# Annex 7. Jack mackerel stock assessment

## Introduction

This document and content is based on discussions and analyses conducted at the SC-04 meeting. An exhaustive stock assessment input data review and discussion of model assumptions were considered in a workshop prior to the SC-04 meeting. The discussions during this workshop and subsequently during the SC04 focused on the following topics:

- Review and update of data sets
- How to weight different data sets (which are of different quality)
- How to deal with ageing error
- The assumptions on fisheries and survey selectivity over the years
- Assumptions on natural mortality
- The extent and mechanisms affecting how selectivity may vary over time
- Consideration of additional diagnostic tools (retrospective analyses, likelihood profiles)
- For projections, information within the data and model configuration that may inform stock productivity (so-called stock recruitment “steepness”).

### *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 stock hypotheses considered in the 11th SWG Meeting, and this continues to be one of the main tasks undertaken at SC-04.

*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 to produce fish meal. In Peru, the fishery is variable from year to year. Here the fish is taken by purse seiners that also fish for other pelagic species (e.g., anchovy, mackerel, sardines). 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 jack 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 jack mackerel fishery in Chilean and offshore waters is generally mono-specific. In the offshore fishery, the catch consists for 90 – 98% of jack mackerel, with minor bycatch of chub mackerel (*Scomber japonicus*) and Pacific bream (*Brama australis*). The available time series of jack mackerel catches in the south-eastern Pacific are 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*

Important environmental events (e.g., the 2016 El Niño) affect oceanographic dynamics. During such events, the depth of the 15$^{o}$C isotherm changed significantly affecting the spatial distribution of Jack mackerel and their availability in different regions. The extent that such changes affect the overall population productivity is unclear.

*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). The catches from each of 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 older international fleet were converted into age distributions using annual Chilean age-length keys. The more recent length composition data from China and EU were converted to age compositions by applying Chilean age-length keys as compiled by quarter of the year and then aggregated (Tables A8.3, A8.4, and A8.5). For Peruvian and Ecuadorian fisheries, length frequency data (Table A8.6) were used directly and fit within the model according to the specified growth curve.

Several CPUE data series are used in the model, with some changes introduced during SC-04. For the Chilean purse seiner fleet, a “General Linear Model” (GLM; McCullagh & Nelder, 1989) approach was used to standardize the CPUE. Here CPUE was modelled as a linear combination of explanatory variables with the goal to estimate a year-effect that is proportional to jack mackerel density. Factors in the GLM included year, quarter, zone, and vessel hold capacity. Effort units were computed as the number of days spent fishing by each vessel. This CPUE series was revised during SC-04 to exclude trips with no jack mackerel catches. This was preferred because it better reflects changes in management over time (particularly the introduction vessel-level quotas starting in 2000). To account for changes in fleet behaviour arising from the changes in management, the revised CPUE series from the GLM was modelled to have a catchability change in year 2000.

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 modelled 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. This CPUE series was also revised during SC-04 and is now based on all trips and not just on those with jack mackerel catches above a pre-specified threshold. This is because the trips of this fleet target a collection of species (anchoveta, jack mackerel, mackerel, etc.) jointly rather than a specific target species. Effectively all trips “target” jack mackerel as part of the species ensemble.

Peruvian CPUE data were unavailable for 2015 apparently due to very low catches of jack mackerel. El Niño conditions were very strong in 2015 and jack mackerel are believed to have been distributed closer to the coast than normal and outside of where the industrial fleet is allowed. For this reason, the 2015 CPUE value was unrepresentative of stock abundance and, hence excluded. However, it was agreed that this should be examined more closely next year.

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 single nominal CPUE series for the offshore fleet was compiled using data from EU, Vanuatu and Korean vessels and updated through 2016.

*Fisheries independent data*

China has a system of observers on board fishing vessels that, among other data collection activities, routinely record environmental variables (wind direction and speed, SST, etc.) while on the fishing grounds. Although this data was presently unavailable to the SC, it may be in the future.

