South Pacific Regional Fisheries Management Organisation

Science Working Group

Viña del Mar, Chile: 21-29 October 2010

REPORT OF THE 9th SCIENCE WORKING GROUP

Will be added when available …….

Annex SWG-01

AGENDAS FOR THE SCIENCE WORKING GROUP and SUB-GROUPS

SCIENCE WORKING GROUP: PLENARY

AGENDA

1. **Welcome & Introductions**
2. **Adoption of Agenda**
3. **Administrative Arrangements**
   3.1. Meeting documents
4. **Nomination of Rapporteurs**
5. **SWG Chairmanship**
6. **Discussion of National Reports**
7. **Inter-Sessional Work**
   7.1. Report from the Interim Secretariat on status of catch & effort data submission
   7.2. Update by the Interim Secretariat on status of the GIS database
8. **Report-Back from the Meeting of the Jack Mackerel Sub-Group**
   8.1. Consideration of the report and summary of the Jack Mackerel Sub-Group meeting
   8.2. SWG Advice on Jack Mackerel Stock Status
9. **Report Back from the Meeting of the Deepwater Sub-Group**
10. **Species and Habitat Profiles**
    10.1. Revisions to existing species or habitat profiles
    10.2. Review of new species or habitat profiles
11. **Future Scientific Work Programme**
12. **Other Matters**
13. **Adoption of SWG Report**
14. **Meeting Closure**

SCIENCE WORKING GROUP: JACK MACKEREL SUB-GROUP

AGENDA

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1. **Opening of the Meeting**
2. **Adoption of Agenda**
3. **Administrative Arrangements**
    - 3.1. Meeting arrangements
    - 3.2. Meeting documents
4. **Nomination of Rapporteurs**
5. **Chairmanship of the Jack Mackerel Sub-Group**
6. **Report on the Assessment Simulation Task Team Technical Workshops**
7. **Jack Mackerel Stock Assessments – Technical Session**
    - 7.1. Selection and specification of base-case, alternative and sensitivity stock assessment runs to be conducted
    - 7.2. Preparation of data sets required for the agreed stock assessment runs
    - 7.3. Conducting of agreed stock assessment runs
    - 7.4. Review and discussion of the results of all stock assessment runs, and specification of further runs considered necessary
    - 7.5. Synthesis and summary of key results from all stock assessment runs conducted
8. **Advice to the Scientific Working Group on Jack Mackerel Stock Status**
9. **Jack Mackerel Stock Structure Research Programme**
    - 9.1. Inter-Sessional Progress with the Jack Mackerel Research Programme
    - 9.2. Application of Hydro-Acoustic Methods to Pelagic Research
10. **Revisions to the Jack Mackerel Species Profile**
11. **Future Jack Mackerel Sub-Group Work Programme**
    - 11.1. Identification of short & medium term research and assessment requirements
12. **Other Matters**
13. **Adoption of Jack-Mackerel Sub-Group Report and Summary**

SCIENCE WORKING GROUP: DEEPWATER SUB-GROUP

AGENDA

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1. **Opening of the Meeting**
2. **Adoption of Agenda**
3. **Administrative Arrangements**
   3.1. Meeting arrangements
   3.2. Meeting documents
4. **Nomination of Rapporteurs**
5. **SPRFMO Bottom Fishery Impact Assessment Standard**
6. **Review of Bottom Fishery Impact Assessments**
7. **Deepwater Species Assessment and Management**
8. **Other Matters**
9. **Adoption of Deepwater Sub-Group Report and Summary**

Annex SWG-02

LIST OF PARTICIPANTS

Will be added when available …….

Annex SWG-03

DOCUMENT LIST

Will be added later …….

Report of the Jack Mackerel Subgroup

Viña del Mar, Chile: 21-29 October 2010

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1. Opening of the Meeting

The meeting of the Jack Mackerel Sub-group (JMSG) of the Science Working Group (SWG) was opened by the chair of the SWG, Mr Andrew Penney (New Zealand), who welcomed all participants. On behalf of all participants, he thanked Chile for hosting the meeting.

Participants introduced the members of their scientific delegations. A list of SWG participants is attached as Annex SWG-02.

2. Adoption of Agenda

The draft agenda (SWG-09-01) was adopted without amendment (Annex SWG-01).

3. Administrative Arrangements

3.1 Meeting Arrangements

The Executive Secretary, Dr Robin Allen, explained the proposed schedule of meetings (SWG-09-03) and other administrative arrangements.

3.2 Meeting Documents

A list of documents from the meeting was provided as SWG-09-02.

4. Nomination of Rapporteurs

Dr. Alexander Glubokov (Russian Federation) and Dr Ilona Stobutzki (Australia) offered to act as rapporteurs for the meeting. Dr Ianelli offered to coordinate the preparation of technical annexes summarising the stock assessment methods used and the results obtained.

5. Chairmanship of the Jack Mackerel Sub-Group

No inter-sessional nominations were received for a Chair of the Jack Mackerel Sub-Group. The Sub-Group agreed that this meeting would be Chaired by the Chair of the SWG.

Participants asked Dr James Ianelli (independent assessment advisor to the meeting, NOAA) whether he was available for nomination to the position of Chair of the Jack Mackerel Sub-Group. Dr Ianelli noted that this would need to be approved by NOAA.

6. Report on the Assessment Simulation Task Team Technical Workshops

The Chair presented key points from his presentation to the 1st SPRFMO Preparatory Conference (Auckland, July 2010) on the first workshop held by the Assessment Simulation Task Team (ASTT) in Lima, Peru, from 6 – 9 April 2010. The report of the workshop (SWG-09-JM-01) is available on the SPRFMO website. The first ASTT workshop explored a number of alternative candidate stock assessment models for use in SPRFMO jack mackerel assessments using simulated data, and made recommendations on preferred assessment methodologies and approaches for jack mackerel assessments to be conducted in 2010 using real data.

Dr Ianelli presented key points from the report of the first week of the 2nd ASTT workshop held in Seattle from 16 – 20 August 2010 (SWG-09-JM-02A). The primary purposes of that workshop were to specify the framework of the joint assessment model to be used for the 2010 JM assessment, to propose projection methods and reference points and to specify provisional input data for the 2010 assessment. The workshop explored reasons for differences found between the reference and Chilean SCA models evaluated during the first workshop, and developed a Joint Jack Mackerel (JJM) SCA assessment model for use in the 2010 assessments. This model was generalised to facilitate addition of fleets and survey indices, to allow sharing of selectivities over different fisheries, to provide projection capabilities, and to add the possibility of using length data and ageing errors for catch-at-age data. Details of the JMM model specifications, fisheries, indices, proposed projections, reference points and input data are described in SWG-09-JM-02A.

Dr Ianelli then presented key points from the report of the second week (23 – 27 August 2010) of the Seattle ASTT workshop (SWG-09-JM-02B), during which participants were trained in the use of the JJM. The week focussed on implementing refinements to the JJM assessment model and developing routines for producing diagnostics and outputs for the assessment. Modifications include allowing any index to share selectivities between different gear types, and allowing for power coefficients to relate an abundance index (such as CPUE data) to population biomass. Details of the revised model specifications are described in SGW-09-JM-2B. A range of alternate model specifications (sensitivity analyses) and projection specifications (recruitment scenarios and future harvest strategies) were used for initial exploratory analysis of the data available at the workshop. Figures showing resulting model fits to the input data, model outputs, estimated selectivities and projections of estimated biomass and fishing mortality are included in the workshop report.

7. Jack Mackerel Stock Assessments

7.1 Selection and specification of base-case and sensitivity stock assessment runs

The Sub-Group reviewed the results of the alternate model assessment runs conducted during the 2nd week of the Seattle ASTT workshop (SWG-09-JM-02B). After consideration of the likelihoods resulting from alternate sensitivity analyses, the group agreed to drop the power fits to CPUE. It was agreed to retain the three growth models used to cohort-slice the Peruvian length-composition data (Peruvian, Kochkin and Gili growth functions). The Gili growth function provided improved model fits in the analyses conducted in Seattle, and it was agreed to use this as the growth function for derivation of Peruvian age-composition in the initial base case assessment model, and to use the other growth formulae in sensitivity runs.

Alternative approaches were adopted for estimation of Soviet catch-at-age, either using Soviet age-length keys or using Chilean age-length keys (see section on model speficiations). It was agreed to add a vessel-type-weighted Russian CPUE index, and to retain all the other indices used in Seattle. It was proposed that one additional sensitivity be run to investigate the effect of the assumption on natural mortality used in the Seattle ASTT workshop.

Other model specifications remained unchanged from those developed by the ASTT during the Seattle workshop. The resulting model base case and sensitivity and projection specifications are summarised below:

Assessment models used: Chile and the EU prepared assessments using the JJM model developed during the ASTT Seattle workshop, in cooperation with Dr Ianelli. The Russian Federation prepared assessments using triple independently separable VPA (TISVPA).

Specifications for the JJM Models:

Model	Description
Basecase Model 1	• All indices assumed proportional to biomass • Soviet age compositions from Russia • Include all index data • Gili growth
Sensitivities	
Model 2	Peruvian growth
Model 3	Kochkin growth
Model 4	Soviet age compositions from Chile
Model 5	Model 4 - Downweight acoustic indices (Double CV)
Model 6	Model 4 - Downweight CPUE data (Double CV)
Model 7	Model 4 - Natural mortality alternative (0.33* instead of 0.23)

(* The alternative M value of 0.33 was estimated using the method of Pauly (1980) On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. CIEM, 39(20) : 175-192.)

Projection specifications:

The initial projection specifications (future recruitment scenarios and alternative harvest strategies) used during the Seattle workshop (SWG-09-JM-02B) were revised as follows:

- Stochastic projections
- Recruitment: 2005 – 2009; 2000 - 2009
- Alternate constant catch levels: 711,783t (2010 total catch up to September), 75%, 50%, 25%, 1%

Further technical details of the specifications of the seven initial assessment model runs are provided in Annexes SWG-JM-01 and SWG-JM-02, together with results for model fits, residuals for key data inputs and example outputs

7.2 Preparation of data sets required for the agreed stock assessment runs

The Russian Federation provided updated data on Soviet historical catches by region (SWG-09-INF-06), data on length and age composition of catches for the historical trawl fishery over the period 1979 – 1991 (SWG-09-JM-INF08) and nominal CPUE by vessel type (SWG-09-JM-04).

Fleet Definitions: It was agreed to use four fleet definitions:

- Fleet 1: Chilean northern area within EEZ purse-seine fishery.
- Fleet 2: Chilean southern area within EEZ and high seas purse seine fishery.
- Fleet 3: Far northern area fishery, inside and outside the Peruvian EEZ.
- Fleet 4: International fleet high seas trawl fishery off the Chilean EEZ.

Catch by Fleet: The catch-by-fleet data table developed at the Seattle ASTT workshop was revised and updated in accordance with the above fleet definitions.

- The updated catch data provided by the Russian Federation were used to replace the USSR/Russian Federation catch data used at the ASTT workshop. These were provided in three regions: Inside Peruvian EEZ, off Peru high seas and off Chile high seas.

- USSR historical catches inside the Peruvian EEZ were already included in the reported Peruvian catch, and so were not added again. USSR catches off Peru were included in catches for Fleet 3.
- Ukrainian historical catches, which were separately specified in the Seattle workshop catch table, are included in the historical USSR catch, so were deleted from the table.
- All international high-seas trawl catches were removed from the previous definition of fleets 1 and 2 and moved to the definition of Fleet 4.
- Cuban high seas catches were apportioned between Fleet 3 (far north) and Fleet 4 (off Chile) in proportion to the distribution of USSR catches between these regions.
- Remaining Chilean purse-seine catches in the Chilean northern EEZ area then constituted the definition of Fleet 1.
- Remaining Chilean purse-seine catches in the southern Chilean EEZ and adjacent high-seas area then constituted the definition of Fleet 2.
- As far as possible, reported catches for 2010 were updated by participants up to the end of September, to provide a provisional catch estimate for the most recent year. After these updates, the provisional total catch for 2010 used in the assessments was 711,783t. Total catch estimates for 2010 are not expected to increase substantially over this total.

The final catch-by-fleet catch table used in the assessments is included in Annex SWG-JM-01. The updates in catch data resulted in slight decreases in total catch in years prior to about 1990 (as a result of removal of double-counted Ukrainian catch), but no change to total catches since 1990.

USSR / Russian Federation Catch-at-Age: There was substantial discussion of the differences in Russian catch-at-age data provided in SWG-09-JM-INF08 (which consist primarily of ages 2 – 5), and the high-seas catch-at-age used in previous Chilean assessments, which was calculated by applying Chilean age-length keys to historical high seas catches (which consist primarily of ages 5 – 9). There is close similarity in the length-composition of the Russian and south-central Chilean catches, but substantial differences between the historical age-length keys. The differences in age-composition therefore results from substantial differences between the Chilean and Russian age-length keys used to raise length-composition to age composition (Figure 1 in Annex SWG-JM-01).

Given the close similarity between length-composition data, and the indications in recent catches of annual cyclical migration of jack mackerel from the Chilean zone out to the extent of the current fishery (to 120°W, see report of the 8^{th} SWG meeting and SWG-09-04), participants considered it unlikely that there would be such substantial differences in age-composition between the Chilean Zone and high seas catches of Chile.

Within the available time, and without additional work on otolith interpretation and growth analysis, the sub-group was not able to reach agreement on which age-length keys are considered to be more correct for the high-seas catches by Fleet 4. It was therefore agreed to use the Russian age-composition data from 1979 – 1991 for Russian catches in the initial JJM assessment model base case specifications (models 1, 2 and 3), and to run an alternate sensitivity analysis using Fleet 4 age composition derived by applying the historical Chilean age-length keys to the Russian length composition data (model 4). For other international fleets, the Chilean age composition was used for the period from 1992 – 2010 (all models).

CPUE Indices: All CPUE indices used by the ASTT workshop were retained, but with a new Vanuatu CPUE series being combined with the EU CPUE series.It was agreed to include the historical Russian nominal CPUE (1989 – 1997) as an additional abundance index for Fleet 4, after simple standardisation to produce a weighted average CPUE index across the vessel types in the data provided (SWG-09-JM-INF 04).

Survey Indices: All survey indices (acoustic and daily egg production) used by the ASTT workshop were retained.

7.3 Conducting of agreed stock assessment runs

The two assessments teams (JJM: Dr Ianelli/Chile/EU and TISVPA: Russian Federation) conducted initial assessments using the agreed model run specifications and input data, and provided results to Dr Ianelli for compilation and presentation to the sub-group.

