Annex 8. Jack mackerel stock assessment

Introduction

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

Scientific name and general distribution

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

Main management units

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

Stock structure

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

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

Fishery

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

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

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

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

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

Management

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

Information on the environment in relation to the fisheries

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

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

Reproductive biology

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

Data used in the assessment

Fishery data

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

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

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

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

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

Fisheries independent data

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

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

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

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

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

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

Biological parameters

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

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

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

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

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

Data sets

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

Description of assessment model

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

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

JJM developments

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

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

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

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

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

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

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

Model details

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

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

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

Models for stock structure hypothesis

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

Description of "update" model explorations

Description of key changes from base case assessment

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

Assessment results

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

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

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

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

Management advice

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

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

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

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

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

Assessment issues

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

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Tables

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

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

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

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

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

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

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

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

Age group (years)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table A8.12. Growth parameters and natural mortality.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

12)	Instantaneous fishing mortality		$F_{ij}^{f} = e^{\mu^f + \eta_j^f + \phi_i}$
13)	Mean fishing effect	μ^f	
14)	Annual effect of fishing mortality in year i	$\varphi_i, \sum_{i=1970}^{2015} \varphi_i = 0$	
15)	age effect of fishing (regularized) In year time variation allowed	$\eta^f{}_j, \sum_{j=1958}^{2015} \eta^f{}_j = 0$	$s_{ij}^{f} = e^{\eta_j^f}$ $j \le \text{maxage}$ $s_{ij}^{f} = e^{\eta_{\text{maxage}}^f}$ $j > \text{maxage}$
	In years where selectivity is constant over time	$\eta_{i,j}^f = \eta_{i-1,j}^f$	$i \ne \text{change year}$
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 $B_0 = R_0 \varphi$ $\varphi = \sum_{j=1}^{12} e^{-M(j-1)} W_j p_j + \frac{e^{-12M} W_{12} p_{12}}{1-e^{-M}}$ h=0.8

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Figures

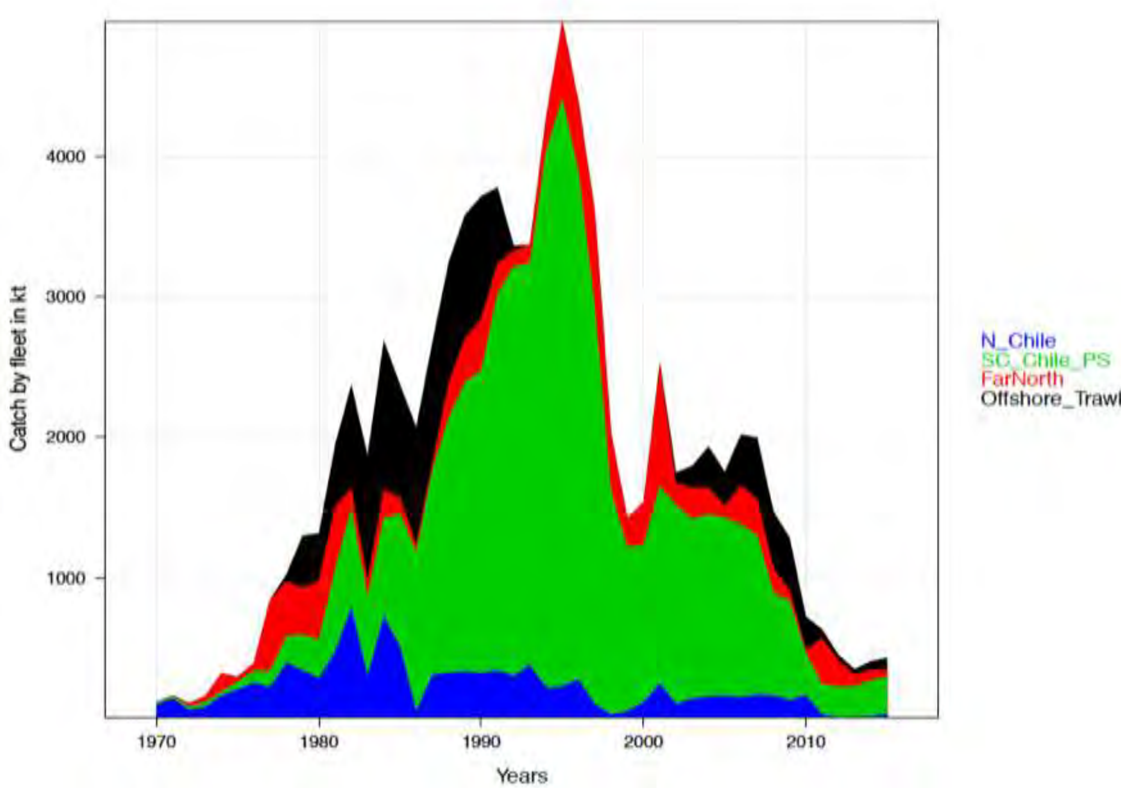


Figure A8.1. Catch of jack mackerel by fleet. Green is the SC Chilean fleet, black is the offshore trawl fleet, red is the far-north fleet, and blue in the northern Chilean fleet.