The Chilean Jack mackerel research program has included conducting surveys using hydro-acoustics and the daily egg production method (DEPM). Acoustic estimates and egg survey results are used as relative abundance indices. For the northern region (N-Chile) data on acoustic biomass and number and weight at age are available annually from 2006 to 2016. For the central-southern regions, these data are available from 1997 to 2009. In previous jack mackerel assessments, the acoustic survey in northern Chile was assigned the same selection-at-age curve as the northern Chile fishing fleet; however, given the survey age composition data indicate that it catches younger ages than the fishing fleet, the SC-04 considered it more appropriate to assign the survey its own selectivity. 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. 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. Age composition data for the acoustic and DEPM Chilean surveys are shown in Tables A8.7. – A8.9.

The Peruvian Jack mackerel research programme includes egg and larvae surveys and hydro-acoustic 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. During SC-03, 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 were being made by using an environmental index describing the potential habitat of this species based on available monthly data on Sea Surface Temperature (SST), Sea Surface Salinity (SSS), water masses (WM), oxycline depth (OD) and chlorophyll (CHL), since 1983 to the present.

Yet another alternative acoustic index for Peru was presented in 2014. This was constructed using backscatter information without converting the information to biomass estimates using length-frequency data. The reasons to propose this method related to the reduced quality of the available length-frequency data in recent years. This alternative series was included in the jack mackerel assessment by SC-04, thus replacing the Peruvian acoustic series used in previous assessments. The last value provided for this series corresponds to 2013. The El Niño conditions in 2014 and 2015 affected the distribution of jack mackerel making them more dispersed and outside the area covered by the anchovy survey. Further work on standardizing and analysis of the survey data to develop a reasonable index from these data.

Acoustic surveys, to estimate the biomass and distribution of jack mackerel, have also been conducted along the Chilean coast, inside and outside of the EEZ and in the Peruvian EEZ, using scientific vessels. Additionally, comprehensive acoustic surveys have been conducted from the Chilean commercial fleet. The available acoustic estimates time series extends from 1984 to 2012 (depending on the area). All abundance indices (fishery CPUE and survey) series used in the model are presented in Table A8.10.

*Biological parameters*

The maturity-at-age assumed for jack mackerel was 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 in the assessment a few years ago. Maturity at length was consistently observed with L50 at about 23 cm fork length (FL). The maturity-at-age values, and those for the far-north stock, are shown in Table A8.11.

To fit the length composition data from the far-north fleet, a growth curve was used to convert age compositions predicted by the model to predicted lengths, with the conversion occurring within the model. The values for the von Bertalanffy growth parameters are given in Table A8.12. Ageing imprecision is acknowledged using an age-error matrix and is shown in Table A8.13. However, because this matrix is based on expert judgement instead of actual data, the discussions during SC-04 led to selecting the final assessment model with this ageing error option turned off.

Mean weight-at-age is required for all fishing fleets and biomass indices in order to relate biomass quantities to the underlying model estimates of jack mackerel abundance (in numbers). The four weight at-age matrices for the fishing fleets correspond to: fleet 1 (northern Chile), fleet 2 (central-south Chile), fleet 3 (the far north fleet) and fleet 4 (the offshore trawl fleet). These values are shown in Tables A8.14 - A8.17.

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. Before SC-03, the same weight at age matrix was used for the Northern Chilean Fleet (Fleet 1) and Southern Chilean Fleet (Fleet 2). From SC-03 onwards 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 1974-2016; for earlier years the weight at age from 1974 was used.

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 1970-2016. The weights at age for the offshore fleet are derived from age-extrapolations from Chilean length frequency data and averages when unavailable.

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 (see Table A8.12).

*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.

**The 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 2016.

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 stock; (ii) the fishery dynamics; (ii) observation models for the data; and (v) the procedure used for parameter estimation (including uncertainties).

Stock dynamics: recruitment is considered to occur in January while the spawning season is considered as an instantaneous process at mid-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 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 index-specific, and there are nine abundance indexes. For some of the indices, time variations in catchability and / or selectivity 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 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 mostly constant over years. For the total catch by fishery (4) and abundance indexes (9), a log-normal assumption has been assumed with constant CV; the CV for the fisheries is 0.05 whereas the CVs for the abundance indices depend on the index.

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 1970-2016 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.

Equations for the assessment model are 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 selectivity and how they are shared among fisheries and indices are given in Table A8.23, A8.24 and A8.25. Depending on the model configuration, some growth functions were employed inside the model to convert model-predicted age compositions to length compositions, in order to fit the model to the length composition data.

