SPRFMO

Scientific Committee

Port Vila, Vanuatu
28 September - 3 October 2015

REPORT OF THE 3rd SCIENTIFIC COMMITTEE MEETING

1. Welcome & Introductions

The participants were welcomed to the meeting by Mr. James Matariki, assistant to the Minister of Agriculture, Forestry, Fisheries, Livestock, and Biosecurity for Vanuatu. Dr James Ianelli, Chair of the Scientific Committee (SC) opened proceedings, and participants introduced themselves.

2. Meeting administrative matters

2.1 Adoption of Agenda

The Chair adopted agenda is attached as Annex 1.

2.2 Meeting documents

Meeting documentation, location and access was presented. The list of participants is attached as Annex 2. Options to consider late papers were reviewed and given their support for activities during the week (rather than requiring careful scientific review) these papers were accepted by the SC.

2.3 Nomination of rapporteurs

Rapporteurs were assigned and included members from several delegations.

3. Annual Reports from participants

Annual Reports were provided for this meeting by Australia, Chile, China (2), Colombia, European Union, Korea, New Zealand (2), Peru (2), Chinese Taipei, United States of America and Vanuatu (papers SC-03-06 to 10, 13, 14, 17-20, 22, 23, and 28). Participants made brief presentations of their reports and provided answers and explanations in response to questions.

The presentations of the annual reports were followed by discussions among representatives as summarised in Annex 3.

4. Commission Guidance and other intersessional activities

4.1. Commission SC roadmap

The roadmap (COMM03 Annex C) provides guidance to the SC. The items were reviewed and it was noted that nearly all should be accommodated based on intersessional activities and from work to be done during the week.

4.2. Secretariat SC related activities

The Secretariat presented paper SC-03-31 informing the SC about relevant meetings that the Secretariat had attended as an observer over the past year, in particular: the Steering Committee meeting of the Fisheries and Resources Monitoring System (FIRMS); the intercessional meeting of the Coordinating Working Party on Fishery Statistics (CWP), the FAO Workshop on VME process and practices and as a stakeholder in the New Zealand South Pacific VME project. The SC is invited to consider whether it would like to recommend that SPRFMO joins the FIRMS and CWP.

Some SC participants emphasised the importance of the Secretariat being cost-effective. Other participants recognised the contribution that CWP and FIRMS make to maintaining linkages and consistency across RFMOS. While issues of data coverage are usually pursued directly between RFMO secretariats, involvement in CWP and FIRMS provides opportunities for staff to keep abreast of the latest developments in fisheries and associated data collection programs. It was decided to postpone a final recommendation to the next SC meeting.

4.3. Data Workshop report

Niels Hintzen chaired a workshop of a sub-group of member scientists that preceded the SC03 meeting. The purpose of the workshop was to provide more focus on the data used for assessments within SPRFMO. While the discussions at the workshop centred on jack mackerel data issues, the recommendations from the group broadly extend to other stocks. Specific activities included evaluating the sampling and procedures that precede data delivery to the SPRFMO Science Committee for assessment purposes, identifying data quality issues and ways to improve the current process (e.g., through the use of data templates).

Recommendations from the group are that in order to improve and provide needed background for the data as input to the assessment, the group recommends the following to the SC:

1. Continue to develop, refine, and use the **data submission protocols and templates** identified during the data workshop for future data submission to the SC. This includes (with current status):
    a. The age and length data for each fleet (1st draft available)
    b. The survey (DEPM and acoustics) data (can be refined further from fishery data)
    c. The CPUE information (needs to be developed)
    d. Biological data, weight-at-age etc; (needs to be developed or added on)
2. Assign a data coordinator or coordinators to streamline the data collation from the completed templates for assessment purposes. This would ensure that any elements included in the assessment are reviewed and made clear and that the protocols were followed. This would support the data manager of SPRFMO with this task.
3. Continue to use the provisional catch estimates (where necessary, e.g., for current year) for the current and previous year and evaluate the impact this variability on advice to the Commission
4. That an inter-sessional benchmark meeting for jack mackerel and other species as requested be pursued. This should include an evaluation of the quality and sensitivity of data (as is normally done) but also in light of the protocols developed at this workshop. Given meeting schedules, a web-based workshop may be an alternative.

The SC endorsed these recommendations with some minor amendments as follows. Relative to recommendation 2 above, the SC recommended that it be adopted and for jack mackerel, the assigned coordinators from the major fleets (Chile, Offshore, and Peru) be identified. They should have the requisite skills and familiarity with the approaches and software involved in developing datasets to those used by the assessment model (e.g., the R package, git, etc). Relative to item 3 regarding the update assessment and provisional catch estimate, the SC discussed this in context of the jack mackerel modelling below.

4.4. Fishery dependent acoustic Task Group

Francois Gerlotto presented a report on the activities of the Task group during the period October-September 2015 using the terms of references defined during the SC02 meeting in Honolulu. Inside these intersessional activities the members of the task group had the opportunity to present results and also participated in discussions during international events (7th ICES Symposium on fisheries acoustics and ICES WGFAST meeting, Nantes, May 2015; Workshop on acoustics from fishing vessels, Schiphol, June 2015; SNP workshop on acoustic protocols for fishing vessels, Lima, Sept. 2015). A workshop was organized in Lima, Sept. 2015 to synthesize the intersessional work, produce a protocol for calibrating echo sounders aboard fishing vessels and list the scientific activities to be developed in the future. The two main results of the task group activities are: the redrafting of the calibration protocol which was submitted to SPRFMO in the annual task group report; and the demonstration that acoustic data from fishing vessels presented all the characteristics allowing incorporating the data in scientific data bases and analyses. For future activities, the suggestion was to continue to work by e-mail in intersessional periods and to organise a workshop in 2016 on the theme of "Acoustic data collection, processing and management".

Ulises Munaylla made a presentation on the report of the 6th Workshop on Diagnosis of the Status of Jack Mackerel Fishery in Peru. He reported that the year 2015 represents a phase of great environmental disturbances in the Peruvian sea, with a phenomenon El Niño that is expected to grow from strong to extraordinary; such environmental situations are likely to affect the state of Jack Mackerel (JM) populations. With low jack mackerel catches in 2015 and almost no new data to process, the SNP Scientific Committee decided to focus the activities of the 6th workshop towards a general review of the methodology used and to produce sound protocols for: estimation of abundance by acoustic and geostatistical methods; estimation of CPUEs; estimation of the potential habitat; estimation of the modal progression of the demographic dynamics; protocol of calibration of echosounders; design of indicators of the fleet fishing effort through VMS data analysis. It was presented abstracts of protocols.

According to the development and use of this information, acoustic indicators provided by fishing vessels should be defined for potential and effective habitat use of jack mackerel. Future work should consider data and information provided by different participant and the use of this information as complementary indices for habitat considerations, complementary information outside surveys areas and their use in assessments.

During its workshop the task group found terminology difficulties for defining in a common way four types of results:

a. The quantity of fish expressed in acoustic units inside the survey area;
b. The quantity of fish expressed in kilos inside the survey area;
c. The quantity of fish expressed in acoustic units all over the population distribution area (including extrapolated values outside the survey area);
d. The quantity of fish expressed in kilos all over the population distribution area (including extrapolated values outside the survey area).

The SC recommends that SPRFMO adopt the following terminology:

- Survey abundance for case (a)
- Survey biomass for case (b)
- Population abundance for case (c)
- Population biomass for case (d)

5. Jack Mackerel

5.1. Report on Intersessional assessment/research by Participants

The group reviewed the report from the web-based meeting held in July and the papers that have been prepared for this SC specific to jack mackerel issues. Key developments include self sampling work covered in SC03-12, likelihood profile for evaluating data and model likelihood components (SC03-JM04).

5.2. Intersessional Progress with the Stock Structure Research Programme

Niels Hintzen presented an update of the EU work on stock structure hypotheses and laid out key remaining uncertainties. He demonstrated that the hydrodynamics as modelled shows a narrowing of coastal habitat which divides the northern part of Chile (and Peru) from the South-Central region of Chile. Key results from the study suggest that the two stock hypothesis is likely more risk averse and should be considered for assessment and advice in order to ensure sustainable exploitation. For a more detailed summary please refer to Annex 4.

Aquiles Sepulveda presented an analysis that has been done recently in Chile regarding the location and seasonality of jack mackerel spawning, included in a scheme of a biophysical modeling with the aim of studying connectivity between spawning and nursery areas and its effect on the dynamics of recruitment under El Niño 97/98 and La Niña 2011. Results demonstrated that the hydrodynamic model in use performed well in reproducing the inter-annual variability of oceanographic conditions of the study area and represent inter-annual variability. There is connectivity between the main spawning area located in the oceanic area off central-southern Chile with the nursery grounds located at the coastal zone of northern Chile and southern Peru. Also, early stages of jack mackerel can be transported from Peru to the North of Chile, reaching the nursery ground and eventually contributing to recruitment. Finally, spawning in the coastal area of Northern Chile are highly retained within the area of the nursery and could contribute to the recruitment dynamics of jack mackerel. In addition, the results suggested that the transport paths for early stages are closely linked to the pattern of surface circulation and mesoscale processes can affect retention or advection locally. This modelling scheme reasonably simulates the early life history of jack mackerel and connectivity between different spawning areas and the nursery area off Northern Chile and can be considered to understanding relative stock structure hypotheses as well.

Cristian Canales presented an analysis where the risk of overfishing and overexploitation was evaluated assuming that there is a single stock when actually are two, and it was compared with the risk of managing two stock units when there is in fact only one (SC03-JM05). In the first case, the impact of the spatial allocation of the catches on local stocks was analysed, while in the second case, it was analysed the impact that has on a single stock, the total catch as result of the management of two independent stocks. The simulation's results showed that under the current fishing management scenario (single stock), the risk of overfishing or overexploitation in the two possible independent stock units was determined to be low and the population recovery could occur before 10 years. In the other case, if fishery management is based on the assumption of two stock units when in fact there is only one, results showed that the probability of overfishing and overexploitation of the true single stock in the long term is estimated to be high. In this paper overfishing and overexploitation are defined as F exceeding Fmsy and spawning biomass being less than Bmsy. This is due to the fact that the sum of Allowable Biological Catches (ABC) of each independent stock generates catches that are larger than the ABC for a single stock.

The SC acknowledges the above presentations and indicated that all of these results were of interest to the group, each with strengths and weaknesses regarding assumptions.

5.3. Intersessional Progress with Age/Growth Task Team

Age and growth data and analyses is an ongoing issue among SPRFMO member scientists. Chile presented two papers on age and growth of jack mackerel—one dealing with micro-structure and another on protocols. The objective was to define methods and develop a manual on how to read the growth structures. A task team was assigned and a schedule for workshops and coordination with Francisco Cerna at IFOP (Valparaiso, Chile). A workshop is planned for December 14-17, 2015 to look at microstructure comparisons and a second workshop in March 14-18 2016 will be chaired by Beatriz Morales-Nin and will focus on annual ring identification. The goal of these workshops are to develop a consistent protocol for jack mackerel age determination approaches.

During the meeting Cristian Canales noted that some progress has been made on the development of an age-determination error matrix to be used within the assessment model. It was noted that there is a paper and software available that may help in further estimating this "ageing error" matrix (see footnote).[1]

The SC noted that these are encouraging developments and **recommends that the Commission encourage members to support scientists' participation. Furthermore, the SC requests that members actively encourage participation within their respective agencies.**

5.4. Jack Mackerel Stock Assessments

The Commission advised the SC that an "update" assessment was preferred this year so that other agenda items can be covered in more detail (summary result provided in Annex 7). The SC discussed and clarified what an "update" involves: incrementing the accepted model configuration by one calendar year and updating the catch and accepted "standard" information. In contrast, a "benchmark" assessment (as has been done annually from 2012-2014) may be conducted in every 2nd or 3rd year, for example. The data and assessment results for this update are provided in Annex 8.

5.4.1. Updating data for stock assessments

The Secretariat provided an updated historical catch data series to 2014 as well as an initial estimate of 2015 catches for use in the assessment (SC03-JM02). Changes to previous versions for this data series are limited to the 2014 final figures as advised by Members and CNCPs. 2015 initial estimates were created by applying the mean observed difference, by fleet, between the provisional 2010-14 figures and the final 2010-14 figures, to the available 2015 monthly catches.

Adjustments based on participant's knowledge were applied for 2015 estimates and comparisons with previous years' performance were evaluated. The SC noted that in some cases the total difference was as high as 4% but that this was based on only two years of data. Such differences are relatively small but the **SC recommended that this type of evaluation be continued next year and allow for some sensitivity analyses within the planned benchmark assessment.** The complete catch data series used in this update assessment are shown in Annex 8, Table A8.1.

Issues arose during the meeting about the "updated" indices and other data differences. This was clarified as there were some modifications to the Northern stock data (as presented in the Peruvian report (SC03-19). The data presented below were based on the same assumptions and indices between the single and two-stock models.

[1] Thorson, James T, Stewart, Ian J, and Punt, Andre E. 2012. nwfscAgeingError: a user interface in R for the Punt et al. (2008) method for calculating ageing error and imprecision. Available from: http://github.com/nwfsc-assess/nwfscAgeingError/.

5.4.2. Model configurations

Based on the advice of the Commission and as noted above, the SC was tasked with updating the data without major modifications or sensitivity analyses regarding model configurations. In previous years several model alternatives were explored in a "benchmark" fashion. This involved large numbers of sensitivities occurring and a considerable amount of extra work required to run the assessment for each area separately then combine them in a software package. Peruvian scientists streamlined this process by developing the assessment software to be more adaptable and deal with multiple stocks and simultaneous treatment of environmental "regimes" which can be specified to have different levels of productivity. Tests of this new model (which can handle multiple stocks) were presented and incorporated into the main SPRFMO github site (www.github.com/sprfmo/jjm) replacing the 2014 repository at www.github.com/sprfmo/jack_mackerel.

The group also developed a list of activities for the benchmark assessment. **The SC recommended that is to be refined by intersessional work and decided at by June 2016**. The current list is:

1. Model diagnostics, e.g., likelihood profiles, retrospective runs, MCMC posterior evaluations, etc…
2. Catch estimation methods
3. Treatment of acoustic data and other indices
4. Review of the sample sizes and CV for all data
5. Growth alternatives (emphasis on average body mass at age assumed)
6. Natural mortality
7. Model fits to catch at age in numbers instead of biomass
8. Standardization of CPUE time series
9. Age-determination error

5.4.3. Stock indicators

Based on new data and indicators, the status of jack mackerel evaluated in detail at the 2014 benchmark assessment are relatively unchanged. The population trend is estimated to be increasing. On balance, the indications of stock improvement (higher abundance observed in the acoustic survey in the northern part of Chile, relatively abundant age 3 jack mackerel in the fisheries, better catch rates apparent in some fisheries) are somewhat offset by declines observed in the Chilean CPUE.

The SC noted the low SSB estimates in the northern area based on preliminary results presented at the last benchmark evaluation (SC02). Alternative exploratory (results presented in SC03-19) provide additional data refinements needed which will be taken up in the next assessment.

5.5. Other jack mackerel topics

5.5.1 Suitable habitat indicators

Aquiles Sepulveda presented analysis of habitat work that has been done recently in Chile. This expands on the initial work of Vasquez et al. (2013) and is summarized in section 5.2 above.

Under the EU study, results on suitable habitat had been presented. Results indicate that suitable habitat may be limited by dissolved oxygen concentration, temperature, depth and food availability.

5.5.2 Tagging feasibility

No papers nor analyses were presented on the feasibility of tagging for jack mackerel.

6. Deepwater species

6.1. Intersessional assessments of deepwater species

New Zealand presented paper SC-03-DW-02 describing how low-information stock assessment methods for orange roughy could be applied within the SPRFMO Area. Analysis of genetic information, life history parameters, size structure of the catch, timing of spawning, and the distribution of fisheries collectively suggest that the stock assessment areas for orange roughy to the west of New Zealand remain appropriate and need not be changed. Areas to the east of New Zealand, on the Louisville Ridge, were refined by shifting the boundaries between the North, Central, and South components. A fine-scale, spatially disaggregated CPUE analysis has been applied to these revised areas. This approach provides better fits to observed data than previous analyses and is designed to overcome potential problems caused by serial depletion of sub-areas. Sensitivities to spatial sub-area weighting choices and the imputation assumptions necessary for this approach have been tested. CPUE indices from these models are assumed proportional to abundance and have been used to develop simple Bayesian state-space biomass dynamic models for putative stocks on the West Norfolk Ridge and the adjusted North, Central and South Louisville Ridge areas. Sensitivity to the assumed shape parameter has been tested, and retrospective performance appears acceptable. Estimated median stock status for these four stocks ranged from 0.23 of K to 0.44 of K, with relatively wide confidence limits. Attempts to model stocks on the Lord Howe Rise and Northwest Challenger Plateau have not been completely successful and biomass estimates were very poorly constrained.

SC sought clarification of the key determinants of the changes to stock assessment area boundaries, especially for the Louisville Ridge. Timing of spawning was the key driver, but all other available data had been examined for patterns. Fishing is generally focussed on spawning orange roughy on features and on the slope.

SC discussed elements of the spatial CPUE modelling seeking clarification on the process of area validation which was explained as cross checking of area data against skipper experience. This had been successfully conducted for New Zealand oreo fisheries but not yet for this analysis. Some catch had been taken outside the modelled areas and vessels have changed over time, and SC sought clarification of how those issues had been dealt with. The models and stock assessments were limited to the six management areas identified, but they contained the great majority of the catch of orange roughy. Vessels were identified individually in the data, offered as an explanatory variable to all GLM models, and usually found to be significant explanatory variables. Changes in the management settings and the spatial distribution of fisheries were also incorporated, and corrected for, in the models. The spatially disaggregated approach can also correct to some extent for the possible effects of disturbance on orange roughy spawning aggregations. SC discussed the sensitivity of the CPUE results to modelling choices, and New Zealand agreed to conduct a simulation analysis to assess performance.

SC noted the scarce data available for stock assessment. New Zealand confirmed that additional data could be included, and it would be especially important to include the catches (and CPUE) of other nations. Other more sophisticated modelling approaches for orange roughy are commonplace in New Zealand and the example of the 2014 New Zealand assessment of three in-zone stocks was raised (and the report provided), but biomass indices in the SPRFMO Area were almost entirely restricted to CPUE so more sophisticated approaches are not yet possible. A summary of multi-frequency acoustic surveying on the Westpac Bank area was shown to the SC (this being part of the straddling stock assessed by New Zealand as ORH7A). SC agreed this was a useful development but the results could not yet contribute to any other stock in the SPRFMO Area. The Bayesian state-space BDM approach had been simulation tested using data from New Zealand's largest in-zone fishery with good results. Stock-specific priors had not yet been applied but would be explored.

The Deep-Sea Conservation Coalition questioned whether New Zealand plans to analyse otoliths already collected for aging information. New Zealand indicated that if any were held this was a possibility depending on funds.

This work is still incomplete but the SC considered that further development, simulation testing, and review would be worthwhile. New Zealand indicated that such work is routinely reviewed through its domestic working group processes but will also explore opportunities to publish the work in the primary literature and present to the SC4.

The Scientific Committee:

- **recognised** the good progress made by New Zealand on the development of stock assessment methods for demersal species in the SPRFMO Area, particularly orange roughy
- **noted** the preliminary estimates of initial biomass, productivity, and stock status for four of the six orange roughy sub-stocks
- **noted** that the work would continue, including simulation testing of the spatially disaggregated CPUE models, and subject to rigorous review
- **agreed** that this work should contribute to the development of a revised CMM for bottom fisheries in the SPRFMO Area

Graham Patchell of HSFG presented a summary on the use of multi-frequency acoustic systems on the Westpac Bank area, part of the straddling stock assessed by New Zealand as ORH 7A, including preliminary biomass estimates for two areas in 2014. Further work in 2015 on the Puysegur area was presented showing how the multi-frequency echo sounder results can be viewed on the vessel real time, and also HD video footage. It was noted that this net-attached AOS has been successfully used to get TS measurements and length of fish the latter using calibrated stereo cameras.

The WG commended the investigations and noted this method could also be useful for acquiring target strength information for jack mackerel. SC discussed the difficulties in distinguishing signals of black oreo and orange roughy as both share a number of key characteristics including being closely associated with the bottom. This was a problem when the species are found together however this is not always the case. From the video, this work appears to have been done on flat sandy bottom, and SC queried the functionality on other bottom types. HSFG indicated this gear had been operated on a number of bottom types and offered to make all of the video footage available. While acknowledging the significant development, New Zealand noted that information from the studies presented could not currently be used in stock assessments for orange roughy in SPRFMO areas other than Westpac Bank and a comprehensive stock assessment is available for the straddling stock in which the work was conducted.

With respect to the work that has been undertaken on Orange Roughy, the representative from the Deep Sea Conservation Coalition (DSCC) provided a statement on assessments concerning CMM 2.03 and noted that there may be insufficient data.

6.2. Applications to fish outside the footprint or above reference period catch levels

For information purposes, Martin Cryer presented paper SC-03-DW-03: *New Zealand notification of amendments to the status of blocks within its bottom fishing footprint for trawl*. Following the classification of midwater trawling for bentho-pelagic species, including alfonsinos, as bottom fishing by SC-02, New Zealand has developed an interim approach to permitting New Zealand vessels to fish in this manner in the SPRFMO Area while reducing the potential for significant adverse effects on VMEs. In this paper, New Zealand notifies changes to the categories within its bottom trawl footprint; two blocks (#s 1 and 2) previously open to bottom trawl methods (subject to move-on considerations) have been closed, and one block previously within the footprint but closed to bottom trawl methods (block #18) has been opened (subject to move-on considerations). Because substantially more records of VME indicator taxa have come from the blocks to be closed than from the block to be opened (for similar numbers of trawl tows), New Zealand is confident that the potential for significant adverse effects on VMEs will be reduced.

The SC noted that through its BFIAS and under CMM 2.03 New Zealand has implemented suitably precautionary arrangements for bottom fishing. New Zealand's arrangements involve a mixture of open, closed and 'move-on' blocks, which are not a formal requirement under SPRFMO's bottom fishing CMM. Block #18 was originally closed because it had been only lightly fished during the reference period and part of New Zealand's approach was to close those parts of the footprint that had been least-heavily fished. Mid-water trawling for bentho-pelagic species like alfonsino had not been considered in the original design.

Block #18 contains slope areas with substantial concentrations of alfonsino and was, therefore, of more interest to mid-water trawling. The SC noted that block #18 also appeared in Australia's bottom fishing footprint and was open to trawling by Australian vessels (subject to move-on rules with higher thresholds for evidence of VMEs than those applied by New Zealand).

New Zealand indicated that it would continue to manage mid-water trawling for bentho-pelagic species under the bottom fishing CMM and that no further changes to its footprint were anticipated to accommodate the redefinition of mid-water trawling by SC2, keeping in mind that CMM 2.03 is considered an interim measure.

The SC **noted** that New Zealand has amended the status of three blocks within its bottom fishing footprint for trawl to reduce possible impacts on VMEs while providing opportunities for the utilisation of bentho-pelagic species.

New Zealand presented a proposal to conduct exploratory bottom longlining (SC-03-DW-01) for toothfish (*Dissostichus* spp) in the SPRFMO Area close to the boundary of the CCAMLR Area in mid-Pacific. This paper forms the first stage of an application for New Zealand vessels to use bottom longlines outside New Zealand’s bottom longline footprint and to catch toothfish in excess of catch in the reference years. New Zealand has a small catch history of *Dissostichus* spp. in the SPRFMO Area but the proposed exploratory fishing is for a species that has not been fished for more than 10 years; and this constitutes a new or exploratory fishery in terms of the SPRFMO Convention. This proposal is, therefore, drafted to conform to Article 22 of the Convention, paragraphs 16–18 of CMM 2.03 and the Bottom Fishery Impact Assessment Standard (BFIAS). A survey design analogous to those adopted for CCAMLR surveys is proposed (see also CCAMLR document WG-FSA-14/61) and a qualitative, expert-based risk assessment for potential adverse impacts has been conducted. Total fishing effort, effort at a given location and retained catch will be limited during the first exploratory fishing visit and, for consistency with work in the adjacent CCAMLR region, a minimum tagging rate of three fish of each *Dissostichus* species per greenweight tonne will be implemented (see CCAMLR CM 41-01 Annex C). Any results will be used to develop proposals for the consideration of New Zealand’s domestic technical working group and (depending on timing) the SC on the design of subsequent trips and fishing. A New Zealand observer will be carried and video recordings will be made of all lines hauled (data to be provided to the New Zealand government). Contingent on the approval of the SC and the SPRFMO Commission, the first trip will take place between July and September 2016 with a precautionary retention limit of 30 t (greenweight, *Dissostichus eleginoides* and *D. mawsoni* combined).

SC participants complimented the level of detail presented in New Zealand's proposal, noting that it represented a systematic and controlled approach to exploratory fishing in the SPRFMO Area. The SC noted the close proximity of the survey to the CCAMLR Area and the likelihood that it will interact with toothfish stocks managed by CCAMLR. CCAMLR currently assesses the Antarctic toothfish stock in the adjacent area as at 77% of unfished biomass. New Zealand undertook to maintain close linkages with CCAMLR for these activities; circulating copies of the proposal for the information of CCAMLR members prior to the October CCAMLR meeting, data sharing and involving CCAMLR scientists in reviewing results.

The biological data and tagging (perhaps amounting to the release of 90 tagged toothfish per year) alone is unlikely to explain the stock structure of toothfish in this area. However, the proposal can be viewed as an extension of CCAMLR's biological research program that was currently underway in adjacent CCAMLR waters (CCAMLR SSRUs 88.1 and 88.2 North). New Zealand's survey will contribute to CCAMLR's wider program and thereby add to the broader understanding of regional stocks.

The SC acknowledged that the SPRFMO Convention and existing CMMs and standards provided little guidance for the development and approval of exploratory fishing proposals. This is an area that needs further attention. Detailed proposals, like New Zealand's, and subsequent results might inform the development of a future exploratory fishing standard or guidelines.

Based on discussions of the paper, New Zealand explained that the 'medium' rating for the duration and overall impact on seabirds in the proposal's risk table was due to seabirds being long-lived and highly migratory; it did not reflect the likely low frequency of interactions. Regardless, SC stressed that the implementation of appropriate and effective mitigation measures was crucial to preventing seabird impacts. The survey would use the most stringent of CCAMLR and SPRFMO seabird mitigation measures, including line-weighting, strict offal management and bird-scaring lines. It was not possible to deploy two observers per trip, but electronic monitoring will be implemented to augment the observer's work. The survey would be subject to New Zealand's existing VME protocols and move-on rules.

The SC noted the possibility of interactions with marine mammals in this area, particularly through depredation (killer whales and sperm whales robbing hooked fish from longlines). Obvious indications of depredation would be recorded by the observer. There was no arrangement to deduct such damaged or removed toothfish from the survey's annual 30 tonne limit. Nevertheless, experience in nearby CCAMLR Areas suggests that depredation is unlikely to occur.

At the completion of this survey, New Zealand intended to present results to its own domestic working group and to CCAMLR and the SPRFMO SC for review. SC agreed that, while it supported New Zealand's proposal, this endorsement did not indicate any prior commitment to an extension of exploratory fishing beyond this two-year survey. Neither does it indicate any future commitment to extending New Zealand's footprint and establishing a commercial fishery in the area (if a commercial resource is eventually proven).

The SC **assessed** New Zealand's proposal to conduct demersal longline fishing for toothfish outside its footprint and in excess of catches in the reference period (limited to 30 tonnes per year) during 2016 and 2017 and the SC:

1. **confirmed** that the proposal is acceptable under Article 22 (CMM 2.03) and the BFIAS.
2. **recognised** the cautious, exploratory nature of the proposal and the scientific benefits of the proposed data collection, including the understanding of the distribution, movement and stock structure of toothfishes.
3. **emphasised** the importance of implementing stringent seabird mitigation measures throughout the surveys, including integrated weighted lines, bird scaring lines when setting gear and strict offal management.
4. **suggested** that, in addition to being reviewed by New Zealand’s domestic working group and the SPFRMO SC, data and analyses from the surveys should be shared with CCAMLR.

The SC **stressed** that this evaluation does not indicate any commitment to extending this survey beyond 2017 or to extending New Zealand's footprint if a toothfish fishery is eventually proved in this area.

6.3. CMM2.03 (bottom fishing) para 5 a-f advice:

(a) undertake an assessment of the likely impact of specific gear types, particularly trawl, on VMEs, to further inform the definition of bottom fishing

No new work assessing the likely impacts of specific gear types was discussed but **The SC reaffirms its recommendation** that the Commission should modify CMM 2.03 to take into account the relative impact on VMEs of different fishing methods and practices, and to specifically address midwater trawling for bentho-pelagic species.

(b) undertake stock assessments of principal deep-sea fishery resources targeted, and, to the extent possible, taken as bycatch and caught incidentally in these fisheries, including straddling resources

New Zealand has made good progress developing stock assessment models for orange roughy stocks straddling the New Zealand EEZ and within the SPRFMO Area. Work on the latter models is not yet complete but final results should be available for SC4. This area of work will be progressed inter-sessionally by a sub-group that has been established by the SC.

(c) develop and provide advice and recommendations to the Commission on criteria for what constitutes evidence of an encounter with a VME, in particular threshold levels and indicator species

In 2014, SC2 recommended that the Commission implements a spatial management approach for bottom fisheries in order to protect VMEs from significant adverse impacts while enabling viable fisheries to operate. SC2 further recommended that the spatial management approach should use open and closed areas defined by the best available evidence, including evidence of where VMEs occur or are likely to occur. Such spatial management may render unnecessary the need for a move-on rule which they considered to be an interim approach. New Zealand has made good progress developing the tools necessary to design such a spatial management system but more work on refining and applying these is required before CMM 2.03 can be revised.

The SC therefore recommends that the Commission develops and implements a scientifically robust spatial management approach for bottom fisheries in order to appropriately protect VMEs while enabling viable fisheries to operate.

The SC also recommends that, to the extent possible, a spatial management approach should seek to define open and closed areas and minimise the need for move-on rules that are impractical to administer.

(d) develop and provide advice and recommendations to the Commission on the most appropriate response to a VME encounter, including inter alia closing particular areas to a particular gear type or types

Responses to evidence of a VME are defined by two different move-on rules (implemented by Australia and New Zealand). If a spatial management approach is implemented, as recommended in (c), and assuming good knowledge of the ecosystem, then encounters with VMEs will be minimised, VMEs will be appropriately protected, and no additional response would be necessary. This area of work will be progressed intersessionally by a sub-group that has been established by the SC.

(e) review and streamline the SPRFMO Bottom Fishery Impact Assessment Standard (SPRFMO BFIAS) agreed by the Scientific Working Group in 2011 to take account of the latest scientific information available

Given other priorities in SPRFMO research, there were no resources to address this issue during the last year. This area of work may be progressed intersessionally by a sub-group that has been established by the SC.

(f) provide advice on the appropriate spatial resolution and time period for footprint mapping

Paper SC-01-20 showed that alternative periods and mapping resolutions have a substantial effect on effort maps and fished area estimates for demersal trawl fisheries in the western SPRFMO Convention Area. These effects vary as a result of historical trends in different fishing areas. Estimates of 'fished area' generated using any mapping resolution other than actual trawl tracks substantially exaggerate the areas within footprints that have actually been impacted: 86% to 91% of a footprint mapped using 6-minute blocks is actually unfished (i.e., 9-14% of the footprint area fished) and 95% to 96% of a footprint mapped using 20-minute blocks is unfished (i.e., 4-5% of the footprint area fished).

The SC reaffirms its recommendation to the Commission that:

- the smallest practical spatial scale should be used for defining footprints and for spatial management purposes; at present, the most practical spatial scale is 6-minute blocks;
- for defining the extent of fishery impacts on VMEs, the longest time period of historic effort information that is available for each fishery should be used provided that the quality (accuracy and completeness) of the positional data is adequate.

(g) develop maps of VME distribution in the Convention Area

New Zealand has made good progress on the very difficult task of predicting the distribution of VMEs within the SPRFMO Area. This had included a research voyage to the Louisville Ridge to test the predictions of previous models. Partly because the global depth layers used in the models were found to be very inaccurate in some of the locations surveyed, the SPRFMO-scale predictive models were found also to be inaccurate. Work has since focussed on finer-scale models of the New Zealand region and additional information has been included. The new models have been tested by cross-validation using independent data and different modelling approaches give broadly similar results.