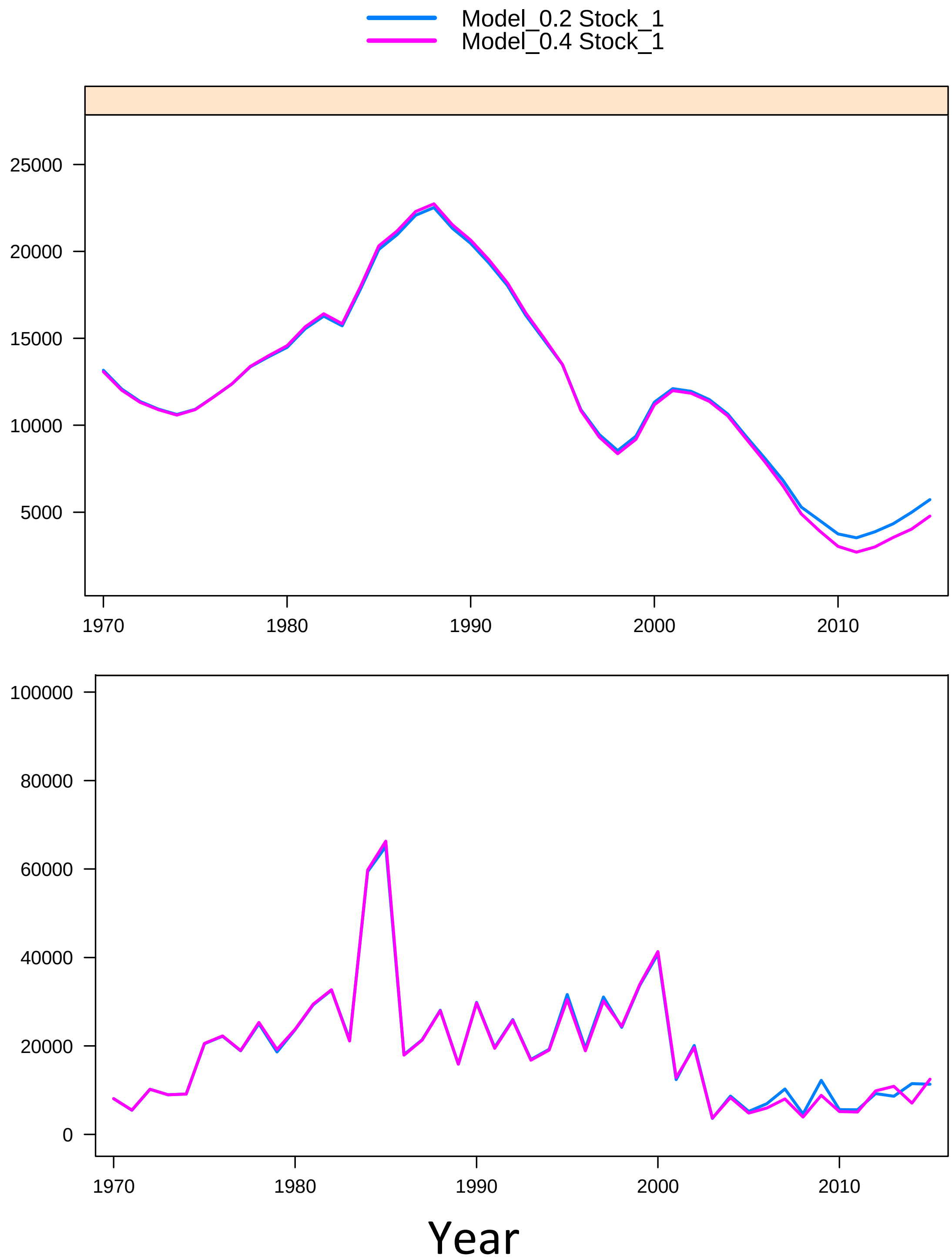


Figure A8.2. Spawning biomass (top; in kt) and age one recruitment estimates (in millions) for the single stock hypothesis comparing model configurations 0.2 and model 0.4 (the others were omitted due to plot overlay issues).

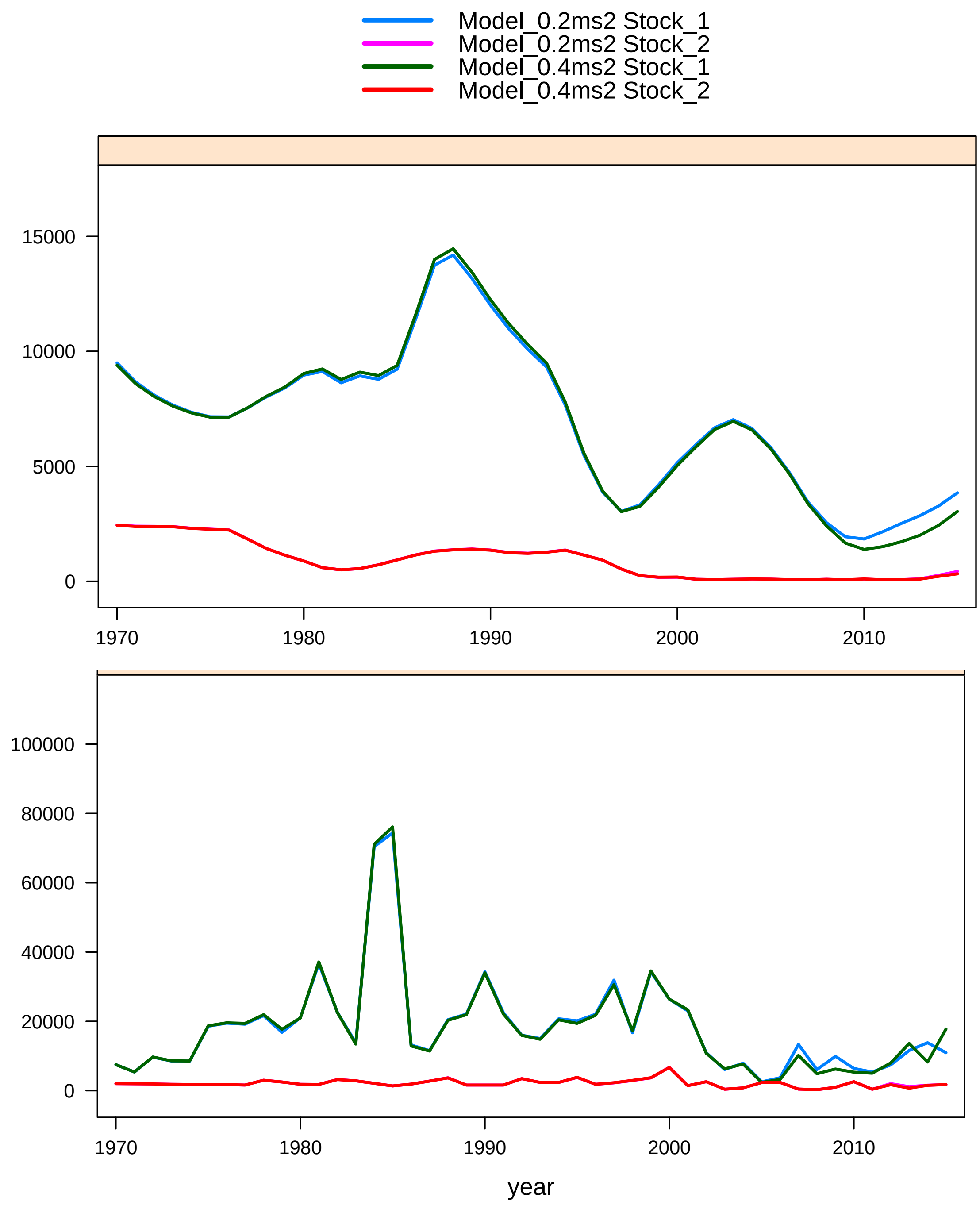


Figure A8.3. Spawning biomass (top; in kt) and age one recruitment estimates (in millions) for the "Far-North" stock and the southern stock under the two-stock hypothesis with the same data progress (comparing models 0.2 and 0.4).