7.4 Review and discussion of the results of stock assessment runs, and specification of further runs

Dr Ianelli presented a summary of the initial results, model fits and residual patterns from the JJM and TISVPA assessment runs conducted (see Annex SWG-JM-01). Key observations by the sub-group included:

- Models 1, 2 and 3 produce unrealistically high and highly uncertain estimates of recruitment in 2010. This appears to result partially from applying different age-length keys to the different fleets in the southern area (Fleet 4). This appears to result in substantial model over-estimation of the proportion of small fish in Fleet 4 catches in the past two years (see fits to Fleet 4 age-composition data for 2009 and 2010). This would affect projections if the final estimate of recruitment is included in the periods used in future recruitment scenarios.
- Model 4 provides better fits to age-composition and fleet selectivity data, partially as a result of applying a consistent age-length key across all of the fleets in the southern area (Fleets 2 and 4).
- There was considered to be little biological justification for the alternative *M* value of 0.33 used in Model 7.
- Results of the sensitivity analyses, particularly Models 5 (down-weighted survey indices) and 6 (down-weighted CPUE) show that there is some degree of tension or contradiction between the biomass trend signals provided by the catch-at-age data, and those provided by the indices.
- There is close correspondence between the trends in estimated biomass in the TISVPA and JJM models over the period of decline between 1990 and 1997, and close agreement in estimates of current biomass. The TISVPA model predicts lower biomass than the JJM models over the period 2000 – 2005, and prior to 1985.

For the reasons identified above, the sub-group agreed to discard Models 1, 2, 3 and 7 from further JMM assessment runs. Models 5 and 6 were considered to be useful in exploring and demonstrating tensions between the alternative indices of abundance.

It was agreed to go forward with assessment Models 4, 5 and 6 as the basis for providing jack mackerel stock status advice in 2010. Assessment model 4 was designated as the final base case assessment, with Models 5 and 6 providing sensitivity analyses, down-weighting of the acoustic and CPUE indices respectively. The specifications of these three models remained unchanged for the final runs.

For the final model runs, the sub-group requested the following additional outputs:

- Historical trends in fishing mortality (F) for each of the model runs.
- Stochastic ten year projections (to 2020) of trends in predicted total biomass (*B*) and fishing mortality (*F*) under the recent 5-year (2005 – 2009) and ten year (2000 – 2009) average recruitment (excluding the 2010 recruitment estimate), under alternative constant proportions (0.01, 0.25, 0.5, 0.75 and 1) of the provisional 2010 catch to September (711,783t).
- Trends in estimated total biomass compared to trends in biomass had no fishing occurred.

7.5 Results from final stock assessment runs conducted

Dr Ianelli coordinated final JJM model runs using the three agreed models, and prepared a technical annex containing the main outputs, model fit results, projection results for the final JJM assessment model runs and main results of the TISVPA analysis (Annex SWG-JM-02).

Participants requested that the final JJM modelling software, control files, output software, projection software, data inputs and indices be made available on the SPRFMO website, for future reference. The SPRFMO Secretariat undertook to prepare an archive containing these files, and to consult with participants regarding potential confidentiality concerns before making the file available on the website.

7.6 Recommendations for Improving Future Assessments

There was substantial discussion regarding the tensions and trade-offs between biomass trend signals provided by catch-at-age data, survey indices and CPUE indices. The sub-group recognised that there are uncertainties and concerns regarding all of these data sources, and that future assessments would be improved by improving each of these data indices. The sub-group recommended that attention be given to the following work in order to improve future assessments:

- Cooperative work between participants to develop consistent otolith ageing protocols and to resolve apparent differences in growth-rate analyses and maturity schedules for the various regions.
- Further work to investigate the effect of spatial and seasonal patterns to improve existing acoustic indices and to evaluate to what extent they provide indices of abundance for particular areas or stock components.
- If CPUE data are to be used to provide indices of abundance, efforts must be made to develop standardised CPUE indices adjusted for factors such as historical changes in vessels, fishing areas, seasonal fishing patterns and environmental factors.
- Investigate the explicit incorporation of length-composition data within the assessment model, with model estimation of growth parameters.

8. Advice on Jack Mackerel Stock Status

9. Jack Mackerel Stock Structure Research Programme

9.1 Inter-Sessional Progress with the Jack Mackerel Research Programme

9.2 Application of Hydro-Acoustic Methods to Pelagic Research

10. Revisions to the Jack Mackerel Species Profile

11. Future Jack Mackerel Sub-Group Work Programme

12. Other Matters

13. Adoption of Jack-Mackerel Sub-Group Report and Summary

ANNEX 1: Assessment models developed and evaluated during the Jack Mackerel Subgroup Meeting

Data

During the meeting, several new pieces of information were presented. The meeting agreed on data sets going forward for catch (Table 1). The detailed catch-age and index data can be provided by the SPRFMO Secretariat. The subgroup evaluated the treatment of the length frequency data for the early period (1979-1991; Fig. 1) relative to how age determinations used to convert these data to ages affect the age compositions. The mean weights-at-age over time used for all gear types and indices, as decided by the ASTT, is provided in Fig. 2 and maturity-at-age is shown in Table 2. The final datasets evaluated by the subgroup are available to members upon request.

Assessment models

TISVPA Model

A "triple-separable" version of the ISVPA model (TISVPA) was used for the assessment runs. This version of the model allows it to take into consideration possible cohort-dependent peculiarities in selection pattern originating from different interactions of different cohorts with fishing fleet, or by possible errors in aging of some cohort or by some other unknown reasons. The catch-at age data of all fleets were summarized. The common weight-at-age values were found by weighting according to the share of the fleet in the total catches.

The non-mixed version of the model was used. Other settings of the model were the following: unbiased separable representation of fishing mortalities and the split selection pattern for two periods - before and after the 1991.

The model settings were chosen to minimize non-contradicting signals from the available catch-at-age data. No additional fitting data were applied and the following settings were used:

- The "catch-controlled" version (catch-at-age is assumed as true and all residuals in catch-at-age are attributed to violations of selection pattern stability) with the assumption of unbiased separable representation of fishing mortalities;
- The window for estimation of cohort-factors – from age 3 to age 10; the measure of closeness of fit for catch-at-age – sum of squared residuals in logarithmic catches;
- The absolute median deviation (AMD) was used to minimize the residuals in the given and estimated catches-at-age.

The year of the change in selection pattern was chosen as 1991.

Joint jack mackerel model

A statistical catch-at-age model was used to evaluate the jack mackerel stock. The JJM ("Joint Jack Mackerel Model") considered different types of information, which corresponds to the available data of the jack mackerel fishery developed on the South Pacific area since 1970 to 2010. A list of this information is listed in Table 3.

Parameters estimated conditionally are listed in Table 4. The most numerous of these involve estimates of annual and age-specific components of fishing mortality for each year from 1970-2010 and each of the four fisheries identified in the model. Parameters describing population numbers at age 2 in each year (and years prior to 1970 to estimate the initial population numbers at ages 2-12) were the second most numerous type of parameter.

The table of equations for the assessment model is given in Tables 5, 6 and 7.

The treatment of selectivities and how they are shared among fisheries and indices is given in Table 8. The numbers of parameters for different model configurations were around 350. Also depending on the model configuration, some growth functions were employed to convert length compositions to age compositions (see Table 9)

Model evaluation

A set of 7 exploratory models were proposed and run for evaluation purposes. The assessment considered 7 model configurations and their detail are showed in Table 10. The last three models 5,6 and 7 (which were based on model 4) correspond to sensitivity analysis, which ocused on evaluating the model response when the weight of abundance indexes is changed, or a different value of natural mortality is used. These specifications are shown in Table 11. The subgroup evaluated the impact of different configurations and selected Model 4 as the “base case” for the work presented in Annex 2, based on comparison of likelihood values shown in Table 12.

References

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.

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.

Figures

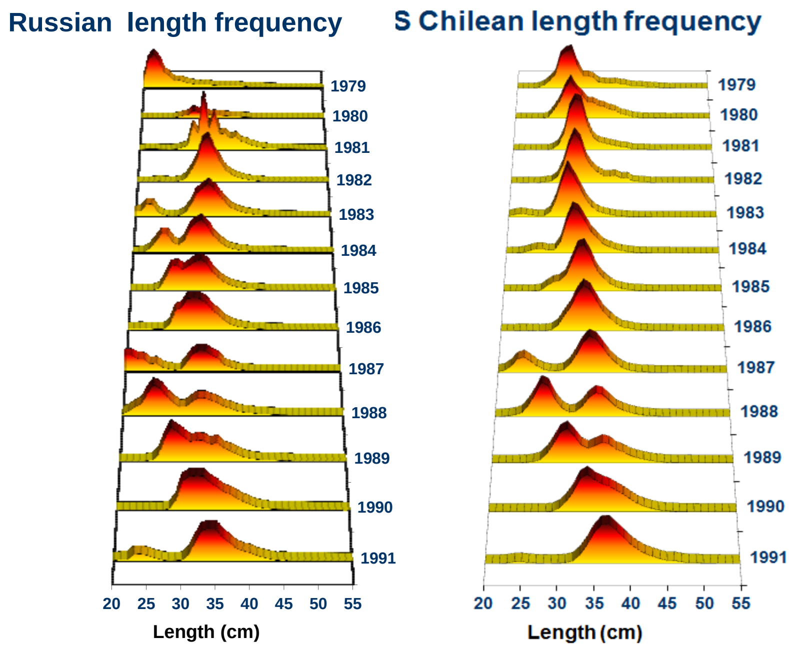

Figure 1. Historical 1979 – 1991 length frequency distributions for the Russian and south-central Chilean fisheries.

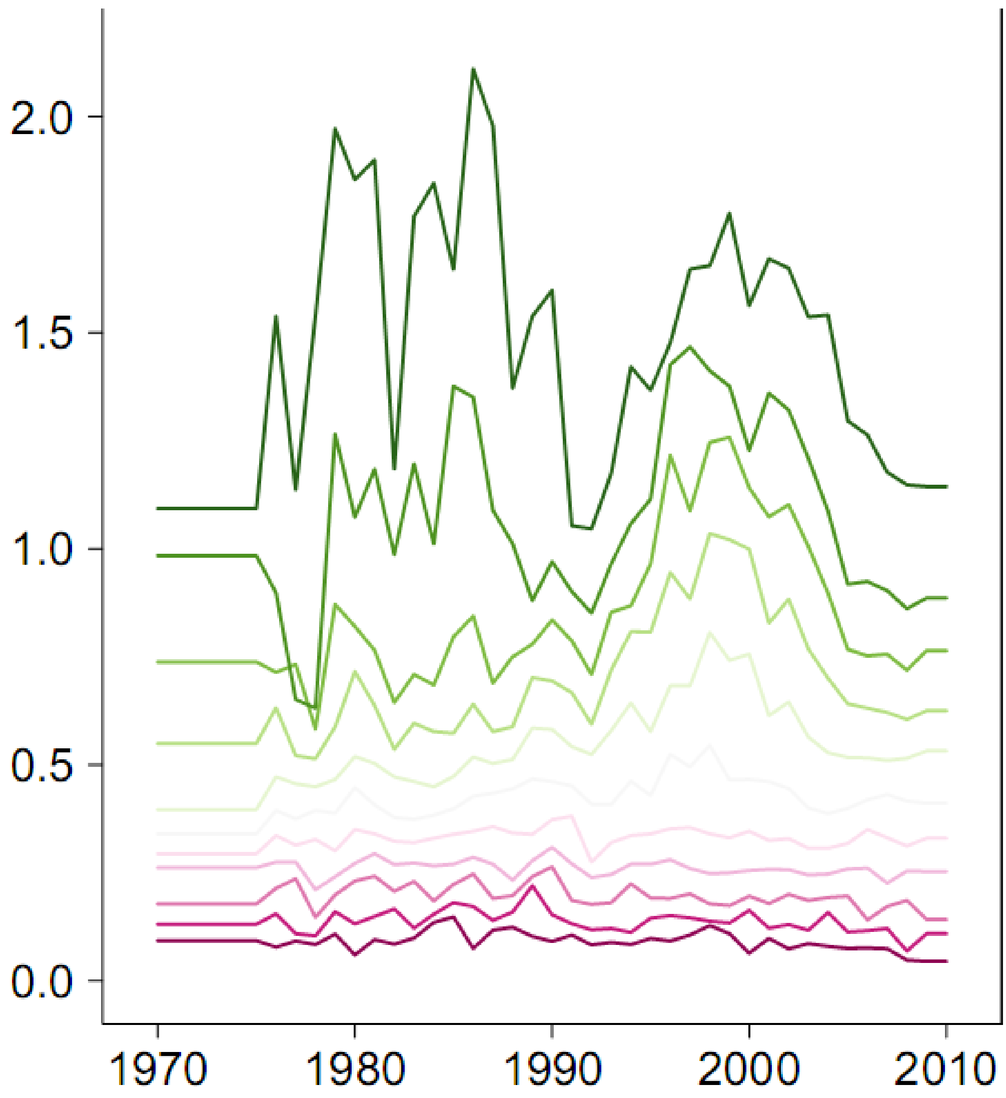

Figure 2. Mean weights-at-age (kg) over time used for all data types in the JJM models. Different lines represent ages 2 to 12.

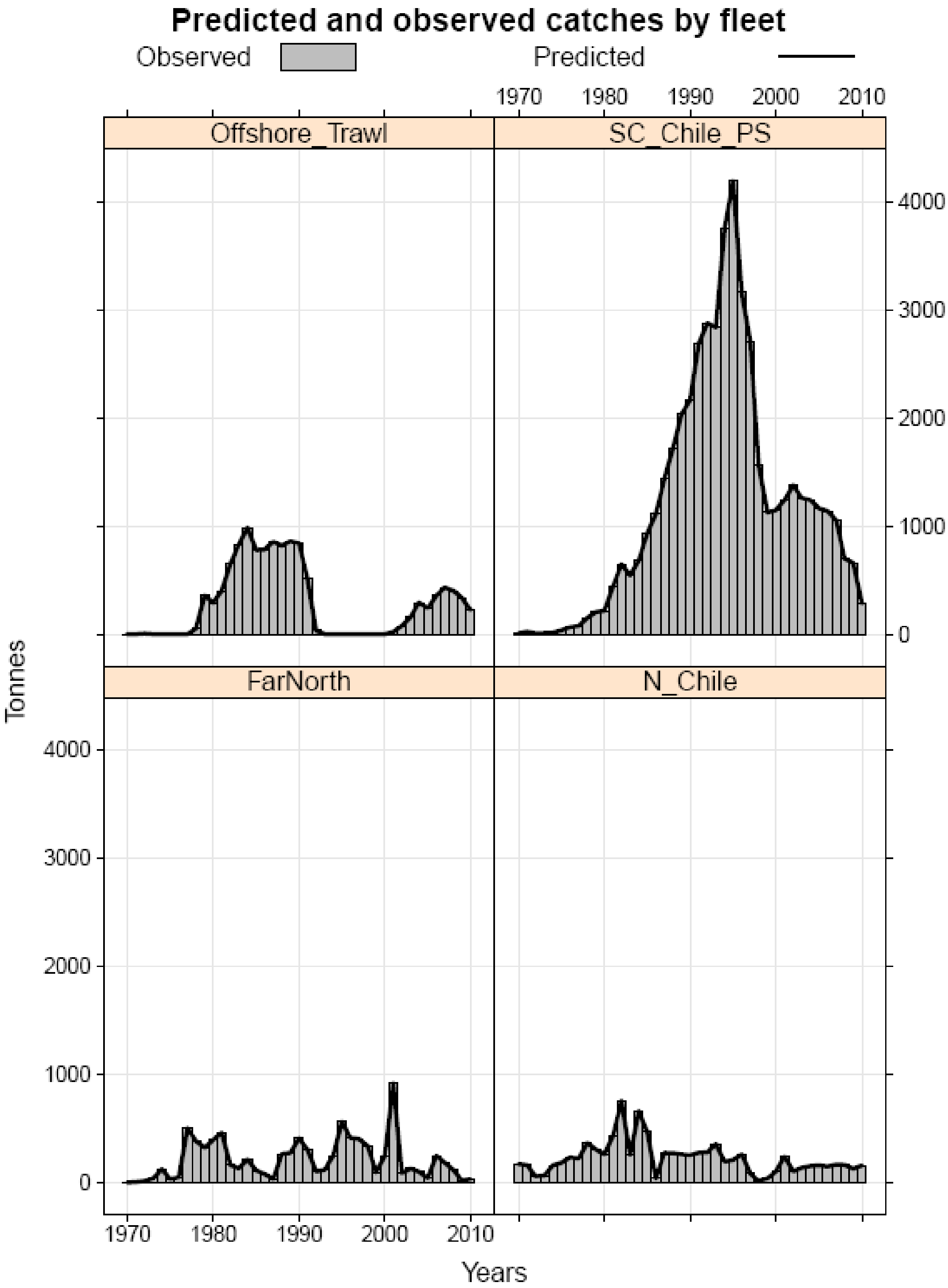

Figure 3. JJM Model fit to the total catches ('000 tonnes) by fleet for Fleet 1 (N_Chile_PS), Fleet 2 (SC_Chile_PS), Fleet 3 (Far_North) and Fleet 4 (Offshore_Trawl). The bars represent the observations and the line represents the predicted values.