The SC noted that New Zealand, Australia, and Chile had agreed to work together intersessionally in an ad hoc working party on the developments needed to recommend revisions to CMM 2.03. The SC recommends that this ad-hoc working group develop a plan for work intersessionally and present this to the 2016 SC.

7. Squid Assessments

The SC evaluated the request from the Commission relative to squid:

> *"The Road map requests the SC to evaluate examples of Squid assessments and determine if they are applicable for the SPRFMO Area."*

To this end, during the online Webinar meeting (SC-03-05) it was reported that:

- Korea and Chinese Taipei presently fish for Jumbo flying squid in the Convention area outside of Peru and have expressed an interest in developing assessment. Korea will start to evaluate stocks as well.
- The Korean government is examining haul-by-haul data using observer data for more samples.
- Peru is preparing a document with detailed information on Jumbo flying squid biology, distribution, assessment, etc.
- Ecuador will send some information on squid captures.
- China fishing for Jumbo flying squid outside of Peru and Chile, and recent two years, the fishing area extend to north of the equatorial. China has done biological research on squid and will present some research about squid such as age, reproduce and stock assessment.

The SC received the following reports relevant to squid:

- SC-03-09: Annual report of China. Part II: the Squid Jigging Fishery.
- SC-03-14: Chilean annual report.
- SC-03-07: Chinese Taipei's annual report
- SC-03-26: Progress with in-season modelling of squid within New Zealand's EEZ and Management strategy evaluation (MSE)
- SC-03-27: Main Biological and fishery aspects of the Jumbo flying squid in the Peruvian Humboldt Current System.
- SC-03-32: The secretariat collated and presented the squid data on catches on official submissions.
- Ecuador provided an executive report on the squid fishery within their national waters.

Summaries of the squid papers are given in Annex 5.

Data

Some annual catches have been voluntarily reported within EEZ waters and international waters by countries but remains incomplete. Participants were encouraged to update the official data in timely fashion to meet the SPRFMO data standards.

Main countries fishing squid in the south eastern Pacific are Perú, Chile, China, Korea, Chinese Taipei and Ecuador. Most of the catches of squid of Perú, Chile and Ecuador are taken by artisanal or small-scale boats, while the others countries fish with industrial jigging vessels. Perú, Chile and Ecuador fish squid mostly within their own jurisdictional waters while the others countries fish in the Convention area, in international waters.

Stock structure and biology

Squid have complex life histories, recruitment processes and population structure and the research presented noted a recent shift in size structure. Such complexity poses a challenge for stock assessment and effective management.

Stock assessments

The countries have applied and continue to develop different stock assessment methods and some have already adopted some fisheries management measures in their EEZ.

Perú presented a paper on the biology and fishery aspects of Jumbo flying squid (*Dosidicus gigas*) in the Peruvian Humboldt Current System, explaining the characteristics of the squid fleet, landings, fishing areas, size structure, reproductive and trophic aspects, main mature and spawning areas, vertical distribution, fishery management and stock assessment.

Since 1999 the assessments of Jumbo flying squid in Peruvian waters has been based predominantly on the biomass estimates obtained through hydro-acoustic surveys, complemented by the monitoring of size frequency distributions and CPUE from the industrial and the artisanal fisheries to obtain an as early possible estimate of recruitment. More recently, as longer CPUE data-series have become available, the Jumbo flying squid assessments have also included the application of a biomass dynamic model. The estimated fishing mortality (F) has been maintained below the estimated F_{MSY} indicating that the stock in Peruvian and adjacent international waters is likely healthy. Since 2012 Peruvian fishery management authorities restricted fishing for jumbo squid and presently only artisanal and small scale fisheries are allowed.

Chile presented two methods (from 2014 work): one based on catch only, and the other using a Schaefer production model tuned to an abundance index based on squid as bycatch of hake scientific surveys and commercial CPUE. The update of these two methods in 2015, suggest a MSY around 200-250 thousand tons for Chilean Coastal waters. In 2015 Chile also applied a depletion model by week based on catch per trip of artisanal vessels. This method was sensitive to the start and ending week and is thus preliminary. Since 2012 Chilean fishery management authority limited effort to the squid fishery and set a quota.

China has applied Schaefer production model with annual catch data derived from FAO to assess the status of Jumbo flying squid in the South East Pacific (2002-2012). However, the annual catch data was incomplete without Peru's annual catch from 2009 to 2012 and this likely resulted in underestimates of biomass. Catch rate of Chinese squid jigging fishery was standardized and was used as the abundance index.

Korea submitted the haul by haul catch data of squid jigging fishery to secretariat of SPRFMO since 2012, and will continue to submit these data. Korean observers will collect the biological data of jumbo flying squid and bycatch information this year and report at the next SC meeting. Korea will do the CPUE analysis and find the stock assessment method for Jumbo flying squid in the future.

Chinese Taipei has applied generalized additive models (GAMs) to study the variation of squid abundance and effects of environmental variables between 2002 and 2013. The results suggested that variation of squid abundance could be explained by the temporal and spatial variables to a degree.

New Zealand is developing and testing an in-season generalized depletion model on its arrow squid *Nototodarus sloanii* fishery. The NZ model allows for pulses in recruitment and non-proportionality between abundance and catch via the inclusion of hyper-parameters. Model outputs and the in-season approach can serve to inform a management strategy evaluation (MSE) with depletion thresholds/triggers and associated decision rules.

Based on these summaries, **the SC agrees**:

- **To recognize and acknowledge** the significance of the fishery for *D. gigas* within the SPRFMO Area, and to engage in the development of science and management tools that will contribute to ensure the long-term sustainability of the Jumbo flying squid stock and fisheries.
- **That monitoring and reporting procedures** on Jumbo flying squid research and fishing activities should be implemented in the Convention area.
- **That countries should be requested to** complete and update their official submissions.
- **To promote** the collation of and standardisation of datasets in the area of the SPRFMO for the database.
- **To consider** the Management Strategy Evaluation (MSE) framework for the integration of biological information and stock assessment methods for the species in the Convention Area.
- **To recognize** that more time will be needed within the SC meeting to address squid assessments and further MSE development and trade-offs will be required.

SC further noted that, with depletion approaches, it was particularly important to have detailed understanding of the temporal and geographical distribution of spawning.

8. Ecosystem Approach to Fisheries Management

8.1. Evaluate the impact of fishing activities (including, inter alia, gear type) on Ecologically or Biologically Significant Marine Areas (EBSAs) and on Vulnerable Marine Ecosystems (VMEs)

Martin Cryer presented paper SC-03-DW-04 Progress on predicting the distribution of VMEs and options for designing spatial management areas for bottom fisheries within the SPRFMO Convention Area. Information on the distribution of VMEs in the SPRFMO Area is very sparse, and limits our ability to design spatial management measures to avoid significant adverse effects in bottom fisheries. This necessitates the use of models to predict the distribution of key VME indicator taxa, especially habitat-forming species, from information that is more readily available, including depth and physico-chemical variables. Many difficulties have been encountered developing such models, and some of these were highlighted by a recent research voyage to the Louisville Ridge, funded by New Zealand. Modelled depths were found to be very inaccurate in places, and this is important because key physico-chemical variables used to predict VME indicator taxa depend strongly on actual depth. Combined with the very scarce biological data outside EEZs, the poor information on substrate in many areas, and the presence-only models being used, these problems led to unreliable habitat suitability predictions by SPRFMO-scale models. New models are being developed at a smaller, New Zealand region-scale, and "absences" from historical databases are being included as well as "presences". The performance of these new models has been assessed using cross-validation against spatially independent data. Predicted distributions of key taxa from habitat suitability models can be combined with the distribution of bottom fishing to design spatial management areas that provide for fishing while avoiding significant adverse impacts on VMEs. Decision-support software is available and New Zealand has focussed primarily on the use of Zonation software to demonstrate the utility of the method and explore sensitivity to modelling choices.

SC noted that cost benefit trade-offs have not always been considered in the development of VME protection measures and commended New Zealand for taking this approach because trade-offs are important to consider in the design of appropriate spatial management. SC requested the rationale for using the 2002-2006 reference years for the footprint. New Zealand indicated that, for several reasons, it was probably better to use the full footprint as a "cost layer", but the precise details of what the industry saw as their "costs" given particular spatial management configurations should be discussed with them. SC also noted that a large number of "absences" had been generated for the New Zealand regional scale models and would like to see maps of these; they also requested that a representative sample of images from the voyage be made available for the SC to study. A copy of the voyage report was made available and will be posted on the SPRFMO website.

SC noted the wide scope of the recommendations in the paper and wanted to understand whether it was New Zealand's intention to pursue all avenues. New Zealand indicated that the cost of modelling was very small relative to research voyages, especially now the groundwork has been done, and it was considered important to draw the most from the available information. SC members enquired as to the specific VME taxa used in these assessments (asking also to have the VME manuals made available) and whether it was intended that the results should inform the spatial management of other nations. New Zealand clarified the 11 taxa used, including four species of reef-forming stony corals, but suggested that application beyond New Zealand vessels was for individual members to consider. New Zealand did consider, however, that there would be advantages of having a single consistent spatial management approach for bottom fisheries. HSFG voiced its concerns with the New Zealand VME encounter protocols and noted that they were more stringent than those used by Australia. New Zealand acknowledged the difference but reiterated that its protocols had been developed using information from deepwater fisheries and rigorously reviewed, including by SC, and the move-on rules were only rarely triggered.

The SC:

- **recognised** the good progress New Zealand had made on the very difficult task of predicting the distribution of VMEs and VME indicator taxa in key parts of the SPRFMO Area for bottom fisheries
- **commended** New Zealand for developing methods of designing spatial management measures for bottom fisheries that can avoid significant adverse effects on VMEs while

minimizing costs to the fishery

- **agreed** that this work should contribute to the development of a revised CMM for bottom fisheries in the SPRFMO Area and, in particular:
    - **agreed** that a range of data sources and modelling approaches should be explored to predict the distribution of VME indicator taxa in the SPRFMO Area and,
    - **agreed** that a range of methods and assumptions should be explored when designing spatial management measures to avoid significant adverse impacts of fishing on VMEs while minimizing costs to the fishery

A discussion paper was tabled by HSFG dealing with the competing narratives related to VMEs (SC03-INF02 summarized in Annex 6).

The representative from the Deep Sea Conservation Coalition observed that the New Zealand Report to the third Scientific Committee (report SC03-22 at page 19) reported that the move-on rule had not been triggered since 2012 and had been triggered only 6 times since 2008.

Martin Cryer thanked HSFG (see Annex 6 for a summary of SC03-INF02) for a thought-provoking paper and presentation and welcomed HSFG's commitment to balance in the design of Conservation and Management Measures. He responded to some of the claims in the paper and noted in particular that information from the NORFANZ voyage had been used extensively, that New Zealand's move-on triggers for evidence of a VME had been developed and reviewed through a formal science process, and that, although it was important to use as much information as possible when making predictions, it was rarely possible to use all information in any particular model. Expert interpretation was always likely to be needed (the sophisticated jack mackerel model is a good example). The New Zealand government and industry had worked closely together on a number of issues in the past 6 months, with good outcomes, and Dr Cryer was keen to see that continue. A working party to start development of a revised CMM for bottom fisheries had been established by SC2 but, following the retirement or resignation of two key members, progress had not been as fast as hoped. However, it appears that Australia and Chile remain committed to the work and Dr Cryer warmly welcomed HSFG's offer of data and participation. He noted there was much work to do for a new CMM for bottom fisheries, especially if consistent measures across the SPRFMO Area were contemplated. The work that had been done was advancing rapidly and would contribute to that development, but it would not be possible to develop new measures in time for the Commission meeting in January 2016 as HSFG proposed.

The Secretariat introduced information received from the Secretariat of the Convention on Biological Diversity (CBD) regarding five areas within the Convention Area that meet the CBD criteria for EBSAs. In line with the roadmap, the SC might consider these areas and evaluate appropriate spatial management options. Chile noted that they have taken action and established MPAs that include part of some identified EBSAs.

FAO provided an update on the ABNJ Deep Seas Project to which the SPRFMO is a partner. FAO described the new VME database and the need for data inputs from SPRFMO. The SC was informed about the development of a range of tools designed to assist future data collection including SMARTFORMS an electronic data collection form for onboard use. FAO is also continuing to produce identification guides for vulnerable deep-sea species, a manual on the collection of data on deepseas species.

FAO confirmed that the VME portal and database was focussed on facilitating access to metadata on VMEs. The SC participants reiterated SPRFMO's long-term need to compile and manage detailed information on VMEs that would eventually support the development of spatial management arrangements. This might include historical and recent observer data, surveys and research datasets. The structure of such a database is yet to be decided, as it might take the form of metadata pointing to relevant datasets (including their data access conditions) through to more detailed data on VME encounters.

FAO encouraged SPFRMO involvement in international FAO workshops on deepsea species descriptions of commercial fish stocks and their fisheries. The 2012 review of alfonsino, for example, included information on species biology, life history, distribution, stock status and management. A similar workshop on orange roughy is scheduled for 2016. FAO would welcome any suggestions from the SC on other deep-sea fish species that might be subject to these reviews. The SC noted FAO's planned expert workshop on orange roughy in 2016. The SC noted that there might be potential for the summaries that are being developed by the SPFRMO secretariat to be aligned with the FAO summaries. At this stage it would be difficult for SPRFMO to develop summaries of other species of interest, such as deepwater sharks.

FAO was also seeking feedback on two options for the SmartForm app: for electronic VME reporting forms or for marine biodiversity (e.g. marine mammal and seabird sightings). Additional uses of the app could be considered if there is further interest to move forward and test the app. There was broad interest among SC participants to involve their national observers in trialling the app. The SC noted that SPRFMO was yet to establish a regional observer program. There can be no commitment to implementing the app at a regional level until a regional program is established.

FAO's work in developing identification guides and data collection manuals (e.g. deepwater corals) is of further interest to SPRFMO and members. Participants emphasised that access to such material needed to be provided down to the level of crewmembers as well as observers and other fishery officers.

The SC reaffirms earlier recommendations that the Commission:

- **remains aware of EBSAs within the Convention Area and of the factors that led to their definition; and**
- **addresses any conservation needs for EBSAs through the normal process of developing Conservation and Management Measures (CMMs) for the fisheries.**

8.2. Other species of concern

No papers nor analyses were presented on defining other species of concern.

8.3. Bycatch information

Kris Ramm (DOC-NZ) introduced document SC-03-25 on data collection protocols for seabird interactions around fishing vessels. The paper provides a comparative assessment of bird observation data collected in the SPRFMO area compared to longer term data sets collected in New Zealand. The paper used this analysis to recommend protocols of data collection for seabird attendance at fishing vessels and standardised protocols for observations of seabird warp strikes or impacts with monitoring cables in trawl fisheries should seabird attendance observations indicate sufficient risk.

The EU and Korea supported this work on defining data protocols and logbooks and enquired how the data would be analysed and used. New Zealand clarified that these protocols were also intended to be presented to ACAP as best practice guidelines. It was clarified that this was intended to be an observer rather than crew task.

Some discussion was had around the potential for camera monitoring to assist this work and how misidentification of species could be dealt with. New Zealand clarified that currently human observers were still the most effective option and the use of generic species codes would ensure that where precise species identifications were not possible appropriate codes were still available.

The SC sought clarity on whether appropriate variables were being collected to ensure that warp-strike observations would be able to inform future mitigation and management. New Zealand confirmed that the range of environmental and operational variables being collected could better inform future mitigation options. Additional materials were presented on a New Zealand initiative to conduct a southern hemisphere seabird risk assessment and support of the SC was sought.

Chile highlighted the need to maintain the appropriate levels of confidentiality for any data being submitted. New Zealand responded that the data scoping stage is only beginning now. Ideally the target for spatial scale and resolution would be similar to the spatial and temporal resolution of data release for RFMOs however this could be adjusted and standardize based on what's available.

SC supported the work being undertaken by New Zealand on seabird risk assessments. It noted that, although it covered the entire southern hemisphere, the risk assessments were limited to seabirds that nested in New Zealand. There is likely to be a future need to extend such assessments to other seabird species that occur in the SPRFMO Area.

The SC **recommends that the Commission:**

- encourage Members and CNCPs to collect data on bird attendance at fishing vessels using the protocols provided in SC-03-25 Appendix 1;
- where potential risk of seabird warp strikes is identified, encourage Members and CNCPs to collect data on warp / monitoring cable strikes using the protocols provided in SC-03-25 Appendix 2;
- request Members and CNCPs to report results from seabird counts and warp / monitoring cable strike observations to the SC.

8.4. Minimizing bycatch

Kris Ramm (DOC - New Zealand) introduced document SC-03-24 on Standardised recording of hook parameters in demersal and pelagic longline fisheries. This paper summarised hook parameter reporting in both New Zealand and international longline fisheries and provided recommendations on those parameters most critical to understanding fisheries interactions with marine mammals, seabirds, reptiles and other species of concern. Specifically, it recommends that observers collect six additional data fields describing hook parameters when working in bottom longline fisheries in the SPRFMO Area.

Some discussion was had by the group as to the wide range of hook types available. It was clarified that the protocols are intended to be easily measurable by observers using standard equipment. Australia noted that a third broad category was the Japanese tuna hook and it was agreed to add this category to the recommendations.

Korea and Chile both noted that in their experience circle hooks were effective in reducing bycatch of turtles however some fishers have found they also reduce target catch. New Zealand confirmed that this proposal was not to alter what hooks fishers used, rather to better document the fishing gear.

Scientific Committee **recommend to the Commission the addition** of the following data fields to Annex 7 D of CMM3.02:

- Brand
- Model name / number
- Hook type (Circle / J / Japanese tuna);
- Total Length (in millimetres measured in a straight line from the tip of the eye to the base of the bend);
- Gape (in millimetres measured from the tip of the point to the inside edge of the shank);
- Bite/Throat (in millimetres from the tip of the point to the inside base of the bend)

8.5. Data collection and reporting

In 2015, a self-sampling protocol has been initiated for the two Pelagic Freezer-Trawler Association (PFA) vessels fishing in the SPRFMO area (KW174 Annelies Ilena and KL855 Margiris; Paper SC-03-12). The self-sampling protocol aims to collect the information required by SPRFMO for all trips carried out in the area. The focus of the self-sampling is on data for jack mackerel.

The SC discussed this work and considered it an extremely valuable complement to the efforts of observer, EM, and other data collection systems. It was clear that the potential for leveraging work already done on some vessels would benefit scientific data collection programs and this type of activity was strongly encouraged by the SC. It was noted that the new system, since coupled with conventional observer data, was used to compile catch-at-length estimates from the EU fleet for 2015 catch-at-age estimates.

From paper SC-03-21 Chile presented a proposal to amend the CMM 3.02 (Data Standards) to include biological data collected by observers during landings. This proposal has already been considered by the SC in 2014 with the result that it was recommended for adoption by the Commission. However, at the last Annual Meeting, the proposal could not be addressed and the SC is now requested to renew its recommendation. In addition, the SC is requested to consider the endorsement of the proposed standards as informal SC guidelines to support the management and utilisation of these types of data. The SC recognizes that the reporting of this data is voluntary, that this dataset will be separate from the at-sea observer dataset, and that these added standards will ensure this data is submitted in a format consistent with data collected from observers at-sea. Participants highlighted the importance of ensuring that such samples are statistically representative and that there is sufficient information to link the sample back to the actual fishing operation and haul. **The SC recommends that Annex 7 (of CMM3.02) be amended to include the proposed data components outlined in the Chilean paper (SC03-21) and that reporting of these data should be facilitated (currently it is voluntary).**

9. Observer programme

Three presentations on observer program schemes were made in the plenary session. Chile introduced its proposal for the establishment of an Observer Programme Working Group (SC-03-29), the SPRFMO Secretariat provide an overview of the Observer Programmes of RFMOs (SC-03-34), and the Pelagic Freezer-trawler Association shared its experience on self-sampling programmes in the SPRFMO Area (SC-03-12).

Chile introduced a proposal for the establishment of an Observer Programme Working Group (OPWG) to be further considered at the upcoming Commission Meeting. The aim of the proposal was to convene a working group in charge of developing – intersessionally - a proposal in accordance with the Article 28 of the Convention and by the provisions of CMM 3.02. The Scientific Committee agreed on the importance of the issue highlighted by Chile, and the discussions were mainly around the mechanism for working on this issue along with the Compliance and Technical Committee (CTC).

During the Secretariat´s presentation it was noted that the nature of RFMO´s observer programs may vary depending on the purpose of the programmes, in particular on whether they are intended primarily for gathering biological information, or primarily for surveillance and compliance purposes although both purposes are often part of each program. It was also noted that the percentage of observer coverage often depends on the purpose of the programme, ranging from 10% (only for scientific observation) to 100% (for monitoring control and surveillance purposes).

Paper SC-03-30 updated the SPRFMO SC on the electronic monitoring program implemented for Australian demersal automatic longline vessels fishing on the high seas areas of the South

Pacific Ocean. Electronic monitoring ('e-monitoring') involves a system of sensors and video cameras mounted on fishing vessels to record detailed information on fishing activities. Sensors transmit information in real time to management agencies on the vessel's location, activities and the status of equipment, e.g. winch activity, status of cameras. The cameras, which are activated by the sensors, are positioned to obtain footage of various aspects of the fishing operation, e.g. line setting, hauling, fish processing. The Australian Fisheries Management Authority collects camera hard disks at the completion of domestic fishing trips and analyses a sample of 10% or more of the footage.

E-monitoring is being increasingly used by other countries and considered by other RFMOs, partly to replace human observers due to comparative advantages in cost, data quality and coverage. E-monitoring is also believed to improve logbook quality, especially for interactions with non-target species. At the same time, e-monitoring has several limitations, including the collection of biological data and samples. With the increasing use of such systems in Australia and elsewhere, SPFRMO will need to consider how e-monitoring can be accommodated to meet data requirements.

SC-03-30 provides technical details of e-monitoring systems currently used in Australia. The Australian Fisheries Management Authority has successfully implemented e-monitoring systems in its domestic pelagic longline, demersal longline and gillnet fisheries. E-monitoring systems have also been fitted on the two Australian demersal longliners that currently operate in the SPRFMO Area. At the same time, human observers have deployed on those vessels to meet SPFRMO's observer coverage requirements.

Australia plans to present a paper at the next SC meeting to initiate the process of reviewing e-monitoring and consideration of how it may meet SPRFMO's data standard (including the specific data requirements set out under Annex 7 of CMM3.02) and how it may relate to observer coverage requirements. Australia's paper will compare data from e-monitoring and human observers, both from the Australian longliners currently fishing in the SPRFMO Area and also comparisons from other relevant fisheries. The intention is that this will lead to the consideration of modifications to the data standard to accommodate new developments, such as e-monitoring.

The Pelagic Freezer-trawler Association showed the results of their 2015 self-sampling programme. Some results of the samples gathered under self-sampling scheme were compared with information collected by observers onboard in the same fishing trips. Slight differences were noted in length distribution between self-sampling method and observer. It was noted that this kind of programme is cost-effective, but the accuracy of the data obtained and the traceability of the self-sampling scheme was questioned.

The **SC agreed to** (a) establish an ad-hoc working group of the SC develop recommendations on the SPRFMO observer programme regarding scientific aspects of the programme, and (b) **recommends that the Commission establish a joint SC and CTC working group to discuss both Scientific and Monitoring, Compliance and Surveillance (MCS) terms of reference for the programme.** The group should start with members from Chile, Australia, New Zealand and the USA.

10. Advice to the Commission

10.1. Jack Mackerel

As presented in section 5 above, new data and indicators on the status of jack mackerel suggest that conditions evaluated in detail from the last benchmark assessment (completed in 2014) are relatively unchanged. The population trend is estimated to be increasing. On balance, the indications of stock improvement (higher abundance observed in the acoustic survey in the northern part of Chile, relatively abundant age 3 jack mackerel in the fisheries, better catch rates apparent in some fisheries) are somewhat offset by declines observed in the Chilean CPUE.

A downward revision in SSB has been observed from the 2014 to the 2015 assessment, as a result of revisions in catch-at-age and weight-at-age data, as well as slightly lower historical recruitment estimates.

Environmental conditions (e.g., strong El Nino that developed in 2015) likely affects jack mackerel distribution and thus age-specific vulnerability to surveys and fisheries. This may have affected the improved CPUE in some of the fisheries.

Historical fishing mortality rates and patterns relative to the provisional biomass target (5.5 million t of spawning biomass) is shown in Figure 1 (so-called Kobe plot).

The SC agreed that the recommendation from 2014 for catches in 2016 is still appropriately precautionary. Namely, that the Commission should set 2016 catches limits for the entire jack mackerel range in the southeast Pacific at or below 460 kt, based on a status quo fishing mortality of 2014. Fishing mortality in the next 10 years at or below current (2015) levels are continuing to have a reasonably good probability of increased spawning biomass from the current level of 2.71 million t with projected increase to 3.2 million t in 2016.

The advice presented above is based on evaluation of indicators including the single and two-stock hypotheses. Within the area of the SE Pacific, the two-stock model shows generally similar trends in the biomass compared to those using single stock model (when summed).

Currently, there is some uncertainty in the “update” assessment for the northern stock under the two stock hypothesis. Indications demonstrated in SC03-19 suggest the importance of considering regime-shift for this region. The SC expects more reliable information on stock status for the northern stock will be available given assessment and data developments planned for 2016.

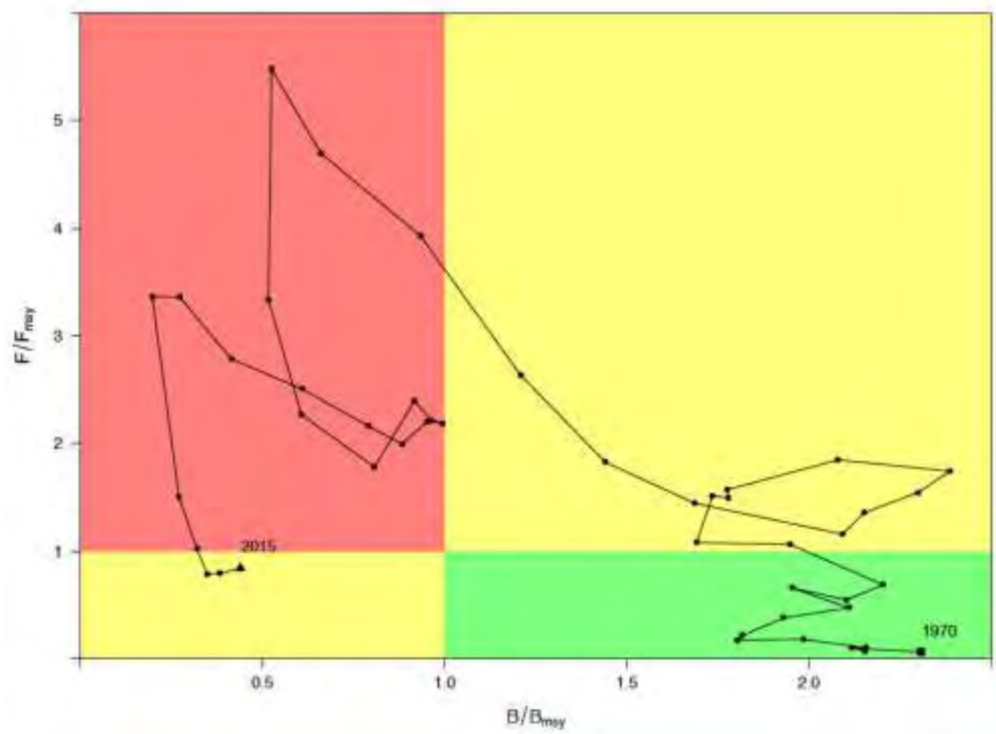

Figure 1. Phase plane (or “Kobe”) plot of the estimated trajectory for jack mackerel under updated from Model 0.4 based on the single stock hypothesis with F_{MSY} and B_{MSY} estimated for the time series 1970-2015.

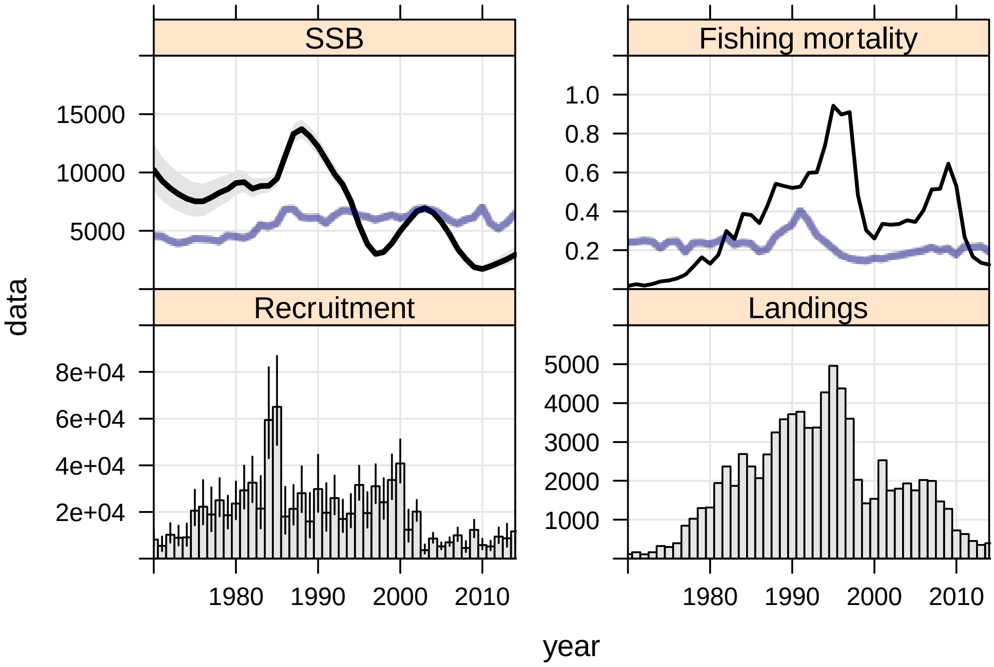

Figure 2. Summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left) total fishing mortality (top right) and total catch (kt; bottom right). Blue lines in top figures represent dynamic estimates of F_{MSY} and B_{MSY} for each year (for model 0.4). Confidence bands reflect $\pm$1 standard deviation of the estimate.

10.2. Deepwater

Recent average landings of orange roughy from SPRFMO Areas have been substantially below those in the reference years 2002-2006 as the average number of participating vessel has declined from 24 to 7. New Zealand has taken an average of 991 t over the past 4 years compared with 1,852 t in the reference years (54%) and Australian has taken an average 52 t over the past 4 years compared with 257 t in the reference years (20%). These landings are similar to existing estimates of sustainable yield for orange roughy combined across areas.

As presented in section 6 above, the SC notes that progress has been made on the development of stock assessment models for orange roughy stocks in the SPRFMO Area. While the work is incomplete, the SC identified additional analyses that will increase the robustness for providing advice in the future. In particular, it will be important to include the catches of all nations from the areas.

Encouraging progress has also been made in the difficult task of predicting and mapping the distribution of VMEs and VME indicator taxa in the SPRFMO Area. New Zealand will continue to conduct scientific studies on VMEs and spatial management and every effort will be made to use all available information. **The SC supports moving towards spatial management**, recognizing that such progress will likely take time. Both Australia and New Zealand would work closely with their industries and both welcome industry participation in providing information for that process.

10.3. Squid

Relative to the squid resources, **the SC recommends that the Commission:**

- Implement monitoring and reporting procedures on Jumbo flying squid research and

fishing activities in the Convention area.
- Engage in the development of science and management tools that will contribute to ensure the long-term sustainability of the Jumbo flying squid stock and fisheries.

11. SC Research Programme

In 2013 the SC published its Research Programme, which highlights SPRFMO's medium and long term research priorities. Based on discussions at SC**, short term** priorities include:

Jack mackerel

1. The SC reviewed the current research programme and determined that no updates are required at this time. The SC noted that progress is being made on a number of Research Programme topics, including jack mackerel stock structure; stock assessment (including acoustic surveys); biology and ecology (including age and growth); and conservation, rebuilding plan and management procedures (MSEs). Such research efforts should continue.
2. The SC recommended that the Commission support the continued development and activities of the fishery-dependent acoustic task group. Specifically, the group should organise a workshop in 2016 on the theme of "Acoustic data collection, processing and management." It should cover:
    a. data collection method,
    b. the data base to compile the data and
    c. the Target Strength (TS) equation(s) to be applied to the CJM data.