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

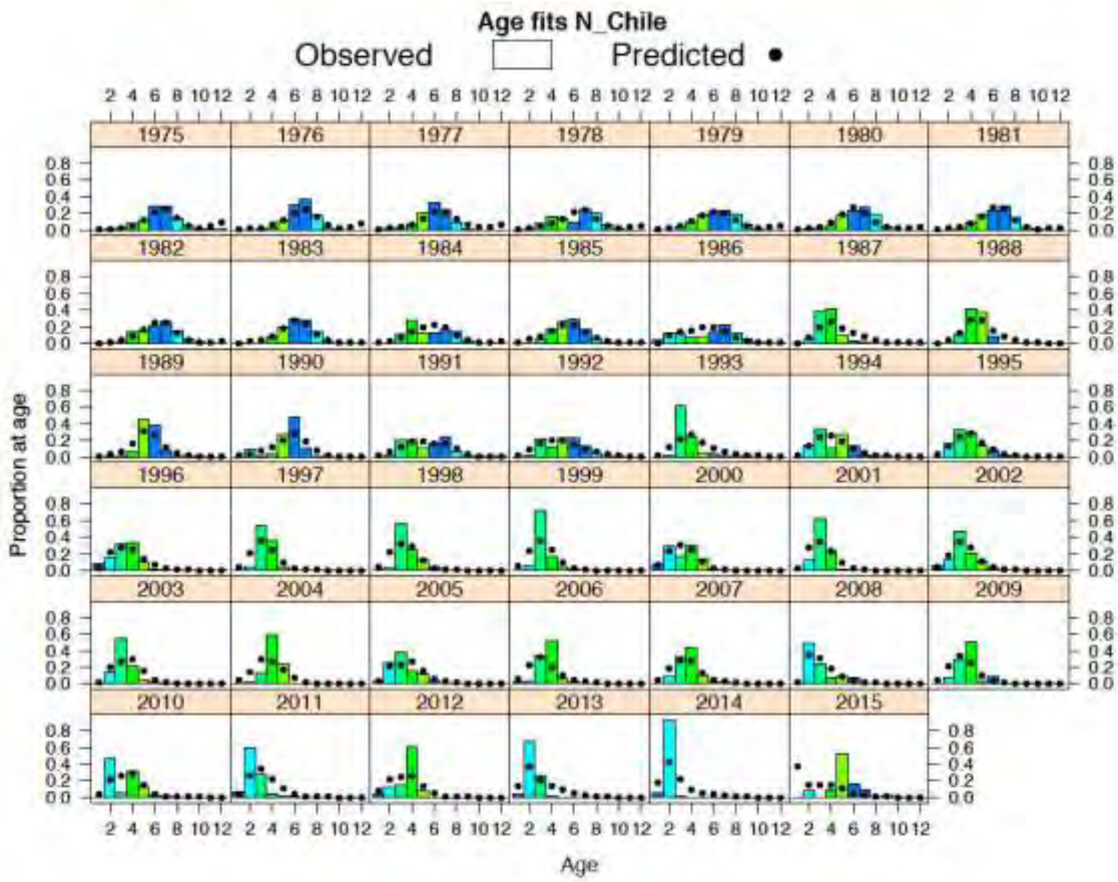


Figure A8.5. Model fit (Model 0.4) to the age compositions for the **Chilean northern zone fishery (Fleet 1)**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

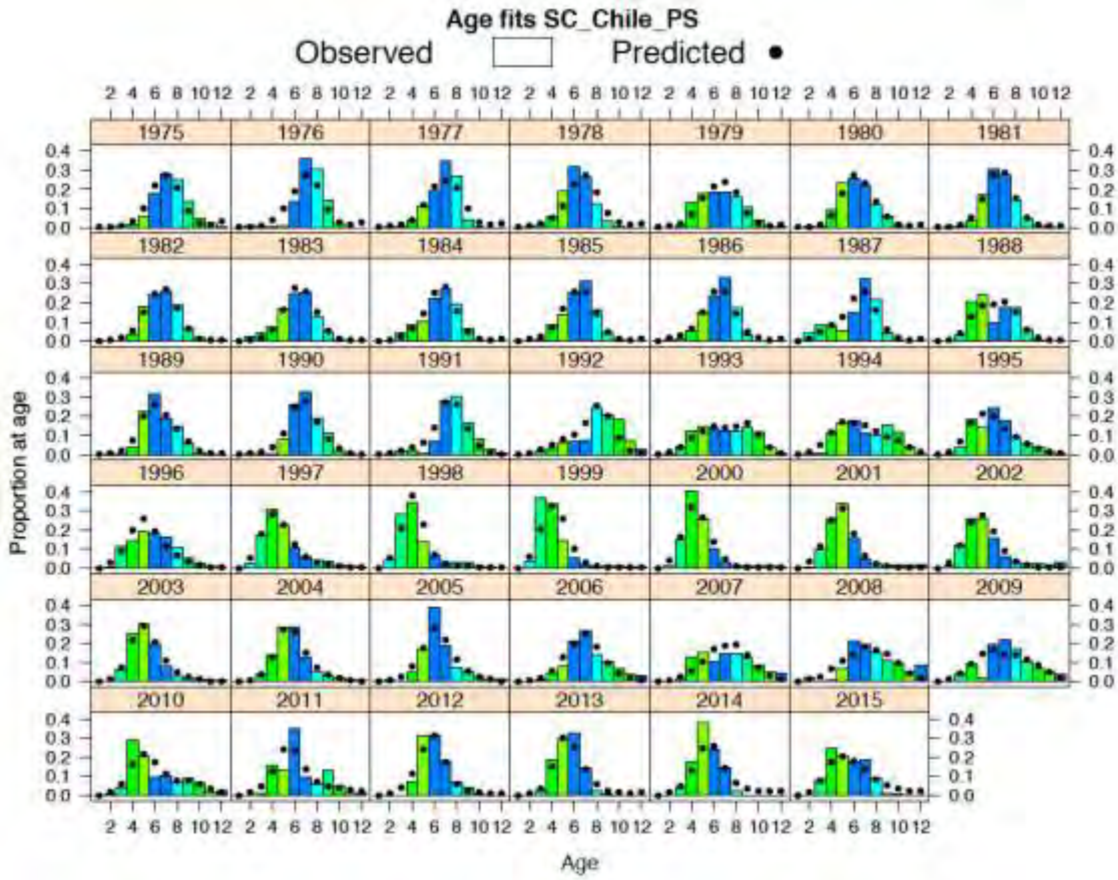


Figure A8.6. Model fit (Model 0.4) to the age compositions for the **South-Central Chilean purse seine** fishery (Fleet 2). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

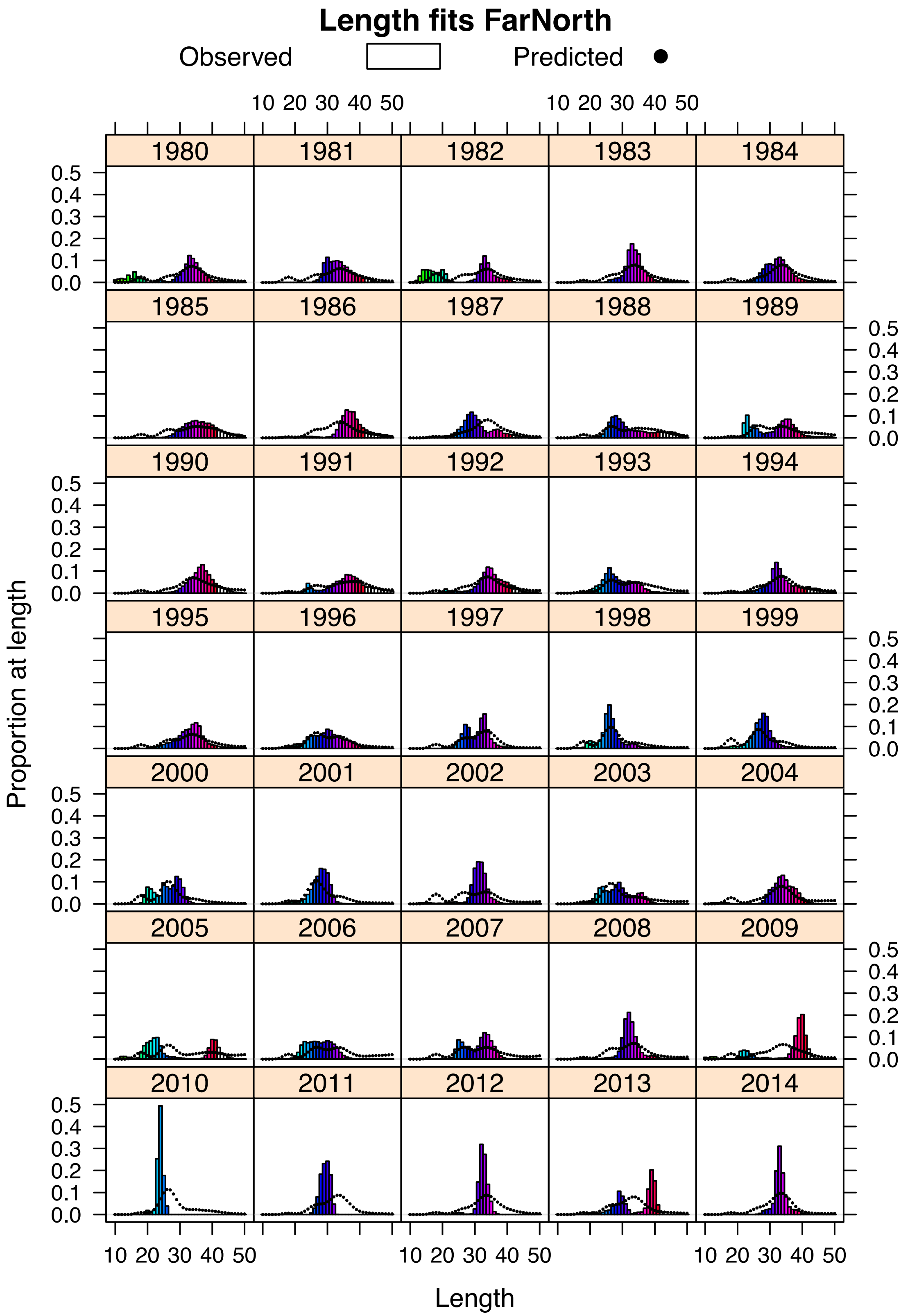


Figure A8.7. Model fit (Model 0.4) to the length compositions for the far north fishery (Fleet 3). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