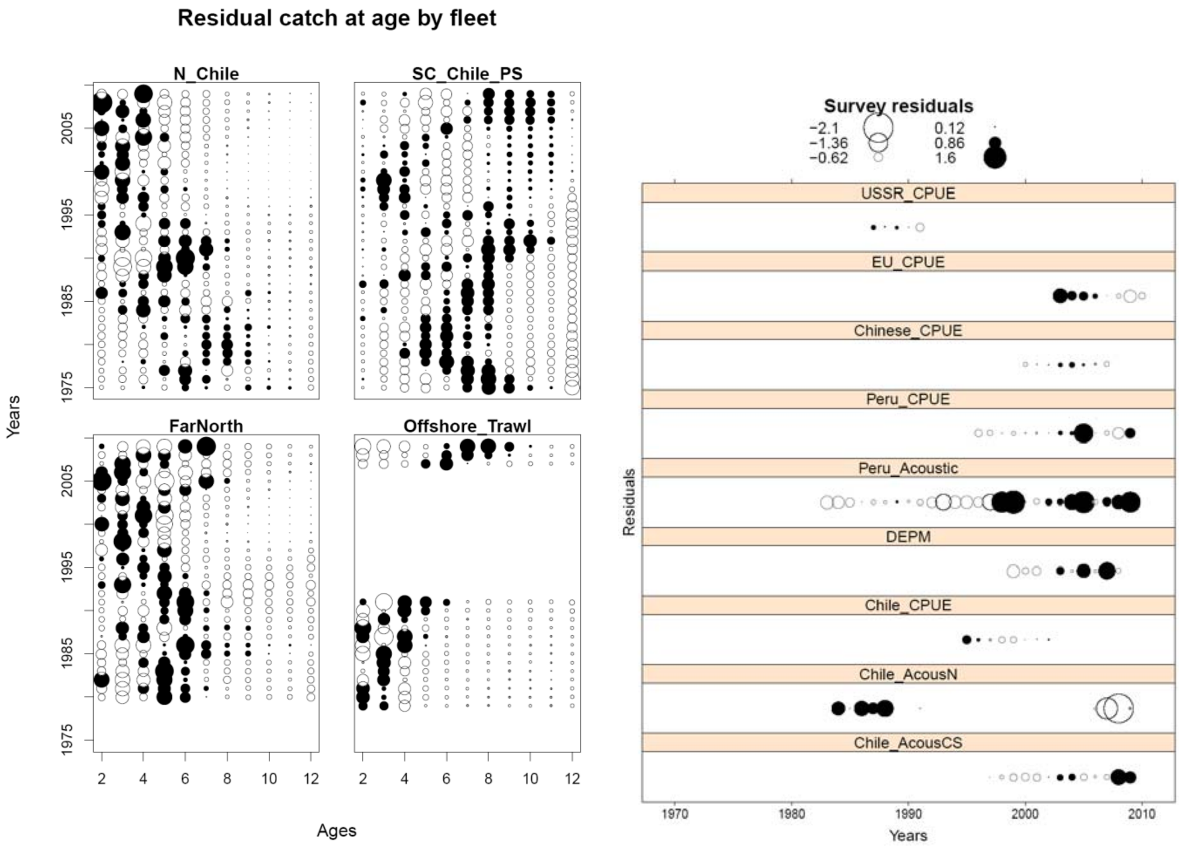

Figure 4. Logged residuals of observed and predicted catch-at-age proportions for the different fleets (left) and residuals for each of the indices (right) from JJM model 4.

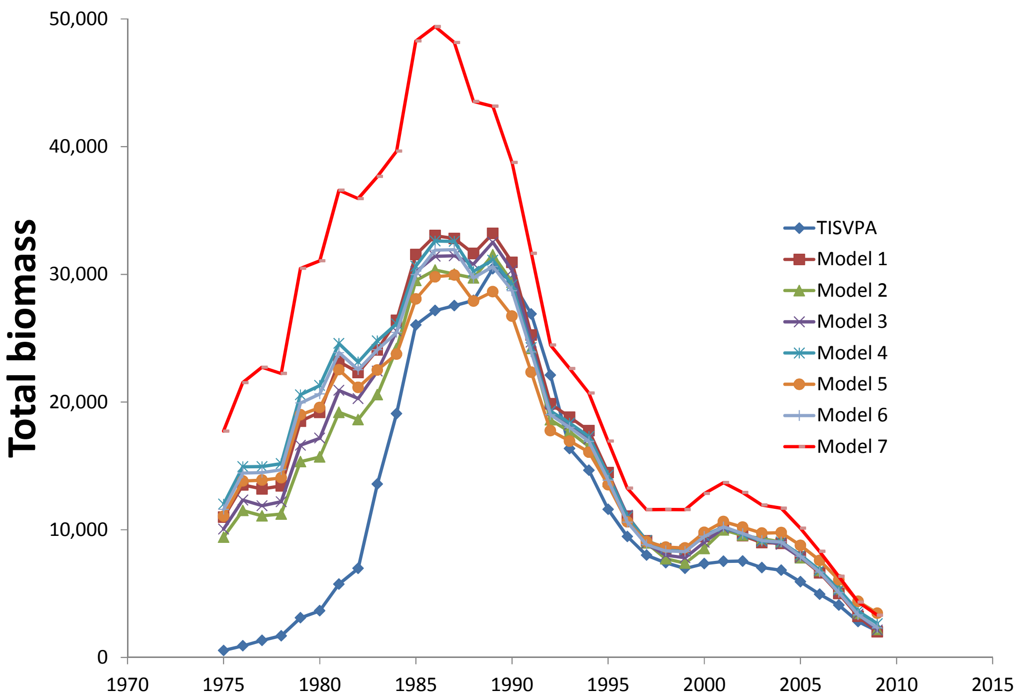

Figure 5. Total biomass estimates comparing the TISVPA model to that of the seven JJM models.

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

1) data provided by Chilean scientists, 2) fraction of catches reported to SPRFMO that was assigned by working group to fleet 2. 2010 data are provisional.

	Fleet 1	Fleet 2	Fleet 3 (Far north)					Fleet 4 Trawler fleet off Chile (outside EEZ)									
Year	N Chilea (1)	Chile CS (1)	Peru(1)	Ecuado (2)	USSR	Cuba (2)	Total fleet 3	Belize	China	EU	Faroe I.	Korea	Russia/USSR 1)	Cuba	Vanuatu	Fleet 4	Grand total
1970	175208	7938	4711				4711									0	187857
1971	164838	21934	9189				9189									0	195961
1972	62634	7100	18782				18782						5500			5500	94016
1973	71762	8904	42781				42781									0	123447
1974	163396	12678	129211				129211									0	305285
1975	186890	34951	37899				37899									0	259740
1976	237876	65570	54154				54154									0	357600
1977	225907	75585	504992				504992									0	806484
1978	367762	150319	386793				386793						49220			49220	954094
1979	311682	203269	151591		175938		327529						356271			356271	1198751
1980	266697	215528	123380		252078	21885	397343						292892	0		292892	1172460
1981	435061	440935	37875		371981	55598	465454						399649	0		399649	1741099
1982	756484	643821	50013		84122	32401	166536						651776	0		651776	2218617
1983	259128	541696	76825		31769	26876	135470						799884	29480		829364	1765658
1984	663695	677910	188893		15781	10510	215184						942479	39623		982102	2538891
1985	471599	923042	79370		26089	12049	117509						762903	13204		776106	2288256
1986	42536	1103200	44292		1100	40282	85674						783900	0		783900	2015310
1987	280594	1416781	38099			0	38099						818628	40413		859041	2594515
1988	278701	1703037	113743		120476	35890	270109						817812	0		817812	3069659
1989	265861	2031058	133671		137033	9264	279968						854020	4635		858655	3435542
1990	258233	2150956	224684	4144	168636	14312	411776						837609	4710		842319	3663284
1991	282817	2649828	234110	45313	30094	507	310024						514534	0		514534	3757203
1992	285387	2796812	93065	15022		0	108087						32000			32000	3222286
1993	359947	2745099	121309	2673		0	123982									0	3229028
1994	197414	3596904	213220	36575			249795									0	4044113
1995	211594	3984244	386748	174393			561141									0	4756979
1996	264631	3017165	357953	56782			414735									0	3696531
1997	88276	2541981	371485	30302			401787									0	3032044
1998	19278	1546704	314123	25900			340023									0	1906005
1999	44582	1130488	82541	19072			101613									0	1276683
2000	107769	1135082	240881	7122			248003									0	1490854
2001	244019	1216754	774603	133969			908572		20090							20090	2389435
2002	108727	1357185	92470	604			93074		76261							76261	1635247

2003	142016	1272302	134975				134975		94690			2010	7540	53959	158199	1707492
2004	157647	1289820	106270				106270		131020			7438	62300	94685	295443	1849180
2005	165552	1248971	46769				46769	867	143000	6179		9126	7040	77356	243568	1704860
2006	154524	1215738	256318				256318	481	160000	62137		10470		129535	362623	1989203
2007	170220	1119713	188450	927			189377	12585	140582	123511	38700	10940		112501	438819	1918129
2008	167258	728850	120749				120749	15245	143182	106665	22919	12600	4800	100066	405477	1422334
2009	133994	690610	25472				25472		117963	112231	20213	13759		79942	344108	1194184
2010*	162371	288048	37413				37413	2240	62159	75747	11643	8183	17493	46487	223952	711784

Table 2. Jack mackerel sexual maturity by age used in the JMM models (SP-07-SWG-JM-SA-05).

Age (yr)	2	3	4	5	6	7	8	9	10	11	12
Proportion mature	0.00	0.04	0.50	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3. 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	1975-2009	-	1970-2010	-	1984-1988; 1991; 2006-2009	1999-2008
South-central Chile purse seine	1975-2009	-	1970-2010	1995-2002	1997-2009	-
FarNorth	-	1980-2009	1970-2010	1996-2009	1983-2009	-
International trawl off Chile	1979-1991	2007-2008	1978-2010	China (2000-2007); EU & Vanuatu (2003-2010); exUSSR (1987-1991)	-	-

Table 4. Symbols and definitions used for model equations

General Definitions	Symbol/Value	Use in Catch at Age Model
Year index: i = {1970, …., 2010}	i	
Age index: j = { 2, 3, …, 12^+}	j	
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
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		
$\phi_i(\#), R_0, h, \varepsilon_i(\#), \mu^f, \mu^s, M, \eta_j^s(\#), \eta_j^f(\#), q^s(\#)$		

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

Table 5. 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	$I_i^s = q^s \sum_{j=2}^{12} N_{ij} W_{ij} S_j^s e^{-\Delta^s Z_{ij}}$
2)	Catch biomass by year	C_i	$\hat{C}_{ij}^f = \sum_{j=2}^{12} N_{ij} W_{ij} \frac{F_{ij}^f}{Z_{ij}} (1 - e^{-Z_{ij}})$
3)	Proportion at age j, in year i	P_{ij}, $\sum_{j=2}^{12} P_{ij} = 1.0$	$p_{ij}^f = \frac{\hat{C}_{ij}^f}{\sum_j \hat{C}_{ij}^f}$ $p_{ij}^s = \frac{N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}{\sum_j N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}$
4)	Initial numbers at age	j = 2	$N_{1970,j} = e^{\mu_R + \varepsilon_{1970}}$
5)		2 < 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 = 2	$N_{i,2} = e^{\mu_R + \varepsilon_i}$
8)		2 < 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 2 and i = 1958, …, 2010	$\varepsilon_i, \sum_{i=1958}^{2010} \varepsilon_i = 0$	$N_{i,2} = e^{\mu_R + \varepsilon_i}$
11)	Index catchability Mean effect Age effect	μ^s, μ^f η_j^s, $\sum_{j=2}^{12^+} \eta_j^s = 0$	$q_i^s = e^{\mu^s}$ $s_j^s = e^{\eta_j^s}$ $j \le$ maxage $s_j^s = e^{\eta_{maxage}^s}$ $j >$ 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	$\phi_i, \sum_{i=1970}^{2010} \phi_i = 0$	
15)	age effect of fishing (regularized) In year time variation allowed	η_{ij}^f, $\sum_{j=2}^{12^+} \eta_{ij} = 0$	$s_{ij}^f = e^{\eta_j^f}$, $j \le$ maxage $s_{ij}^f = e^{\eta_{maxage}^f}$ $j >$ maxage
	In years where selectivity is constant over time	$\eta_{i,j}^f = \eta_{i-1,j}^f$	$i \ne$ change year
16)	Natural Mortality	M	Set fixed at 0.23 in basecase
17)	Total mortality		$Z_{ij} = \sum_f F_{ij}^f + M$
17)	Spawning biomass (note spawning taken to occur at mid of November)	Bi	$B_i = \sum_{j=2}^{12} N_{ij} e^{-\frac{10,5}{12} Z_{ij}} W_{ij} p_j$
18)	Recruitments (Beverton-Holt form) at age 2.	$\tilde{R}_i$	$\tilde{R}_i = \frac{\alpha B_i}{\beta + B_i}$, $\alpha = \frac{4hR_0}{5h-1}$ and $\beta = \frac{B_0(1-h)}{5h-1}$ where $B_0 = R_0 \varphi$ $\varphi = \sum_{j=2}^{12} e^{-M(j-1)} W_j p_j + \frac{e^{-12M} W_{12} p_{12}}{1 - e^{-M}}$ h=0.8

Table 6. Specification of objective function that is minimized (i.e., the penalized negative of the log-likelihood).

