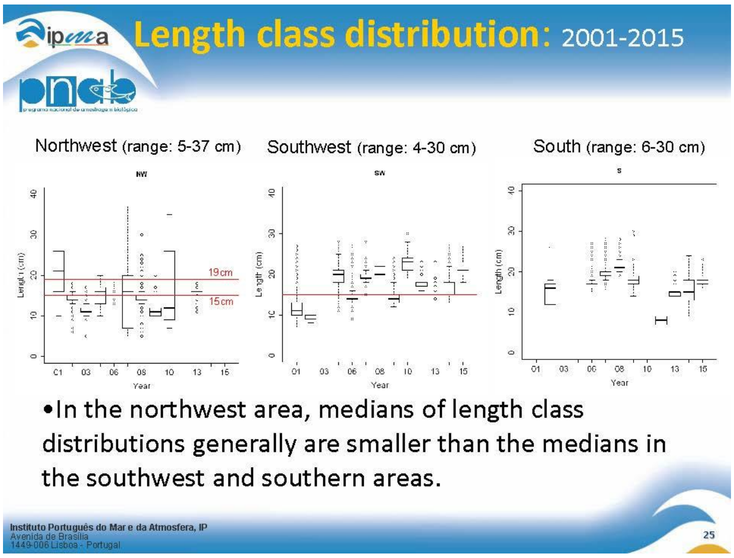
Horse mackerel available data: 2001-2015

- *Trachurus trachurus* appears in **166** hauls.

Year	01	02	03	05	06	07	08	09	10	11	13	14	15
Nº	10	11	5	8	12	17	22	21	6	6	15	19	14

- Hauls >= 30 individuals in sampling: **84**

Year	01	02	03	05	06	07	08	09	10	11	13	14	15
Nº	5	7	1	4	8	10	9	13	3	2	9	9	4


ipma
Length class distribution: 2001-2015
Northwest (range: 5-37 cm)
Southwest (range: 4-30 cm)
South (range: 6-30 cm)
19cm
15cm
Year
•In the northwest area, medians of length class distributions generally are smaller than the medians in the southwest and southern areas.
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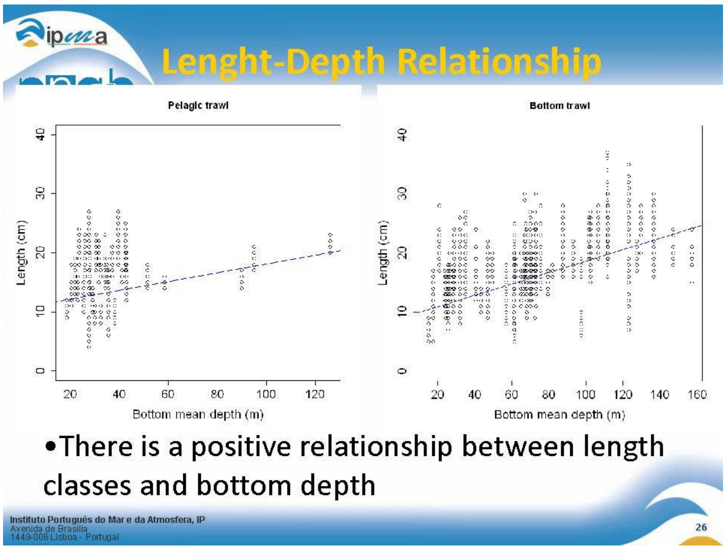
ipma
Lenght-Depth Relationship
Pelagic trawl
Bottom trawl
Length (cm)
Bottom mean depth (m)
•There is a positive relationship between length classes and bottom depth
Instituto Português do Mar e da Atmosfera, IP
Avenida de Brasília
1449-006 Lisboa - Portugal
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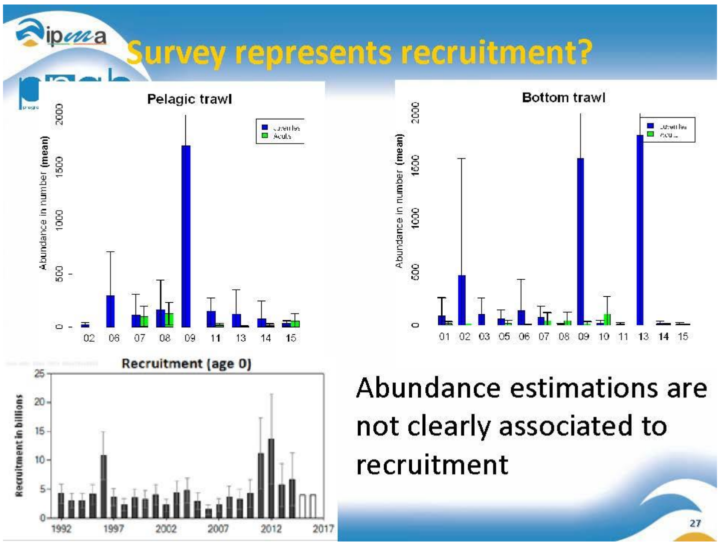
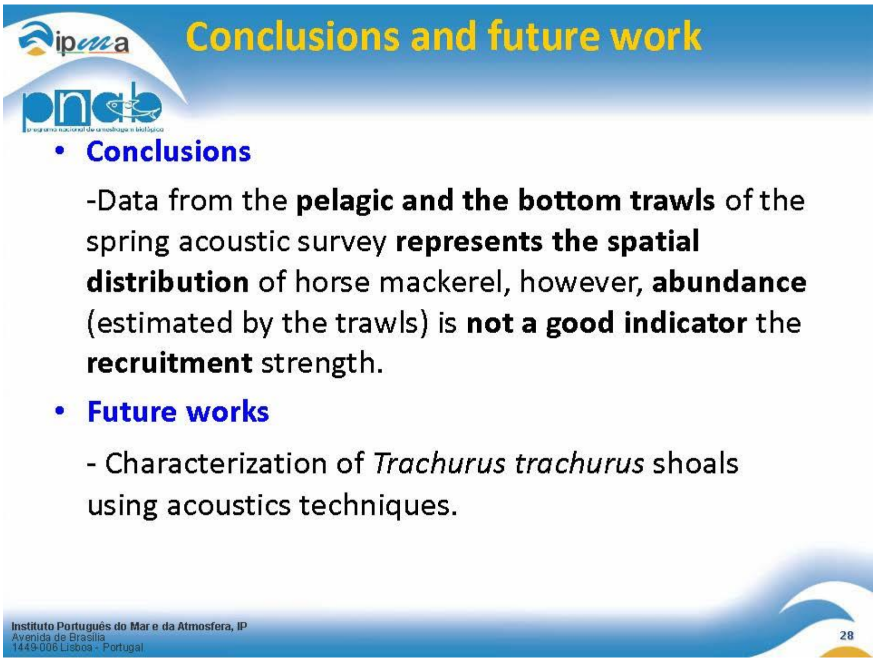

ipma
Survey represents recruitment?
Pelagic trawl
Bottom trawl
Abundance in number (mean)
Recruitment (age 0)
Recruitment in billions
Abundance estimations are not clearly associated to recruitment
27


Conclusions and future work
• Conclusions
-Data from the pelagic and the bottom trawls of the spring acoustic survey represents the spatial distribution of horse mackerel, however, abundance (estimated by the trawls) is not a good indicator the recruitment strength.
• Future works
- Characterization of Trachurus trachurus shoals using acoustics techniques.
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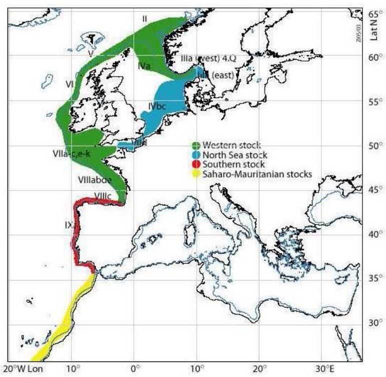
Historical Spanish catch data in ICES 9.a North

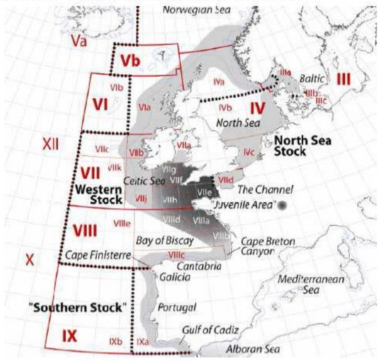
Gersom Costas

Data evaluation Workshop for Southern Horse Mackerel (DEWPELA hom-soth).
Lisbon. 21–23 November 2016.

Former boundaries Horse mackerel Stocks in North Eastern Atlantic Ocean



CURRENT boundaries Horse mackerel Stocks in North Eastern Atlantic Ocean

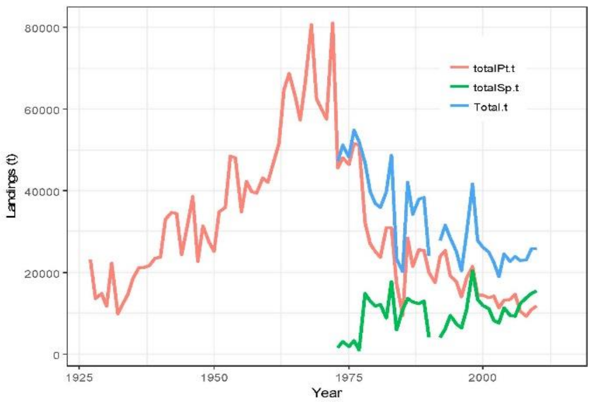


Since 2004

1992 backward Spanish number of catch at age data are aggregated in former southern horse mackerel stock (division 8.c + 9.a)

Problems recovering old catch at age Spanish data split by division: 8.c + 9.a

Historical Catch data for Southern horse mackerel (division 9.a)



DEWKshom, 21-23 November 2016, Lisbon

Commercial size category approach to estimate horse mackerel catch length composition for stock assessment

Manuela Azevedo & Cristina Silva

Adapted from WKSDO, 2014 & ICES CM 2016/O

Azevedo *et al*, 2014. Report of the Workshop on Sampling Design and Optimization of fisheries data – WKSDO. *Relat. Cient. Téc. do IPMA(http://ipma.pt)*, *nº 2*, 80 pp.

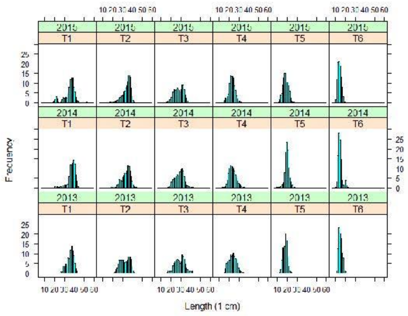
Azevedo M, Silva C and Volstad JH, 2016. Modeling length distribution by commercial size category to estimate species catch length composition for stock assessment. ICES CM 2016/O

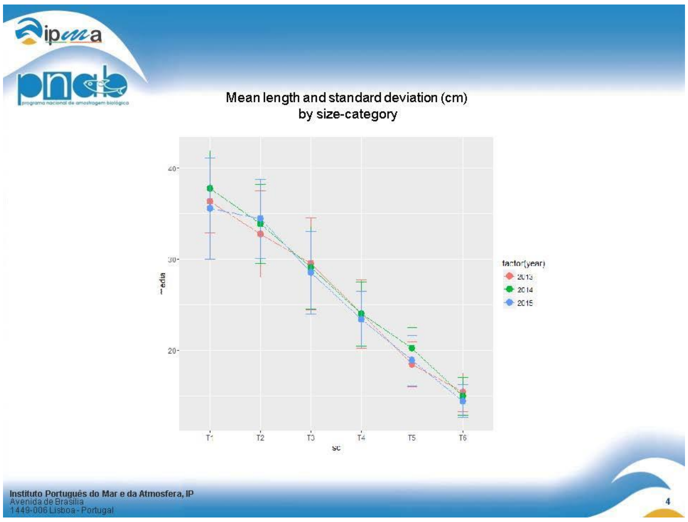
Sampling data (onshore)

Horse mackerel length composition by commercial size-category

Number of fish sampled by category and year

Size-category	2013	2014	2015
T1	1165	1271	1716
T2	4157	3751	3475
T3	6223	6864	6170
T4	5342	6729	8907
T5	9558	9112	6794
T6	2473	1947	2863




Mean length and standard deviation (cm)
by size-category
factor(year)
2013
2014
2015
T1 T2 T3 T4 T5 T6
sc
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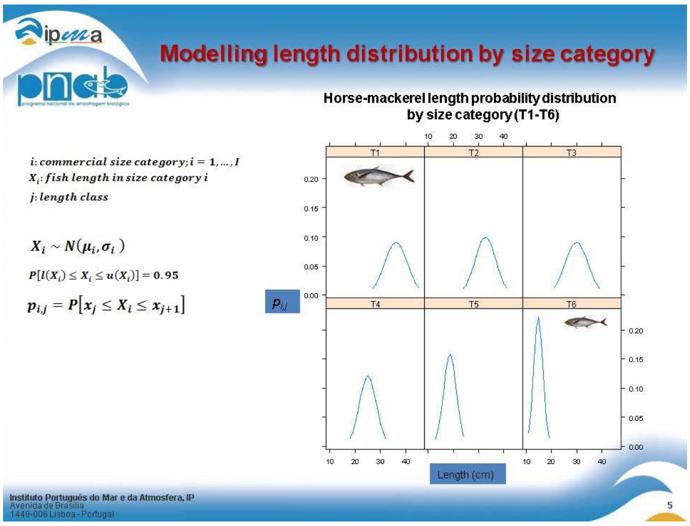
Modelling length distribution by size category
Horse-mackerel length probability distribution
by size category (T1-T6)
i: commercial size category; $i = 1, \ldots, I$
X_i: fish length in size category i
j: length class
$X_i \sim N(\mu_i, \sigma_i)$
$P[l(X_i) \leq X_i \leq u(X_i)] = 0.95$
$p_{i,j} = P[x_j \leq X_i \leq x_{j+1}]$
$p_{i,j}$
T1 T2 T3 T4 T5 T6
Length (cm)
Instituto Português do Mar e da Atmosfera, IP
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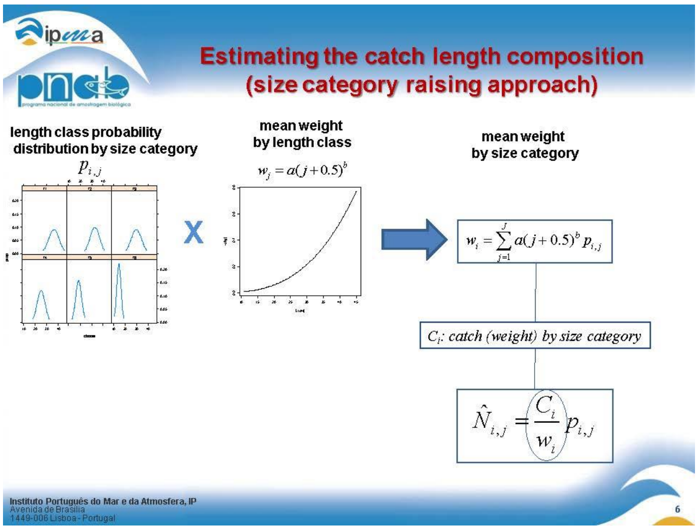
Estimating the catch length composition
(size category raising approach)
length class probability
distribution by size category
$p_{i,j}$
mean weight
by length class
$w_j = a(j+0.5)^b$
X
mean weight
by size category
$w_i = \sum_{j=1}^{J} a(j+0.5)^b p_{i,j}$
C_i: catch (weight) by size category
$\hat{N}_{i,j} = \frac{C_i}{w_i} p_{i,j}$
Instituto Português do Mar e da Atmosfera, IP
Avenida de Brasília
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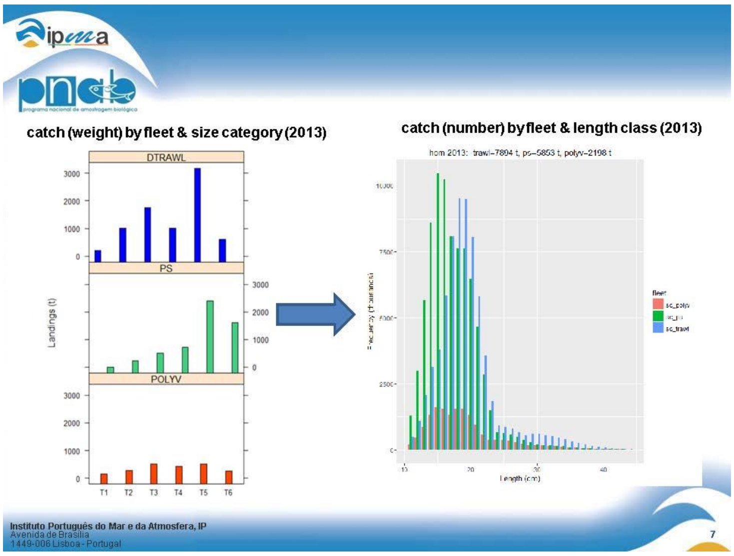
6


ipma
pnab
programa nacional de amostragem biológica
catch (weight) by fleet & size category (2013)
catch (number) by fleet & length class (2013)
DTRAWL
PS
POLYV
Landings (t)
T1 T2 T3 T4 T5 T6
Length (cm)
Instituto Português do Mar e da Atmosfera, IP
Avenida de Brasília
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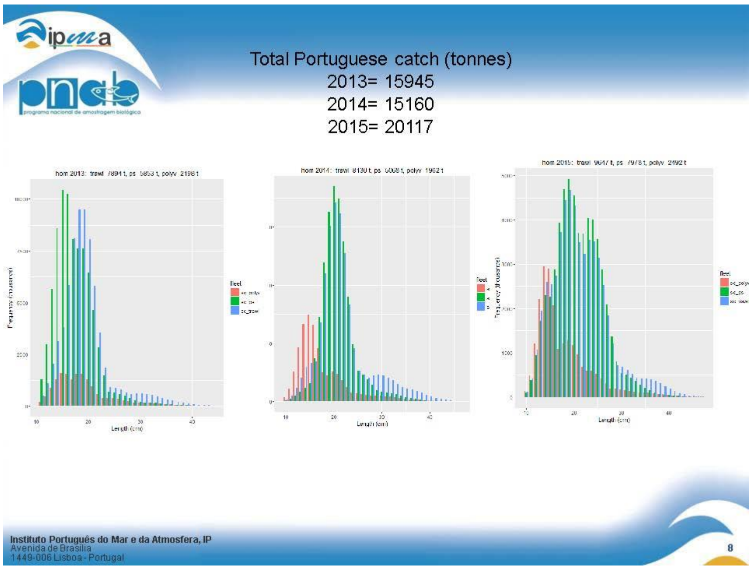
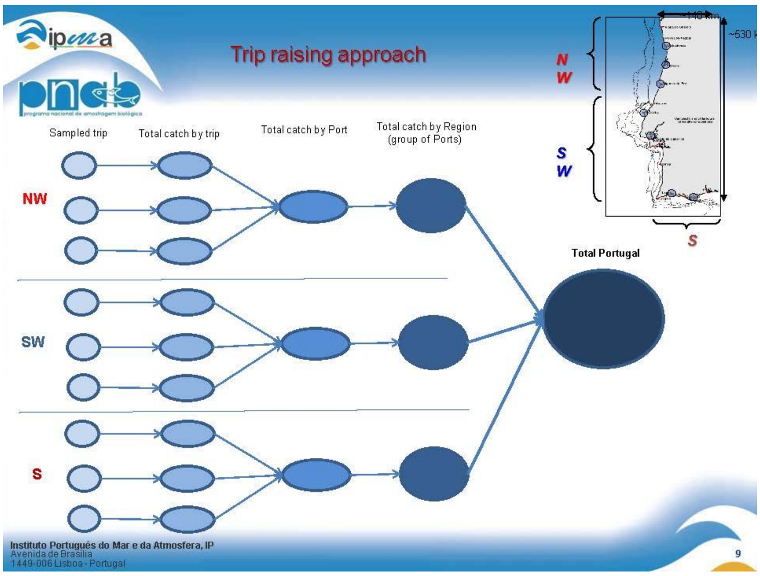
7


