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South Pacific Regional Fisheries Management Organisation

14th SCIENTIFIC COMMITTEE WORKSHOP REPORT

Jack Mackerel Benchmark Workshop (SCW14)

Seattle, United States of America
4 to 8 July 2022

SPRFMO SCW14 Report

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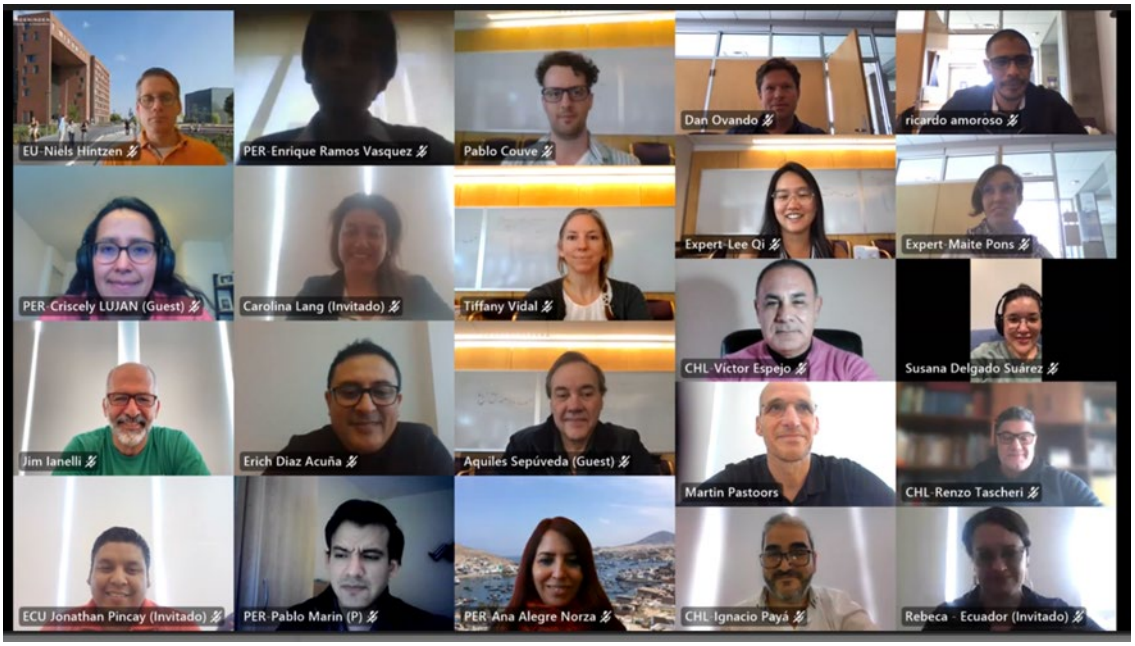
The invited experts Lee Qi, Giancarlo Correa, Ricardo Amoroso, Maite Pons and Dan Ovando are acknowledged for their significant contributions.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SPRFMO SCW14 REPORT EXECUTIVE SUMMARY

A benchmark workshop for the jack mackerel stock assessment was most recently completed in 2018. Since then, significant new age-determination data, specifically for the jack mackerel caught off Chile, were presented to the Scientific Committee. The main objective of the SCW14 workshop was to integrate into the assessment the new data that were based on the updated aging criteria developed by Chile, including age compositions and weight-at-age in the catches of Chile and the offshore fleets, and in the acoustic surveys of Central and North of Chile. As a consequence of this update, a new maturity-at-age vector was estimated and a new value of natural mortality has been derived (M=0.28). Overall, the changes caused by the new aging criteria led to the understanding of a faster-growing species that is earlier to mature.

In addition, CPUE indexes have been updated to include a factor for increases in the efficiency of fishing effort ("effort creep"). For the Chilean CPUE index this efficiency factor was a very preliminary guess (1% per year accumulated at 30%). Reference points have also been updated. In addition, for the single-stock hypothesis a new reference point has been derived for a limit biomass, B_{lim}, which was estimated at 8% of unfished spawning biomass (Figure 1). Compared to the most recent assessment using the 'old' age composition data, the perception of stock is relatively unchanged (Figure 2) and is estimated to be well above B_{MSY} and fishing mortality is well below F_{MSY}.

Comparison of the new assessment (1.13) with the SC9 assessment (0.00).

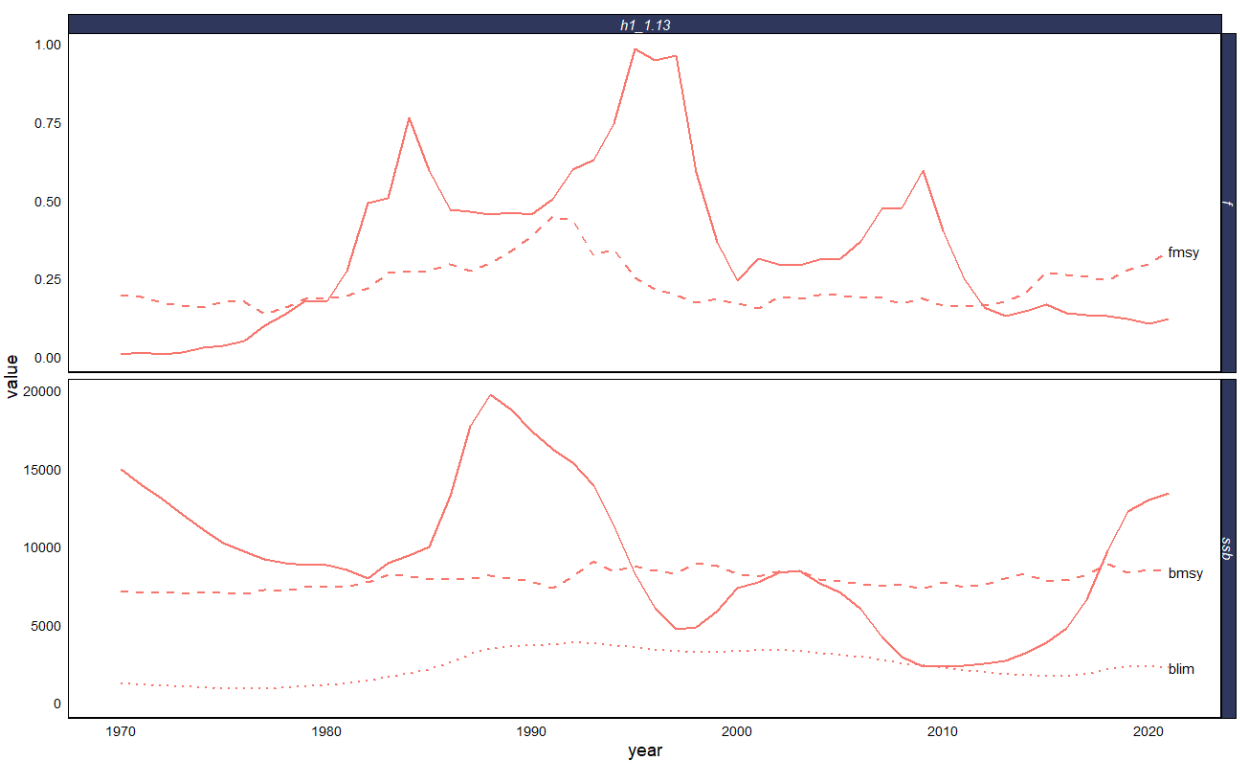

Figure 1. Summary estimates of fishing mortality (top) and spawning biomass (bottom) relative to reference points for jack mackerel based on the single-stock hypothesis, 1970-2021.

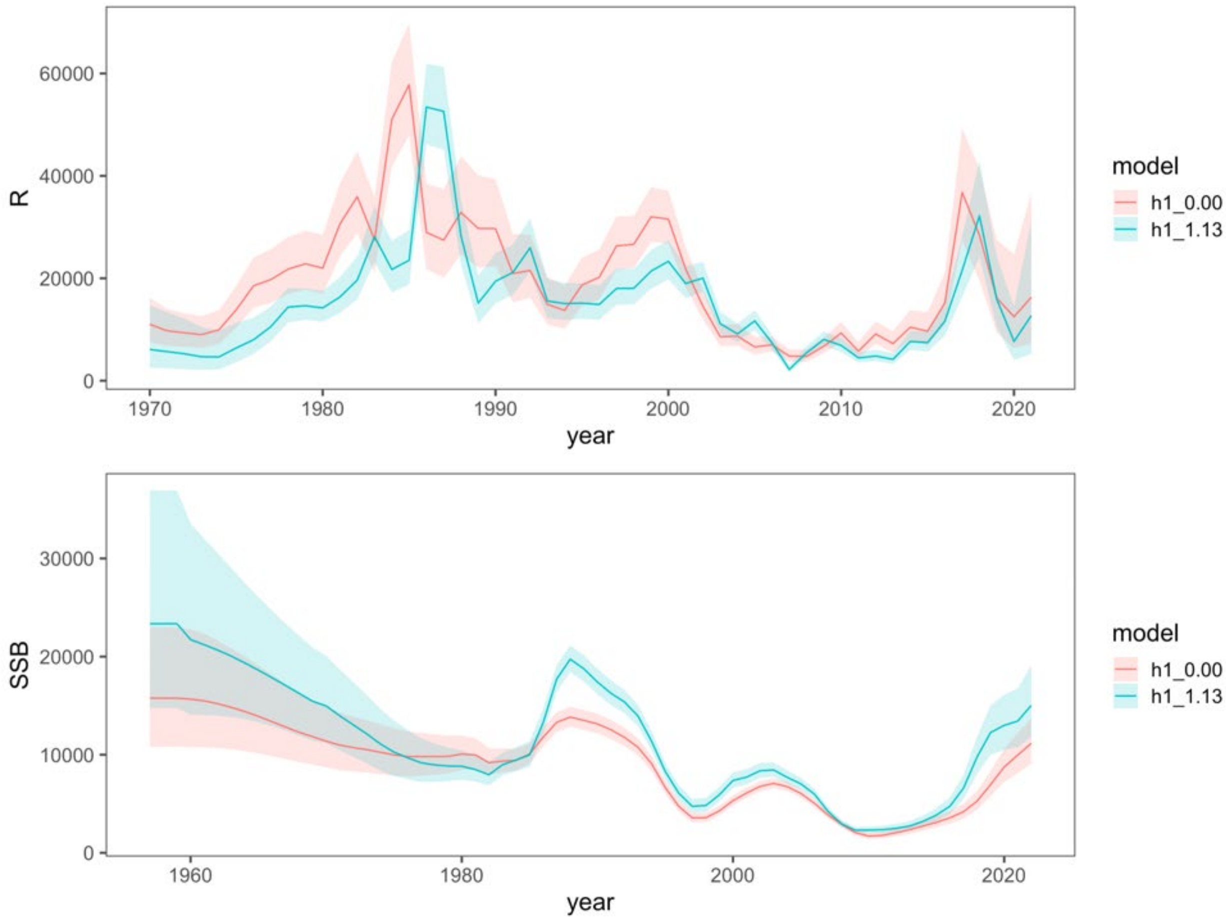

Figure 2. Summary estimates of recruitment (top) and spawning biomass (bottom) for jack mackerel based on the single-stock hypothesis for the 2021 model (h1_0.00) and the model developed from the conclusion of the benchmark (h1_1.13).

SPRFMO SCW14-REPORT

Report of the 2022 Jack Mackerel Benchmark Workshop (SCW14)

Seattle, United States of America
4 to 8 July 2022

1. Opening

1. The 14th SPRFMO Scientific Committee Working Group (SCW14) was held in Seattle, USA, from 4 to 8 July 2022. It was conducted in a hybrid format, with people participating both in person and online. The participant list is provided in Annex 1. The Chair of the SC Jack Mackerel Working Group (WG), Martin Pastoors, welcomed all participants and gave an overview of the Terms of Reference for the benchmark workshop. Members were asked to indicate where they planned to make contributions/presentations over the course of the week. The approved agenda can be found in Annex 2. This document is organized along the agenda items as specified in the agenda. The workshop participants were asked to review the past benchmark workshop report, last year's data workshop (SCW11), and the report from the modelling workshop held in June 2022 as shown in the Teams folder.

2. The host (and Chair of the Scientific Committee), Jim Ianelli provided an overview of the jack mackerel assessment so that participants were reminded of the data and components of the model used for providing advice to the Commission. Niels Hintzen (vice-Chair of the Scientific Committee) then provided an overview of the data-processing approach used to estimate age compositions and mean weight-at-age for the fishing fleets. In particular, he addressed fleets that were missing catch-at-age data for certain quarters. He provided details on how the processing of those data occurs. The group requested that the code for data preparation and processing be stored in GitHub in a new repository within the SPRFMO organisation (jjmData). The data are stored on a data repository on Teams. The group also suggested that there be a "data-report" (e.g., generated pdf or html) to summarize the data reported from each Member. This would allow scientists and submitting Members to check that the data is being imported correctly into the assessment, as well as identify bugs in the import and submission process. This would also improve transparency of the assessment process. Niels agreed to continue work on this.

1.1 Age determination data and associated biological parameters

3. The new ageing data for the jack mackerel caught off Chile (referred to as the "validacion" dataset as presented at the data workshop) were presented at the JM data workshop (SCW11). They are considered to be an improvement on the old ageing data as the timing of the first annulus has been validated. The first and third annuli counted previously are now considered to be incorrect ("false annuli"). This change means that all age-composition data used in the assessment as well as life history parameters require updating. The report from SCW11 noted in particular that model assumptions, such as natural mortality, age at maturity and weight-at-age would be affected.

4. Francisco Cerna (Chile) presented SCW14-WD04 Life History Parameters of Jack Mackerel (*Trachurus murphy*i, Nichols 1920) based on the new validated ageing criteria and also made available a pre-print of his journal article Cerna *et al.* (2022) on age validation of *Trachurus murphyi*.

5. The new ageing criteria were applied to the Chilean catch-at-age data (Chile CS and Chile N), to part of the offshore fleets where ageing data was lacking, and the age compositions of the Chilean acoustic surveys (Chile_AcousCS, Chile_AcousN). The Chilean egg survey (DEPM) age composition data were not updated; consequently, they were given negligible weight in the model.

6. It was noted in the discussions that there are many gaps in the Chilean age distribution for age-zero fish, which is surprising given that the northern fishery should have relatively high selectivity for the youngest fish. The survey data seem to have small fish that should have been age 0 but were age 1. Chile clarified that the true age (number of rings or annuli), used for fitting the growth model, is different to the age group (age assigned to a calendar year), used to build catch-at-age matrices. The procedure to assign age group uses the month of catch and the type of edge as well as the width of the marginal increment together to result in assignment to an age group (SC8-JM07). The date of the sampling is therefore a very important factor. Fish are only considered age-0 from hatching time (approximately November) until 31st of December. As such, age-0 (age group) fish will be very rarely collected in the survey, as the survey occurs in March. For all subsequent age classes, the year spans from spawning to spawning (in November). For example, a fish hatched in November 2020 would be age-2 (age group) in December 2021. In contrast the data used in SCW14-WD04 are true ages so the ring count was the only method used to age fish, thus resulting in the sampling of true age-0 fish. Data used in SCW14-WD04 were collected over a full year and the dates were not registered. These differences in procedures explained the absence of age-0 in the catch.