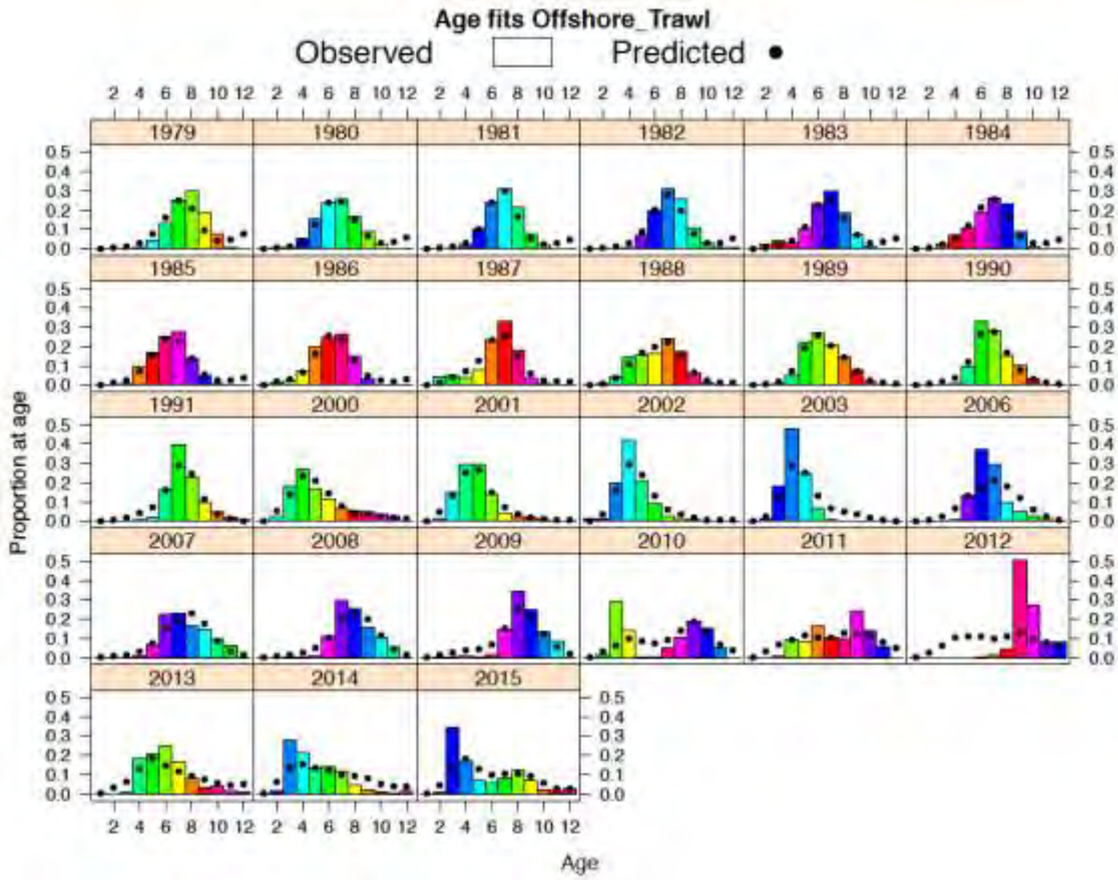


Figure A8.8. Model fit (Model 0.4) to the age compositions for the **offshore trawl** fishery (Fleet 4). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

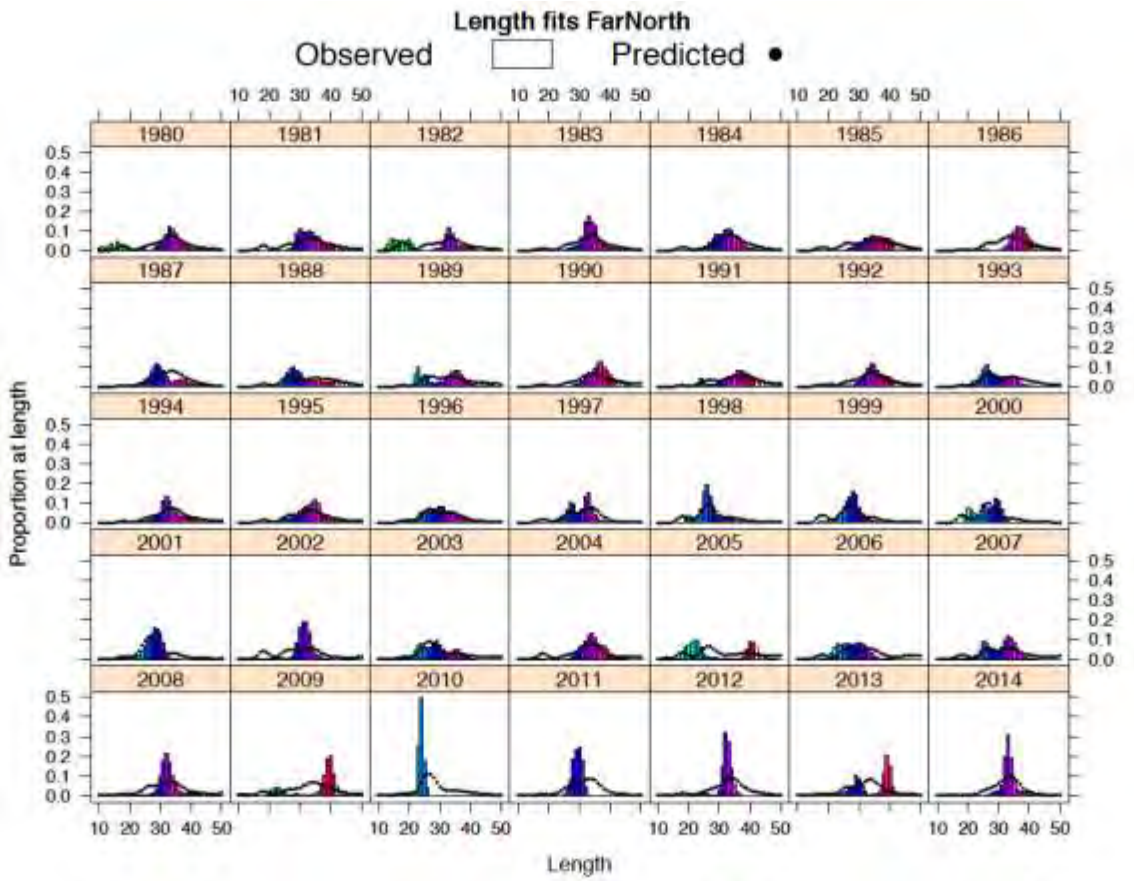
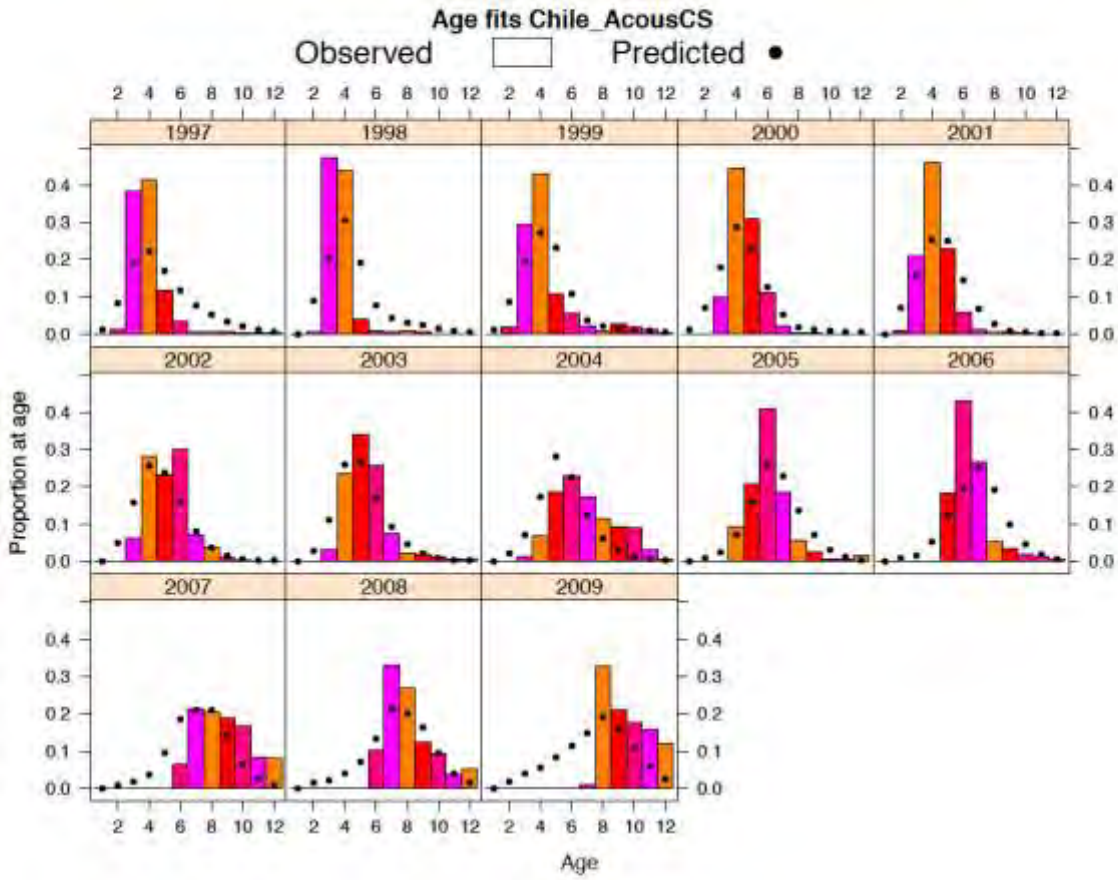