ipma
pnab
Total Portuguese catch (tonnes)
2013= 15945
2014= 15160
2015= 20117
Instituto Português do Mar e da Atmosfera, IP
Avenida de Brasília
1449-006 Lisboa - Portugal
8


ipma
pnab
Trip raising approach
Sampled trip
Total catch by trip
Total catch by Port
Total catch by Region (group of Ports)
NW
SW
S
Total Portugal
N W
S W
S
Instituto Português do Mar e da Atmosfera, IP
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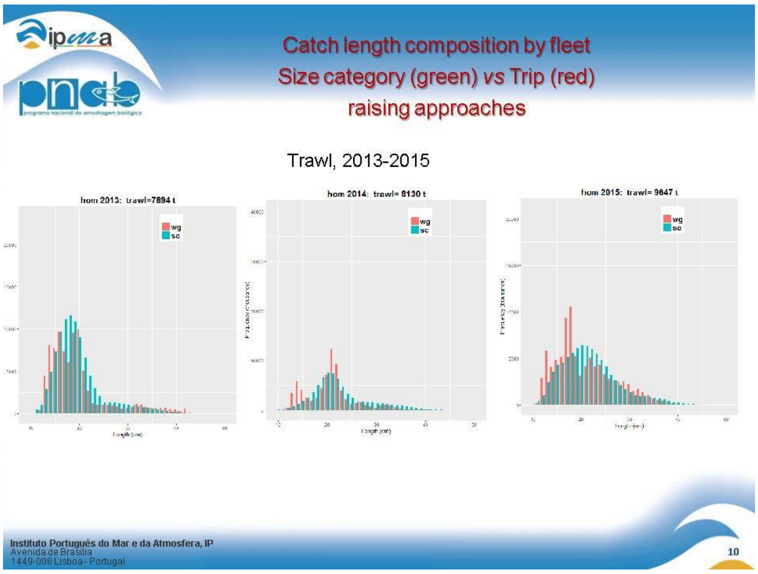
9


ipma
pnab
programa nacional de amostragem biológica
Catch length composition by fleet
Size category (green) *vs* Trip (red)
raising approaches
Trawl, 2013-2015
hom 2013: trawl=7894 t
hom 2014: trawl= 8130 t
hom 2015: trawl= 9647 t
wg
sc
Instituto Português do Mar e da Atmosfera, IP
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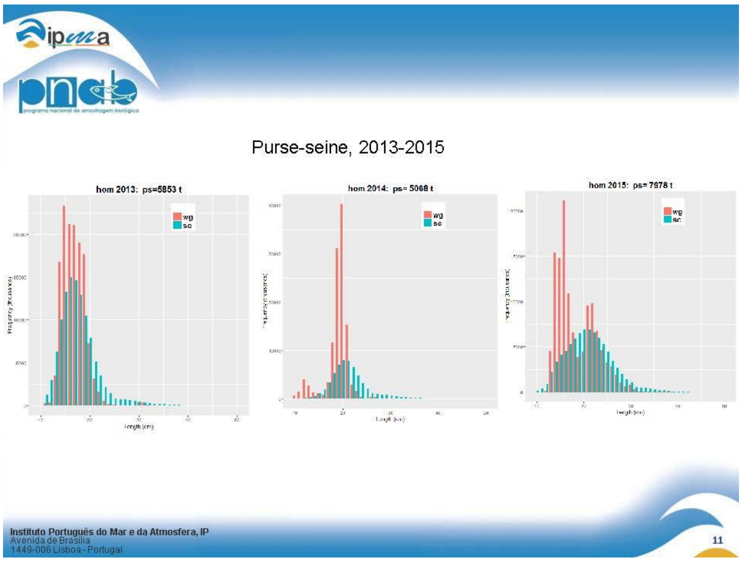
ipma
pnab
programa nacional de amostragem biológica
Purse-seine, 2013-2015
hom 2013: ps=5853 t
hom 2014: ps= 5068 t
hom 2015: ps= 7978 t
wg
sc
Instituto Português do Mar e da Atmosfera, IP
Avenida de Brasília
1449-006 Lisboa - Portugal
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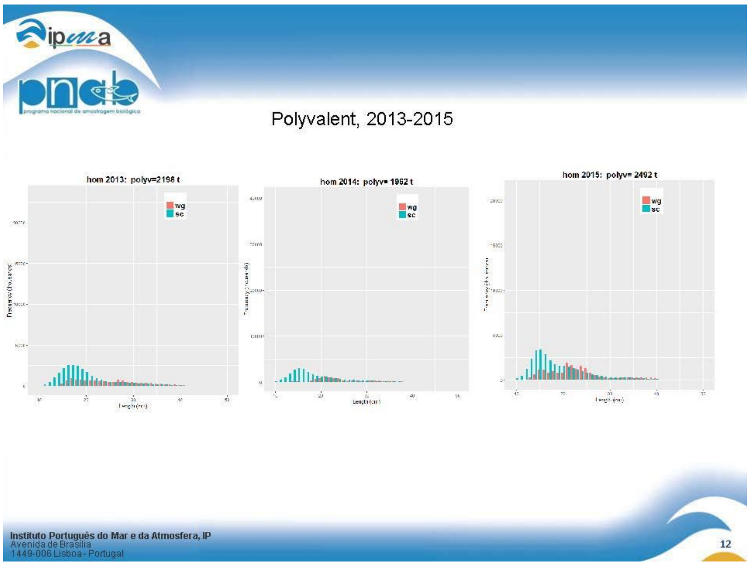
ipma
pnab
programa nacional de amostragem biológica
Polyvalent, 2013-2015
hom 2013: polyv=2198 t
hom 2014: polyv= 1962 t
hom 2015: polyv= 2492 t
wg
sc
Instituto Português do Mar e da Atmosfera, IP
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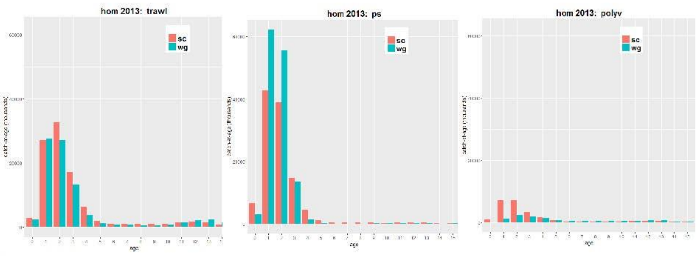
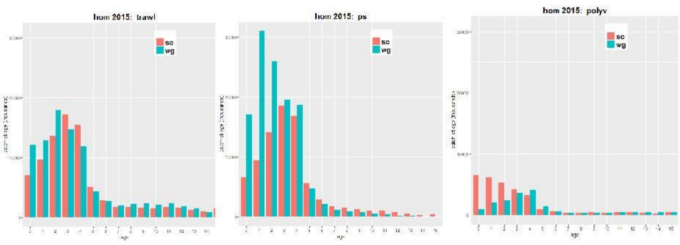
Catch-at-age

2013
Trawl, Purse-seine, Polyvalent



Catch-at-age

2015
Trawl, Purse-seine, Polyvalent



Main conclusions & Future work

✓ Size-category approach allows estimating the catch length composition at trip level

- trip approach under/overestimating the catch length composition; e.g in 2013 few onshore samples from PS catch were collected in the NW-SW area, mainly in the 3rd quarter hence raising sampled trips to total catch resulted in overestimation of small size fish in PS catches
- pos-stratification of trips by fleet segment; better characterization of PS and polyvalent catch length composition

✓ Size-category approach requiring lower onshore sampling effort

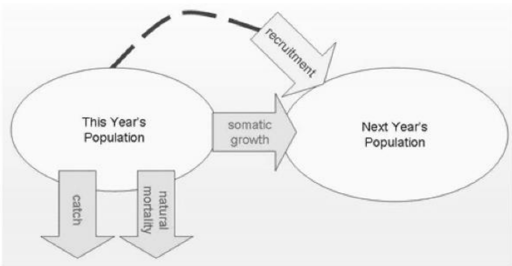
- Pilot sampling plan during 2017

Test in the field (Portuguese onshore sampling) a size category sampling design and sampling effort to estimate horse-mackerel catch-at-length and catch-at-age composition

AMISH :Assessment Method for the Ibero-Atlantic Stock of Horse-Mackerel.

Data evaluation Workshop for Southern Horse Mackerel (DEWPELA hom-soth).
Lisbon. 21–23 November 2016.

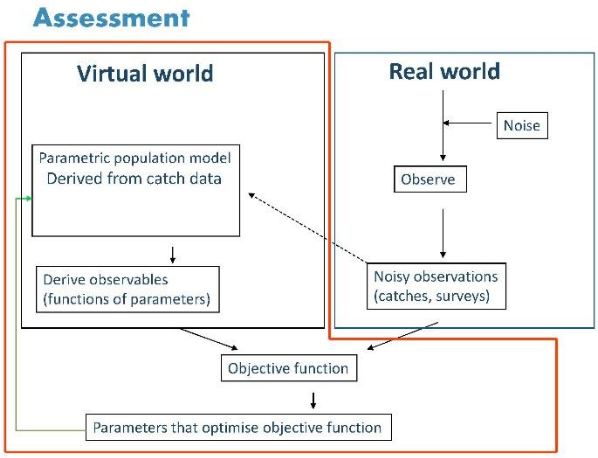
Stock Assessment

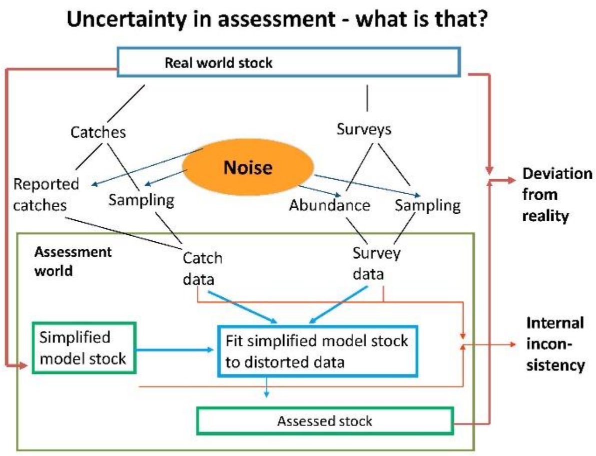


Objectives of Stock Assessment

Tasks:

1. Determine stock status
2. Evaluate uncertainties in the determination
3. Provide projections for management scenarios





INPUTS

Fixed parameters

Maturity at age:

maturation ogive

Age	0	1	2	3	4	5	6	7	8	9	10	11+
Maturity	0	0	0.36	0.82	0.95	0.97	0.99	1	1	1	1	1

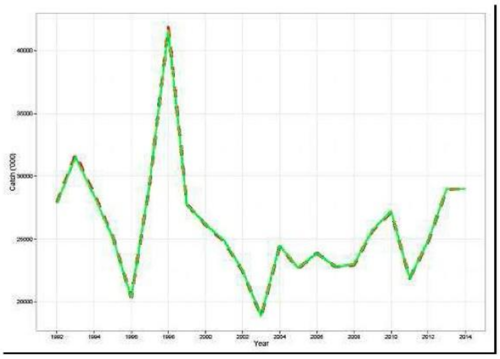
Natural mortality

Proportion of natural mortality before spawning

Age	0	1	2	3	4	5	6	7	8	9	10	11+
Nat Mort	0.9	0.6	0.4	0.3	0.2	0.15	0.15	0.15	0.15	0.15	0.15	0.15

INPUTS

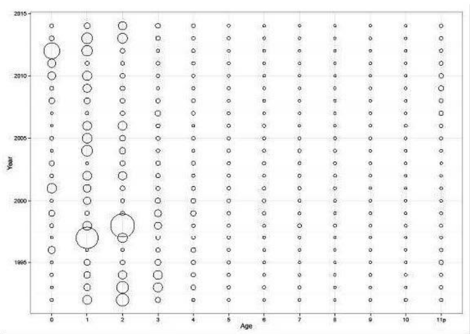
Catch in tonnes by year



INPUTS

Catch at age in numbers

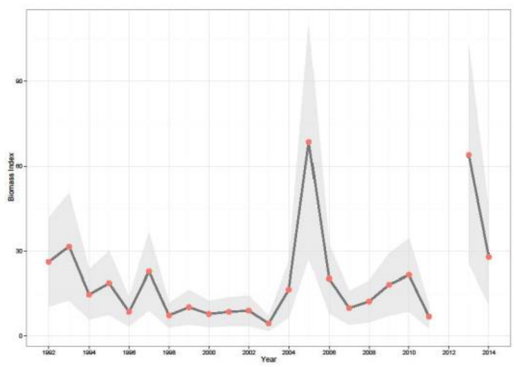
Length distribution apply ALK



INPUTS

Tunning index

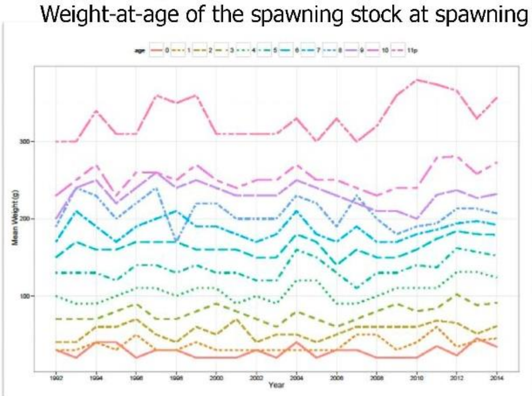
Combined survey abundance index by year



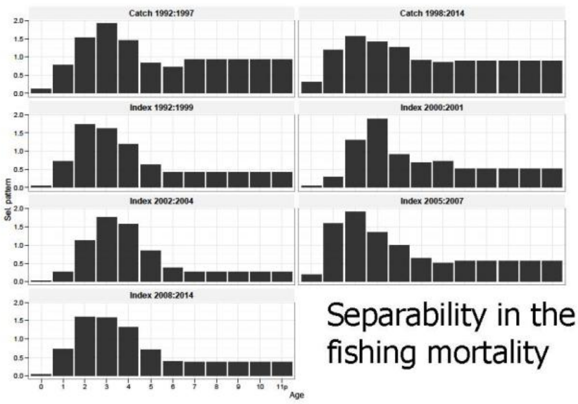
INPUTS

Weight at age

Weight-at-age in the commercial catch
Weight-at-age of the spawning stock at spawning time.



Selectivity



Separability in the fishing mortality

Annex 11 Report of the WKPELA Workshop to evaluate the management plan for Iberian sardine (WKEMPIS)

Contents

Executive Summary

The Workshop on the Evaluation of Management Plan of Iberian Sardine (WKEMPIS) took place in Lisbon, Portugal, on 29–31 May 2017, hosted by IPMA (in Algés). It was chaired by Andrés Uriarte (ICES Chair), Spain, and by Dankert Skagen (External Chair), Norway, with the assistance of the invited external expert Martin Dorn, USA, (and ICES Professional secretary: David Miller/ Support secretary: Sarah Millar). The meeting was attended entirely or part time by eight scientists from Portugal, Spain and France and several stakeholders from Portugal (at the ad-hoc meetings held at the start and the end of the workshop - Annex 1 list of participants).

The WK addressed the special request of the EU to ICES "For the stock sar-south re-evaluate whether the Portuguese-Spanish sardine fishery management plan remains precautionary taking into account the new agreed analytical assessment method and potential new biological reference points. In addition, it should be evaluated whether the plan remains precautionary when adding the following condition to the original plan: "In cases where applying the plan results in catches of less than 50% of catches in the previous year, then ICES catch advice on a precautionary basis should apply." The assessment of the Iberian Sardine (sar-south) was revised and updated this year through a benchmark (WKPELA2017) and Biological reference points (BRPs) were estimated as background for the present evaluation of the LTMP. A Blim was estimated at 337 448 tons as the change point of the Hockey-stick model fitted to the S-R data for the period 1993–2015. The benchmarked assessment estimated the 2016 SSB in less than half that value (151 785 tons, CV=17%).

The harvest control rule (HCR) of the LTMP sets a TAC as a function of biomass: It has 3 parameters, a lower biomass B0, below which the fishery is stopped (B0 = 135 kt), a breakpoint Btrigger below which the TAC is reduced (Btrigger = 368.4 kt) and a standard TAC equivalent to a target catch which applies at all biomasses above Btrigger (target catch = 86kt). The performance of the current HCR was tested by forward simulations of the population and the fishery using the HCS program for two scenarios of recruitment as reflected by a) a Hockey-stick stock–recruitment relationship fitted to the period 1993–2015 (the recent productivity regime; the one of reference) and b) the mean and variance of the most recent period of poor series of recruitment (2006–2015). All other inputs were taken from the most recent period of the fishery (2010–2015). For the compliance with the precautionary approach the Risk to Blim and to a Blow value (the recent mean biomasses in the period 2012–2015 to assess recovery rates) were assessed in the short (1–5years), medium (6–10 years) and long term (up to 30 years), in addition to other performance indicators (catch, realized fishing mortality, etc).

Fishing under the current HCR, rebuilding the spawning biomass in 5 years from the current low SSB level to above Blim is very unlikely (less 10% probability) and in the long term the probability that the stock is above Blim will be considerably lower than 95% (about 50%). For this reason, the HCR cannot be considered precautionary. However, this HCR would prevent further stock decline even at the most recent poor level of recruitments (2006–2015). In both recruitment regimes, the biomass has high probability (> 75%) to be above of the recent low value (132 thousand tons) since the beginning of the simulation period (such probability exceed 95% around 2020 onwards). For the recent productivity regime and with no fishing, rebuilding the stock to above Blim with high (>95%) probability would take about 15 years. Furthermore, if the recent regime of persistent low levels of recruitments (since 2006) holds on, Blim cannot be reached even without fishery.

Developing alternative harvest rules to cope with the present poor state of the stock and poor productivity regime was outside the terms of reference for this group. However, some

variants of the current HCR were tested regarding the target catch and Btrigger. For the recent productivity regime, a decrease of the target catch in the HCR below 25 800 tons results in a high probability (>95%) that the biomass increases to above Blim no later than 2037 (21 years from 2017) and to more than 50% probability that biomass increases above Blim in 2024–2025. For both recruitment scenarios and keeping the target catch at 86 kt, none of the Btrigger variants of the harvest rule will lead to a recovery of the biomass above Blim with >95% certainty in the long term, though setting Btrigger=446.4 (=Bpa) leads to moderate probability (>50%) that the biomass increases to above Blim from 2030 onwards.

Given that the current HCR is not considered precautionary then in the present situation, introducing the additional condition mentioned in the request "In cases where…", does not lead to the sardine plan becoming precautionary. Preliminary exploration of stabilizing elements in the rule confirmed that such measures tend to increase the risk to limit points and to delay recovery.

The External expert endorsed the estimation of the BRPs and the simulations carried out to assess whether the current HCR can be considered precautionary. Nonetheless he pointed out some concern on the relatively high Blim level in comparison with potential Bmsy estimates for the recent productivity regime, which is associated to the difficulties in rebuilding the stock, this being a matter of discussion in the report.

1 Introduction

1.1 Terms of reference

The workshop on the Evaluation of the southern-Sardine management plan compliance with the precautionary approach was set up to address a specific request from the EU associated to the process of benchmarking of this stock. The meeting took place in Lisbon from 29 to 31 May 2017, at IPMA (Algés), and it was attended by 8 scientists from three European countries and an invited external expert from USA (see Annex 1).

The EU request was included in TORs g and f of the Benchmark Workshop on Pelagic Stocks (WKPELA2017), which referred to the Evaluation of the current Long Term management plan for southern sardine regarding to its compatibility with the precautionary approach in the light of the new stock annex and biological reference points (BRPs) proposed for this stock during the benchmark process. As such ToRs f and g are:

a) For the stock sar-soth re-evaluate whether the Portuguese-Spanish sardine fishery management plan remains precautionary taking into account the new agreed analytical assessment method and potential new biological reference points. In addition, it should be evaluated whether the plan remains precautionary when adding the following condition to the original plan: "In cases where applying the plan results in catches of less than 50% of catches in the previous year, then ICES catch advice on a precautionary basis should apply." To the largest extent possible, the evaluation should follow the guidelines provided by the "Workshop on Guidelines for Management Strategy Evaluations" (WKGMSE, ICES CM 2013 ACOM 39), including the guidelines for reporting provided in Section 6 of the WKGMSE report. The agreed ACOM criteria for considering management plans as precautionary should also be taken into account in the evaluation.

b) Prepare the first draft of the advice to address the EU request on whether the Portuguese and Spanish sardine fishery management plan remains precautionary by introducing the condition "In cases where applying the plan results in catches of less than 50% of catches in the previous year, then ICES catch advice on a precautionary basis should apply".