7. The workshop noted that the use of true age (number of rings) could also have implications for natural mortality (M), particularly for age-specific M values. It was suggested that given SCW14-WD04 Figure 2, modelling length-at-age data by month would provide a better fit and a higher K parameter which would in turn affect M. However, the length-at-age data were not available at a monthly resolution. It was also noted that the assessment model uses a single fixed value of M across all ages and the use of age-specific M values remains a sensitivity analysis.

8. The age composition of Peruvian catches is inferred from length composition data, using fixed growth parameters in the stock assessment as estimated from Dioses (2013). However, the workshop identified an inconsistency in the maximum length (L_∞) value between the single-stock and the two-stock model. The single-stock model used an L_∞ value of 74.4 cm, whereas the two-stock model used 74.4 cm for the south stock and 80.4 cm for the north stock. The workshop determined that the 80.4 cm was obtained from the total length measurements of jack mackerel. Converting this value to fork length measurements (using the method described in SCW14-WD03) gives a value of 74.4 cm. As the growth relationship was being used to convert total length (not fork length) measurements to ages, the workshop agreed to correct the L_∞ to the total length value of 80.4 cm for both the single-stock and two-stock models.

9. The workshop agreed that a separate model run will be required to evaluate the change of L_∞ from fork length to total length (model 0.04). In addition, the model parameter L_0 was updated to use the mean length at age 1 from historical Peruvian data.

10. The following sections discuss the effect of the updated age criteria on various aspects of the model:

Age of first selection

11. Initial selection into the fisheries is believed to be close to 1-2 years old for the southern Chilean fishery. Fish that are selected into the northern fishery tend to be much smaller, as the fishery there generally targets anchovy with small mesh purse seines. Comparison of the maturity-at-length with the length at age 1 or 2 was suggested as a useful cross check. The underlying data for Figure 1 of SCW14-WD04 (maturity-at-age ogive estimation) was requested and it was reported that sample sizes from age 0 to age 4 were 0, 82, 42 and 1, respectively. Immature fish were found in age 1 only.

Natural mortality

12. The workshop discussed the use of the new natural mortality estimates. Propagation of uncertainty for the new *M* estimates is not currently considered in the analysis. The estimates of *M* from Chile differ greatly, depending on the empirical model used (ranging from about 0.25 to 1.4). This suggested that analytical sensitivity analyses to estimate *M* were unlikely to be useful, so that it would be necessary to have a discussion and settle on a final assumption on *M*, *a priori*. It was also noted that natural mortality has to be below about 0.5 in order to expect to see any age 10 individuals, even in an unfished population. The workshop therefore agreed that it was a reasonable assumption for the *M* value to be between 0.23 and 0.37.

13. Given the uncertainty in the parameters estimated in SCW14-WD04, the workshop agreed to use Peru's growth parameters (from Dioses 2013) in the interim to obtain the estimate of *M* (hence approximately 0.28). They also noted that this procedure could be updated when better estimates are available. They noted that the value of *M* is strongly influenced by longevity, and if a maximum age of 18 is assumed then *M* will be around 0.28, whereas if a maximum age of 12 is assumed then *M* will be around 0.33. Previous attempts to estimate *M* within the assessment model have not been successful.

14. Using the Natural Mortality Tool (https://connect.fisheries.noaa.gov/natural-mortality-tool/), values of *M* range from roughly 0.1 to 0.35 with a mode at 0.28 (Figure 3). For this exercise, L_{∞} was assumed to be 80.4cm, *k* was assumed at 0.16 and t_0 at –0.356. In addition to the age-invariant point estimates the tool also provides an age-specific *M* (Figure 4).

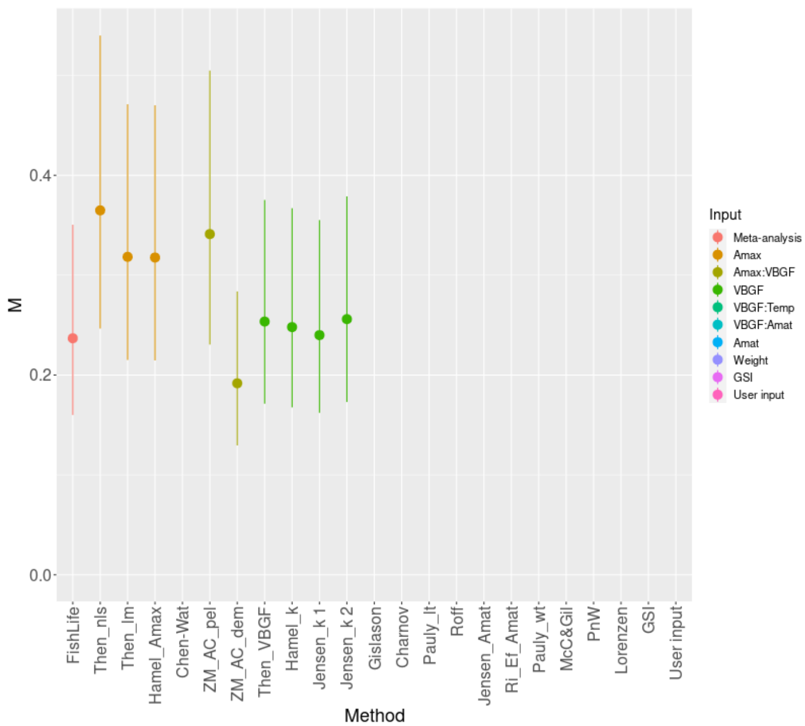

Figure 3. Estimates of natural mortality from Natural Mortality Tool application.

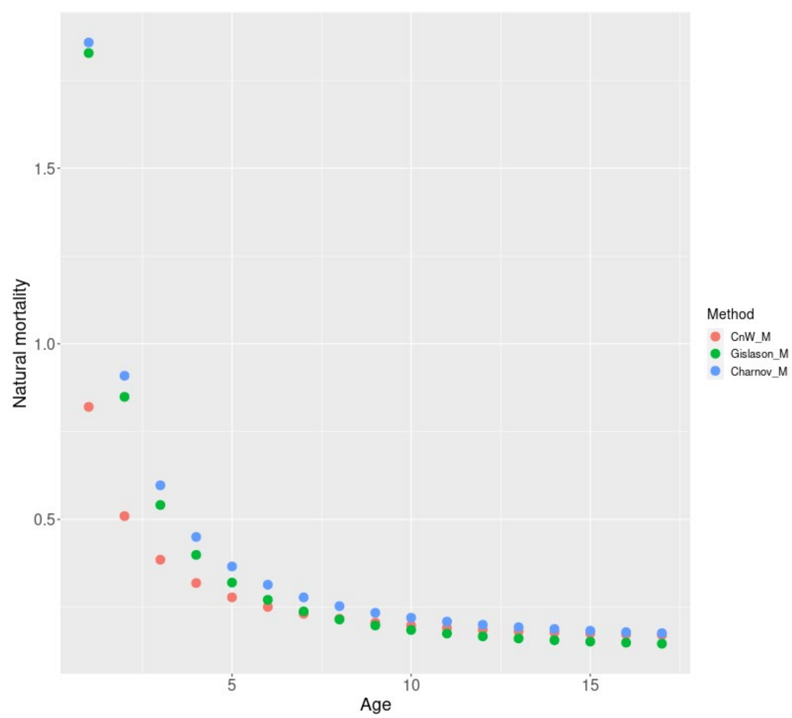

Figure 4. Estimates of natural mortality-at-age from Natural Mortality Tool application.

15. The workshop discussed whether *M* should be age-specific in the model, as biologically *M* is likely to vary by age. A mortality-at-age vector might therefore better reflect the fact that predation mortality diminishes with age/size. A similar exercise was conducted in SC4.

Length-at-age (growth models)

16. The workshop noted differences in estimates of biological parameters between Peru and Chile (as presented in SCW14-WD04). As such, a comparison was needed. The parameters for comparison included those for maturity, longevity, and growth. The workshop noted the differences in the longevity of jack mackerel in Peru and Chile – the current estimate in Peru is 12 years and in Chile is 17 years. As mentioned previously, this led to differences in *M* estimates as well. $L_{\infty}$was also quite different between Chile and Peru's growth models (Dioses 2013), although there is more similarity in growth parameters with recent studies such as Diaz (2013) and Goicochea et al. (2013).

17. The length-at-age data are compared between the Peruvian and the Chilean datasets in Figure 5. However, these data were not used in the assessment. The age-reading criteria for Chile were improved after 2018 as described at SCW11. Peru uses the parameters estimated by Dioses 2013, which used data from 1977 to 1979. The Chilean growth models use fork length while in Peru the total length is used instead. In order to compare growth curves, the estimated fork length in the Chilean models was converted to total length using a linear relationship (TL= *a* + *b* FL). The parameters of the linear model were obtained from Cubillos & Arancibia (1995): TL = 0.514 + 1.091 FL. Figure 6 shows an examination of the length distribution from the Peruvian fleet over time compared to estimates of length at age 0 and age 1 (lines).

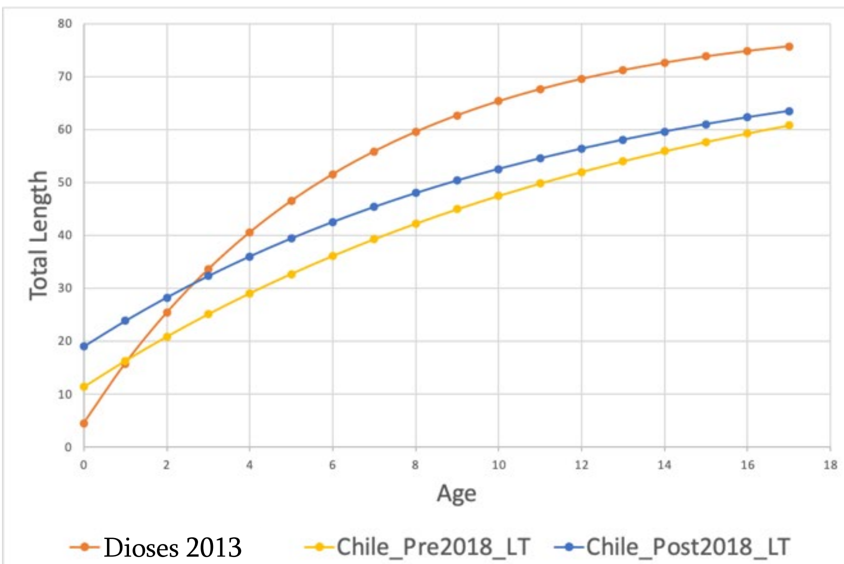

Figure 5. Comparison of length-at-age curves.

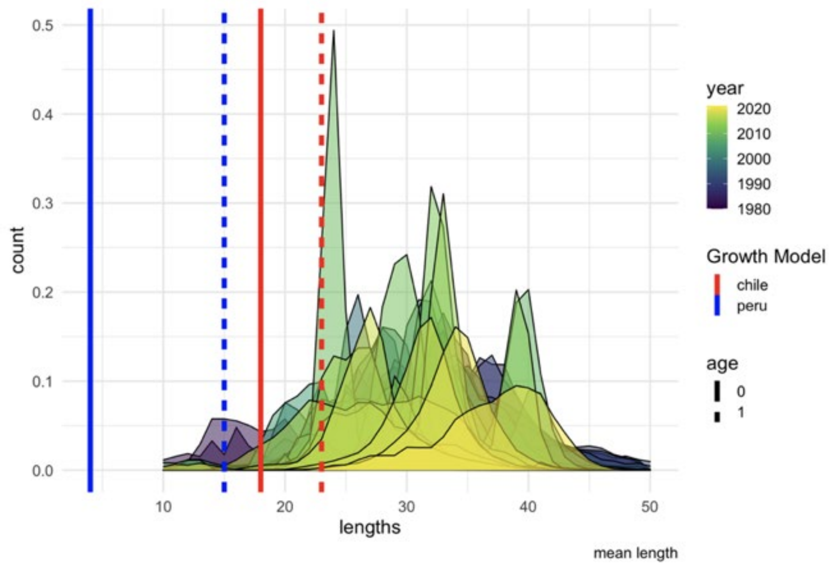

Figure 6. Examination of length distribution from Peruvian fleet over time compared to estimates of length at age 0 and age 1 (lines).

18. In the one stock model, L_∞ is assumed to be the same for the northern and southern regions, even though the growth parameters only apply to data from the northern region. There was discussion about whether it is appropriate to use growth parameters from one region in the other region (i.e., use growth parameters from a Chilean study on data from Peru) in the single stock model – as the hypothesis is that there is one stock with one growth rate. However, it was suggested that even with a single stock there could be differential growth rates across the region due to factors such as water temperature. The specified growth model is only applied to the catch-at-length (length composition) data and does not propagate to the catch-at-age information. Due to the different ageing methods used by Chile and Peru, use of Peru's growth parameter estimates for all of the data may be not consistent with the rest of the data, and this might introduce a bias.

19. Also, it was noted that the size composition data from Peru were in total length, while the data used in the Chilean study were in fork length. This has important implications for the growth parameters used in the model and should be standardized. There is a formula for converting them, TL = 0.514 + 1.091 FL, (Cubillos & Arancibia, 1995) and it was agreed that a table of growth parameters for both FL and TL would be included. However, length data are binned to the nearest centimetre, so when converting between length measurement types, holes can be created. If length frequencies would need to be converted from FL to TL, this would require so-called length-length keys (e.g., Hansen *et al.* 2019). However, it was considered that there is no need to transfer length frequencies to different metrics as long as the growth parameters are estimated with the same length metrics and the length frequencies.

Maturity-at-age

20. A comparison of estimated maturity-at-age from Chile and Peru is shown in Figure 7. The maturity-at-age for jack mackerel in Chile was estimated by Leal *et al.* (2013) by applying the new ageing criteria (SCW14-WD04) to the otoliths and histological maturity data collected between September 2011 and January 2012. In Peru (Perea *et al.* (2013) fitted a logistic model to all available data on the proportion of mature individuals at length observed between 1967-2012. The maturity-at-length was converted to maturity-at-age using the growth parameters estimated by Dioses (2013).

21. The group noted that the Peruvian and Chilean maturity ogives are very different, with the age at 50% maturity for Chile estimated at 1 year, and at 2.12 years for Peru. The value from Peru was based on a 50% proportion mature at a length of 26.5 cm, and then converted to age using the growth equation. The workshop noted that the length at 50% maturity estimated from Chile was 22 cm FL (Leal *et al.*, 2013), which corresponds to 24.7 cm TL (TL = 0.514 + 1.091 FL), therefore the estimations of maturity-at-length for Chile and Peru are closer than maturity-at-age.