Figure A8.9. Model fit (Model 0.4) to the age compositions for the **SC Chilean acoustic survey**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.


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

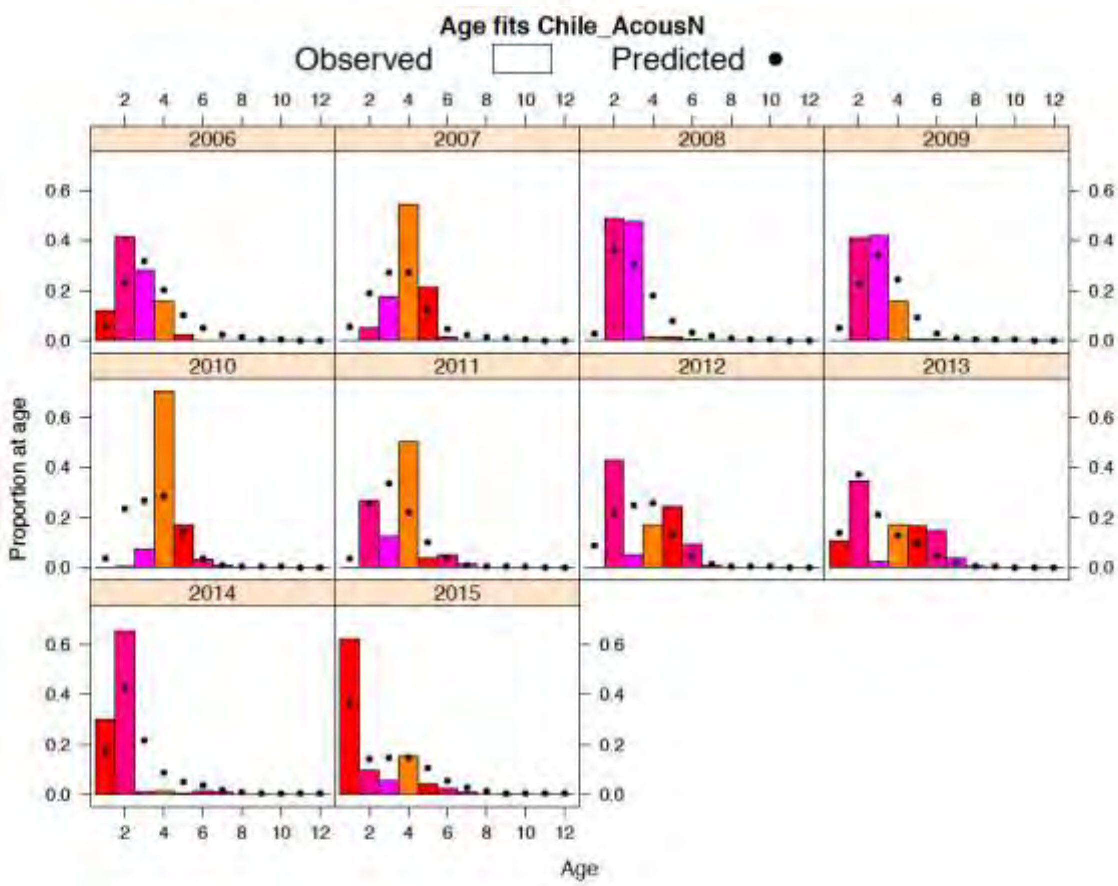

Age fits Chile_AcousN
Observed
Predicted
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Proportion at age
Age