Given that the benchmark work on the assessment procedure and BRPs had to be finished before addressing these two ToRs, it was decided that a posterior meeting to WKPELA February meeting was required to carry out the Evaluation of the LTMP and it was schedule on 29–31 May 2017.

1.2 Request-background

A request was received from the European Commission to evaluate a potential change to a part of the southern sardine management plan.

In relation to ICES' advice of July 2013 on the management plan for sardine in Divisions VIIIc and IXa, could ICES advise whether by introducing the condition below the sardine plan remains precautionary?

"In cases where applying the plan results in catches of less than 50% of catches in the previous year, then ICES catch advice on a precautionary basis should apply."

The advice should be delivered before 31 August 2016, the latest.

The request was received on 25 May 2016 and initially the deadline was set for 15 June 2016, but following discussion with the client it was agreed to postpone the answering of the request until after the benchmark of southern sardine at the beginning of 2017.

The previous 'Precautionary Approach' option used by ICES for this stock was to adjust the observed average F in the years 2002–2007 according to the ratio between current B1+ biomass and the average B1+ biomass observed from 2002–2007: F = F2002–2007 × (B1+2015/ B1+2002–2007). This is a non-standard application of the ICES precautionary approach.

Following the benchmark changes to data and the assessment model set up for this stock have led to a change in the perception of the historic time series of biomass and F (the new assessment scaled the biomass estimated in 2015 and 2016 downwards by 20% and 24% and the 2015 F upwards by 14%). This impacted on the work to be done in two ways:

1) With a new assessment and reference points, the MP needs to be re-evaluated to determine whether or not the MP is still considered precautionary. The constant catch value and the breakpoints used in the HCR may need to be revisited.
2) New reference points are also being defined for the stock. With the new assessment and reference points for the stock, were the precautionary approach to be applied by ICES in future it would likely be different to the approach previously used.

1.3 Current Harvest Control Rule of the LTMP

The Spanish and Portuguese governments have accepted a management plan for this stock (Sardine Fishery Management Plan, (2012–2015)).

The key element in the management plan is a harvest rule, which sets a TAC as a function of biomass. It has 3 parameters, a lower biomass B0 below which the fishery is stopped (B0 = 135 kt), a breakpoint Btrigger below which the TAC is reduced (Btrigger = 368.4 kt, equal to 1.2 Bloss in the 2012 assessment; 306 000 t) and a standard TAC equivalent to a target catch which applies at all biomasses above Btrigger (target catch = 86kt) (Figure 1.3.1):

when B1+ ≥ Btrigger; Catch = 86 kt

when Btrigger > B1+ ≥ B0, Catch = 0.36 x [(B1+)-B0];

when B1+ < B0, Catch = 0.

Figure 1.3.1. Illustration of the proposed harvest rule.

ICES evaluated the plan in 2013 at the request of the EU (ICES, 2013) and it was considered to be provisionally precautionary.

1.4 Stakeholders informal meetings

Stakeholders were invited to attend the meeting as observers as part of the benchmark process. The chair notified the meeting to the secretariat of the southwestern waters Advisory council (SWWAC), who prevented their associated members about the possibility to attend the meeting, previous notification to ICES secretariat.

Informal meetings took place both at the beginning (in the morning of Monday 29) and at the end of the meeting (in the afternoon of the Wednesday 31) in total with about 9 stakeholders (see the list of attendees).

The main messages and questions passed to them during the first informal meeting were:

- The result of the latest assessment from WKPELA 2017 (summary presentation)
- Definition of Blim and difficulties in the definition of the BRPs
- The current Rule and the objective of this meeting is to assess the compatibility of current HCR with PA
- Message: This is a critical situation. Since 2006 there has been a decrease of biomass about 80%. Therefore there has to be a recovery plan for a set of years (how many? 5 years?) etc, until noticing a recovery a LTMP which would allow designing a proper LTMP
- Some preferences for a new setting of HCRs? And for properties (such as stability of catches, minimum TACs, Maximum TAC, reference biomasses to set the TAC of just last year or several years, etc)?
- Regarding the additional condition on the application of the HCR, we prevented them that interpretation of the PA advice in the past (taking as reference the mean F in the period 2002–2017 corrected by the ratio of past and most recent biomass estimates) would not apply now if the BRPs are accepted

Some stakeholder comments during the meeting of the first day were: The situation for the fishing and canning sector is critical and they look forward for effective proposals to recover the stock. They have not yet a clear idea of what a minimum TAC might be to assure the viability of the fishery. They could address this issue elsewhere. While the stock may recover thanks to a substantial recruitment they would like at least to have effective management that prevents any further depletion of the stock. To overcome this situation it would be of the interest of fishermen to open other possibilities of fishing on other pelagic species (it was mentioned the horse mackerel). Catch stability has always been desired for the fishery. That was behind the demand of the additional clause to the implementation of the HCR of the current LTMP.

Stakeholders representing the fishery (ANOPCERCO), the canning industry (ANICP, by Skype), NGOs (PONG-PESCA) and managers (DGRM and Secretary of State of Fisheries) participated on the last day of the meeting. The co-chair (Andrés Uriarte) presented the main conclusions of the workshop, in particular that the current harvest rule of the management plan is not precautionary neither in the short nor in the long term and that any possibly fishery in the short term should be very low catches (possibly below 10 000 tons) if the recent low recruitment continues. ANOPCERCO representative expressed their concern that this might represent further restrictions of catches and stated that they've already made severe restrictions in previous years leaving the impression that the fishing sector will be reluctant to accept any further restriction of catches. ANOPCERCO representative stated that the fishermen they represent have the impression that the stock started to recover since they are seeing and catching a lot of sardine at sea and that they feel that the stock is in a better situation than 2 years ago. ANOPCERCO has difficulties to accept the perceived differences between their stakeholders and scientific data. PONG-PESCA emphasized the fact that the stock is at a very low level and with very low recruitments. They consider that stakeholders should entail joint efforts to develop new solutions to face the present situation. The chair explained the procedure and the timeline that ICES will follow to provide advice this year.

1.5 Organization of the group and approach to address the request

The WG was organized during the first day of the meeting (see agenda).

The first day it was focused to clarify the general approach including discussions on the following issues:

- Current formulation of the HCR and definition of potential variants to this HCR to be tested: Main variants were explored regarding the Btrigger value and the standard TAC or catch of reference beyond the Btrigger value.
- Potential biological reference points (presentation by Alexandra Silva): discussions took place on the validity of the Blim, particularly taking into account the possibility that Recruitment might not be driven so much by SSB but more by environmental factors. Current Blim is problematic but follows the standard guidelines of ICES. It would be useless trying to define alternative Blims or reference points. In any case a minimum observed biomass in the recent years was taken as a second biomass of reference to assess also the degree of recovery of the stock from current situation under any tested HCR.
- Productivity regimes: Different approaches to the Stock Recruitment relationships and the scenarios of productivity were defined. The fitted Hockey stick S–R relationship to the period 1993–2015 was kept as the reference model of stock productivity in terms of Recruitment. Alternative scenarios of even poorer recruitments were also outlined.

- Interpretation of the additional condition to the implementation of the current HCR by using alternatively the PA approach when catches would result in less than 50% of the catches in the previous year, in the context of the new assessment and Biological reference points and taking into account stakeholders considerations (see above), was decided to be reoriented into a stabilizer catch rule, either by constraining maximum interannual catch options by +/- 15%, or by applying a 50–50 filter rule in which the final TAC is the mean of the TAC derived from the application of the rule with the TAC of the previous year TAC.
- Considerations about what properties a recovery plan should have. Provided that under current low recruitment regime there is no way for the stock to recover above Blim, it was considered that it should also be assessed the likelihood for any HCR in a time horizon to recover not only above Blim but also to increase the stock to higher levels than current low levels (and by how much). That should be incorporated in the performance indicators.
- Setting up the Input basis for the assessment of the current HCR and the performance indicators.

The rest of the day was passed with the informal meeting with stakeholders and with more extended discussions on these issues.

The second day was devoted to finalizing the conditioning of the modelling, and running the assessment of the current HCR and variants, and examination of results. Draft structure of the report and of the introductory sections were written down.

The third day was spent with final discussion, writing of the report and producing the first draft of the answer to the EU request. In the afternoon, a second meeting with stakeholders was held up to provide them with a short summary of the main results achieved.

The report is structured as follows:

- A general introduction and description of the request and of the HCR of the LTMP.
- Followed by a general section of the Biology of sardine
- Summary of proposed Biological reference points
- A section on the software and operating model, inputs and conditioning of the model.
- Definition of the Simulations done including the variants to the current HCR being tested.
- And the presentation of results and discussion.

This is followed by several annexes with details of attendees, agenda, detailed table outputs and the Summary Template for HCR modelling from WKGMSE, etc.

2 Biological considerations

European sardine (*Sardine pilchardus* Walbaum, 1792) is a small clupeoid distributed in the Northeast Atlantic from the southern Celtic Sea and North Sea to Mauritania and Senegal, and also across the western and northern Mediterranean. The sardine stock assessed by ICES covers the Atlantic waters of the Iberian Peninsula (ICES areas 8c and 9a), extending from the Strait of Gibraltar in the south to the border with France in the Inner Bay of Biscay in the north. Sardine is fished in the coastal waters of the Iberian Peninsula by Spanish and Portuguese purse-seiners. Fisheries catching sardine also increasingly operate in the Bay of Biscay (purse-seiners and trawlers) and English Channel (purse-seiners and trawlers).

2.1 Population abundance and recruitment

The historical series of Iberian sardine catches used in the assessment goes back to 1978 and is provided by the national laboratories of both Spain and Portugal. During the last decades, catches have exhibited some fluctuations, peaked in 1981 at 217 thousand tons, and thereafter showing a general decrease that has been steeper since the early 2010s (Figure 2.1.1).

An age (0–6+) structured stock assessment model, Stock synthesis 3 (Methot, 2012) has been applied since 2012 (WKPELA12, ICES, 2012a, benchmarking in February 2017, WKPELA17) to fishery dependent and independent data (acoustic and DEPM surveys) to derive estimates of population abundance, recruitment and fishing mortality.

Recruitment has extensive variability showing peak values with some regularity (Figure 2.1.2). A time series analysis of recruitment indicated a significant autocorrelation at lag 1 year and cyclical variations of 4–5 years (Santos *et al*., 2012). Both the level of recruitment and stock productivity (number of recruits per spawner) show a downward trend over time that appears to be partly explained by the environment (Solari *et al*., 2010; Santos *et al*., 2012).

Despite little or no unequivocal evidence of a clear regime shift, at least at a regional scale, the historical stock dynamics suggests sardine productivity has declined over time (from the early 1990's, indicate that sardine population may have been more than two times its actual size). The mean productivity of the stock across the whole historical period may not be representative of future productivity. The mean stock productivity in some recent period is a plausible scenario for future stock dynamics.

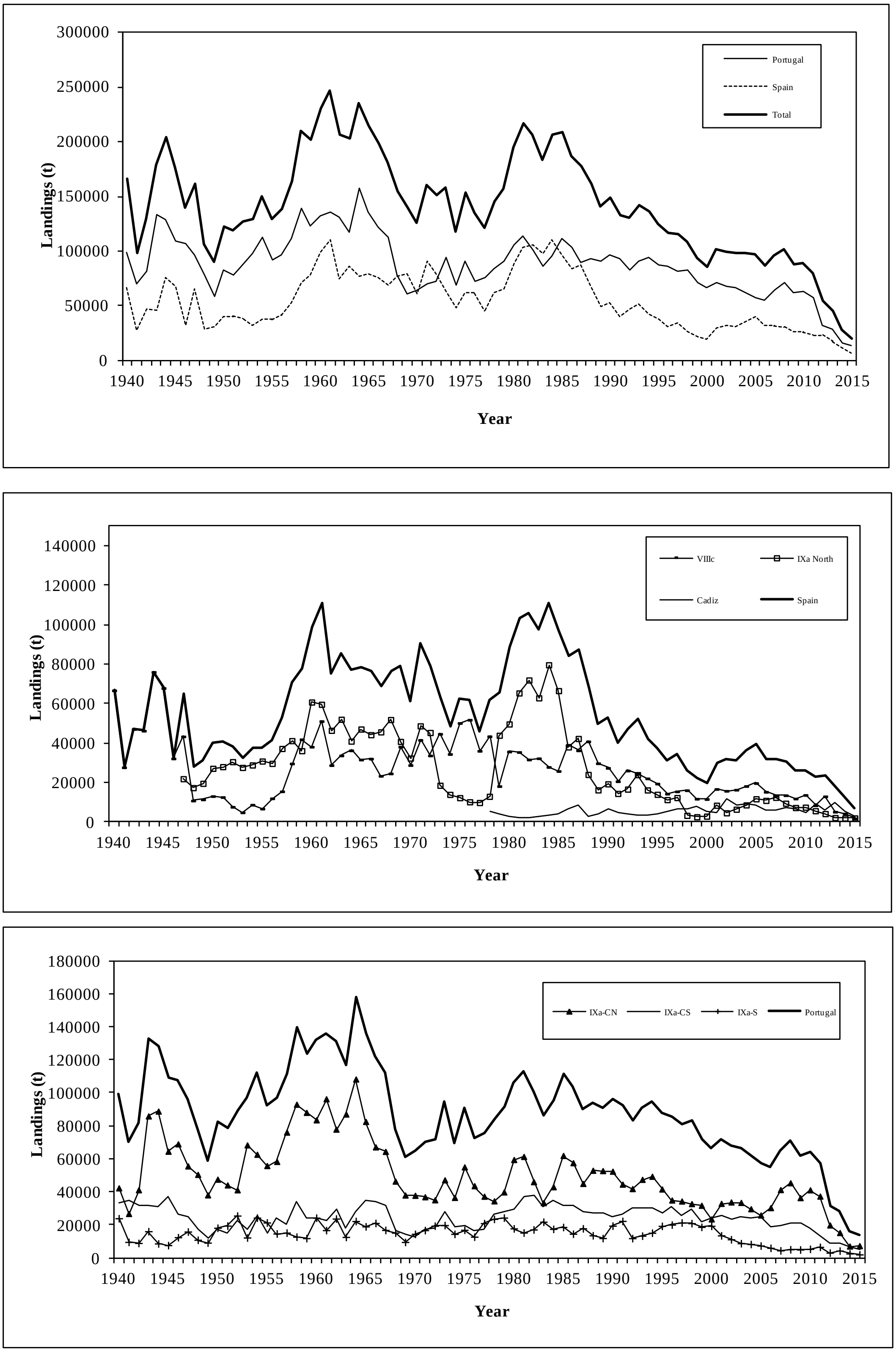
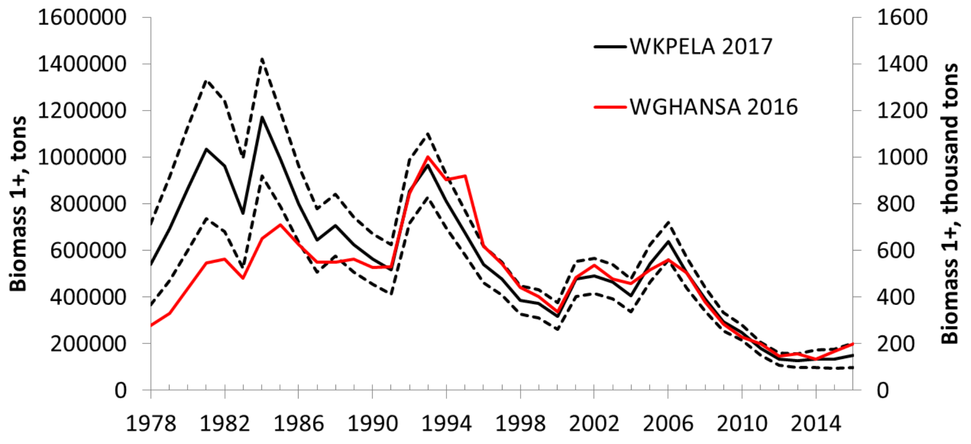


Figure 2.1.1. Sardine landings in 1978–2015.



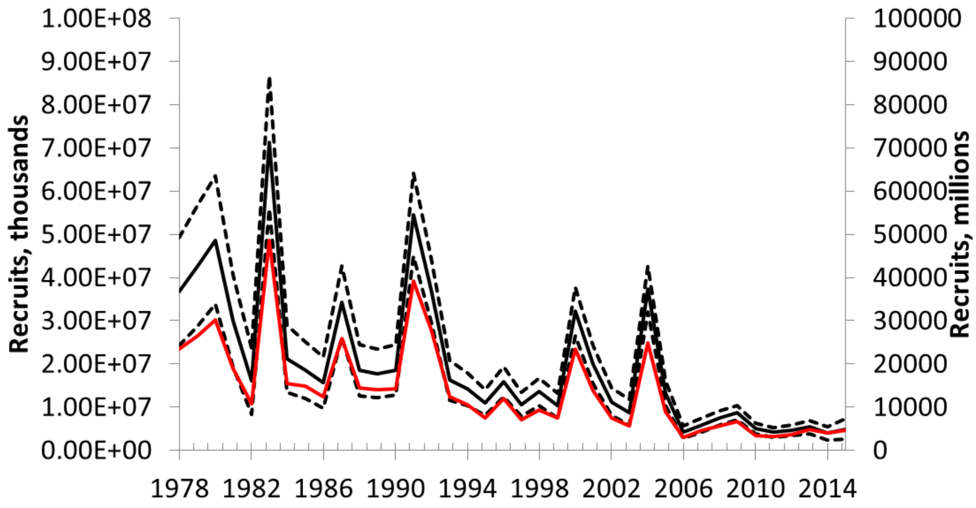


Figure 2.1.2. Sardine 8c and 9a: Historical B1+ (top) and recruitment (bottom) trajectories in the period 1978–2016 (ICES, 2017). Dashed lines show mean values ± 2 Standard Deviations. The 2016 assessment (WGHANSA 2016) is shown for comparison.

2.2 Age and growth

In the Iberian waters, typical longevity is 7–8 years and maximum length 25 cm. The Von Bertalanffy growth coefficient is 0.44 year–1 and individuals reach ~90% of maximum length at age 4 (Silva *et al.*, 2008).

Growth is strongly seasonal, taking place mostly outside the spawning period. Growth in length is greater in late spring and summer. Body condition and fat content of sardines peak in early autumn (when spawning resumes), and the lowest values are observed in late winter/early spring with the cessation of spawning (Bandarra *et al.*, 1997).

Mean weights-at-age in the stock in the new assessment comes from DEPM surveys (Nunes *et al.*, 2017), with several considerations:

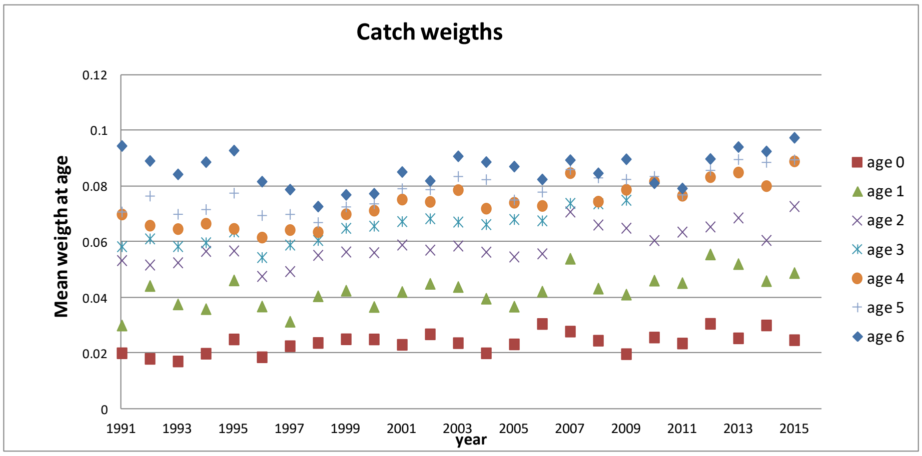
- For years with no DEPM survey between 1998 and 2014 (last DEPM survey at the moment), a linear interpolation was carried out to obtain the intermediate estimates of mean weight at age.
- For the period 1978–1998 (before DEPM series started) it was decided to consider the two closest DEPM surveys, and assume for that period the average between 1999 and 2002 estimates. The reasoning behind it is the apparent increasing trend

in mean weights shown by several age classes (see ages 2 to 4) throughout the time series.

