A4. 2014 jack mackerel stock assessment

Introduction

This document and content is based on discussions analyses conducted at the SC-02 meeting. Changes in the data used compared to the 2013 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 for SC-02.

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 A4.1.

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 A4.1 and forms four "fleets" which are intended to be consistent with the gear and general areas of fishing (Figure A4.1). These fleets are presented in Table A4.2.

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 A4.3, A4.4, and A4.5. For Peruvian and Ecuadorian catches, catch-at length compositions are used (Table A4.6). 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 A4.7. – A4.9.

All CPUE (and fishery-independent) series used in the model are presented in Table A4.10.

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 A4.11.

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 A4.12. Ageing imprecision is acknowledged through the use of an age-error matrix and is shown in Table A4.13.

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 A4.14 - A4.17.

In Peru the mean weight at age is calculated by year taking the invariant mean length at age estimated from the growth function (Table A4.12) and the length-weight relationship of the year. The information covers the period 1970-2012.

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 summary list of all data available for the assessment is provided in Table A4.18.

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 2013.

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 A4.19. 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 A4.20 and A4.21. Table A4.22 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 A4.23, A4.24 and A4.25. 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 exploratory assessments

Description of key changes from base case assessment to exploratory assessment

Sensitivities for the assessment began with Model 1.0 (set to be the same as Model 0.2). The first sensitivity was based on applying the alternative acoustic backscatter index from the Peruvian zone (Model 1.1). Other sensitivities included downweighting the CPUE indices (inflating the observation errors by a factor of 10, Model 1.2), downweighting the offshore fishery age compositions (decreasing the sample sizes by a factor of 10, Model 1.3) and downweighting the fit to the catch data (Model 1.4). As with the previous assessment, an examination of natural mortality sensitivity was carried out (Models 1.5-1.8) and also refinements to data weights in recent years (models 1.9-1.11). These model configurations are summarized in Table A4.26.

Assessment results

During the meeting a series of alternatives were examined. To evaluate these, the negative-log likelihood components were presented to evaluate trade-offs between different data components and model assumptions (Table A4.27). It is important to note that some values in this table for some subsets of models cannot be compared across models because some models introduce new data (i.e., the revised acoustic survey index for Peru). Also, comparison between models with different stock structure hypotheses requires consideration of the number of parameters.

For projection purposes, alternative considerations about recruitment regimes and productivity were configured as Models 2.0-2.3. Based on results over all models and sensitivities including ageing error, Model 2.0 (which is identical to 1.11) and Model 2.0n (identical to 1.1n) were selected as the base case for assessment results.

Results comparing the impact of new data (models 0.0-0.2) 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 A4.2). The rationale for selecting model 1.11 as the base case was due to a better specification of uncertainties and reasonable fits to indices and age compositions. The other alternative configurations were largely consistent (except for 1.5 in which an unrealistically high value of M was assumed). Comparing model 1.11 with the alternative stock structure indicated that the “south” model (1.11S) was very similar to the combined stock-structure model (model 1.11; Figure A4.3). 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 A4.4. The model numbers-at-age estimates are given in Table A4.28. The fishery age and length composition fits are shown in Figures A4.5, A4.6, A4.7, and A4.8. The age composition data from the surveys are given in Figures A4.9 and A4.10. This model fit the indices reasonably well (Figure A4.11). Fits to the index and fishery mean age compositions are shown in Figures A4.12 and A4.13.

Selectivity estimates for the fishery and indices is shown over time in Figures A4.14. A summary of the time series stock status (spawning biomass, F, recruitment, total biomass) for the single-stock hypothesis is shown in Figure A4.15 and for the two-stock hypothesis in Figure A4.16. 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 A4.17).

Fishing mortality rates at age (combined fleets) were relatively high starting in about 1992 but has declined in the past few years (Table A4.29). 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

Projections and risk analysis

Considering the actual population status of jack mackerel under both the single and two stock structure hypotheses, the subgroup recommended examining constant fishing mortality scenarios with current levels (F_{2014}) and at 125%, 75%, 50%, and 0% (no catch) as well as the proposed Commission management plan. For evaluation purposes, two recruitment scenarios were developed which reflected hypotheses about the scale of the recruitment (by period or “regime”) and the stock recruitment productivity near the origin (stock recruitment "steepness"). The scale of recruitment was affected by the "regime" (2000-2012) and steepness hypotheses were specified at values of 0.8 and 0.65. In addition to these specified sources of uncertainty, uncertainty in all other internally estimated model parameters along with future recruitment variability were also propagated forward. An evaluation of risk was developed that was conditioned on this uncertainty. Objectives considered included the goal to rebuild the stock to the long-term expected B_{MSY} level using likely recruitment scenarios expected in the near-term.

Conditions for the jack mackerel stock remain at low levels and new information is consistent with the results from previous assessments. Historical fishing mortality rates and patterns relative to the provisional biomass target are shown in Figure A4.18 (so-called Kobe plot). Projection results under the assumption of recent average recruitment at the levels estimated for the recent period (2000–2012) indicate that if fishing mortality is maintained at or below 2014 levels the likelihood of spawning biomass increases are improved. This results in catches for 2015 on the order of 460 kt or lower (Table A4.30). Note that this table shows that under the two-stock hypothesis projected spawning biomass sums to higher values than under the single stock hypothesis. Fishing effort in the next 10 years at or below current (2014) levels are projected to have a reasonably good probability of increased spawning biomass from the current level of 2.7 million t with projected increase to 3.2 million t in 2015 (with approximate 90% confidence bounds of 2.5 - 4.1 million t; Figure A4.19).

Assessment issues

The quality of the input data improved considerably from 2012 to 2013 with the inclusion of variable weight-at-age matrices for different datasets and standardization of indices. Further improvements to the data were made for the 2014 assessment but they were minor in comparison. The lack of standardization in the EU and Russian CPUE time series is still a concern, but does not seem to affect the assessment results. Potentially, allowing the stock assessment model to fit to length frequency data of these fisheries might improve the offshore fleet fits.

Overall, the assessment appears to be maturing to the point where issues of model specification and data sensitivities are diminishing. As such, it may be useful to concentrate work in other pursuits at the next SC meeting (in 2015) and have full assessments, such as this, occur every two or three years. This way, effort towards developing a more fully conditioned operating model (given current assessment configurations) for use to test management procedures (or management strategies) can be pursued. Also, a re-evaluation of all data inputs would provide better confidence in the assessments going forward.

A4. References

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A4. Tables

Table A4.1. 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	47230	341720
2014	*30337*	*240789*			*6*	*65008*		*65014*		*19738*		*19990*	*0*		*4178*	*0*			*15039*	*58945*	*395085*

Underlined values have been updated relative to the 2013 assessment; the *2014* estimates are preliminary and based on methods described in Section 6.2.1 of the SC-02 report.

Table A4.2. Input catch by fleet (combined) for the stock assessment model. Note that 2014 data are preliminary.

	Fleet 1	Fleet 2	Fleet 3	Fleet 4
1970	101,685	10,309	4,711	0
1971	143,454	14,988	9,189	0
1972	64,457	22,546	18,782	5,500
1973	83,204	38,391	42,781	0
1974	164,762	28,750	129,211	0
1975	207,327	53,878	37,899	0
1976	257,698	84,571	54,154	35
1977	226,234	114,572	504,992	2,273
1978	398,414	188,267	386,793	51,290
1979	344,051	253,460	333,810	370,290
1980	288,809	273,453	414,299	339,802
1981	474,817	586,092	445,638	438,123
1982	789,912	704,771	143,724	733,204
1983	301,934	563,338	110,690	894,300
1984	727,000	699,301	200,674	1,059,927
1985	511,150	945,839	114,622	799,323
1986	55,210	1,129,107	51,029	837,502
1987	313,310	1,456,727	46,304	863,423
1988	325,462	1,812,793	244,229	863,215
1989	338,600	2,051,517	316,247	875,821
1990	323,089	2,148,786	370,823	872,059
1991	346,245	2,674,267	213,447	543,659
1992	304,243	2,907,817	111,682	37,932
1993	379,467	2,856,777	133,354	0
1994	222,254	3,819,193	233,346	0
1995	230,177	4,174,016	550,993	0
1996	278,439	3,604,887	495,518	0
1997	104,198	2,812,866	680,053	0
1998	30,273	1,582,639	412,846	0
1999	55,654	1,164,035	203,751	7
2000	118,734	1,115,565	303,700	2,318
2001	248,097	1,401,836	857,744	20,090
2002	108,727	1,410,266	154,823	76,261
2003	143,277	1,278,019	217,734	158,199
2004	158,656	1,292,943	187,369	295,443
2005	165,626	1,264,808	80,663	243,576
2006	155,256	1,224,685	277,568	362,627
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	30,337	240,789	65,014	58,945

Table A4.3. 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.

Year	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

Table A4.4. 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.

Year	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

Table A4.5. 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.

	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	0	0	1	19	39	29	8	2	1	1	0

Table A4.6. 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 A4.7. 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.

	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	41	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 A4.8. 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.

	1	2	3	4	5	6	7	8	9	10	11	12+
2006	0	1	39	42	12	3	1	1	1	0	0	0
2007	0	1	48	44	4	1	1	1	1	0	0	0
2008	0	2	29	43	11	6	2	1	3	2	1	0
2009	0	0	10	45	31	11	2	0	0	0	0	0
2010	0	1	21	46	23	6	1	1	1	0	0	0
2011	0	0	6	28	23	30	7	4	1	0	0	0
2012	0	0	3	23	34	26	7	2	2	1	1	0
2013	0	0	1	7	18	23	17	11	9	9	3	1
2014	0	0	0	9	21	41	18	5	2	0	1	1

Table A4.9. 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.

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

Table A4.10. Index values used within the assessment model. 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

Year	Chile (1)	Chile (2)	Chile (3)	Chile (4)	Peru(1)	Peru(2)	Peru(3)	China	EU_U	Russia/USSR
1983			0.797							
1984		99	0.700							
1985		324	0.568							
1986		123	0.491		17811	108				
1987		213	0.590		22955	110				55.0
1988		134	0.493		9459	114				58.2
1989			0.506		15034	157				51.1
1990			0.401		14139	230				52.6
1991		242	0.497		16486	232				61.0
1992			0.419		6266	180				
1993			0.368		19659	146				
1994			0.441		10768	95				
1995			0.392		6429	54				
1996			0.408		7271	30				
1997	3530		0.362		2561	32				
1998	3200		0.347		190	44				
1999	4100		0.401	5724	342	53				
2000	5600		0.382	4688	2373	106				
2001	5950		0.473	5627	2052	132		1.40		
2002	3700		0.416		248	97	212.7	1.97		
2003	2640		0.365	1388	1118	67	244.1	1.74		
2004	2640		0.397	3287	864	52	276.6	1.44		
2005	4110		0.363	1043	1025	75	193.2	1.44		
2006	3192	112	0.398	3283	1678	111	245.9	1.02	310	
2007	3140	275	0.302	626	522	80	231.0	1.13	308	
2008	487	259	0.204	1935	223	24	222.6	0.86	256	77.4
2009	328	18	0.167		849		184.2	0.81	209	59.6
2010		440	0.120			7	255.4	0.57	124	
2011		432	0.069		678	35	264.9	0.33	57	45.2
2012		230	0.217		94	50	264.7	0.37		
2013		144	0.162		890	64	139.3	0.58	81	
2014		87	0.135				240.4			

Table A4.11. 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
Southern Stock	0.07	0.31	0.72	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Far North Stock	0.00	0.37	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table A4.12. Growth parameters and natural mortality.

Parameter	Far North stock	South 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	0.23

Table A4.13. 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 A4.14. Input mean body mass (kg) at age over time assumed for fleet 1.