    To develop a TS value for CJM, the task group will collate, compare and evaluate the existing information on CJM TS, compare the effect of TS on biomass estimates, and if possible, trial the collection of in situ reference data (i.e. using the AOS methodology developed by initially by Australia and subsequently modified NZ scientists) for estimating TS of CJM. The SC is encouraged that there will be fishing sectors of different countries involved in the work of this task-group.

Squid

3. To promote research on the effects that the depletion by fishing of potential predators of the different life-history stages of Jumbo flying squid may have in favouring the growth and expansion of Jumbo flying squid.
4. To promote research on the population structure and the presence and distribution of strains, groups or population subunits of Jumbo flying squid and their migration routes and intermix patterns throughout the Southeast Pacific.
5. To promote research on the reproductive process and the effect of environmental factors in determining the timing and the location and extension of spawning areas.
6. To promote or undertake research to obtain early estimations of recruitment and timely assessment of escapement.

Deepwater

7. Finalise the preliminary assessments of orange roughy stocks, including the addition of data from other fleets and simulation testing of spatial CPUE analyses and biomass dynamics models.
8. Continue the collation of relevant data and development of models to predict VME indicator taxa.
9. Continue the testing of methods to design spatial management areas.
10. Convene the ad hoc working party (currently involving New Zealand, Australian and Chile) to initiate the development of a revised CMM for bottom fisheries.

Ecosystem approach to fisheries management

11. Support New Zealand's risk assessments of southern hemisphere seabird populations through the collection and provision of seabird observations using standard protocols.

Observer programme (new section)

12. Compare observer data and data collected through e-monitoring to inform the consideration of how e-monitoring might meet SPRFMO's data requirements.
13. Establish an ad-hoc Observer Programme Working Group which will include advice on scientific issues related to the development of a draft SPRFMO Observer Programme to meet the requirements of Article 28 and CMM 3.02.

12. Next Meeting

The SC was informed that the EU offered to host SC04 in the Netherlands (most likely the Hague). Dates proposed are 7th-8th of October for jack mackerel benchmark preparation, and the week of October 10th 2016 for the SC. **The SC accepted this generous offer**.

13. Other Matters

The Secretariat noted that some funds are available for the SC purposes. The SC discussed that having a reserve of funds for high-priority issues would be advantageous so that activities highlighted in the research programme can be effectively pursued. One example high-priority activity would be support for the age-determination workshops that are planned within the next year.

The Secretariat paid tribute to Dr. Robin Allen who passed away in March of 2015. The SC observed a moment of silence in remembrance of the former SPRFMO Executive Secretary. The SC extends their condolences to Robin’s family. His energy, humour, and integrity will be greatly missed.

14. Adoption of Report

The SC unanimously adopted the report.

15. Meeting Closure

The meeting was closed at 2222 hours on 2nd October 2015.

Annex 1. Adopted Agenda

1. Welcome and Introduction
2. Administrative Arrangements
   - 2.1. Adoption of Agenda
   - 2.2. Meeting documents
   - 2.3. Nomination of Rapporteurs
3. Discussion of Annual Reports
4. Commission guidance and other Intersessional activities
   - 4.1. Commission SC Roadmap
   - 4.2. Secretariat SC related activities
   - 4.3. Data Workshop report
   - 4.4. Fishery dependent acoustic Task Group
5. Jack Mackerel Working Group
   - 5.1. Report on Intersessional assessment/research by Participants
   - 5.2. Intersessional Progress with the Jack Mackerel Stock Structure Research Programme
   - 5.3. Intersessional Progress with Jack Mackerel Age/Growth Task Team
   - 5.4. Jack Mackerel Stock Assessments – Technical Session
     - 5.4.1. Updating stock assessment data sets
     - 5.4.2. Re-run of the 2014 stock assessment model configuration including new data
     - 5.4.3. Conducting additional stock assessment runs to investigate alternative stock structures
   - 5.5. Advice to the Commission on Jack Mackerel stock status
     - 5.5.1. Apply the Adjusted Rebuilding plan
   - 5.6. Other Jack Mackerel topics
     - 5.6.1. Suitable Habitat Indicators
     - 5.6.2. Tagging Feasibility
6. Deepwater Working Group
   - 6.1. Intersessional assessments of Deepwater species
   - 6.2. Applications to fish outside the footprint or above reference period catch levels
   - 6.3. Collate and present advice as requested under CMM 2.03 Para 5(a)-(f)
     - 6.3.1. Impact of gear type on VMEs
     - 6.3.2. Deepwater stock assessments
     - 6.3.3. VME encounter evidence
     - 6.3.4. VME encounter response
     - 6.3.5. SPRFMO Bottom Fishery Impact Assessment Standard
     - 6.3.6. Bottom Footprint definition
     - 6.3.7. VME distribution in the Convention Area
7. Squid Assessment
8. Ecosystem Approach to Fisheries management
   - 8.1. Fishing activities, Vulnerable Marine Ecosystems (VMEs) and EBSAs
   - 8.2. Other Species of Concern
   - 8.3. Bycatch information
   - 8.4. Minimizing bycatch
   - 8.5. Data collection and reporting
9. Observer Programme
10. Advice to the Commission
    - 10.1. Jack Mackerel
    - 10.2. Deepwater
    - 10.3. Other
11. SC Research Program
12. Other Matters
13. Next Meeting
14. Adoption of Report
15. Meeting Closure

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Annex 3. Summaries of annual reports

New Zealand

Paper SC-03-22 noted that New Zealand did not fish for jack mackerel in the Convention Area during 2014 but conducted bottom fishing for orange roughy (by trawl, 6 vessels) and bluenose / wreckfish (by line, 4 vessels). No New Zealand vessels fished for bentho-pelagic species (e.g., alfonsinos) using midwater trawls in 2014. The catch of orange roughy remained at about 1,000 t, well below the average for the reference years (1,852 t). Most was taken from the Louisville Ridge. The total catch by bottom line fishing was 99 t, well below the average for the reference years (144 t). New Zealand observers were present on all bottom trawling trips and on two bottom longlining trips (see also **SC-03-23**). They observed 340 trawl tows and 30 bottom longline sets and measured 3,520 fish. Length frequency distributions for the key target species were typical of those collected over the last 5 years. Only two bottom trawls were conducted in move-on areas and neither exceeded the move-on triggers.

New Zealand has made progress on developing "low information" stock assessments for orange roughy in the SPRFMO Area (see also SC-03-DW-02) and has updated the stock assessment for the straddling stock on the Challenger Rise. These should contribute to the development of a revised CMM for bottom fisheries. Work on predicting and mapping the distribution of Vulnerable Marine Ecosystems (VMEs) has continued, including a field test of model predictions on the Louisville Ridge in 2014 and trialling of spatial decision support tools (see also SC-03-DW-04). Further development and testing is clearly required but this work should also contribute to the development of a revised CMM for bottom fisheries. The development and testing of an in-season depletion method for New Zealand's domestic squid trawl fishery has continued (see also SC-03-26) and this may be useful for considering approaches in the SPRFMO Area.

In paper SC-03-23 New Zealand reported on the observer implementation report and noted that the data standards and coverage requirements set out in CMM2.03 (Bottom Fishing) are easily met. Observers were placed on 100% of trawl trips and at least 10% of trips where other types of gear were used in 2014. In addition to training on data requirements and standards, observers were also informed on benthos identification related to the VME evidence process. All 2014 data in the SPRFMO region have been reported to the SPRFMO Secretariat.

Chile

Between January and July 2015, the industrial purse seine fleet operating on jack mackerel fishery in both, the SPFRMO area and Chilean EEZ combined, consisted of 88 vessels operating.

Until July 2015 the accumulated catch was 269,893 metric tons, which is higher than the catch registered at the same month in 2014 (by 17,000 metric tons). Unlike 2014, this year 56,223 metric tons have been caught in the SPRFMO Area, which represent nearly 20% of the total catch of the national fleet.

During the first quarter of 2015, monthly catches of jack mackerel fluctuated around 22 thousand metric tons, the lowest value recorded for period 2010-2015. This condition is mainly explained by low catches registered in February, when a high presence of juveniles was detected. Nevertheless, a significant increase in catches occurred during second quarter of current year, which reflects a slight shift in the fishing season, extending the fleet's operations by more than one month.

Until May of 2015, the spatial distribution of jack mackerel catches were concentrated inside the Chilean EEZ, between 29°- 37° SL. Nevertheless in June 2015 the fleet exhibited a different operational pattern with catches obtained away from the coast, even outside the EEZ.

Unlike the observed between 2012 and 2014, during the first half of 2015, the size structure of jack mackerel showed a multimodal distribution, with a shift of the main mode toward smaller individuals. In 2015, the main mode was 26-27 cm FL, followed by a secondary mode of 35 cm FL. These modes belong to fish caught in the south-center area of the fishery, where juveniles have been present during most part of this year

The Chilean government announced that it will set aside a large no-take marine protected area within the Chilean EEZ around the Nazca ridge/Desventurada Islands, which includes jack mackerel juvenile habitat. Penalties for discarding, defined as release of an organism back to the sea, range from fines to sanctions, depending on the species discarded and the number of violations. These penalties are waived when an observer is on board to facilitate scientific data collection. The size structure of jack mackerel off of central Chile differs from the size structure in the north. Smaller jack mackerel are concentrated north and closer to the coast, and also in the central area. The size structures off of central and southern Chile are similar. In 2015, jack mackerel catches continued into August which is an extension of the season from previous years. This season extension is occurring because the fleet caught fewer fish in February as it was avoiding the capture of smaller juvenile fish, so the fleet is continuing to fish in July and August as it tries to capture its full quota. There was a question of whether Chile has any information about jack mackerel Gonadosomatic index studies over time (similar to that compiled and reported on from Peru) in that it may be useful for comparisons (stock structure) and in identifying anomalous patterns that may relate to environmental conditions.

Chinese Taipei

The scientist from Chinese Taipei report on their jumbo flying squid fishery in the region. The number of vessels varied between 5 and 29 from 2002 to 2014. The catch of Jumbo flying squid declined to 4,795 tons in 2014 along with the decrease in number of vessels and fishing days (nominal CPUE has been stable in recent years). The major fishing ground for this fishery was located at the area around 76–83°W and 15–20°S. Detailed logbook, trans-shipment and landing records from this fleet have been reported. Analyses on the stock status and spatial dynamics of jumbo flying squid but limited port and at sea scientific sampling has occurred.

China

The update on 2014 jack mackerel fishery notes that three large pelagic trawlers operated in the South East Pacific with a total catch of jack mackerel was 21,154 tons from 3,655 hours of trawling. The nominal CPUE was 5.8 tons per hour which is nominally higher than that observed in 2013. However, the estimated standardized CPUE decreased from 0.57 in 2013 to 0.52 in 2014. The fishing season was shortening and there was no fishing activity in the first-three-month in 2013 and 2014. Spatial distribution of catch in 2014 was similar to that in 2012 and 2013. Fishing ground moved eastward and closed to the Chilean EEZ and jack mackerel catch form North Chile was increasing. The scientific observer sampled 4967 jack mackerel randomly on board, measured fork length and weight and collected other biological information.
For the squid fishery, developments from 2001-2014 indicate a steady increase with annual catch and numbers of active fishing vessels reaching a peak in 2014. Furthermore, the fishing effort also remained at high level with the nominal CPUE fluctuant between 4.0 and 6.4 ton/day-vessel. The two observers took biological samples from 732 jumbo flying squid in the Eastern Central Pacific in 2014.

The SC had a number of questions for clarification. Given that 2015 is considered an El Nino year, there was interest in biological information collected from the Chinese JM fishery but unfortunately there is only catch information available. For the squid jigging fishery, the Chinese delegation indicated they consider asking observers to record squid size to 1 cm for next year instead of by 5 cm bins used in 2015, to facilitate future calculation of size distributions. The Chinese delegation also clarified that there is minimal observed bycatch by this fishery, due to depth and the fact that fishing operations are conducted at night. Although the number of vessels has increased in the past few years, it may be less likely that squid fishing effort will increase in the future.

European Union

In 2015 trawlers fished in different areas relative to previous years. At the start of the season in April and early May, the fishery occurred further to the south and from May to July unusual quantities of young jack mackerel were taken in the area between 40 - 44°S. The abnormal distribution of both the adult and juvenile component of the jack mackerel stock in the first half of 2015 may have been caused by the El Niño conditions during this time of the year. Therefore, the high abundance of young jack mackerel outside the Chilean EEZ may have been partly the result of an abnormal distribution of this year-class, rather than of its absolute size.

Peru

During 2013-2014 the Peruvian fleet that fished in the SPRFMO Convention area operated off Peru and Chile at distances from 201 nm to 1000 nm from the coast, in a general area encompassed by 14°00'S and 45°00'S and 79°40'W and 80°50'W. No fishing activity (through July) in the SPRFMO area has occurred in 2015. Only 1 fishing vessel operated during 2013 catching a total of 2697 tonnes between April and July 2013. No catches were reported latter in the year. Jack mackerel (*Trachurus murphyi*) represented 99% (2670 tonnes) of this total, chub mackerel (*Scomber japonicus*) represented 0.7% and other species 0.3%. The fishing areas in 2013 were within the 38°S and 45°S with a general distribution within 220 and 480 miles from the coast. Up to 5 fishing vessels operated in the Convention area during 2014, accumulating a total catch of 3574. No catches were reported until mid-June although some unfruitful attempts to search and trawl for Jack mackerel in a wide area off central-southern Chile were made between 10 March and 10 June 2014. During late June and July 2014 the fleet mainly targeted on jumbo squid (*Dosidicus gigas)* further north, between 14°S and 1rs off Peru. Their total catch was 1092 tonnes in the two months, of which 1087 tonnes (99%) were jumbo squid while the other species (1 %) included lightfish (*Vinciguerria* sp) and bonito (*Sarda chiliensis*). From August to October 2014 the fleet moved back south to a fishing area between 26°S and 29°S at around 300 miles from the coast off central Chile. The total catch reported during this three-month period was 2482 tonnes, of which 2223 tonnes (almost 90%) where Jack mackerel, 256 tonnes (1 0%) chub mackerel and 4 tonnes of other species. Jack mackerel CPUE values during the second semester of 2014 were lower than those observed during the second semester of 2012 and the first semester of 2013, but similar to those observed during the first semester of 2012. The size frequency distribution of Jack mackerel caught between August and October 2014 ranged from 18 to 54 cm total length, with a main modal size at 30 cm and secondary modes at 21 and 37 cm. The size frequency distribution of jumbo squid caught between 24 June and 31 July 2014 ranged from 13 to 41 cm mantle length, with a main modal size at 21 .7 cm for females and 21.3 for males. A variety of biological and fisheries data is collected by the Onboard Observer's Programme, which for the Peruvian fishing fleet had an almost 100% coverage during 2014, with an observer on each of the 5 Peruvian fishing vessels that operated in the Convention area.

Within national jurisdiction, Peruvian jack mackerel catches have been small relative to recent years likely due to a weak El Niño that developed during 2014 and a moderate to strong one developed during the first part of 2015. During 2014 and particularly during 2015 Jack mackerel concentrations were only found in coastal areas, within 20 and sometimes within 10 nm from the coast. This change in the spatial distribution is related to the closeness to the coast of the Subtropical Surface Waters and the almost disappearance of the mixed layer with Cold Coastal Waters. In 2014 the Jack mackerel landings in Peru by all fleets was 74,528 t.

Catches of jack mackerel by the industrial purse seine fleet during the first semester of 2015 were reported as zero and the only catches of this species in Peruvian waters during the first semester of 2015 consist of the ~13,000 t caught by the artisanal and small scale fleets. Several modal groups of Jack mackerel were observed in the fishery between January and May 2014, with a predominance of adults with modal lengths between 31 and 34 cm total length. Jack mackerel ranging from 15 to 37 cm TL were observed from September 2014 to May 2015, with a predominate of fish with modal sizes between 25 and 31 cm TL and a higher incidence of juveniles (smaller than 31 cm TL). The estimated TAC for 2015 using the JJM model assuming a risk of 16% that the projected biomass to January 1st 2016 be lower than that estimated for 2015 was 96,000 t and this was the TAC included in the recommendations to the Government, which also included a proposal for an intensified monitoring of the fishery and of the environmental conditions to ensure early detection of possible stock and environmental changes. This IMARPE recommendation was accepted by the Government and was included in the R.M. N° 003-2015-PRODUCE of 6 January 2015, which sets the total allowable catch (TAC) to be taken between January and December 2015.

In response to questions from the SC regarding the figure indicating variability of Gonadosomatic Index of Peruvian Jack Mackerel, they noted that samples are collected from commercial catches at landing sites along the coast, with a sample size of at least 100 individuals per month per port, and only individuals greater than 31 cm total length (~29 cm fork length) are sampled for this purpose. Reproduction of jack mackerel is affected by El Nino/La Nina temperature effects.

The diet studies were completed using samples obtained from survey vessels and not fishing vessels. The shift in species composition of jack mackerel diet starting in ~2000 is unlikely due to shifts in stock distribution.

Australia

The Australian annual report summarised catch and fishing activities in the SPRFMO Convention Area, up to and including the 2014 calendar year. Two demersal longline and two bottom trawl vessels actively fished in the SPRFMO Area in 2014, for a total catch of 204 t. The 99 t of longline catch consisted of 30 t of morwong (30%), 21 t of blue-eye trevalla (21%) and 26 t of yellowtail kingfish (26%). The 104 t of trawl catch consisted of 102 t of orange roughy (98%). Australia's trawlers did not target alfonsino in 2014 (<1 t). Observers participated in two non-trawl trips, monitoring 22% of all hooks deployed in 2014. Observers covered six of the seven trawl trips (72% of all tows). Observers reported no catches of marine mammals, seabirds or marine reptiles during 2014, and VME thresholds were not triggered.

USA

In SC-03-06 the United States delegate noted that the US is currently a Cooperating non-Contracting Party (CNCP) of SPRFMO and has applied for continued CNCP status. The U.S. process for final ratification under domestic law is ongoing. The United States remains committed to participation in SPRFMO. Currently, the United States has no vessels participating in the fisheries managed by SPRFMO.

Colombia

Members were referred to their annual report (SC-03-13).

Vanuatu

Vanuatu observed that the catch rate of its vessels in 2015 has increased significantly, that the entire Vanuatu quota had been caught and that there was a substantial quantity of small (apparently 3 yr-old) fish in its catches.

Ecuador

Jack Mackerel

During the 2015 catches of jack mackerel they occurred from April to August with a total of 250t, 140t being captured on June with sea surface temperatures around 25° C and 26° C.

Catches of this species were in the Santa Elena lace (the fullest part of the coast of Ecuador), being unusual, it is only presented something when the resource has remained steadily (several weeks) in our waters as well as north of the island of Santa Clara (the western Gulf of Guayaquil). They were punctual events on certain days of the months mentioned above.

The size structure of organisms was captured between 25-32 cm total length, the individuals of 28-29 cm when the most representative sampling. With regard to maturity all captured sexually immature individuals (stage 2) were found.

Squid

Ecuador has maintained a handmade squid fishery since the 70 s basically in coastal waters and seasons when there is influence of the Humboldt Current in this fishery have been estimated some reference data as cpue and fishing areas that we gladly can present to the Commission at this meeting.

Occasionally industrial fishing has been carried out in previous years but at the end of 2014 Ecuador opened an industrial fishery with 6 vessels interested in this activity, which are capable of operating in international waters, at this time only 2 fishing vessels has begun the tasks of fishing, these boats are improving in their operation and which is still collecting information, according to information submitted by the company is estimated that until the first half of 2015 has captured about 1500 tons, this information will be sent to the Commission as the same is complete.

Korea

Observers on Jack mackerel vessels also record other species encountered (sightings), and the incidence of these ~20 species is quite low. Species observed include pelagic armorhead, sunfish, jumbo flying squid, skipjack, blue shark, swordfish, 10-11 observed seabird species, and some marine mammals. Since this information is publicly available, there was a request to append this useful information to the Korea annual report (understanding the information is currently available only in Korean).

Russia

The Russian delegation presented preliminary data of the Russian fisheries in the SPRFMO Convention area for 2015 and provided information about Russian studies in the South Pacific in the past. Observers collect otoliths and will be investigating age structure of jack mackerel. The studies on the genetic differentiation of jack mackerel populations are ongoing, but sampling programme needs to be re-initiated.

Annex 4. EU study summary

Jack mackerel in the South Pacific has been exploited by fisheries since the 1970's. Owing to large recruitment influxes in the mid-eighties, the stock grew to approximately 14 million tonnes of spawning biomass, estimated to have been one of largest fish stocks in the world, sustaining catches up to 5 million tons per year. This stock is distributed throughout the sub-tropical waters of the South Pacific Ocean, from South America to New Zealand and Australia. Management of Jack mackerel at the high seas is officially organised through the South Pacific Regional Fisheries Management Organisation since 2013. The SPRFMO area does not include the jurisdictional areas of Chile and Peru, while in both these areas the majority of Jack mackerel is observed throughout the year where it migrates from the high-seas into the coastal zones and vice versa. The stock assessment that is carried out yearly assumes that Jack mackerel constitute one single stock. Survey, climatic and catch observations suggest that more complex stock structures may exist. These observations have resulted in intense discussions among SPRFMO scientists on likely population and stock structure and preparation of TAC advice.

Therefore, in this study we were tasked to identify the most likely stock structure hypotheses of Jack mackerel, considering the most likely stock structure, identify management objectives for Jack mackerel and finally evaluate sustainable management strategies to achieve these objectives. These three elements were considered through literature review, statistical and population dynamics modelling. Two different structure conclusions were drawn: a conclusion towards most likely population structure and a conclusion towards most likely stock structure. The latter is predominantly relevant for management while the first needs to be considered to appropriately address the second.

In total, six different population structure hypotheses were considered. In this study, information has been collected that clearly shows that the population structure of Jack mackerel cannot be considered as a single discrete population, two or multiple discrete populations or a patchy population. No strong evidence was presented to reject the metapopulation hypothesis. Therefore, we conclude that the metapopulation structure is most likely for Jack mackerel in the South Pacific.

Considering stock structure required the analyses of fishing patterns in combination with likely population structure. The Jack mackerel inside Peruvian waters is bounded by its habitat during the fishing season from January till May with peak catches in April. We therefore conclude that Jack mackerel in the Northern area constitutes a separate stock. Jack mackerel inside the Chilean coastal areas is targeted around the same time of the year, with a peak around April. The catches inside the Chilean coastal area however cannot be considered in isolation from the catches at the high-seas. The Jack mackerel in the Southern area is considered to constitute another stock, resulting in a two-stock assumption for the entire South Pacific. Given that over years changes in the dynamics of Jack mackerel in the Southern zone affect Jack mackerel in the Northern zone, management of the two areas cannot be considered in complete isolation from each other.

Sustainable exploitation of the Jack mackerel population in the short term will be associated with an FMSY around 0.14. Under more optimistic recruitment scenarios, sustainable exploitation can be associated with an FMSY around 0.21 under the single stock hypothesis and between 0.15 – 0.2 for the two stock hypothesis. Any Harvest Control Rule that ensures setting TACs in the short to medium term close to an FMSY of 0.14 can be considered sustainable. In addition, there appears to be little gain in implementing an increase in either mesh size or minimum landing size. Given that conclusions related to population and stock structure are uncertain, different Harvest Control Rules were tested under a range of population and stock structure hypotheses. Results suggest that management structures assuming two stocks rather than one are less likely to over-exploitation than under a one stock assumption, even when in reality there is only one population unit. It is therefore recommended to consider two-stocks in the South Pacific, each being managed by a separate Harvest Control Rule, though these rules being co-developed to account for the connectivity between the two main population units.

Annex 5. Summary of papers relating to squid

In paper SC-03-27 authors note that jumbo squid (*Dosidicus gigas*) are found in high abundance along the whole Peruvian coast from 10 to more than 500 nm from the coast. Jumbo squid performs diel vertical migrations from 0 to more than 650 m depth, and regular inshore—offshore ontogenetic migrations and less regular latitudinal migrations of several hundred miles. Younger and/or smaller jumbo squids predominate in oceanic waters, while larger jumbo squids are more neritic. Jumbo squid maintains some reproductive activity all year round, with increased reproductive activity from July to February and peaks between October and January. The life span is usually one year, although some specimens can live up to two years. Slight differences in the age or size of sexual maturity and main distribution areas suggests that there are least three strains, groups or population subunits of jumbo squid inhabiting the Peruvian Humboldt Current System. Is a very aggressive predator and prey availability seems to be more important than temperature or other environmental parameters in shaping its geographic distribution. It has a wide food spectrum, mostly feeding on cephalopods (26.4%, by weight) and mesopelagic fish *Vinciguerria lucetia* (24.4%) and Myctophidae (18.3%).

The development of the jumbo squid fishery in Peru is characterized an initial rapid development in the early 1990s of a licensed foreign industrial fishery and a local artisanal fishery that gradually has phased out of the industrial fishery. Total catches of jumbo squid in Peruvian jurisdictional waters peaked at 559,000 t during 2008, with a total of 506,000 t in 2014, all taken by the local artisanal fleet. The size frequency distribution of jumbo squid in both the artisanal and the industrial fishery has been highly variable with a significant shift since 2000. From 1989 to 1999 most jumbo squid was under 50 cm ML, with one or two modes between 20 and 40 cm ML; while since 2000 there is a prevalence of jumbo squid larger than 50 cm ML, with 2 or 3 modes between 22 cm and 93 cm ML. Since 1999 the assessments of jumbo squid in Peruvian waters has been based predominantly on the biomass estimates obtained through hydro-acoustic surveys and more recently, as longer CPUE time series become available ,these assessments have also included the application of a surplus production model. Both assessment methods have provided estimates that are compatible with the high current catches and an under-exploited state.

Paper SC-03-32 identifies and describes Jumbo flying squid data sets held by the SPRFMO Secretariat. The Jumbo flying squid fishery is a very large fishery, recent catches within the SPRFMO Area have exceeded 330 000 t while catches from within adjacent areas under national jurisdiction are around 580 000 t. During 2014 there were 264 Chinese vessels, 6 Korean vessels, 5 vessels from Peru and 5 vessels from Chinese Taipei operating in the SPRFMO Area.

Ecuador discussed how jumbo squid migrates and performs vertical movements towards deepwater in the day (06h00) and surface at night (18h00) with daily horizontal movements and a South-North movement, is captured overnight (18h00-06h00), mainly in dark (newmoon). Three species of squid in Ecuadorian waters belonging to Ommastrephid family and one species belonging to Thysanoteuthidae family, dominated by the species *Dosidicus gigas* (95%) were identified. In coastal waters, fishing areas with the highest concentration were distributed facing the Gulf of Guayaquil, mainly on the border with Peru from July to October and spread north to the coast of Ecuador in the provinces of Manabí and Esmeraldas. In the Galapagos Islands, jumbo squid found mainly distributed in front of the Isabela and San Cristobal Islands. Little is known about his abundance out of the 80 nm, but is considered an excellent potential for giant squid fishing area. The sea surface temperature (SST), conditioned the presence and / or absence of the giant squid fishing areas of the Ecuadorian sea.

New Zealand presented paper SC-03-26 describing a CPUE-depletion analysis of squid fishery dynamics that has been successful for squid stocks around the Falkland Islands and appears to have potential for developing in-season management advice on New Zealand stocks, including on limiting catch. CPUE from various fishing seasons has sufficient signal to enable the depletion model to be fitted. Further investigation is required to determine how to fit the depletion model through the season when there are breaks in effort. Future developments will include: the sensitivity of the model to variation in natural mortality; testing the utility of remote-sensed chlorphyll concentrations as a pre-season indicator; and developing predictive capability within the model (using historical data to estimate probabilities that depletion will go below a certain point given the current state). This analysis is in its early stages but the approach appears to have potential within the New Zealand EEZ and may be useful for squid fisheries in the SPRFMO Area.

Annex 6. Summary of information papers

Summary of SC-03-INF01

The representative from Oceana presented a stock assessment of the South Eastern Pacific (SEP) jack mackerel stock that was conducted considering two hypotheses about stock structure and two scenarios for the steepness of the stock-recruitment function. Life history parameters such as somatic growth were taken from the most recent and updated parameters available from literature. Testing both hypotheses lead to the conclusion that the biomass from Peru and Ecuador did not make a significant contribution to the spawning biomass of the jack mackerel stock in the South Pacific. All combinations of stock hypotheses and scenarios of h (h=0.80 and h=0.65) lead to the same diagnosis of stock status. Jack mackerel stock in South Eastern Pacific is overexploited and with some probability of being depleted (close to Blim). We explore robustness of the model using a retrospective analysis concluding that he model proposed is robust to estimate abundance in jack mackerel. Projections of the abundance included the combination of two level of recruitments (1970-2012 and 2000-2012), two level of steepness (h=0.80 and h=0.65) and five level of fishing mortality (F) obtained from different multiplier of F in 2014. We assessed the probabilities to reach the maximum sustainable yield (MSY) or the 80% of MSY under different combinations of recruitment, steepness and F. Results show that the selection of recruitment period for projections is the factor that mostly influences the recovery of abundance. Steepness plays a secondary role, by influencing the time or the probability required to accomplish the management strategies based on MSY. Using long periods of recruitment (1970-2012) is misleading and overestimates the rebuilding capacity of the stock; thus the last period of recruitment (2000-2012) is recommended when simulating exploitation strategies. Harvesting at a 50% of fishing mortality estimated in 2014 has a 30% chance of reaching Bmsy at the end of the projection period (year 2034). Harvesting with any higher fishing mortality (>50%F), will reduce the chances below an 8% to reach Bmsy in 2034 and thus it is not recommendable as a sustainable management strategy.

Summary of SC-03-INF-02

Andy Smith of HSFG presented paper SC-03-INF-02 Competing narratives – Getting your VME story heard above the rest. He noted three themes that stood out in the ongoing debate over conservation and protection of fragile deep-sea benthic fauna from the effects of fishing activities. The first of these is the frequent reference to Resolution 61/105 on Sustainable Fishing of the United Nations General Assembly in 2006. Four paragraphs of this resolution, 83 - 86, have gained almost iconic status in this ongoing discourse. These paragraphs provide an early use, but no definition, of the concept of a vulnerable marine ecosystem, and the obligation of states to protect such entities through controls of high seas fishing operations. The second theme has been the evolution of the concept of the vulnerable marine ecosystem and what constitutes a VME, and the related issue of what is destructive fishing. In this regard we have seen groups of 'experts' undertake subjective definitions of these concepts and then commonly undertake analyses leading to conclusions framed in terms of the definitions they have proposed.

Equally often, the scientific literature may use the term without any formal description. The third of the themes has been the manner of adoption of the concept of the vulnerable marine ecosystem, inevitably uncritically, to describe or justify a wide range of research on benthic fauna and justified by the need to undertake research on vulnerable marine ecosystems. However, much of this research may be better described as basic marine research that is of tangential benefit to ensuring better practices of sustainable fishing no matter the quality of the research being undertaken.

This paper examines the growing development of the concerns with conservation of fragile deep-sea benthic fauna, starting with the IMO resolution of 1992 and continuing through a series of advisory reports of the Secretary General of the United Nations, meetings of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea, an initiative of the Division of Ocean Affairs and Law of the Sea, and resolutions of the United Nations General Assembly. These resolutions become the 'marching orders' for national delegations and through them, national departments of fisheries of states undertaking fishing on the high seas. Jointly, UNGA Resolution 61/105 and the implicit importance of vulnerable marine ecosystems have provided the basis for the different stakeholder groups to promote and develop narratives pertaining to fragile benthic fauna and the programmes of their respective institutions. A series of future steps are identified to address the deficiencies of the various narratives that are discussed in this paper. A particular concern has been claims based on the UNGA Resolution 61/105 and subjective definitions as to what is a VME to justify public funding of self-evidently flawed applications of predictive model.

Annex 7. Jack mackerel stock status summary

South Pacific Regional Fisheries Management Organisation

Stock status summary for jack mackerel, October 2015

Stock: Jack Mackerel (*Trachurus murphyi*)
Region: Southeast Pacific

Advice for 2016

Noting that The SPRFMO Science Committee conducted an "update" assessment in 2015, they advise to maintain 2016 catches at or below 460 000t.