22. The workshop discussed the need to test the sensitivity of the model to the maturity-at-age vectors. The workshop also agreed to move forward with the Chilean maturity curve only for the single-stock model, while using two different maturity curves in the two-stock model. This is consistent with what has historically been done for the single-stock and two-stock models.

23. The group discussed the availability of maturity data over time. Such data could be analysed as a function of length, age, or weight, to see whether there is a consistent trend across any one metric. While differences in sampling procedures could lead to variability in maturity estimates, Perea et al. (2013) indicate that there seems to be stable maturity at length in Peru. On the other hand, Chilean data in SCW 14-WD04 did not have any estimates by year. For other species, such as herring, condition is believed to be important for spawning. It was noted that dedicated sampling for maturation staging during the spawning season could be informative, but fish staged outside of the spawning season can be misclassified as immature when in fact they are resting. It was agreed that if there is no good evidence for a decision the assumptions and caveats should be documented explicitly.

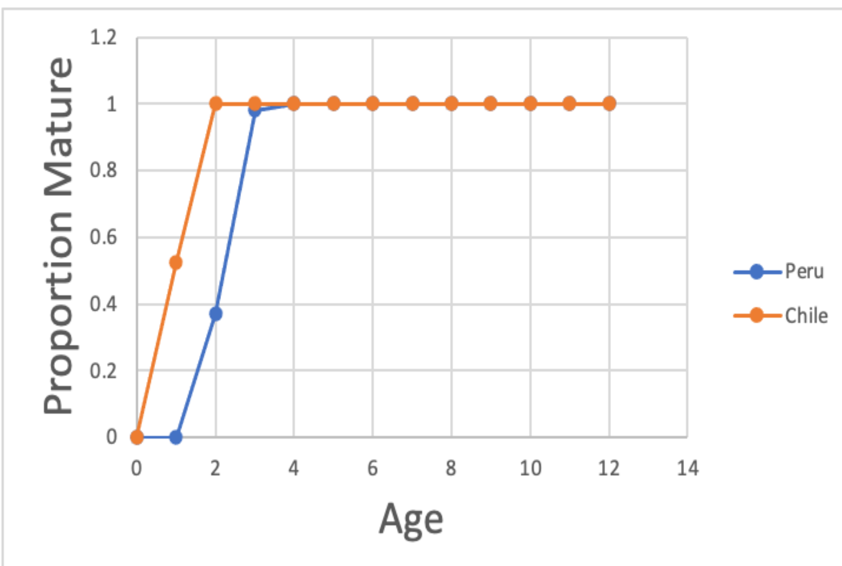

Figure 7. Comparison of maturity-at-age for Chile and Peru

Catch-at-age for the offshore fleet

24. Based on presentations to the group, the workshop noted that the process for raising catch-at-age data has been automated this year with results being similar to the data used in previous assessments. The workshop recommended that a comparison between the EU, RUS, and CHL age-length keys be pursued as part of the otolith exchange programme.

25. The Chilean age-length key has been historically applied to the length composition of the offshore fleet in years/quarters when no age data are available from the offshore fleet itself. As such, the workshop identified the need to re-estimate the catch-at-age data for the offshore fleet using the new age-length key. The re-estimation could only be done back to 2015 because no detailed length compositions were available prior to that year. The workshop therefore agreed to remove the age compositions of the offshore fleet before 2015 from the assessment.

26. The workshop discussed the possibility of shifting the model to start at age 0 instead of age 1. This would affect the FarNorth fleet which catches age 0, as well as surveys, and may affect the acoustic survey biomass (which might need to be recomputed to start at age 1+). There may also be implications for the plus group, which might need to be adjusted down as well. The question of an appropriate natural mortality value for the age-0 fish was raised but remained unresolved. Trial runs were conducted for the model beginning at age-0, and will be discussed in further detail below.

Weight-at-age

27. The workshop noted some gaps for certain ages in particular years when inputting the weight-at-age data. This occurred when there were no observations for that particular length or age bin in that year. The mean weight-at-age of jack mackerel can be highly variable between years. Historically, missing data were replaced with data from the previous year. The workshop noted that this may not be truly reflective of the weight-at-age dynamics of the population. As such, the group recommended that missing data be replaced with appropriate mean values, either by fleet, or if necessary, by using a global mean by age.

28. The workshop revisited how the "stock" or population weight-at-age at the first of January had been computed. This was particularly important for projections of biomass. It was noted that weight-at-age will also be needed to transfer between numbers and biomass in order to advise on a suitable total allowable catch (TAC) that would achieve a particular level of fishing mortality. However, note that the catch weight-at-age data are time-varying whereas the population weights at the first of January are input as a single vector.

29. The population vector was calculated as the average through years from the population weight-at-age matrix. The population weight-at-age matrix was computed using the commercial catch weight-at-age matrix. The population weight at age *a* at the start of year *t* is computed from commercial catches as the average of the mean weight between age *a-1* at year *t-1* and age *a*, at year *t*. The mean weight-at-age in catches is calculated by transforming the mean length-at-age using the allometric parameters and the bias correction proposed by Pienaar & Ricker (1968). Note that the catch weight-at-age is calculated separately by quarter (*q*) of year, year (*y*), and fleet (*f*) using the formula:

$$W_{a,q,y,f} = a' L_{a,q,y,f}^{\ -b'}$$

Where, *a'* and *b'* are parameters corrected using Pienaar & Ricker (1968).

30. The possibility of investigating a time-varying stock weight-at-age in the model was considered, in case there was a directional change in weight-at-age. However, an examination of the data (Figure 8) shows no indication of a trend, so it was decided to continue to use a single weight-at-age vector for the stock weight.

31. The previous method of obtaining a population weight-at-age was unrelated to the best estimate during the spawning season. Therefore, the group proposed calculating the mean weight-at-age, by quarter, across all years, and using the period associated with the spawning season (i.e., quarter 4) to define the population weight-at-age. The calculated weight-at-age for CS Chile from quarter 4 (from the data already provided) will be used as the input for the calculation of stock weight-at-age.

32. The workshop recommended that quarter 4 mean weight-at-age from 1995-2020 be used as the population weight-at-age in the single-stock model (for SSB calculations). The data from 1995 onwards was considered as the data appeared fairly complete, without any directional trend. For the two-stock model, the population weight-at-age for the FarNorth stock would remain the same as currently used, while the population weight-at-age for the southern stock was the same as the one-stock hypothesis.

Use of the plus group in the assessment

33. The workshop discussed how to handle the plus group, which is currently used for ages 12 years and above. Using a 10+ group was suggested, but there was a counterargument to include all ages as the computation constraints are not an issue for this model. There are recent best-practice recommendations to model more ages than you have and plus groups make mean weight-at-age less precise. However, the workshop noted that estimating selectivity can be difficult for ages without much data. The workshop recommended maintaining the 12+ group.

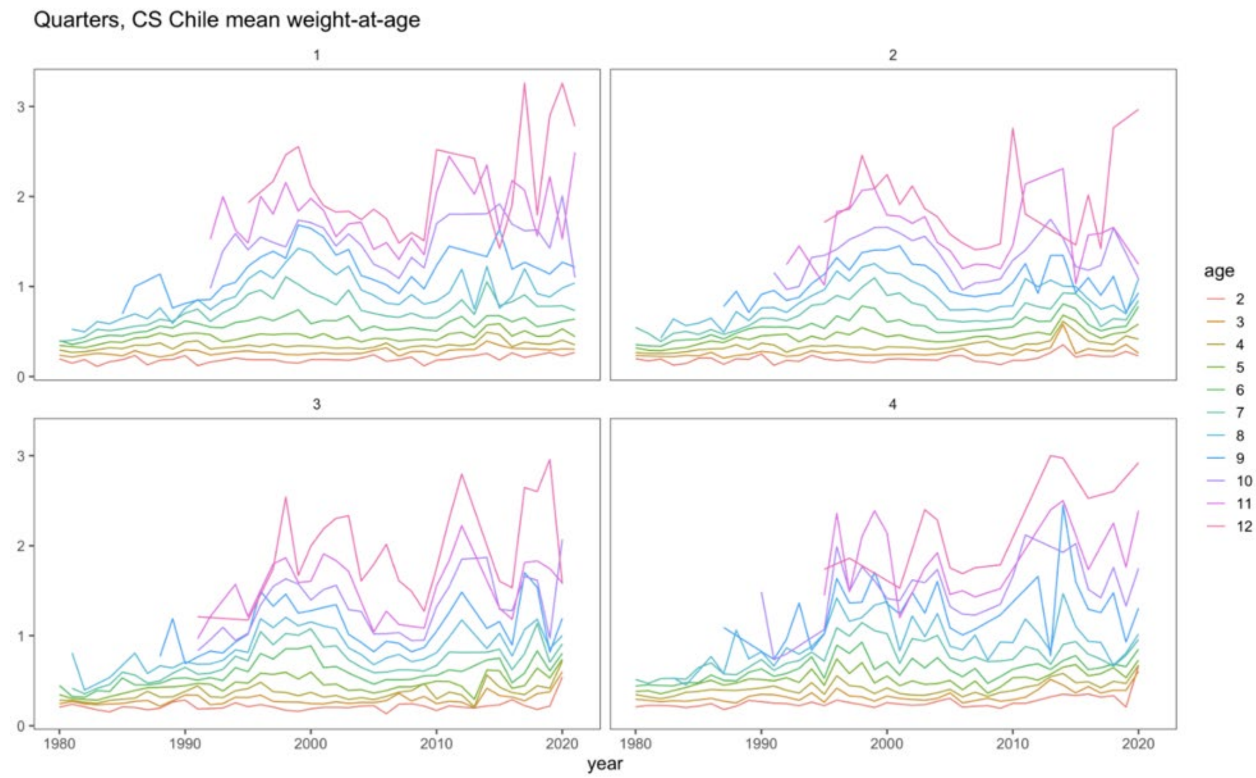

Figure 8. Mean weight-at-age through time for CS Chile by quarters (1 to 4).

1.2 Review of potential bias in CPUE indices

34. The workshop reviewed the potential bias in CPUE indices due to fishing efficiency changes and changes in jack mackerel distribution. The group noted the possibility of using Vector Autoregressive Spatio-Temporal (VAST) to investigate potential bias in CPUE indices. Tiffany Vidal (Secretariat) offered to explore this potential with interested parties in the future.

35. The group discussed how technological efficiency changes can impact catchability and index standardizations (and catchability assumptions). For the offshore fleet in particular, the workshop debated how such changes (referred to as "effort creep") could apply. An average of a 2.6% annual increase in efficiency has previously been estimated (see Rousseau et al. 2019). Based on these discussions, the group recommended that for the offshore fleet CPUE, an effort creep value of 2.5% be used in the base case assessment. More details of how this effort creep was included in the standardisation process can be found in SCW14-WD01.

36. For the other two CPUE series (Chile and Peru), the application of effort creep was also discussed. Although no formal evaluations for those particular fleets had been carried out, the group agreed that some level of effort creep should be applied. As an interim measure, the workshop recommended that a 1% efficiency improvement be applied to these series and be used in the base case assessment. In the case of the Chilean CPUE index covering 39 years, the 1% accumulated at 30% in the last year. Because previous stock assessments had shown that this CPUE index determined the biomass stock trend, an important impact on biomass trend was expected. However, the model showed only a slight impact on biomass trend. This inconsistency in results was discussed, including the possible impact of two blocks of catchability coefficients and changes in selectivity. The workshop agreed that further analyses would be required to understand the model reaction to the effort creep factor and noted that at this stage this factor does not appear to have an important effect on model results. The workshop further recommended specific studies to evaluate the potential efficiency improvements for these fleets, including the technical equipment (e.g., those under consideration by the SPRFMO Scientific Committee's Habitat Monitoring Working Group), and any other factors that could influence effective fishing effort.

1.3 Other survey indices

37. No new or modified time series from surveys were provided for review at the workshop.

1.4 "Self-sampling" data

38. Martin Pastoors (EU) presented paper SCW14-WD02 on fishery collected data to supplement observer data ("self-sampling"). Self-sampling data consists of species composition and length frequency data collected by the EU fishing industry. The number of length samples is lower than on trips covered by observers, but self-sampling provides data on trips that would be missing information otherwise.

39. In response to an inquiry as to whether the crew were trained in the same way as observers, Martin noted that they are required to measure fish for commercial purposes. Hence, accuracy is critical. These data are also available in near-real time, so they can be made available during the current year in advance of any observer data becoming available.

40. The workshop recommended using the self-sampling data in combination with the observer data. The workshop requested sufficient documentation regarding the protocols for collecting and including self-sampling data in the data submitted by the EU. The EU indicated that they will provide such information in their Annual Report. This will also include an annual quality assessment of the self-sampling and observer data.

1.5 Model evaluations

41. Model evaluations were carried out in two phases. During the first phase, the new age composition data were introduced and evaluations were carried out with a different starting age (age-0) for the assessment. The age composition data from the DEPM survey were downweighted, as the age composition had not been updated with the new ageing criteria. As very limited data were available that included age-0 information in the catches or in the surveys, the workshop decided to keep the starting age of the model at age-1, the same as historical runs. As mentioned previously, the growth parameter L_∞ was corrected in the single-stock hypothesis to reflect the total length (as opposed to fork length) of the fish. Run 0.04 which included the new age data, but where the starting age was kept the same as in the previous assessment (age 1) was selected as the base case (1.00) for subsequent model development in the next phase. Runs 0.00 to 0.04 are described in the following table:

Model	Description
0.00	Exact 2021 (single stock h1 and two-stock h2) model and data set through 2020 (mod1.0 from SC09)
0.01	As 0.00 but with the model beginning at age-0.
0.02	As 0.01 but replacing previous age data with updated data; mean stock weight-at-age calculated as a mean from SC_Chile 4th quarter, 1995-2020; natural mortality set to 0.25; downweighting DEPM.
0.03	As 0.00 but replacing previous age data with updated data; mean stock weight-at-age calculated as a mean from SC_Chile 4th quarter, 1995-2020; natural mortality set to 0.25; downweighting DEPM.
0.04	As 0.03 but with L_infinity updated to reflect TL (80.4) instead of FL (74.4); Lo updated to 15.75 to reflect the mean total length of age-1 fish.