Fleet 1	1	2	3	4	5	6	7	8	9	10	11	12+
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	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1979	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1980	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1981	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1982	0.050	0.089	0.129	0.189	0.248	0.313	0.396	0.488	0.584	0.728	0.880	1.115
1983	0.050	0.105	0.124	0.163	0.204	0.314	0.369	0.405	0.434	0.453	0.590	1.115
1984	0.050	0.108	0.163	0.179	0.217	0.274	0.370	0.420	0.474	0.629	0.633	1.115
1985	0.050	0.069	0.118	0.210	0.256	0.324	0.410	0.451	0.511	0.998	0.880	1.115
1986	0.050	0.094	0.139	0.214	0.269	0.331	0.412	0.481	0.580	0.661	1.112	1.115
1987	0.071	0.093	0.168	0.202	0.248	0.305	0.356	0.411	0.446	0.471	0.719	1.115
1988	0.084	0.099	0.119	0.221	0.264	0.314	0.377	0.429	0.475	0.528	0.540	1.115
1989	0.050	0.164	0.186	0.217	0.273	0.345	0.394	0.437	0.497	0.568	0.786	1.115
1990	0.050	0.167	0.173	0.224	0.271	0.340	0.401	0.465	0.536	0.582	0.726	1.115
1991	0.096	0.099	0.143	0.222	0.289	0.332	0.418	0.497	0.550	0.869	0.880	1.115
1992	0.092	0.121	0.146	0.189	0.233	0.336	0.427	0.477	0.513	0.650	0.803	1.115
1993	0.050	0.110	0.167	0.197	0.230	0.298	0.472	0.545	0.586	0.711	0.880	1.115
1994	0.050	0.123	0.167	0.230	0.270	0.310	0.379	0.491	0.541	0.569	0.713	1.115
1995	0.069	0.099	0.160	0.248	0.290	0.338	0.409	0.533	0.651	0.677	0.756	1.115
1996	0.049	0.121	0.143	0.201	0.277	0.366	0.408	0.478	0.637	0.720	0.794	0.883
1997	0.069	0.092	0.127	0.201	0.268	0.300	0.373	0.444	0.512	0.595	0.681	0.786
1998	0.021	0.116	0.152	0.205	0.298	0.364	0.422	0.489	0.528	0.596	0.774	0.889
1999	0.059	0.097	0.107	0.235	0.291	0.330	0.387	0.459	0.565	0.748	0.798	0.898
2000	0.069	0.101	0.137	0.186	0.263	0.321	0.357	0.434	0.561	0.668	0.880	1.115
2001	0.067	0.000	0.140	0.170	0.229	0.295	0.367	0.507	0.657	0.639	0.880	1.115
2002	0.029	0.063	0.125	0.177	0.246	0.357	0.503	0.615	0.584	0.728	0.880	1.115
2003	0.000	0.082	0.104	0.195	0.249	0.290	0.390	0.475	0.634	0.728	0.880	1.115
2004	0.071	0.074	0.089	0.147	0.270	0.315	0.446	0.722	0.584	0.728	0.880	1.115
2005	0.043	0.054	0.138	0.191	0.225	0.251	0.372	0.488	0.584	0.728	0.880	1.115
2006	0.066	0.093	0.112	0.133	0.204	0.286	0.421	0.488	0.584	0.728	0.880	1.115
2007	0.029	0.059	0.092	0.172	0.238	0.327	0.398	0.416	0.628	0.728	0.880	1.115
2008	0.036	0.082	0.102	0.141	0.227	0.309	0.416	0.464	0.534	0.728	0.880	1.115
2009	0.037	0.078	0.164	0.186	0.203	0.257	0.342	0.488	0.584	0.728	0.880	1.115
2010	0.029	0.076	0.111	0.175	0.222	0.268	0.281	0.488	0.584	0.728	0.880	1.115
2011	0.032	0.074	0.114	0.132	0.204	0.374	0.442	0.506	0.606	0.728	0.880	1.115
2012	0.087	0.075	0.122	0.158	0.222	0.296	0.404	0.514	0.614	0.723	0.723	1.115
2013	0.042	0.047	0.066	0.187	0.243	0.291	0.388	0.563	0.616	0.748	0.880	1.115
2014	0.015	0.047	0.106	0.138	0.239	0.285	0.335	0.526	0.584	0.728	0.880	1.115

Table A4.15. Input mean body mass (kg) at age over time assumed for fleet 2.

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

Table A4.16. Input mean body mass (kg) at age over time assumed for fleet 3.

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

Table A4.17. Input mean body mass (kg) at age over time assumed for fleet 4.

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

Table A4.18. 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	1975-2014	-	1970-2014	-	Index: 1984-1988; 1991; 2006-2014 Age comps: 2006-2014	Index: 1999-2008 Age comps: 2001-2008
South-central Chile purse seine	1975-2014	-	1970-2014	1983-2014	1997-2009 Age comps: 1997-2009	-
FarNorth	-	1980-2012	1970-2014	2002-2009, 2011-2013	1983-2013	-
International trawl off Chile	1979-1991	2007-2014*	1978-2014	China (2001-2013); EU & Vanuatu (2006-2013); Russian (1987-1991, 2008-09, 2011)	-	-

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

Table A4.19. Symbols and definitions used for model equations.

General Definitions	**Symbol/Value**	**Use in Catch at Age Model**
Year index: i = {1970, …., 2014}	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 A4.20. 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	$\varepsilon_i, \sum_{i=1958}^{2014} \varepsilon_i = 0$	$N_{i,1} = e^{\mu_R + \varepsilon_i}$
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	$\eta^s{}_j, \sum_{j=1958}^{2014} \eta^s{}_j = 0$	$s_j^s = e^{\eta_{\text{maxage}}^s}$ $j > \text{maxage}$

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	$\varphi_i, \sum_{i=1970}^{2014} \varphi_i = 0$	
15) age effect of fishing (regularized) In year time variation allowed	$\eta^{f}{}_{j}, \sum_{j=1958}^{2014} \eta^{f}{}_{j} = 0$	$s_{ij}^{f} = e^{\eta_j^{f}}$ $j \le \text{maxage}$ $s_{ij}^{f} = e^{\eta_{\text{maxage}}^{f}}$ $j > \text{maxage}$
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.	$\tilde{R}_i$	$\tilde{R}_i = \frac{\alpha B_t}{\beta + B_i}$, $\alpha = \frac{4hR_0}{5h-1}$ and $\beta = \frac{B_0(1-h)}{5h-1}$ where h=0.8 $B_0 = R_0 \varphi$ $\varphi = \sum_{j=1}^{12} e^{-M(j-1)} W_j p_j + \frac{e^{-12M} W_{12} p_{12}}{1 - e^{-M}}$

Table A4.21. 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	$L_4 = 0.5\sum_f \frac{1}{cv_f^2}\sum_{j=1970}^{2014} log\left(\frac{C^f{}_j}{\hat{C}^f{}_j}\right)^2$	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	$L_6 = \frac{0.5}{cv_r^2}\sum_{j=1970}^{2011} log\left(\frac{N_{i,1}}{\tilde{R}_i}\right)^2$	Conditioning on stock-recruitment curve over period 1977-2011.
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 A4.22. 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		0.7

Table A4.23. 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 A4.24. 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 A4.25. 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; 2005-2013.
6)	Acoustic survey in northern Chile	Estimated from age composition data. Annual variations were considered since 1984.
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; 2003-2012.
9)	Acoustic survey in Peru	Completely available since 3 yrs old.
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 A4.26. Systematic model progression from the 2013 assessment data to the agreed revised datasets for 2014. 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)	Only updated catch to 2014 (no other new data)
mod0.1.dat (ctl)	As 0.0 but with all new accepted indices updated
mod0.2.dat (ctl)	As 0.1 but with all new size and age composition data
mod1.0.dat (ctl)	Identical to 0.2
mod1.1.dat (ctl)	As 1.0 but with new Echo index for peruvian acoustic
mod1.2.dat (ctl)	As 1.0 but down weight fishery CPUE indices
mod1.3.dat (ctl)	As 1.0 but down weight offshore age compositions
mod1.4.dat (ctl)	As 1.0 but down weight catch biomass (from 0.05 to 0.15) in CV terms for last 5 years
mod1.5.ctl	As 1.0 but set M = 0.3
mod1.9.dat (ctl)	As 1.0 but down weight 2012-2014 offshore fishery age compositions
mod1.10.dat (ctl)	Features of 1.9, 1.4, and 1.2
mod1.11.dat (ctl)	As 1.0 but downweight 2014 age composition for Chilean and Offshore fisheries
mod2.0.dat (ctl)	As 1.11 (new basecase), h=0.8, 1970-2012 recruitment in fitting SRR
mod2.1.dat (ctl)	As 1.11 (new basecase), h=0.8, 2000-2012 recruitment in fitting SRR
mod2.2.dat (ctl)	As 1.11 (new basecase), h=0.65, 1970-2012 recruitment in fitting SRR
mod2.3.dat (ctl)	As 1.11 (new basecase), h=0.65, 2000-2012 recruitment in fitting SRR

Table A4.27. Comparison of jack mackerel models by contributions from negative log-likelihood components based on data and model conditioned priors for one stock hypothesis model (1.0-1.11) and the two-stock hypothesis (1.1N and 1.11S). Some rows are not comparable across all models due to different input data and model assumptions.

Model	1.0	1.1	1.2	1.3	1.4	1.5	1.9	1.10	1.11	1.1N	1.11S
Catch biomass	1.1	1.0	0.9	1.0	1.5	1.0	1.0	0.6	1.0	0.6	1.0
Fishery age	458.7	460.0	427.5	338.7	458.4	445.2	419.5	413.0	434.9	0.0	434.9
Fishery lengths	433.6	421.4	434.6	427.0	433.5	433.6	433.4	431.9	434.1	463.5	433.8
Fishery selectivity	312.1	288.1	302.9	276.5	311.7	306.5	308.5	291.8	306.4	125.0	306.2
Abundance Indices	268.2	222.9	263.4	266.7	268.2	263.5	268.0	217.2	266.3	94.2	266.9
Survey ages	213.9	221.7	214.0	216.9	214.1	215.8	212.3	208.8	214.6	0.0	214.7
Survey selectivity	19.5	20.4	19.6	21.0	19.5	20.1	19.8	19.5	19.9	0.0	19.9
Recruitment	32.4	30.5	26.0	16.6	31.9	25.9	31.5	30.9	31.4	8.2	25.4
Q prior	1.9	2.9	1.9	1.6	1.8	1.5	1.8	1.9	1.8	4.2	1.8
Total	1,741.3	1,668.8	1,691.0	1,565.9	1,740.8	1,713.0	1,695.8	1,615.7	1,710.5	695.6	1,704.6

Table A4.28. Estimated begin-year numbers 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	8,049	5,259	3,363	1,907	1,441	1,215	1,028	899	787	688	597	5,443
1971	5,465	6,394	4,176	2,666	1,510	1,135	940	769	688	619	541	4,753
1972	10,156	4,340	5,075	3,306	2,107	1,183	864	679	576	537	484	4,143
1973	8,925	8,063	3,443	4,009	2,613	1,658	914	644	513	451	423	3,642
1974	9,106	7,080	6,382	2,700	3,155	2,048	1,266	665	477	400	354	3,191
1975	20,496	7,205	5,569	4,903	2,100	2,450	1,535	888	486	370	311	2,759
1976	22,184	16,264	5,706	4,377	3,851	1,628	1,811	1,040	631	374	287	2,382
1977	18,879	17,598	12,871	4,473	3,428	2,969	1,183	1,179	718	481	288	2,059
1978	24,994	14,841	13,629	9,385	3,379	2,610	2,136	759	795	544	370	1,804
1979	18,656	19,721	11,595	10,232	7,153	2,528	1,747	1,150	445	580	407	1,628
1980	23,650	14,737	15,450	8,783	7,831	5,330	1,633	807	551	312	419	1,471
1981	29,335	18,668	11,525	11,636	6,727	5,904	3,578	845	441	396	230	1,394
1982	32,646	23,181	14,597	8,614	8,861	4,975	3,717	1,589	398	303	285	1,172
1983	21,458	25,850	18,303	11,331	6,591	6,302	2,691	1,096	514	242	197	946
1984	59,451	17,030	20,459	14,291	8,783	4,841	3,753	990	395	312	155	733
1985	65,073	47,170	13,441	15,815	10,816	6,143	2,601	1,050	277	196	167	477
1986	18,064	51,650	37,326	10,494	12,037	7,632	3,379	802	304	129	103	340
1987	21,386	14,346	40,961	29,440	8,156	8,932	4,803	1,328	252	135	67	231
1988	28,084	16,977	11,346	32,036	22,467	5,953	5,691	1,921	380	89	56	124
1989	15,899	22,260	13,263	8,733	24,110	15,935	3,746	2,617	545	100	27	54
1990	29,893	12,598	17,407	10,148	6,591	17,253	10,106	1,930	982	155	27	22
1991	19,657	23,690	9,891	13,286	7,588	4,773	11,479	5,740	836	311	38	12
1992	25,937	15,584	18,640	7,592	9,891	5,483	3,236	6,720	2,509	257	73	12
1993	16,967	20,566	12,262	14,304	5,611	7,008	3,689	1,982	3,229	658	47	16
1994	19,253	13,446	16,072	9,198	10,175	3,771	4,469	2,205	1,019	1,202	112	11
1995	31,538	15,252	10,495	11,921	6,308	6,139	2,066	2,257	895	263	175	18
1996	19,367	24,903	11,645	7,116	6,847	2,715	2,320	738	683	179	34	25
1997	31,118	15,249	18,700	7,514	3,294	1,948	761	708	220	168	38	12
1998	24,211	24,505	11,374	11,565	2,127	540	464	251	239	66	45	13
1999	33,719	18,987	18,319	7,896	4,776	728	234	232	128	116	30	26
2000	40,820	26,618	14,537	13,224	4,150	2,297	400	140	142	75	64	31
2001	12,492	32,148	20,164	10,711	8,297	2,195	1,319	248	88	85	42	53
2002	19,999	9,683	22,795	14,027	6,750	4,179	1,155	762	146	49	42	47
2003	3,642	15,765	7,476	17,129	9,503	3,800	2,372	688	447	76	22	40
2004	8,556	2,856	11,989	5,502	11,960	5,782	2,202	1,446	410	231	32	26
2005	5,103	6,717	2,180	8,763	3,826	7,688	3,329	1,288	837	202	93	23
2006	6,623	3,996	5,053	1,542	6,094	2,564	4,614	1,921	732	420	83	48
2007	8,674	5,151	2,832	3,239	1,019	4,087	1,565	2,506	990	323	163	51
2008	4,495	6,789	3,741	1,701	1,892	631	2,444	837	1,135	360	103	68
2009	12,162	3,522	4,794	2,201	1,007	1,151	357	1,300	381	437	115	55
2010	5,936	9,586	2,625	3,180	1,306	536	531	160	454	118	111	43
2011	5,477	4,677	7,271	1,817	1,852	734	281	281	72	153	36	47
2012	8,814	4,318	3,454	5,059	1,320	1,286	439	168	169	38	77	41
2013	10,086	6,980	3,352	2,441	3,843	936	762	280	112	107	24	73
2014	10,501	7,986	5,439	2,511	1,875	2,781	631	527	195	74	68	61