	Likelihood /penalty component		Description / notes
19)	Abundance indices	$L_1 = \sum_s \lambda_1^s \sum_i \ln\left(\frac{I_i^s}{\hat{I}_i^s}\right)^2$	Survey abundances
20)	Prior on smoothness for selectivities	$L_2 = \sum_l \lambda_2^l \sum_{j=2}^{12^+} \left(\eta_{j+2}^l + \eta_j^l - 2\eta_{j+1}^l\right)^2$	Smoothness (second differencing), Note: *l={s*, or *f}* for survey and fishery selectivity
21)	Prior on recruitment regularity	$L_3 = \lambda_3 \sum_{i=1958}^{2010} \varepsilon_i^2$	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	$L_4 = \sum_f \lambda_4^f \sum_{i=1970}^{2010} \ln\left(\frac{C_i^f}{\hat{C}_i^f}\right)^2$	Fit to catch biomass in each year
23)	Proportion at age likelihood	$L_5 = -\sum_{l,i,j} T_i^l P_{ij}^l \ln\left(\hat{P}_{ij}^l\right)$	*l={s, f}*for survey and fishery age composition observations
24)	Fishing mortality regularity	F values constrained between 0 and 5	(relaxed in final phases of estimation)
25)	Recruitment curve fit	$L_6 = \lambda_6 \sum_{i=1977}^{2010} \ln\left(\frac{N_{i,2}}{\tilde{R}_i}\right)^2$	Conditioning on stock-recruitment curve over period 1977-2004.
26)	Priors or assumptions	R_0 non-informative σ_R^2 fixed at 0.6	
27)	Overall objective function to be minimized	$\dot{L} = \sum_k L_k$	

Table 7. Penalties used on log-likelihood functions in the base model.

L	*s*	Abundance index	$\lambda^{s\ (1)}$	*L*	*f*	Catch biomass likelihood	$\lambda^{f\ (1)}$
1	1	Acoustic CS- Chile	5.6	4	1	N-Chile	200
	2	Acoustic N-Chile	2		2	CS- Chile	200
	3	CPUE – Chile	12.5		3	Peru	200
	4	DEPM – Chile	3.1		4	International	200
	5	Acoustic-Peru	5.6		5	ex USSR	200
	6	CPUE – Peru	12.5				
	7	CPUE- China	3.1				
	8	CPUE-EU	12.5				
	9	CPUE- ex USSR	12.5				
2	*s*	Smoothness for selectivities	$\lambda^{s\ (1)}$	5	*s*	Proportion at age likelihood	T^s
	1	Acoustic CS- Chile	100		1	Acoustic CS- Chile	30
	2	Acoustic N-Chile	100		2	DEPM – Chile	20
	3	CPUE – Chile	100				
	7	CPUE- China	100				
	8	CPUE-EU	100				
	9	CPUE ex-USSR	100				
	f	Smoothness for selectivities	$\lambda^{f\ (1)}$	6	*f*	Proportion at age likelihood	T^f
	1	N-Chile	1		1	N-Chile	20
	2	CS- Chile	25		2	CS- Chile	50
	3	Peru	12.5		3	Peru	30
	4	Internacional	12.5		4	Internacional	30
	5	ex – USSR	12.5		5	ex - USSR	30
3		Recruitment regularity	$\lambda^{s\ (1)}$			S-Recruitment curve fit	$\lambda^{\ (1)}$
			1.4				1.4

(1) λ corresponds to $0.5/\sigma^2$:

σ	λ
0.05	200.0
0.10	50.0
0.20	12.5
0.30	5.6
0.40	3.1
0.50	2.0
0.60	1.4

Table 8. Description of JJM model components and how selectivity was treated.

Item	Description	Selectivity assumption
Fisheries		
1)	Chilean northern area fishery	Estimated from age composition data
2)	Chilean central and southern area fishery	Estimated from age composition data
3)	Peruvian fishery	Estimated from transformed length data to age.
4)	Recent offshore trawl fishery and	Estimated from recent age composition data (post 1992)
	Ex-USSR trawl fishery	Estimated from historical age composition data.
Index series		
5)	Acoustic survey in central and southern Chile	Estimated from age composition data
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
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 9. Growth parameters employed to convert the length compositions (Peru) to age compositions for the Fleet 3 far north fishery.

Parameter	Peru (Unpublished)	Russia (Kochkin, 1994)	Chile (Gili et al, 1995)
Loo (cm)	68.8	74.2	70.8
k (year-1)	0.165	0.11	0.094
to (year)	-0.902	-0.89	-0.896

Table 10. Particular specifications for the different models applied.

Model	Description
Initial base case Model 1	• All indices assumed proportional to biomass • Soviet age compositions based on Soviet age-length keys • Include all index data • Gili growth parameters to convert length frequencies from the far-north fishery to age compositions
Sensitivities	
Model 2	Peruvian growth parameters to convert length frequencies from the far-north fishery to age compositions
Model 3	Kochkin growth parameters to convert length frequencies from the far-north fishery to age compositions
Model 4	Soviet age compositions based on Chilean age-length keys
Model 5	Downweight acoustic indices (Double CV)
Model 6	Downweight CPUE data (Double CV)
Model 7	Natural mortality alternative: M=0.33

Table 11. Different cases (coefficients of variation) considered on the sensitivity analysis

Index	n *	model 4 (base case)	model 5	model 6	model 7
Acoustic Chile CS	13	0.2	0.4	0.2	0.2
Acoustic Chile N	10	0.5	1.0	0.5	0.5
CPUE Chile	8	0.2	0.2	0.4	0.2
DEPM Chile	9	0.5	0.5	0.5	0.5
Acoustic Peru	27	0.2	0.4	0.2	0.2
CPUE Peru	14	0.2	0.2	0.4	0.2
CPUE China	8	0.4	0.4	0.8	0.4
CPUE Vanuatu & EU (**)	8	0.25 (2003-06) 0.20 (2007-10)	0.25 (2003-06) 0.20 (2007-10)	0.50 (2003-06) 0.40 (2007-10)	0.25 (2003-6) 0.20 (2007-10)
CPUE USSR	5	0.25	0.25	0.5	0.25
M		0.23	0.23	0.23	0.33

Notes:

* number of observations

** between parenthesis the years

Table 12. Values of components of the objective function for the 7 different JJM models. Note that Model 5 and Model 6 values use different weightings for indices and hence are not strictly comparable.

	Model1	Model2	Model3	Model4	Model5	Model6	Model7
Data							
Indices likelihoods	425.7	409.4	423.4	435.2	222.2	361.0	428.4
Fishery Age compositions	945.0	945.1	965.7	838.2	788.6	828.1	791.6
Survey age compositons	132.8	127.3	133.3	136.5	124.4	133.5	138.6
Catch biomass	6.9	3.7	5.2	6.8	2.0	5.2	5.8
Priors							
Fishery selectivity	50.2	59.2	55.2	31.8	30.6	31.5	30.5
Indices selectivity	24.0	24.7	24.1	26.4	21.1	26.1	27.5
Stock-recruitment	39.1	42.1	38.3	21.0	22.8	24.9	14.4
total	1,623.9	1,611.7	1,645.3	1,496.2	1,212.0	1,410.7	1,437.1

ANNEX 2: Results from final selected models for the 2010 Jack mackerel stock assessment

This annex contains the main results from the final models specified at the subgroup meeting.

Assessment model results

Total catch used for this assessment is shown in Fig. 3. Other data in the model is shown in the fit figures below or in Annex 1. For the purposes of this section the three models presented represent the base case (Model 4 from Annex 1) and alternatives that seem to bracket model uncertainty (Models 5 and 6 from Annex 1).

The base case fit (Model 4) to the fishery age composition data is shown in Figures 4, 5, 6, and 7. This model fit to the indices is shown in Figure 8 while the fit to the index age compositions are shown in Figures 9, and 10. Selectivity estimates for the fishery and indices is shown over time in Figs. 11 and 12 respectively. A summary of the time series stock status (spawning biomass, F, recruitment, total biomass) is shown in Fig. 13.

Model sensitivities

As an initial model evaluation, the impact of downweighting different types of indices was selected to illustrate potential structural errors in model assumptions and the influence it may have on trends and current abundance levels. For fishing mortality, the comparison of the base case and model sensitivities indicate higher levels for Model 6 (which downweighted CPUE data) relative to the base case and the model which downweights the acoustic indices (Model 5; Fig. 14). In terms of the effect on stock status relative to "unfished", the differences were relatively minor and in all cases, the 2010 total biomass is estimated to be between 9 – 14% of the unfished level (Fig. 15).

These models compared similarly with each other and with the TISVPA for total biomass (Fig. 16).

Projections

The following recruitment scenarios were proposed for projections during the subgroup meeting:

1) Use average recruitment as estimated from 2005-2009
2) Use average recruitment as estimated from 2000-2009.

For each of these periods, 100 stochastic simulations (in recruitment) were conducted assuming the same mean and variance for these two time periods. *Important: these recruitments are generated without regard to a stock recruitment relationship—mean recruitment is constant over all spawning biomass levels.* These were run for the base case (Model 4) and the two sensitivities (Models 5 and 6). The subgroup further recommended examining constant catch scenarios with current levels (711 kt) and at 75%, 50%, 25%, and 1%. Constant catch solutions were obtained by iterating F's (assuming ratios among the 4 fleets to be similar to that observed in 2010) within the Baranof catch equation. The 3 models and 5 constant catch strategies and two recruitment scenarios results in 30 unique projection configurations. Each of these were projected for 11 years (to 2020) and simulated 100 times. These simulations show that for the base case, future constant catches held at 75% of current catches (533.25 kt) for the 5-year average recruitment scenario may result in continued stock declines and increased fishing mortality (Fig. 17). A more optimistic recruitment scenario (based on the 10-year average recruitment projection) indicates that the current catch level (711 kt) is likely to result in reduced fishing mortality for many individual simulations but with a large degree of uncertainty (Fig. 18).

For the 5-year average recruitment scenario, examination of mean values from projections indicates that, for the stock to show signs of increase, a reduction in catch by about 50% would be required regardless of the model (Fig. 19). The more optimistic recruitment scenario based on the 10-year average recruitment projection indicates that even at the current catch level (711 kt) the stock is likely to increase (Fig. 20).

Figures

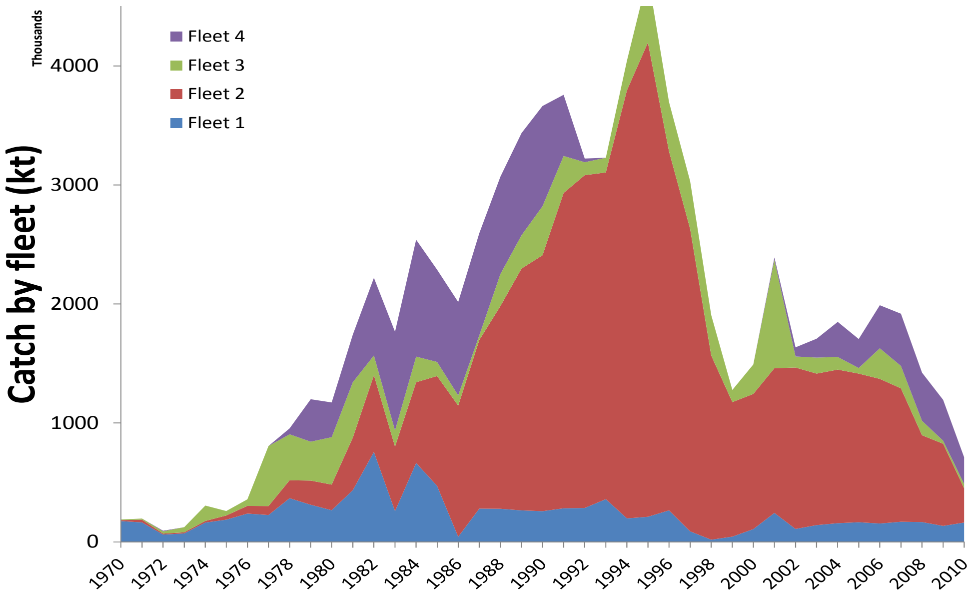

Figure 1. Total catch and catch components used for the joint jack mackerel assessment, 1970-2010. Fleet 1 corresponds to the N Chile purse seine, Fleet 2 the SC Chilean purse seine, Fleet 3 the far north fishery, and Fleet 4 the Offshore trawl fishery.

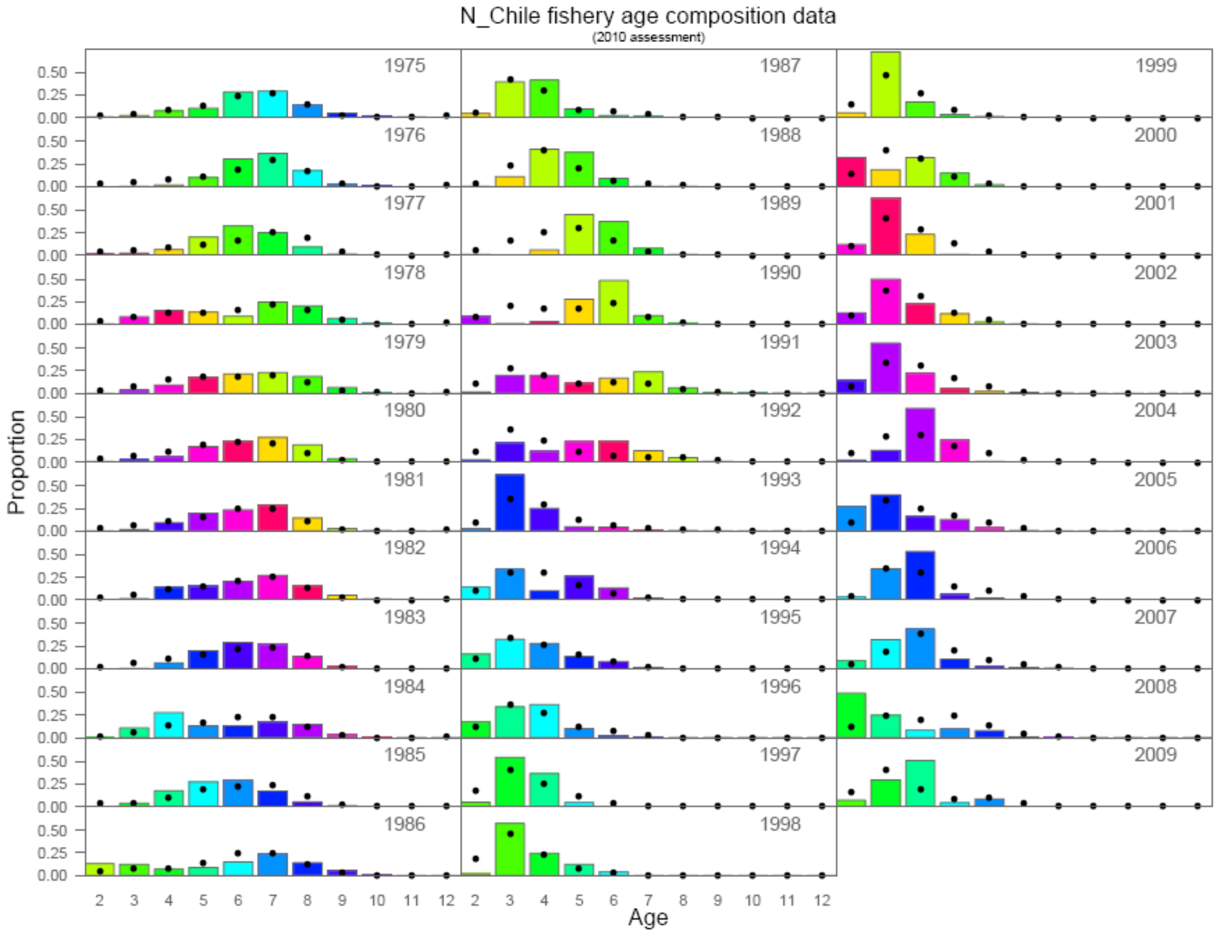

Figure 2. Base case (model 4) fit to the age compositions for the **Chilean northern zone fishery (Fleet 1)**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