*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 model explorations*

The first set of explorations involved incrementally adding new data components relative to last year’s jack mackerel model. These are labelled “Mod0.x” where x represents the number when a component was added (Table A8.26).

The rationale for the main updates and data revisions occurring through model configurations 0.0 to 0.13 has been explained in the “Data used in the assessment” section, earlier in this Annex. The data exercise concluded with Model 0.13.

The next set of explorations (1.0 – 1.19) started from Model 0.13, renamed as Model 1.0, and evaluated aspects such as changes in selectivity, the assumption on natural mortality and weighting of specific input datasets. The most salient features from this exploration for the assessment of jack mackerel (for simplicity under the single stock hypothesis) are described below.

Some models were run purely as sensitivity tests, (e.g., Models 1.1 and 1.2). In Model 1.3, the CVs of abundance indices and multinomial sample sizes of fleets and indices were adjusted based on the overall conclusions of the data quality workshop held in 2015 (SC-03). The same weights were applied in Model 1.14. It was, however, observed that the fits to some of the datasets (such as the mean age in the catch of some fisheries) deteriorated when these weights were used. Moreover, the procedure led to increasing the weight of the Chilean Acoustic North survey index and, given the uncertainties associated with this index (related to inter-annual changes in availability), there was some concern that increasing the weight of this abundance index in the model may be inappropriate. The SC noted that the weights in Model 1.3 were based on the first-pass subjective results from the data quality workshop without further review. Consequently, another iteration of refinements to the weightings is required before adopting them as part of the new reference case.

An alternative weighting scheme for the multinomial sample sizes, based on Francis T1.8 method was proposed in SC-04-JM-07. This alternative was another initial exploration that the SC should be considered further in future assessments.

Selectivity blocks were explored in Models 1.5 and 1.6. However, the SC noted that deciding when a new block should be introduced was subjective, including how future changes might be considered. Consequently, the current approach of allowing more gradual annual evolutions via random walks was preferred.

Models 1.9, 1.10 and 1.16 evaluated alternative natural mortality assumptions. Profiling over M was conducted under Model 1.9; this showed a preference towards larger values of M that seemed to be driven mainly by the age composition data (Figure A8.2). An age-varying natural mortality, inversely related to weight-at-age (Lorenzen, 1996), and scaled to take a value of 0.23 at the oldest age, was considered in Model 1.10. The higher values of M resulted in higher estimates of recruitment and SSB. The estimated value of $F_{msy}$ became very high in this model configuration (even higher than 1 for the period before the mid 1990s). Model 1.16 attempted to use the same age-varying M but rescaled to an average of 0.23 over all the ages. However, this model run configuration had convergence issues that require more time to investigate than was available during the SC. It was concluded that a more comprehensive analysis would be necessary before considering changing natural mortality assumptions.

**Results**

Results comparing the impact of new data (Models 0.0-0.13) show that especially a change in the Peruvian echo-abundance influences the biomass trends, as well as changing the selectivity in the Chilean acoustic survey. This survey observed high densities of young individuals but these observations are expected to be influenced by the strong El Nino in 2015. Models 1.0 – 1.19 evaluated changes in selectivity, the assumption on natural mortality and weighting of specific input datasets. The final model is like the 2015 model but allows more flexibility in the selectivity parameters in the acoustic survey.

Model 1.11 (and the corrected version, Model 1.18, which included additional years of selectivity changes that should have been in earlier model configurations but had been omitted by mistake) provided an important change that had a clear impact on assessment results, particularly on the recruitment (age 1) estimate for the most recent year. In 2015 and 2016 the Chile North Acoustic survey index has very high values at age 1, which are expected to have likely arisen from availability changes (e.g. they could be related to El Niño event in 2015 and 2016) rather than reflect true changes in stock abundance. The very high 2015 age 1 index in this survey is not followed by a high 2016 age 2, and the strength of the 2015 and 2016 (age 1) recruitments is considered very uncertain now. To account for the likely availability changes in 2015 and 2016, Model 1.11 (and Model 1.18) includes selectivity changes for the Chile North Acoustic survey index in these two years. The SC considered this to be a sensible way forward and, even though additional model alternatives were examined, the conclusion was that Model 1.18 should be taken as the best model for providing advice this year.