Table A4.29. 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	0.001	0.002	0.003	0.009	0.027	0.06	0.037	0.011	0.01	0.01	0.01
1971	0	0.001	0.004	0.006	0.014	0.043	0.095	0.06	0.018	0.015	0.015	0.015
1972	0.001	0.002	0.006	0.005	0.009	0.028	0.064	0.049	0.014	0.009	0.009	0.009
1973	0.002	0.004	0.013	0.009	0.014	0.04	0.087	0.07	0.019	0.012	0.012	0.012
1974	0.004	0.01	0.034	0.022	0.023	0.058	0.125	0.084	0.026	0.021	0.021	0.021
1975	0.001	0.003	0.011	0.011	0.024	0.072	0.16	0.112	0.032	0.024	0.024	0.024
1976	0.002	0.004	0.014	0.014	0.03	0.09	0.199	0.14	0.04	0.03	0.03	0.03
1977	0.011	0.026	0.086	0.05	0.043	0.099	0.213	0.165	0.048	0.033	0.033	0.033
1978	0.007	0.017	0.057	0.042	0.06	0.172	0.39	0.304	0.084	0.06	0.06	0.06
1979	0.006	0.014	0.048	0.038	0.064	0.207	0.543	0.505	0.126	0.095	0.095	0.095
1980	0.007	0.016	0.053	0.037	0.052	0.169	0.43	0.374	0.102	0.074	0.074	0.074
1981	0.005	0.016	0.061	0.042	0.072	0.233	0.582	0.522	0.146	0.096	0.096	0.096
1982	0.003	0.006	0.023	0.038	0.111	0.385	0.991	0.898	0.268	0.202	0.202	0.202
1983	0.001	0.004	0.017	0.025	0.079	0.288	0.77	0.79	0.271	0.214	0.214	0.214
1984	0.001	0.007	0.027	0.049	0.127	0.391	1.043	1.043	0.47	0.391	0.391	0.391
1985	0.001	0.004	0.017	0.043	0.119	0.368	0.947	1.008	0.539	0.41	0.41	0.41
1986	0	0.002	0.007	0.022	0.068	0.233	0.704	0.925	0.583	0.423	0.423	0.423
1987	0.001	0.005	0.016	0.04	0.085	0.221	0.686	1.022	0.81	0.644	0.644	0.644
1988	0.002	0.017	0.032	0.054	0.114	0.233	0.547	1.031	1.106	0.976	0.976	0.976
1989	0.003	0.016	0.038	0.051	0.105	0.225	0.433	0.75	1.027	1.091	1.091	1.091
1990	0.003	0.012	0.04	0.061	0.093	0.177	0.336	0.607	0.92	1.184	1.184	1.184
1991	0.002	0.01	0.035	0.065	0.095	0.159	0.305	0.598	0.951	1.214	1.214	1.214
1992	0.002	0.01	0.035	0.072	0.115	0.166	0.26	0.503	1.108	1.457	1.457	1.457
1993	0.003	0.017	0.057	0.111	0.167	0.22	0.284	0.435	0.758	1.544	1.544	1.544
1994	0.003	0.018	0.069	0.147	0.275	0.372	0.453	0.672	1.122	1.698	1.698	1.698
1995	0.006	0.04	0.159	0.324	0.613	0.743	0.799	0.966	1.378	1.819	1.819	1.819
1996	0.009	0.056	0.208	0.54	1.027	1.042	0.957	0.979	1.172	1.325	1.325	1.325
1997	0.009	0.063	0.251	1.032	1.579	1.204	0.88	0.856	0.983	1.089	1.089	1.089
1998	0.013	0.061	0.135	0.654	0.843	0.605	0.463	0.44	0.497	0.563	0.563	0.563
1999	0.006	0.037	0.096	0.413	0.502	0.369	0.283	0.265	0.306	0.366	0.366	0.366
2000	0.009	0.048	0.075	0.236	0.407	0.325	0.249	0.235	0.278	0.347	0.347	0.347
2001	0.025	0.114	0.133	0.232	0.456	0.412	0.319	0.301	0.367	0.467	0.467	0.467
2002	0.008	0.029	0.056	0.159	0.344	0.337	0.288	0.304	0.419	0.582	0.582	0.582
2003	0.013	0.044	0.077	0.129	0.267	0.316	0.265	0.287	0.428	0.638	0.638	0.638
2004	0.012	0.04	0.083	0.133	0.212	0.322	0.306	0.316	0.48	0.682	0.682	0.682
2005	0.014	0.055	0.116	0.133	0.17	0.281	0.319	0.336	0.46	0.656	0.656	0.656
2006	0.021	0.114	0.215	0.184	0.169	0.264	0.381	0.433	0.587	0.715	0.715	0.715
2007	0.015	0.09	0.28	0.308	0.25	0.284	0.396	0.562	0.781	0.912	0.912	0.912
2008	0.014	0.118	0.301	0.294	0.267	0.339	0.401	0.558	0.724	0.913	0.913	0.913
2009	0.008	0.064	0.18	0.292	0.402	0.544	0.576	0.822	0.938	1.137	1.137	1.137
2010	0.008	0.046	0.138	0.31	0.345	0.415	0.407	0.568	0.858	0.966	0.966	0.966
2011	0.008	0.073	0.133	0.09	0.135	0.285	0.284	0.275	0.401	0.459	0.459	0.459
2012	0.003	0.023	0.117	0.045	0.113	0.294	0.218	0.174	0.227	0.249	0.249	0.249
2013	0.003	0.02	0.059	0.034	0.093	0.165	0.139	0.133	0.192	0.231	0.231	0.231
2014	0.01	0.042	0.044	0.035	0.098	0.105	0.099	0.107	0.174	0.227	0.227	0.227

Table A4.30. Summary results for the medium and long term predictions for models 2.0-2.3. Note that "B" in all cases represents thousands of t of spawning stock biomass and B_{MSY} is provisionally taken to be 5.5 million t of spawning biomass in all cases and the bottom panel is the result of north and south models combined (for 2.3).

Model 2.0, steepness=0.8, recruitment from 1970-2012

Multiplier of F_{2014}	B_{2016}	P(B_{2016} > B_{MSY})	B_{2024}	P(B_{2024} > B_{MSY})	B_{2034}	P(B_{2034} > B_{MSY})	Catch 2015 (kt)	Catch 2016 (kt)
0.00	4,569	4%	12,874	100%	18,456	100%	0	0
0.50	4,241	1%	9,428	98%	11,749	98%	240	300
0.75	4,091	0%	8,248	94%	9,843	94%	350	430
1.00	3,948	0%	7,300	86%	8,432	86%	460	550
1.25	3,814	0%	6,524	75%	7,349	75%	570	660

Model 2.1, steepness=0.8, recruitment from 2000-2012

Multiplier of F_{2014}	B_{2016}	P(B_{2016} > B_{MSY})	B_{2024}	P(B_{2024} > B_{MSY})	B_{2034}	P(B_{2034} > B_{MSY})	Catch 2015 (kt)	Catch 2016 (kt)
0.00	4,283	1%	8,198	97%	8,892	97%	0	0
0.50	3,957	0%	5,482	49%	5,387	49%	240	290
0.75	3,808	0%	4,628	20%	4,453	20%	350	420
1.00	3,668	0%	3,977	6%	3,779	6%	460	540
1.25	3,535	0%	3,469	1%	3,270	1%	570	650

Model 2.2, steepness=0.65, recruitment from 1970-2012

Multiplier of F_{2014}	B_{2016}	P(B_{2016} > B_{MSY})	B_{2024}	P(B_{2024} > B_{MSY})	B_{2034}	P(B_{2034} > B_{MSY})	Catch 2015 (kt)	Catch 2016 (kt)
0.00	4,434	2%	11,891	100%	18,612	100%	0	0
0.50	4,109	0%	8,468	95%	11,427	95%	240	290
0.75	3,960	0%	7,294	86%	9,342	86%	350	420
1.00	3,819	0%	6,351	71%	7,786	71%	460	540
1.25	3,685	0%	5,580	52%	6,586	52%	560	650

Model 2.3, steepness=0.65, recruitment from 2000-2012

Multiplier of F_{2014}	B_{2016}	P(B_{2016} > B_{MSY})	B_{2024}	P(B_{2024} > B_{MSY})	B_{2034}	P(B_{2034} > B_{MSY})	Catch 2015 (kt)	Catch 2016 (kt)
0.00	4,226	1%	7,979	96%	8,949	96%	0	0
0.50	3,901	0%	5,257	41%	5,217	41%	240	290
0.75	3,753	0%	4,396	14%	4,207	14%	350	420
1.00	3,613	0%	3,737	3%	3,473	3%	460	540
1.25	3,481	0%	3,221	0%	2,919	0%	570	650

Model 2.3 North + South, steepness=0.65, recruitment from 2000-2012

Multiplier of F_{2014}	B_{2016}	P(B_{2016} > B_{MSY})	B_{2024}	P(B_{2024} > B_{MSY})	B_{2034}	P(B_{2034} > B_{MSY})	Catch 2015 (kt)	Catch 2016 (kt)
0.00	5,152	16%	9,483	94%	10,042	93%	0	0
0.50	4,784	6%	6,485	58%	6,330	47%	240	290
0.75	4,616	4%	5,523	30%	5,284	20%	350	420
1.00	4,458	2%	4,776	10%	4,501	5%	470	540
1.25	4,309	1%	4,183	3%	3,888	1%	570	640

Figures

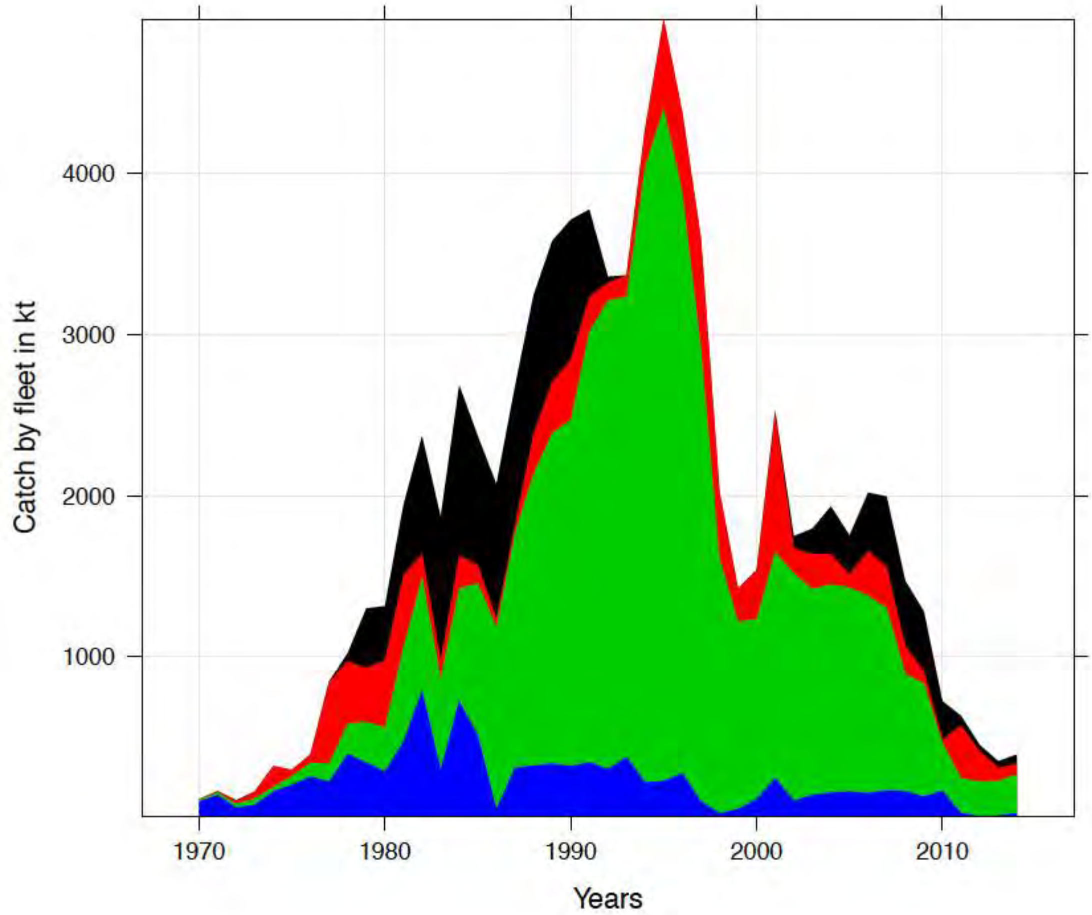


Figure A4.1. Catch of jack mackerel by fleet. Green is the SC Chilean fleet, black is the offshore trawl fleet, red is the far-north fleet, and blue in the northern Chilean fleet.