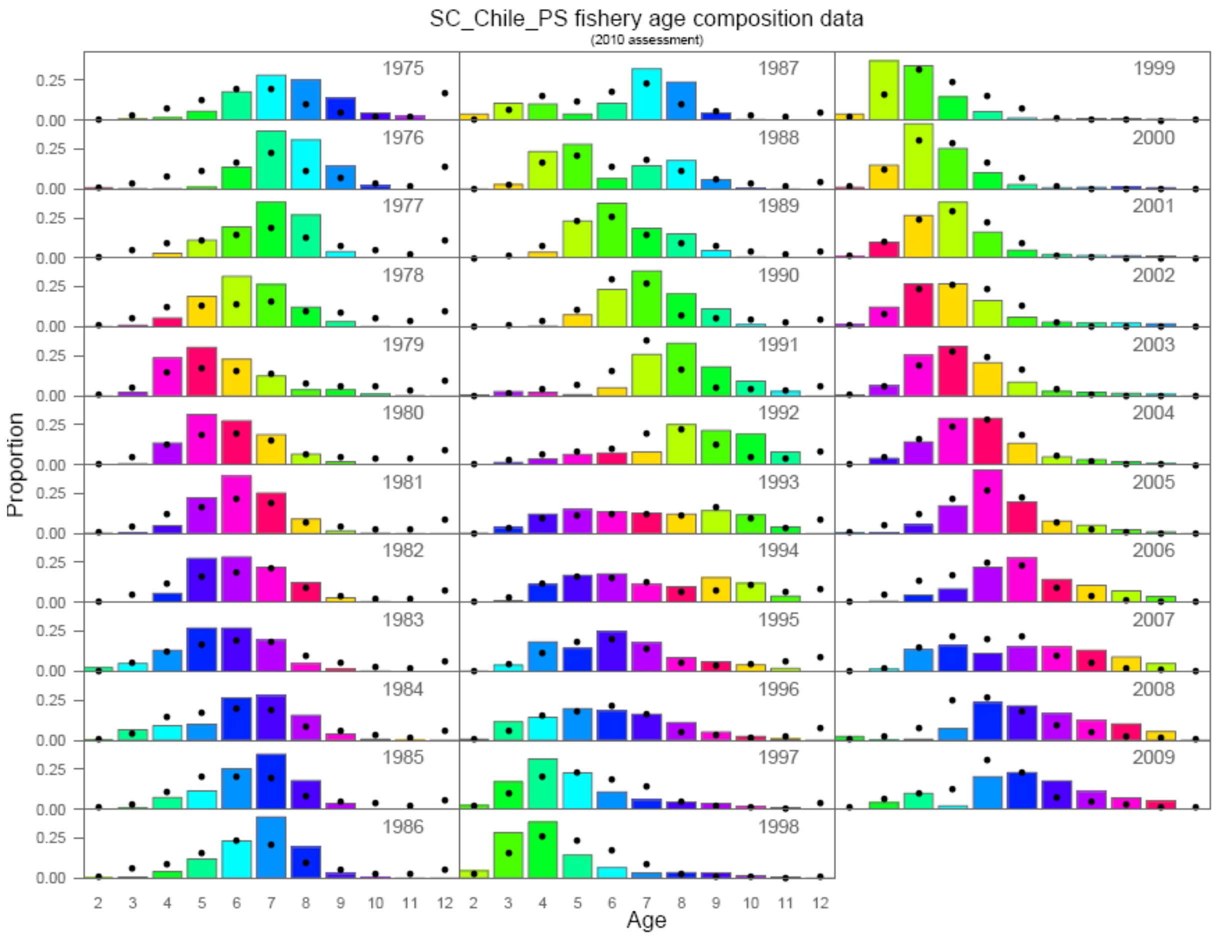

Figure 3. Base case (model 4) fit to the age compositions for the **South-Central Chilean purse seine** fishery (Fleet 2). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

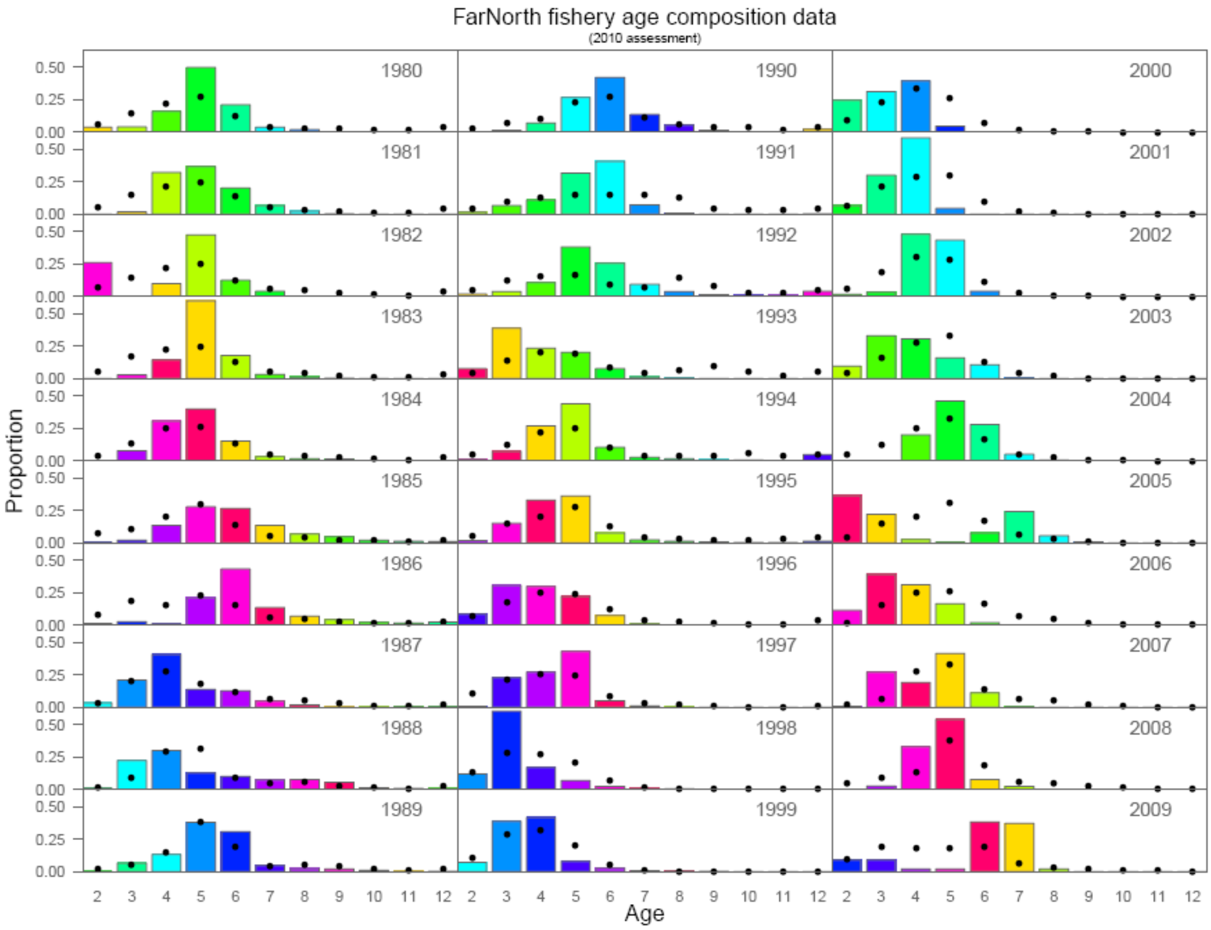

Figure 4. Base case (model 4) fit to the age compositions for the far north fishery (Fleet 3). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

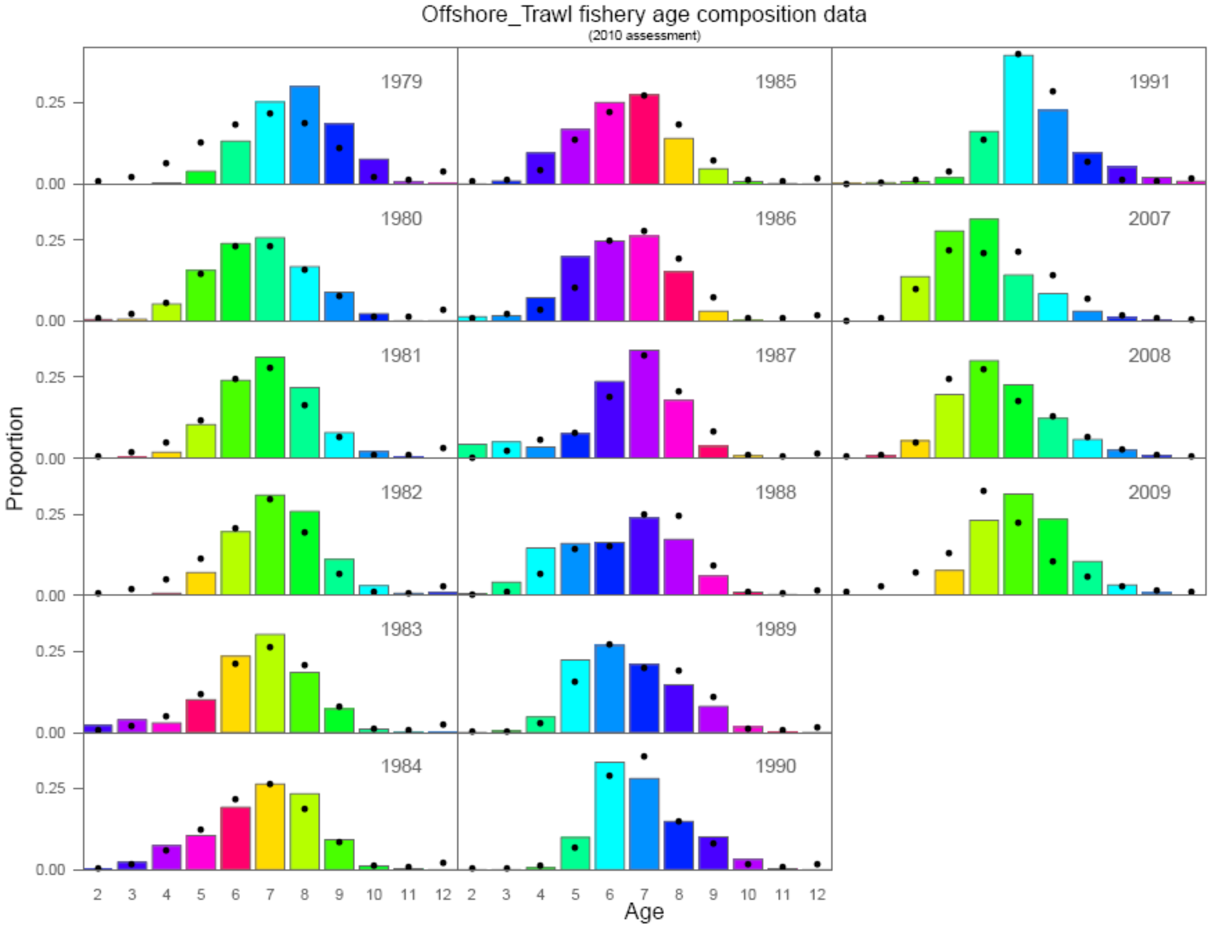

Figure 5. Base case (model 4) fit to the age compositions for the **offshore trawl** fishery (Fleet 4). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

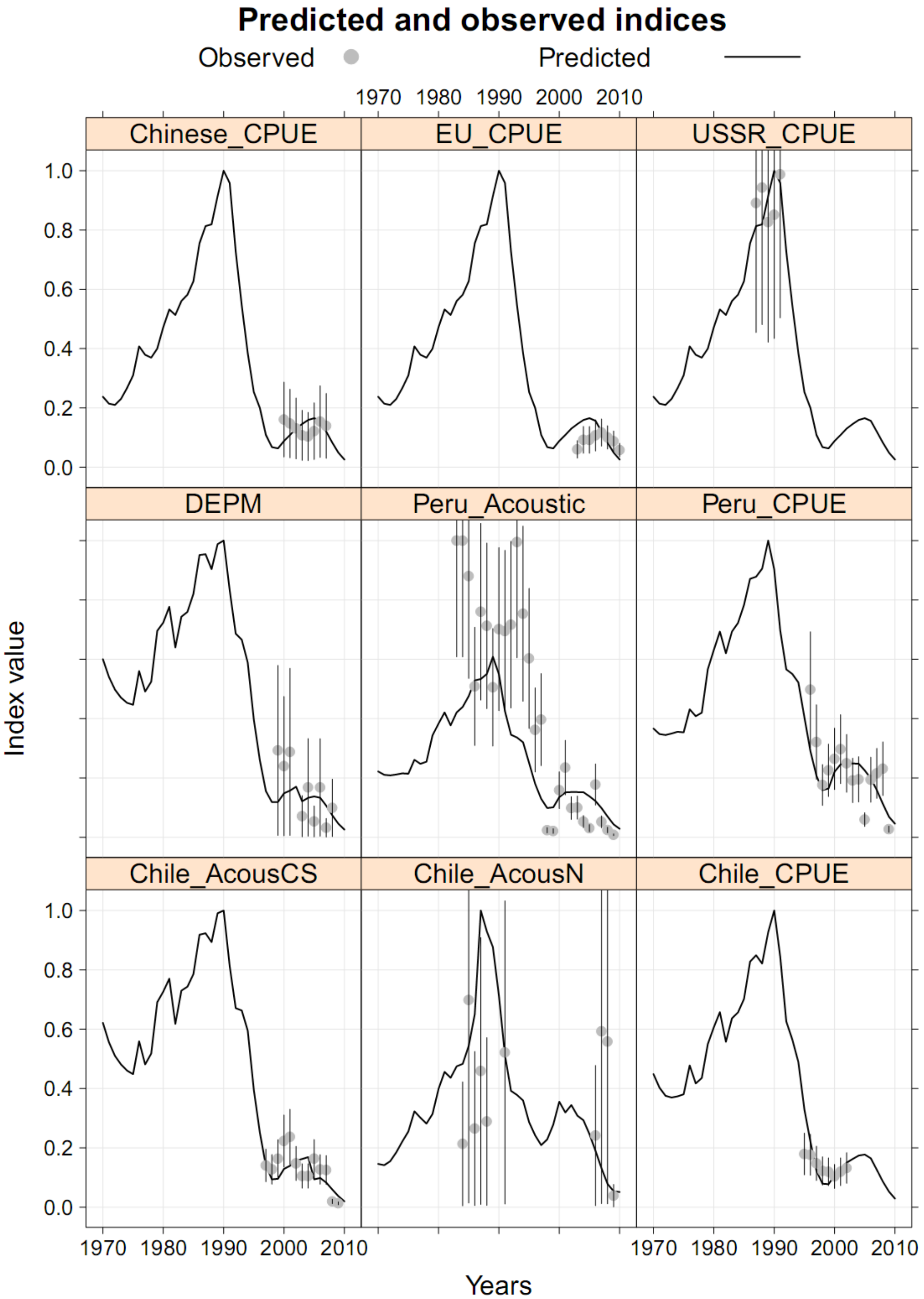

Figure 6. Base case (model 4) fit to different indices. Vertical bars represent 2 standard deviations around the observations.