42. During the second phase, a sequence of different scenarios was explored for new approaches to the assessment. This included different ways of handling selectivity (1.01), age-varying natural mortality (1.02), CPUE indices that included effort creep (1.03, 1.06), updated CVs for age composition data (1.05), removal of erroneously included years in the Chilean Acoustic CS age compositions, and several runs for iterative reweighting of the model (Francis weights, 1.10, 1.11, 1.12, 1.13, 1.14). All scenarios were run for both the one-stock hypothesis (H1) and two-stock hypothesis (H2) and are detailed in the following table:

Model	Description
1.00	As 0.04.
1.01	As 1.00 but with changes in selectivity. (JNI)
1.02	As 1.00 but with age-varying M (Chen and Watanabe method (Chen & Watanabe 1989); scaled to 0.28 (average over entire vector)). (NH)
1.03	As 1.00 but with the new offshore CPUE index that incorporates effort creep. (MP)
1.04	As 1.00 but with pre-weighted sample sizes for composition data. (IP)
1.05	As 1.04 but with sample sizes for composition data and CVs of index data based on expert judgement.
1.06	As 1.03 but with the Chilean CPUE index that incorporates a 1% effort creep. (NH)
1.07	As 1.04 but with the updated CVs on all the indices (Candidate for future).
1.08	As 1.07 but with high weights on composition data (compare Francis weights with 1.07).
1.09	As 1.07 and 1.06 (combination) but with Peruvian CPUE index that incorporates a 1% effort creep, and updated CVs because the index series had changed.
1.10	As 1.09 with 5x the sample size (., 150, 250, 200) for the multinomials (composition data).
1.11	As 1.10 but removing recent age compositions from Chile AcousCS.
1.12	As 1.11 but Francis weights applied only in one iteration.
1.13	As 1.12 but Francis weights applied second iteration.

43. Figure 9 shows the impact of introducing the new age data into the final model agreed upon in SC09. Updating the CVs impacted the results to some extent (models 1.04 and 1.09) but removing missing data years had a relatively minor impact (stemming from 1.09 to 1.13; Figure 10). In summary, comparing the 2021 assessment with the update at the end of the benchmark showed some substantive differences (Figure 11). Nonetheless, the general conditions remained very similar for providing advice.

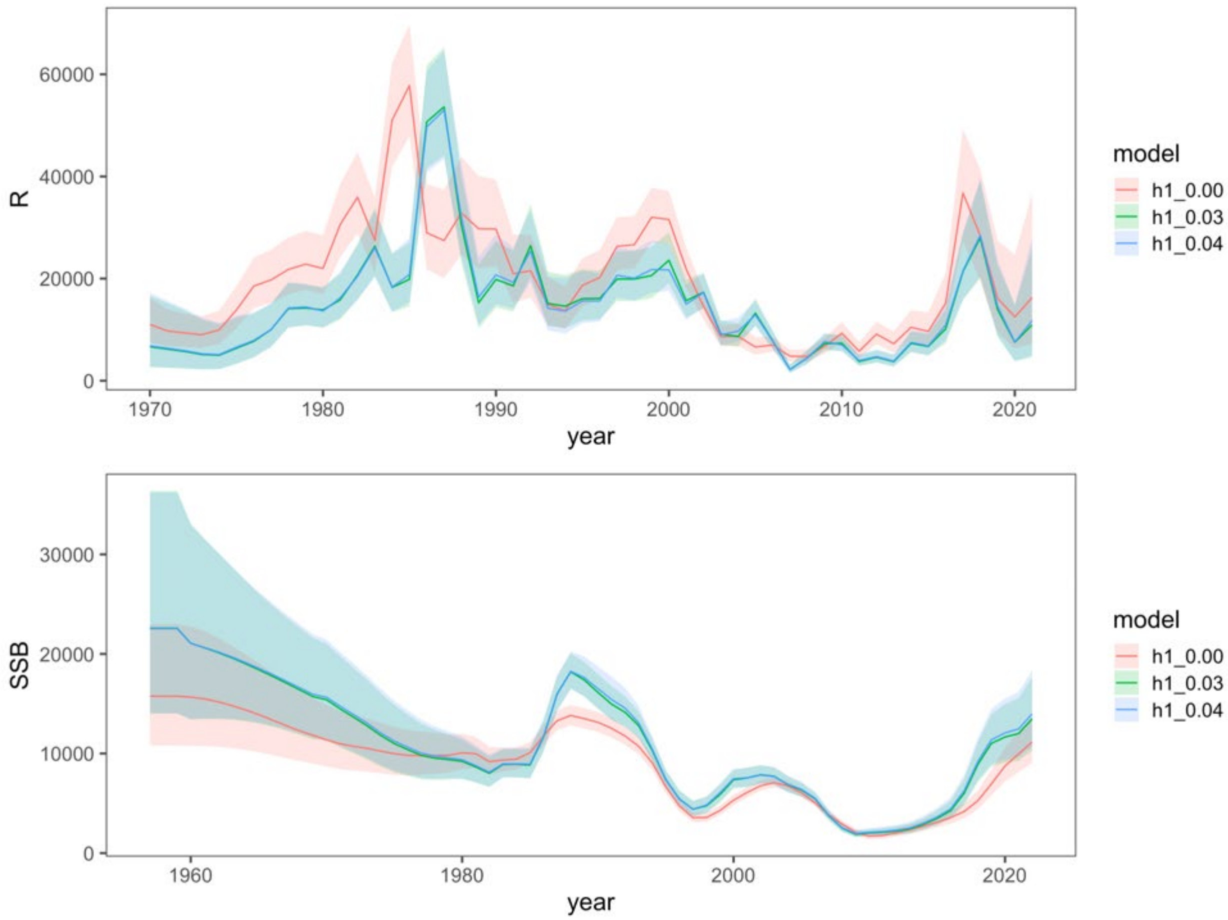

Figure 9. Results showing recruitment (top) and spawning biomass (SSB; bottom) for selected models under the one stock hypothesis and how estimates have changed.

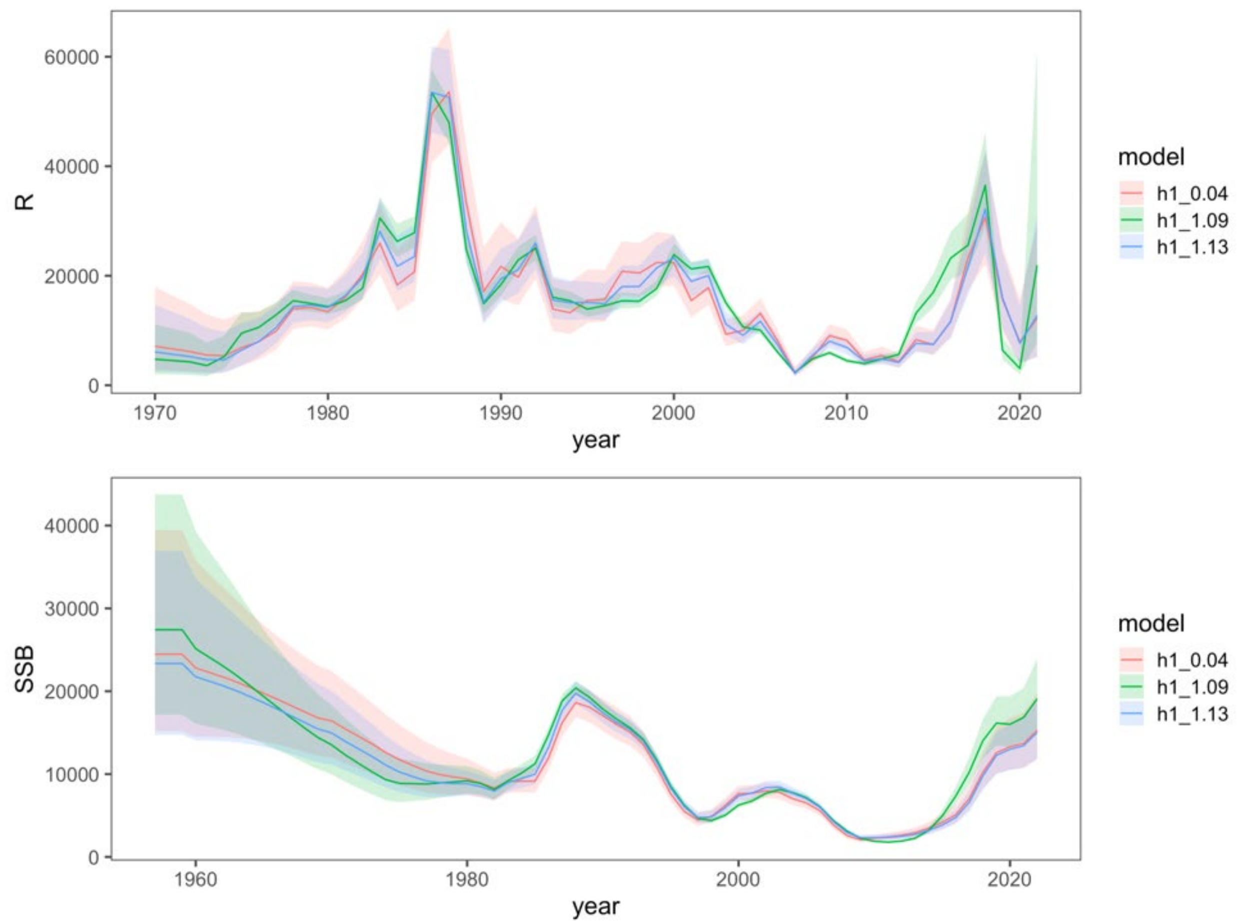

Figure 10. Results showing recruitment (top) and spawning biomass (SSB; bottom) for selected models under the one stock hypothesis and how estimates have changed.

Data re-weighting and final model selection

44. The group discussed trade-offs and alternatives for tuning the effective sample sizes to be used for the age composition data. The original input sample sizes were based on expert advice determined during the 2015 data workshop. Beginning in 2018, as discussed in SC4 and agreed upon in SCW6, the Francis T1.8 weighting method (Francis 2011) has been used to assign weighted sample sizes for age-frequency data. The Francis weights calculated in SCW6 reduced the effective sample sizes considerably. Instead of iterating the weighting method over the previously-agreed-upon weighted sample sizes, SCW14 recommended starting with estimates of relative input sample sizes that were based on expert judgement. This was done in order for other parts of the model to be first evaluated, with sample sizes then updated as required.

45. The weights on the age composition data are based on Francis (2011), and this is affected by the CVs specified for the indices. The approach, adopted by Clark and Hare (2006, p. 17) and suggested by Francis (2011), was proposed. This alternative involves fitting a simple smoother to an individual CPUE time series, obtaining the residuals of the fit, and using the CV of those residuals as an estimate of the CPUE uncertainty (Figure 12). This allowed the workshop to refine the input CVs to “conventional” values (e.g., 20%) scaled in a relative sense based on the analysis applying smoothers to the input data.

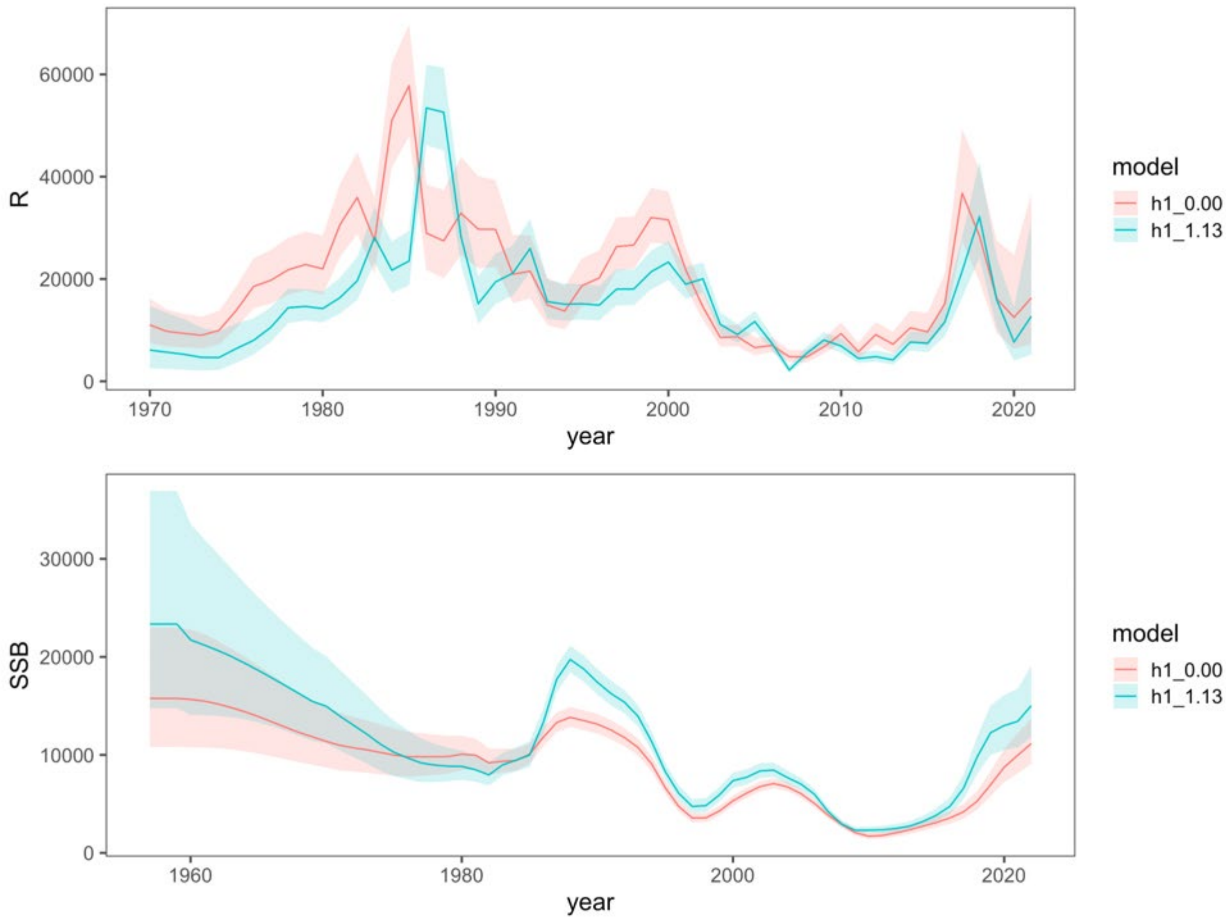

Figure 11. Results showing recruitment (top) and spawning biomass (SSB; bottom) for the 2021 model from SC09 (model h1_0.00) and the model arising from the conclusion of the benchmark workshop (model h1_0.13).