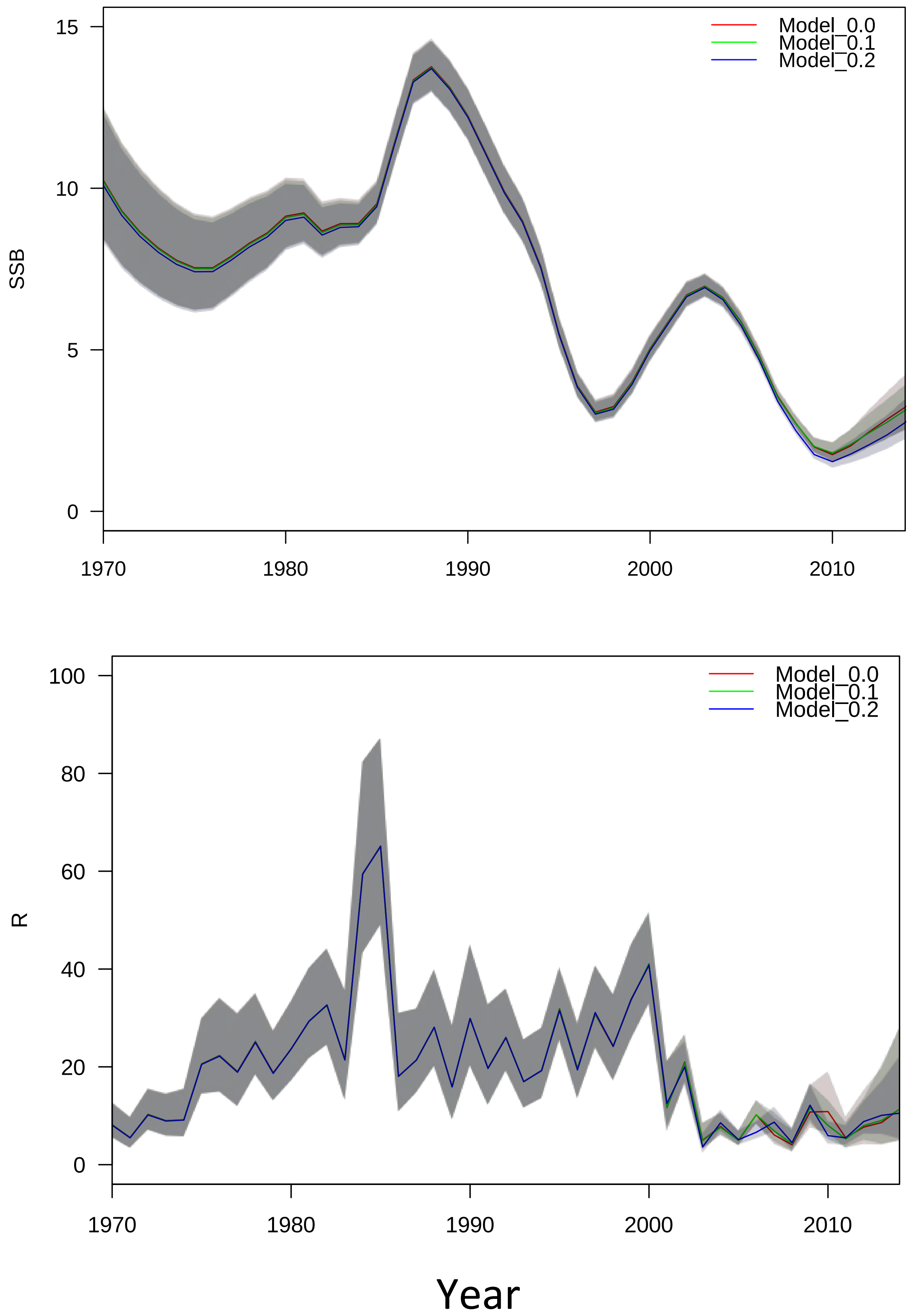


Figure A4.2. Spawning biomass (top; in kt) and age one recruitment estimates (in millions) comparing model configurations 0.0 - 0.2.

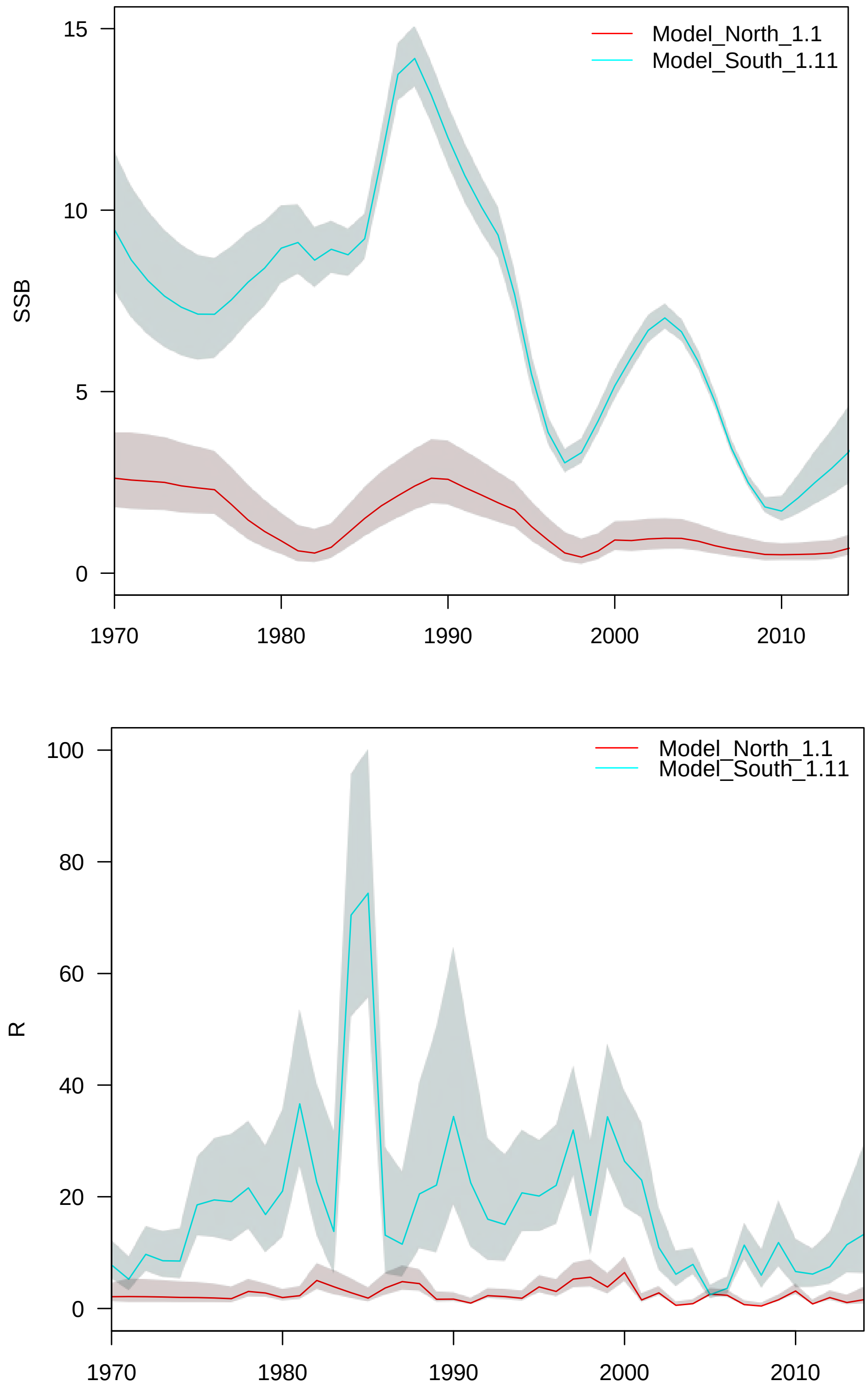


Figure A4.3. Spawning biomass (top; in kt) and age one recruitment estimates (in millions) for the “Far-North” stock and the southern stock under the two-stock hypothesis.

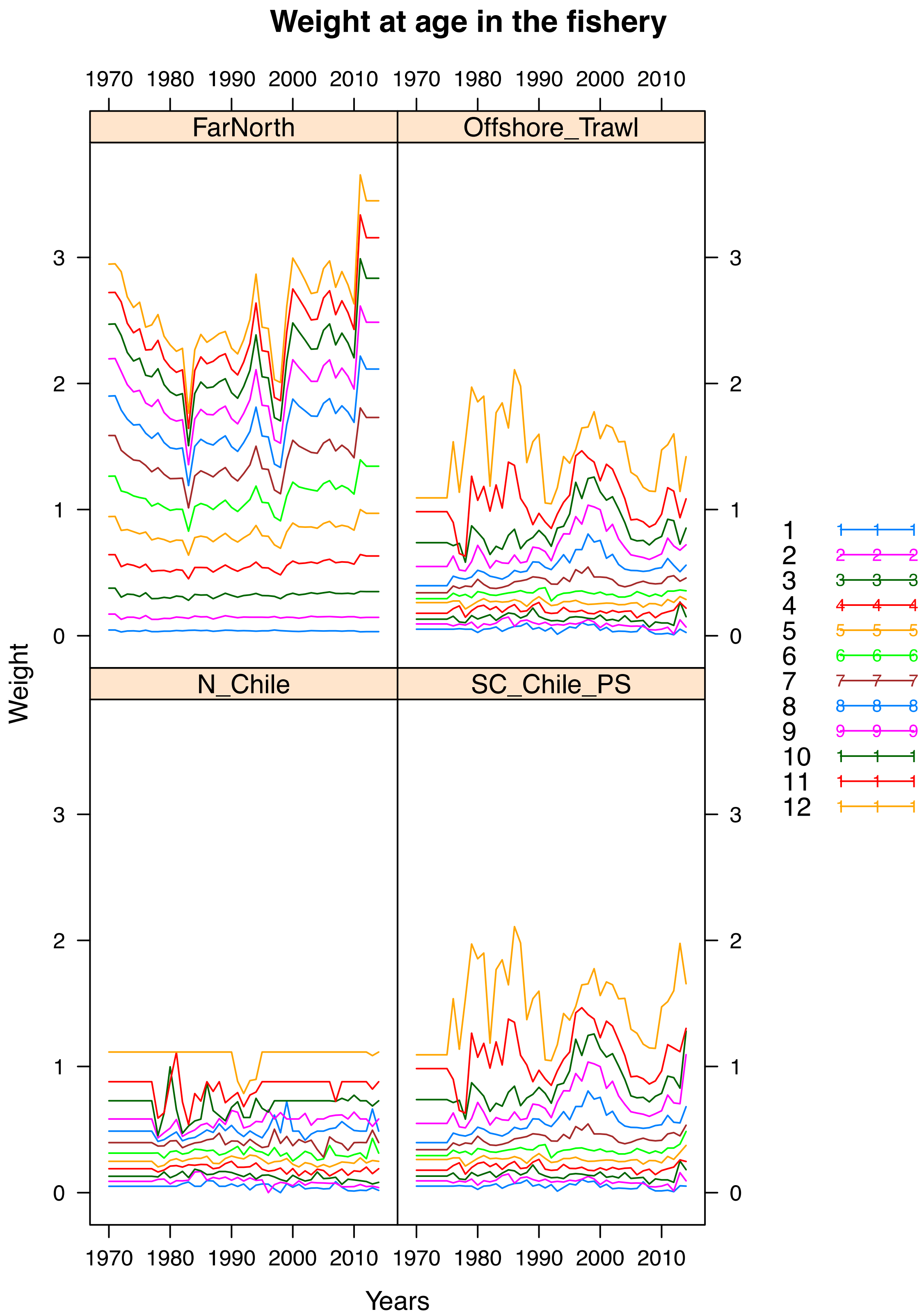


Figure A4.4. Mean weights-at-age (kg) over time used for all data types in the JJM models. Different lines represent ages 1 to 12.