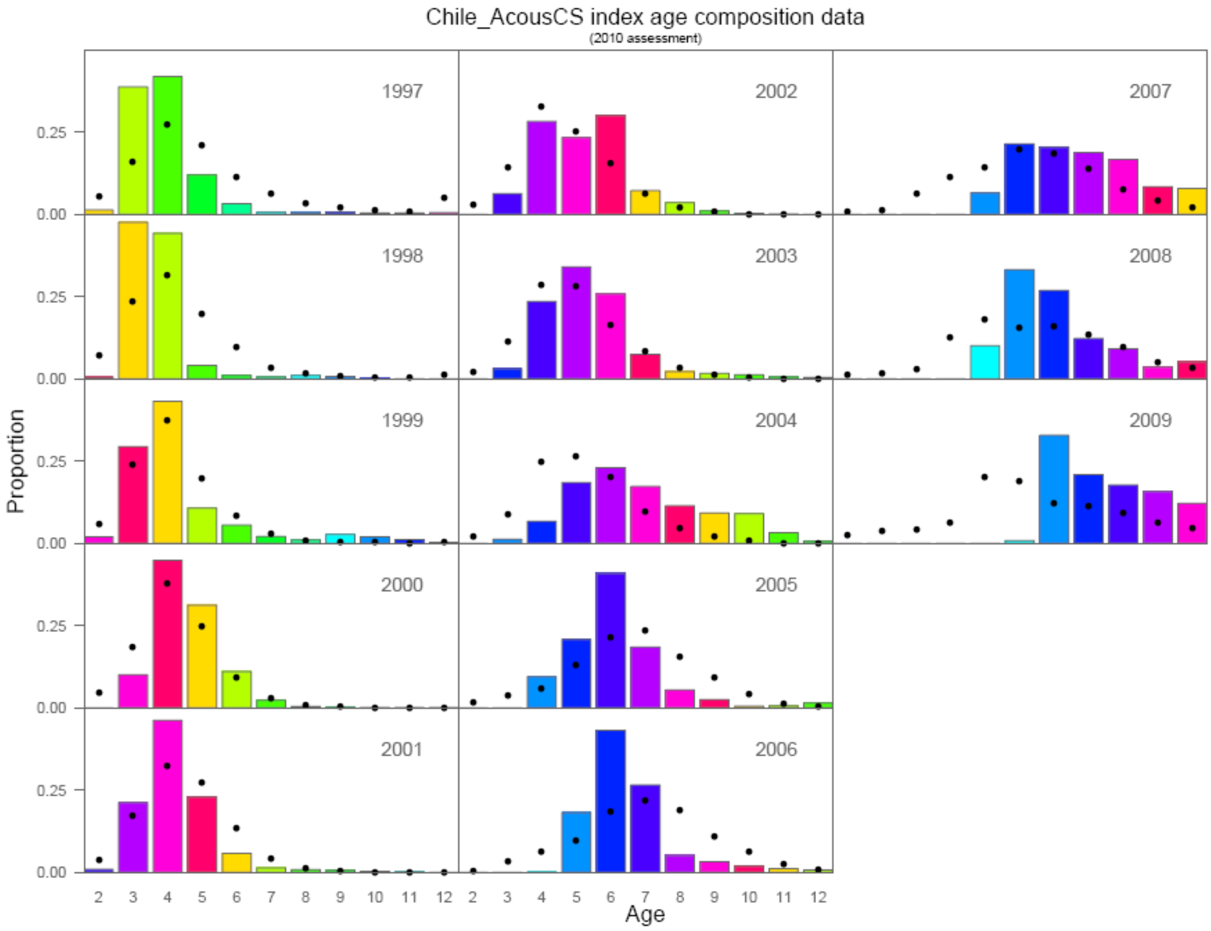

Figure 7. Base case model fit (x's) to age composition data (columns) for age samples collected during the CS Chilean region acoustic surveys.

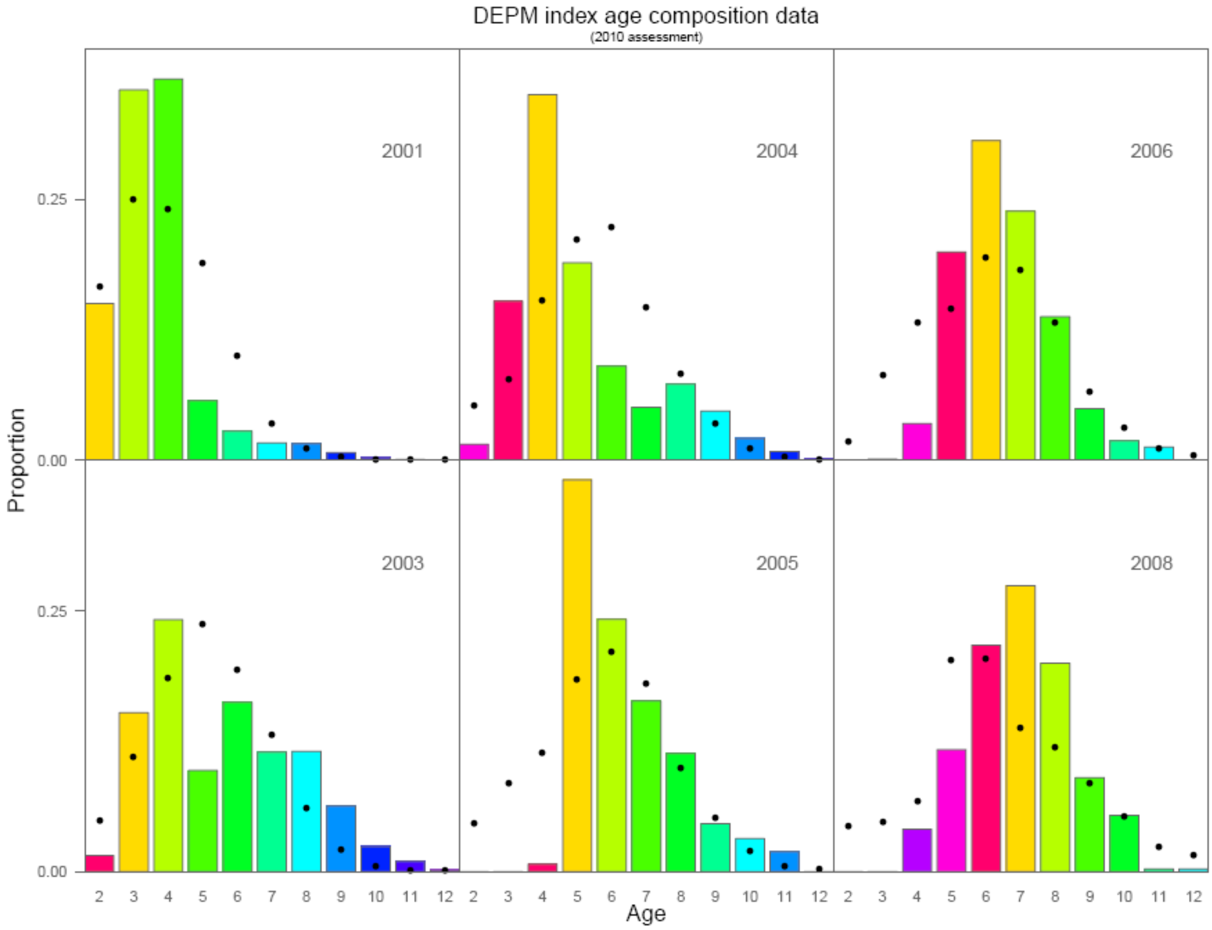

Figure 8. Base case (model 4) fit (dots) to age composition data (columns) for age samples collected during the daily egg production surveys.

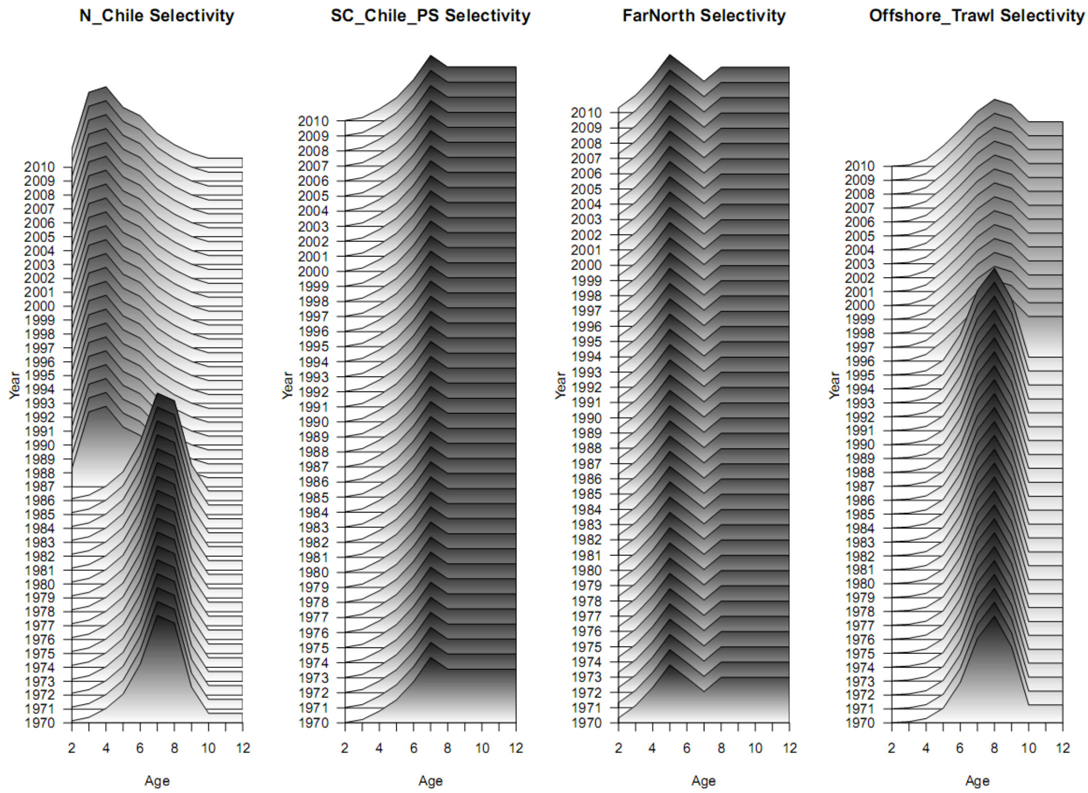

Figure 9. Base case (model 4) estimates of selectivity by fishery over time.

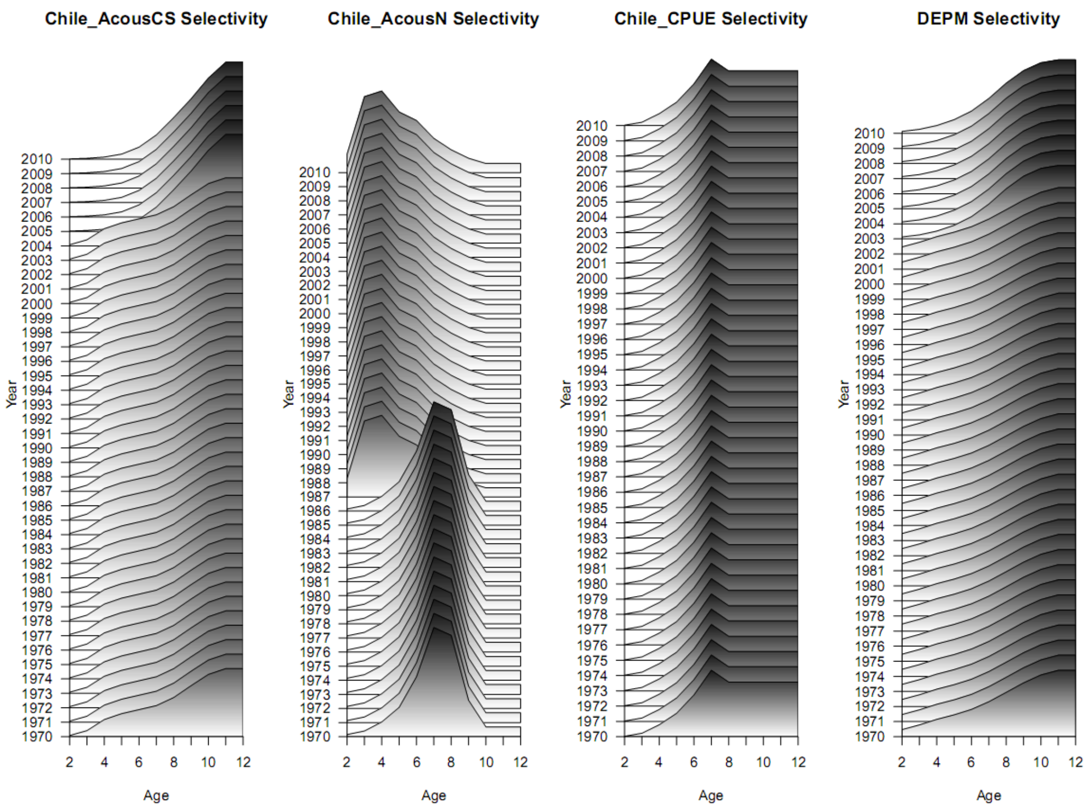

Figure 10. Base case (model 4) estimates of selectivity for each index over time.