- For 2015 (year after the last DEPM survey), 2016 estimates were assumed.

Historical weights at age show an increase over time. This increase is seen in catch and stock weights since the early 1990s but may have started earlier (in earlier years, fixed weights are used in the assessment; a fixed catch weight of 0.1Kg is used for age 6+).

The weight increase is significant for all age groups in the catches and most age groups in the stock (2–4 and 6+) (Figure 2.2.1). Weight trends might reflect an improvement of sardine condition possibly associated to enhanced feeding rate and efficiency induced by temperature noticed since the early 1970s (Silva *et al.*, 2010).



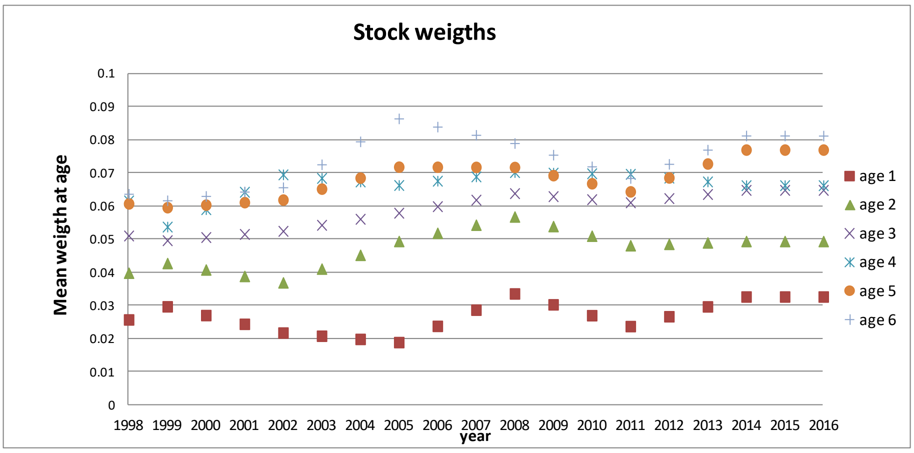


Fig 2.2.1. Illustration of trends in weights-at-age.

2.3 Reproduction and maturity

Sardine is a batch spawner with indeterminate fecundity (Ganias *et al.*, 2007). The main spawning period is between October and June (peak December–March), with a latitudinal gradient in the duration and peak of the season, i.e., longer duration and earlier peak in the south (Stratoudakis *et al.*, 2007).

Most individuals mature at age 0 or age 1 with a length of 14 cm (Silva *et al.*, 2006).

Maturity ogives for assessment purposes come from DEPM spring surveys (triennial), whilst for the years without DEPM surveys, for the period 1998–2014, a linear interpolation is carried out to obtain the intermediate estimates of maturity at age. Prior 1998, constant proportions of mature at age were assumed, based on the average of the estimates obtained from the 6 DEPM surveys of the 1999–2014 period, thus including both years of strong year classes and years of low recruitment. For the years 2015 and 2016 (years after the last DEPM survey), after the observation that the age composition of sardine population was similar between 2014 and 2016, the same estimates were assumed for the period 2014–2016 (Nunes *et al*., 2017).

3 Biological Reference Points

Currently, there are no defined reference points for the southern sardine stock and the basis of ICES advice is the Sardine Fishery Management Plan agreed by Spanish and Portuguese governments and evaluated by ICES to be provisionally precautionary (ICES, 2013a).

An estimation of biological reference points (BRP) for this stock was performed based on data from the latest assessment (ICES, in press). The methodology used followed the framework proposed in ICES (2017) guidelines for fisheries management reference points. All statistical analyses were carried out in R environment (R core team 2017). Sardine's latest stock information was converted to an 'FLStock' object using the 'FLCore' package (version 2.6.0.20170130). Simulations analyses were conducted with the package "msy" using the EqSim routines (https://github.com/ices-tools-prod/msy; ICES 2016a), a stochastic equilibrium reference point software that provides MSY reference points based on the equilibrium distribution of stochastic projections.

Several scenarios were explored (whole time series with and without auto-correlation in recruitment; period 1993–2015 with Blim equal to the change point of the Hockey-stick S–R relationship and with Blim equal to B2000). Here we summarize the results for the base scenario (1993–2015 with Blim equal to the change point of the Hockey-stick S–R relationship), for further details on the other scenarios please see Wise *et al*., (WD to WKPELA 2017 report in Annex 11+ ICES, in press).

In relation to stock productivity the group decided to use as the base scenario the period 1993–2015 (Table 3.1) similarly to the evaluation of the sardine MP (ICES, 2013a). There is evidence that sardine productivity has declined over time despite little or no unequivocal evidence of a clear regime shift. In approximately the last 20 years, recruitment is at a lower level and biomass range is narrower than in the previous 15 years. Following the analysis performed in ICES (2013a) a productivity break was identified in 1992–1993 in the time series. The group agreed to maintain the same break as in the historical series and assume that the stock productivity in the period 1993–2015 is a plausible scenario for future stock dynamics. However, the group acknowledged that recruitments since 2006 are well below the average of the period 1993–2015 and recommends a close monitoring of the stock productivity and a re-evaluation of reference points in case there are signs that the current very low productivity continues in the future.

Simulations were performed with stochasticity in population biology parameters using the observed historical stock variation from the last six years (2010–2015). This period was chosen due to trends (positive) in stock and catches weight-at-age. Stock weight-at-age is calculated from DEPM surveys, which are carried out on a triennial basis. For years in between DEPM surveys, weight-at-age is linearly interpolated from adjacent surveys. A period of six years was chosen to include two survey estimates. This procedure is similar to the one adopted for the short term forecast (ICES, in press).

Table 3.1. Model and data selection settings

DATA AND PARAMETERS	SETTING	COMMENTS
SSB-recruitment data	Scenario 1) 1993–2015	Sardine productivity has declined over time; productivity in 1993-2015 has been generally lower than in the earlier period. The period 1993-2015 broadly corresponds to the period where survey information is available. The current MP is based on productivity since 1993. The stock shows a wide dynamic range of SSB and evidences that recruitment is impaired.
Exclusion of extreme values	No	
Trimming of R values	No	
Mean weights and proportion mature; natural mortality	2010–2015	6 yr. period was chosen due to trends (positive) in stock and catches weight-at-age. Knife-edge maturity ogive with 100% mature at age 1+. Biomass 1+ is the stock index. Natural mortality is age dependent and time invariant.
Exploitation pattern	2010–2015	6 yr. period. Corresponds to a constant selectivity period.
Assessment error of fishing mortality in the advisory year	0.233	Default value from ICES, 2016a. No robust estimates once assessment settings have changed during the 2017 benchmark.
Autocorrelation of fishing mortality in assessment error	0.423	Default value from ICES, 2016a
Assessment error in the spawning stock in the advisory year	0.170	Value from the sardine south stock assessment (ICES, in press)

Several S–R relationships (Ricker, Beverton-Holt and Hockey-stick) were fit to the 1993–2015 data. The models showed comparable maximum likelihood estimates but the Hockey-stick achieved slightly better fits. The automatic weighting method implemented in EqSim (ICES, 2016a) was used to weight the combination of the three S-R models fitted from bootstrap samples of the SSB and recruit pairs (Figure 3.1). Again, the Hockey-stick had better results than the Ricker and Beverton-Holt with weights estimated to be 84%, 5% and 11%. The WG recognized the weighted S–R model had the advantage to acknowledge model uncertainty. However, the difference is small in this case as the Hockey-stick dominates the S–R combination by far (84% weight) and reference points from the two approaches were similar. The WG also considered that using a single S–R facilitates Management Strategy Evaluation (MSE) analyses in practical terms. In conclusion, the Hockey-stick S–R was adopted for the calculation of reference points.

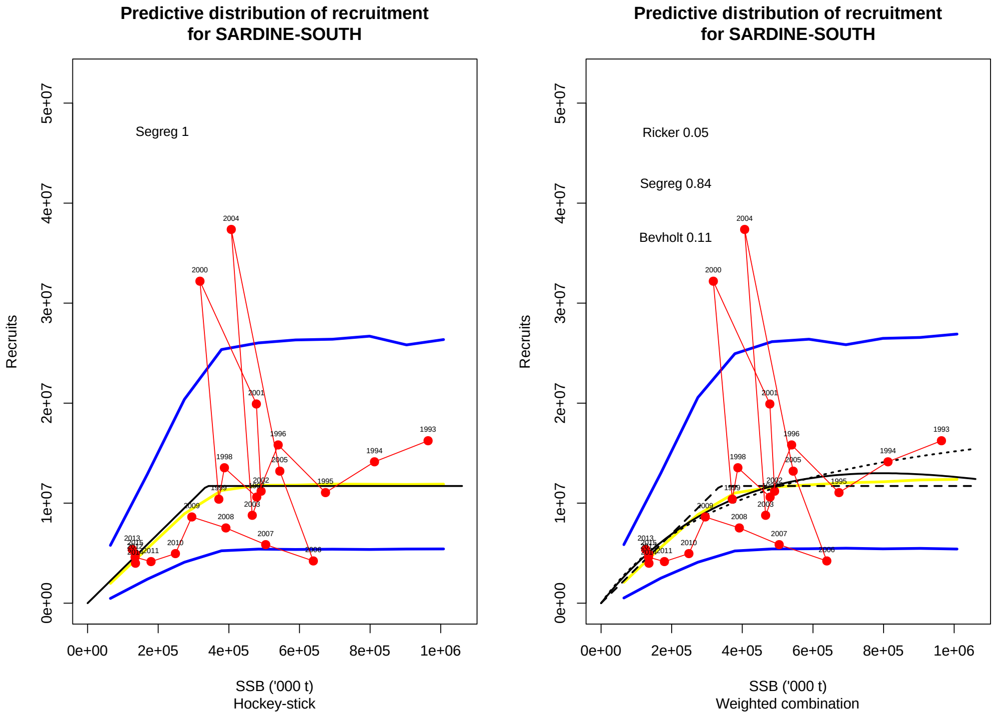


Figure 3.1. Fitted Hockey-stick (black) (left panel) and fitted Ricker (black), Beverton-Holt (black dotted) and Hockey-stick (black dashed) (right panel) with 90% intervals (blue) for the period 1993–2015. The weighting/contribution of each model is showed and the median recruitment based on the weighted distributions of each model (yellow). Red lines are the historic sequence of recruitment.

Following ICES (2017) guidelines, the S–R data of this stock is consistent with a Type 2 pattern given the wide dynamic range of SSB and evidence that recruitment is impaired. In this case, Blim is equal to the change point of a Hockey-stick model fitted to S-R data. The Blim candidate calculated as the change point of the Hockey-stick model was 337 448 tons. Bpa was derived as Bpa = Blim * exp(1.645* σ), with σ = 0.17, the coefficient of variation of SSB2016 from the WKPELA 2017 assessment (ICES, in press).

Reference points were estimated based on the Hockey-stick S-R relationship with Blim and Bpa as defined above and no MSY Btrigger (i.e., without applying the ICES MSY AR). An initial simulation was performed over a range of F values (0–2) using historical variation in population and productivity parameters, re-sampled at random from the specified range of years but with no assessment/advice error (Table 3.1).

The technical basis and the estimated BRP are shown in Table 3.2. Flim, the equilibrium F that gives a 50% probability of SSB>Blim was estimated at 0.25. Fpa was estimated as Fpa = Flim * exp(-1.645* σ), with σ = 0.17, the coefficient of variation of apical F2015 from the WKPELA 2017 assessment. Fpa was estimated at 0.19. Follow-up simulations with the same settings as well as assessment/advice error in fishing mortality and in spawning stock biomass, estimated the median FMSY at 0.20.

Following ICES guidelines, and the fact that the stock has not been fished at/around FMSY for 5 years, MSY Btrigger = Bpa. With the ICES MSY AR (Advice Rule) and setting MSY Btrigger = Bpa the precautionary criterion for FMSY level was also tested, i.e. fishing at FMSY is precautionary in the sense that the probability of SSB falling below Blim in a year in long term simulations with fixed F is ≤ 5% (Fp.05). The Fp.05 was estimated at 0.12.

Fp.05 is well below FMSY. Although the reasons for this fact were not fully explored, a possible cause is that MSY Btrigger (= Bpa) is close to the mean stock biomass. It is also noted that Fp.05 estimates have a wide range with a highly right skewed distribution.

Table 3.2. Biological Reference Points estimated during WKPELA 2017.

BRP	1993–2015	Technical basis
B_{lim}	337 448 t	B_{lim} = Hockey-stick change point
B_{pa}	446 331 t	$B_{pa} = B_{lim} * \exp(1.645 * \sigma)$, $\sigma = 0.17$ (ICES, in press)
F_{lim}	0.25	Stochastic long-term simulations (50% probability SSB < B_{lim})
F_{pa}	0.19	$F_{pa} = F_{lim} * \exp(-1.645 * \sigma)$, $\sigma = 0.17$ (ICES, in press) If $F_{pa} < F_{MSY}$ then $F_{MSY} = F_{pa}$
$B_{trigger}$	446 331 t.	$B_{trigger} = B_{pa}$
$F_{p0.5}$	0.12	Stochastic long-term simulations with ICES MSY AR (≤ 5% probability SSB < B_{lim}); Constraint to F_{msy} if $F_{p0.5}$<F_{msy}
F_{MSY}	0.20	Median F_{target} which maximizes yield without $B_{trigger}$
Adopted F_{MSY}	0.12	If $F_{p0.5} < F_{MSY}$ then $F_{MSY} = F_{p0.5}$

Discussion / Sensitivity

1) Sardine recruitment is affected by a variety of environmental factors and only weakly related to spawning stock biomass (Santos *et al.*, 2012 and references therein); to the contrary the recruitment-stock relationship is strong, high recruitments lead to major increases of biomass in a short period;

2) Since 2006, there were only low recruitments, around the lowest historical level and biomass decreased sharply; both biomass and recruitment remain low;

3) It is evident that the stock has very low abundance and that recruitment is impaired although the influence of stock size on both recruitment impairment and recovery is uncertain;

4) The stock-recruitment plot is consistent with Type 2 (ICES, 2017) therefore, the group agreed that B_{lim} should be set at the change point of the Hockey-stick model fitted to the S–R data for the period 1993–2015, 337 448 tons;

5) The latest assessment indicates the biomass in 2016, 151 785 tons, is far below the proposed B_{lim} thus the most urgent action is to rebuild the stock to above B_{lim} with high probability in a given time frame (ICES 2013b, 2016b);

6) In rebuilding situation, the B_{pa} = 446 331 tons derived from the proposed B_{lim}, may be considered a target biomass reference point.

The WK adopted the estimated Biological Reference points derived from the Blim definition at the change point of the Hockey-stick model fitted to the S–R data for the period 1993–2015 (Table 3.2).

4 Simulations

4.1 Brief description of HCS (HCR type, etc)

Simulations were done with the HCS software (Skagen, 2015), version 15_1. A complete description can be found in the manual, which can be downloaded from www.dwsk.net, and also from the working group SharePoint site. Some modifications were made for the present purpose, as described below.

HCS was developed to provide a versatile tool for designing and exploring harvest rules. It allows scanning over options both for harvest rule parameters and for noise in the observation and implementation process. It does not, however, include a full analytic assessment at each time step, but rather attempts to reproduce some of the effects on the assessment that would appear if there is structured noise in the input data.

Program revisions

The present version HCS15_1 is a revision compared to the version 13_3 that was used in the first evaluation of the Sardine plan. The revision was mostly to reorganize data structures in the code and a new design of the input files.

Furthermore, the initial stock numbers are now distributed using the observation model, while previously, their logarithms were distributed according to a multinormal distribution function. The previous version led to a substantial bias, which has almost disappeared with the revised version.

Backward compatibility has not been extensively controlled with the present data. Use in other HCR evaluations has not revealed severe compatibility problems between recent versions of HCS. A brief comparison of the outcome with the data from the 2013 key run did not reveal major changes apart from the lower stock abundance and catches in the first years which could be attributed to the different handling of the initial stock numbers.

For the present study, some minor modifications were made to the program that are not described in the manual.

7) A bug that precluded the use of SSB in the last assessment year as decision basis was fixed. It was checked that this did not alter results with other decision bases.

8) A bug in the calculation of TAC under the 15% TAC variation constraint was fixed.

9) An additional Blim was included. The program will present risk to both Blim values. Both these Blim are used only for reporting, the biomass values that go into the decision process are independent of these.

10) An extract of the results table was printed as a separate file, to facilitate reading the output in R

11) A printout of recovery after being below Blim was made, on a yearly basis. This was requested during the meeting, but only coded after the meeting, and not used so far.

12) The criterion for reporting a crashed stock was changed from Blim/10 to Blim/100.

Program overview

HCS is a stochastic simulation program for exploring harvest control rules, designed the standard way for harvest rule simulation programs. It consists of a population (operating) model that generates yearly 'true' stock numbers at age, an observation ('assessment') model that transfers the 'true' stock numbers into noisy, 'observed' numbers, a decision rule by which a TAC is derived according to the observed stock (projected forward if relevant) and an implementation model that translates the TAC into actual removals. These removals are then input to the population model for the next time step. The outline is shown in Figure 4.1.1, which also indicates the terminology used in the following.

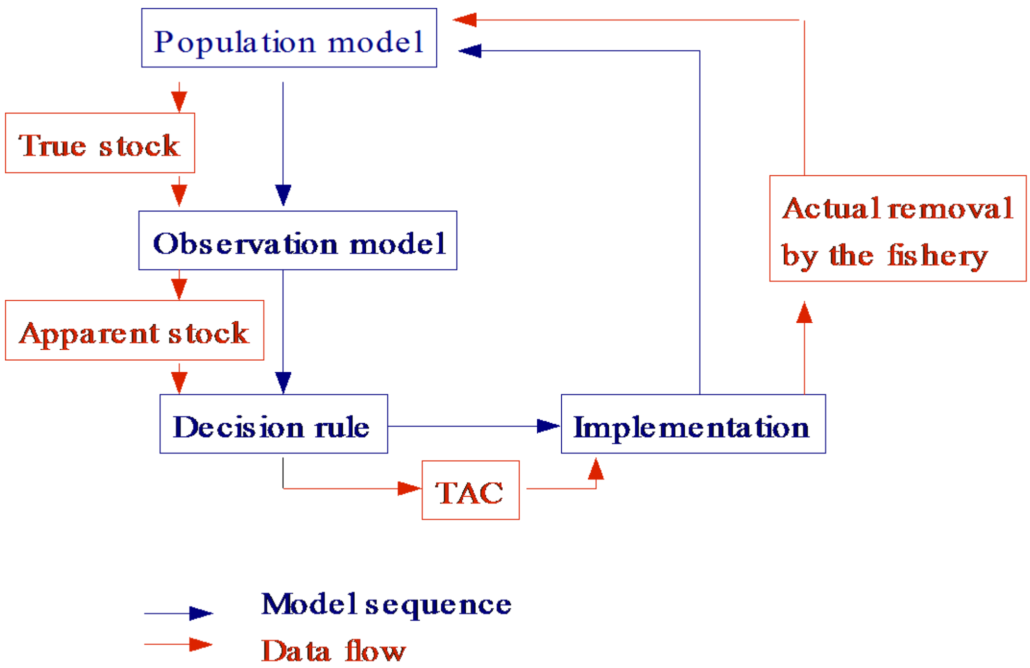


Figure 4.1.1. Outline of the simulation loop and the terminology in the HCS programs.