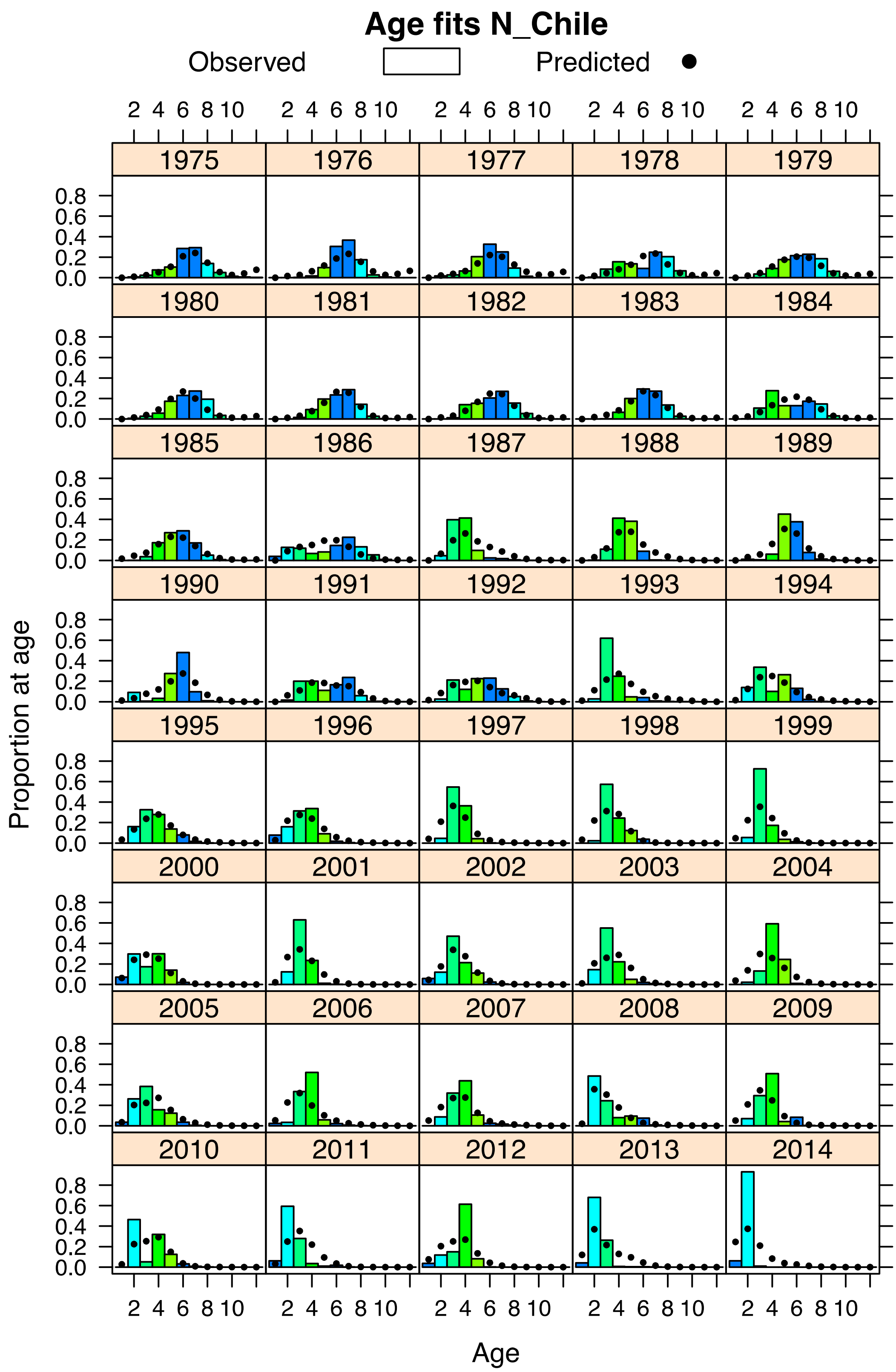


Figure A4.5. Model fit (Model 1.11) to the age compositions for the **Chilean northern zone fishery (Fleet 1)**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

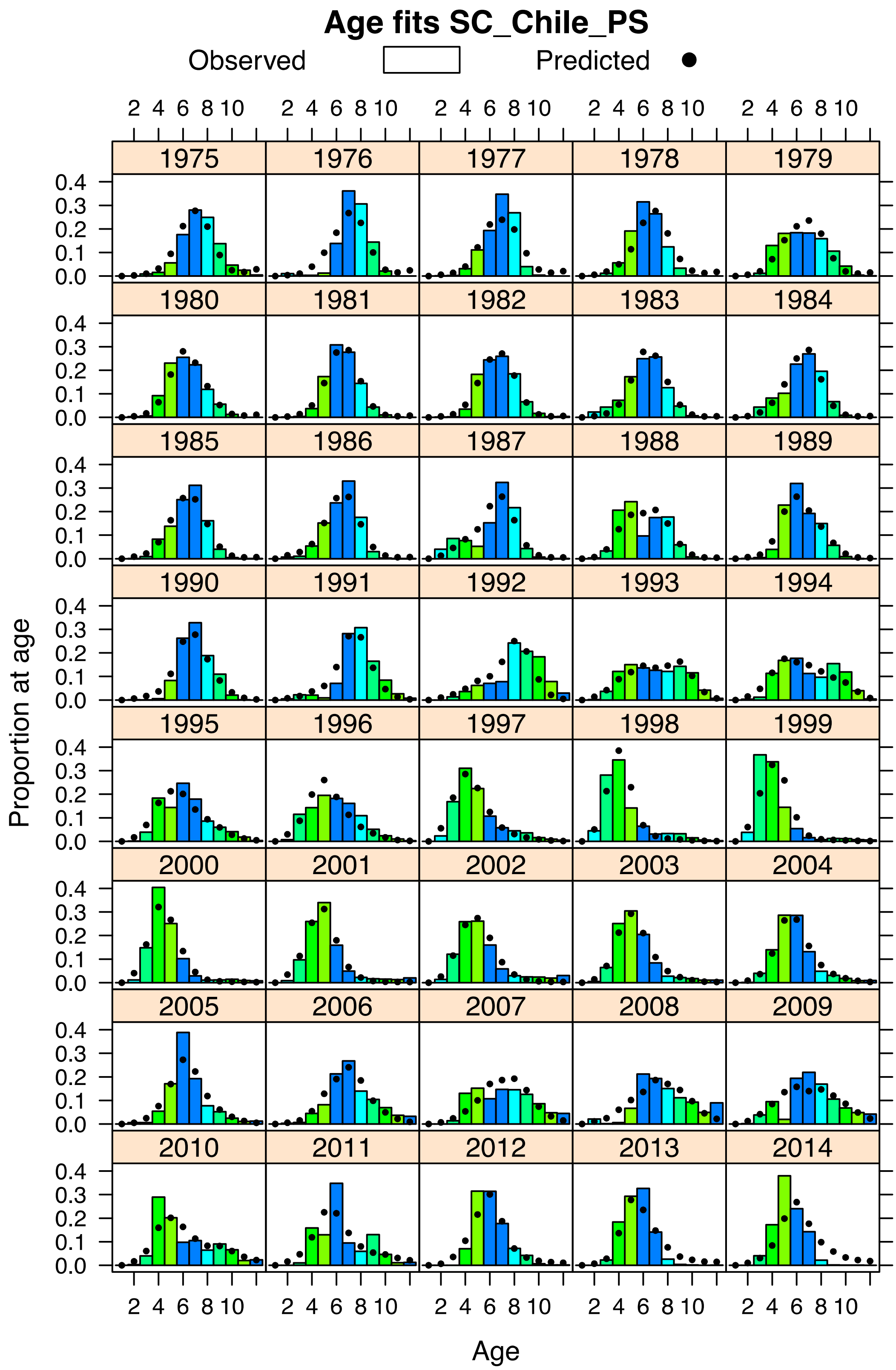


Figure A4.6. Model fit (Model 1.11) to the age compositions for the **South-Central Chilean purse seine** fishery (Fleet 2). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

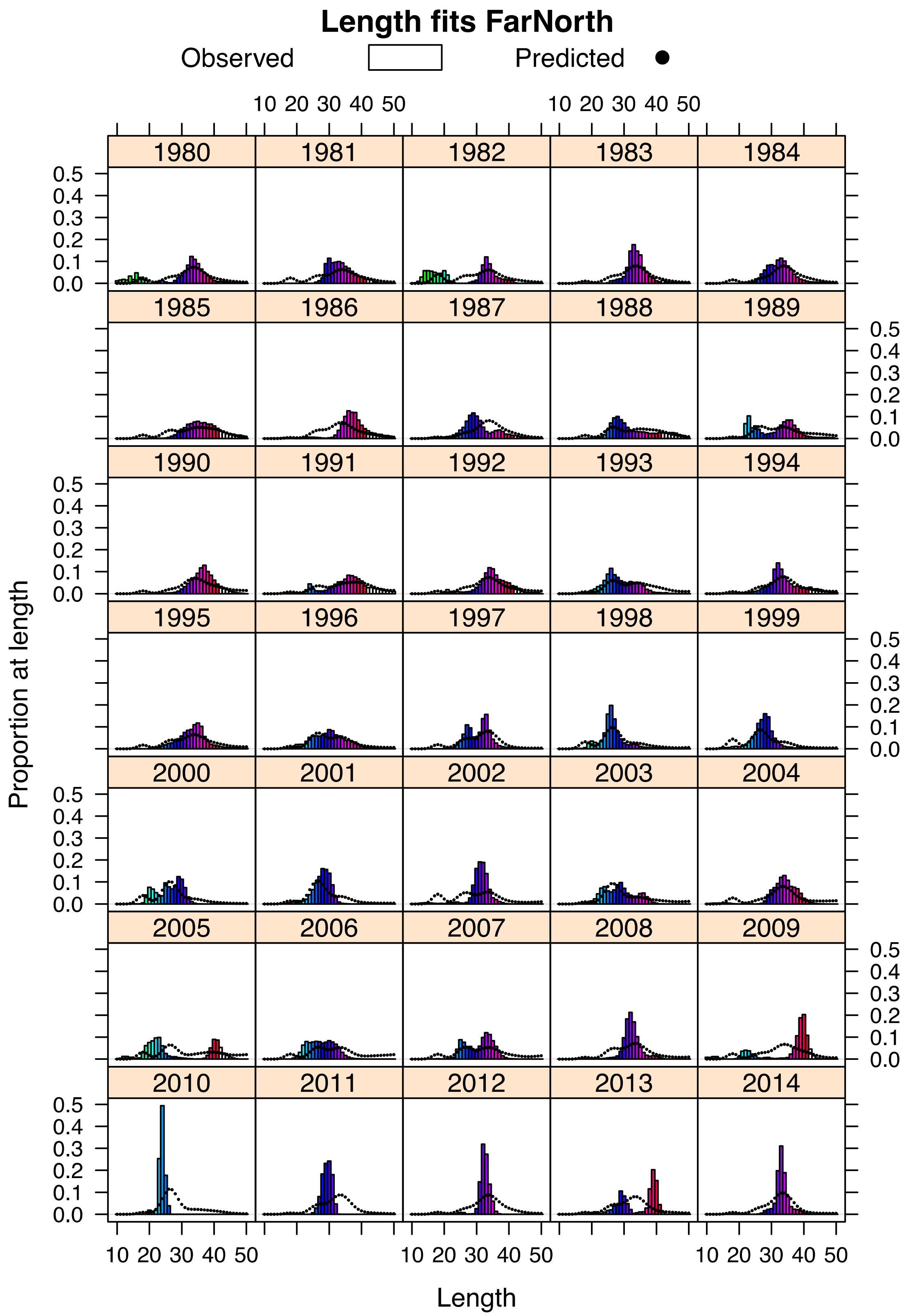


Figure A4.7. Model fit (Model 1.11) to the length compositions for the far north fishery (Fleet 3). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

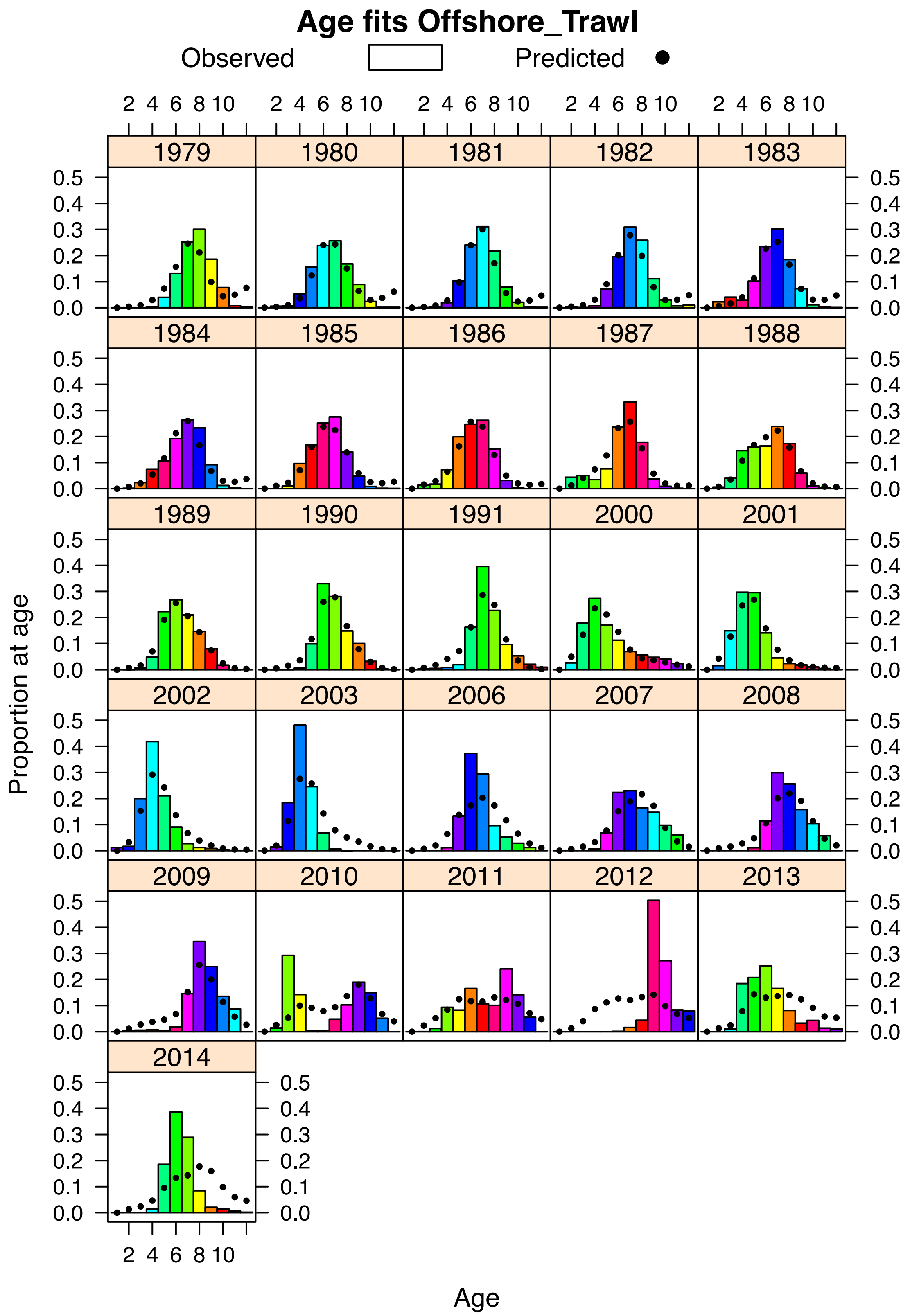


Figure A4.8. Model fit (Model 1.11) to the age compositions for the **offshore trawl** fishery (Fleet 4). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