To gain additional understanding of the assessment model properties and the impact of different datasets on model results, a profiling system was created so that the population scale could be effectively changed to see how likelihood components interact and which are most influential. The parameter for mean recruitment was fixed (instead of estimated) at a grid of values and results consequently plotted in terms of the derived quantity of the spawning biomass in 2016 (SSB). This grid was completed to explore Models 1.14 and 1.18 (Figure A8.3). Results of the profiling indicate that the largest impact affecting stock size uncertainty was structural: the configuration of Model 1.18 resulted in a considerably lower 2016 SSB than the Model 1.14 configuration. Within each of these configurations, the likelihood components were affecting the result in similar directions (i.e., the fishery age-composition likelihood favoured smaller 2016 SSB and the index data favoured higher stock sizes. In both configurations, the contribution to the recruitment likelihood was quite influential presumably due to interactions with fixing the mean recruitment values in each trial.

A new diagnostic was developed at this meeting which is common in many assessment analyses. This is the so-called "retrospective analysis" and involves running the model multiple times, each time removing one more year of data. For example, if the full model spanned 50 years of data, results from this would be compared to running the same model but only to 49 years, then 48 years and so on. This shows how sensitive the model is to additional data and may reveal tendencies for systematic bias. The estimated time series of recruitment and SSB shows a slight tendency to over-estimate SSB and that as more data are accumulated, estimates of recruitment magnitude can change (Figure A8.4).

The assessment model was also run under the 2-stock hypothesis. In that case, Model 1.18 resulted in unrealistic results for the north stock (e.g. unrealistically high Fs in some years). The relatively small amount of information available for the north stock does not seem to be able to handle the high parameter complexity of Model 1.18. The simpler Model 1.6, which considers only 2 time blocks instead of annually-varying selectivity, was instead used for the north stock. Model 1.18 was used for the south stock.

Assumed fishery mean weight-at-age assumed for all models are shown in Figure A8.5. The model numbers-at-age estimates are given in Table A8.27. The fishery age and length composition fits are shown in Figures A8.6, A8.7, A8.8, and A8.9. The age composition data from the surveys are given in Figures A8.10 and A8.11. This model fit the indices reasonably well (Figure A8.12). Fits to the index and fishery mean age compositions are shown in Figures A8.13 and A8.14.

Selectivity estimates for the fishery and indices is shown over time in Figures A8.15. A summary of the time series stock status (spawning biomass, F, recruitment, total biomass) for the single-stock hypothesis is shown in Figure A8.16 and for the two-stock hypothesis in Figure A8.17. 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 35% of what is estimated to have occurred had there been no fishing (Figure A8.18).

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).   To evaluate the potential for alternative "regimes", stock recruitment curves were estimated over different periods and found that within the current period (2001-2013) 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 2016) are relatively unchanged. The population trend is estimated to be increasing. The indications of stock improvement (higher abundance observed in the acoustic survey in the northern part of Chile, survival of age 4 fish in 2015 to age 5 fish in 2016, better catch rates apparent in some fisheries) drive the increase.

Historical fishing mortality rates and patterns relative to the provisional biomass target are shown in Figure 1 (Section 10 above). Projections carried out in 2016 indicated that that if fishing mortality is maintained at or below intended 2016 levels and under the assumption of recent average recruitment at the levels estimated for the recent period (2000–2014), the likelihood of future spawning biomass increases. This led to recommended catches for 2017 in the order of 493 kt or lower (Table A4.30 of SC02). Fishing effort in the next 10 years at or below current (2016) levels were projected to have a reasonably good probability of increased spawning biomass from the 2016 level of about 4.1 million t with projected increase to 5.2 million t in 2017.

In summary, the 2016 update assessment has resulted in an upward revision in SSB relative to the 2015 estimates due to updated data presented (Table A8.29; Figure A8.19). 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 Chilean northern acoustic survey and those conducted in Peruvian waters.

Relative to the rebuilding analysis, the conclusions from SC02 benchmark assessment continues to apply and the recommendation satisfies the rebuilding plan specified by the Commission. The time series of key model estimates are presented in Table A8.30.

**Assessment issues**

Based on the results of the 2016 assessment workshop, as noted previously, assessment plans for 2017 should be developed several months prior to SC05 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 continues to be the catch-at-age estimates (based on age-determinations being conducted from different labs) and mean body weights at age assumed in the model.