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

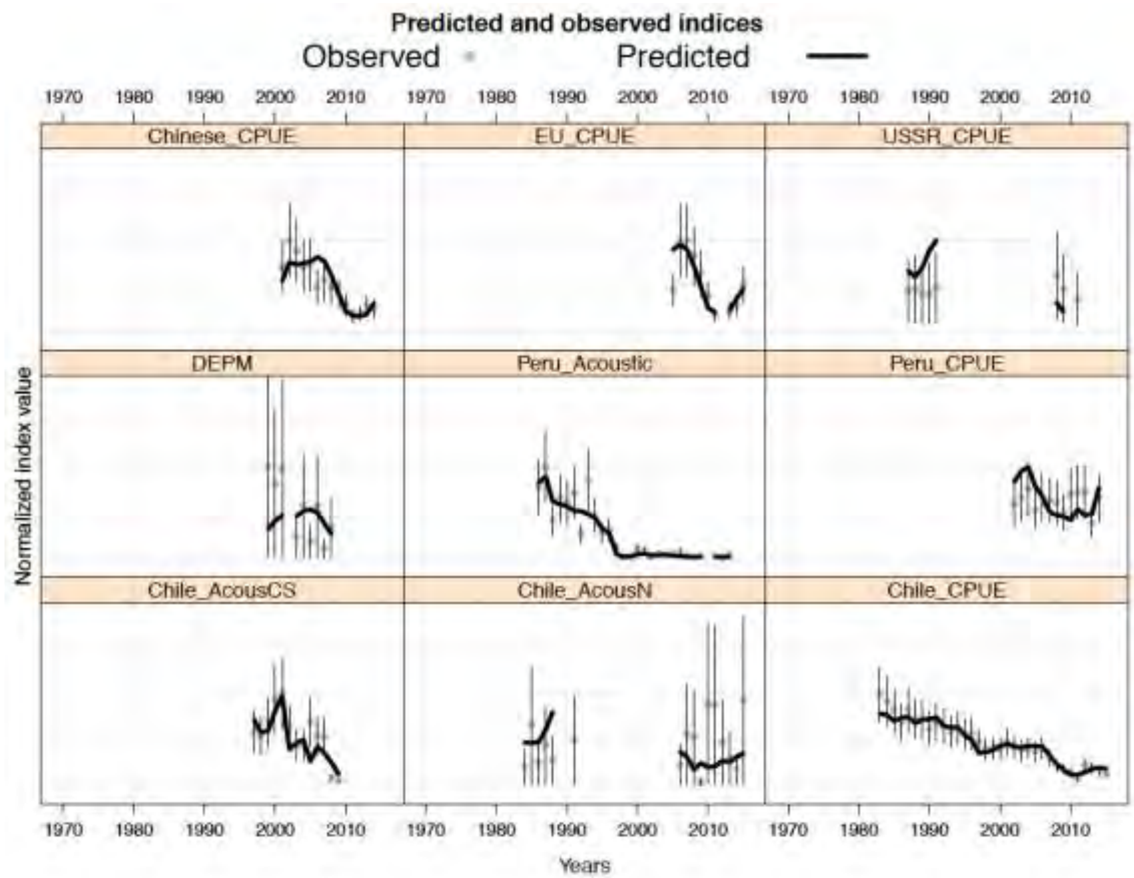


Figure A8.11. Model fit (Model 0.4) to different indices. Vertical bars represent 2 standard deviations around the observations.

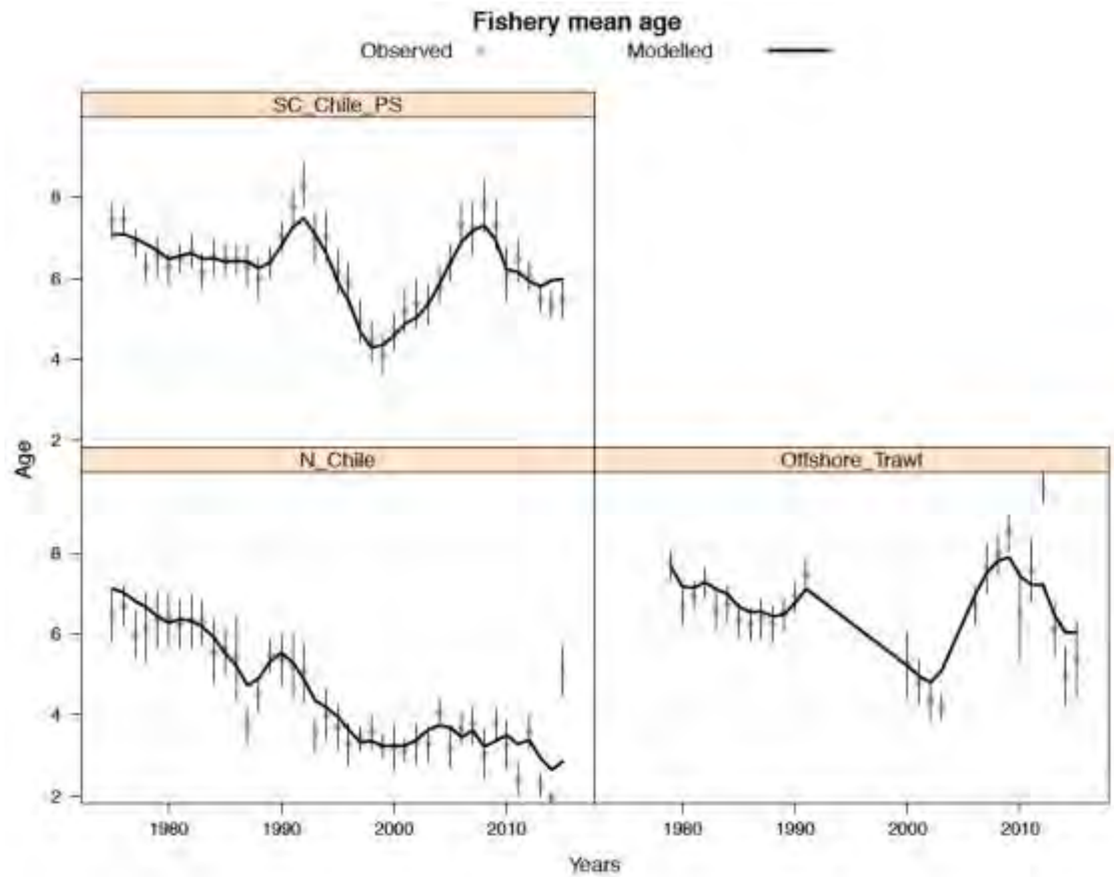


Figure A8.12. Mean age by year and fishery. Line represents the model and dots the observed values.