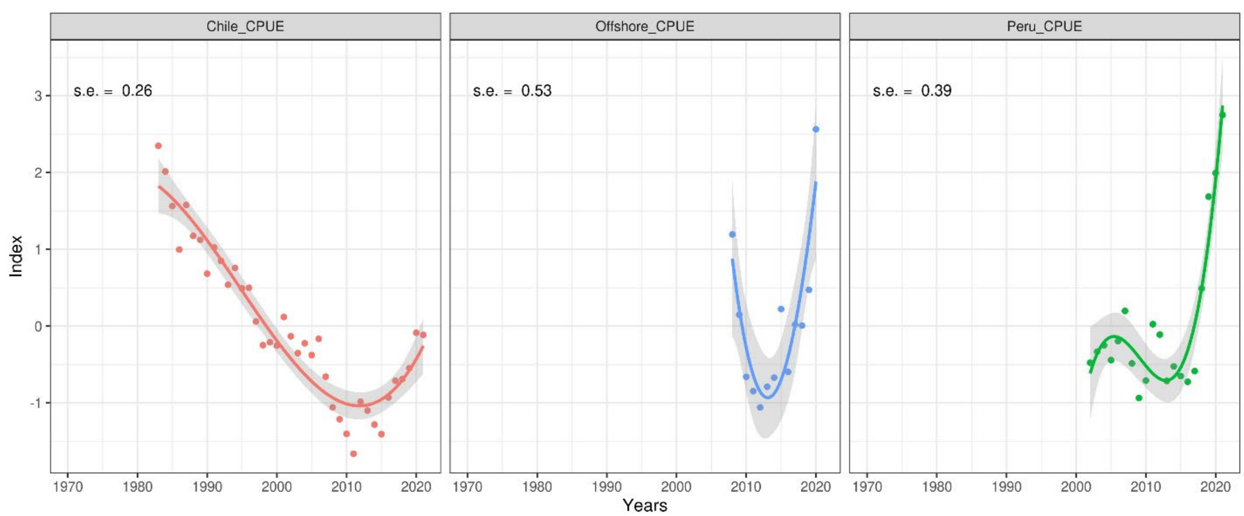

Figure 12. Fit of data smoothers to the available CPUE data (scaled) to inform the input CVs following Francis (2011; page 1132) suggestion. Standard errors of each fit are included as annotations.

Comparison of one-stock and two-stock hypotheses (h1_1.13, h2_1.13)

46. The workshop further reviewed the single-stock and two-stock hypothesis implementations of the JJM assessment model, projections, environmental regimes, and reference points.

47. In the two-stock model, a single recruitment regime has been used for the southern stock, while two regimes are defined for the northern stock. Beginning in 2000, there appears to have been an environmental shift, leading to colder coastal waters in the northern region. This is documented in Peru's Annual Report to the Scientific Commission (SC9-Doc23), and the document that describes Peru's national catch limit. There are different recruitment scenarios used in the model projections and it was suggested that the regime shift could be impacting both the recruitment estimates and the estimates of biological reference points.

48. It was noted that there is a stronger retrospective pattern in the southern stock in the 2-stock model than in the single stock model (Figure 13). This could perhaps be explained by fish from the southern stock recruiting to the northern stock, thereby creating an overestimation of SSB. Also, the indices that apply to the Peruvian data in the single stock model appear to stabilize the estimation, at least as suggested by the retrospective pattern.

49. The group discussed the retrospective patterns and why the weighting of age compositions could have an impact on the retrospective patterns (particularly in comparing the results from models 1.11 and 1.13). They suggested that the Francis weights should be calculated independently for the two-stock model (for models 1.11-1.13). However, two iterations of the Francis weight methods for the two-stock model resulted in very similar weightings as in the one-stock model.

50. Figure 14 shows that the results for the two-stock hypothesis model are also affected by the changes from model 0.00 to 1.13. This reflects to some degree the specification of different "regimes" for the Peruvian stock. Due to the strong retrospective pattern in the two-stock model, it was suggested that – until the management strategy evaluation (MSE) has been completed - the one-stock model should preferably be used for management advice. However, it must be noted that generally the management advice has been based on the model (i.e., one or two stocks hypothesis) with the most precautionary result. In the MSE, the issue of one-stock and two-stock models and the interaction between them can be explicitly taken into account resulting in an overall management strategy that would be robust to different mixing hypotheses.

H1 one-stock model	H2 two-stock model (southern stock)

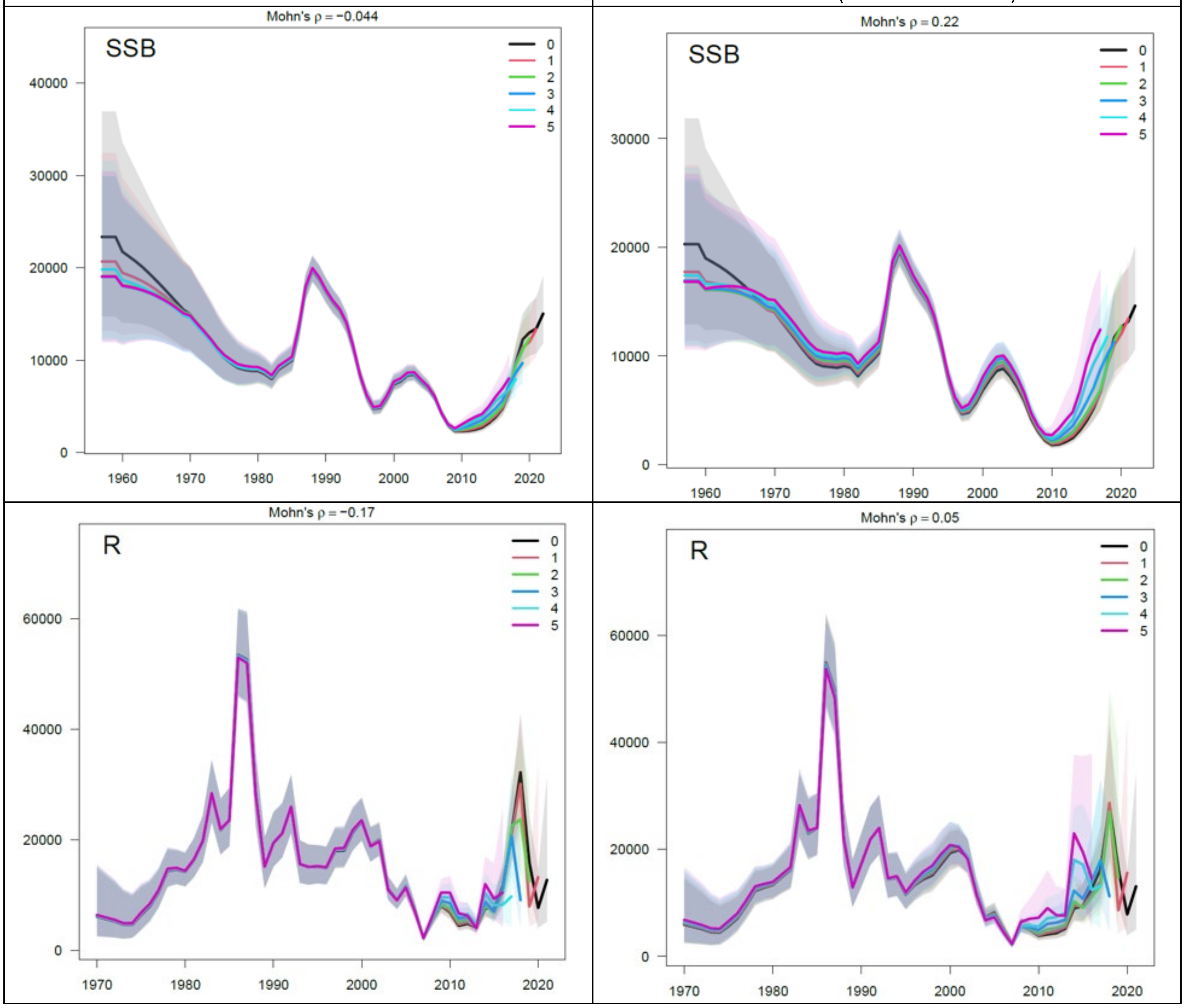

Figure 13. Retrospective analysis of SSB and recruitment in single-stock model H1 (left, h1_1.13) and two-stock model H2 (right, h2_1.13; southern stock only).

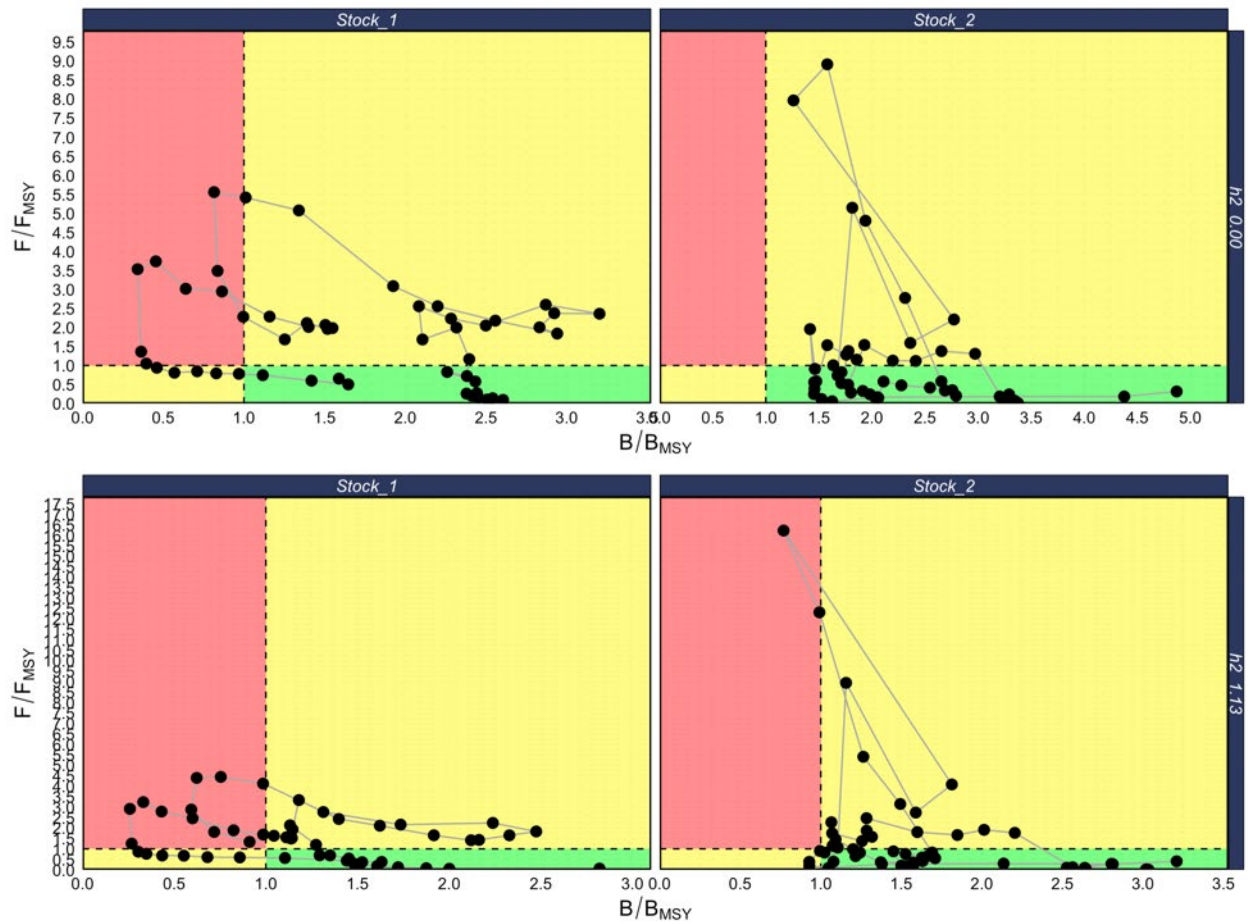

Figure 14. Results showing Kobe plots for the 2021 model from SC09 (model h2_0.00; top row) and the model arising from the conclusion of the benchmark workshop (model h2_0.13; bottom row). Columns are for stock 1 (left, south zone) and northern stock (right).

Developments on uncertainty and selectivity parameterizations

51. Jim Ianelli gave a short presentation on the draft working paper SCW14-WD05 on selectivity parameterizations and uncertainty evaluations in the jjm model. This paper was drafted to document a new selectivity parameterization that is available in jjm (v1.00.00). The initial implementation shown of the time-varying selectivity (Figure 15) showed promise and reduced the number of parameters by about one half. However, the interaction with the posterior MCMC sampling performed more poorly, so further work is needed. The working document outlines the preliminary steps for computing the full MCMC posterior distribution and an experimental way to show the interaction between different data components and a quantity of interest (in this case ending year spawning biomass) was developed (Figure 16). This figure is intended to show how different data components conflict. For example, the index data (age and biomass) suggest better fits for higher values of spawning biomass which conflicts moderately with the fishery age data. This MCMC posterior analysis has a number of useful aspects including diagnostics for parameter confounding, computing posterior predictive statistics to aid in model selection, provides a more complete consideration of uncertainty, and the ability to develop projects useful for catch advice.

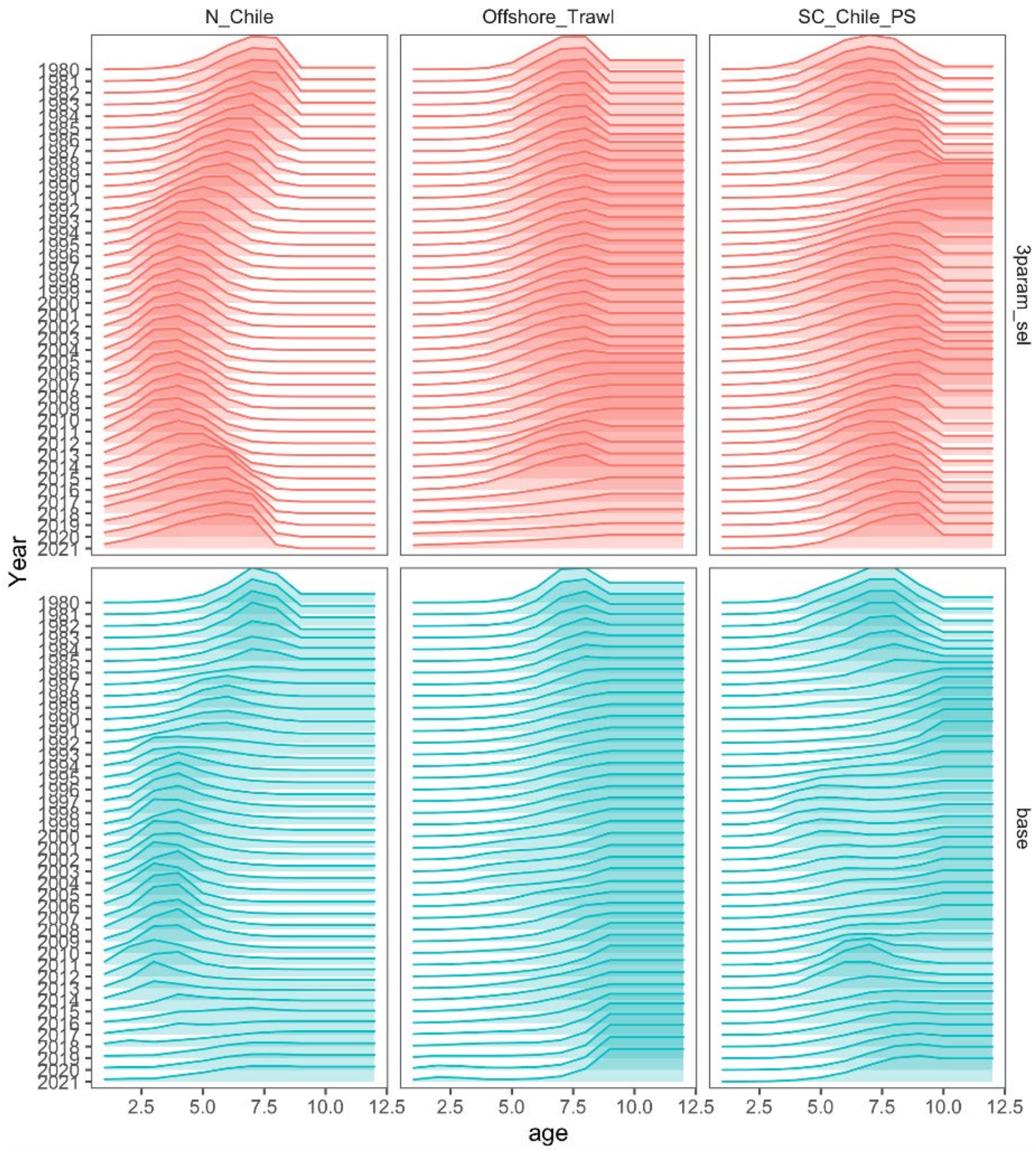

Figure 15. Selectivity for three main fisheries (columns) over time using the base (default) model (bottom row) and using the new 3-parameter double logistic (top row).