The issue of evaluating sensitivities to the early fishery age composition data was raised. The SC noted that this might be a fruitful avenue for investigation in subsequent assessments, particularly since these data (pre-1990) are less well documented.

**References**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Tables**

Table A8.1. Sources and values of catch (t) complied for the four fleets used for the assessment (2016 is preliminary)

| | Fleet 1 | Fleet 2 | Fleet 3 (Far North) | | | | | | Fleet 4 (Offshore Trawl) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Chile | Chile | Cook Islands | Cuba | Ecuador | Peru | USSR | Total | Belize | China | Cuba | European Union | Faroe Islands | Japan | Korea | Peru | Russian Federatio | Ukraine | Vanuatu | Total | Grand 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 | | 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 | | 20539 | 0 | | 4078 | 2557 | | | 15324 | 63652 | 410698 |
| 2015 | 34886 | 250327 | | | 289 | 22158 | | 22447 | | 29180 | | 27955 | 0 | | 5749 | 0 | 2606 | | 21227 | 86717 | 394377 |
| 2016 | 21069 | 270411 | | | 0 | 16853 | | 16853 | | 20000 | | 12300 | | | 4300 | | | | 15563 | 52163 | 360496 |

Table A8.2. Input catch (tonnes) by fleet (combined) for the stock assessment model. Note that 2016 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 | 34,886 | 250,327 | 22,447 | 86,717 |
| 2016 | 21,069 | 270,411 | 16,853 | 52,163 |

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 | 11 | 3 | 11 | 49 | 20 | 6 | 1 | 0 | 0 | 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 | 11 | 40 | 17 | 11 | 10 | 7 | 2 | 1 | 0 | 0 |
| 2016 | 0 | 0 | 4 | 28 | 33 | 20 | 7 | 4 | 3 | 1 | 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 | 0 | 10 | 19 | 14 | 15 | 16 | 14 | 5 | 3 | 2 | 2 |

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.

Total length (cm)

| | 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 |
| 2015 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 10 | 13 | 12 | 14 | 14 | 9 | 5 | 4 | 4 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2016 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 6 | 10 | 8 | 6 | 6 | 7 | 7 | 7 | 6 | 7 | 6 | 6 | 5 | 4 | 3 | 2 | 1 | 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 |
| 2016 | 80 | 5 | 8 | 6 | 1 | 0 | 0 | 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 | | | 1.908 | | | | | | | |
| 1984 | | 99 | 1.904 | | | | | | | |
| 1985 | | 324 | 1.698 | | | 94 | | | | |
| 1986 | | 123 | 1.418 | | 17811 | 108 | | | | |
| 1987 | | 213 | 1.698 | | 22955 | 110 | | | | 55 |
| 1988 | | 134 | 1.503 | | 9459 | 114 | | | | 58.2 |
| 1989 | | | 1.476 | | 15034 | 157 | | | | 51.1 |
| 1990 | | | 1.262 | | 14139 | 230 | | | | 52.6 |
| 1991 | | 242 | 1.423 | | 16486 | 232 | | | | 61 |
| 1992 | | | 1.327 | | 6266 | 180 | | | | |
| 1993 | | | 1.202 | | 19659 | 146 | | | | |
| 1994 | | | 1.319 | | 10768 | 95 | | | | |
| 1995 | | | 1.187 | | 6429 | 54 | | | | |
| 1996 | | | 1.189 | | 7271 | 30 | | | | |
| 1997 | 3530 | | 0.992 | | 2561 | 32 | | | | |
| 1998 | 3200 | | 0.854 | | 190 | 44 | | | | |
| 1999 | 4100 | | 0.874 | 5724 | 342 | 53 | | | | |
| 2000 | 5600 | | 0.863 | 4688 | 2373 | 106 | | | | |
| 2001 | 5950 | | 1.031 | 5627 | 2052 | 132 | | 1.462 | | |
| 2002 | 3700 | | 0.905 | | 248 | 97 | 80 | 2.049 | | |
| 2003 | 2640 | | 0.797 | 1388 | 1118 | 67 | 176 | 1.857 | 81.3 | |
| 2004 | 2640 | | 0.876 | 3287 | 864 | 52 | 167 | 1.498 | 105.8 | |
| 2005 | 4110 | | 0.802 | 1043 | 1025 | 75 | 127 | 1.517 | 110.7 | |
| 2006 | 3192 | 112 | 0.876 | 3283 | 1678 | 111 | 152 | 1.056 | 140.6 | |
| 2007 | 3140 | 275 | 0.662 | 626 | 522 | 80 | 224 | 1.143 | 182.7 | |
| 2008 | 487 | 259 | 0.462 | 1935 | 223 | 24 | 187 | 0.911 | 156.6 | 77.4 |
| 2009 | 328 | 18 | 0.388 | | 849 | | 132 | 0.857 | 139.7 | 59.6 |
| 2010 | | 440 | 0.299 | | | 7 | 81 | 0.604 | 87.5 | |
| 2011 | | 432 | 0.167 | | 678 | 35 | 232 | 0.347 | 38.1 | 45.2 |
| 2012 | | 230 | 0.526 | | 94 | 50 | 247 | 0.407 | 36.4 | |
| 2013 | | 144 | 0.464 | | 890 | 65 | 83 | 0.557 | 57.7 | |
| 2014 | | 87 | 0.356 | | | | 83 | 0.521 | 65.1 | |
| 2015 | | 459 | 0.293 | | | | | 1.024 | 104.1 | |
| 2016 | | 512 | 0.547 | | | | | | 85.8 | |