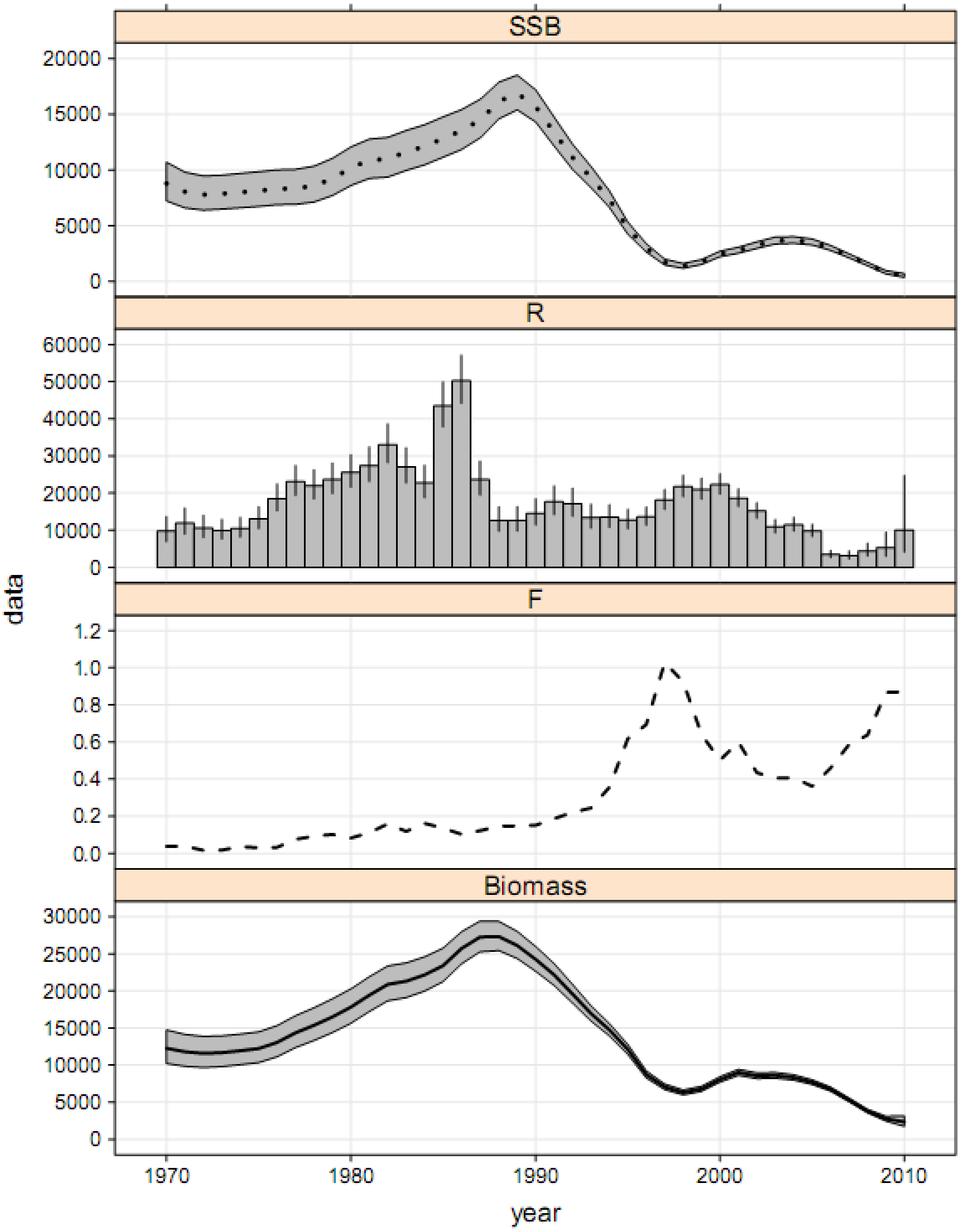

Figure 11. Base case (model 4) summary estimates over time showing spawning biomass (kt; top), recruitment at age 2 (millions; 2nd from top) total fishing mortality (3rd) and total biomass (kt; bottom). Shaded areas represent the approximate 95% confidence bands.

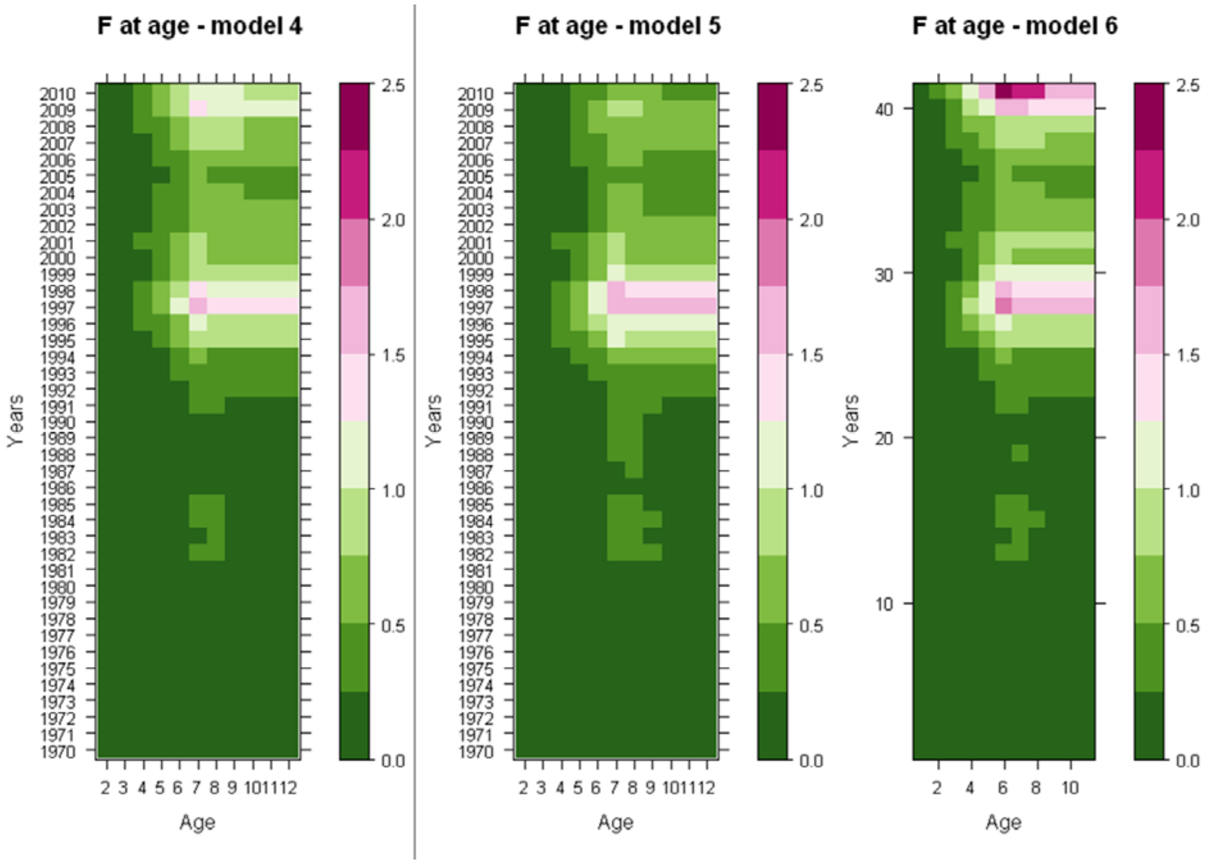

Figure 12. Historical fishing mortality at age for the base casel (Model 4; left most) and sensitivities (Models 5, and 6).

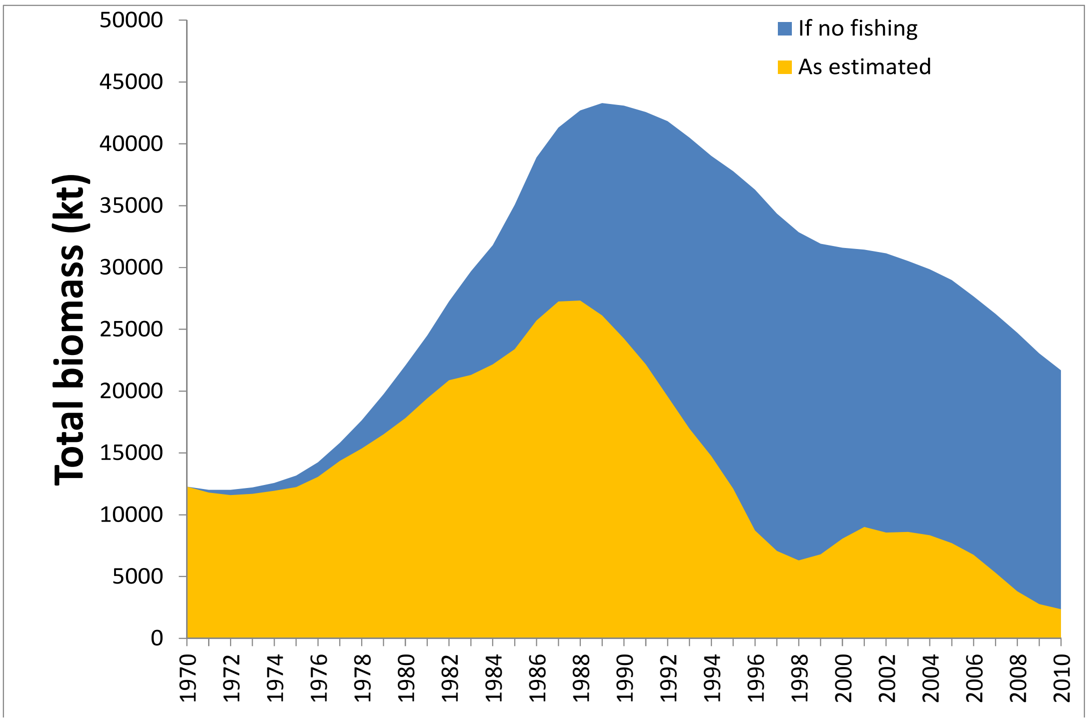

Figure 13. Total biomass trajectories for the base case (Model 4) under a hypothetical scenario of no fishing relative to the total biomass as estimated in the assessment. The 2010 ratio of estimated total biomass relative to the unfished is 11%. The values for the sensitivities (model 5 and 6) were 14% and 9%, respectively.

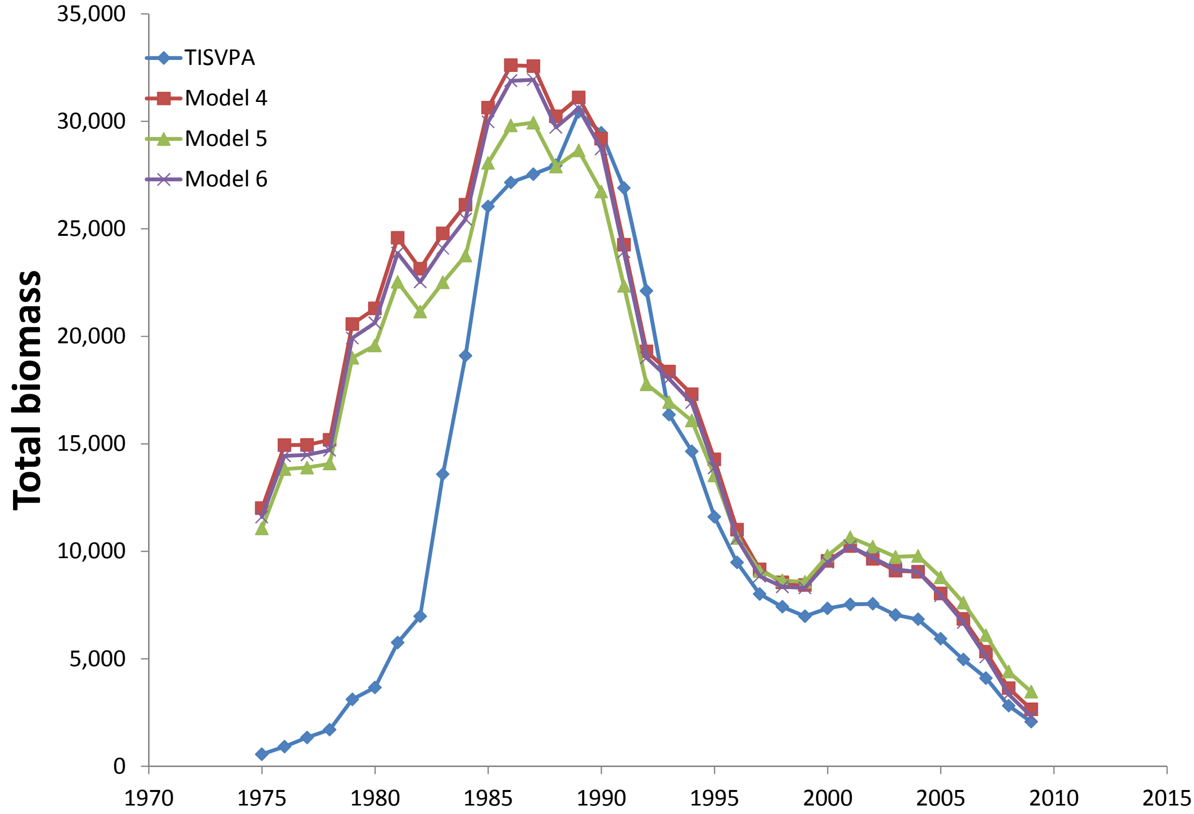

Figure 14. Total biomass (kt) estimates comparing the TISVPA model to that of the base case (Model 4) and the two sensitivities that were selected (Models 5 and 6).