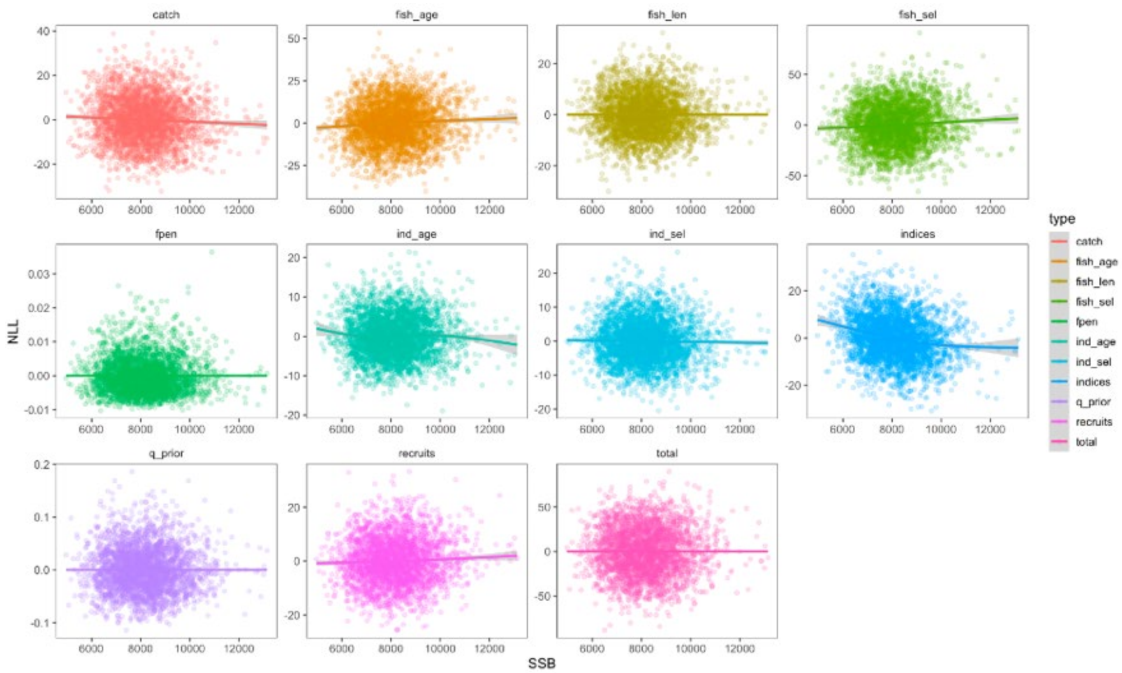

Figure 16. Results from the jjm model run with the adnuts package showing the component negative log-likelihood values given the spawning biomass (SSB) at the end of the model period.

1.6 Projections

52. The workshop reviewed the methods used to carry out projections and considered exploring alternatives.

53. The group noted that historically the Kobe plot for the 2-stock model indicated that the northern stock had never been overfished (Figure 14). This was likely an artifact of the regime specification. A recommendation was made to use the full time series to estimate recruitment, to be comparable with the southern stock. A short time series has historically been used because the stock appeared to be in a low recruitment phase. The workshop recommended that the SC reconsider this practice as there have been higher recruitments recently. The question remains whether the stock is still generally in a low productivity/recruitment regime, and whether the recent higher recruitments can be relied upon to continue.

54. Given the changes in the age data, it was suggested that the time period for recruitment estimates used in the projections should perhaps be changed. The proposal for this year's projections is to use the selectivity and weight-at-age from the terminal year, and average recruitment over a short period (shifted to cover 2001-2015 because of the change in the ageing that affected the period of poor recruitment and explicitly excluding the recent years of strong recruitment). As was done previously, the group recommended including low and higher values of steepness to reflect uncertainty in the stock productivity. However, the group recommended continuing to use only the lower value of steepness for the F_{MSY} estimation.

55. A Bayesian approach to developing posterior predictive distributions could be considered based on the demonstration that the MCMC integration appears to be working well. Further development on this is encouraged by members and could be pursued through collaborations with invited experts.

56. The group discussed whether the SC advice should be given based on the simpler one-stock hypothesis. This would provide consistency from year to year and also avoid complications for how different regimes are treated in the two-stock hypothesis. **This recommendation shall be considered further at SC10.**

1.7 Documentation and options

57. The workshop reviewed existing documentation, including outputs from the recent jjm workshop, and the suggestion from Peru to develop a complete set of documentation for presentation at SC11. The workshop reviewed existing options to ensure that they are complete and up to date.

58. New additions to the jjmR package were developed during the workshop (credits to Dan Ovando). The new features allow the extraction and comparison of metrics from the JJM model by first extracting data frames from the model objects and having standardized methods for plotting different types of metrics.

1.8 Biological reference points and the harvest control rule

59. The workshop discussed the generation of initial estimates of biological reference points using the same methodology as used in the 2018 benchmark workshop. It was agreed that while it would be useful to use the MSE work to develop reference points and update Annex K, some interim reference points should be established until those are ready.

60. B_{MSY} is taken as the long-term average of biomass fished under MSY from the jjm model. It was originally evaluated with simulations. It was requested that both B_{MSY} and F_{MSY} be added to the Technical Annex. B_{MSY} is a function of the assumed steepness of the stock-recruitment relationship. Note that in the current code the equilibrium virgin biomass also changes over time due to changes in the weight-at-age (Figure 17).

61. The group recommended that the extent to which the reference points are influenced by assumptions about steepness should continue to be explored and include a range of values.

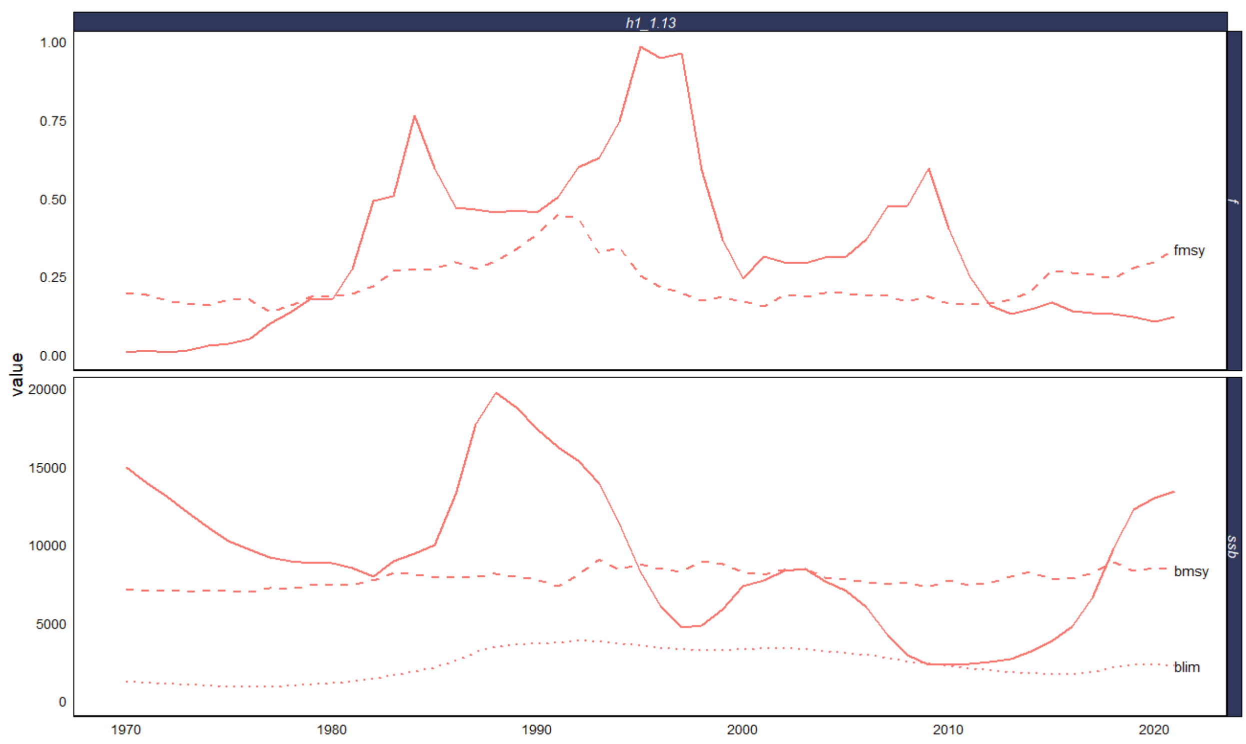

Figure 17. Model 1.13 results showing the reference points for *F* and for SSB (B_{MSY}) under the one-stock hypothesis model.

62. Since 2014, the Scientific Committee has used biological reference points as specified in Annex K of COMM02-Report. SCW14 reviewed these biological reference points and introduced a limit reference point (B_{lim}; where *B* refers to spawning biomass). The proposed harvest control rule (HCR; based on both Annex K of the COMM02-Report and the "adjusted Annex K" HCR defined in the SC2 Report) is thus as follows:

   a) if the biomass in the coming year is estimated to be below B_{lim} then the TAC is set to zero and directed fishing for jack mackerel is prohibited. B_{lim} is to be computed from the ratio $\gamma_{lim} = min(B_t/B_{0,t})$; that is, the lowest ratio of historical spawning biomass relative to unfished. So, for the 2022 stock assessment, $B_{lim} = \gamma_{lim} B_{0,2023}$.

   b) If B is below 80% B_{MSY} the trial catch for next year would be based on the minimum of the current F or F_{MSY}, which would mean that in theory B would not go down. If the trial catch is greater than the replacement yield (i.e., the catch level that would result in the same SSB for the subsequent year) then the TAC would be set at the replacement yield. This would mean that at a minimum the biomass would remain stable and would not decrease.

   c) If B is above 80% B_{MSY}, the trial catch for the next year would be based on the estimated F_{MSY}. If the trial catch is less than the replacement yield, the TAC will be set at or below the trial catch. If the trial catch is above the replacement yield, the method outlined in the previous bullet point should be used. The TAC will not be allowed to vary by more than 15% between years.

   d) If B is above B_{MSY} (proxy), then the TAC would be set based on F_{MSY}. The TAC will not be allowed to vary by more than 15% between years.

63. The workshop proposed setting B_{lim} as a function of the ratio γ_{lim} which is based on unfished biomass estimates. Here, unfished biomass is defined as the estimated spawning biomass that would have occurred had there been no fishing. That is, it is the biomass based on the estimated recruitment adjusted by the stock-recruit relationship under no fishing. For illustration, we show the impact of two values for the stock-recruit relationship steepness parameter in Figure 18. It has no impact on estimated recruits nor biomass, but as noted, adjusts recruitment under the "no-fishing" recast of history

64. The workshop noted that the current estimate of γ_{lim} would be about 0.08 (8%). However, with updated data, this value could change over time. If you have high recruitment in a year, $B_{0,t}$ could be above average and increase the value of B_{lim}. The workshop agreed that there could be an impact, and it is necessary to look at how this relationship changes with different steepness values and how that impacts the reference point. The workshop noted that there should be some thought given to minimum stock size and Allee effects. The risk is that if dynamic B0 is very low, and the reference point shifts down, there may be insufficient concern about stock status.

65. The workshop noted that SSB is higher now compared to the last model because given the new age data they mature earlier and grow faster. The F is more dynamic because there is more activity of younger ages in the fishery compared to in the previous assessment. This raises the question of what period should be used to average selectivity over to compute F_{MSY}\ (e.g., terminal, 5 or 10-yr average). It was also suggested that F_{MSY} should be compared at different steepness values.

66. Regarding reference points with respect to stock status the workshop agreed to abandon the previously assumed value of B_{MSY}. As steepness may affect B_{MSY} to an unknown extent, the workshop also agreed that a low steepness value (0.65) should be used. B_{MSY} will no longer be fixed at the interim level of 5.5 million t and will be dynamically estimated. A value of B_{MSY} will however be required for the risk table and it was suggested that this be an average over a few years. It was also noted that there should be a relationship between B_{MSY} and F_{MSY}. Generally, the workshop noted a need for some clarity in the documentation of how dynamic points are estimated as it can be confusing when reference points change over time.

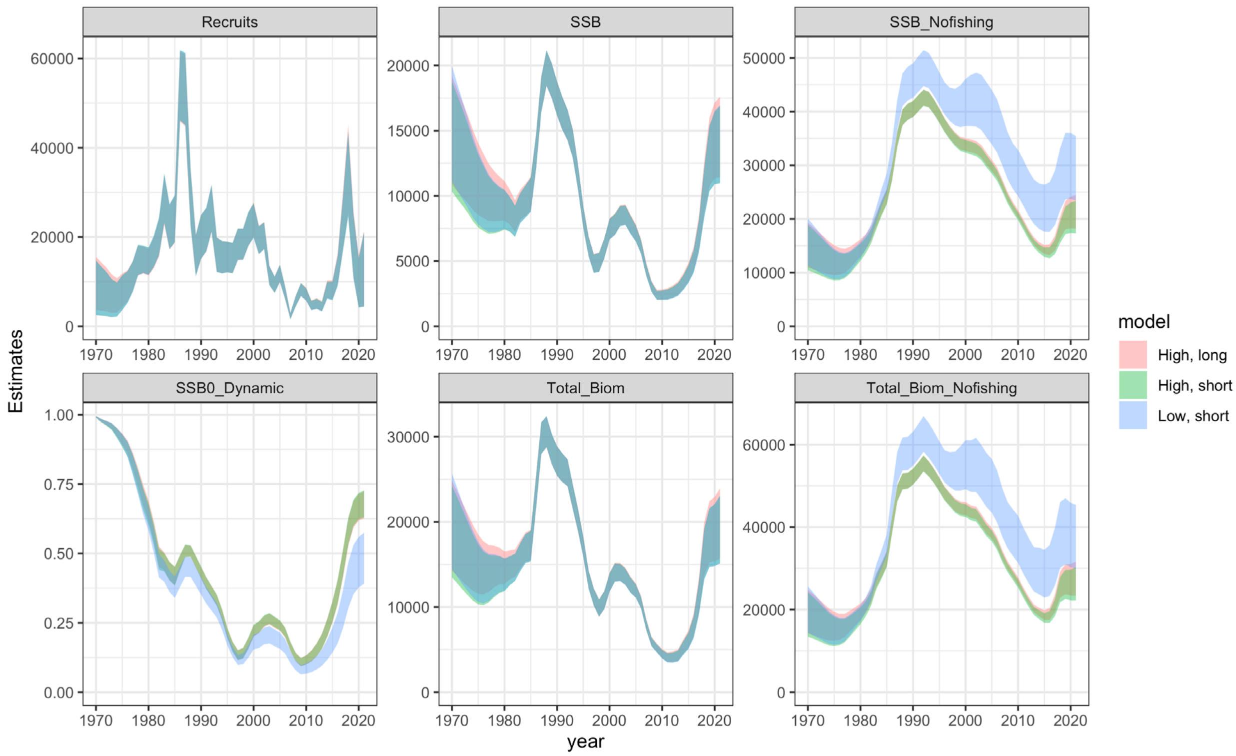

Figure 18. Model 1.13 results under different recruitment productivity specifications where "High" is with stock-recruit relationship steepness set to 0.9 and "Low" is with it set to 0.65. "Long" and "short" refer to the time frame over which the stock-recruit relationship was tuned (the latter being years from 2000-2015 and the former being over the whole period up until 2018).