Stock status

		2013	2014	2015
Fishing mortality in relation to	F_{MSY}	Below	Below	Below
Spawning stock biomass in relation to	B_{MSY}	Below	Below	Below

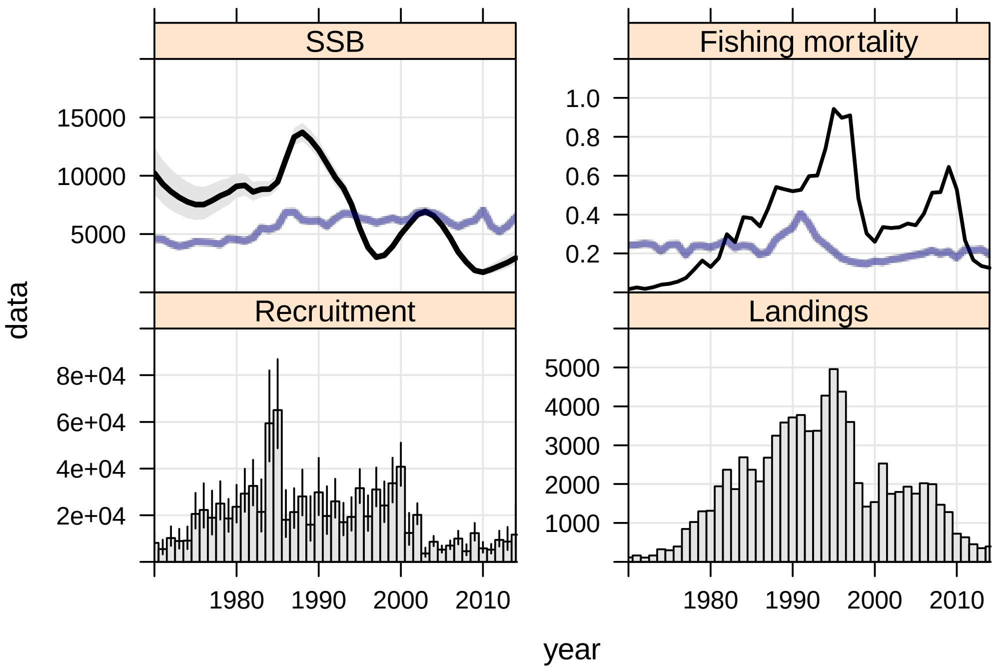


Figure 3. Jack mackerel in the southeast Pacific. Summary of stock assessment. Recruitment (age one) is measured in thousands, catch and SSB in thousands of tonnes, and harvest (fishing mortality) as a rate per year. Note that *dynamic* values for F_{MSY} and B_{MSY} are shown by horizontal blue lines. Confidence bands reflect $\pm$1 standard deviation of the estimate.

Table 1. Advised and reported catch of Jack Mackerel in the southeast Pacific.

Year	Advised maximum catch	Reported catch
2008		1,472,631
2009		1,283,474
2010		726,573
2011	711,783	634,580
2012	520,000	454,774
2013	441,000	353,123
2014	440,000	410,335*
2015	460,000	433,650*
2016	460,000	

2011, 2012, 2013, & 2014 advice was given by the Science Working Group.
* As estimated at SC03

Annex 8. Jack mackerel stock assessment

Introduction

This document and content is based on discussions analyses conducted at the SC-03 meeting. Changes this year are only based on data (an "update" assessment) to the 2014 assessment include new age compositions for the acoustic surveys from the Northern area of Chile, updates on the main abundance indices as CPUE of Chile and Peru, and an alternative acoustic index based on the same surveys of Peru. Model modifications relative to the most recent assessment are presented below and mainly involve how selectivity was allowed to vary over time and how different data sets were weighted in model fitting.

Scientific name and general distribution

The Chilean Jack mackerel (*Trachurus murphyi*, Nichols 1920) is widespread throughout the South Pacific, along the shelf and oceanic waters adjacent to Ecuador, Peru, and Chile, and across the South Pacific along the Subtropical Convergence Zone in what has been described as the "Jack mackerel belt" that goes from the coast of Chile to New Zealand within a 35^{o} to 50^{o} S variable band across the South Pacific.

Main management units

At least five management units of *T. murphyi* associated to distinct fisheries are identified in the SE Pacific: the Ecuadorian fishery, which is managed as part of a more general pelagic fishery within the Ecuadorian EEZ; the Peruvian fishery, which is managed as part of a Jack mackerel, mackerel and sardine fishery directed exclusively for direct human consumption taking place almost entirely within the Peruvian EEZ; the northern and the central-southern Chilean fisheries which are managed as separate management units, with the northern fishery being mostly within Chilean EEZ and the central-southern Chilean fishery which straddles the Chilean EEZ and the adjacent high sea; and, the purely high sea fishery which is a multinational fishery being managed entirely within the context of the SPRFMO. At present there is no directed fishery for *T. murphyi* in the central and western South Pacific and around New Zealand, where, if any, incidental catches are very small.

Stock structure

There are a number of competing stock structure hypotheses, and up to five and more separate stocks have been suggested: i) a Peruvian stock (northern stock) which is a straddling stock with respect to the high seas; ii) a Chilean stock (southern stock) which is also a straddling stock with respect to the high seas; iii) a central Pacific stock which exists solely in the high seas; iv) a southwest Pacific stock which exist solely in the high seas; v) and, a New Zealand-Australian stock which straddles the high seas and both the New Zealand and Australian EEZs. Regarding specifically the eastern and central South Pacific, the SPRFMO has identified the following four alternative stock structure working hypotheses: 1) Jack mackerel caught off the coasts of Peru and Chile each constitute separate stocks which straddle the high seas; 2) Jack mackerel caught off the coasts of Peru and Chile constitute a single shared stock which straddles the high seas; 3) Jack mackerel caught off the Chilean area constitute a single straddling stock extending from the coast out to about 120°W; and, 4) Jack mackerel caught off the Chilean area constitute separate straddling and high seas stocks.

Accordingly, the Jack Mackerel Sub-group (JMSG) of the Science Working Group (SWG) of the SPRFMO at its 11th Session (SWG-11) carried out parallel assessments of the Jack mackerel stock(s) in the Eastern South Pacific under the two main working hypothesis already identified. That is: that Jack mackerel caught off the coasts of Peru and Chile each constitute separate stocks (Peruvian or northern and Chilean or southern stocks - hypothesis 1) which straddle the high seas; and, that Jack mackerel caught off the coasts of Peru and Chile constitute a single shared stock (hypothesis 2) which straddles the high seas. In following up on the SWG-11 recommendations, the SPRFMO Commission at its 1st Commission Meeting requested the newly established Scientific Committee to continue the work on evaluating alternative hypotheses on Jack mackerel stock population. Pending more conclusive findings on the stock population structure of Jack mackerel, the 2nd Commission meeting requested the Scientific Committee (SC) to continue and expand the stock assessment work under both the stock hypotheses considered in the 11th SWG Meeting, and this continues to be one of the main tasks undertaken at SC-03.

Fishery

The fishery for jack mackerel in the south-eastern Pacific is conducted by fleets from the coastal states (Chile, Peru and Ecuador), and by distant water fleets from various countries, operating beyond the EEZ of the coastal states.

The fishery by the coastal states is done by purse seiners. The largest fishery exists in Chile, where the fish are used mainly for the production of fish meal. In Peru, the fishery is variable from year to year. Here the fish is taken by purse seiners that also fish for anchovy. According to government regulations, the jack mackerel in Peru may only be used for human consumption. Ecuador constitutes the northern fringe of the distribution of jack mackerel. Here the fish only occur in certain years, when the local purse seiners may take substantial quantities (80 000 tons in 2011). Part of the catch is processed into fish meal but recently horse mackerel has been promoted to be used for human consumption.

The distant water fleets operating for jack mackerel outside the EEZs have been from a number of parties including Belize, China, Cook Islands, Cuba, European Union (Netherlands, Germany and Lithuania), Faroe Islands, Korea, Japan, Russian Federation, Ukraine and Vanuatu,. These fleets consist exclusively of pelagic trawlers that freeze the catch for human consumption. In the 1980s a large fleet from Russia and other Eastern European countries operated as far west as 130° W. After the economic reforms in the communist countries around 1990, the fishery by these countries in the eastern Pacific was halted. It was not until 2003 that foreign trawlers re-appeared in the waters outside the EEZ of the coastal states.

The fishery for jack mackerel is generally a mono-specific fishery. In the offshore fishery the catch consists for 90 – 98% of jack mackerel, with minor by-catches of chub mackerel (*Scomber japonicus*) and Pacific bream (*Brama australis*).

The development of the catches of jack mackerel in the south-eastern Pacific is shown in Table A8.1.

Management

Jack mackerel were managed by coastal states beginning in the mid-1990s. National catch quotas for jack mackerel were introduced by Peru in 1995 and by Chile in 1999. Peru introduced a ban on the use of jack mackerel for fish meal in 2002. For the international waters, the first voluntary agreement on limitation of the number of vessels was introduced in 2010. Starting from 2011, catch limits for jack mackerel were established for all countries fishing in the convention area in the south-eastern Pacific.

Information on the environment in relation to the fisheries

Peru is currently using the Coastal El Niño Index (ICEN, from Indice Costero de El Niño) to describe the short-term variability of the environment. Data to calculate this index on a monthly basis is available from 1950 to date. In 2014, El Niño conditions began to develop but so far have been relatively weak.

Large-scale variability has also been observed and analyzed off Peru, especially with respect to changes in water masses dynamics and depth of the 15^{o}C isotherm between 1961 and 2013. These variables influence the spatial distribution Jack mackerel, and probably in the long run also influence its availability and abundance. The various environmental and biological signals help explain the drastic decline in abundance towards the end of the 1990s implied by the results of the acoustic estimates. This decline took place in the absence of significant fishing pressure and with very low catches in the 1980s and 1990s. Long-term changes in the distribution pattern of the Sea Surface Temperature in Peruvian waters have by themselves left noticeable impacts on the Peruvian Jack mackerel stock, as suggested by the tight parallelism between the decline of the area covered by warm isotherms (22°C-25°C) and acoustic biomass estimates since mid-1990s.

Reproductive biology

The main spawning season happens from October to December; however, spawning has been described to occur from July to March. Gonadosomatic index and eggs surveys have been used to determine the time of spawning.

Data used in the assessment

Fishery data

The catch data for the model sums values from Table A8.1 and forms four “fleets” which are intended to be consistent with the gear and general areas of fishing (Figure A8.1). These fleets are presented in Table A8.2.

Length data are available from all major fisheries both inside and outside the EEZs. Length distributions from Chile and the international fleet are converted into age distributions using Chilean age-length keys. These data are shown in Tables A8.3, A8.4, and A8.5. For Peruvian and Ecuadorian catches, catch-at length compositions are used (Table A8.6). There was a compilation of length compositions (partial results 2013) for countries that don’t have age compositions (EU, China, Vanuatu and Korea). A weighted frequency was done as a representation of the offshore fleet. The age conversion for these fleets was done considering age-length keys of central-south area of Chile. A similar procedure was applied considering the information since 2000 for all offshore fleets that have operated off Chile.

Several CPUE data series are used in the model. For the Chilean purse seiner fleet, “General Linear Models” (GLM; McCullagh & Nelder, 1989) were used to standardize the CPUE. Following this approach, CPUE is predicted as a linear combination of explanatory variables, and the ultimate objective is to estimate the annual effect. A normal delta and delta gamma models were assessed (Pennington, 1983; Ortiz and Arocha, 2004), which models separately the positive tows from the number of catch successes, where the index is obtained as the product between the proportion of positive tows and the index estimated for the rates of fishing with catch (Lo et al, 1992). A deviance analysis was conducted to assess the importance of each main effect. Factors in the GLM included year, quarter, zone and the vessel hold capacity. Effort units were computed as the number of days of a trip multiplied by the vessel hold capacity. The rationale being that trip duration can serve as a proxy for search time.

The Peruvian CPUE was standardized using a GAM model, allowing the inclusion of non-linear relationships among the explained and explanatory variables. The independent variable (catch by trip) in a monthly scale was previously normalized using the Box-Cox transformation and modeled using time (Gregorian) month, hold capacity, latitude, and distance to the coast as explanatory variables. The standardized CPUE was estimated fixing the hold capacity, latitude, and distance to the coast to the median value and the month to March, assuming the continuous time captures the variability in the abundance of Jack mackerel.

The Chinese CPUE was standardized using a GLM and updated earlier studies. This series was included as an index of exploitable biomass for offshore fleet. As from previous assessments, the Russian time series of CPUE was included but with low weight since it remains unstandardized. Also, for the international trawler fleet, a CPUE series for the EU fleet was used with an updated value for 2013.

Fisheries independent data

China has a system of observers onboard fishing vessels that, among others, collect data on environmental variables (wind direction and speed, SST, etc.) in the fishing grounds. Although this data is not available at the moment, it might be in the future.

In Chile the Jack mackerel research program includes stock assessment surveys using hydroacoustics and the daily egg production method (DEPM). For the northern region (XV-III) data on acoustic biomass and number and weight at age are available from 2006 to 2012 on a yearly basis. For the central-southern regions (V-X), these data are available from 1997 to date. Egg surveys (through the Daily Egg Production Method), to estimate the abundance of the spawning stock, were conducted on an annual basis from 1999 to 2008 along the central zone of the Chilean coast. Acoustic estimates and egg survey results are used as relative abundance indices to fine-tune the stock assessment model. Besides that, for the central-southern regions there are estimates of abundance and numbers at age based on DEPM for the years 2001, 2003, 2004, 2005, 2006, 2008.

In Peru the Jack mackerel research programme includes egg and larvae surveys and hydroacoustic stock assessment surveys. Results of these egg and larvae surveys provide information on the spatial and temporal variability of Jack mackerel larvae along the Peruvian coast from 1966 to-date. A new series of acoustic biomass was provided by Peru for years 1986-2013. This series represents estimations based on the assumption of shifts in habitat area and its impact over traditional estimations. Acoustic biomass estimates of Jack mackerel are available from 1983 to-date. Because these surveys have the Peruvian anchoveta as the main target, data only covers the first 80 miles and eventually 100 miles from the coast. Corrections to compensate for this partial coverage of acoustic biomass estimates of Jack mackerel are being made by using an environmental index describing the potential habitat of this species based on available data on Sea Surface Temperature (SST), Sea Surface Salinity (SSS), water masses (WM), oxycline depth (OD) and chlorophyll (CHL), since 1983 to the present on a monthly basis. In 2014, an alternative acoustic index was presented which was constructed using backscatter information without converting the information to biomass estimates through the use of length-frequency data. The reasons to propose this method relate to the reduced quality of the available length-frequency data in recent years.

Acoustic surveys, to estimate the biomass and distribution of jack mackerel, have been conducted along the Chilean coast, inside and outside of the EEZ and in the Peruvian EEZ, using scientific vessels and well-equipped vessels from the commercial fleet. The available acoustic estimates time series extends from 1984 to 2012 (depending on the area).

In 2012, the conversion of length composition (to age) from Peru and Ecuador was developed. Fishery length compositions (total length since 1980, converted to fork length) were included in the assessment. Age composition data for the surveys and DEPM are shown in Tables A8.7. – A8.9.

All CPUE (and fishery-independent) series used in the model are presented in Table A8.10.

Biological parameters

The maturity-at-age was updated based on a Chilean study (SWG-11-JM-07). The application of these results reduced the age at first reproduction by about one year, to 2-3 years from the 3-4 years used previously. Maturity at length was consistently observed with L50 at about 23 cm FL. These values, and those for the far-north stock, are shown in A8.11.

To fit the length composition data from the far-north fleet, a growth curve was used to convert age compositions to predicted lengths in the model. The values for the von Bertalanffy growth parameters are given in Table A8.12. Ageing imprecision is acknowledged through the use of an age-error matrix and is shown in Table A8.13.

In Chile the mean weight at age is calculated by year by taking the mean length at age in the catch and a length-weight relationship of the year. In previous years, the same weight at age matrix was used for the Northern Chilean Fleet (Fleet 1) and Southern Chilean Fleet (Fleet 2). This year a weight at age matrix specific for Northern Chile has been applied. The method uses two information sources: the length-age keys and the parameters of the weight-at-length relationship from IFOP's monitoring program of the Chilean fisheries. The information was separated in two zones which correspond to fishing areas (and acoustic surveys) that occur in Chile. Annual weight-at-length relationship was fitted to the data by each fleet independently, and these relationships were applied to mean length at-age within each zone. The information covers the period 1974-2013; for earlier years the weight at age from 1974 was used. The four weight at-age matrices correspond to: fleet 1 (northern Chile), fleet 2 (central-south Chile), fleet 3 (the far north fleet) and fleet 4 (the offshore trawl fleet); see Tables A8.14 - A8.17.

In Peru the mean weight at age is calculated by year taking the invariant mean length at age estimated from the growth function (Table A8.12) and the length-weight relationship of the year. The information covers the period 1970-2015.

Estimates of natural mortality are derived from Pauly´s method, using the Gili et al (1995) growth function for Chile and the Dioses (2013) growth function for Peru. The estimated M values are assumed to be the same for all ages and all years within the given stock.

Data sets

A full description of data sets used for the assessment of jack mackerel is in Annex 3 of the SC Data workshop 2015. A summary list of all data available for the assessment is provided in Table A8.18.

Description of assessment model

A statistical catch-at-age model was used to evaluate the jack mackerel stocks. The JJM ("Joint Jack Mackerel Model") is implemented in ADMB and considers different types of information, which corresponds to the available data of the jack mackerel fishery in the South Pacific area since 1970 to 2015.

The JJM model is an explicit age-structured model that uses a forward projection approach and maximum likelihood estimation to solve for model parameters. The operational population dynamics model is defined by the standard catch equation with various modifications such as those described by Fournier and Archibald (1982), Hilborn and Walters (1992) and Schnute and Richards (1995). This model was adopted as assessment method in 2010 after several technical meetings (http://www.sprfmo.int/jack-mackerel-sub-group/).

JJM developments

Since its adoption, the JJM model has been improved by participating scientists. The most noted change has been options to include length composition data (and specifying or estimating growth) and the capability to estimate natural mortality by age and time. The model is now more flexible and permits the use of catch information either at age or size for any fleet, and explicitly incorporates regime shifts in population productivity.

The model can be considered to consist of several components, (i) the dynamics of the fish population; (ii) the fishery dynamics; (ii) observation models for the data; and (v) parameter estimation procedure.

Population dynamics: the recruitments are considered to occur in January while the spawning season is considered as instantaneous process at mid of November. The population's age composition considers individuals from 1 to 12+ years old for the single stock hypothesis (hypothesis 2) as well as for the southern stock in the two stock hypothesis (hypothesis 1), while for the northern stock (hypothesis 1) 1 to 8+ years old are considered. In all cases a stochastic relationship (Beverton & Holt) between stock and recruitment is included. The survivors follow the age-specific mortality composed by fishing mortalities at-age by fleet and the natural mortality, the latest one supposed to be constant over time and ages. The model is spatially aggregated except that the fisheries are geographically distinct. The initial population is based on an equilibrium condition and occurs in 1958 (12 years prior to the model start in 1970) in the case of the single stock (hypothesis 2) and in the southern stock in the case of the two stock hypothesis (hypothesis 1), while in the northern stock equilibrium condition occurs in 1962 (8 years prior to the model start in 1970).

Fishery dynamics: The interaction of the fisheries with the population occurs through fishing mortality. Fishing mortality is assumed to be a composite of several separable processes – selectivity (by fleets), which describes the age-specific pattern of fishing mortality; catchability, which scales fishing effort to fishing mortality; and effort deviations, which are a random effect in the fishing effort − fishing mortality relationship. The selectivity is non-parametric and assumed to be fishery-specific and time-variant. The catchability is fixed by index and is estimated in nine abundance indexes. However, for some of these, e.g. the acoustic biomass from Peru and Chile (south) and the CPUE of southern area of Chile, time variations have been considered.

Observation models for the data: There are five data components that contribute to the log-likelihood function − the total catch data, the age-frequency data, the length-frequency data and the abundance indexes data. The observed total catch data are assumed to be unbiased and relatively precise, with the CV of residuals being 0.05.

The probability distributions for the age and length-frequency proportions are assumed to be approximated by multinomial distributions. Sample size is specified to be different by gear but constant over years. Total catch data by fishery (4) and abundance indexes (9), a log-normal assumption has been assumed with constant CV but different by fishery.

- Parameter estimation: The model parameters were estimated by maximizing the log-likelihoods of the data plus the log of the probability density functions of the priors and smoothing penalties specified in the model. Estimation was conducted in a series of phases, the first of which used arbitrary starting values for most parameters. The model has been implemented and compiled in ADMB and whose characteristics can be consulted in Fournier et al (2012)

Model details

Parameters estimated conditionally are listed in Table A8.19. The most numerous of these involve estimates of annual and age-specific components of fishing mortality for each year from 1970-2012 and each of the four fisheries identified in the model. Parameters describing population numbers at age 1 in each year (and years prior to 1970 to estimate the initial population numbers at ages 1-12+ and 1-8+) were the second most numerous type of parameter.

The table of equations for the assessment model is given in Tables A8.20 and A8.21. Table A8.22 contains the initial variance assumptions for the indices and age and length compositions.

The treatment of selectivities and how they are shared among fisheries and indices are given in Table A8.23, A8.24 and A8.25. Also depending on the model configuration, some growth functions were employed inside the model to convert length compositions to age compositions.

Models for stock structure hypothesis

During SWG 11, two types of population structure were evaluated and this was continued for SC-01 and SC-02 evaluations. Models under the two stock hypotheses carry the same naming convention but have the letters "N" or "S" appended to designate split-stock model runs (for North and South stock structure hypothesis).

Description of "update" model explorations

Description of key changes from base case assessment

Since this assessment is considered an "update", sensitivities for the assessment began with Model 0.0 (set to be exactly as the model selected at SC02) and simply incremented with catch updates and updated indices and catch-at-age (Table A8.26).

Assessment results

Results comparing the impact of new data (models 0.0-0.4) show that for the starting model configuration, the biomass trend was a bit more gradual and recruitment varied more as all the data were included (Figure A8.2). Comparing model 0.4 with the alternative stock structure indicated that the "south" model (0.4S) was very similar to the combined stock-structure model (Figure A8.3). Comparing the recruitment patterns in this figure, it appears that the far-north model has some synchrony in recruitment except for in 1990 and a few other years. This may be due to divergent environmental conditions and may lend some support to the two-stock hypothesis.

Assumed fishery mean weight-at-age assumed for all models are shown in Figure A8.4. The model numbers-at-age estimates are given in Table A8.27. The fishery age and length composition fits are shown in Figures A8.5, A8.6, A8.7, and A8.8. The age composition data from the surveys are given in Figures A8.9 and A8.10. This model fit the indices reasonably well (Figure A8.11). Fits to the index and fishery mean age compositions are shown in Figures A8.12 and A8.13.

Selectivity estimates for the fishery and indices is shown over time in Figures A8.14. A summary of the time series stock status (spawning biomass, F, recruitment, total biomass) for the single-stock hypothesis is shown in Figure A8.15 and for the two-stock hypothesis in Figure A8.16. As in past years, the biomass can be projected forward based on the estimated recruits (with an adjustment due to the change in spawning biomass through the stock recruitment relationship) to evaluate the impact of fishing. This can be informative to distinguish environmental effects relative to direct fishing impacts. For jack mackerel fishing has appeared to be a major cause of the population trend with the current level at below 20% of what is estimated to have occurred had there been no fishing (Figure A8.17).

Fishing mortality rates at age (combined fleets) were relatively high starting in about 1992 but has declined in the past few years (Table A8.28). In order to evaluate the potential for alternative “regimes”, stock recruitment curves were estimated over different periods and found that within the current period (2000-2012) the level of expected recruitment was considerably lower than the alternatives.

Management advice

New data and indicators on the status of jack mackerel suggest that conditions evaluated in detail from the last benchmark assessment (completed in 2014) are relatively unchanged. The population trend is estimated to be increasing. On balance, the indications of stock improvement (higher abundance observed in the acoustic survey in the northern part of Chile, relatively abundant age 3 jack mackerel in the fisheries, better catch rates apparent in some fisheries) are somewhat offset by declines observed in the Chilean CPUE.

Historical fishing mortality rates and patterns relative to the provisional biomass target are shown in Figure 1 (Section 10 above). Projections carried out in 2014 indicated that that if fishing mortality is maintained at or below 2014 levels and under the assumption of recent average recruitment at the levels estimated for the recent period (2000–2012), the likelihood of future spawning biomass increases. This led to recommended catches for 2015 in the order of 460 kt or lower (Table A4.30 of SC02). The 2015 update assessment shows that fishing effort in the next 10 years at or below current (2014) levels were projected to have a reasonably good probability of increased spawning biomass from the 2015 level of about 2.71 million t and projected to increase in a similar fashion as estimated in 2014.

In summary, the 2015 update assessment has resulted in a downward revision in SSB relative to the 2014 estimates due to updated data presented. Environmental conditions (e.g., strong El Nino that developed in 2015) likely affects jack mackerel distribution and thus age-specific vulnerability to surveys and fisheries. This may have affected the improved CPUE in some of the fisheries.

The SC agreed that the recommended catch advice for 2016 from SC02 are still appropriate. This is particularly relevant since there appears to be a slight downward retrospective pattern from recent assessments (Table A8.29). The summary of the update results (for the single stock hypothesis) are given in Table 8.30).

Relative to the rebuilding analysis, the conclusions from last year’s benchmark assessment provided last year continues to apply and the recommendation satisfies the rebuilding plan specified by the Commission.

Assessment issues

Based on the results of the data workshop, the assessment plans for 2016 should be developed several months prior to SC04 so that data coordinators can configure alternatives and conduct a careful evaluation of all available information to best guide the Commission. One of the higher priority items for consideration includes the catch-at-age estimates (based on age-determinations being conducted from different labs) and mean body weights at age assumed in the model. Finally, it was made clear at SC03 that the estimation uncertainty for a particular model configuration is only part of the uncertainty and that for SC04, a greater push to present an ensemble of plausible models be presented to capture more of the structural uncertainty that exists. This should be a priority task for the upcoming benchmark. For the ensemble set, ideally an evaluation of retrospective patterns should be evaluated.

References

Dioses, T. 2013. Edad y crecimiento del jurel *Trachurus murphyi* en el Perú. In: Csirke J., R. Guevara-Carrasco & M. Espino (Eds.). Ecología, pesquería y conservación del jurel (*Trachurus murphyi*) en el Perú. Rev. Peru. biol. número especial 20(1): 045- 052

Fournier, D. & C.P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 39: 1195-1207

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

Gavaris, S., Ianelli, J. N., 2001. Statistical issues in fisheries stock assessment. Scand. J. Statistics: Theory and Appl., 29, 245-272.

Gang Li, Xiaorong Zou, Yinqi Zhou & Lin Lei. Update Standardization of CPUE for Chilean Jack Mackerel (*Trachurus murphyi*) from Chinese Trawl Fleet. SWG-11-JM-08, 2011. 11th Meeting of the Science Working Group, Lima, Perú.

Gili, R., L. Cid, V. Bocic, V. Alegría, H. Miranda & H. Torres. 1995. Determinación de la estructura de edad del recurso jurel. In: Estudio biológico pesquero sobre el recurso jurel en la zona centro-sur, V a IX Regiones. Informes Técnicos FIP/IT-93-18.

Hilborn, R. & C.J. Walters. 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. Chapman and Hall, New York: 570 p.

Kochkin, P.N., 1994. Age determination and estimate of growth rate for the Peruvian jack mackerels, *Trachurus symmetricus murphyi*. J. of Ichthyol. 34(3): 39-50.

Leal, E., E. Diaz & J.C. Saavedra, 2011. Reproductive Timing and Maturity at Length and Age of Jack Mackerel Trachurus murphyi, in the Chilean Coast SWG-11-JM-07, 2011. 11th Meeting of the Science Working Group, Lima, Perú.

Lo, N. C. H., I. D. Jacobson, and J. L. Squires. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515–2526.

McCullagh, P. and Nelder, J. 1989. Generalized linear models. Chapman and hall. London. 511 pp.

Ortiz, M and F. Arocha. 2004. Alternative error distribution models for the standardization of catch rates of non-target species from a pelagic longline fishery: billfish species in the Venezuelan tuna longline fishery. Fisheries Research. 70: 275-297.

Pennington, M. 1983. Efficient estimators of abundance, for fish and plankton surveys. Biometrics 39: 281-286.

Saavedra J.C, L. Caballero & C. Canales, 2011. Analysis of the CPUE in the Jack Mackerel Fishery in centre-southern Chile. SWG-11-JM-06. 11th Meeting of the Science Working Group, Lima, Perú.

Serra R. and C. Canales 2009. Short review of some biological aspects of the Chilean jack mackerel, *Trachurus murphyi*. Working Paper SP-07-SWG-JM-SA-05. Jack Mackerel Stock Assessment Methods Workshop. Lima, Peru.

Schnute, J.T., & L.J. Richards. 1995. The influence of error on population estimates from catch-age models. Canadian Journal of Fisheries and Aquatic Sciences, 52(10): 2063-2077

SPRFMO/FAO. 2008. Report of the South Pacific Fisheries Management Organization (SPRFMO) Chilean Jack Mackerel Workshop. Chilean Jack Mackerel Workshop, organized and convened jointly by the SPRFMO and the Government of Chile, with Technical Assistance from the Food and Agriculture Organization of the United Nations (FAO). Santiago, Chile, 30 June-4 July 2008: 71pp.

Tables

Table A8.1. Sources and values of catch (t) complied for the four fleets used for the assessment

	Fleet 1	Fleet 2	Fleet 3 (Far North)						Fleet 4 (Offshore Trawl)												
Year	Chile N	Chile CS	Cook Islands	Cuba (2)	Ecuador (ANJ)	Peru (ANJ)	USSR	Subtotal	Belize	China	Cuba	European Union	Faroe Islands	Japan	Korea	Peru	Russia/ USSR	Ukraine	Vanuatu	Subtotal	Total
1970	101685	10309				4711		4711												0	116705
1971	143454	14988				9189		9189												0	167631
1972	64457	22546				18782		18782									5500			5500	111285
1973	83204	38391				42781		42781												0	164376
1974	164762	28750				129211		129211												0	322723
1975	207327	53878				37899		37899												0	299104
1976	257698	84571				54154		54154						35						35	396458
1977	226234	114572				504992		504992						2273						2273	848071
1978	398414	188267				386793	0	386793						1667	403		49220			51290	1024764
1979	344051	253460		6281		151591	175938	333810			12719	1180		120			356271			370290	1301611
1980	288809	273453		38841		123380	252078	414299			45130	1780					292892			339802	1316363
1981	474817	586092		35783		37875	371981	445638			38444			29			399649			438123	1944670
1982	789912	704771		9589		50013	84122	143724			74292	7136					651776			733204	2371611
1983	301934	563338		2096		76825	31769	110690			52779	39943		1694			799884			894300	1870262
1984	727000	699301		560		184333	15781	200674			33448	80129		3871			942479			1059927	2686902
1985	511150	945839		1067		87466	26089	114622			31191			5229			762903			799323	2370934
1986	55210	1129107		66		49863	1100	51029			46767			6835			783900			837502	2072848
1987	313310	1456727		0		46304	0	46304			35980			8815			818628			863423	2679764
1988	325462	1812793		5676		118076	120476	244229			38533			6871			817812			863215	3245699
1989	338600	2051517		3386	35108	140720	137033	316247			21100			701			854020			875821	3582185
1990	323089	2148786		6904	4144	191139	168636	370823			34293			157			837609			872059	3714757
1991	346245	2674267		1703	45313	136337	30094	213447			29125						514534			543659	3777618
1992	304243	2907817		0	15022	96660	0	111682			3196						32000	2736		37932	3361674
1993	379467	2856777			2673	130681		133354												0	3369598
1994	222254	3819193			36575	196771		233346												0	4274793
1995	230177	4174016			174393	376600		550993												0	4955186
1996	278439	3604887			56782	438736		495518												0	4378844
1997	104198	2812866			30302	649751		680053												0	3597117
1998	30273	1582639			25900	386946		412846												0	2025758
1999	55654	1164035			19072	184679		203751						7						7	1423447
2000	118734	1115565			7121	296579		303700		2318										2318	1540317
2001	248097	1401836			134011	723733		857744		20090										20090	2527767
2002	108727	1410266			604	154219		154823		76261										76261	1750077
2003	143277	1278019			0	217734		217734		94690					2010		7540		53959	158199	1797229
2004	158656	1292943			0	187369		187369		131020					7438		62300		94685	295443	1934411
2005	165626	1264808			0	80663		80663	867	143000		6187			9126		7040		77356	243576	1754673
2006	155256	1224685			0	277568		277568	481	160000		62137			10474		0		129535	362627	2020136
2007	172701	1130083	7		927	254426		255360	12585	140582		123523	38700		10940		0		112501	438831	1996975
2008	167258	728850	0		0	169537		169537	15245	143182		108174	22919		12600		4800		100066	406986	1472631
2009	134022	700905	0		1935	74694		76629	5681	117963		111921	20213	0	13759	13326	9113		79942	371918	1283474
2010	169012	295796	0		4613	17559		22172	2240	63606		67497	11643	0	8183	40516			45908	239593	726573
2011	30825	216470	0		69153	257241		326394	0	32862	8	2248	0	0	9253	674	8229		7617	60891	634580
2012	13256	214204	0		104	187292		187396	0	13012	0	0	0	0	5492	5346	0		16068	39918	454774
2013	16361	214999	0		3564	77022		80586		8329		10102	0		5267	2670			14809	41177	353123
2014	18219	254295	0		4	74528		74532		21155		20509	0		4078	2223			15324	63289	410335
2015	*36000*	*262100*			*350*	*50000*		*50350*		*29200*		*26500*	*0*		*5750*	*0*	*2500*		*21250*	*85200*	*433650*

Underlined values have been updated relative to the 2014 assessment; the *2015* estimates are preliminary and based on methods described in SC02 report.