The population (operating) model is age disaggregated and projects the stock numbers at age forwards in annual time steps, by reducing stock numbers according to mortalities, and applying weights and maturities at age. A new year class is introduced each year, according to a recruitment model. The mortalities are fixed natural mortalities and fishing mortalities that come from implementing annually decided TACs. The fishing mortalities are derived in the implementation model as described below. Selectivity in the fishery is fixed, but may deviate from the fixed values when the TAC is implemented. Weights and maturities vary randomly according to a distribution around fixed mean values. Density dependence can be simulated, but is not used in the present study.

The recruitment model derives the actual recruitment from a deterministic stock recruit function, with a stochastic multiplier with specified CV. The distribution of the multiplier is truncated to avoid extremes and to modify the shape of the distribution as needed. In addition, the recruitment can have regular or irregular spikes, and/or periodic fluctuations.

Several recruitment regimes can be applied, with various rules for shifting between regimes. For sardine, a single regime without spikes or periodicities was applied, as described in section 4.2.

The observation model derives 'observed' stock numbers at age from the true population. There is no full assessment done in this model, but an algorithm that imitates some of the effect of noise in the input data to an assessment. The algorithm, which is fully described in the manual, multiplies the true stock numbers at age with the product of several stochastic multipliers. These include a bias factor, a year-noise factor, an age-noise factor and an autoregressive process along the year classes. The primary purpose of the autoregressive process is to imitate retrospective error caused by noise in survey data. It will also to some extent create autocorrelations in the noise, but there is no attempt to calibrate that autocorrelation explicitly. The observed stock numbers are those that the decision makers will see. The historical stock numbers (i.e. the matrix of stock numbers backwards in time as seen in an assessment) can be updated each year, if needed – this option was not needed in the present study.

The decision model derives a TAC according to the perceived state of the stock. In HCS, the managers decision is always a TAC. If needed, the perceived stock is projected forwards in time starting at the time of the most recent assessment. The general outline of the model is that first, a basis for decision (typically, but not necessarily, a biomass value in one or several years) is derived from the perceived stock numbers at age. Then, a rule is applied that derives a measure of exploitation according to the basis. The measure of exploitation can be an F-value, a harvest rate or a value for the TAC, as in the present case. If needed (i.e. if the exploitation measure is not the TAC itself), the exploitation measure is translated into a TAC assuming the 'observed' stock numbers. This TAC (termed the primary TAC) can be modified by applying additional rules to restrict catch variation from year to year and/or applying a lower and upper limit for the TAC. This leads to the final TAC which is the outcome of the decision model.

In the present formulation, the rule was to set a TAC directly depending on the SSB from the last assessment (i.e. at the end of the last assessment year, without predicting the stock numbers through the intermediate year). These were the decisions made when the HCR was developed in 2013. No alternative rules were explored to address the present request.

The implementation model removes the final TAC from the true stock, expanded with a noise multiplier. The multiplier can be biased if needed. The implementation algorithm is to first find the fishing mortality that leads to the TAC when applied to the true stock numbers with the input standard selection at age. This gives intended removals in numbers at age. These removals are altered by applying noise to the catch numbers at age. These numbers are normalized to correspond to the TAC in biomass (as decided, but biased if asked for). New F–values are derived by solving the catch equation with the altered catch numbers at age and the true stock numbers. Hence, the true removals at age correspond to a selection at age that differs from the standard selection that is input.

For the present study, the program was run as a bootstrap with 1000 replicas for each rule scenario, with the following stochastic elements:

- Recruitment: Hockey stick model with truncated lognormal distribution
- Weights at age: Fixed values but with individual uncorrelated noise with CVs as in the historical data
- Observation model:

a) Age factors taken from the inverse Hessian estimates of variance in the stock numbers at age, as estimated in the SS3 assessment.

b) Year factor calibrated to give a final CV of the SSB of 17%, as for the last year in the assessment.

c) The products of the year and the age factor are generated each year, and kept as x(a,y) values to be used in the autoregressive model.

d) Autoregressive model for noise: The noise multiplier applied to the stock number at age is $\xi(a,y) = \alpha 0^*x(a,y) + \alpha 1^*x(a-1,y-1) + \alpha 2^*x(a-2,y-2)$, where the sum of the α's is 1. The α values were chosen to represent the decline of a year class with an average z at about 0.6.

e) Implementation noise at age: CVs taken close to the estimates of the variance of the selection at age in the assessment

The conditioning of the model is further described in Section 4.2.

4.2 Model conditioning

4.2.1 Recruitment

Two recruitment scenarios were considered:

13) Recruitment obtained from a Hockey-stick stock–recruitment relationship fitted to the period 1993–2015, as for the calculation of BRPs (Wise *et al*., 2017). This will be termed the recent productivity scenario. This scenario had R_{MAX} = 11 718 485 million fish and breakpoint at B_{lim}= 337 448 thousand tons. Year to year variability was implemented by applying a noise multiplier, that was log-normally distributed (bias corrected) with a sigma of 0.49, and truncated at 0.3 and 3.0. The truncation was decided to restrict future recruitment to approximately the range in historical data. The reality check of the distribution suggested that the historical data were not quite log-normally distributed, as shown in Figure 4.2.1.

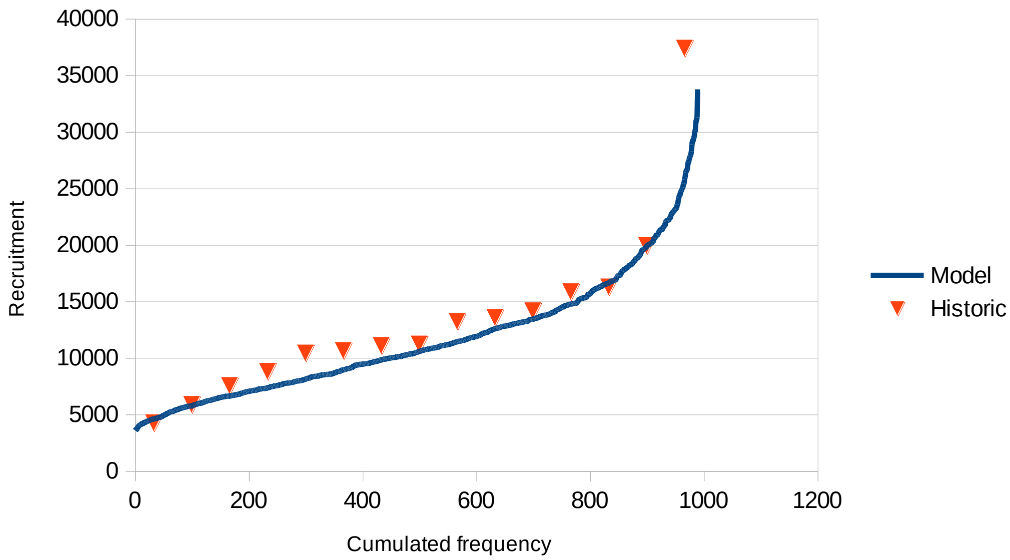


Figure 4.2.1. Modeled and historic cumulated distribution of recruitments, average recruitment scenario. The model recruitment is a collection of 1000 drawn recruitments, when no dependence of SSB was assumed.

Recruitment as in the most recent period of poor series of recruitment: period 2006–2015. This scenario had R_{MAX} = 5252 million fish and no breakpoint. Year to year variability was implemented by applying a noise multiplier, that was lognormally distributed (bias corrected) with a sigma of 0.26, and truncated at 0.3 and 3.0 (Figure 4.2.2). The R_{MAX} was the geometric mean over the period and the sigma was the SD of the log-transformed numbers. Since the purpose was to find rule formulations that would avoid further depletion of the stock assuming the present low recruitment, no breakpoint was included.

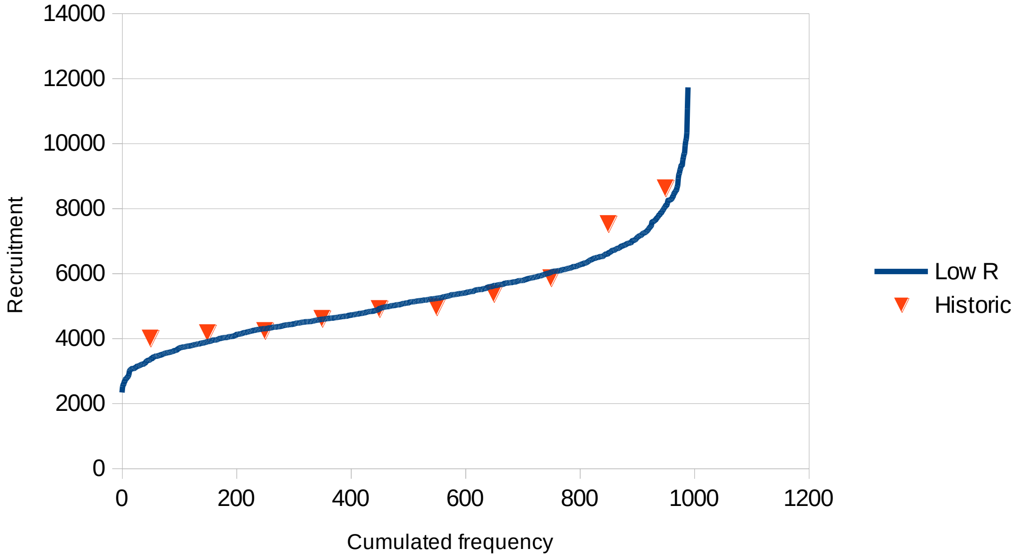


Figure 4.2.2. Modeled and historic cumulated distribution of recruitments, low recruitment scenario. The model recruitment is a collection of 1000 drawn recruitments, when no dependence of SSB was assumed.

4.2.2 Weights-at-age

Weights-at-age in the stock were calculated as the arithmetic mean value of the last six years of the assessment (period 2010–2015) (Table 4.2.1) with their associated CV. This comprises two DEPM surveys from which the current weight at age in the stocks is derived.

Analogously, mean weight at age in the catches are taken as the arithmetic mean value of the last six years of the assessment (period 2010–2015) with their associated CV (Table 4.2.1).

The population biomass in 2016, the start of the simulation, is lower than that estimated in the assessment (WKPELA 2017) because the stock weights used to start the simulations are slightly lower. The stock weights assumed for 2016 in the assessment were equal to stock weights in 2015.

Table 4.2.1. Input data for the Sardine population for the simulations of the Harvest strategy

Age	Population		Natural		Stock weights		Catch weights		Selectivity	
	Number	CV	mortality	Maturity	Mean	CV	Mean	CV	Mean	CV
0	5252	0.26	0.98	0	0.000		0.027	0.11	0.163	0.40
1	1789	0.24	0.61	1	0.029	0.12	0.049	0.08	0.479	0.30
2	717	0.21	0.47	1	0.049	0.02	0.065	0.07	0.835	0.28
3	484	0.19	0.4	1	0.063	0.02	0.076	0.03	1.000	0.08
4	197	0.20	0.36	1	0.068	0.02	0.083	0.05	1.000	0.08
5	79	0.24	0.35	1	0.071	0.08	0.086	0.06	1.000	0.08
6	109	0.30	0.32	1	0.075	0.07	0.089	0.08	0.829	0.24

4.2.3 Maturity

Following the last Benchmark for this sardine the study is based on the B1+ and the S-R relationships are fitted on that population indicator. This is a reasonable assumption as actual maturity for age 1 is very close to 1 (on average about 0.8) and it was 1 as well in the last DEPM application.

In this report, where HCS software requires a maturity ogive, a knife-edge ogive with 100% mature at age 1+ was adopted, without any consideration of uncertainties (Table 4.2.1).

4.2.4 Selectivity

Selectivity at ages of the fishery correspond to the fitted values for the latest period of the assessment (period 2006–2015) with their associated CV (Table 4.2.1). HCS assumes a fixed selection, except for allowing deviation selection in the implementation step. Accordingly, there is no uncertainty associated with the input selection, the only uncertainty on selection is implementation error. Therefore, the uncertainties estimated for selectivity (Table 4.2.1) were used as implementation uncertainties.

4.2.5 Natural mortality

Natural mortality was assumed to be equal to that in the assessment. Uncertainty to this parameter was not taken into account. The values are tabulated in Table 4.2.1.

4.2.6 Initial population

The initial stock size corresponds to the assessment estimates for ages 1–6+ at the final year of the assessment (2016). Starting Recruitment corresponds to the geometric mean of the last ten years (the period 2006–2015) where the poorest recruitment has persistently appeared. A stochastic range of these numbers was obtained by applying the observation model, i.e. assuming that the present and future assessments are equally uncertain.

4.2.7 Observation ('Assessment') uncertainty

The observation model was conditioned to reproduce the assessment uncertainty in the final year of the assessment (2016). The algorithm for assessment uncertainty in HCS is quite complex, and consists of a year factor multiplier, an age factor multiplier and an autoregressive model. To calibrate it, the observation model was applied to the initial population. The age factors were taken from the assessment and an autoregressive model was applied as in the 2013 evaluation. The assessment uncertainty year factor was then calibrated to give a CV of the SSB in year 0 similar to that estimated for the last assessment year, i.e. 17%. The corresponding year factor was 0.20. The relation between the assessment uncertainty year factor and CV of the SSB in year 0 is shown in Figure 4.2.3.

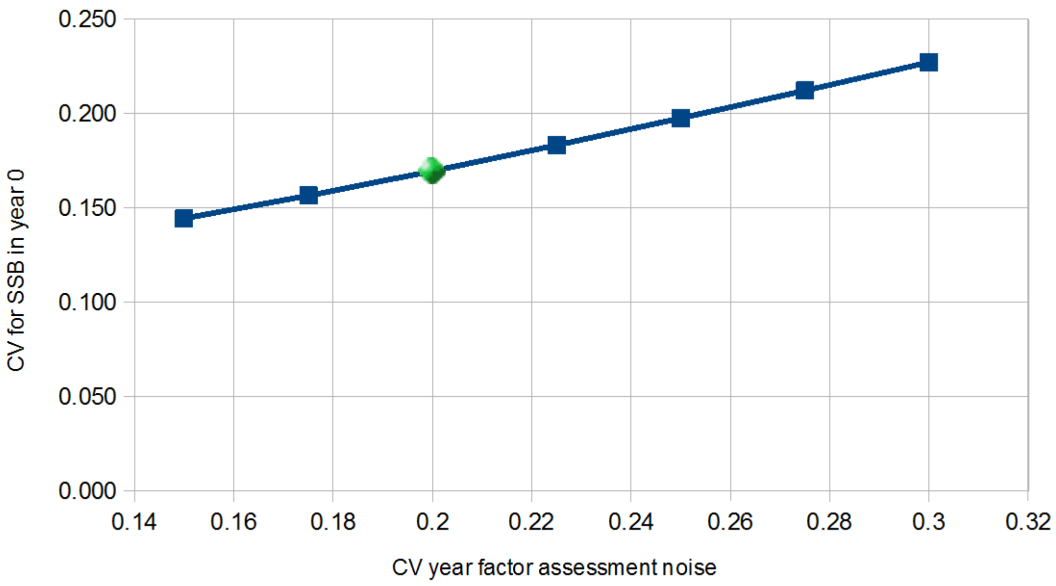


Figure 4.2.3. The relation between the assessment uncertainty year factor and CV of the SSB in year 0. The CV = 0.17 in the assessment requires a CV for the assessment uncertainty year factor of 0.2, marked with a green symbol.

4.2.8 Implementation error

No implementation bias was assumed. An age factor on implementation error on stock numbers was included, with a CV equal to the estimated CV of the selection at age (Table 4.2.1).

4.3 Performance indicators

HCS has a wide range of output options, both for presenting results and screening over rule parameters, and for diagnostics and calibration. The main output consists of tables of the main interest parameters by year, and overview tables with means and percentiles over several years, typically for comparing options. There are also tables of individual trajectories and deterministic stock-recruit calculations.

- The main performance indicators are
- TACs and realized catches
- True SSB and TSB
- True (realized) F
- Inter-annual variation of TAC: $(TAC_y-TAC_{y-1})/[(TAC_y+TAC_{y-1})/2]$
- Probability of SSB < Blim or the alternative Blim (named here as Blow) made for the sardine study (Blow=132 thousand tons = rounded geometric mean of SSB in 2012–2015). This is presented annually (percent of the 1000 iterations) and as the highest annual percentage over a time period (Risk 3 in the ICES terminology).
- The probability of being below the trigger biomass in the rule. If there are several triggers, the first one is reported. The probability is the percentage over iterations, average over all years in time periods.
- Probability of crashing the stock: Percentage of trajectories that at some stage before the end of the reported period either are below 1% of Blim or where the decided TAC cannot be taken due to shortage of fish.

They are all presented as mean, and 10, 50 and 90 percentiles taken over all iterations, either by year or over a specified period. The tables by year ('Results' file) are useful when considering recovery or the route towards a steady state, while the tables over specified periods are mostly intended for comparing options.

4.4 Simulations done (Summary table)

4.4.1Test of Current HCR

The base simulation, Run1, was carried out to test the current harvest rule, conditioning the model as described in section 4.2 (see also Annex 4). Risks were evaluated assuming B_{lim} = 337 448 tons, corresponding to the change point of the S–R model used to calculate BRPs (Wise *et al.*, WD_WKPELA2017 and section 3). The S–R model is a Hockey-stick model fitted to S–R data for the period 1993–2015, with R_{max} = 11 718 million individuals assuming log-normal errors with a CV = 0.49. We termed this recruitment scenario the recent productivity regime.

The group recognized that the above recruitment scenario leads to future recruitments substantially higher than those the stock has been producing since 2006. Therefore, a second run, Run2, was set up to explore the consequences to the population and fishery trajectories if future recruitment continues to be low (termed poorest recruitment regime). Therefore, in Run2 a flat recruitment model was assumed with R_{max} = 5252 million individuals (geometric mean recruitment of the period 2006–2015) and log-normal errors with a CV = 0.26.

4.4.2 Sensitivity analyses/alternative harvest rules

The target catch assumed in the current harvest rule, 86 000 tons is not achieved in either of the scenarios of recruitment considered. A high target catch is likely to decrease the performance of the rule in terms of precautionary criteria. The group decided to test the performance of the rule scanning through lower catch target values. Two sets of simulations were carried out to scan target catch values from zero to 94.6 thousand t in steps of 8.6 thousand t: S1 with the recent productivity regime and S2 with the poorest recruitment regime.

In addition, the effect of changing $B_{trigger}$ to achieve the target catch was tested for the following alternative values (steps of 78 kt): 212.4, 290.4, and 368.4 (current value) and 446.4 kt (= B_{pa}). Finally, catch stabilizers were combined with variants in C_{target} and $B_{trigger}$ of the current HCR for the two productivity scenarios and two periods: short term (years 2–5) and medium term (years 6–10). Two types of catch stabilizers were tested: 1) the 50–50 filter rule in which the final TAC is the mean of the TAC derived from the application of the rule with the TAC of the previous year and 2) the 15% percentage rule in which the final TAC is constrained to not deviate more than 15% from the TAC in the previous year. The stabilizers, when used, were applied at all levels of biomass.

4.5 Results

4.5.1 Test of Current HCR of the LTMP

Assuming the recent productivity regime will continue in the future the probability that the stock is above B_{lim} will increase from 1% in 2018 to 49–51% at the end of the simulation period (2044–2046) (Figure 4.5.1.1; Annex 5-Table A.5.1). Assuming the poorest recruitment regime, the probability that the stock is above B_{lim} will be nearly zero along the whole simulation period (Figure 4.5.1.1; Annex 5–Table A.5.2).

In both recruitment regimes, the biomass has high probability (> 75%) to be above of the recent low value (132 thousand t) since the beginning of the simulation period (Figure 4.5.1.2). Yearly probabilities are similar in the two regimes and will be higher than 95% from 2019 onwards in the poorest recruitment regime and from 2020 onwards in the recent productivity regime. These probabilities, as well as the simulated stock and catch values are very dependent on the recruitment and catches that will actually be realized in the first years. Even though, ICES catch advice for 2017 was 23 tons, the simulations were conditioned on the applications of the HCR, which restricted the catch options to just 9 thousand tons. This would simply imply that the results of the simulations are to be taken as relative to the starting year of the implementation of the harvest strategy being tested.