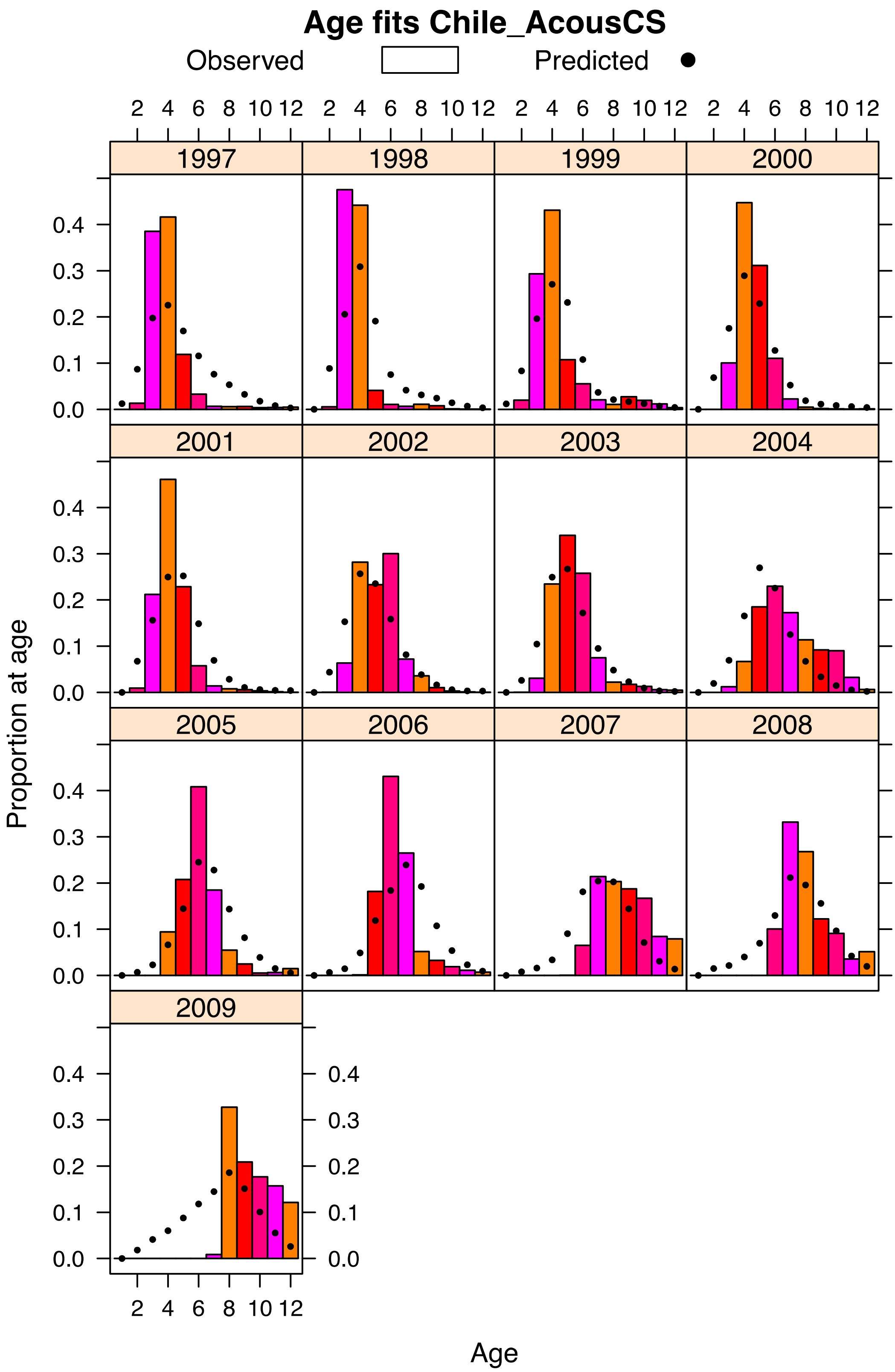


Figure A4.9. Model fit (Model 1.11) to the age compositions for the **SC Chilean acoustic survey**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

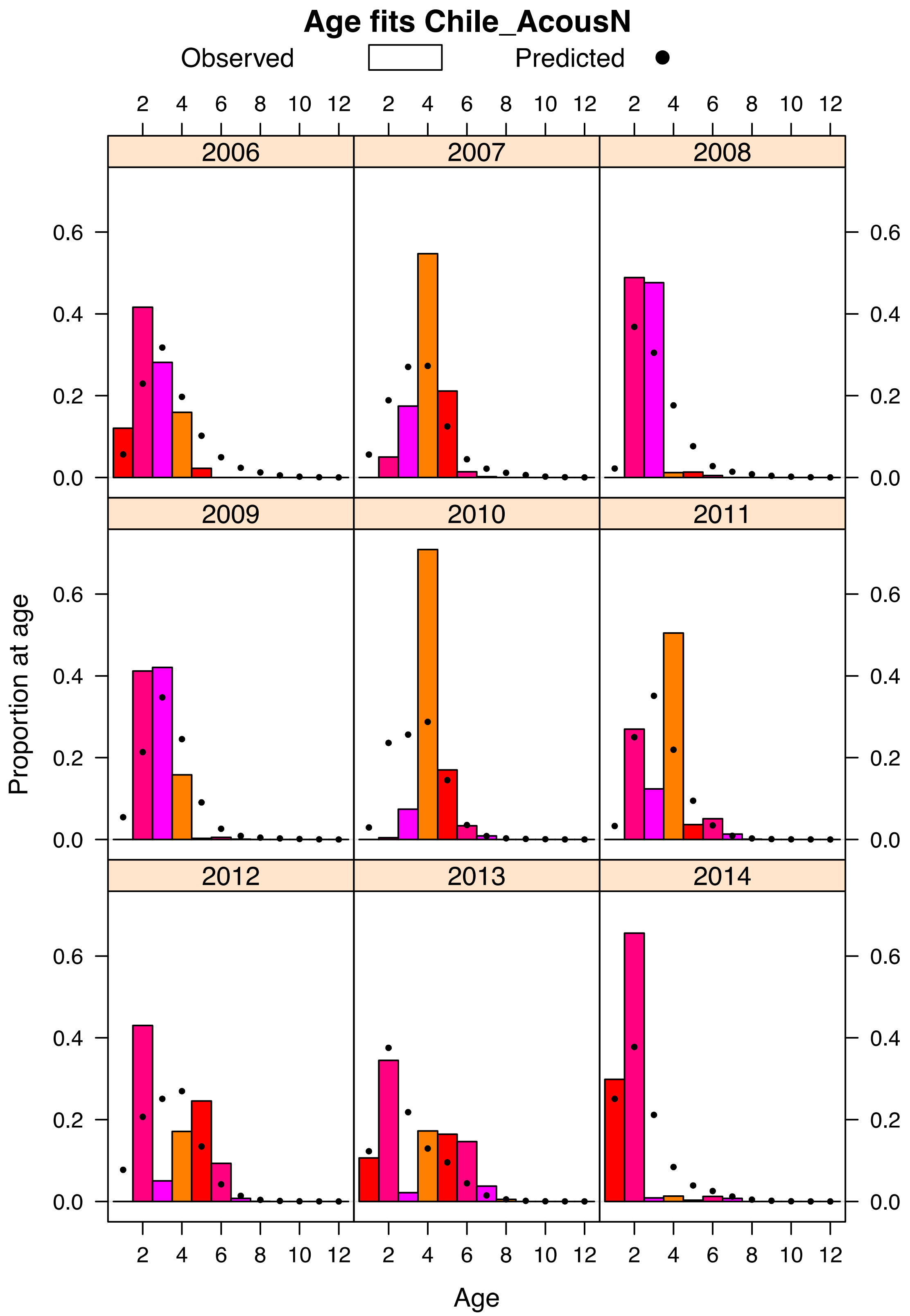


Figure A4.10. Model fit (Model 1.11) to the age compositions for the **N Chilean acoustic survey**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

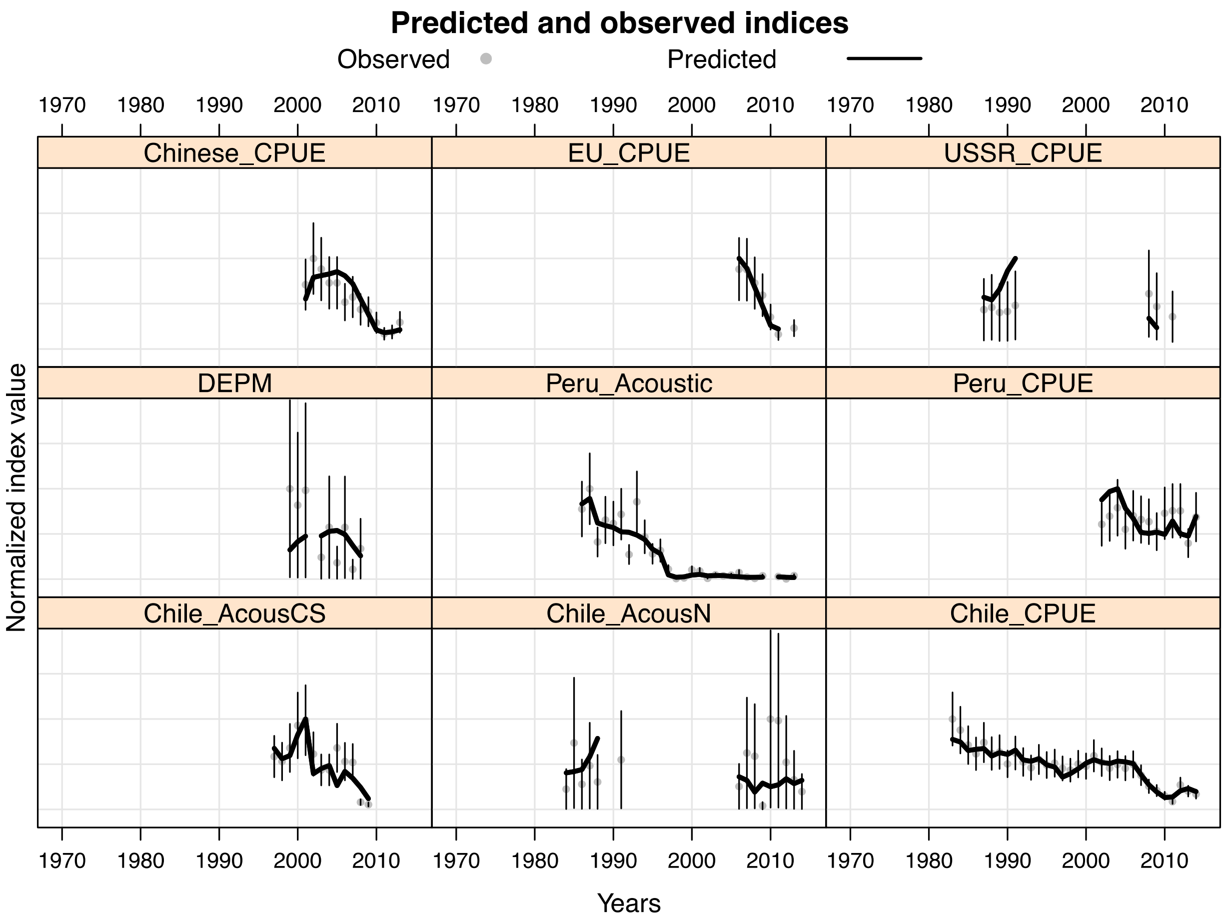


Figure A4.11. Model fit (Model 1.11) to different indices. Vertical bars represent 2 standard deviations around the observations.