Table A8.2. Input catch (tonnes) by fleet (combined) for the stock assessment model. Note that 2015 data are preliminary.

Year	Fleet 1	Fleet 2	Fleet 3	Fleet 4
1970	101,690	10,310	4,710	0
1971	143,450	14,990	9,190	0
1972	64,460	22,550	18,780	5,500
1973	83,200	38,390	42,780	0
1974	164,760	28,750	129,210	0
1975	207,330	53,880	37,900	0
1976	257,700	84,570	54,150	40
1977	226,230	114,570	504,990	2,270
1978	398,410	188,270	386,790	51,290
1979	344,050	253,460	333,810	370,290
1980	288,810	273,450	414,300	339,800
1981	474,820	586,090	445,640	438,120
1982	789,910	704,770	143,720	733,200
1983	301,930	563,340	110,690	894,300
1984	727,000	699,300	200,670	1,059,930
1985	511,150	945,840	114,620	799,320
1986	55,210	1,129,110	51,030	837,500
1987	313,310	1,456,730	46,300	863,420
1988	325,460	1,812,790	244,230	863,220
1989	338,600	2,051,520	316,250	875,820
1990	323,090	2,148,790	370,820	872,060
1991	346,250	2,674,270	213,450	543,660
1992	304,240	2,907,820	111,680	37,930
1993	379,470	2,856,780	133,350	0
1994	222,250	3,819,190	233,350	0
1995	230,180	4,174,020	550,990	0
1996	278,440	3,604,890	495,520	0
1997	104,200	2,812,870	680,050	0
1998	30,270	1,582,640	412,850	0
1999	55,650	1,164,040	203,750	10
2000	118,730	1,115,570	303,700	2,320
2001	248,100	1,401,840	857,740	20,090
2002	108,730	1,410,270	154,820	76,260
2003	143,280	1,278,020	217,730	158,200
2004	158,660	1,292,940	187,370	295,440
2005	165,630	1,264,810	80,660	243,580
2006	155,260	1,224,690	277,570	362,630
2007	172,701	1,130,083	255,360	438,831
2008	167,258	728,850	169,537	406,986
2009	134,022	700,905	76,629	371,918
2010	169,012	295,796	22,172	239,593
2011	30,825	216,470	326,394	60,891
2012	13,256	214,204	187,396	39,918
2013	16,361	214,999	80,586	41,177
2014	18,219	254,295	74,532	63,289
2015	36,000	262,100	50,350	85,200

Table A8.3. Input catch at age for fleet 1. Units are relative value (they are normalized to sum to one for each year in the model). Green shading reflects relative level. Note that 2015 data are preliminary.

	Age group (years)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1975	0	1	2	8	10	28	29	14	5	1	1	0
1976	0	0	0	2	10	30	37	17	3	1	0	0
1977	0	2	3	7	20	33	25	9	1	0	0	0
1978	0	1	8	15	14	9	25	20	7	1	0	0
1979	0	0	4	9	18	22	23	18	6	1	0	0
1980	0	1	3	6	17	23	27	19	4	0	0	0
1981	0	0	2	9	20	24	29	14	3	0	0	0
1982	0	0	1	14	15	20	27	16	5	1	0	0
1983	0	0	0	7	20	29	27	14	3	0	0	0
1984	0	0	11	28	13	13	17	15	3	0	0	0
1985	0	0	4	17	27	29	17	5	1	0	0	0
1986	4	13	12	7	8	15	22	13	5	1	0	0
1987	0	5	40	41	10	2	2	1	0	0	0	0
1988	0	0	11	41	38	9	0	0	0	0	0	0
1989	0	1	1	6	45	38	8	1	0	0	0	0
1990	1	9	1	3	28	48	10	1	0	0	0	0
1991	0	2	20	20	11	17	24	6	0	1	0	0
1992	0	3	21	12	23	23	13	5	1	0	0	0
1993	0	3	62	25	5	4	1	0	0	0	0	0
1994	0	14	34	10	26	13	2	0	0	0	0	0
1995	0	16	32	28	14	8	2	0	0	0	0	0
1996	8	16	31	34	9	2	0	0	0	0	0	0
1997	0	5	55	36	4	0	0	0	0	0	0	0
1998	0	2	57	24	12	4	0	0	0	0	0	0
1999	0	6	72	17	4	1	0	0	0	0	0	0
2000	7	30	17	30	14	2	0	0	0	0	0	0
2001	0	12	63	23	1	0	0	0	0	0	0	0
2002	6	12	47	21	11	2	1	0	0	0	0	0
2003	1	14	55	22	5	2	1	0	0	0	0	0
2004	0	2	13	59	24	1	0	0	0	0	0	0
2005	4	26	38	16	12	4	0	0	0	0	0	0
2006	2	3	33	52	6	2	1	0	0	0	0	0
2007	0	9	32	44	10	3	2	1	0	0	0	0
2008	1	49	24	8	9	8	1	0	0	0	0	0
2009	0	7	29	51	4	8	0	0	0	0	0	0
2010	0	46	5	32	12	3	1	0	0	0	0	0
2011	6	59	28	3	1	2	0	0	0	0	0	0
2012	4	12	15	61	8	0	0	0	0	0	0	0
2013	4	68	26	1	0	0	0	0	0	0	0	0
2014	6	93	1	0	0	0	0	0	0	0	0	0
2015	0	9	0	10	53	16	10	0	2	0	0	0

Table A8.4. Input catch at age for fleet 2. Units are relative value (they are normalized to sum to one in the model). Green shading reflects relative level. Note that 2015 data are preliminary.

	Age group (years)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1975	0	0	1	2	6	18	28	25	14	5	2	0
1976	0	1	0	0	1	14	36	31	14	2	0	0
1977	0	0	0	3	11	19	35	27	4	0	0	0
1978	0	0	1	6	19	31	26	12	3	0	0	0
1979	0	0	1	13	18	18	18	16	11	4	0	0
1980	0	0	1	9	23	25	22	12	6	1	0	0
1981	0	0	0	4	17	31	28	14	4	1	0	0
1982	0	0	0	3	18	24	26	18	7	2	0	0
1983	0	2	4	7	17	25	26	13	5	1	0	0
1984	0	0	4	8	10	23	27	20	7	1	0	0
1985	0	0	1	8	14	25	31	16	4	0	0	0
1986	0	1	1	5	15	24	33	18	3	0	0	0
1987	0	4	9	8	5	15	32	22	4	1	0	0
1988	0	0	3	21	24	10	17	18	6	1	0	0
1989	0	0	0	4	23	32	19	15	6	1	0	0
1990	0	0	0	1	8	26	33	19	11	2	0	0
1991	0	1	2	2	1	7	28	31	16	8	3	1
1992	0	0	1	4	6	7	8	24	21	18	8	3
1993	0	0	4	12	15	14	13	12	14	12	4	1
1994	0	0	1	11	17	18	11	10	15	12	4	0
1995	0	0	4	18	14	25	18	9	6	4	2	0
1996	0	1	11	14	20	18	16	11	5	2	1	0
1997	0	2	17	31	22	11	6	4	4	2	1	0
1998	0	4	28	35	14	6	3	3	3	1	1	0
1999	0	4	37	34	14	5	2	1	1	1	1	1
2000	0	1	15	40	25	10	3	1	1	1	1	1
2001	0	1	10	26	34	16	5	2	2	2	1	2
2002	0	1	12	26	26	16	6	3	2	2	2	3
2003	0	0	6	25	30	20	8	3	2	2	1	1
2004	0	0	4	14	29	29	13	5	3	2	1	1
2005	1	1	1	5	17	39	19	8	5	2	1	1
2006	0	0	1	4	8	21	27	14	10	7	4	3
2007	0	0	1	13	15	11	15	15	13	9	5	4
2008	1	2	0	1	7	21	19	15	11	9	5	9
2009	0	0	4	9	2	19	22	17	11	7	5	4
2010	0	0	4	29	20	10	10	6	9	7	2	2
2011	0	0	1	16	13	35	10	6	13	5	1	1
2012	0	0	0	7	31	31	18	7	4	1	0	0
2013	0	0	2	18	29	33	14	3	0	0	0	0
2014	0	0	4	17	38	24	14	2	0	0	0	0
2015	0	0	9	25	21	17	19	9	1	0	0	0

Table A8.5. Input catch at age for fleet 4. Units are relative value (they are normalized to sum to one for each year in the model). Green shading reflects relative level. Catch-at-age 1979-2013 were calculated considering Age-Length Key from fleet 2. Note that 2015 data are preliminary.

	Age group (years)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**
1979	0	0	0	0	4	13	25	30	19	8	1	0
1980	0	1	1	5	16	24	26	17	9	2	0	0
1981	0	0	0	2	10	24	31	22	8	2	0	0
1982	0	0	0	1	7	20	31	26	11	3	1	1
1983	0	2	4	3	10	23	30	18	7	1	0	0
1984	0	0	2	7	11	19	26	23	9	1	0	0
1985	0	0	1	10	17	25	28	14	5	1	0	0
1986	0	1	2	7	20	25	26	15	3	0	0	0
1987	0	4	5	3	8	24	33	18	4	1	0	0
1988	0	1	4	15	16	16	24	17	6	1	0	0
1989	0	0	1	5	22	27	21	15	8	2	0	0
1990	0	0	0	1	10	33	28	15	10	3	0	0
1991	0	0	0	1	2	16	40	23	10	5	2	1
2000	0	3	18	27	17	11	7	6	5	4	2	0
2001	0	2	15	30	30	14	4	2	2	1	0	0
2002	1	2	20	42	21	9	3	1	1	0	0	0
2003	0	1	18	48	25	7	1	0	0	0	0	0
2006	0	0	0	1	13	37	29	10	5	3	1	0
2007	0	0	0	1	7	22	23	16	15	10	6	0
2008	0	0	0	0	1	11	30	26	16	10	6	0
2009	0	0	1	1	0	2	15	35	25	14	9	0
2010	0	1	29	14	0	0	5	10	19	15	5	0
2011	0	0	1	9	8	17	11	10	24	14	6	0
2012	0	0	0	0	0	0	2	4	50	27	8	8
2013	0	0	1	18	21	25	17	8	3	4	1	1
2014	0	2	28	21	14	14	12	5	2	1	1	1
2015	0	1	35	17	7	6	8	13	7	2	1	3

Table A8.6. Input catch at length for fleet 3. Units are relative value (they are normalized to sum to one for each year in the model). Green shading represents the relative level.

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1980	1	2	2	2	3	2	5	3	2	1	0	0	0	1	1	1	0	0	1	3	3	5	8	12	11	9	7	5	3	2	1	1	1	1	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	9	11	9	10	10	9	8	7	6	4	3	3	2	2	2	1	0	0	0	0	0	0
1982	0	0	1	3	6	6	6	5	4	5	6	4	1	0	0	0	0	0	0	1	1	4	8	12	9	6	3	2	2	2	1	1	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	3	7	15	18	15	13	7	5	3	2	1	1	1	1	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	6	8	8	8	11	11	10	8	6	4	3	2	1	1	1	1	1	0	1	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	4	5	7	7	8	8	7	7	7	7	6	5	3	3	2	2	2	1	2	1	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	2	4	7	10	13	12	12	8	6	5	3	3	2	2	2	1	1	1	0
1987	0	0	0	0	0	0	0	1	0	0	1	1	1	2	2	4	5	8	11	12	10	8	5	3	2	3	4	4	3	2	2	2	1	1	1	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	7	9	10	9	7	5	4	3	3	3	3	3	2	2	2	3	3	2	3	3	2	2	1	1	0
1989	0	0	0	0	0	0	0	0	0	0	0	1	7	10	5	6	4	3	2	2	2	3	4	6	8	8	8	6	4	3	1	1	1	1	1	1	1	1	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	5	6	7	9	12	13	10	8	6	4	3	3	2	1	1	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	2	1	1	1	2	2	3	4	5	5	7	8	8	8	7	6	4	3	3	2	2	2	2	1	1	1
1992	0	0	0	0	0	0	0	0	0	0	1	2	1	1	1	1	1	1	1	2	3	4	7	9	12	11	8	6	6	5	5	4	3	2	1	1	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	1	2	2	3	4	6	9	12	9	7	6	5	5	6	5	5	5	4	2	1	1	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	3	3	5	11	14	11	8	6	4	3	3	3	3	2	3	2	2	2	1	1	1	1	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	4	5	6	7	8	9	11	12	10	6	3	2	2	1	1	1	1	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	1	2	2	2	3	5	6	6	6	6	7	9	8	6	6	5	4	4	3	3	2	1	1	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	7	11	10	5	4	8	14	16	8	4	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	1	2	4	3	2	4	7	16	20	14	8	4	3	2	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	1	1	1	1	1	1	1	2	3	5	7	12	13	16	15	8	5	3	2	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	4	8	7	5	4	4	10	8	7	8	12	11	7	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	1	2	1	1	2	4	7	10	12	16	16	14	9	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	1	3	9	16	19	19	14	7	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	1	1	2	5	7	8	6	5	6	9	10	7	5	4	3	4	5	5	3	2	1	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	6	7	9	12	13	11	8	8	7	5	3	2	1	0	0	0	0	0	0	0	0
2005	0	0	1	1	1	0	0	1	3	6	8	8	10	10	6	3	1	1	1	1	1	0	0	0	0	0	0	0	2	5	9	9	5	3	2	1	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	2	3	6	8	7	8	8	8	7	8	8	8	7	5	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	9	8	5	6	4	3	6	10	12	11	8	6	3	1	1	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	3	10	18	21	17	10	6	3	2	1	2	1	1	0	0	0	0	0	0	0	0	0
2009	1	1	1	1	0	0	0	0	0	0	1	4	4	4	2	2	1	0	1	1	0	0	0	0	0	1	2	5	11	19	20	11	5	1	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	2	0	2	25	49	18	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	8	18	23	24	18	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	15	32	27	14	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	2	2	4	4	11	8	5	2	0	1	1	1	3	12	20	15	4	1	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	5	20	31	19	8	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0

Table A8.7. Input catch at age for acoustic surveys at southern of Chile. Units are relative value (they are normalized to sum to one for each year in the model). Green shading reflects relative level.

	Age group (years)											
	1	2	3	4	5	6	7	8	9	10	11	12+
1997	0	1	39	42	12	3	1	1	1	0	0	0
1998	0	1	48	44	4	1	1	1	1	0	0	0
1999	0	2	29	43	11	6	2	1	3	2	1	0
2000	0	0	10	45	31	11	2	0	0	0	0	0
2001	0	1	21	46	23	6	1	1	1	0	0	0
2002	0	0	6	28	23	30	7	4	1	0	0	0
2003	0	0	3	23	34	26	7	2	2	1	1	0
2004	0	0	1	7	18	23	17	11	9	9	3	1
2005	0	0	0	9	21	42	18	5	2	0	1	1
2006	0	0	0	0	18	43	27	5	3	2	1	1
2007	0	0	0	0	0	7	21	20	19	17	8	8
2008	0	0	0	0	0	10	33	27	12	9	4	5
2009	0	0	0	0	0	0	1	33	21	18	16	12

Table A8.8. Input catch at age for acoustic surveys at northern of Chile. Units are relative value (they are normalized to sum to one for each year in the model). Green shading reflects relative level.

	Age group (years)											
	1	2	3	4	5	6	7	8	9	10	11	12+
2006	12	42	28	16	2	0	0	0	0	0	0	0
2007	0	5	17	55	21	1	0	0	0	0	0	0
2008	0	49	48	1	1	0	0	0	0	0	0	0
2009	0	41	42	16	0	1	0	0	0	0	0	0
2010	0	0	7	71	17	3	1	0	0	0	0	0
2011	0	27	12	50	4	5	1	0	0	0	0	0
2012	0	43	5	17	25	9	1	0	0	0	0	0
2013	11	35	2	17	16	15	4	1	0	0	0	0
2014	30	66	1	1	0	1	1	0	0	0	0	0
2015	62	10	5	15	4	2	1	0	0	0	0	0

Table A8.9. Input catch at age for DEPM surveys at southern of Chile. Units are relative value (they are normalized to sum to one for each year in the model). Green shading reflects relative level.

	Age group (years)											
	1	2	3	4	5	6	7	8	9	10	11	12+
2001	15	36	37	6	3	2	2	1	0	0	0	0
2003	2	15	24	10	16	11	12	6	2	1	0	0
2004	2	15	35	19	9	5	7	5	2	1	0	0
2005	0	0	1	38	24	16	11	5	3	2	0	0
2006	0	0	4	20	31	24	14	5	2	1	0	0
2008	0	0	4	12	22	27	20	9	5	0	0	0

Table A8.10. Index values used within the assessment model.

Year	Chile (1)	Chile (2)	Chile (3)	Chile (4)	Peru(1)	Peru(2)	Peru(3)	China	EU_U	Russia/USSR
1983			0.994							
1984		99	0.912							
1985		324	0.808							
1986		123	0.686		17811	108				
1987		213	0.817		22955	110				55.0
1988		134	0.723		9459	114				58.2
1989			0.713		15034	157				51.1
1990			0.616		14139	230				52.6
1991		242	0.689		16486	232				61.0
1992			0.643		6266	180				
1993			0.578		19659	146				
1994			0.624		10768	95				
1995			0.562		6429	54				
1996			0.567		7271	30				
1997	3530		0.468		2561	32				
1998	3200		0.397		190	44				
1999	4100		0.406	5724	342	53				
2000	5600		0.396	4688	2373	106				
2001	5950		0.477	5627	2052	132		1.47		
2002	3700		0.419		248	97	212.7	2.07		
2003	2640		0.370	1388	1118	67	244.1	1.83		
2004	2640		0.403	3287	864	52	276.6	1.47		
2005	4110		0.369	1043	1025	75	193.2	1.51	141	
2006	3192	112	0.404	3283	1678	111	245.9	1.01	310	
2007	3140	275	0.304	626	522	80	231	1.16	308	
2008	487	259	0.211	1935	223	24	222.6	0.99	256	77.4
2009	328	18	0.176		849		184.2	0.84	200	59.6
2010		440	0.132			7	255.4	0.61	121	
2011		432	0.074		678	35	264.9	0.35	56	45.2
2012		230	0.229		94	50	264.7	0.41		
2013		144	0.191		890	64	139.3	0.57	72	
2014		87	0.160				240.4	0.52	89	
2015		459	0.131						160	

Legend:
Chile (1): Acoustics for south-central zone in Chile
Chile (2): Acoustics for northern zone in Chile
Chile (3): Chilean south-central fishery CPUE for fleet 1
Chile (4): Daily Egg Production Method
Peru(1): Peruvian acoustic index in fleet 3
Peru(2): Peruvian echo-abundance index in fleet 3 (alternative)
Peru(3): Peruvian fishery CPUE in fleet 3
China: Chinese CPUE for fleet 4
EU_U: CPUE for EU in fleet 4
Rus./USSR: Catch per day from Russian/USSR in fleet 4

Table A8.11. Jack mackerel sexual maturity by age used in the JMM models.

Age (yr)	1	2	3	4	5	6	7	8	9	10	11	12
Single Stock	0.070	0.310	0.720	0.930	0.980	0.990	1.000	1.000	1.000	1.000	1.000	1.000
Far North Stock	0.000	0.370	0.980	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table A8.12. Growth parameters and natural mortality.

Parameter	Far North stock	Single stock
L_∞ (cm) (Total length)	80.77	80.77
k	0.16	0.16
t_0 (year)	-0.356	-0.356
M (year^{-1})	0.33	0.23

Table A8.13. Ageing error matrix of jack mackerel.

	1	2	3	4	5	6	7	8	9	10	11	12+
1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.76	0.22	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.24	0.51	0.23	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.02	0.23	0.50	0.23	0.02	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.02	0.23	0.49	0.23	0.02	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.03	0.23	0.48	0.23	0.03	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.03	0.24	0.46	0.24	0.03	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.03	0.24	0.45	0.24	0.03	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.24	0.44	0.24	0.04	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.24	0.43	0.24	0.04
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.24	0.42	0.29
12+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.24	0.71

Table A8.14. Input mean body mass (kg) at age over time assumed for fleet 1.

	1	2	3	4	5	6	7	8	9	10	11	12+
1970	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1971	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1972	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1973	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1974	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1975	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1976	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1977	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1978	0.050	0.105	0.124	0.163	0.204	0.314	0.369	0.405	0.434	0.453	0.590	1.115
1979	0.050	0.108	0.163	0.179	0.217	0.274	0.370	0.420	0.474	0.629	0.633	1.115
1980	0.050	0.069	0.118	0.210	0.256	0.324	0.410	0.451	0.511	0.998	0.880	1.115
1981	0.050	0.094	0.139	0.214	0.269	0.331	0.412	0.481	0.580	0.661	1.112	1.115
1982	0.071	0.093	0.168	0.202	0.248	0.305	0.356	0.411	0.446	0.471	0.719	1.115
1983	0.084	0.099	0.119	0.221	0.264	0.314	0.377	0.429	0.475	0.528	0.540	1.115
1984	0.050	0.164	0.186	0.217	0.273	0.345	0.394	0.437	0.497	0.568	0.786	1.115
1985	0.050	0.167	0.173	0.224	0.271	0.340	0.401	0.465	0.536	0.582	0.726	1.115
1986	0.096	0.099	0.143	0.222	0.289	0.332	0.418	0.497	0.550	0.869	0.880	1.115
1987	0.092	0.121	0.146	0.189	0.233	0.336	0.427	0.477	0.513	0.650	0.803	1.115
1988	0.050	0.110	0.167	0.197	0.230	0.298	0.472	0.545	0.586	0.610	0.880	1.115
1989	0.050	0.123	0.167	0.230	0.270	0.310	0.379	0.491	0.541	0.569	0.713	1.115
1990	0.069	0.099	0.160	0.248	0.290	0.338	0.409	0.533	0.651	0.677	0.756	1.115
1991	0.049	0.121	0.143	0.201	0.277	0.366	0.408	0.478	0.637	0.720	0.794	0.883
1992	0.069	0.092	0.127	0.201	0.268	0.300	0.373	0.444	0.512	0.595	0.681	0.786
1993	0.021	0.116	0.152	0.205	0.298	0.364	0.422	0.489	0.528	0.596	0.774	0.889
1994	0.059	0.097	0.107	0.235	0.291	0.330	0.387	0.459	0.565	0.748	0.798	0.898
1995	0.069	0.101	0.137	0.186	0.263	0.321	0.357	0.434	0.561	0.668	0.880	1.115
1996	0.067	0.000	0.140	0.170	0.229	0.295	0.367	0.507	0.657	0.639	0.880	1.115
1997	0.029	0.063	0.125	0.177	0.246	0.357	0.503	0.615	0.584	0.728	0.880	1.115
1998	0.000	0.082	0.104	0.195	0.249	0.290	0.390	0.475	0.634	0.728	0.880	1.115
1999	0.071	0.074	0.089	0.147	0.270	0.315	0.446	0.722	0.584	0.728	0.880	1.115
2000	0.043	0.054	0.138	0.191	0.225	0.251	0.372	0.488	0.584	0.728	0.880	1.115
2001	0.066	0.093	0.112	0.133	0.204	0.286	0.421	0.488	0.584	0.728	0.880	1.115
2002	0.029	0.059	0.092	0.172	0.238	0.327	0.398	0.416	0.628	0.728	0.880	1.115
2003	0.036	0.082	0.102	0.141	0.227	0.309	0.416	0.464	0.534	0.728	0.880	1.115
2004	0.037	0.078	0.164	0.186	0.203	0.257	0.342	0.488	0.584	0.728	0.880	1.115
2005	0.029	0.076	0.111	0.175	0.222	0.268	0.281	0.488	0.584	0.728	0.880	1.115
2006	0.032	0.074	0.114	0.132	0.204	0.374	0.442	0.506	0.606	0.728	0.880	1.115
2007	0.087	0.075	0.122	0.158	0.222	0.296	0.404	0.514	0.614	0.723	0.723	1.115
2008	0.042	0.047	0.066	0.187	0.243	0.291	0.388	0.563	0.616	0.748	0.880	1.115
2009	0.015	0.047	0.106	0.138	0.239	0.285	0.335	0.526	0.584	0.728	0.880	1.115
2010	0.013	0.048	0.101	0.172	0.233	0.301	0.397	0.493	0.639	0.772	0.880	1.115
2011	0.019	0.065	0.095	0.167	0.276	0.314	0.398	0.488	0.584	0.728	0.880	1.115
2012	0.016	0.048	0.088	0.202	0.235	0.269	0.396	0.488	0.584	0.728	0.880	1.115
2013	0.038	0.052	0.069	0.151	0.255	0.430	0.495	0.664	0.525	0.687	0.821	1.086
2014	0.018	0.040	0.082	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
2015	0.021	0.051	0.087	0.176	0.249	0.325	0.416	0.524	0.583	0.729	0.868	1.109

Table A8.15. Input mean body mass (kg) at age over time assumed for fleet 2.

	1	2	3	4	5	6	7	8	9	10	11	12+
1970	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1971	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1972	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1973	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1974	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1975	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1976	0.052	0.078	0.155	0.214	0.275	0.336	0.394	0.472	0.632	0.714	0.898	1.538
1977	0.055	0.092	0.109	0.236	0.275	0.314	0.375	0.456	0.521	0.732	0.651	1.137
1978	0.052	0.084	0.104	0.147	0.211	0.327	0.394	0.449	0.514	0.583	0.631	1.538
1979	0.052	0.108	0.160	0.199	0.241	0.301	0.388	0.466	0.588	0.871	1.265	1.972
1980	0.026	0.060	0.132	0.231	0.272	0.350	0.447	0.519	0.716	0.820	1.073	1.854
1981	0.052	0.095	0.149	0.242	0.294	0.340	0.407	0.503	0.637	0.765	1.184	1.900
1982	0.055	0.085	0.166	0.207	0.269	0.323	0.378	0.472	0.536	0.644	0.987	1.185
1983	0.070	0.099	0.122	0.230	0.273	0.320	0.374	0.461	0.596	0.709	1.196	1.769
1984	0.035	0.135	0.154	0.185	0.266	0.330	0.383	0.449	0.577	0.685	1.012	1.846
1985	0.058	0.148	0.181	0.223	0.270	0.339	0.398	0.473	0.573	0.796	1.376	1.647
1986	0.073	0.075	0.172	0.247	0.286	0.346	0.427	0.518	0.640	0.844	1.351	2.110
1987	0.076	0.117	0.140	0.191	0.270	0.357	0.434	0.503	0.577	0.689	1.089	1.979
1988	0.100	0.124	0.159	0.197	0.233	0.342	0.444	0.512	0.588	0.750	1.012	1.372
1989	0.052	0.103	0.220	0.241	0.278	0.339	0.467	0.585	0.702	0.779	0.880	1.538
1990	0.064	0.091	0.153	0.264	0.309	0.373	0.461	0.582	0.694	0.835	0.970	1.598
1991	0.037	0.106	0.132	0.186	0.271	0.381	0.451	0.542	0.667	0.787	0.901	1.053
1992	0.063	0.083	0.118	0.177	0.239	0.275	0.409	0.524	0.594	0.709	0.851	1.046
1993	0.011	0.089	0.121	0.181	0.246	0.320	0.408	0.579	0.719	0.853	0.965	1.174
1994	0.041	0.084	0.112	0.224	0.270	0.336	0.462	0.643	0.808	0.868	1.058	1.421
1995	0.070	0.098	0.145	0.192	0.270	0.340	0.429	0.577	0.807	0.965	1.115	1.367
1996	0.061	0.092	0.151	0.191	0.280	0.352	0.524	0.683	0.945	1.216	1.426	1.477
1997	0.104	0.106	0.146	0.201	0.260	0.355	0.495	0.683	0.884	1.088	1.467	1.647
1998	0.084	0.128	0.138	0.178	0.248	0.340	0.545	0.806	1.035	1.246	1.412	1.655
1999	0.090	0.109	0.134	0.174	0.250	0.331	0.465	0.742	1.021	1.258	1.376	1.776
2000	0.043	0.064	0.163	0.196	0.255	0.346	0.466	0.756	0.999	1.141	1.228	1.563
2001	0.066	0.098	0.122	0.179	0.258	0.325	0.461	0.614	0.828	1.074	1.360	1.671
2002	0.031	0.074	0.130	0.200	0.257	0.329	0.445	0.645	0.883	1.102	1.321	1.649
2003	0.036	0.086	0.117	0.186	0.245	0.307	0.400	0.564	0.768	1.005	1.209	1.537
2004	0.034	0.080	0.158	0.193	0.247	0.307	0.387	0.528	0.700	0.897	1.087	1.541
2005	0.029	0.075	0.113	0.196	0.259	0.318	0.399	0.517	0.641	0.767	0.918	1.296
2006	0.033	0.076	0.116	0.141	0.261	0.350	0.419	0.516	0.631	0.752	0.924	1.263
2007	0.086	0.074	0.121	0.172	0.226	0.331	0.431	0.510	0.621	0.756	0.903	1.177
2008	0.036	0.048	0.069	0.186	0.254	0.312	0.416	0.515	0.605	0.719	0.861	1.148
2009	0.014	0.045	0.109	0.142	0.253	0.330	0.411	0.532	0.625	0.764	0.886	1.144
2010	0.014	0.052	0.101	0.175	0.237	0.313	0.415	0.539	0.649	0.787	0.964	1.473
2011	0.019	0.067	0.101	0.190	0.287	0.353	0.466	0.613	0.774	0.923	1.173	1.514
2012	0.007	0.014	0.082	0.202	0.264	0.353	0.476	0.558	0.711	0.912	1.146	1.600
2013	0.054	0.158	0.251	0.260	0.318	0.385	0.450	0.553	0.705	0.829	1.117	1.977
2014	0.052	0.093	0.182	0.247	0.375	0.485	0.534	0.682	1.094	1.281	1.302	1.656
2015	0.029	0.077	0.143	0.215	0.296	0.378	0.468	0.589	0.787	0.946	1.140	1.644

Table A8.16. Input mean body mass (kg) at age over time assumed for fleet 3.