Finally, the two recruitment scenarios seem to give counterintuitive results in the first years of the simulation period (e.g. slightly higher recruitment levels and faster increase of biomass in the lower recruitment scenario). This is explained by the fact that the very low biomasses in the first years produce recruitments according to the recent productivity regime (i.e. to the Hockey-stick fitted over the 1993–2015 period), which are actually lower than those obtained in the poorest recruitment scenario.

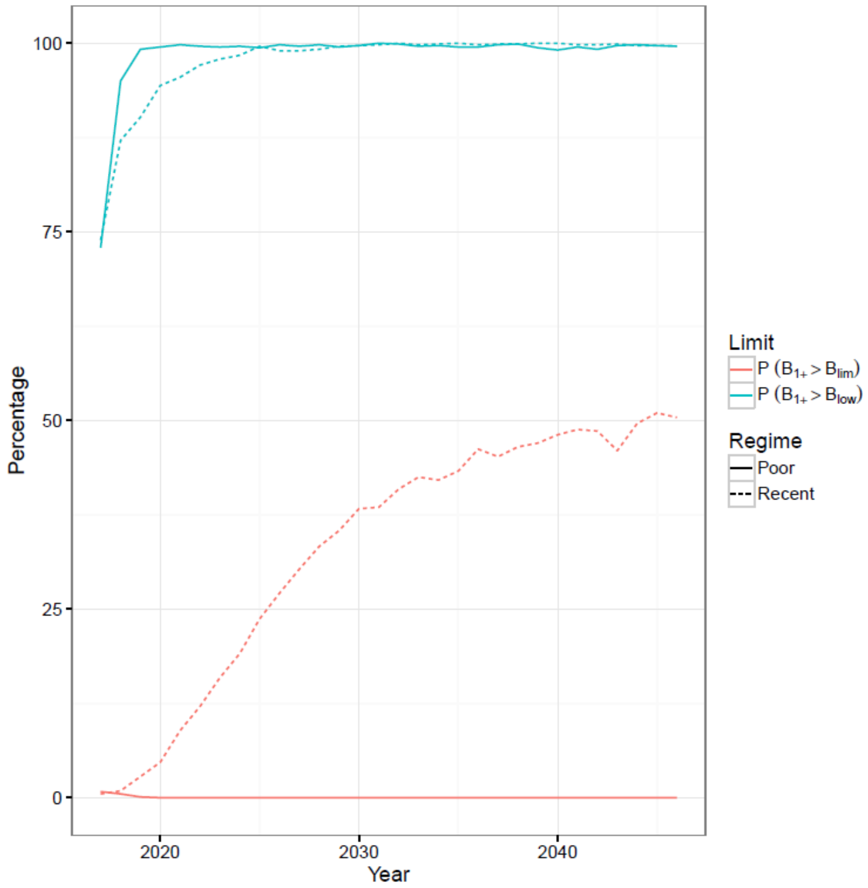


Figure 4.5.1.1. Probability that the stock is above Blim (red) and above the recent low average of 132 thousand tons (Blow blue) under the current HCR for the two productivity scenarios (different line types). Recent regime corresponds to the Hockey-stick S–R model (Run1) and poor regime corresponds to the poorest recruitment regime (Run2).

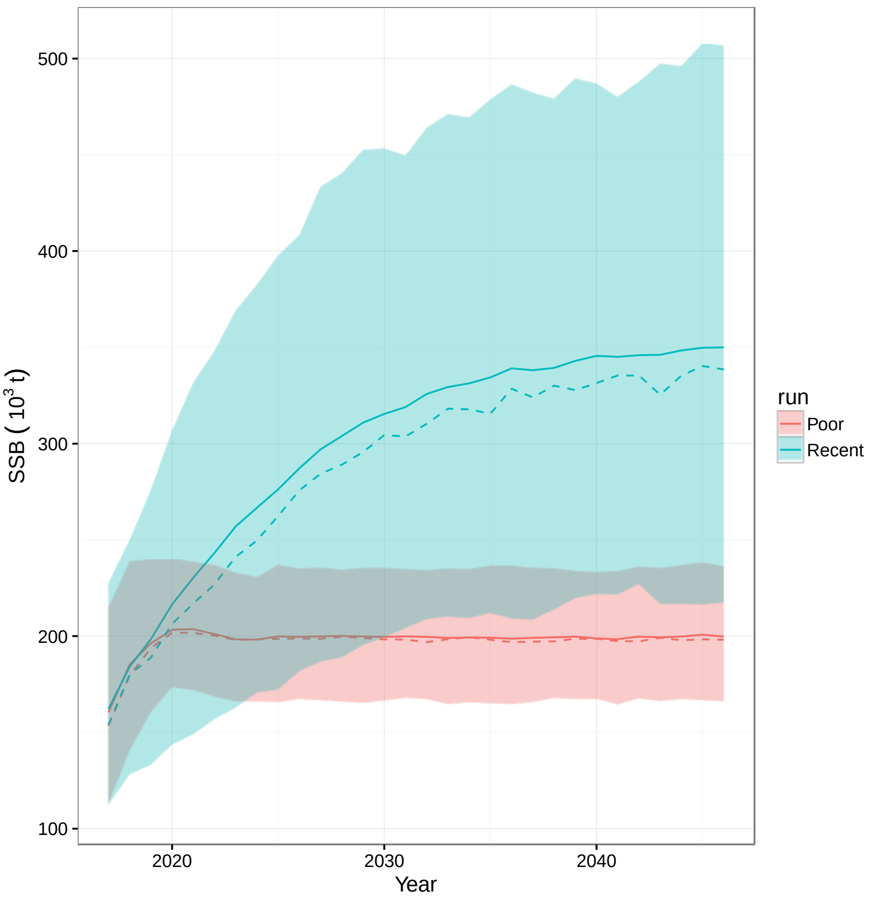


Figure 4.5.1.2. Biomass of age–1 and older fish trajectory through the years under the current HCR for the two productivity scenarios (different colors). Solid lines correspond to mean values; dashed lines correspond to median values (P50). Upper limits correspond to percentile 90 (P90) and lower limits correspond to percentile 10 (P10). The recent run corresponds to the Hockey–stick S–R model (Run1) and the poor run corresponds to the poorest recruitment regime (Run2).

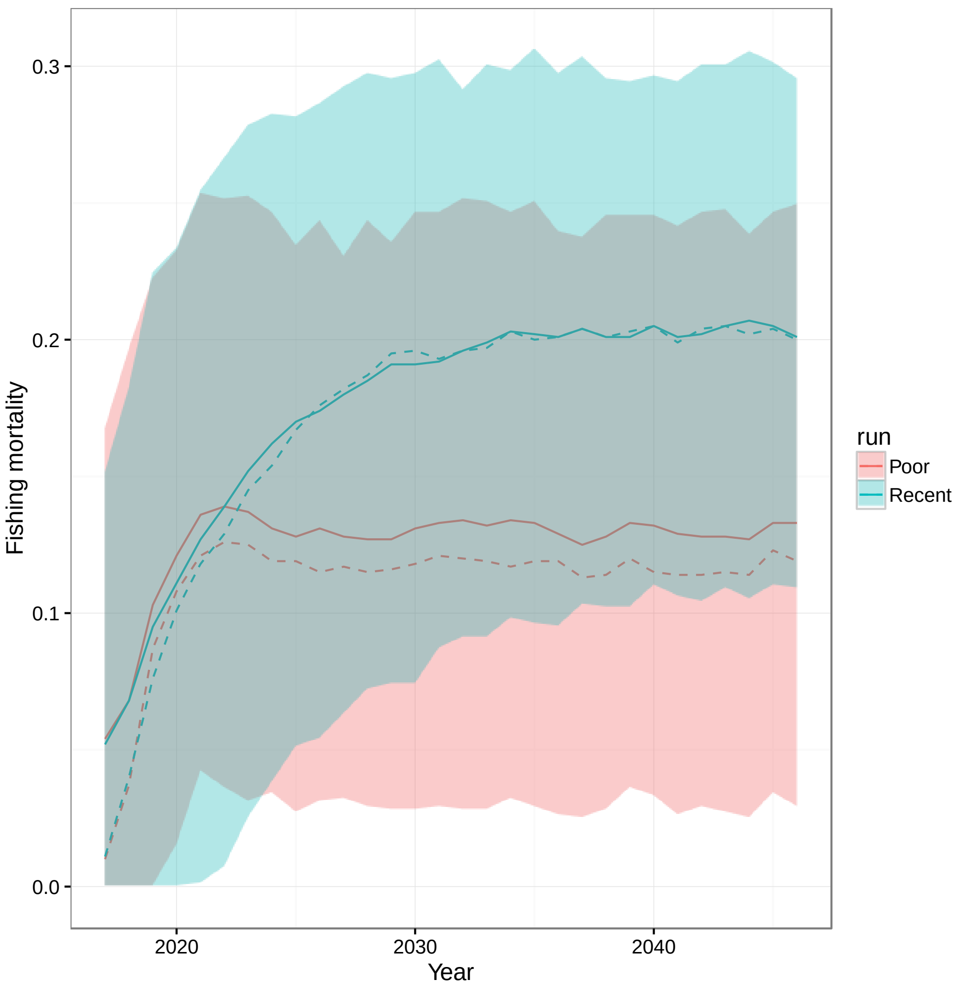


Figure 4.5.1.3. Fishing mortality trajectory through the years under the current HCR for the two productivity scenarios (different colors). Solid lines correspond to mean values; dashed lines correspond to median values (P50). Upper limits correspond to percentile 90 (P90) and lower limits correspond to percentile 10 (P10). The recent run corresponds to the Hockey-stick S–R model (Run1) and the poor run corresponds to the poorest recruitment regime (Run2).

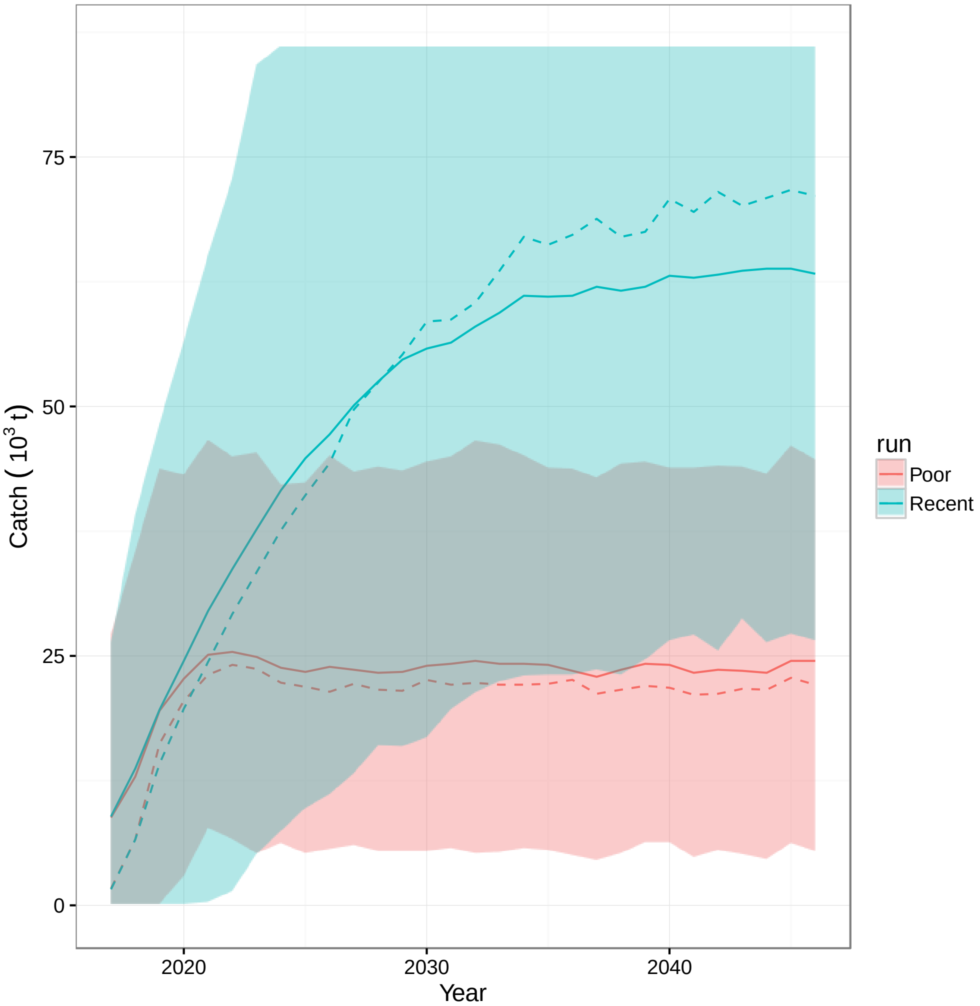


Figure 4.5.1.4. Catch trajectory through the years under the current HCR for the two productivity scenarios (different colors). Solid lines correspond to mean values; dashed lines correspond to median values (P50). Upper limits correspond to percentile 90 (P90) and lower limits correspond to percentile 10 (P10). The recent run corresponds to the Hockey-stick S–R model (Run1) and the poor run corresponds to the poorest recruitment regime (Run2).

4.5.2 Testing of Variants in maxCatch of current HCR (for the two productivity scenarios)

If the poorest recruitment regime continues in the future, none of the variants of the harvest rule will lead to a recovery of the biomass above B_{lim} with 50% probability until 2046 (in 29 years from 2017; Table 4.5.2.1, Figures 4.5.2.1 and 4.5.2.2).

Assuming the recent productivity regime (1993–2015), a decrease of the catch target to below 25 800 tons (all other settings being equal) results in harvest rules that lead to high probability (>95%) that the biomass increases above B_{lim} no later than 2037 (21 years from 2017) (Table 4.5.2, Figure 4.5.2.1-2). The same variants lead to more than 50% probability that biomass increases above B_{lim} in 2024–2025. If the fishery would be permanently closed (zero catches), the biomass would be above B_{lim} with 95% probability in 2031 (15 years from 2017).

In all harvest rule variants that are precautionary in the medium to long term, mean catches and mean fishing mortality in the first years of the simulation period (2017–2021) are substantially lower than those observed in the past two years (Figure 4.5.2.2).

Table 4.5.2.1. Year in which the stock biomass is above Blim with more than 50% and 95% probability for target catch levels from 0 to 86 thousand t and the recent productivity regime (1993–2015).

Target catch (thousand t)	$P(B_{1+} > B_{lim})>0.50$	$P(B_{1+} > B_{lim})>0.95$
0.00	2024	2031
8.60	2024	2032
17.20	2024	2033
25.80	2025	2037
34.40	2025	-
43.00	2026	-
51.60	2027	-
60.20	2028	-
68.80	2030	-
77.40	2033	-
86.00	2045	-

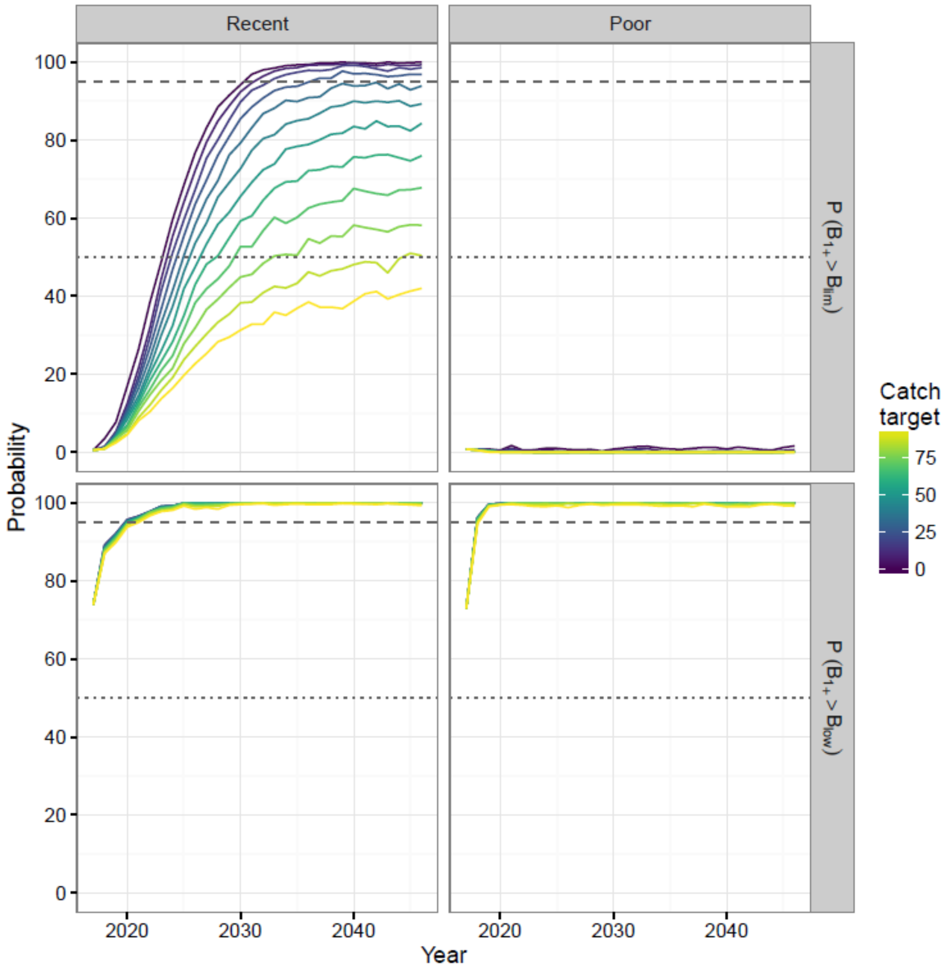


Figure 4.5.2.1. Probability that the stock is above Blim (upper panels) and above the recent low average of 132 thousand t (Blow lower panels) under variants of the current HCR testing for different maximum catch (Catch target in different colours) for the two productivity scenarios. Recent corresponds to the Hockey-stick S–R model (left panels) and poor corresponds to the poorest recruitment regime (right panels). Dashed line corresponds to probability of 95% and dotted line corresponds to probability of 50%.

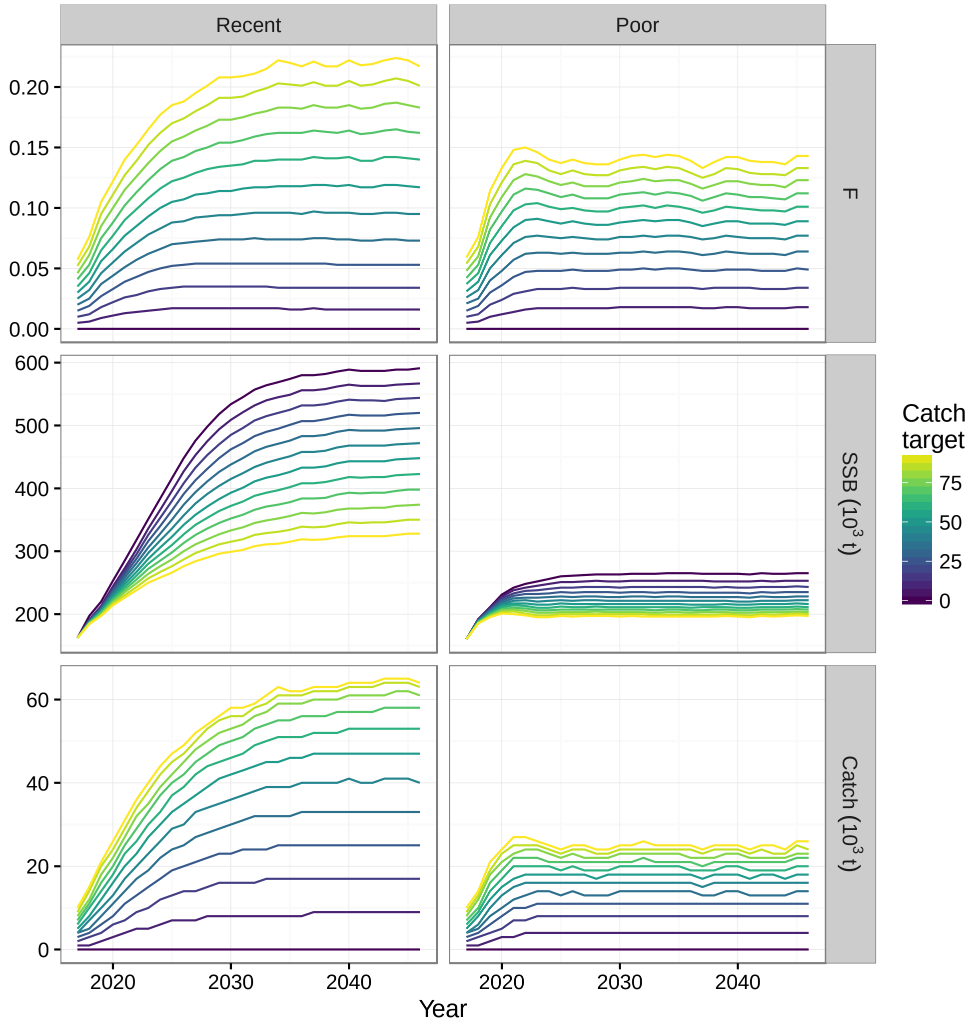


Figure 4.5.2.2. Fishing mortality, biomass of age-1 and older fish and catch (upper, middle and bottom rows) under variants of the current HCR testing for different maximum catch (Catch target in different colours) for the two productivity scenarios (columns). Recent corresponds to the Hockey-stick S-R model (left panels) and poor corresponds to the poorest recruitment regime (right panels).