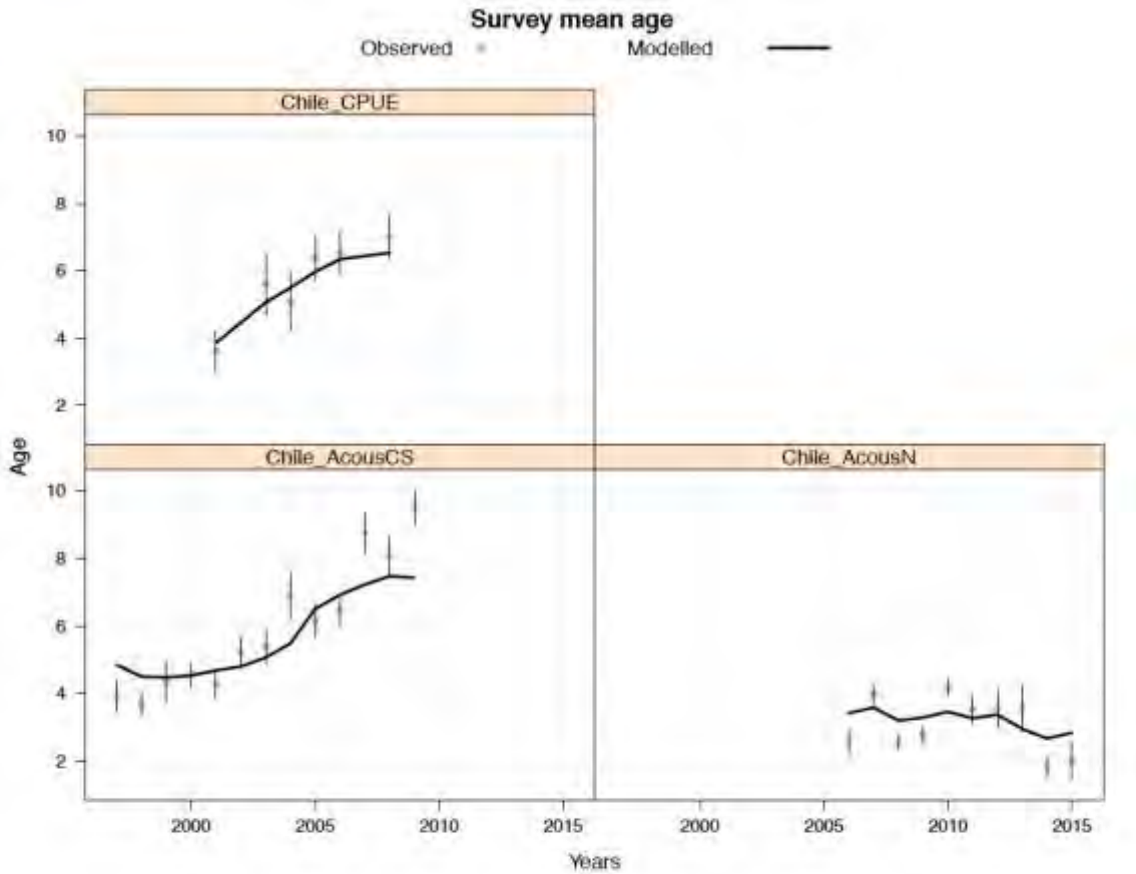


Figure A8.13. Mean age by year and survey. Line represents the model and dots the observed values.

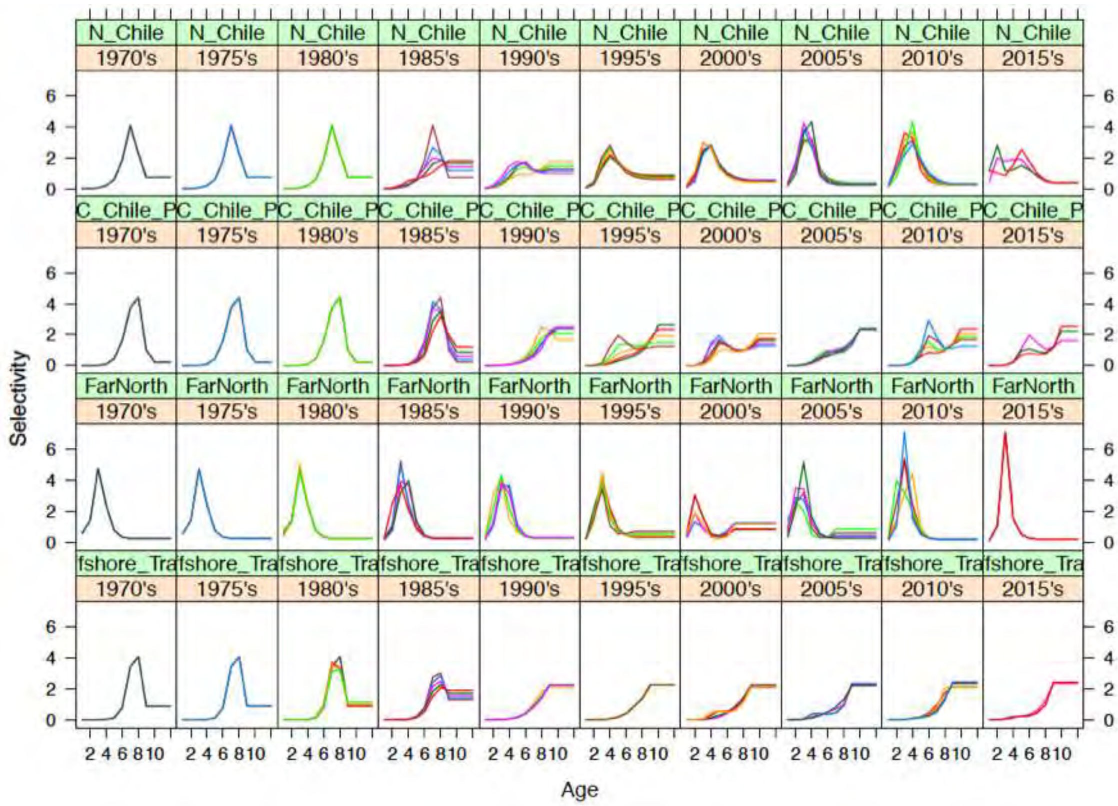


Figure A8.14. Estimates of selectivity by fishery over time for Model 0.4. Each cell represents a 5-year period).

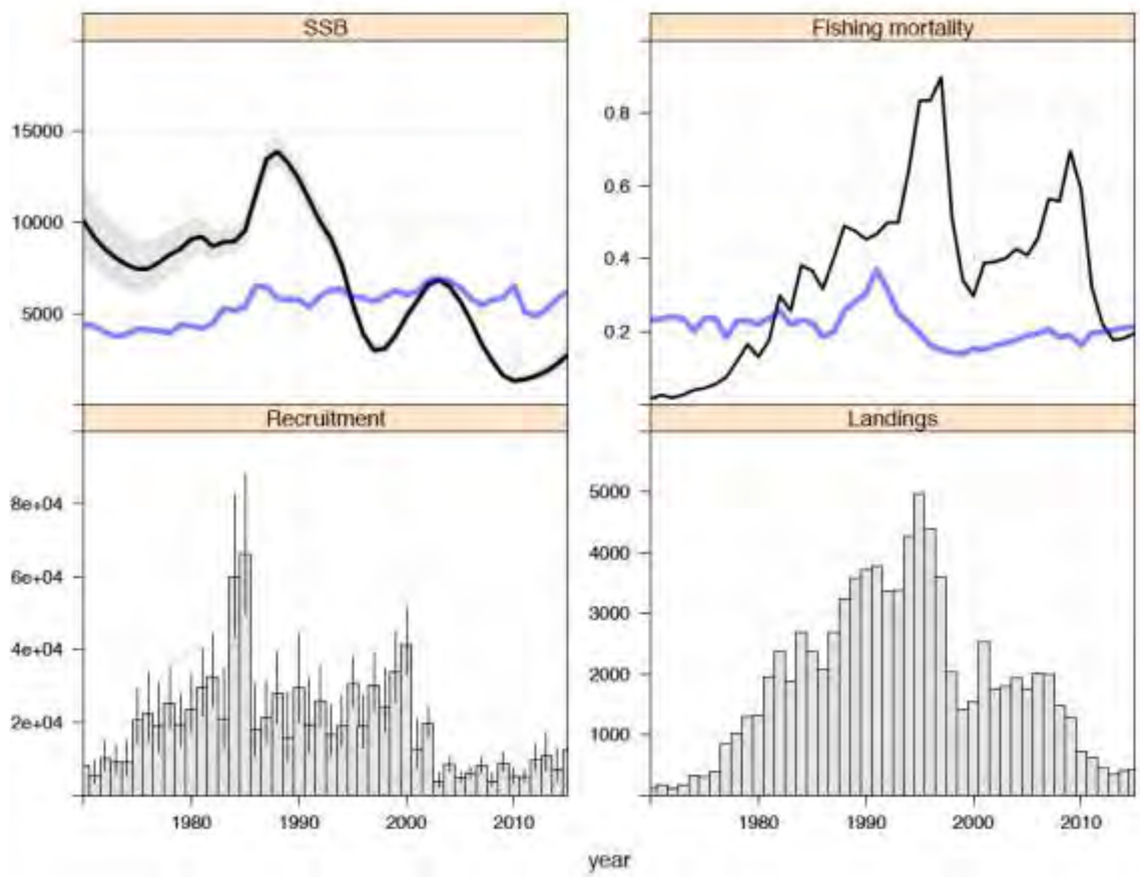


Figure A8.15. Summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left) total fishing mortality (top right) and total catch (kt; bottom right) for the single stock hypothesis.