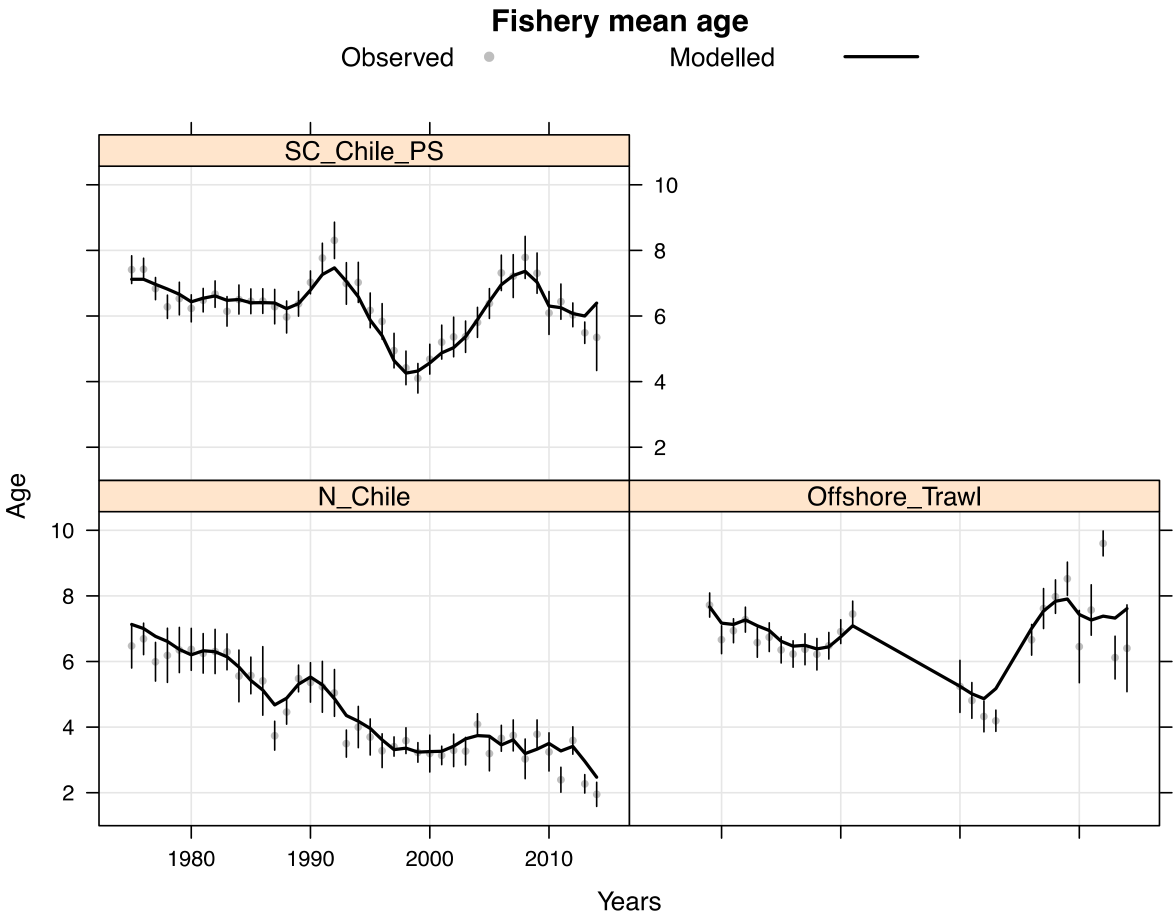


Figure A4.12. Mean age by year and fishery. Line represents the model and dots the observed values.

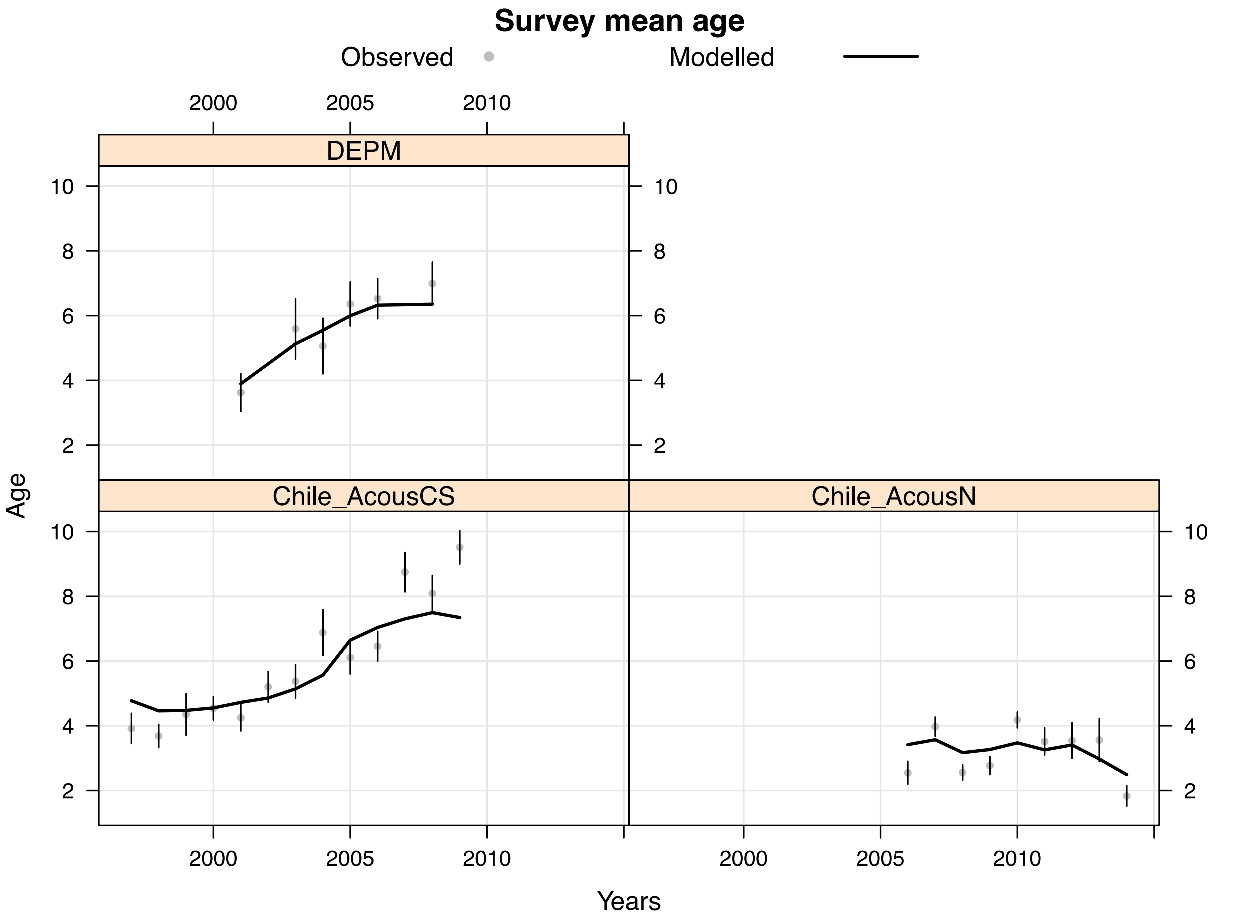


Figure A4.13. Mean age by year and survey. Line represents the model and dots the observed values.

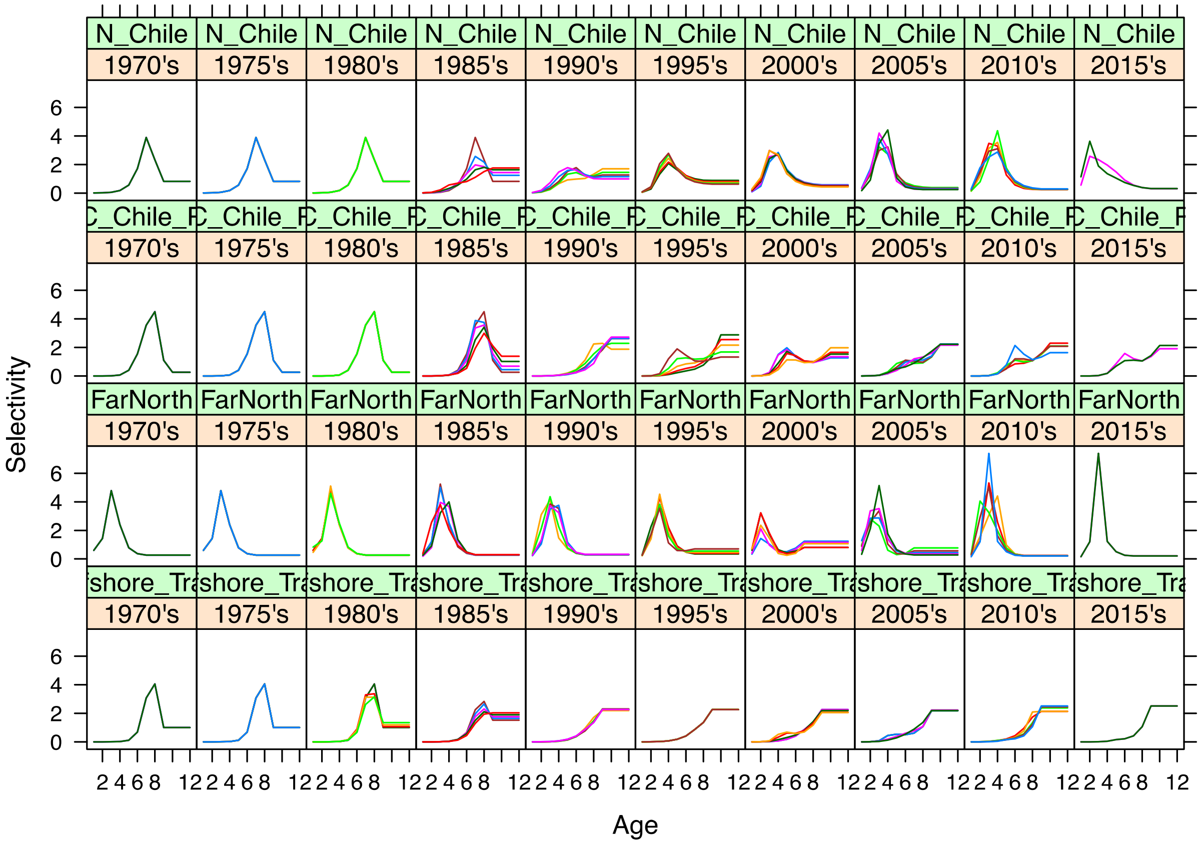


Figure A4.14. Estimates of selectivity by fishery over time for Model 1.11. Each cell represents a 5-year period).

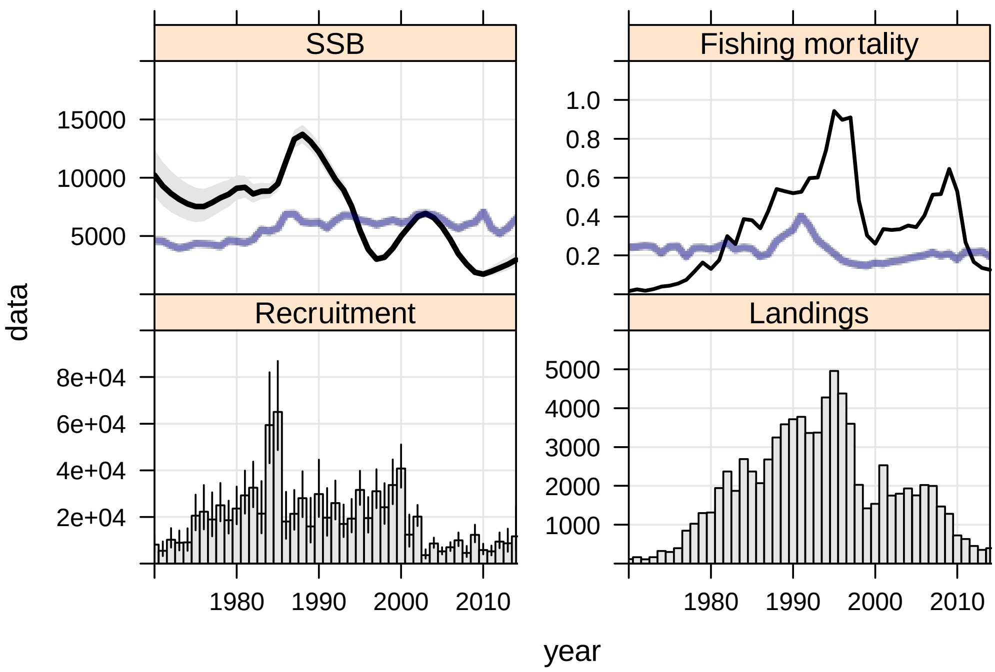


Figure A4.15. Summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left) total fishing mortality (top right) and total catch (kt; bottom right).