4.5.3 Testing of Variants in Btrigger of current HCR (for the two productivity scenarios).

For both recruitment regimes and keeping the target catch at 86 kt, none of the $B_{trigger}$ variants of the harvest rule will lead to a recovery of the biomass above B_{lim} with >95% probability until the end of the simulation period, 2046 (Figures 4.5.3.1 and 4.5.3.2). On the other hand, except for the lowest of the $B_{triggers}$ (212.4) all variants lead to a high probability (P>95%) that the biomass increases from the recent low value (132 thousand tons).

Assuming the recent productivity regime (1993–2015), changing $B_{trigger}$ has a large effect on stock recovery. For example, a rule with $B_{trigger}$ = 446.4 (= B_{pa}) leads to moderate probability (>50%) that the biomass increases to above B_{lim} from 2030 onwards. This is approximately 15 years earlier than observed with the current harvest rule (Figure 4.5.3.1 and 4.5.3.2). This comes at the cost of lower mean catches and mean fishing mortality in the first ten years of the simulation period (Figure 4.5.3.2).

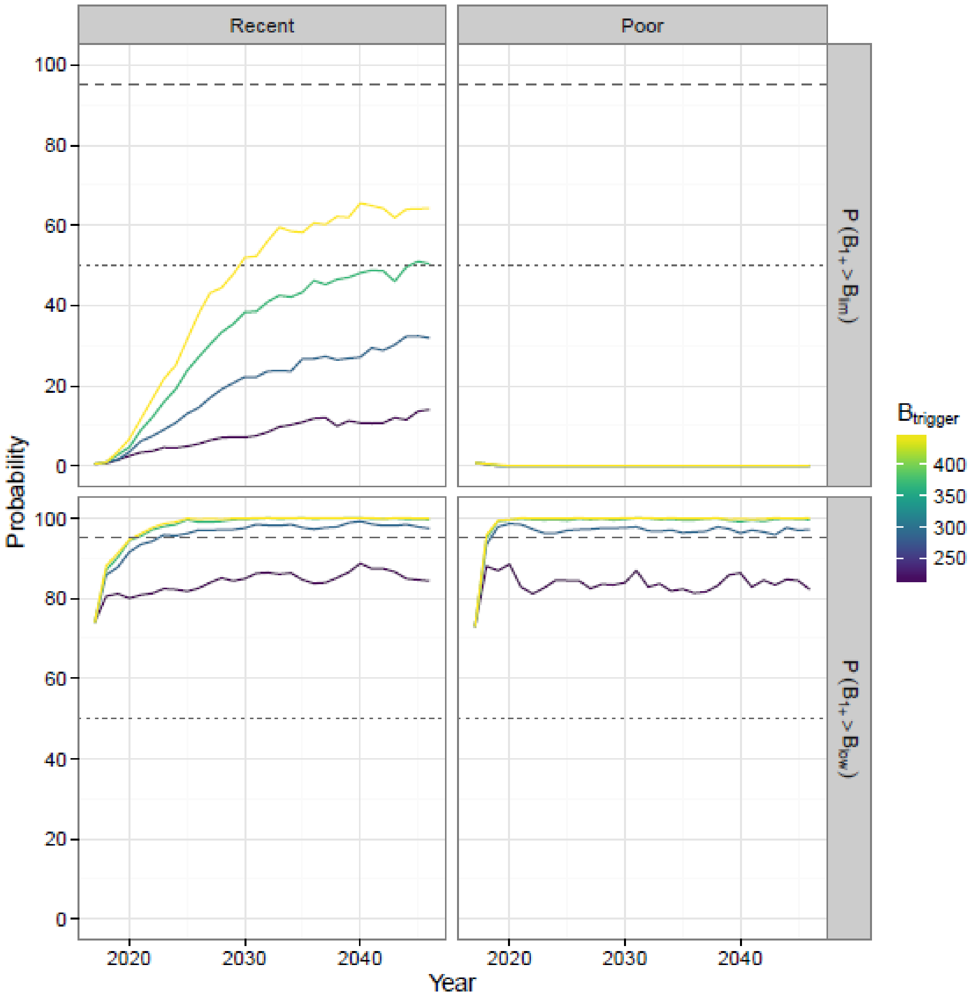


Figure 4.5.3.1. Probability that the stock is above Blim (upper panels) and above the recent low average of 132 thousand t (Blow lower panels) under variants of the current HCR testing for different Btrigger values (Btrigger in different colours) for the two productivity scenarios. Recent corresponds to the Hockey-stick S–R model (left panels) and poor corresponds to the poorest recruitment regime (right panels). Dashed line corresponds to probability of 95% and dotted line corresponds to probability of 50%.

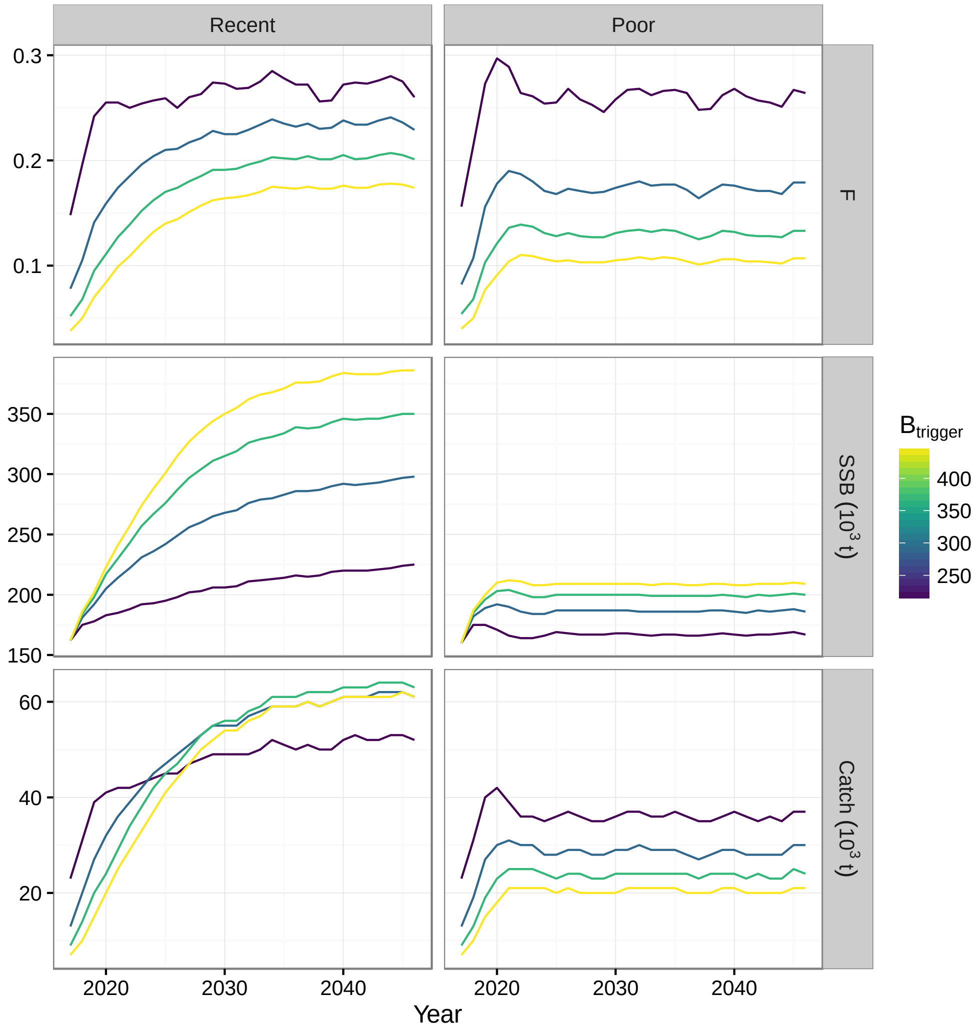


Figure 4.5.3.2. Fishing mortality, biomass of age-1 and older fish and catch (rows) under variants of the current HCR testing for different Btrigger values (Btrigger in different colours) for the two productivity regimes (columns). Recent corresponds to the Hockey-stick S-R model (left panels) and poor corresponds to the poorest recruitment regime (right panels).

4.5.4 Combining catch stabilizers with variants in target Catch (C_{target}) and $B_{trigger}$ of the current HCR

Catch stabilizers (the 50–50 filter rule and the +/-15% maximum variability in TAC rule) were combined with variants in C_{target} and $B_{trigger}$ of the current HCR for the two productivity regimes and two periods: short term (years 2–5) and medium term (years 6–10). The exploration was restricted to the case where the stabilizers were applied without exceptions at all levels of stock abundance.

The results (Figures 4.5.4.1-2) confirm that the risk of not recovering from recent poor biomass levels is lowest when no stabilizers are applied (-5 rows, dot symbols in Figures). The effect of including stabilizers is complex and sometimes counter-intuitive. Starting with a relatively high TAC compared to what the rule would indicate, the way the TAC is reduced in the coming years, and what that reduction leads to, is mostly decided by the stabilizer, and less by the rule itself. This exercise should be taken as a demonstration of the complexity rather than a full exploration of stabilizing measures. Deciding on the use of stabilizers in future management plans would require testing well beyond the simple exploration done here.

In the short-term and for the two recruitment scenarios, both types of stabilizer increase the risk of not recovering from recent poor biomass levels using all variants of the rule with different C_{target} and $B_{trigger}$ (Figure 4.5.4.1). The increase of the risk is higher if the two types of stabilizer are used in sequence.

Compared to the short term, the risk of not recovering from recent poor biomass levels is overall lower in the medium term scenarios and lower than 5% in a large number of scenarios (Figure 4.5.4.2). The simultaneous applications of the Catch stabilizers increases the risk of future depletion in the 1993–2015 recruitment regime, not in the poorest recruitment regime (the latter might probably be a result of the population in the medium term becoming independent of the starting population levels in such poorest regime though It was not possible in the time available to the group to clarify the reasons for this result). In the medium term, Risks below 5% are associated with realized fishing mortalities below 0.20 (and to catches below 30 000 tons).

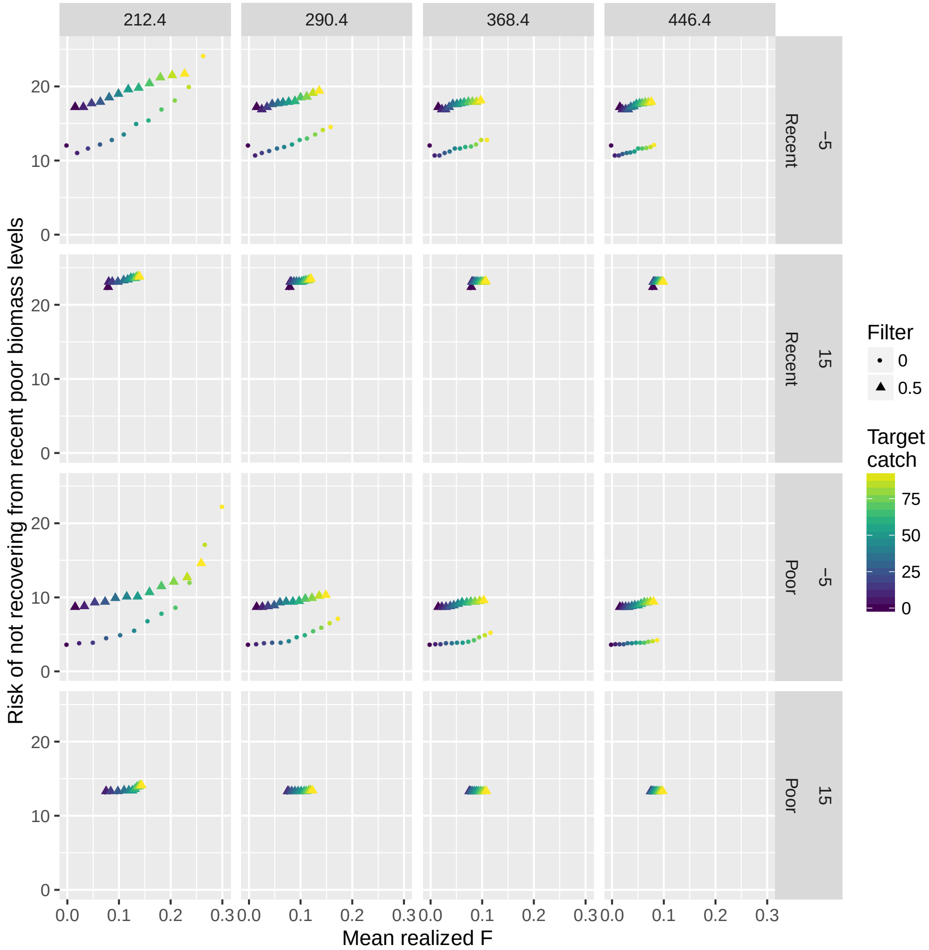


Figure 4.5.4.1. Short term (maximum risk in years 2-5) risk of future depletion of the stock, i.e. that the stock decreases below the recent low average of 132 thousand t, under variants of the current HCR testing for different Ctarget (gradient colour), Btrigger (different columns) and catch stabilizers for the two productivity regimes: Recent corresponds to the Hockey-stick S–R model and poor corresponds to the poorest recruitment regime. Labels -5 and 15 indicate scenarios where the 15% maxVariability TAC rule is either not applied or applied respectively. Triangles and points report results with and without the application of the 50–50 filter rule respectively

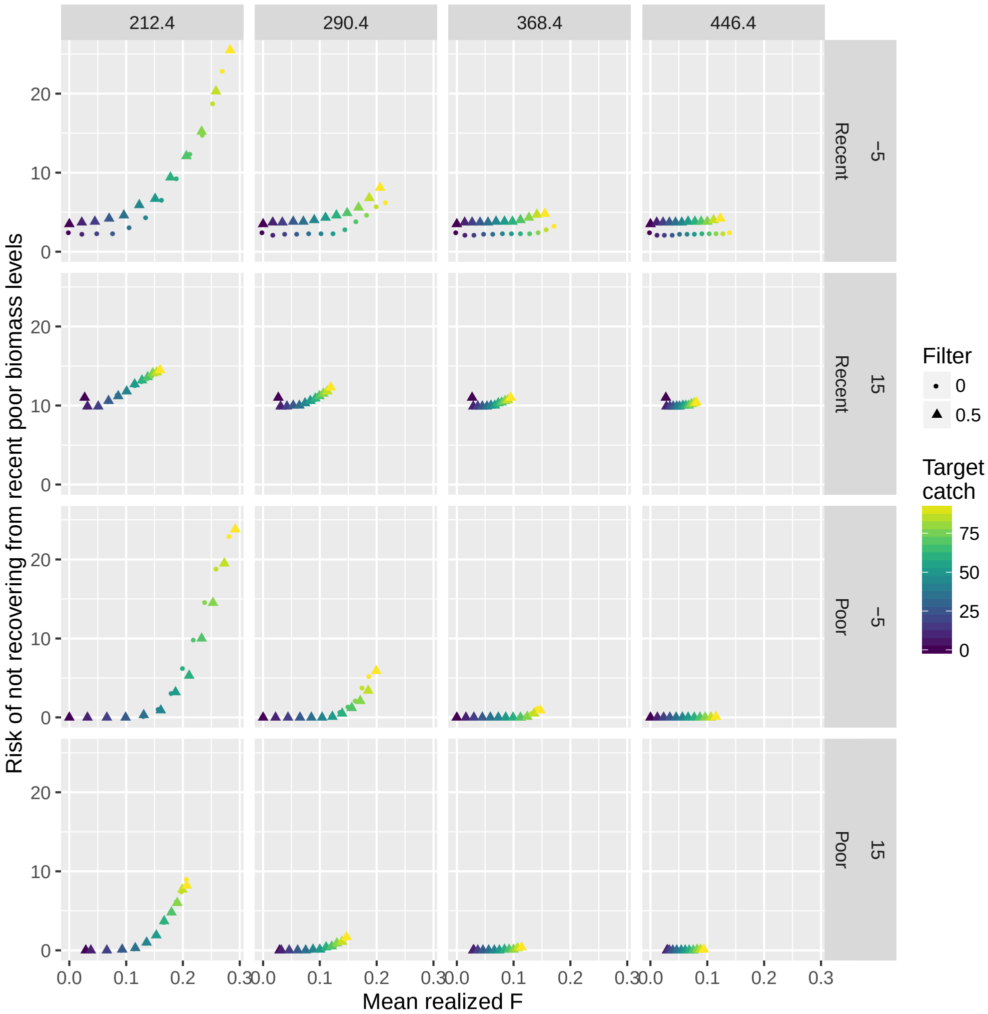


Figure 4.5.4.2. Medium term (maximum risk in years 6–10) risk of future depletion of the stock, i.e. that the stock decreases below the recent low average of 132 thousand tons, under variants of the current HCR testing for different Ctarget (gradient colour), Btrigger (different columns) and catch stabilizers for the two productivity regimes: Recent corresponds to the Hockey-stick S–R model and poor corresponds to the poorest recruitment regime (lower panels). Labels -5 and 15 indicate scenarios where the 15% maxVariability TAC rule is either not applied or applied respectively. Triangles and points report results with and without the application of the 50–50 filter rule respectively.

Discussion of results and conclusions

The harvest rule as it stands is not in accordance with the precautionary approach as interpreted by ICES. Since this rule was developed, a limit reference biomass (Blim) has been defined according to ICES standards (Section 3). At present, the SSB is far below the Blim, and the rule as it stands is not expected to bring SSB above Blim with high probability, even in the long term.

When the rule was developed in 2013 (ICES (2013). Management plan evaluation for sardine in Divisions VIIIc and IXa, Advice July 2013; 7.3.5.1), it was accepted without having a defined Blim. The justification was that, assuming a recruitment as experienced in the period after 1993, the rule would imply a high probability of staying above the lowest observed SSB at the time (306 000 tons), and that rapid recovery would be likely if the SSB dropped below that value. The recruitment in the following years has always been poor, however, in line with the series of poor recruitment since 2005. The latest estimate of SSB is at 152 kt, and SSB has been less than half the former target of 306 kt in all years since 2013. Thus, the recruitment did not behave as assumed when the rule was evaluated and accepted, and the SSB remains low because of that. Other assumptions made at the time (growth, maturation, assessment uncertainty and implementation errors) have generally been within the bounds that were assumed.

The sardine stock, like many small pelagics, has fluctuated greatly over time. There is a downward trend in recruitment since the early 1990s, only interrupted by a few stronger year classes. The reason for this, and the impact of the fishery on the poor recruitment, is not well known.

The Blim, which is derived from a fit of a Hockey-stick function, is somewhat unusual. The virgin biomass with the assumed recruitment regime is slightly below 600 000 tonnes (see Figure 4.5.2.2). Thus, Blim is quite high compared to the virgin biomass, which indicates a very low productivity and tolerance to exploitation. It may be worth considering if the apparent low productivity may be linked to an environmentally driven downward trend in recruitment.