2. Summary of Jack Mackerel Assessment Changes

a. Fishery and survey age compositions

- New age compositions for the Chilean fleets (Central South and Northern) based on the new ageing criterion. Also new weight-at-age in the catch information used.
- New age compositions for the offshore fleet, partly taking into account the new Chilean ALKs; truncating of the time series to 2015-2020.
- EU "self-sampling" data will be included
- Chilean new ageing criterion has been applied to the two Chilean acoustic surveys age compositions
- Chilean DEPM survey has been downweighted in the assessment because the new ageing criterion had not been applied to that survey

b. Survey and CPUE data

- Effort creep has been applied to the standardized CPUE series (Chilean, Peruvian, Offshore fleet). For the Offshore fleet and effort creep of 2.5% was used based on Rousseau *et al.* (2019). For the Chilean and Peruvian CPUE, an interim effort creep of 1.0% was used as an initial value. However, this is pending further reviews prior to the upcoming SC meetings.
- The index data CVs were evaluated and revised, and the values were chosen based on expert opinion

c. Natural mortality

- Value of 0.28 for all ages and all years for the single-stock model and the south stock of the two-stock model, derived from the mode of M values estimated with multiple methods using the Natural Mortality Toolbox

d. Maturity

- Maturity-at-age vector from SCW14-WD04, estimated using data from jack mackerel in Chile between September 2011 and January 2012 using the new ageing criteria for the single-stock model and the south stock of the two-stock model.

e. Stock weights-at-age

- One vector of weight-at-age derived from the average weight-at-age in the catch of the Chilean fleets during the fourth quarter between 1995 and the current year, for the single-stock model and the south stock of the two-stock model.

f. Weighting of age compositions

- Rationale of why iterative reweighting has been carried out
- Francis weights of effective sample size for age compositions has been derived for one-stock hypothesis. These weights will be kept constant until a future benchmark is carried out. The same weights will also be applied in the two-stock model.

	Initial Sample Size	Francis Weight		Final Sample Size
Model	h1_1.10	h1_1.11	h1_1.12	h1_1.13
N_Chile	100	0.416	0.574	23.9
SC_Chile_PS	250	0.443	0.580	64.3
Offshore_Trawl	150	0.214	0.393	12.6
Chile_AcousCS	150	0.058	0.785	6.8
Chile_AcousN	150	0.129	0.642	12.4

g. Regimes

- Regimes for calculating reference points
- Regimes for calculating low recruitment phase
- Average recruitment over a short period (2001-2015 because of the change in the ageing that affected the period of poor recruitment)
- Both low (0.65) and higher (0.8) values of steepness to estimate stock status
- Only the lower value of steepness (0.65) for FMSY estimation.

Fleet nr	Fleet	Variable	variable type	SC9	SCW14	Comments
1	North Chile purse seine	Catch-at-age	age compositions	1975-2021	**1980-2020**	
1	North Chile purse seine	Landings	biomass	1970-2021	1970-2021	
1	North Chile purse seine	Acoustic survey North	age compositions	2006-2021	2006-2021	
1	North Chile purse seine	Acoustic survey North	index	1984-1988; 1991; 2006-2021	1984-1988; 1991; 2006-2021	
1	North Chile purse seine	DEPM	age compositions	2001-2008	2001-2008	Downweighted in SCW14
1	North Chile purse seine	DEPM	index	1999-2008	1999-2008	
2	Chile South-Central	Catch-at-age	age compositions	1975-2021	**1980-2020**	
2	Chile South-Central	Landings	biomass	1970-2021	1970-2021	
2	Chile South-Central	CPUE	index	1983-2021	1983-2021	
2	Chile South-Central	Acoustic survey CS	age compositions	1997-2009	**2001-2009**	
2	Chile South-Central	Acoustic survey CS	index	1997-2009	**2001-2009**	
3	FarNorth (Peru)	Catch-at-length	length compositions	1980-2020	1980-2020	length in TL
3	FarNorth (Peru)	Landings	biomass	1970-2021	1970-2021	
3	FarNorth (Peru)	CPUE	index	2002-2021	2002-2021	
3	FarNorth (Peru)	Acoustic survey	index	1985-2013	1985-2013	
4	Offshore fleet	Catch-at-age	age compositions	1979-1991; 2000-2004; 2006-2020	**2015-2020**	
4	Offshore fleet	Catch-at-length	length compositions	2007-2019	**2015-2020**	
4	Offshore fleet	Landings	biomass	1970-2021	1970-2021	
4	Offshore fleet	CPUE	index	2008-2020	2008-2020	

h. Reference points

67. With steepness set at 0.65, the workshop proposed that the SC consider using B_{lim} (in female spawning biomass units) as a reference point defined as the biomass below which recruitment is likely to be impaired. B_{lim} is estimated as the minimum of the ratio between spawning biomass (SSB_t) and unfished spawning biomass ($SSB_{f=0,t}$, adjusted by the stock-recruit relationship). The estimated ratio during the benchmark is 8% and this estimate appeared to be robust to sensitivity analyses.

68. The workshop recommended that the SC use B_{MSY} (also expressed as spawning biomass) as estimated and conditioned on variable growth which has changed slightly over time.

69. F_{MSY} is also conditioned on changes over time (including selectivity estimates).

i. Projections

70. The stock-recruit relationship used in the assessment is copied below (for details see the technical annex). The workshop agreed that steepness (h) equal to 0.65 will be used for projection purposes.

$$\tilde{R}_i = \frac{\alpha B_t}{\beta + B_i},$$

$$\alpha = \frac{4hR_0}{5h-1} \text{ and } \beta = \frac{B_0(1-h)}{5h-1} \text{ where}$$

$$B_0 = R_0\varphi$$

$$\varphi = \sum_{j=1}^{12} e^{-M(j-1)} W_j p_j + \frac{e^{-12M} W_{12} p_{12}}{1-e^{-M}}$$

71. The model estimates values of B_{MSY} and F_{MSY} using a Newton-Raphson minimization routine that finds the value of fishing mortality, given the terminal year relative catches (and selectivities-at-age) by fleet, and the terminal year weights-at-ages for each fleet, that maximizes catch. Since weights-at-age and "effective" selectivity change each year, these values can vary. Note that as a cross-check to these calculations a grid of yields for different fishing mortality multipliers is provided as part of the standard output (and included in the jjmR pdf file that is made for each model).

72. The workshop concluded that, given environmental conditions and uncertainty in the recent few high recruitments, advice on the stock projections should be based on the current low productivity regime. The period over which the low productivity is calculated (for estimating the SRR curve) has been updated due to the new ageing and is now 2001-2015.

3. Preparation of Advice to the Scientific Committee

73. During the workshop, a range of models was developed to test different approaches and hypotheses. The details of these models are given in Annex 3. At the end of the workshop Model 1.13 was selected as the final model, which is a model incorporating the new age data from Chile, has no age-0 fish and which has been reweighted using the Francis weights. The retrospective patterns for this model look good, and the fit appears much improved over previous models. The issue of the pattern of residuals in the age compositions for the North Chile fleet has not been resolved, and the selectivity pattern should be evaluated in the next year. The largest impact of the change to the ageing method appears to be a shift in the recruitment. This model will be used as the base model for the 2022 stock assessment. As usual, this base case configuration will be adapted to run the two-stock hypothesis model.

74. The workshop sought out member volunteers to conduct the assessment work for the coming SC and suggested that a technical team be formed to take advantage of the training and experiences gained from the benchmark and earlier assessment modelling workshops.

4. Comments by reviewers

75. Three invited experts actively participated in the benchmark workshop and reviewed the work involved in preparing the assessment and providing advice. They had jointly prepared some brief comments as follows.

76. Overall, the assessment process seemed transparent and effective although we found that the hybrid format (online and in-person) limited the participation of some delegations. As reviewers, it was hard sometimes to follow the discussion because the limited background documents available to us prior to the meeting. This made it difficult to understand some of the points raised during the discussions. These points were familiar to participants with long involvement and history with the jack mackerel assessments. Reading the suggested documents, the last benchmark assessment in 2018 and the Technical Annex, was not enough because important details were missing. For example, the Annex fails to show how the reference points were calculated and included some vague statements such as "For some of the indices, time variations in catchability and / or selectivity have also been considered." It was unclear which indices were treated that way and why. The rationale for excluding some years of the Chilean survey data due to methodological changes was also unclear and documentation on this survey was lacking.

77. Many of our comments and questions are reflected already in the report document, but there are a few specific points we would like to share as well.

1) Effort Creep

78. The group spent quite a bit of time on the discussion of "effort creep", the idea that there should be some exogenous "extra" rate of increase of catchability over time. Overall, the evaluated rate (1% per year for the Chilean fleet) had minimal impact. However, there are two broader points that should be considered in the long term.

79. First, effort creep is unlikely to evolve at a continuous rate over time; if every year the fleet gets 1% or 2.5% more efficient, catchability will eventually reach 100%, which is unrealistic. Some consideration should be given to a functional form that perhaps asymptotes at some maximum catchability, or much more ideally, effort placed into explicitly controlling for the factors that go into effort creep.

80. Second and relatedly, the estimates of effort creep defined by Rousseau et al., (2019) were intended as a correction for raw effort data. In this case though, we are applying this effort creep factor to an already standardized index of abundance. In theory then, some of the total effort creep should be soaked up by the covariates in the CPUE standardization, such as vessel power. As more covariates associated with fishing efficiency are included in the CPUE standardization process, the rate of effort creep should be adjusted accordingly, though determining how this should be done is not trivial.

81. Overall, the impact of effort creep is likely to be minimal over the short term, but could grow more pronounced over time, and some thought should be given to a more long-term solution to this problem.

2) Database Management

82. Overall database management appears to be improving, and the team did an admirable job of pulling together the diverse array of data used in the assessment. However, there remained substantial areas of uncertainty as to the source and version of various pieces of data throughout the assessment. This is understandable but is an area of potential improvement.

83. Given the massive amount of data in this assessment, both in terms of data the model is fitting to and exogenously set parameters such as natural mortality, a spreadsheet approach to database management just doesn't seem up to the task. Ideally, the data should be moved to a more formal database structure that in particular supports robust metadata storage. A new user should have a clear way of knowing the last time a particular kind of data was updated, what the update did, etc. Or, in the case of exogenous parameters, the process by which they were set clearly articulated. There is a large number of private and open-source database structures out there that could be explored, to find the right balance of ease of use with functionality.

3) Simulation Testing and Posterior Predictive Checks

84. The ability of the model to be quickly run in a Bayesian fashion using ADNUTS opens up a range of new diagnostics. One that we would be interested in seeing is a series of tests around the model's ability to separate out changes in abundance from changes in catchability and selectivity. Under a Bayesian framework, the model specifies a data-generating process. So, the model can be used to generate data from a fixed set of known parameters, which are then passed back to the model. In theory, the model should be able to recover the known parameters. So, one test might be to pull or force a run from the posterior in which the stock became severely depleted, then pass the data generated from that state back to the model to ensure that it correctly identifies this and does not attribute the loss of say large individuals to a change in selectivity instead. We do not suspect this is necessarily happening, but it is an area that could be explored.

85. Posterior predictive checks also provide a means to evaluate the two-vs-one-stock hypotheses. Posterior predictive checks provide a measure of potential model misspecification, by exposing models that fit the supplied data relatively well but would not necessarily generate new data that is representative of the patterns observed in the fishery. Posterior predictive checks could be performed with ADNUTS to test whether there is more support for the two or one stock hypothesis.

5. References

Chen, S.; Watanabe, S. (1989). Age Dependence of Natural Mortality Coefficient in Fish Population Dynamics. *Nippn Suisan Gakkaishi 55(2)*: 205-208.

Cerna, F.; Moyano, G.; Valero, C.; Muñoz, L.; Plaza, G.; Campana, S. (2022). Bomb Radiocarbon, Otolith Daily Increments and Length Modes Validate Age Interpretations of Chilean Jack Mackerel (*Trachurus murphyi*). *Front. Mar. Sci. 9*:906583

Chen, S.; Watanabe, S. (1989). Age Dependence of Natural Mortality Coefficient in Fish Population Dynamics. *Nippn Suisan Gakkaishi 55(2)*: 205-208.

Charnov, E.L.; Gislason, H.; Pope, J.G. (2013). Evolutionary assembly rules for fish life histories. *Fish and Fisheries 14*, 213-224. https://doi.org/10.1111/j.1467-2979.2012.00467.x

Clark, W.G.; Hare, S.R. (2006) Assessment and management of Pacific halibut: data, methods, and policy. International Pacific Halibut Commission Scientific Report No. 83.

Cubillos, L.; Arancibia, H. (1995) Comparative growth performance of horse mackerel of the genus *Trachurus*, with emphasis on *T. symmetricus murphyi*. In: "International symposium on middle-sized pelagic fish", C. Bas, J.J. Castro y J.Ma. Lorenzo (Eds.), *Scientia Marina 59(3-4)*:647-652.

Díaz, E. (2013). Estimación del crecimiento del jurel Trachurus murphyi capturado en el Perú, a partir del análisis de las frecuencias por tallas. *Revista peruana de biología, 20(1)*, 061-066.

Dioses, T. (2013). Age and growth of Jack mackerel Trachurus murphyi (Nichols 1920) in Peru. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (Trachurus murphyi) in *Peru. Rev. peru. biol. special issue 20 (1)*: 045-052. (Volume published in Spanish with titles, abstracts and captions in English).

Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124–1138.