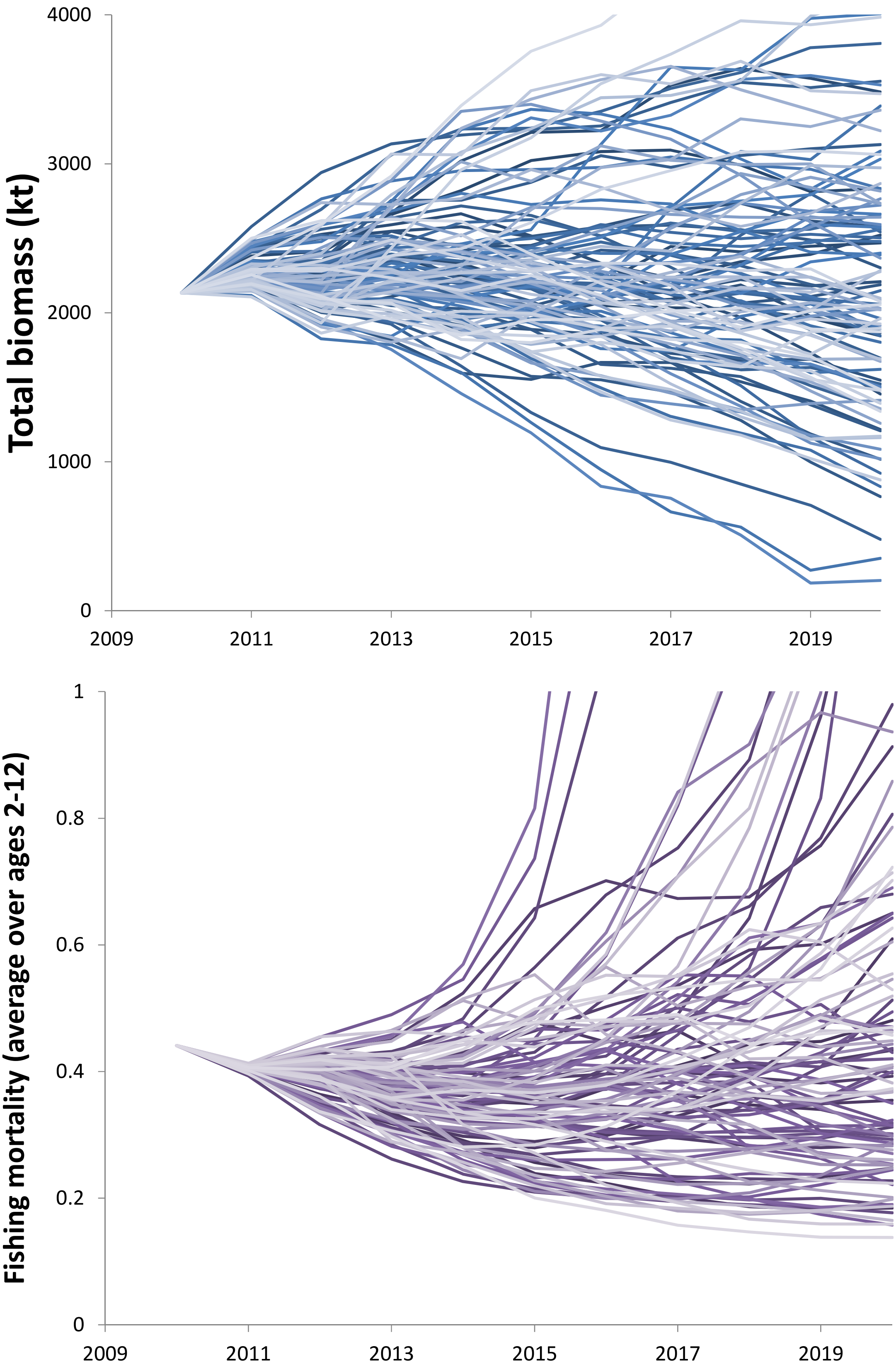

Figure 15. Stochastic projections of biomass (kt; top panel) and fishing mortality (average ages 2-12; bottom panel) for the base case model (Model 4) under the assumption that future recruitment has the same mean and variance as the **5-year** period 2005-2009 and assuming constant catch of 533.25 kt (75% of 2010 catch).

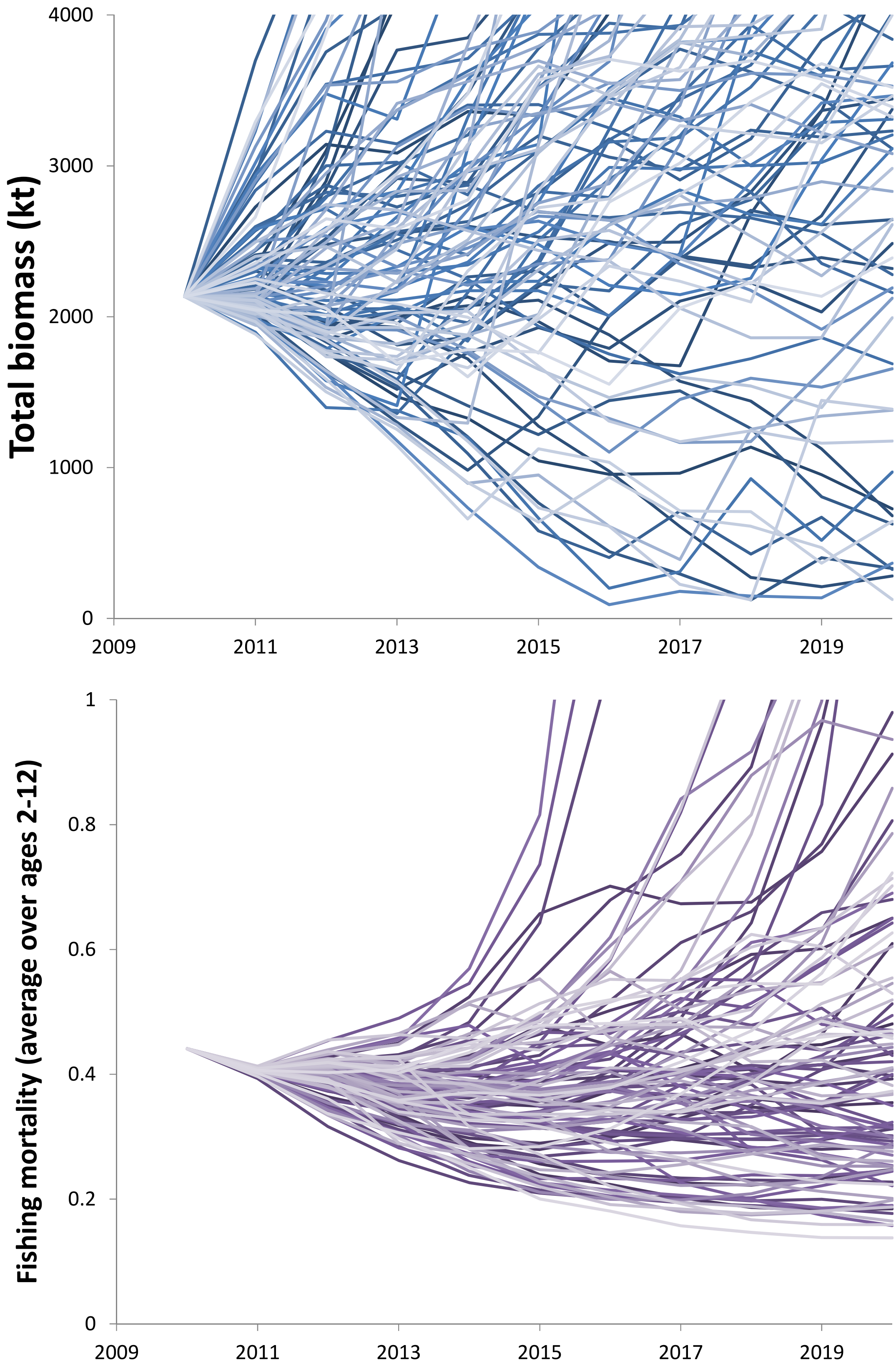

Figure 16. Stochastic projections of biomass (kt; top panel) and fishing mortality (average 2-12; bottom panel) for the base case model (Model 4) under the assumption that future recruitment has the same mean and variance as the **10-year** period 2000-2009 and assuming constant catch of 711 kt (equal to the 2010 catch).

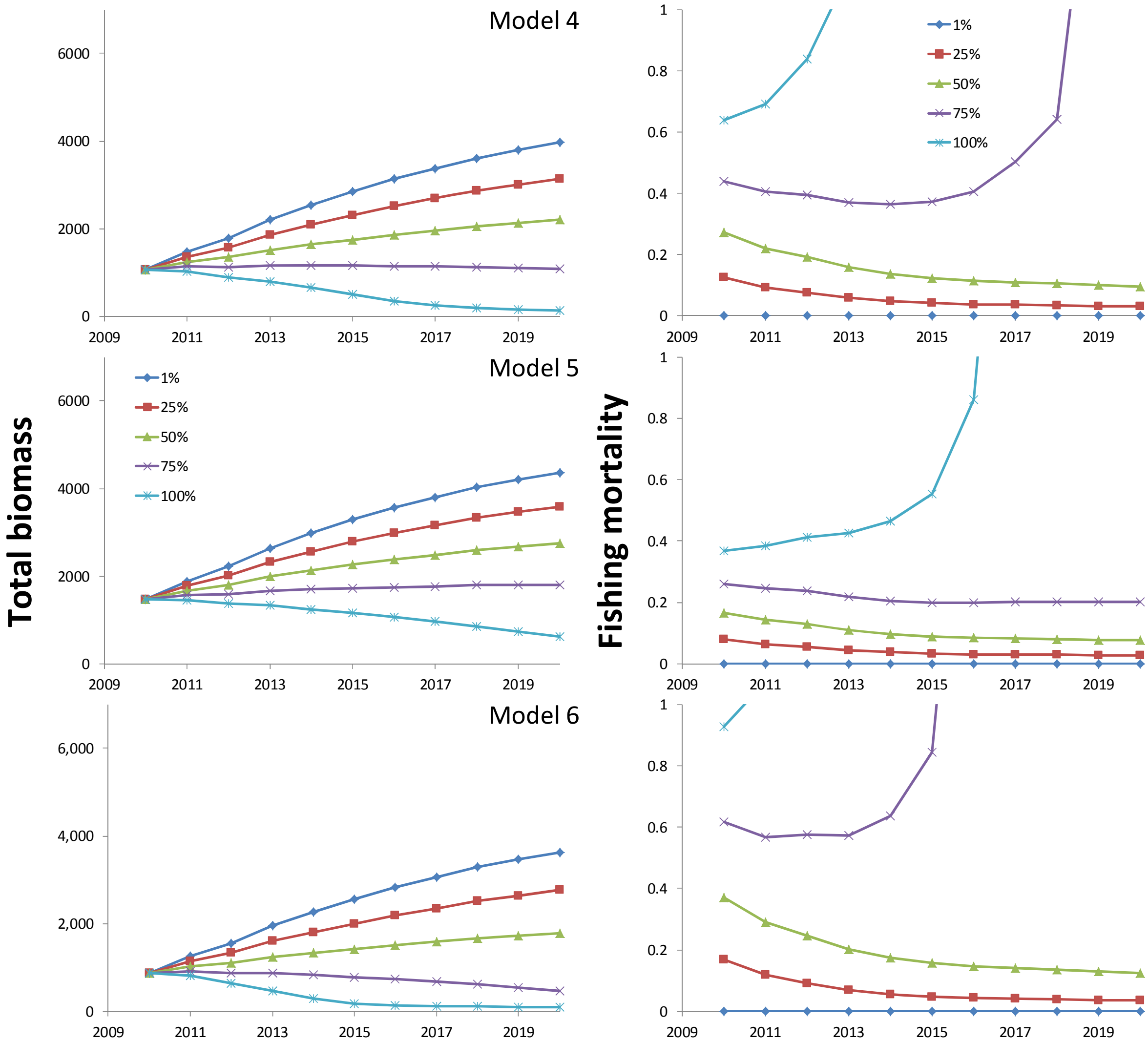

Figure 17. Projections of mean biomass (kt, left panels) and average fishing mortality (over ages 2-12; right panels) for the base case model (Model 4; top row) and the 2 sensitivities (Models 5 and 6) under the assumption that future recruitment has the same mean and variance as the **5-year** period 2005-2009 (which is different for each model). Total biomass is on the left, and future catch is on the right. The different harvest levels are based on 1%, 25%, 50%, 75%, and 100% of the status quo catch.

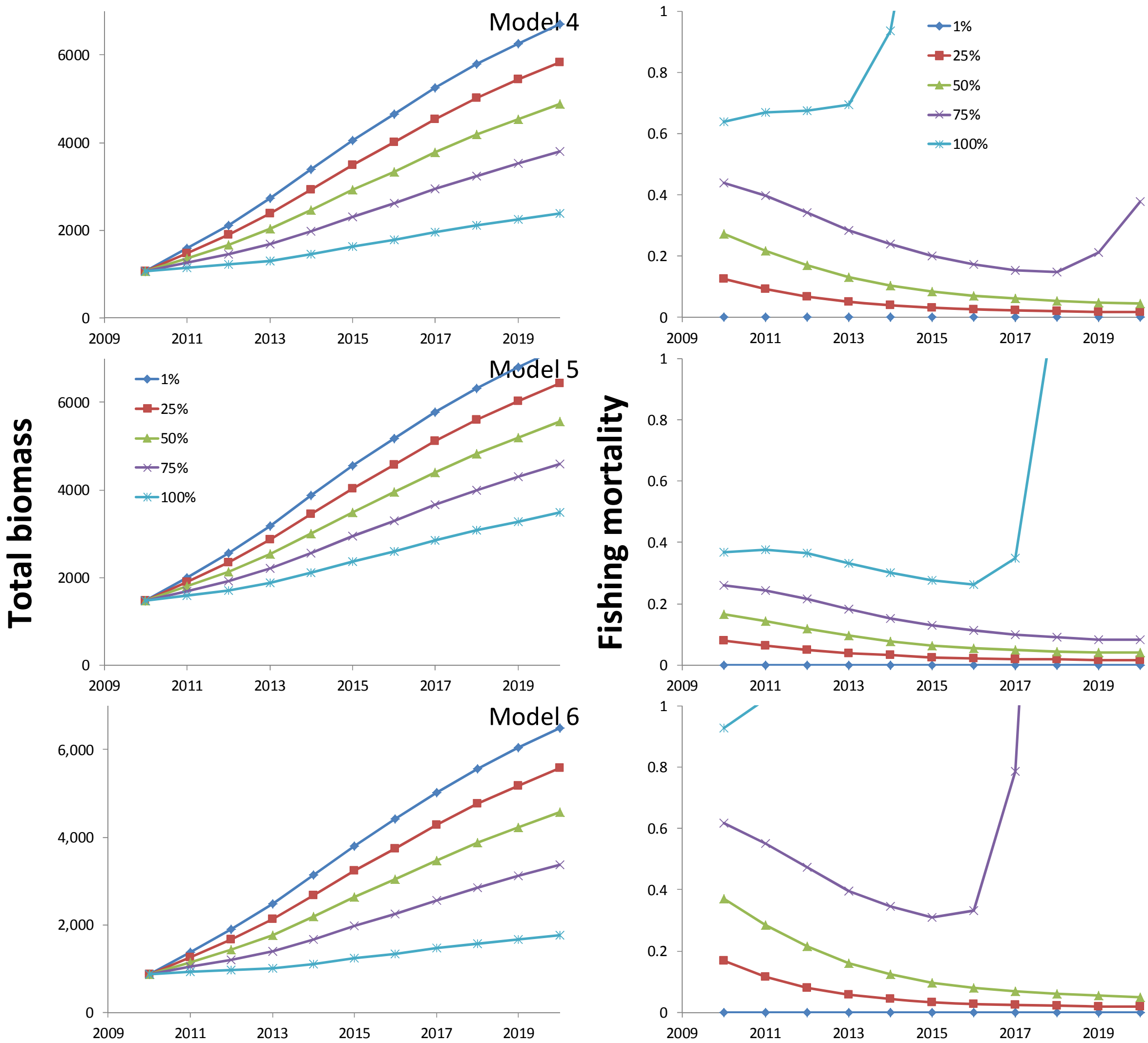

Figure 18. Projections of mean biomass (kt, left panels) and average fishing mortality (over ages 2-12; right panels) for the base case model (Model 4; top row) and the 2 sensitivities (Models 5 and 6) under the assumption that future recruitment has the same mean and variance as the **10-year** period 2000-2009 (which is different for each model). Total biomass is on the left, and future catch is on the right. The different harvest levels are based on 1%, 25%, 50%, 75%, and 100% of the status quo catch.

Annex SWG-05

Report of the Deepwater Subgroup

Viña del Mar, Chile: 21-29 October 2010

Will be added when available …….