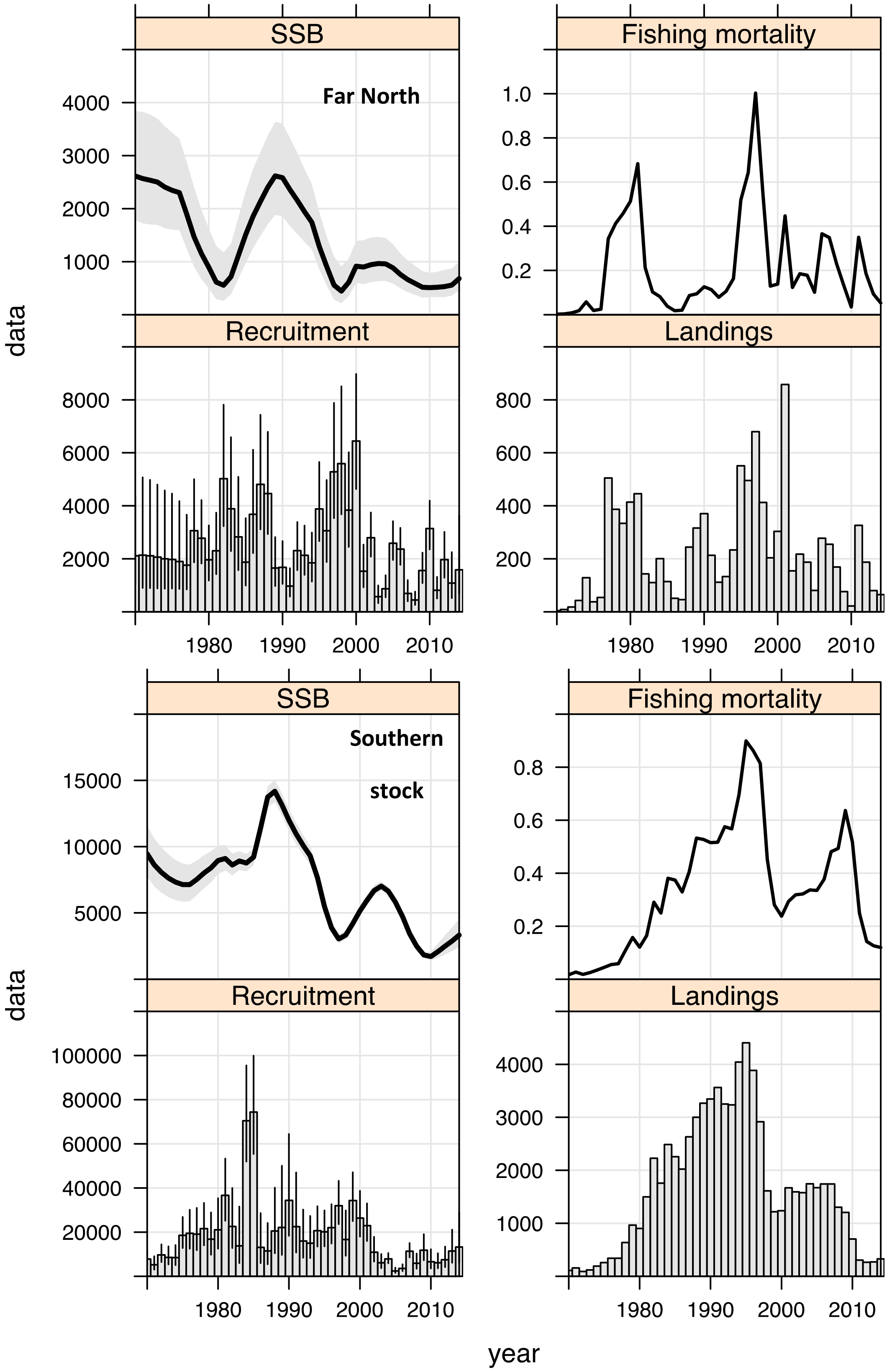


Figure A4.16. Summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left) total fishing mortality (top right) and total catch (kt; bottom right) for Models 1.1N (top set) and 1.11S (bottom set).

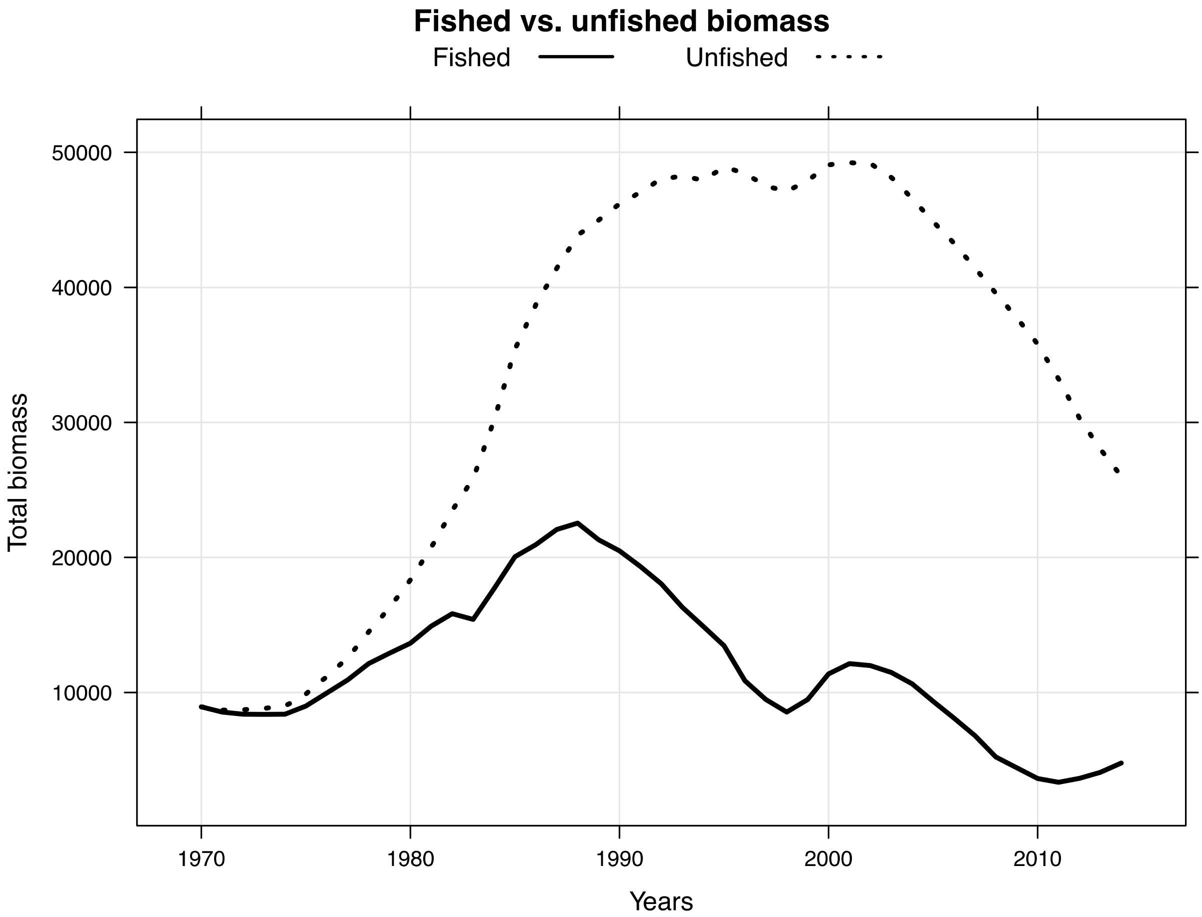


Figure A4.17. Model 1.11 results the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place, 1970-2014.

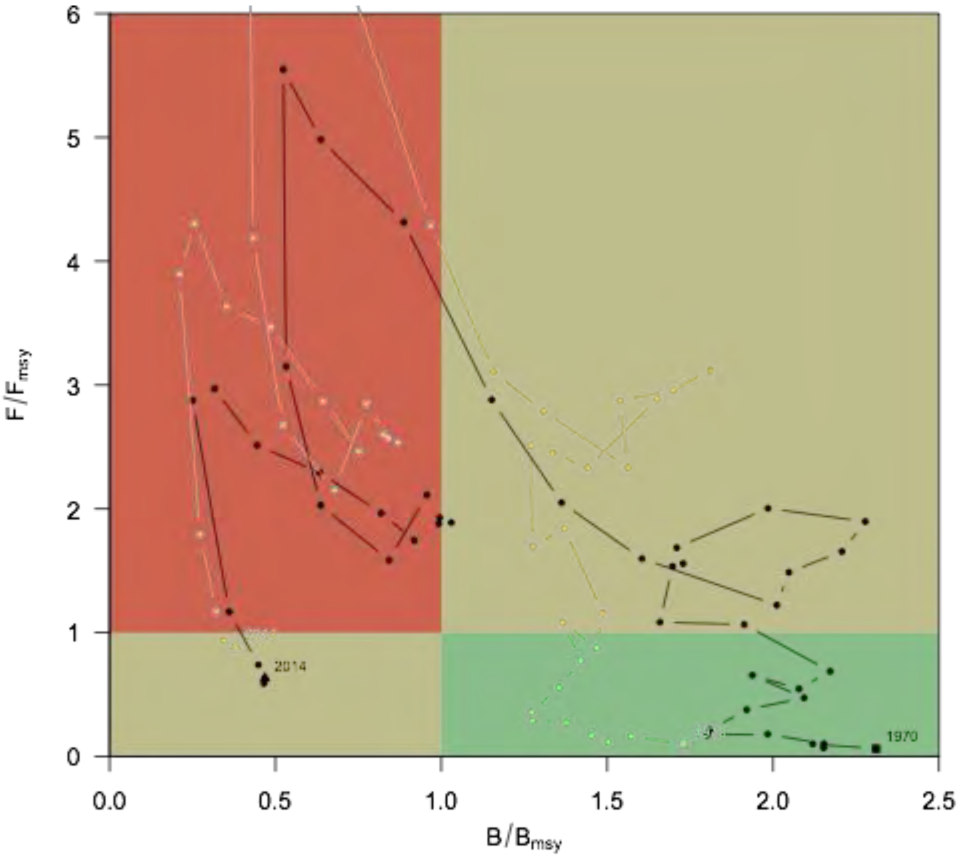
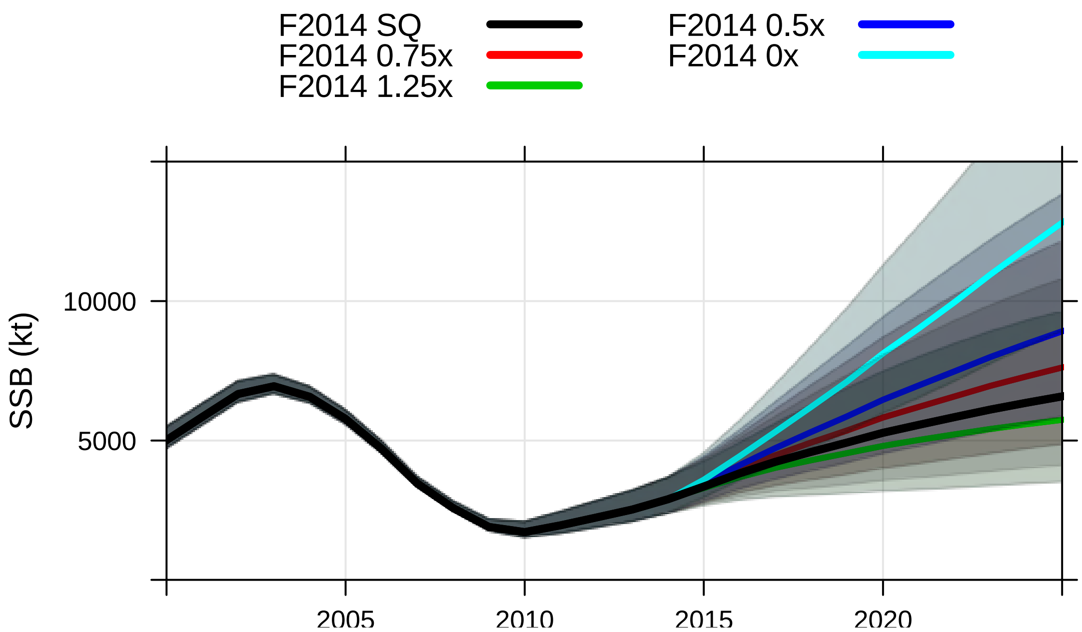


Figure A4.18. Phase plane (or "Kobe") plot of the estimated trajectory for jack mackerel under Model 2.2 (steepness = 0.65; black line) compared with Model 2.0 (pale line, steepness = 0.8; higher productivity) with reference points set to F_{MSY} and B_{MSY} estimated for the time series 1970-2012.



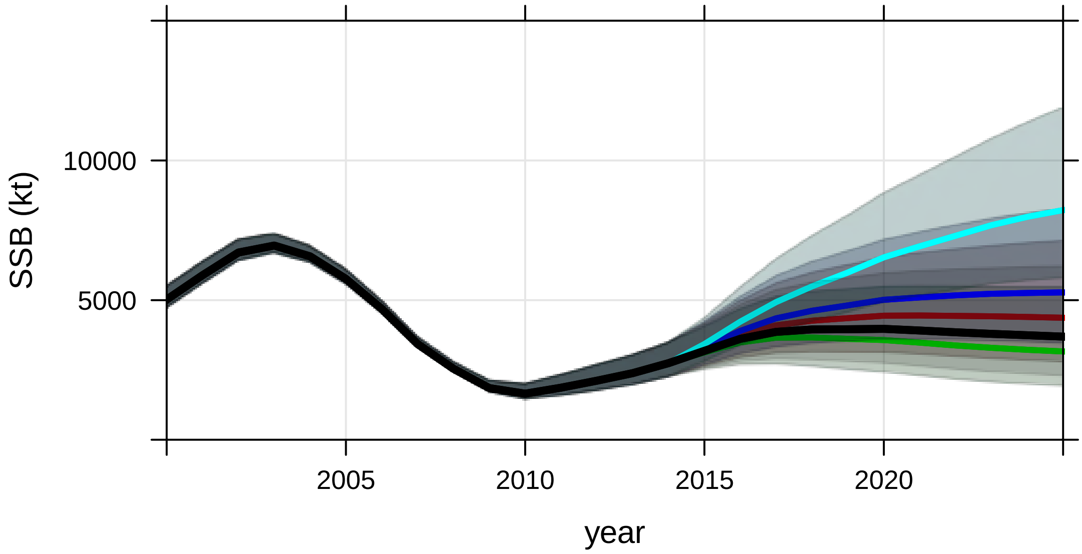


Figure A4.19. Projections of jack mackerel population trajectories for different multipliers of the estimated 2014 fishing mortality rate under models 2.2 (recruitment from 1970-2012; top) and 2.3 (recruitment from 2000-2012; bottom). The provisional B_{MSY} is 5.5 million t.