For the stock management, the immediate implication of the poor recruitment will be that the exploitation should be reduced to adapt to this situation. One requirement could be that exploitation should not lead to further reduction in the spawning biomass, given a recruitment typical of the recent poor period. The group therefore explored to some extent a poor recruitment scenario, corresponding to the period 2006-2015, referred to above as the 'poorest recruitment regime' (Run2). The results of this run are that the probability is low for a further depletion of the stock, even with the current rule. However, this is because the present SSB quite likely is close to or below the SSB level below which the fishery should be closed according to the rule. Hence, the low average TAC in the next years includes a large proportion of zeroes. In the long term perspective, the SSB under this poor productivity regime is very unlikely to reach Blim, even without fishery (see Figure 4.5.2.1).

If the recent (1993–2015) recruitment regime can be assumed, recovery to above Blim is possible, but only after a long time and with low catches. To reach Blim with a high probability (>95%) it will take about 15 years without fishery.

To develop harvest rules to cope with the present poor state of the stock and the poor recruitment was outside the terms of reference for this group, and would require extensive considerations, dialogue and analyses, way beyond what could be done in a short meeting. It may be necessary not only to consider variants of harvest rules, but in more general terms how to handle a situation where Blim is close to the equilibrium biomass without fishery and there is sustained poor recruitment.

Some analyses were done that may indicate possible ways forward. If the objective is to avoid further depletion of the stock, it seems that the current rule may be kept, as it prescribes a drastic reduction in the catches in the coming years that seems sufficient to keep the stock above the recent low. If an objective is to rebuild the stock to Blim (which is out of reach with the recent poor recruitment), It can be reached after a long time with the 1993–2015 recruitment regime (in about 9 years and 21 years with 50% and 95% certainty respectively), provided the Max. catch in the rule is reduced to 25 000 tons (Table 4.5.2.1). Increasing the rule Btrigger to the current Bpa will help to bring the stock above Blim, although the effect is modest at the current low SSBs (Figures 4.5.4.1-2).

However, other rules may be possible. One important finding is that across variants of the rule, both the risk of further depleting the stock and the mean catch are largely determined by the actual realized F. In the short term (years 2–5) the risk reaches 5% at F around 0.1; in the medium term (years 6–10), F between 0.15 and 0.2 may be tolerable (see Figures 4.5.4.1-3). The introduction of stabilizers may require lower Fs, in particular in the short term, which again may be because the low risk is associated with drastic reductions in the catches in the immediate future.

Given that the current HCR is not considered precautionary then in the present situation, introducing the additional condition mentioned in the request "In cases where applying the plan results in catches of less than 50% of catches in the previous year, then ICES catch advice on a precautionary basis should apply", cannot lead to the sardine plan becoming precautionary. Preliminary exploration of stabilizing elements in the rule confirmed that such measures tend to increase the risk to limit points and to delay recovery.

CONCLUSIONS.

- For the current productivity regime, fishing under the current HCR would result in a zero probability of rebuilding the spawning biomass above Blim from the current low SSB level in the short term. In the long term the probability that the stock exceeds Blim will be considerably lower than 95% (about 50%).
- For this reason, the HCR cannot be considered precautionary.
- However, this HCR would prevent further stock decline leading, in the two recruitment regimes, to an increase of the stock above of the recent low value (132 thousand t) since the beginning of the simulation period with high probability (such probability exceeds 95% from around 2020 onwards).
- To develop alternative harvest rules to cope with the present poor state of the stock and productivity regime was outside the terms of reference for this group, and would require extensive considerations, dialogue and analyses beyond what could be done in a short meeting.
- The analysis of some variants of the current HCR showed that options such as a decrease of the catch target and an increase of Btrigger (or a combination of both) would lead to rebuilding the stock to Blim after a long time for the recent productivity regime.
- Given that the current HCR is not considered precautionary then in the present situation, introducing the additional condition mentioned in the request "In cases where…", cannot lead to the sardine plan becoming precautionary. Preliminary exploration of stabilizing elements in the rule confirmed that such measures tend to increase the risk to limit points and to delay recovery.

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Annex 1: List of Participants

Report of the WLPELA 2017 Workshop to evaluate the management plan for Iberian sardine (WKEMPIS)

29–31 May 2017

LIST OF PARTICIPANTS

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Annex 2: Agenda of work

Actual agenda of WKPELA 2017 sardine LTMP evaluation (may meeting).

Monday, May 29:

Start 09:30 / End at 19:00

Work focused in clarifying the procedure to evaluate the LTMP, the BRPs and the stakeholder meeting, In particular the following issues were addressed

14) Review of the two TORs f & g and organization of the work during the three days, including a discussion on the interpretations of the precautionary advice for ICES to address the

15) A Presentation of the WD on the BRP for southern sardine followed by a discussion on them and any related further work;

16) Presentations on advances on the Evaluation of the LTMP for this sardine and definition of related issues: Considerations about what properties a recovery plan should have; Setting up the Input basis for the assessment of the current HCR and the performance indicators.

The rest of the day was passed with the informal meeting with stakeholders (between 11 and 12:30 h) and with more extended discussions on these issues.

Tuesday May 30:

Start 09:00 / End 19:30

The second day was devoted to finalizing the conditioning of the modelling, and running the assessment of the current HCR and variants, and examination of results. Draft structure of the report and of the introductory sections were already written down.

Wednesday 31

Start 09:00 / End 18:45

Main issues covered sequentially during the third day were:

- Final discussion on the results and preparation of tables and figures to be included in the report,
- Advancing drafts of the report
- Producing the first draft of the answer to the EU request.
- In the afternoon, a second meeting with stakeholders was held up (from 16:00 to 17:15 to provide them with a short summary of the main results achieved.

Before closing, pending work was scheduled for the following days.

Annex 3: External Expert review

Martin Dorn (US) participated as external expert in the WGPELA working group meeting in Lisbon during March 29–31 to address two TORs concerning the management procedure (MP) for the southern sardine stock. The working group developed an analysis of the stock-recruit relationship using data from the benchmark stock assessment of southern sardine that was completed earlier this year. This analysis was very thorough, and considered both the set of stock and recruitment pairs that were used in the analysis, and alternative functional forms for the stock recruit relationship. This analysis followed the guidance developed by ICES, and produced estimates of B_{lim} and other management reference points. I support the results of this analysis, but note that they are somewhat unusual because the estimate of B_{MSY} (i.e., the intercept of the replacement line for F_{MSY} (= 0.20) with the stock recruit curve) is only 14% higher than B_{lim}. These results are indication there is very little productive capacity in the stock, which is consistent with recent regime of declining and low recruitment, but may not be reflective of long term patterns.

The management simulation program HCS was used to evaluate the performance of the southern sardine MP as well as other control rules. Two recruitment scenarios were considered, a scenario using the hockey-stick stock recruit relationship that was used to estimate B_{lim}, and a less optimistic scenario where recruitment is based on the mean over 2006–2015. Since the stock is presently far below the estimate of B_{lim}, the focus was on evaluating the probability and the time period for the stock to rebuild to above B_{lim}. The evaluation used standard simulation procedures, and model inputs and configurations were carefully checked. Consequently I support the conclusion that the Sardine MP could not be considered precautionary according to criteria established by ICES, i.e., the stock will not rebuild to above B_{lim} within 5 years with greater than 95% probability.

Simulations of the southern sardine MP indicate that the MP has some desirable characteristics, given current stock status. It would prevent further stock decline with high probability, and would lead to a gradual increase in stock size on average, even under the low recruitment scenario. In addition, application of the MP results in short-term fishing mortalities that would generally be considered relatively low and sustainable for a small pelagic species, i.e., less than half of natural mortality (equal to approximately 0.40 for ages 2–5) for the southern sardine stock. Finally, a model run where fishing mortality was set to zero still would not result in rebuilding with sufficiently high probability to be considered precautionary according to ICES criteria, suggesting such a standard may be unrealistic given the stock's current status and recent history of low productivity.

Annex 4: Summary Template for HCR modelling from WKGMSE

Background		
Motive/initiative/background	Re-evaluate whether the Portuguese-Spanish sardine fishery management plan remains precautionary taking into account the new agreed analytical assessment method and potential new biological reference points from the benchmark assessment (WKPELA 2017). In addition, it should be evaluated whether the plan remains precautionary when adding the following condition to the original plan, as requested by the EU to ICES: "In cases where applying the plan results in catches of less than 50% of catches in the previous year, then ICES catch advice on a precautionary basis should apply."	
Main objectives	High probability of recovery to above Blim = 337 448 tons in 5 years' time frame, precautionary and stable catches after recovery.	
Formal framework	ICES on request from EU	
Who did the evaluation work	WKPELA 2017 Workshop to evaluate the management plan for Iberian sardine (WKEMPIS)	
Method		
Software	HCS_15_1 ("Harvest Control Simulation")	
Name, brief outline	Age-structured operating model, "short cut" type.	
Reference or documentation	Unpublished, documented in Skagen 2015, code available from www.dwsk.net	
Type of stock	Short-medium life span, pelagic, very valuable	
Knowledge base*	Analytic assessment (Stock Synthesis 3, v. 3.24AB), annual catches-at-age, annual spring acoustic survey, triennal DEPM survey	
Type of regulation	Catch and effort limitations agreed between Portugal and Spain	
Operating model conditioning		
	Function, source of data	Stochastic? – how (distribution, source of variability)
Recruitment	Hockey-stick fitted to SR pairs 1993–2015	Log-normal, CV = 0.49 from residuals
Growth & maturity	Average over 2010–2015, no density dependence. B1+ was used as a proxy for SSB.	Random lognormal noise on weights-at-age.
Natural mortality	M-at-age 0–6+ = 0.98, 0.61, 0.47, 0.40, 0.36, 0.35, 0.32 (Gislason *et al.*, 2010 formula)	No
Selectivity	F-at-age estimate in the benchmark assessment , scaled to the mean of ages 2–5 (selectivity fixed from 2006 to 2015, flat at ages 3–5)	No, except deviations at the implementation step, with CVs for all ages similar to those in the assessment
Initial stock numbers	From assessment, 0-group abundance replaced by the geometric mean of 0-group abundance in 2006–2015	According to the variance–covariance matrix from the assessment (inverse Hessian)
Decision basis **	B1+ at the start of the intermediate year	

Number of iterations	1000	
Projection time	30 years	
Observation and implementation models		
With assessment		
Input data		
Comparison with ordinary assessment? ***		
Deviations from EG practice?		
No assessment	*(example of how to present this when there is no assessment)*	
Type of noise	Year factor + age factor in an auto-regressive model on stock numbers-at-age along year classes.	Both log-normal and auto-regressive model among year classes Age factor from CV estimates in the assessment Year factor adapted to reproduce CV of the SSB estimate in the assessment
Comparison with ordinary assessment? ***	Year factor scaled to give CV of SSB in year 10 as CV of SSB in the assessment	
Projection: If yes, how?	Yes, deterministic with recruitment according to deterministic SR function, with provisional official catches in 2016 = 22 700 tons reported by WK members	
Projection: Deviations from EG practice?	TAC constraint in projections, EG uses F_{sq}	
Implementation	Catches in numbers-at-age from projection according to the rule	Log-normally distributed error, CV 10%, no bias
Harvest rule		
Harvest rule design	Catch rule with two breakpoints B0 and Btrigger. Catch = 0 below B0, fixed catch above Btrigger, linear reduction between these points.	
Stabilizers	None in the proposed rule.	
Duration of decisions	Annual	
Revision clause		
Presentation of results		
Interest parameters	Risk to Blim and to Blow=rounded geometric mean SSB in 2012–2016= 132 thousand tons (very close but below B0 in the HR), Catch (Mean and 10–50–90 percentiles), Inter-annual variation, P (B1+>Blim) > 0.50 and P (B1+>Blim) > 0.95, probability that the biomass increase from the recent low =Blow	
Risk type and time interval****	Type 3	
Precautionary risk level	5%	
Experiences and comments		
Review, acceptance		
Experiences and comments		

Annex 5: Tables of results

Table A1. Results of Run 1

Mean annual values of recruitment (billions of individuals), fishing mortality (F, year-1), biomass of age 1 and older fish (B1+, thousand t), catch (thousand t) and probabilities of B1+ being above Blim= 337 448 tons and above Blow= 132 thousand tons (mean SSB in 2012–2015).

Table A1.

Year	F	Recruits	B1+	Catch	AbsIAV	P ($B_{1+} > B_{lim}$)	P ($B_{1+} > B_{low}$)
2016	0.17	5402	145	23	0	0.0	67.2
2017	0.05	5093	162	9	43	0.5	73.9
2018	0.07	5606	184	14	34	0.9	87.1
2019	0.10	6269	198	20	40	2.8	90.2
2020	0.11	6754	217	24	45	4.7	94.4
2021	0.13	7290	230	29	46	8.9	95.5
2022	0.14	7740	243	34	44	12.1	97.1
2023	0.15	7933	257	38	42	15.9	97.9
2024	0.16	8310	267	42	43	19.1	98.4
2025	0.17	8753	276	45	40	23.7	99.6
2026	0.17	9090	287	47	40	27.1	99.0
2027	0.18	9123	297	50	38	30.3	99.0
2028	0.19	9430	304	53	34	33.3	99.2
2029	0.19	9496	311	55	33	35.4	99.6
2030	0.19	9511	315	56	30	38.3	99.7
2031	0.19	9991	319	56	30	38.5	99.8
2032	0.20	9889	326	58	31	40.9	100.0
2033	0.20	9906	329	59	28	42.5	99.8
2034	0.20	10187	331	61	28	42.1	99.9
2035	0.20	10312	334	61	27	43.3	100.0
2036	0.20	9924	339	61	27	46.2	99.8
2037	0.20	10174	338	62	28	45.2	99.9
2038	0.20	10351	339	62	26	46.5	99.9
2039	0.20	10374	343	62	27	47.0	100.0
2040	0.21	10194	346	63	26	48.1	100.0
2041	0.20	10386	345	63	26	48.8	99.8
2042	0.20	10296	346	63	26	48.6	99.8
2043	0.21	10519	346	64	25	46.0	99.9
2044	0.21	10573	348	64	25	49.6	99.7
2045	0.21	10347	350	64	26	51.0	99.7
2046	0.20	10354	350	63	27	50.4	99.6

Table A2. Results of Run 2

Table A2.

Year	F	Recruits	B1+	Catch	AbsIAV	P ($B_{1+} > B_{lim}$)	P ($B_{1+} > B_{low}$)
2016	0.18	5295	145	23	0	0.0	68.3
2017	0.05	5302	160	9	44	0.8	72.9
2018	0.07	5182	185	13	36	0.5	95.0
2019	0.10	5325	196	19	42	0.1	99.2
2020	0.12	5249	203	23	49	0.0	99.5
2021	0.14	5184	204	25	50	0.0	99.8
2022	0.14	5206	201	25	49	0.0	99.6
2023	0.14	5305	198	25	52	0.0	99.5
2024	0.13	5345	198	24	50	0.0	99.6
2025	0.13	5205	200	23	50	0.0	99.4
2026	0.13	5275	200	24	49	0.0	99.8
2027	0.13	5250	200	24	48	0.0	99.6
2028	0.13	5195	200	23	50	0.0	99.8
2029	0.13	5193	200	23	49	0.0	99.5
2030	0.13	5292	200	24	49	0.0	99.7
2031	0.13	5302	200	24	49	0.0	100.0
2032	0.13	5220	200	24	53	0.0	99.9
2033	0.13	5268	199	24	52	0.0	99.6
2034	0.13	5246	199	24	52	0.0	99.7
2035	0.13	5208	199	24	50	0.0	99.5
2036	0.13	5260	199	24	52	0.0	99.5
2037	0.13	5210	199	23	51	0.0	99.8
2038	0.13	5233	199	24	52	0.0	99.9
2039	0.13	5210	200	24	51	0.0	99.4
2040	0.13	5225	199	24	49	0.0	99.1
2041	0.13	5300	198	23	52	0.0	99.5
2042	0.13	5190	200	24	50	0.0	99.2
2043	0.13	5287	199	23	51	0.0	99.7
2044	0.13	5256	200	23	50	0.0	99.8
2045	0.13	5290	201	25	51	0.0	99.7
2046	0.13	5229	200	24	50	0.0	99.6

Table A3. Results of Run 2

P (B_{1+} >B_{lim}) ≥ 95	**Year**	**Catch target**
96.9	2031	0
96.4	2032	8.6
95.8	2033	17.2
95.9	2037	25.8

Table A4. Results of Run 2

P (B_{1+} >B_{lim}) ≥ 50	**Year**	**Catch target**
59.6	2024	0
55.3	2024	8.6
51.1	2024	17.2
55.4	2025	25.8
50.4	2025	34.4
53.6	2026	43
53.4	2027	51.6
50.3	2028	60.2
52.7	2030	68.8
50.3	2033	77.4
51	2045	86

Separate: Draft advice of the answer to the EU special request

Annex 12: Other appended relevant Working documents to WKPELA 2017

This appendix (Annex 12) is downloaded separately from the main WKPELA report.

At ICES WKPELA2017 website.

It contains the following Working Document which were made available to WKPELA2017:

For southern sardine (Atlanto-Iberian sardine):

Maria Manuel Angélico, Cristina Nunes, Jose Ramón Pérez and Paz Díaz: Summary of the revised DEPM data series estimations for the Atlanto-Iberian sardine (ICES 9a + 8c), 1988–2014, using the traditional methodology (in line with the 2012 revision).

Paz Díaz, Ana Lago de Lanzós, Isabel Riveiro, Pablo Carrera, Cristina Nunes, Vitor Marques, Elisabete Henriques, Maria Manuel Angélico: Atlanto-Iberian sardine (ICES 9a + 8c) spawning stock biomass reanalysis for the DEPM data series, 1988–2014, considering egg production estimation using a mortality model obtained from aggregated data and with temperature as covariate. Part I. SSB reanalysis for the DEPM data series, 1988–2014, considering egg production estimation using a mortality model obtained from aggregated data and with temperature as covariate. (With a Part II. - Comparison of trends in the sardine SSB estimates (ICES 9a + 8c) obtained from DEPM and acoustics surveys)

Maria Manuel Angélico, E. Henriques, A. Lago de Lanzós, Paz Díaz and Isabel Riveiro: Sardine Egg Production Estimation (ICES áreas 9a + 8c) using data from EPM surveys directed at mackerel and horse-mackerel.

Nunes C., Uriarte A., Diaz Conde P., Perez J.R., Soares E., Riveiro I., Angelico M.M., Silva A.: Revision of the life history parameters (proportion of mature and mean weights at age) for the Iberian (south) sardine stock (ICES 8c and 9a)

Alexandra Silva, Eduardo Soares and Delfina Morais: Revision of Portuguese acoustic data (PELAGO) – age classification of sardine small individuals.

Alexandra Silva and Isabel Riveiro: Revision of the assessment of the sardine south stock (sardine in ICES Divisions 8.c and 9.a) – Impact of revisions of input data on the 2016 assessment.

Alexandra Silva and Isabel Riveiro: Revision of the assessment of the sardine south stock (sardine in ICES Divisions 8.c and 9.a). Model configuration: initial population and stock-recruitment.

Posterior contribution on Southern Sardine (after WKPELA2017 meeting):

Laura Wise, Alexandra Silva, Hugo Mendes, David Miller, Manuela Azevedo: Estimates of biological reference points for southern sardine stock (ICES Division 8.c and 9.a). (First version issued on 10/05/2017 by email to members of WKPELA)

For Northern Sardine

Leire Citores, Leire Ibaibarriaga, Andrés Uriarte and Lionel Pawlowski: Stock assessment for sardine in 8abd and 7 using a4a and its variants.

For Southern Horse Mackerel

Costa, A.M., Villamor, B., Silva, C., Nunes, C., Pinto, D., Perez, J.R., Inácio, M., Abreu, P., Azevedo, M.: Spawning season, maturity and fecundity: Southern horse mackerel, Trachurus trachurus, Life-history: Reproduction.

Hugo Mendes, Manuela Azevedo, Corina Chaves, Gersom Costas, Francisco Velasco: Characterization of Southern horse mackerel survey indices and implications for stock assessment.