Gislason, H.; Daan, N.; Rice, J.C.; Pope, J.G. (2010). Size, growth, temperature and the natural mortality of marine fish. *Fish and Fisheries 11*: 149-158.

Goicochea, C.; Mostacero, J.; Moquillaza, P.; Dioses, T.; Topiño, Y.; Guevara-Carrasco, R. (2013). Validación del ritmo de formación de los anillos de crecimiento en otolitos del jurel *Trachurus murphyi* Nichols 1920. *Revista peruana de Biología, 20(1)*, 053-060.

Hansen, F.T.; Burns, F.; Post, S.; Thygesen, U.H.; Jansen, T. (2018). Length measurement methods of Atlantic mackerel (*Scomber scombrus*) and Atlantic horse mackerel (*Trachurus trachurus*) – current practice, conversion keys and recommendations. *Fisheries Research 205*: 57-64.

Leal, E.; Díaz, E.; Saavedra-Nievas, J.C.; Claramunt, G. (2013). Ciclo reproductivo, longitud y edad de madurez de jurel *Trachurus murphyi*, en la costa de Chile. *Revista de Biología Marina y Oceanografía Vol. 48*, No3: 601-611.

Pienaar, J.V.; Ricker, W.K. (1968). Estimating Mean Weight from Length Statistics. *Journal of the Fisheries Research Board of Canada*, 25(12). 27432747.

Rousseau, Y., R. A. Watson, J. L. Blanchard and E. A. Fulton (2019). "Evolution of global marine fishing fleets and the response of fished resources." Proceedings of the National Academy of Sciences 116(25): 12238-12243.

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ANNEX 2. SCW14 Workshop Agenda

1. OPENING OF THE MEETING

    - Introduction of participants
    - Confirmation of discussion topics
    - Report from workshop on stock assessment modelling (including additional topics)

2. The topics to be considered in this workshop will include:

    a. Evaluate how the new ageing data presented at the JM data workshop (SCW11) affect essential model assumptions, namely natural mortality and weight-at-age variability over time;

    b. Review the potential bias in CPUE indices due to fishing efficiency changes and changes in jack mackerel distribution;

    c. Review the useability of any other survey series that could be included in the assessment;

    d. Review the protocol to be developed on how self-sampling data could be integrated with observer data for inclusion in the assessment;

    e. Review the single-stock and two-stock hypothesis implementations of the JJM assessment model, projections, environmental regimes and reference points;

    f. Review the methods used to carry out projections and, if needed, explore alternatives;

    g. Ensure documentation and options are up to date;

    h. Generate initial estimates of biological reference points using the same methodology as used in the 2018 benchmark workshop.

3. Preparation of Advice to the Scientific Committee

4. Action Points and further work

ANNEX 3. Technical Aspects of the Model and Other Developments

Software "releases"

There are two key repositories discussed throughout the benchmark, that pertaining to the R package "jjmR" and that specific to the assessment itself ("jjm"). A third repository was developed at the workshop named "jjmData". For the main assessment model, we have traditional posted "tags" or releases on the github site at the end of each SC meeting so that the exact model / data / configuration can be easily be retrieved. The developers propose changing this slightly such that we adopt a semantic versioning approach that is used for virtually all software (e.g., example here). For the main jjm model, we recommend that the SC adopt jjm version 1.00.00 for use in the next stock assessment. For an explanation of how versioning should proceed going forward see the following figure:

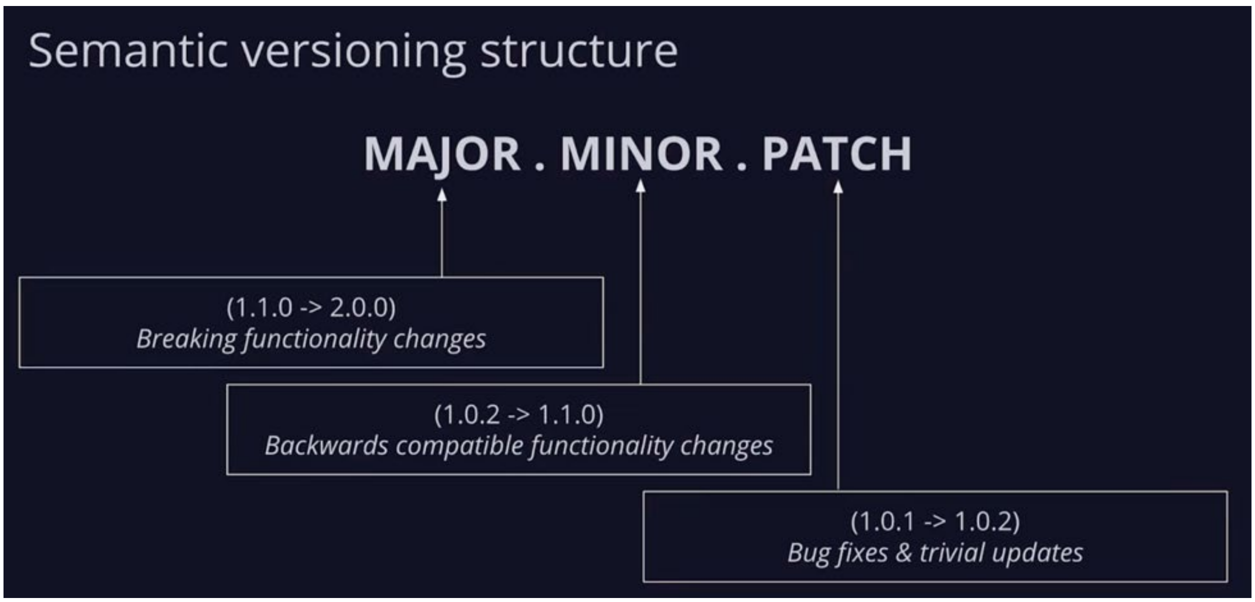

Figure to illustrate the process for updating semantic version numbers for future revisions to the jjms.tpl file.

jjmR and jjmRtidy

The R package "jjmR" has been upgraded by Dan Ovando during the workshop and now includes a series of helper functions to "tidy" up the data (for general ideas on this functionality, see https://r4ds.had.co.nz/tidy-data.html). These are designed to help users access and compare results across multiple models and stocks and what follows is an example of how to apply the new jjmR features. Note that previous functionality of jjmR remains unchanged.

First, let's load up two different model runs. As always with jjmR, make sure your working directory is set to the "assessment" folder:

```
library(jjmR)
library(ggplot2)
library(dplyr)
library(tidyr)
theme_set(theme_jjm(base_size = 15))
```

Now read in model results (assumed these have been run already)

```
model_results_1<- readJJM("h1_1.13", path = "config", input = "input")
model_results_2 <- readJJM("h2_1.13", path = "config", input = "input)
# compare to another model run
m1_v_m2 <- combineModels(model_results_1,model_results_2)
```

We can now use the tidy_JJM function to tidy up the results. As of now tidy_JJM provides support for a number of the most commonly used outputs of the JJM model, but not all. The function returns a list with objects for each tidied data type (e.g., selectivities and "msy_mt"), with columns denoting the model, stock, etc. for a given observation.

```
tidy_jjm <- tidy_JJM(m1_v_m2)
str(tidy_jjm)
#> List of 8
#>  $ age_fits        : tibble [2,736 × 9] (S3: tbl_df/tbl/data.frame)
#>   ..$ model       : chr [1:2736] "h1_1.13" "h1_1.13" "h1_1.13" "h1_1.13" ...
#>   ..$ stock       : chr [1:2736] "Stock_1" "Stock_1" "Stock_1" "Stock_1" ...
#>   ..$ fleet_type  : chr [1:2736] "fsh" "fsh" "fsh" "fsh" ...
#>   ..$ fleet_number: int [1:2736] 1 1 1 1 1 1 1 1 1 1 ...
#>   ..$ year        : num [1:2736] 1980 1980 1980 1980 1980 1980 1980 1980 1980 1980 ...
#>   ..$ age         : num [1:2736] 1 2 3 4 5 6 7 8 9 10 ...
#>   ..$ predicted   : num [1:2736] 0.0237 0.0889 0.1637 0.2124 0.2444 ...
#>   ..$ observed    : num [1:2736] 0.00415 0.04683 0.13615 0.24455 0.30796 ...
#>   ..$ fleet_name  : chr [1:2736] "N_Chile" "N_Chile" "N_Chile" "N_Chile" ...
#>  $ catchabilities   :'data.frame':   324 obs. of  8 variables:
... and so one...
```

This tidy form is useful for users wishing to quickly generate new plots or analyses based on the results of different model runs. For example, suppose we want to plot the predicted index values for each of the indices across models, as well as the residuals:

```
index_fits <- tidy_jjm$index_fits
index_fits %>%
  ggplot() +
  geom_pointrange(aes(year, observed_ind, ymin = observed_ind - 1.96 * observed_se, ymax =  observed_ind + 1.96 * observed_se), alpha = 0.5)
+
  geom_path(aes(year, pred_ind, color = model)) +
  facet_wrap(~ fleet_name, scales = "free_y") +
  scale_x_continuous(name = "Year", guide = guide_axis(n.dodge = 2)) +
  scale_y_continuous(name = "Index Values")
```

```
index_fits %>%
  mutate(residual = pred_ind - observed_ind ) %>%
  group_by(fleet_name, model) %>%
  mutate(standardized_residual = residual / sd(residual)) %>%
  filter(!is.na(standardized_residual)) %>%
  ggplot() +
  geom_hline(yintercept = 0,linetype = 2) +
  geom_col(aes(x = year, y =standardized_residual, fill =model), position = position_dodge(width = 0.5)) +
  facet_wrap(~ fleet_name, scales = "free_x") +
  scale_x_continuous(name = "Year", guide = guide_axis(n.dodge = 2)) +
  scale_y_continuous(name = "Standardized Residuals")
```

Using get_ Functions: Plotting Selectivities

You can also access the helper functions that underlay tidy_JJM directly. Each of these is named get_X, where X is the name of the data. For example, to access the estimated selectivity ogives, we can use get_selectivities.

```
selectivities <- get_selectivities(m1_v_m2)
```

```
head(selectivities)
#> # A tibble: 6 × 10
#>   model   stock   sel   fleet_type fleet_number index  year   age selectivity
#>   <chr>   <chr>   <chr> <chr>           <int> <dbl> <dbl> <int>       <dbl>
#> 1 h1_1.13 Stock_1 sel   fsh                 1     1  1970     3      0.0242
#> 2 h1_1.13 Stock_1 sel   fsh                 1     1  1970     4      0.121
#> 3 h1_1.13 Stock_1 sel   fsh                 1     1  1970     5      0.339
#> 4 h1_1.13 Stock_1 sel   fsh                 1     1  1970     6      0.968
#> 5 h1_1.13 Stock_1 sel   fsh                 1     1  1970     7      2.46
#> 6 h1_1.13 Stock_1 sel   fsh                 1     1  1970     8      3.21
#> # … with 1 more variable: fleet_name <chr>
```

Selectivities alone have a dedicated plotting function added to them by the “tidy” functions of jjmR. You can use this by running plot_selectivities, or by calling plot directly.

```
plot_selectivities(selectivities)
plot(m1_v_m2,what="selectivity",fleet="fsh", alpha = 0.2, scale = 10,
   years = 2000:2020)
plot(model_results_2,what="selectivity",fleet="ind", alpha = 0.2, scale = 10,
   years = 2015:2020)
```

Miscellaneous Examples

To access the MSY values and other reference points

```
msy_my_results = get_msy_mt(m1_v_m2)

head(msy_my_results)
#>     model   stock year    fspr survivespr  f_fmsy    fmsy       f fsprmsy
#> 1 h1_1.13 Stock_1 1970 0.93883    0.06117 0.04775 0.19387 0.00926 0.39827
#> 2 h1_1.13 Stock_1 1971 0.90789    0.09211 0.07387 0.19295 0.01425 0.39700
#> 3 h1_1.13 Stock_1 1972 0.93468    0.06532 0.05551 0.17223 0.00956 0.39851
#> 4 h1_1.13 Stock_1 1973 0.89745    0.10255 0.09177 0.16290 0.01495 0.39476
#> 5 h1_1.13 Stock_1 1974 0.80025    0.19975 0.19747 0.15713 0.03103 0.39570
#> 6 h1_1.13 Stock_1 1975 0.78939    0.21061 0.19796 0.17709 0.03506 0.39661
#>        msy    msyl     bmsy    bzero      ssb  b_bmsy
#> 1 1185.945 0.30467 7112.403 23344.93 14975.36 2.10553
#> 2 1195.226 0.30321 7078.308 23344.93 13967.12 1.97323
#> 3 1228.022 0.30494 7118.856 23344.93 13043.27 1.83221
#> 4 1264.748 0.30061 7017.823 23344.93 12109.89 1.72559
#> 5 1298.217 0.30169 7043.001 23344.93 11093.99 1.57518
#> 6 1205.963 0.30274 7067.550 23344.93 10266.56 1.45263

kobe(model_results_1, engine = "ggplot")
```

To evaluate catchabilities

```
qs = get_catchabilities(model_results_1)

qs %>%
  ggplot(aes(year, q, color = model)) +
  geom_line() +
  facet_wrap(~ fleet_name, scales = "free_y")
```

Biomass plots

```
totals <- get_totals(m1_v_m2)
totals %>%
  ggplot(aes(year, value, color = stock, linetype = model)) +
  geom_line() +
  facet_wrap(~ metric, scales = "free_y")
```

Index fits

```
index_fits <- get_index_fits(m1_v_m2)

index_fits %>%
  ggplot() +
  geom_pointrange(aes(year, observed_ind, ymin = observed_ind - 1.96 * observed_se, ymax =  observed_ind + 1.96 * observed_se), alpha = 0.5)
+
  geom_path(aes(year, pred_ind, color = model)) +
  facet_wrap(~ fleet_name, scales = "free_y")
```

Fits to the age composition data

```
age_fits <- get_age_fits(m1_v_m2)


age_fits %>%
  filter(model == "h2_1.13", stock == "Stock_1", year > 2015) %>%
  pivot_longer(predicted:observed) %>%
  ggplot() +
  geom_density(aes(age, value, fill = name),stat = "identity", alpha = 0.5) +
  facet_grid(year~fleet_name)
```

Recruitment

```
recruits <- get_recruits(m1_v_m2)

recruits %>%
  ggplot() +
  geom_ribbon(aes(year, ymin = lower_recruits, ymax = upper_recruits, fill = stock),alpha = 0.5) +
  geom_line(aes(year, recruits, color = stock)) +
  facet_wrap(~model)
```

Fishing mortality

```
fishing_mortality <- get_fishing_mortality(m1_v_m2)

fishing_mortality %>%
  ggplot(aes(year, mortality, color = age, group = age)) +
  geom_line() +
  facet_grid(model~stock, scales = "free_y")
```

Suggested Future Enhancements

- A function to apply Francis weights in a script (important to account for how one would track changes)
- An R function analogous to runit and readJJM for sampling and evaluating the posterior distribution of the model
- Revisit past ability to simulate data (needs updating)