	1	2	3	4	5	6	7	8	9	10	11	12+
1975	0.034	0.136	0.310	0.540	0.808	1.095	1.387	1.674	1.946	2.201	2.434	2.645
1976	0.044	0.160	0.340	0.567	0.822	1.087	1.351	1.606	1.845	2.065	2.266	2.446
1977	0.032	0.130	0.294	0.510	0.760	1.028	1.300	1.566	1.818	2.054	2.270	2.465
1978	0.032	0.129	0.295	0.516	0.774	1.050	1.332	1.608	1.872	2.117	2.343	2.547
1979	0.036	0.138	0.304	0.518	0.762	1.020	1.280	1.532	1.770	1.991	2.193	2.375
1980	0.036	0.136	0.298	0.506	0.743	0.994	1.245	1.490	1.721	1.934	2.130	2.306
1981	0.041	0.148	0.314	0.524	0.758	1.003	1.247	1.481	1.702	1.905	2.089	2.255
1982	0.039	0.144	0.309	0.519	0.755	1.002	1.249	1.488	1.712	1.920	2.108	2.278
1983	0.042	0.138	0.280	0.451	0.638	0.828	1.014	1.191	1.356	1.507	1.643	1.764
1984	0.044	0.156	0.328	0.541	0.778	1.024	1.267	1.501	1.719	1.921	2.103	2.267
1985	0.040	0.149	0.322	0.541	0.789	1.048	1.308	1.558	1.794	2.012	2.211	2.389
1986	0.042	0.151	0.323	0.539	0.781	1.033	1.285	1.527	1.755	1.965	2.156	2.327
1987	0.034	0.132	0.294	0.504	0.745	1.001	1.260	1.512	1.751	1.973	2.176	2.359
1988	0.038	0.145	0.315	0.533	0.780	1.041	1.302	1.554	1.793	2.013	2.215	2.396
1989	0.044	0.158	0.337	0.561	0.812	1.074	1.334	1.585	1.821	2.038	2.236	2.413
1990	0.042	0.150	0.320	0.532	0.769	1.017	1.263	1.499	1.722	1.927	2.113	2.280
1991	0.039	0.142	0.305	0.511	0.743	0.985	1.227	1.461	1.680	1.883	2.068	2.234
1992	0.040	0.148	0.318	0.534	0.776	1.031	1.286	1.531	1.763	1.976	2.171	2.346
1993	0.039	0.147	0.323	0.549	0.807	1.080	1.354	1.620	1.871	2.104	2.317	2.508
1994	0.036	0.147	0.335	0.584	0.874	1.186	1.503	1.813	2.109	2.385	2.638	2.867
1995	0.038	0.146	0.318	0.540	0.792	1.058	1.325	1.583	1.827	2.053	2.260	2.446
1996	0.038	0.145	0.317	0.537	0.788	1.053	1.318	1.576	1.820	2.045	2.251	2.436
1997	0.045	0.152	0.312	0.506	0.720	0.940	1.155	1.361	1.553	1.729	1.889	2.031
1998	0.040	0.140	0.294	0.483	0.693	0.911	1.126	1.333	1.526	1.703	1.864	2.008
1999	0.037	0.146	0.324	0.557	0.824	1.107	1.394	1.673	1.938	2.183	2.408	2.611
2000	0.035	0.145	0.336	0.592	0.893	1.218	1.550	1.877	2.189	2.481	2.750	2.994
2001	0.033	0.139	0.324	0.572	0.864	1.180	1.504	1.822	2.127	2.412	2.674	2.912
2002	0.036	0.145	0.330	0.576	0.861	1.167	1.478	1.783	2.074	2.344	2.593	2.817
2003	0.040	0.154	0.341	0.584	0.862	1.157	1.454	1.743	2.017	2.272	2.504	2.714
2004	0.038	0.149	0.333	0.574	0.852	1.148	1.447	1.740	2.017	2.275	2.511	2.724
2005	0.037	0.150	0.341	0.595	0.890	1.206	1.527	1.842	2.142	2.422	2.678	2.911
2006	0.038	0.152	0.347	0.606	0.907	1.230	1.558	1.880	2.187	2.473	2.735	2.973
2007	0.038	0.149	0.335	0.579	0.861	1.161	1.465	1.762	2.044	2.306	2.546	2.763
2008	0.036	0.146	0.334	0.585	0.876	1.190	1.510	1.823	2.122	2.400	2.656	2.888
2009	0.038	0.150	0.337	0.582	0.865	1.167	1.474	1.773	2.057	2.321	2.563	2.782
2010	0.039	0.150	0.332	0.567	0.837	1.123	1.411	1.691	1.956	2.203	2.428	2.631
2011	0.031	0.143	0.351	0.644	1.000	1.395	1.806	2.217	2.614	2.990	3.337	3.655
2012	0.032	0.145	0.349	0.632	0.971	1.344	1.731	2.115	2.485	2.834	3.156	3.449
2013	0.032	0.145	0.349	0.632	0.971	1.344	1.731	2.115	2.485	2.834	3.156	3.449
2014	0.032	0.145	0.349	0.632	0.971	1.344	1.731	2.115	2.485	2.834	3.156	3.449
2015	0.033	0.146	0.346	0.621	0.950	1.310	1.682	2.051	2.405	2.739	3.047	3.327

Table A8.17. Input mean body mass (kg) at age over time assumed for fleet 4. Weight-at-age 1970-2013 were assumed to be similar than fleet 2

	1	2	3	4	5	6	7	8	9	10	11	12+
1970	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1971	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1972	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1973	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1974	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1975	0.052	0.093	0.131	0.178	0.262	0.294	0.340	0.396	0.549	0.738	0.984	1.093
1976	0.052	0.078	0.155	0.214	0.275	0.336	0.394	0.472	0.632	0.714	0.898	1.538
1977	0.055	0.092	0.109	0.236	0.275	0.314	0.375	0.456	0.521	0.732	0.651	1.137
1978	0.052	0.084	0.104	0.147	0.211	0.327	0.394	0.449	0.514	0.583	0.631	1.538
1979	0.052	0.108	0.160	0.199	0.241	0.301	0.388	0.466	0.588	0.871	1.265	1.972
1980	0.026	0.060	0.132	0.231	0.272	0.350	0.447	0.519	0.716	0.820	1.073	1.854
1981	0.052	0.095	0.149	0.242	0.294	0.340	0.407	0.503	0.637	0.765	1.184	1.900
1982	0.055	0.085	0.166	0.207	0.269	0.323	0.378	0.472	0.536	0.644	0.987	1.185
1983	0.070	0.099	0.122	0.230	0.273	0.320	0.374	0.461	0.596	0.709	1.196	1.769
1984	0.035	0.135	0.154	0.185	0.266	0.330	0.383	0.449	0.577	0.685	1.012	1.846
1985	0.058	0.148	0.181	0.223	0.270	0.339	0.398	0.473	0.573	0.796	1.376	1.647
1986	0.073	0.075	0.172	0.247	0.286	0.346	0.427	0.518	0.640	0.844	1.351	2.110
1987	0.076	0.117	0.140	0.191	0.270	0.357	0.434	0.503	0.577	0.689	1.089	1.979
1988	0.100	0.124	0.159	0.197	0.233	0.342	0.444	0.512	0.588	0.750	1.012	1.372
1989	0.052	0.103	0.220	0.241	0.278	0.339	0.467	0.585	0.702	0.779	0.880	1.538
1990	0.064	0.091	0.153	0.264	0.309	0.373	0.461	0.582	0.694	0.835	0.970	1.598
1991	0.037	0.106	0.132	0.186	0.271	0.381	0.451	0.542	0.667	0.787	0.901	1.053
1992	0.063	0.083	0.118	0.177	0.239	0.275	0.409	0.524	0.594	0.709	0.851	1.046
1993	0.011	0.089	0.121	0.181	0.246	0.320	0.408	0.579	0.719	0.853	0.965	1.174
1994	0.041	0.084	0.112	0.224	0.270	0.336	0.462	0.643	0.808	0.868	1.058	1.421
1995	0.070	0.098	0.145	0.192	0.270	0.340	0.429	0.577	0.807	0.965	1.115	1.367
1996	0.061	0.092	0.151	0.191	0.280	0.352	0.524	0.683	0.945	1.216	1.426	1.477
1997	0.104	0.106	0.146	0.201	0.260	0.355	0.495	0.683	0.884	1.088	1.467	1.647
1998	0.084	0.128	0.138	0.178	0.248	0.340	0.545	0.806	1.035	1.246	1.412	1.655
1999	0.090	0.109	0.134	0.174	0.250	0.331	0.465	0.742	1.021	1.258	1.376	1.776
2000	0.043	0.064	0.163	0.196	0.255	0.346	0.466	0.756	0.999	1.141	1.228	1.563
2001	0.066	0.098	0.122	0.179	0.258	0.325	0.461	0.614	0.828	1.074	1.360	1.671
2002	0.031	0.074	0.130	0.200	0.257	0.329	0.445	0.645	0.883	1.102	1.321	1.649
2003	0.036	0.086	0.117	0.186	0.245	0.307	0.400	0.564	0.768	1.005	1.209	1.537
2004	0.034	0.080	0.158	0.193	0.247	0.307	0.387	0.528	0.700	0.897	1.087	1.541
2005	0.029	0.075	0.113	0.196	0.259	0.318	0.399	0.517	0.641	0.767	0.918	1.296
2006	0.033	0.076	0.116	0.141	0.261	0.350	0.419	0.516	0.631	0.752	0.924	1.263
2007	0.086	0.074	0.121	0.172	0.226	0.331	0.431	0.510	0.621	0.756	0.903	1.177
2008	0.036	0.048	0.069	0.186	0.254	0.312	0.416	0.515	0.605	0.719	0.861	1.148
2009	0.014	0.045	0.109	0.142	0.253	0.330	0.411	0.532	0.625	0.764	0.886	1.144
2010	0.014	0.052	0.101	0.175	0.237	0.313	0.415	0.539	0.649	0.787	0.964	1.473
2011	0.019	0.067	0.101	0.190	0.287	0.353	0.466	0.613	0.774	0.923	1.173	1.514
2012	0.007	0.014	0.082	0.202	0.264	0.353	0.476	0.558	0.711	0.912	1.146	1.600
2013	0.052	0.125	0.268	0.263	0.310	0.362	0.431	0.507	0.678	0.726	0.936	1.143
2014	0.026	0.128	0.253	0.334	0.439	0.515	0.602	0.780	0.895	0.989	1.086	1.251
2015	0.024	0.206	0.226	0.260	0.436	0.546	0.687	0.783	0.885	1.045	1.122	1.241

Table A8.18. Years and types of information used in the JJM assessment models.

Fleet	Catch-at-age	Catch-at-length	Landings	CPUE	Acoustic	DEPM
North Chile purse seine	1975-2015	-	1970-2015	-	Index: 1984-1988; 1991; 2006-2015 Age comps: 2006-2015	Index: 1999-2008 Age comps: 2001-2008
South-central Chile purse seine	1975-2015	-	1970-2015	1983-2015	1997-2009 Age comps: 1997-2009	-
FarNorth	-	1980-2014	1970-2015	2002-2009, 2011-2013	1983-2013	-
International trawl off Chile	1979-1991 2014-2015	2007-2013*	1978-2015	China (2001-2014); EU & Vanuatu (2005-2011; 2013-2015); Russian (1987-1991, 2008-09, 2011)	-	-

(*)Are converted to age using age-length keys of central-southern area off Chile

Table A8.19. Symbols and definitions used for model equations.

General Definitions	Symbol/Value	Use in Catch at Age Model
Year index: i = {1970, …., 2015}	I	
Age index: j = { 1,2,…, 12^{+}}	J	
length index: l = { 10,11,…, 50}	l	
Mean length at age	L_j	
Variation coefficient the length at age	cv	
Mean weight in year t by age j	$W_{t,j}$	
Maximum age beyond which selectivity is constant	$Maxage$	Selectivity parameterization
Instantaneous Natural Mortality	M	Fixed M=0.23, constant over all ages
Proportion females mature at age j	p_j	Definition of spawning biomass
Ageing error matrix	T	
Proportion of length at some age	Γ	Transform from age to length
Sample size for proportion in year i	T_i	Scales multinomial assumption about estimates of proportion at age
Survey catchability coefficient	q^s	Prior distribution = lognormal(μ_q^s , σ_q^2)
Stock-recruitment parameters	R_0	Unfished equilibrium recruitment
	h	Stock-recruitment steepness
	σ_R^2	Recruitment variance
Unfished biomass	φ	Spawning biomass per recruit when there is not fishing
Estimated parameters		
$\phi_i(\#), R_0, h, \varepsilon_i(\#), \mu^f, \mu^s, M, \eta_j^s(\#), \eta_j^f$		

Note that the number of selectivity parameters estimated depends on the model configuration.

Table A8.20. Variables and equations describing implementation of the joint jack mackerel assessment model (JJM).

Eq	Description	Symbol/Constraints	Key Equation(s)
1)	Survey abundance index (s) by year (Δ^s represents the fraction of the year when the survey occurs)	I_i^s	$I_i^s = q^s \sum_{j=1}^{12} N_{ij} W_{ij} S_j^s e^{-\Delta^s Z_{ij}}$
2)	Catch biomass by year and age/length	$\hat{C}_{il}, \hat{C}_{ij}, \hat{Y}_i$	$\hat{C}_{i,j'}^f = T\left[N_{i,j}\frac{F_{i,j}}{Z_{i,j}}\left(1-e^{-Z_{i,j}}\right)\right]$ $\hat{Y}_i = \sum_{j=1}^{12+} \hat{C}_{i,j}^f w_{i,j}^f$ $\hat{C}_{il} = \Gamma_{l,j}\hat{C}_{ij}$ $\Gamma_{l,j} = \int_j^{j+1} e^{-\frac{1}{2\sigma_j^2}(l-L_j)^2} dl$ $L_j = L_{00}(1-e^{-k}) + e^{-k}L_{j-1}$ $\sigma_j = cv\, L_j$
3)	Proportion at age j, in year i	$P_{ij}, \sum_{j=1}^{12} P_{ij} = 1.0$	$p_{ij}^f = \frac{\hat{C}_{ij}^f}{\sum_j \hat{C}_{ij}^f}$ $p_{ij}^s = \frac{N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}{\sum_j N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}$
	Proportion at length l, in year i	$P_{il}, \sum_{l=10}^{50} P_{il} = 1.0$	$P_{il} = \frac{C_{il}}{\sum_{l=10}^{50} C_{il}}$
4)	Initial numbers at age	j = 1	$N_{1970,j} = e^{\mu_R + \varepsilon_{1970}}$
5)		1 < j < 11	$N_{1970,j} = e^{\mu_R + \varepsilon_{1971-j}} \prod_{j=1}^{j} e^{-M}$
6)		j = 12+	$N_{1970,12} = N_{1970,11}\left(1-e^{-M}\right)^{-1}$
7)	Subsequent years (i >1970)	j = 1	$N_{i,1} = e^{\mu_R + \varepsilon_i}$
8)		1 < j < 11	$N_{i,j} = N_{i-1,j-1} e^{-Z_{i-1,j-1}}$
9)		j = 12+	$N_{i,12^+} = N_{i-1,11}\, e^{-Z_{i-1,10}} + N_{i-1,12}\, e^{-Z_{i-1,11}}$
10)	Year effect and individuals at age 1 and i = 1958, …, 2014	$\varepsilon_i, \sum_{i=1958}^{2015} \varepsilon_i = 0$	$N_{i,1} = e^{\mu_R + \varepsilon_i}$
11)	Index catchability	μ^s, μ^f	$q_i^s = e^{\mu^s}$
	Mean effect		$s_j^s = e^{\eta_j^s}$ $j \le \text{maxage}$
	Age effect	$\eta^s{}_j, \sum_{j=1958}^{2015} \eta^s{}_j = 0$	$s_j^s = e^{\eta_{\text{maxage}}^s}$ $j > \text{maxage}$

12)	Instantaneous fishing mortality		$F_{ij}^{f} = e^{\mu^{f} + \eta_j^{f} + \phi_i}$
13)	Mean fishing effect	μ^{f}	
14)	Annual effect of fishing mortality in year i	$\varphi_i, \sum_{i=1970}^{2015} \varphi_i = 0$	
15)	age effect of fishing (regularized) In year time variation allowed	$\eta^{f}{}_{j}, \sum_{j=1958}^{2015} \eta^{f}{}_{j} = 0$	$s_{ij}^{f} = e^{\eta_j^{f}}$ $j \le \text{maxage}$ $s_{ij}^{f} = e^{\eta_{\text{maxage}}^{f}}$ $j > \text{maxage}$
	In years where selectivity is constant over time	$\eta_{i,j}^{f} = \eta_{i-1,j}^{f}$	$i \neq \text{change year}$
16)	Natural Mortality	M	fixed
17)	Total mortality		$Z_{ij} = \sum_{f} F_{ij}^{f} + M$
17)	Spawning biomass (note spawning taken to occur at mid of November)	B_i	$B_i = \sum_{j=2}^{12} N_{ij} e^{-\frac{10,5}{12} Z_{ij}} W_{ij} p_j$
18)	Recruitments (Beverton-Holt form) at age 1.	$\tilde{R}_i$	$\tilde{R}_i = \dfrac{\alpha B_t}{\beta + B_i}$, $\alpha = \dfrac{4hR_0}{5h-1}$ and $\beta = \dfrac{B_0(1-h)}{5h-1}$ where $B_0 = R_0 \varphi$ $\varphi = \sum_{j=1}^{12} e^{-M(j-1)} W_j p_j + \dfrac{e^{-12M} W_{12} p_{12}}{1-e^{-M}}$ h=0.8

Table A8.21. Specification of objective function that is minimized (i.e., the penalized negative of the log-likelihood).

	Likelihood /penalty component		Description / notes
19)	Abundance indices	$L_1 = 0.5 \sum_s \frac{1}{cv_s^2} \sum_j log\left(\frac{I_j}{\hat{I}_j}\right)^2$	Surveys / CPUE indexes
20)	Prior on smoothness for selectivities	$L_2 = \sum_l \lambda_2^l \sum_{j=1}^{12} \left(\eta_{j+2}^l + \eta_j^l - 2\eta_{j+1}^l\right)^2$	Smoothness (second differencing), Note: *l={s,* or *f}* for survey and fishery selectivity
21)	Prior on recruitment regularity	$L_3 = \lambda_3 \sum_{j=1958}^{2013} \varepsilon^2{}_j$	Influences estimates where data are lacking (e.g., if no signal of recruitment strength is available, then the recruitment estimate will converge to median value).
22)	Catch biomass likelihood	$L_4 = 0.5 \sum_f \frac{1}{cv_f^2} \sum_{j=1970}^{2015} log\left(\frac{C^f{}_j}{\hat{C}^f{}_j}\right)^2$	Fit to catch biomass in each year
23)	Proportion at age/length likelihood	$L_5 = -\sum_{v,i,j} n^v P_{i,j/l}^v \log(\hat{P}_{i,j/l}^v)$	*v={s, f}* for survey and fishery age composition observations $P_{i,j/l}$ are the catch-at-age/length proportions n effective sample size
24)	Fishing mortality regularity	F values constrained between 0 and 5	(relaxed in final phases of estimation)
25)	Recruitment curve fit	$L_6 = \frac{0.5}{cv_r^2} \sum_{j=1970}^{2013} log\left(\frac{N_{i,1}}{\tilde{R}_i}\right)^2$	Conditioning on stock-recruitment curve over period 1977-2013.
26)	Priors or assumptions	R_0 non-informative	(Explored alternative values of σ_R^2)
27)	Overall objective function to be minimized	$\dot{L} = \sum_k L_k$	

Table A8.22. Coefficients of variation and sample sizes used in likelihood functions.

Abundance index	cv	Catch biomass likelihood	cv
Acoustic CS- Chile	0.20	N-Chile	0.05
Acoustic N-Chile	0.50	CS- Chile	0.05
CPUE – Chile	0.15	Farnorth	0.05
DEPM – Chile	0.50	Offshore	0.05
Acoustic-Peru	0.20		
CPUE – Peru	0.20		
CPUE- China	0.20		
CPUE-EU	0.20		
CPUE- ex USSR	0.40		
Smoothness for selectivities (indexes)	**λ**	**Proportion at age likelihood (indexes)**	**n**
Acoustic CS- Chile	100	Acoustic CS- Chile	30
Acoustic N-Chile	100	Acoustic N- Chile	30
CPUE – Chile	100	DEPM – Chile	20
CPUE- China	100		
CPUE-EU	100		
CPUE ex-USSR	100		
Smoothness for selectivities (fleets)	**λ**	**Proportion at age likelihood**	**n**
N-Chile	1	N-Chile	20
CS- Chile	25	CS- Chile	50
Farnorth	12.5	Farnorth	30
Offshore	12.5	Offshore	30
Recruitment regularity	**λ**	**S-Recruitment curve fit**	**cv**
	1.4		0.6

Table A8.23. Description of JJM model components and how selectivity was treated (Far North Stock).

Item	Description	Selectivity assumption
Fisheries		
1)	Peruvian and Ecuadorian area fishery	Estimated from length composition data (converted to age inside the model). Annual variations were considered since 1984
Index series		
2)	Acoustic survey in Peru	Completely available since 3 yrs old.
3)	Peruvian fishery CPUE	Assumed to be the same as 1)

Table A8.24. Description of JJM model components and how selectivity was treated (South stock).

Item	Description	Selectivity assumption
Fisheries		
1)	Chilean northern area fishery	Estimated from age composition data. Annual variations were considered since 1984
2)	Chilean central and southern area fishery	Estimated from age composition data. Annual variations were considered since 1984.
3)	Offshore trawl fishery	Estimated from age composition data. Annual variations were considered since 1984.
Index series		
4)	Acoustic survey in central and southern Chile	Estimated from age composition data. Two time-blocks were considered 1970-2004; 2005-2009.
5)	Acoustic survey in northern Chile	Estimated from age composition data. Annual variations were considered since 1984.
6)	Central and southern fishery CPUE	Assumed to be the same as 2)
7)	Egg production survey	Estimated from age composition data. Two time-blocks were considered 1970-2002; 2003-2008.
8)	Chinese fleet CPUE (from FAO workshop)	Assumed to be the same as 3)
9)	Vanuatu & EU fleets CPUE	Assumed to be the same as 3)
10)	ex-USSR CPUE	Assumed to be the same as 3) but for earlier period

Table A8.25. Description of JJM model components and how selectivity was treated for the single stock cases.

Item	Description	Selectivity assumption
Fisheries		
1)	Chilean northern area fishery	Estimated from age composition data. Annual variations were considered since 1984
2)	Chilean central and southern area fishery	Estimated from age composition data. Annual variations were considered since 1984.
3)	Peruvian and Ecuadorian area fishery	Estimated from length composition data (converted to age inside the model). Two time-blocks were considered, before and after 2002.
4)	Offshore trawl fishery	Estimated from age composition data. Annual variations were considered since 1984.
Index series		
5)	Acoustic survey in central and southern Chile	Estimated from age composition data. Two time-blocks were considered 1970-2004; 2005-2015.
6)	Acoustic survey in northern Chile	Assumed to be the same as 1)
7)	Central and southern fishery CPUE	Assumed to be the same as 2)
8)	Egg production survey	Estimated from age composition data. Two time-blocks were considered 1970-2002; 2003-2015.
9)	Acoustic survey in Peru	Assumed to be the same as 3)
10)	Peruvian fishery CPUE	Assumed to be the same as 3)
11)	Chinese fleet CPUE (from FAO workshop)	Assumed to be the same as 4)
12)	Vanuatu & EU fleets CPUE	Assumed to be the same as 4)
13)	ex-USSR CPUE	Assumed to be the same as 4) but for earlier period

Table A8.26. Systematic model progression from the 2014 assessment data to the agreed revised datasets for 2015. Note that the data file names corresponding to each model follow the convention e.g., “Mod0.1.dat” and “Mod0.1.ctl”.

Model	**Description**
mod0.0.dat (ctl)	Identical to the 2014 final assessment data
mod0.1.dat (ctl)	Identical to the 2014 final assessment data but with updated catch series
mod0.2.dat (ctl)	Identical to the 2014 final assessment data extended to 2015 with updated catch only
mod0.3.dat (ctl)	As in mod0.2 but series and data added (except revised EU age and CPUE data)
mod0.4.dat (ctl)	As in mod0.2 but all series and data added

Table A8.27. Estimated begin-year numbers at age (Model 0.4), 1970-2014. Green shading reflects relative level.

Year	1	2	3	4	5	6	7	8	9	10	11	12+
1970	8,094	5,309	3,399	1,920	1,453	1,226	1,037	907	794	693	602	5,411
1971	5,494	6,429	4,216	2,695	1,520	1,144	948	777	694	624	546	4,732
1972	10,204	4,364	5,103	3,338	2,130	1,191	871	686	581	541	488	4,129
1973	8,955	8,102	3,461	4,031	2,639	1,676	921	650	519	456	426	3,634
1974	9,132	7,104	6,413	2,715	3,173	2,068	1,281	671	482	404	358	3,188
1975	20,578	7,226	5,589	4,927	2,111	2,465	1,552	899	490	373	315	2,759
1976	22,263	16,329	5,723	4,392	3,871	1,638	1,824	1,053	639	377	290	2,384
1977	18,968	17,661	12,923	4,486	3,441	2,986	1,191	1,190	728	488	291	2,062
1978	25,328	14,910	13,680	9,427	3,390	2,621	2,151	767	803	551	375	1,809
1979	19,221	19,984	11,651	10,274	7,187	2,538	1,757	1,161	450	587	413	1,635
1980	23,787	15,183	15,658	8,829	7,865	5,359	1,643	815	559	316	424	1,480
1981	29,450	18,776	11,877	11,800	6,764	5,932	3,602	852	447	402	233	1,405
1982	32,701	23,273	14,686	8,887	8,992	5,006	3,742	1,606	404	308	290	1,183
1983	21,140	25,894	18,377	11,403	6,803	6,404	2,720	1,115	526	247	200	958
1984	59,789	16,778	20,494	14,350	8,841	5,002	3,831	1,013	409	321	159	747
1985	66,290	47,439	13,242	15,846	10,870	6,201	2,715	1,102	295	207	174	492
1986	17,933	52,616	37,540	10,341	12,069	7,683	3,418	862	347	144	112	360
1987	21,339	14,242	41,728	29,611	8,038	8,952	4,825	1,356	295	166	79	258
1988	27,968	16,939	11,264	32,643	22,615	5,870	5,701	1,942	414	114	75	152
1989	15,874	22,168	13,234	8,672	24,596	16,065	3,694	2,620	580	125	40	80
1990	29,719	12,578	17,336	10,128	6,551	17,637	10,218	1,900	1,004	183	40	38
1991	19,494	23,552	9,876	13,235	7,581	4,754	11,770	5,809	832	345	56	24
1992	25,788	15,455	18,532	7,581	9,855	5,476	3,222	6,924	2,577	272	100	23
1993	16,791	20,450	12,163	14,228	5,608	6,985	3,686	1,973	3,335	757	71	32
1994	19,069	13,307	15,985	9,131	10,134	3,774	4,450	2,196	1,010	1,300	188	26
1995	30,507	15,107	10,389	11,862	6,265	6,116	2,059	2,231	890	287	267	44
1996	18,894	24,090	11,537	7,054	6,841	2,709	2,309	732	683	206	54	59
1997	30,168	14,877	18,085	7,449	3,272	1,947	756	695	222	185	54	30
1998	24,433	23,754	11,081	11,155	2,109	542	457	244	232	68	54	24
1999	33,905	19,161	17,746	7,674	4,570	711	229	221	120	108	30	34
2000	41,323	26,764	14,669	12,781	4,027	2,178	379	132	129	67	55	33
2001	12,862	32,545	20,263	10,800	7,994	2,109	1,227	229	80	74	35	45
2002	19,659	9,972	23,082	14,105	6,817	3,980	1,079	687	129	41	33	35
2003	3,683	15,497	7,708	17,345	9,574	3,839	2,218	628	388	62	16	26
2004	8,322	2,887	11,781	5,671	12,117	5,844	2,218	1,329	362	183	22	15
2005	4,851	6,529	2,200	8,595	3,940	7,799	3,389	1,291	745	159	60	12
2006	5,992	3,795	4,897	1,550	5,967	2,640	4,712	1,968	723	341	54	25
2007	8,024	4,651	2,665	3,114	1,022	4,003	1,621	2,577	1,014	301	114	26
2008	3,945	6,270	3,348	1,567	1,795	627	2,398	875	1,183	356	82	38
2009	8,842	3,085	4,375	1,912	903	1,070	352	1,284	404	453	102	35
2010	5,181	6,959	2,279	2,845	1,085	445	471	156	460	125	107	32
2011	5,085	4,078	5,220	1,535	1,572	558	212	240	69	151	36	40
2012	9,828	4,005	2,977	3,459	1,084	1,051	297	117	139	36	73	37
2013	10,887	7,782	3,104	2,059	2,579	740	559	179	75	84	21	65
2014	7,098	8,622	6,073	2,311	1,560	1,778	465	368	120	47	51	52
2015	12,489	5,600	6,709	4,622	1,748	1,088	1,224	325	254	74	26	56

Table A8.28. Estimated total fishing mortality at age (Model 2.0), 1970-2014. Green shading reflects relative level.

Year	1	2	3	4	5	6	7	8	9	10	11	12+
1970	0.000	0.001	0.002	0.003	0.009	0.027	0.059	0.037	0.011	0.010	0.010	0.010
1971	0.000	0.001	0.004	0.006	0.014	0.042	0.094	0.060	0.018	0.015	0.015	0.015
1972	0.001	0.002	0.006	0.005	0.009	0.028	0.063	0.049	0.013	0.009	0.009	0.009
1973	0.002	0.004	0.013	0.009	0.014	0.039	0.087	0.069	0.019	0.012	0.012	0.012
1974	0.004	0.010	0.033	0.022	0.023	0.057	0.123	0.083	0.025	0.021	0.021	0.021
1975	0.001	0.003	0.011	0.011	0.024	0.071	0.158	0.111	0.032	0.024	0.024	0.024
1976	0.002	0.004	0.013	0.014	0.030	0.089	0.197	0.139	0.040	0.030	0.030	0.030
1977	0.011	0.025	0.085	0.050	0.042	0.098	0.211	0.164	0.048	0.033	0.033	0.033
1978	0.007	0.017	0.056	0.041	0.059	0.170	0.386	0.303	0.084	0.060	0.060	0.060
1979	0.006	0.014	0.047	0.037	0.064	0.205	0.539	0.501	0.125	0.094	0.094	0.094
1980	0.007	0.016	0.053	0.036	0.052	0.167	0.427	0.371	0.101	0.074	0.074	0.074
1981	0.005	0.016	0.060	0.042	0.071	0.231	0.578	0.516	0.143	0.096	0.096	0.096
1982	0.003	0.006	0.023	0.037	0.109	0.380	0.980	0.886	0.263	0.200	0.200	0.200
1983	0.001	0.004	0.017	0.024	0.078	0.284	0.758	0.774	0.263	0.209	0.209	0.209
1984	0.001	0.007	0.027	0.048	0.125	0.381	1.016	1.002	0.452	0.382	0.382	0.382
1985	0.001	0.004	0.017	0.042	0.117	0.366	0.917	0.925	0.492	0.386	0.386	0.386
1986	0.000	0.002	0.007	0.022	0.069	0.235	0.694	0.843	0.507	0.372	0.372	0.372
1987	0.001	0.005	0.016	0.040	0.084	0.221	0.680	0.957	0.719	0.565	0.565	0.565
1988	0.002	0.017	0.031	0.053	0.112	0.233	0.548	0.978	0.970	0.817	0.817	0.817
1989	0.003	0.016	0.037	0.051	0.103	0.222	0.435	0.729	0.924	0.907	0.907	0.907
1990	0.003	0.012	0.040	0.060	0.090	0.174	0.335	0.595	0.839	0.947	0.947	0.947
1991	0.002	0.010	0.034	0.065	0.095	0.159	0.301	0.583	0.888	1.004	1.004	1.004
1992	0.002	0.010	0.034	0.072	0.114	0.166	0.260	0.501	0.995	1.113	1.113	1.113
1993	0.003	0.016	0.057	0.109	0.166	0.221	0.288	0.440	0.712	1.161	1.161	1.161
1994	0.003	0.018	0.068	0.147	0.275	0.376	0.460	0.673	1.029	1.354	1.354	1.354
1995	0.006	0.040	0.157	0.320	0.609	0.744	0.804	0.954	1.234	1.437	1.437	1.437
1996	0.009	0.057	0.208	0.538	1.027	1.046	0.970	0.962	1.074	1.101	1.101	1.101
1997	0.009	0.065	0.253	1.032	1.567	1.219	0.902	0.869	0.953	1.007	1.007	1.007
1998	0.013	0.062	0.137	0.662	0.857	0.633	0.497	0.475	0.533	0.600	0.600	0.600
1999	0.007	0.037	0.098	0.415	0.511	0.400	0.319	0.304	0.360	0.442	0.442	0.442
2000	0.009	0.048	0.076	0.239	0.417	0.344	0.275	0.268	0.329	0.428	0.428	0.428
2001	0.025	0.114	0.132	0.230	0.467	0.440	0.350	0.343	0.440	0.585	0.585	0.585
2002	0.008	0.028	0.056	0.158	0.344	0.355	0.312	0.341	0.504	0.737	0.737	0.737
2003	0.014	0.044	0.077	0.129	0.264	0.319	0.282	0.319	0.522	0.819	0.819	0.819
2004	0.013	0.042	0.085	0.134	0.211	0.315	0.311	0.349	0.595	0.885	0.885	0.885
2005	0.016	0.058	0.120	0.135	0.170	0.274	0.314	0.350	0.551	0.845	0.845	0.845
2006	0.023	0.123	0.223	0.187	0.169	0.258	0.373	0.433	0.646	0.868	0.868	0.868
2007	0.017	0.099	0.302	0.321	0.258	0.282	0.386	0.549	0.817	1.065	1.065	1.065
2008	0.016	0.130	0.330	0.321	0.287	0.349	0.395	0.544	0.729	1.018	1.018	1.018
2009	0.009	0.073	0.200	0.337	0.477	0.591	0.580	0.797	0.945	1.217	1.217	1.217
2010	0.010	0.058	0.165	0.363	0.436	0.511	0.443	0.587	0.886	1.016	1.016	1.016
2011	0.009	0.085	0.182	0.118	0.172	0.401	0.361	0.314	0.432	0.493	0.493	0.493
2012	0.003	0.025	0.139	0.064	0.151	0.401	0.275	0.213	0.274	0.295	0.295	0.295
2013	0.003	0.018	0.065	0.048	0.142	0.234	0.189	0.172	0.234	0.280	0.280	0.280
2014	0.007	0.021	0.043	0.050	0.130	0.144	0.130	0.141	0.250	0.364	0.364	0.364
2015	0.011	0.012	0.032	0.055	0.116	0.128	0.118	0.144	0.257	0.430	0.430	0.430

Table A8.29. Spawning biomass point estimates of jack mackerel from last three SPRFMO scientific Committee (SC) meetings.