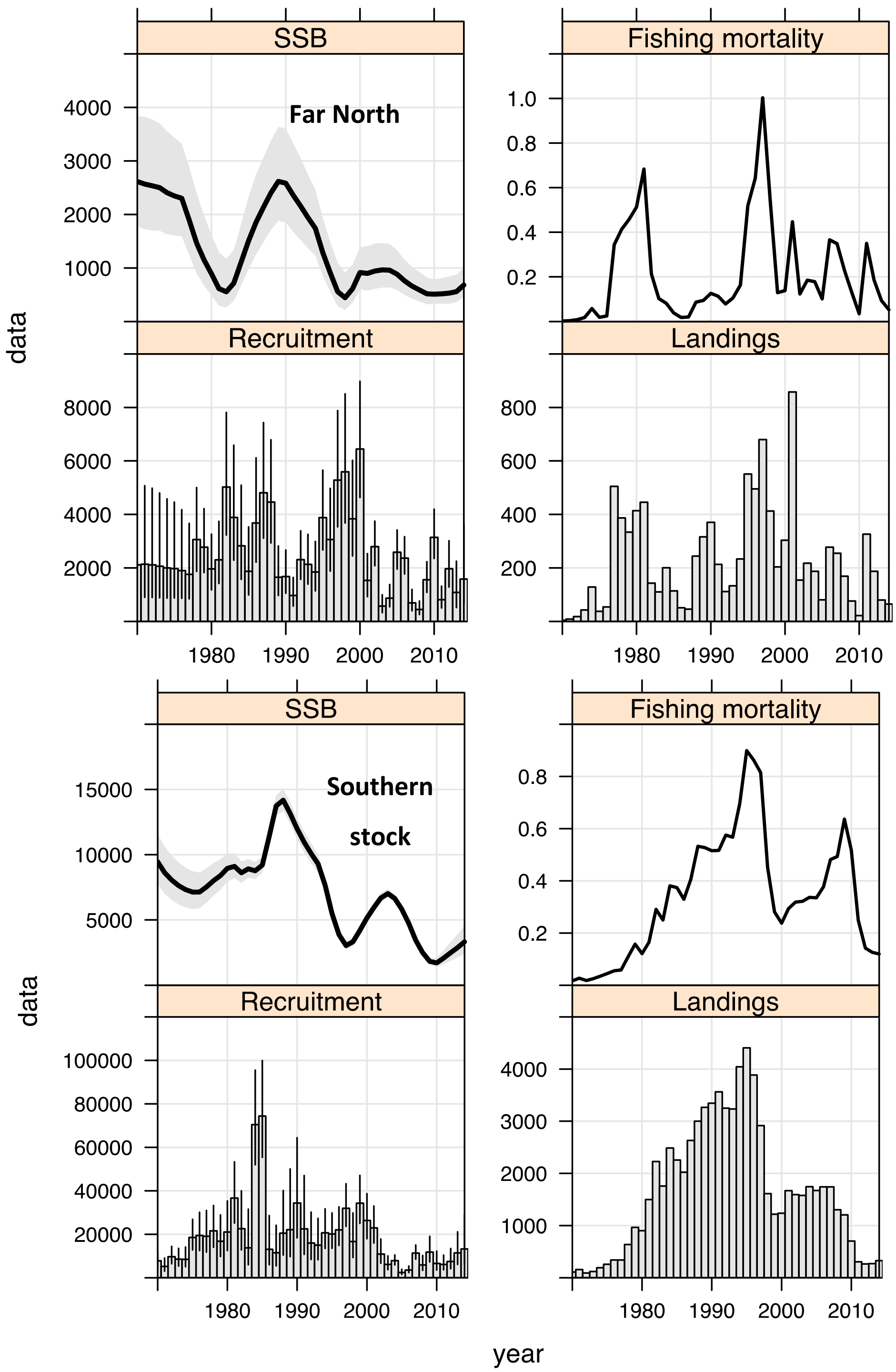


Figure A8.16. Summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left) total fishing mortality (top right) and total catch (kt; bottom right) for Models 1.11N (from 2014 SC02 configuration, top set) and 0.4S (bottom set) for the two-stock hypothesis.

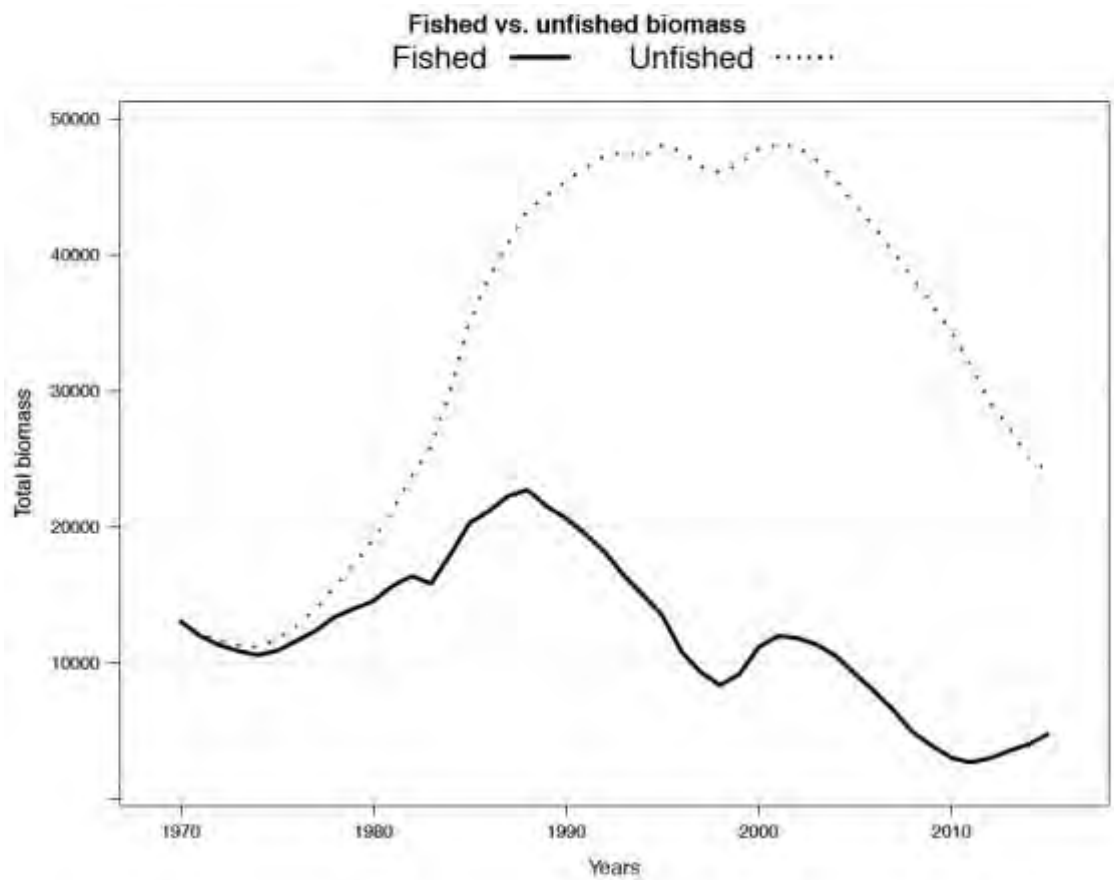


Figure A8.17. Model 0.4 results the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place, 1970-2014.