	Spawning biomass		
	SC01	SC02	SC03
1970	8,761	6,629	10,082
1971	8,112	6,303	9,164
1972	7,818	6,105	8,527
1973	7,726	5,958	8,042
1974	7,676	5,861	7,673
1975	7,763	5,852	7,446
1976	8,141	6,039	7,454
1977	8,810	6,558	7,808
1978	9,551	7,124	8,224
1979	10,189	7,590	8,553
1980	10,854	8,256	9,085
1981	11,171	8,505	9,213
1982	10,806	8,110	8,679
1983	11,092	8,494	8,926
1984	11,122	8,629	8,942
1985	11,554	9,338	9,557
1986	13,159	11,352	11,531
1987	14,919	13,281	13,459
1988	15,496	13,714	13,895
1989	15,050	13,080	13,256
1990	14,228	12,204	12,371
1991	13,098	11,029	11,197
1992	11,909	9,854	10,018
1993	10,802	8,939	9,082
1994	9,271	7,516	7,634
1995	7,154	5,445	5,532
1996	5,819	3,817	3,862
1997	4,950	2,986	2,965
1998	4,985	3,152	3,074
1999	5,668	3,928	3,795
2000	6,671	5,008	4,834
2001	7,481	5,883	5,690
2002	8,083	6,692	6,544
2003	8,201	6,947	6,848
2004	7,641	6,560	6,475
2005	6,708	5,760	5,676
2006	5,486	4,679	4,595
2007	4,119	3,428	3,324
2008	3,067	2,543	2,382
2009	2,130	1,849	1,598
2010	1,709	1,648	1,291
2011	1,855	1,865	1,382
2012	2,304	2,126	1,552
2013	3,085	2,402	1,814
2014		2,767	2,222
2015			2,720

Table A8.30. Summary table of key “updated” model results computed at SC03.

	Landings	SSB (thousand tonnes)	Recruitment (age 1)	F (average 1-12)	Fmsy	Bmsy
1970	117	10,082	8,094	0.01	0.23	4,370
1971	168	9,164	5,494	0.02	0.23	4,329
1972	111	8,527	10,204	0.02	0.24	3,960
1973	164	8,042	8,955	0.02	0.24	3,731
1974	323	7,673	9,132	0.04	0.20	3,865
1975	299	7,446	20,578	0.04	0.24	4,129
1976	396	7,454	22,263	0.05	0.24	4,103
1977	848	7,808	18,968	0.07	0.18	4,045
1978	1,025	8,224	25,328	0.11	0.23	3,898
1979	1,302	8,553	19,221	0.15	0.23	4,378
1980	1,316	9,085	23,787	0.12	0.22	4,322
1981	1,945	9,213	29,450	0.16	0.24	4,180
1982	2,372	8,679	32,701	0.27	0.26	4,454
1983	1,870	8,926	21,140	0.24	0.22	5,275
1984	2,687	8,942	59,789	0.35	0.23	5,155
1985	2,371	9,557	66,290	0.34	0.22	5,372
1986	2,073	11,531	17,933	0.29	0.19	6,492
1987	2,680	13,459	21,339	0.37	0.20	6,473
1988	3,246	13,895	27,968	0.45	0.26	5,821
1989	3,582	13,256	15,874	0.44	0.28	5,764
1990	3,715	12,371	29,719	0.42	0.31	5,750
1991	3,778	11,197	19,494	0.43	0.37	5,351
1992	3,362	10,018	25,788	0.46	0.32	5,942
1993	3,370	9,082	16,791	0.46	0.25	6,302
1994	4,275	7,634	19,069	0.59	0.22	6,314
1995	4,955	5,532	30,507	0.76	0.19	5,921
1996	4,379	3,862	18,894	0.77	0.16	5,848
1997	3,597	2,965	30,168	0.82	0.15	5,648
1998	2,026	3,074	24,433	0.47	0.14	5,950
1999	1,423	3,795	33,905	0.31	0.14	6,253
2000	1,540	4,834	41,323	0.27	0.15	5,992
2001	2,528	5,690	12,862	0.36	0.15	6,204
2002	1,750	6,544	19,659	0.36	0.16	6,792
2003	1,797	6,848	3,683	0.37	0.17	6,880
2004	1,934	6,475	8,322	0.39	0.18	6,801
2005	1,755	5,676	4,851	0.38	0.19	6,425
2006	2,020	4,595	5,992	0.42	0.19	5,810
2007	1,997	3,324	8,024	0.52	0.21	5,454
2008	1,473	2,382	3,945	0.51	0.18	5,743
2009	1,283	1,598	8,842	0.64	0.19	5,848
2010	727	1,291	5,181	0.54	0.16	6,533
2011	635	1,382	5,085	0.30	0.20	5,103
2012	455	1,552	9,828	0.20	0.20	4,846
2013	353	1,814	10,887	0.16	0.21	5,205
2014	410	2,222	7,098	0.17	0.21	5,804
2015	434	2,720	12,489	0.18	0.21	6,191

Figures

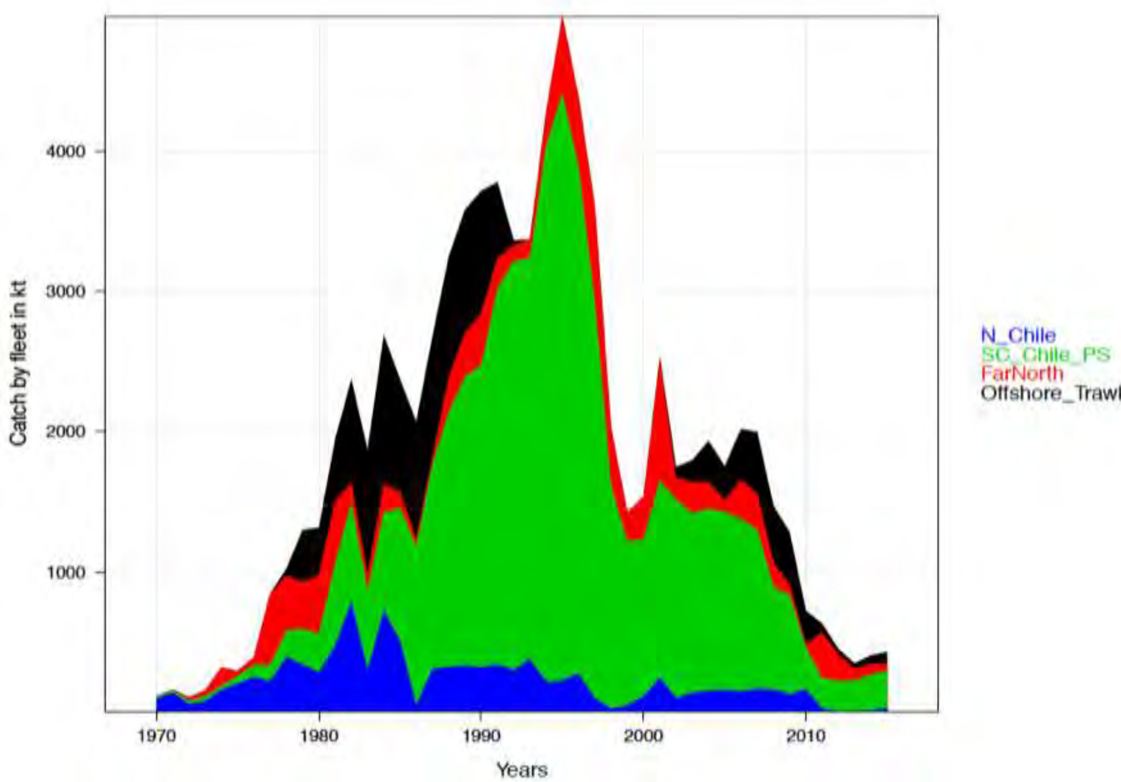


Figure A8.1. Catch of jack mackerel by fleet. Green is the SC Chilean fleet, black is the offshore trawl fleet, red is the far-north fleet, and blue in the northern Chilean fleet.

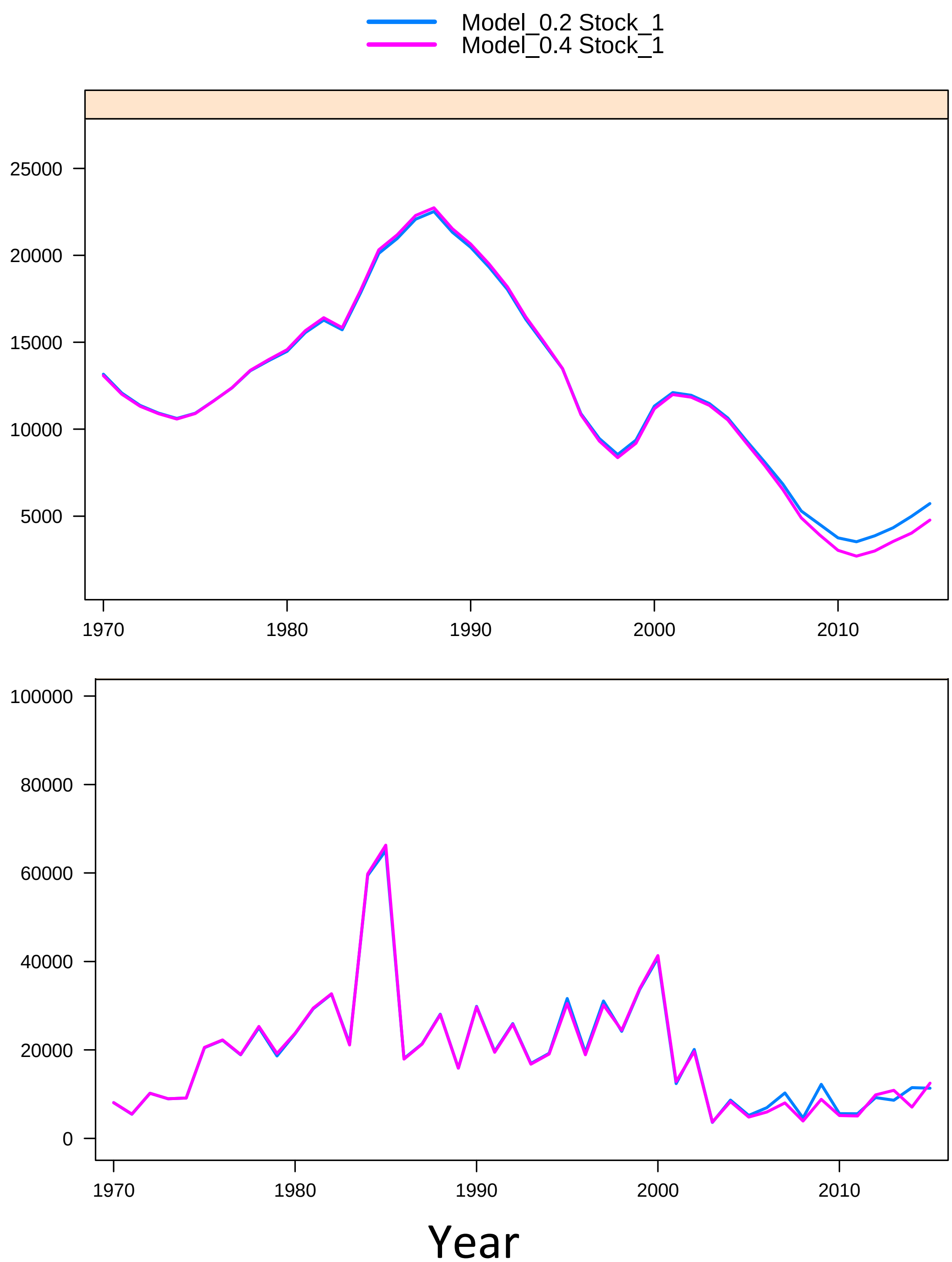


Figure A8.2. Spawning biomass (top; in kt) and age one recruitment estimates (in millions) for the single stock hypothesis comparing model configurations 0.2 and model 0.4 (the others were omitted due to plot overlay issues).

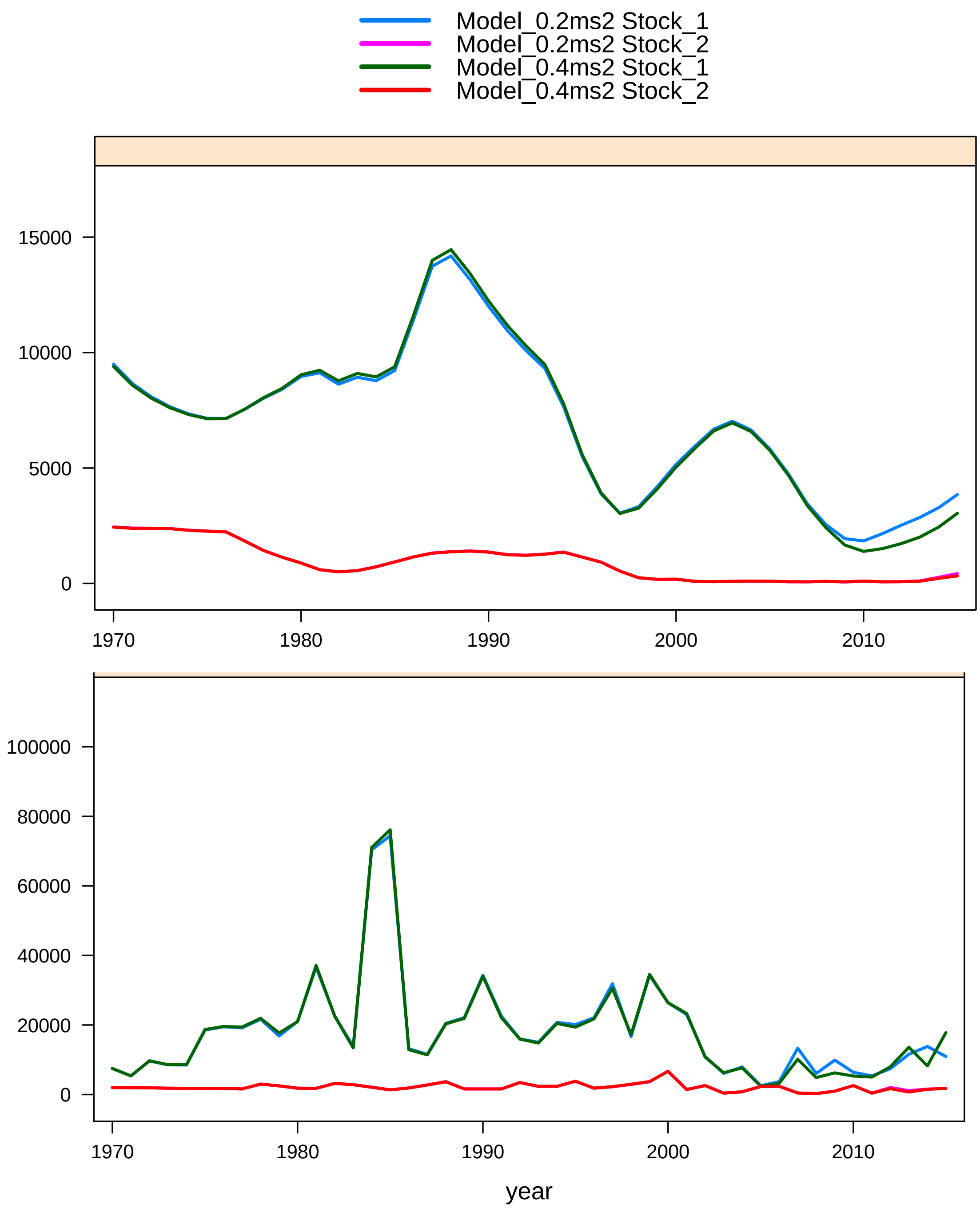


Figure A8.3. Spawning biomass (top; in kt) and age one recruitment estimates (in millions) for the "Far-North" stock and the southern stock under the two-stock hypothesis with the same data progress (comparing models 0.2 and 0.4).

Figure A8.4. Mean weights-at-age (kg) over time used for all data types in the JJM models. Different lines represent ages 1 to 12.

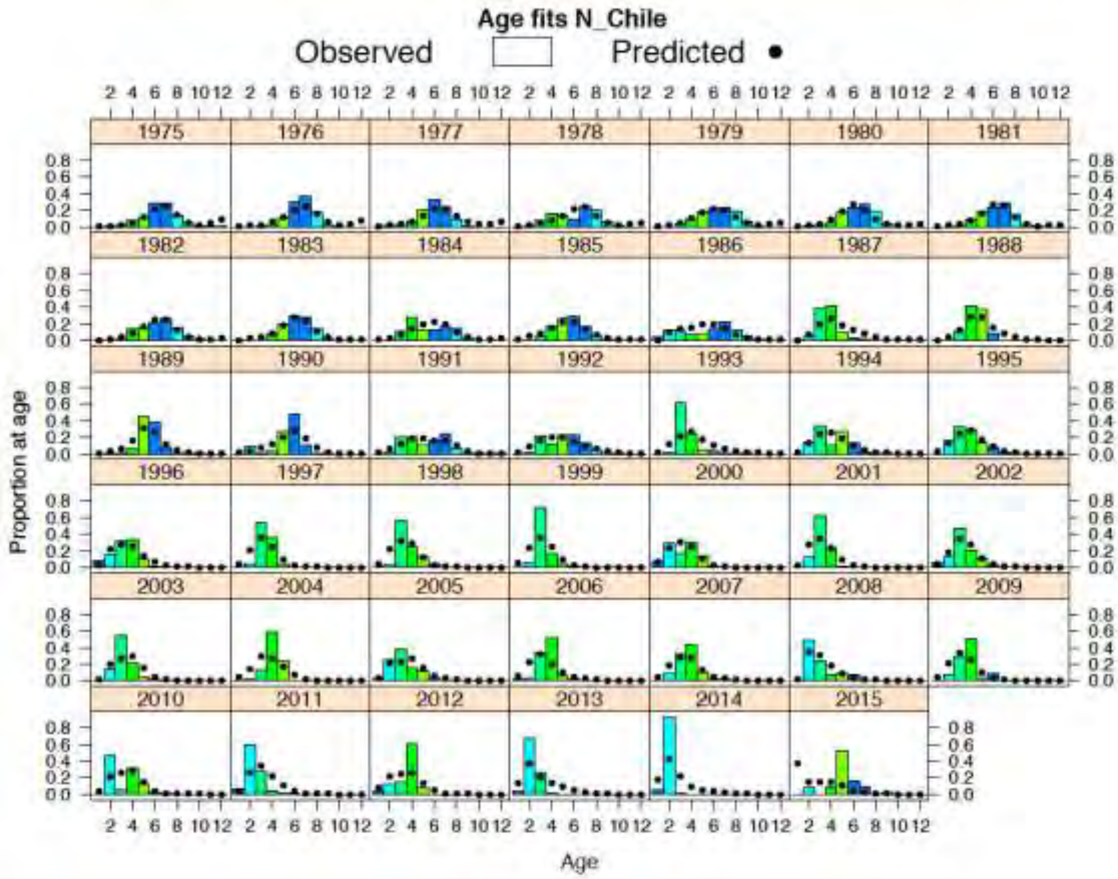


Figure A8.5. Model fit (Model 0.4) to the age compositions for the **Chilean northern zone fishery (Fleet 1)**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

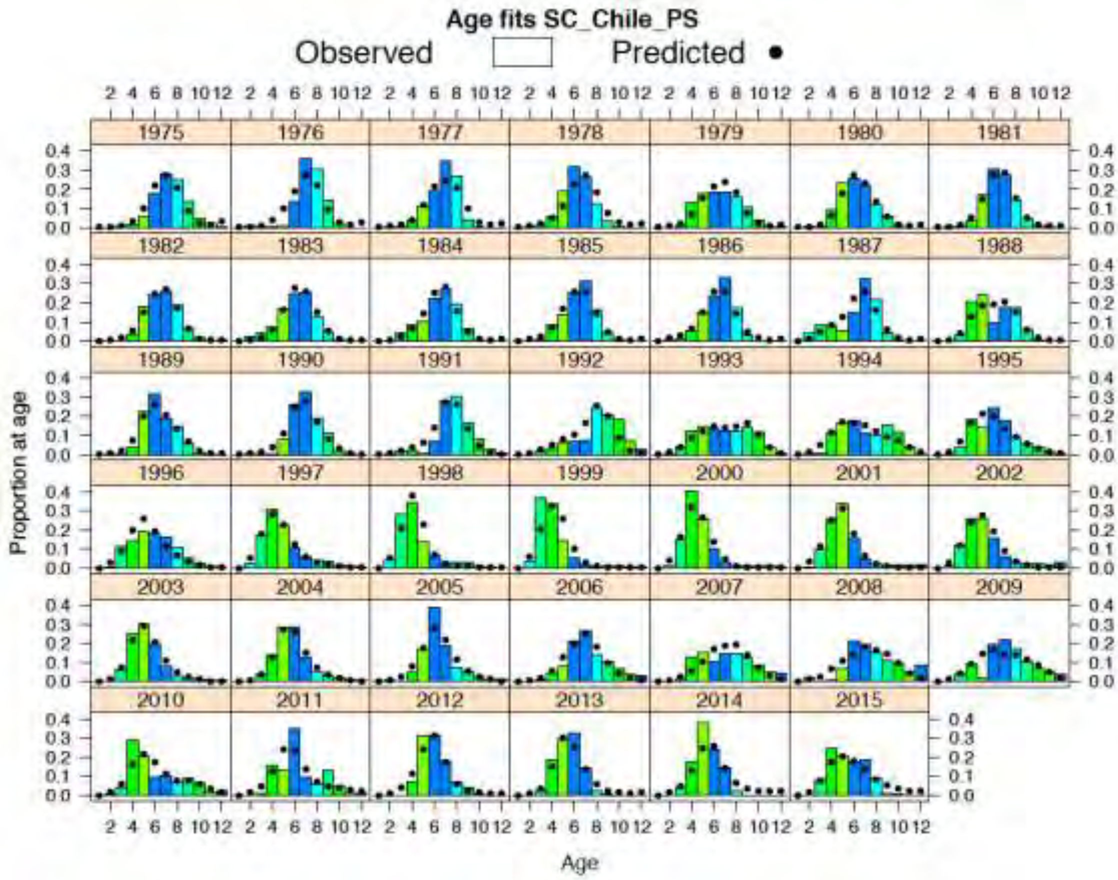


Figure A8.6. Model fit (Model 0.4) to the age compositions for the **South-Central Chilean purse seine** fishery (Fleet 2). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

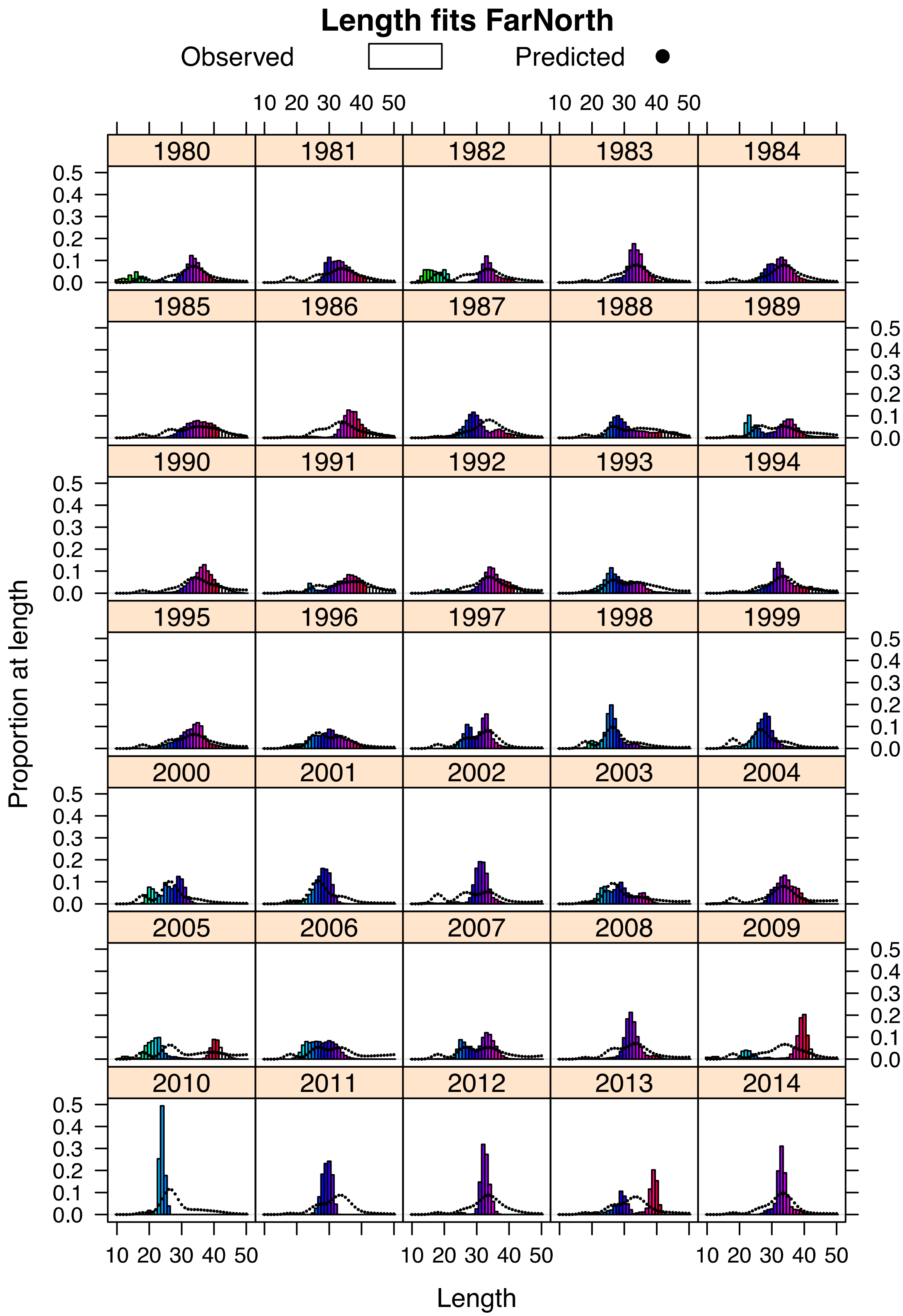


Figure A8.7. Model fit (Model 0.4) to the length compositions for the far north fishery (Fleet 3). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

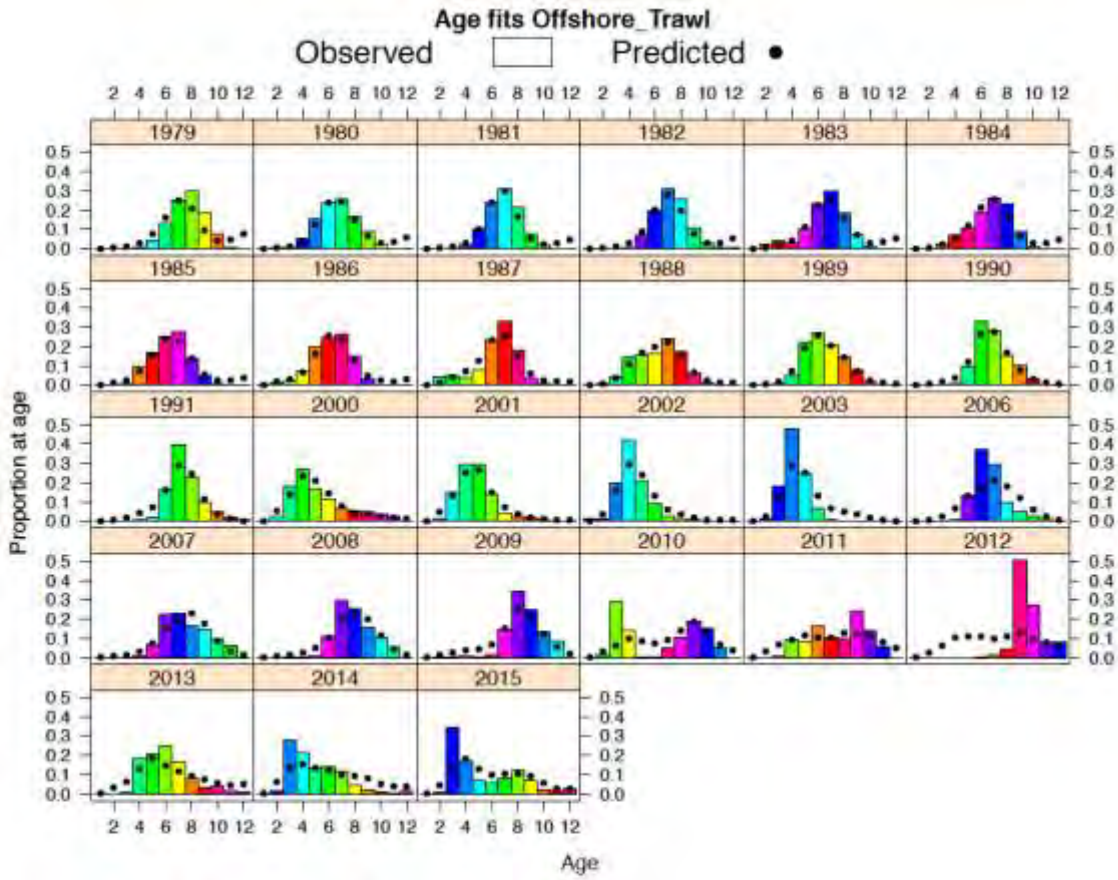


Figure A8.8. Model fit (Model 0.4) to the age compositions for the **offshore trawl** fishery (Fleet 4). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

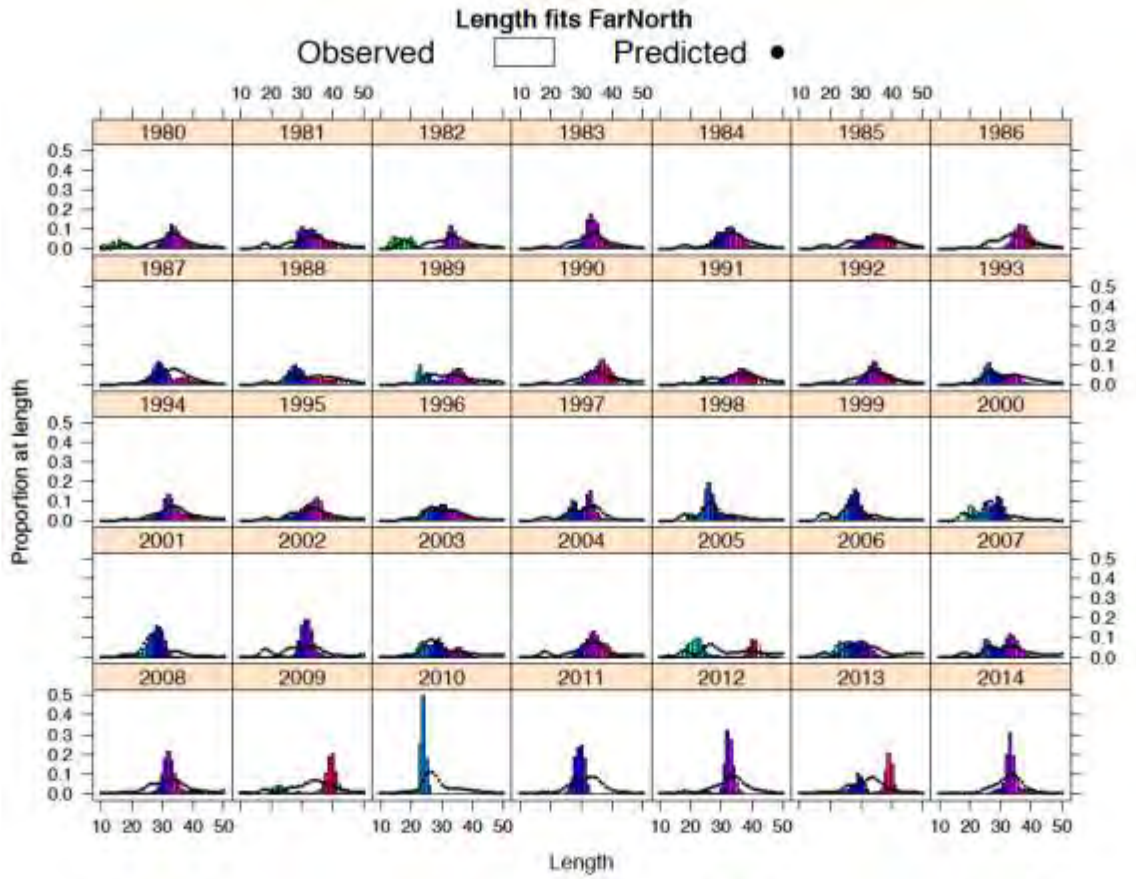
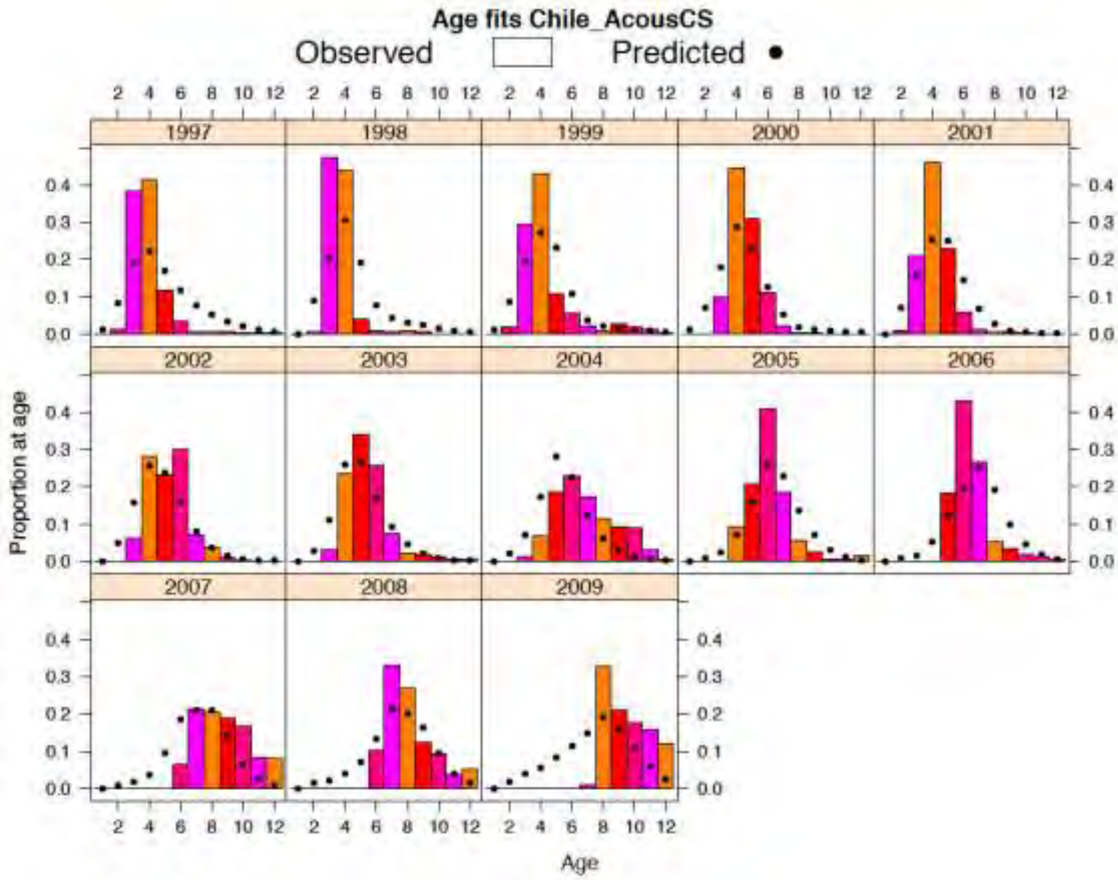


Figure A8.9. Model fit (Model 0.4) to the age compositions for the **SC Chilean acoustic survey**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.


Age fits Chile_AcousCS
Observed
Predicted
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Proportion at age
Age

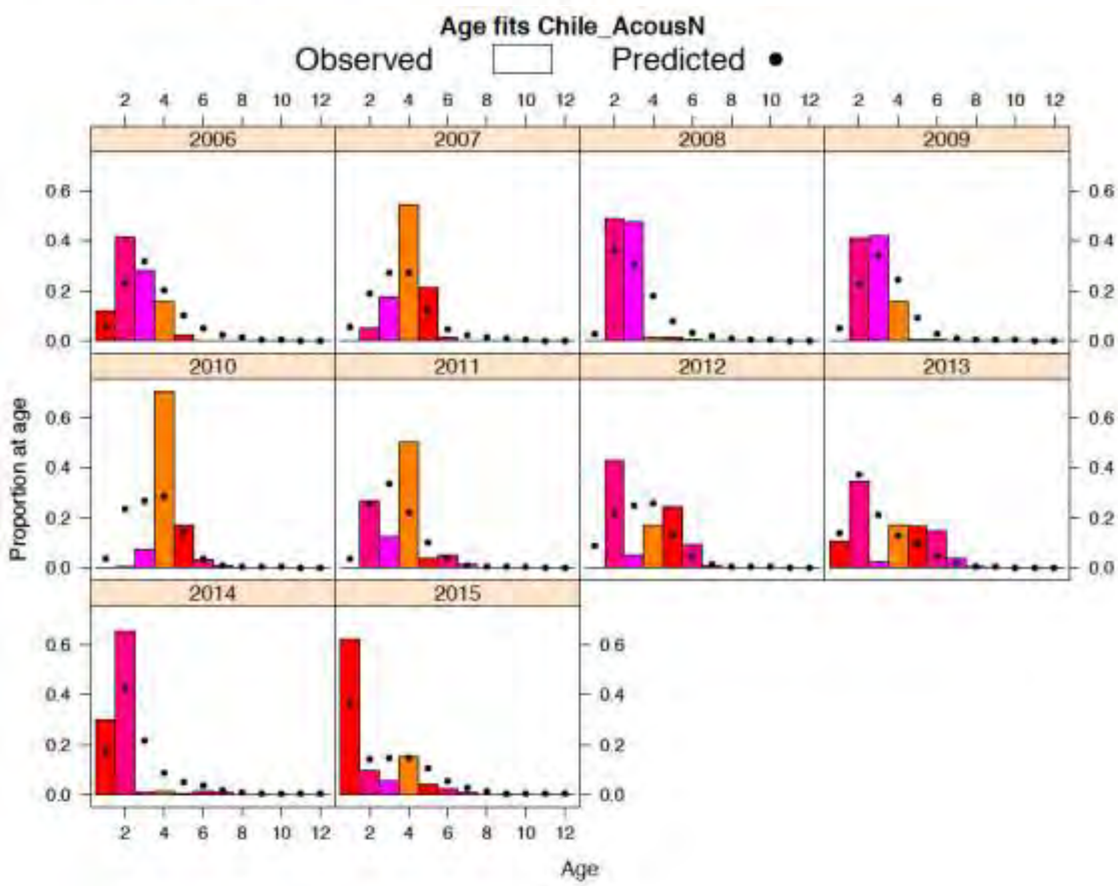

Age fits Chile_AcousN
Observed
Predicted
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Proportion at age
Age

Figure A8.10. Model fit (Model 0.4) to the age compositions for the **S-Central Acoustic survey (top) and N Chilean acoustic survey (bottom)**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

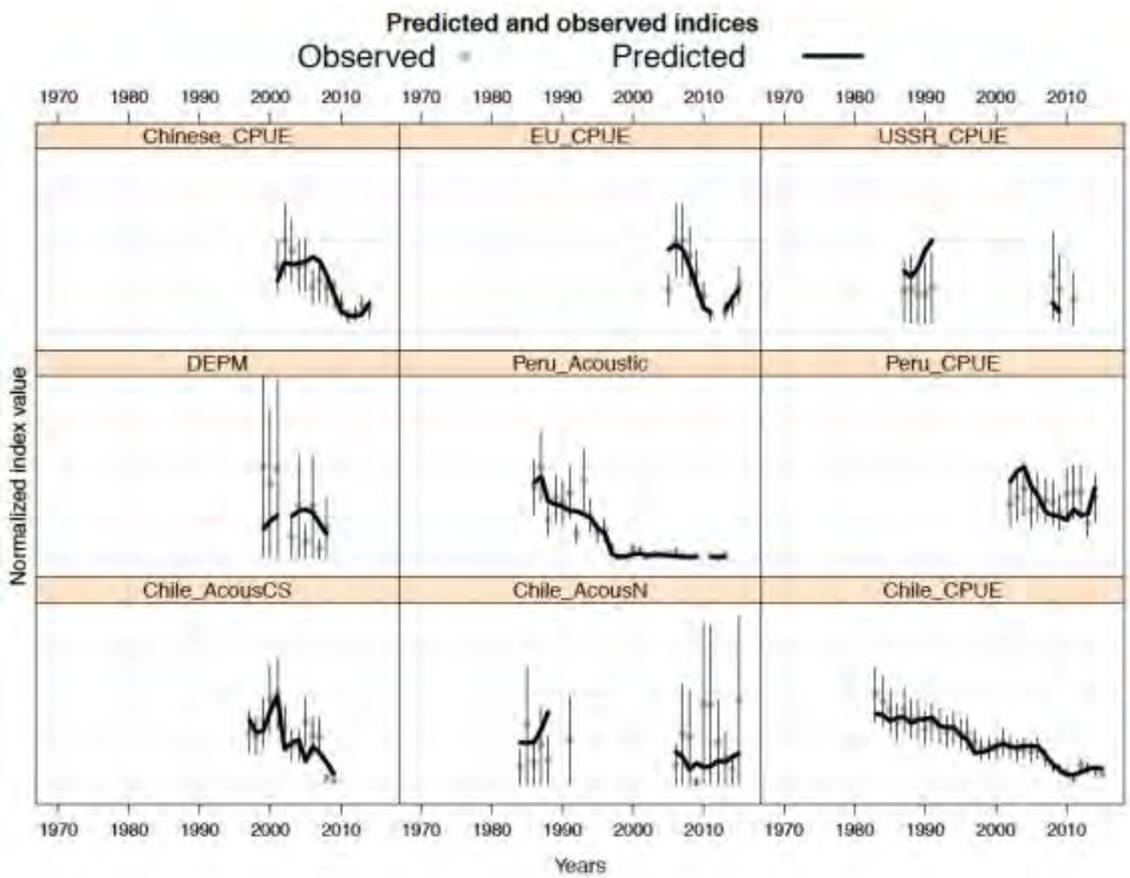


Figure A8.11. Model fit (Model 0.4) to different indices. Vertical bars represent 2 standard deviations around the observations.

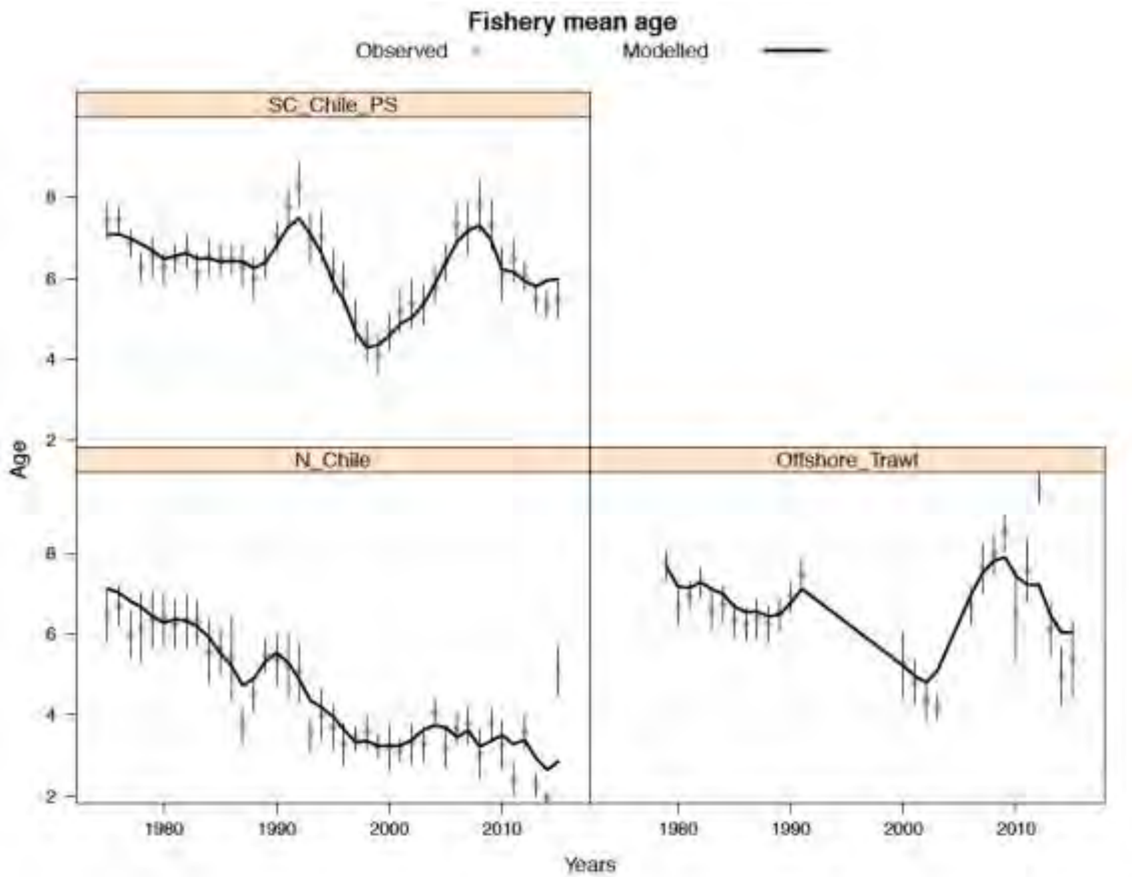


Figure A8.12. Mean age by year and fishery. Line represents the model and dots the observed values.

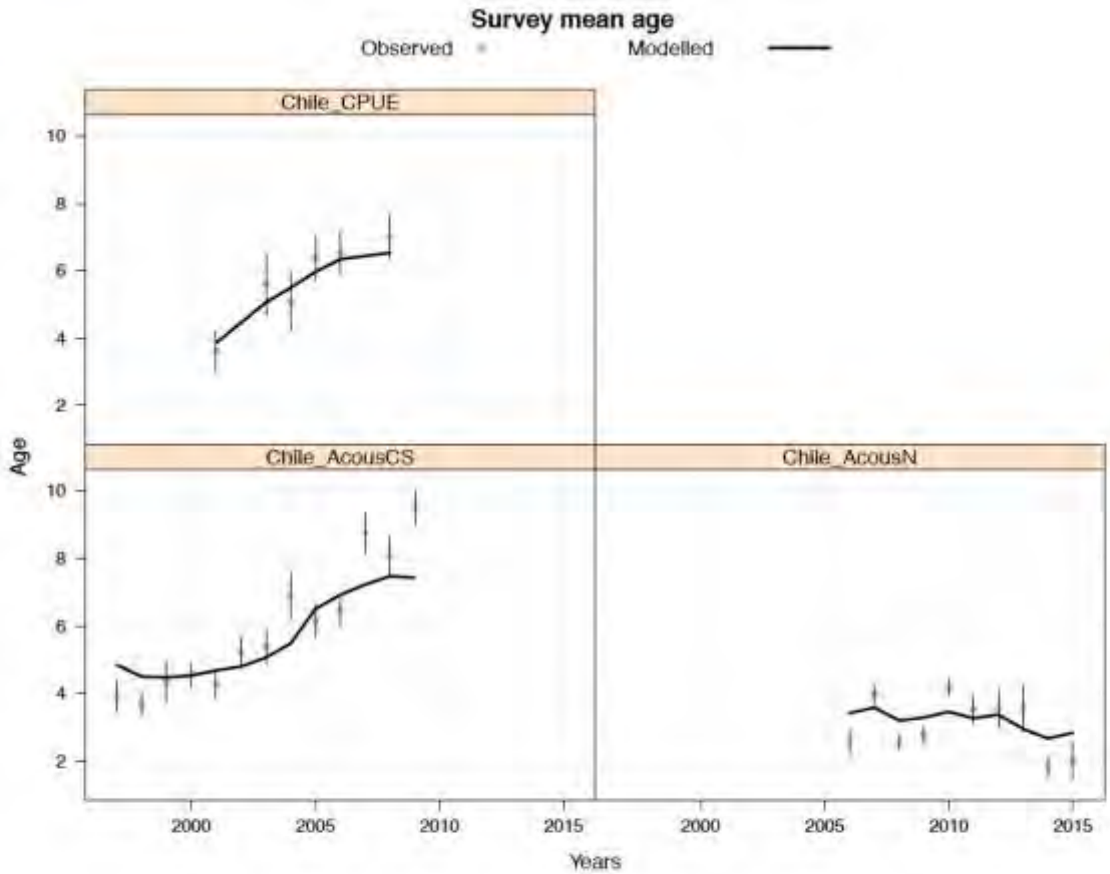


Figure A8.13. Mean age by year and survey. Line represents the model and dots the observed values.

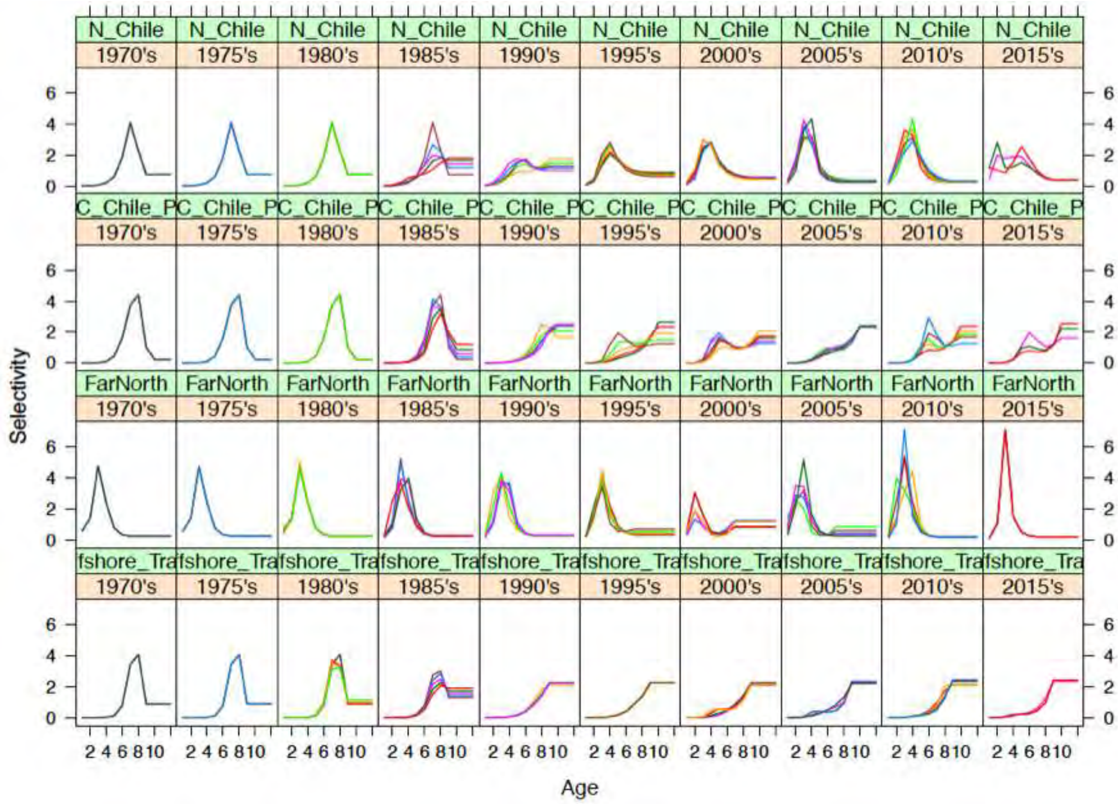


Figure A8.14. Estimates of selectivity by fishery over time for Model 0.4. Each cell represents a 5-year period).

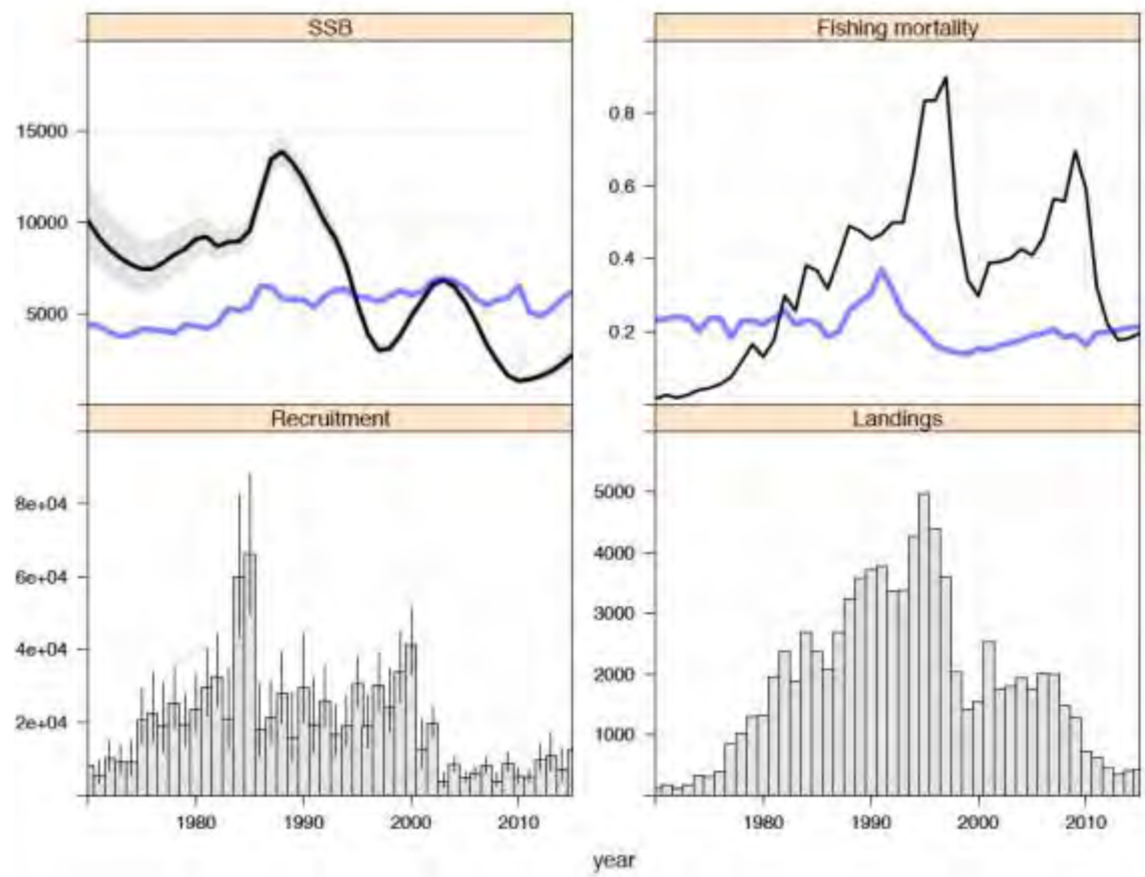


Figure A8.15. Summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left) total fishing mortality (top right) and total catch (kt; bottom right) for the single stock hypothesis.

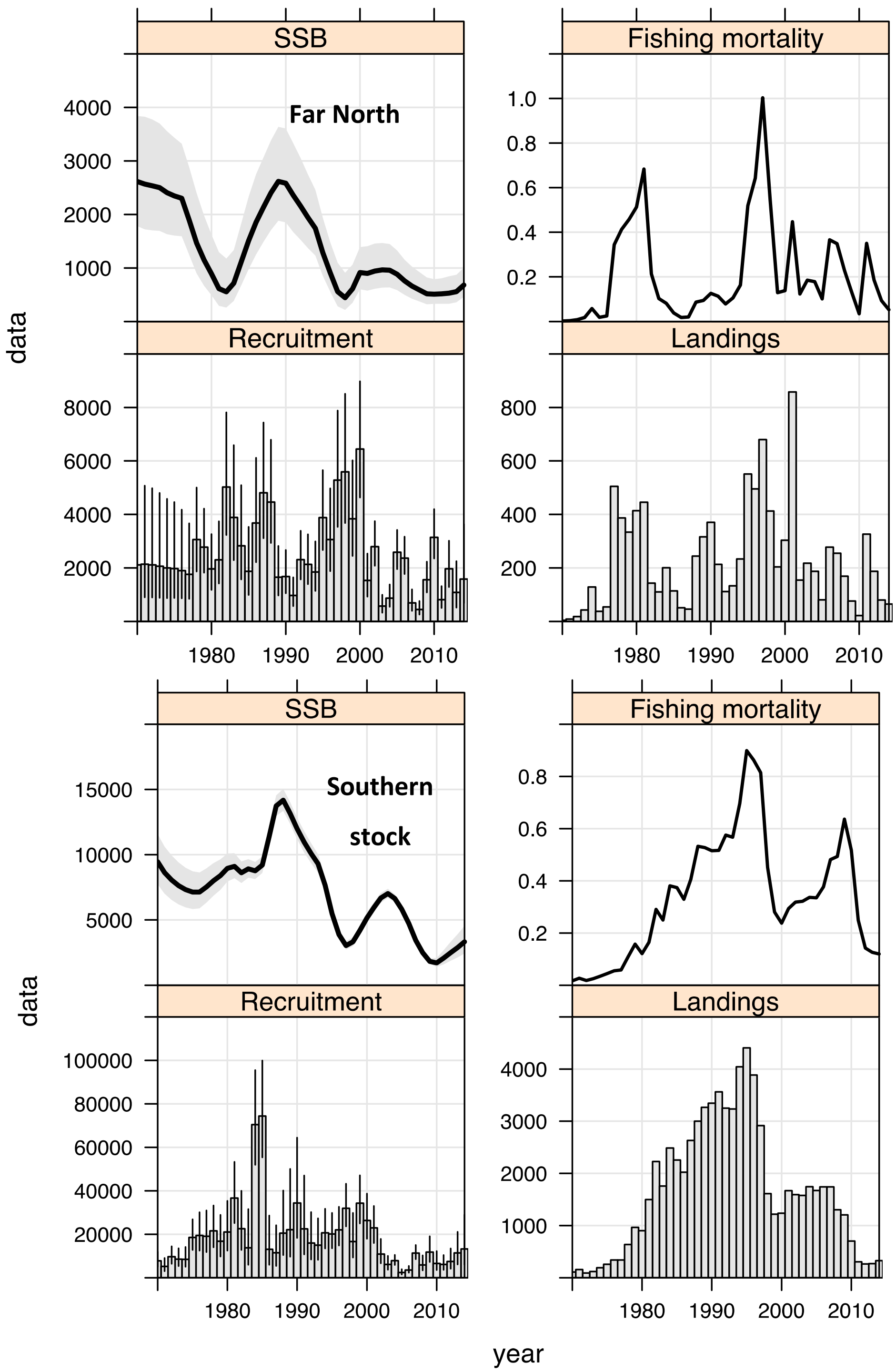


Figure A8.16. Summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left) total fishing mortality (top right) and total catch (kt; bottom right) for Models 1.11N (from 2014 SC02 configuration, top set) and 0.4S (bottom set) for the two-stock hypothesis.

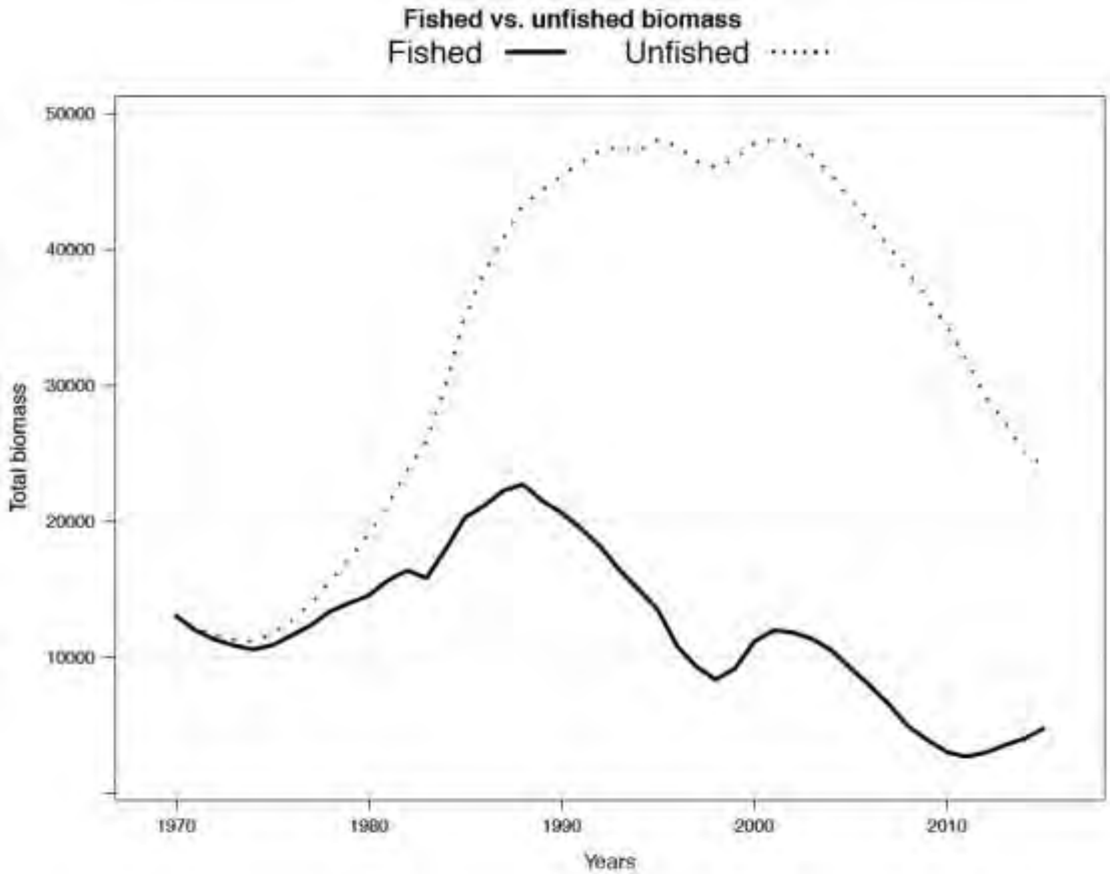


Figure A8.17. Model 0.4 results the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place, 1970-2014.