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 JJM 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 |
|---|---|---|
| $L_\infty$ (cm) (Total length) | 80 .4 | 74.4 |
| $k$ | 0.16 | 0.16 |
| $L_0$ (cm) | 18.0 | 18.0 |
| M (year$^{-1}$) | 0.33 | 0.23 |

$L_o$ is the mean length at the recruitment age (1 yrs).

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 | 0.027 | 0.058 | 0.177 | 0.183 | 0.298 | 0.442 | 0.621 | 0.520 | 0.583 | 0.729 | 0.868 | 1.109 |
| 2016 | 0.027 | 0.058 | 0.177 | 0.183 | 0.298 | 0.442 | 0.621 | 0.520 | 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 | 0.050 | 0.340 | 0.358 | 0.393 | 0.488 | 0.713 | 0.928 | 1.334 | 1.041 | 1.496 | 1.131 | 1.265 |
| 2016 | 0.050 | 0.340 | 0.192 | 0.279 | 0.324 | 0.348 | 0.463 | 0.594 | 0.829 | 0.923 | 1.241 | 1.738 |

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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1970 | 0.045 | 0.171 | 0.377 | 0.642 | 0.945 | 1.265 | 1.587 | 1.900 | 2.196 | 2.470 | 2.721 | 2.946 |
| 1971 | 0.045 | 0.171 | 0.377 | 0.643 | 0.946 | 1.266 | 1.588 | 1.902 | 2.198 | 2.472 | 2.723 | 2.949 |
| 1972 | 0.030 | 0.130 | 0.306 | 0.548 | 0.835 | 1.148 | 1.470 | 1.789 | 2.095 | 2.382 | 2.647 | 2.887 |
| 1973 | 0.037 | 0.147 | 0.330 | 0.568 | 0.842 | 1.134 | 1.430 | 1.718 | 1.991 | 2.246 | 2.478 | 2.688 |
| 1974 | 0.038 | 0.147 | 0.326 | 0.558 | 0.825 | 1.108 | 1.393 | 1.671 | 1.934 | 2.178 | 2.402 | 2.603 |
| 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 |
| 2016 | 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 the same as 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 | 0.052 | 0.093 | 0.217 | 0.266 | 0.372 | 0.470 | 0.603 | 0.650 | 0.747 | 0.753 | 1.636 | 1.720 |
| 2015 | 0.050 | 0.340 | 0.358 | 0.393 | 0.488 | 0.713 | 0.928 | 1.334 | 1.041 | 1.496 | 1.131 | 1.265 |
| 2016 | 0.050 | 0.340 | 0.358 | 0.393 | 0.488 | 0.713 | 0.928 | 1.334 | 1.041 | 1.496 | 1.131 | 1.265 |

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 | - | 1970-2016 | - | Index: 1984-1988; 1991; 2006-2015 Age comps: 2006-2015 | Index: 1999-2008 Age comps: 2001-2008 |
| South-central Chile purse seine | 1975-2016 | - | 1970-2016 | 1983-2016 | 1997-2009 Age comps: 1997-2009 | - |
| FarNorth | - | 1980-2016 | 1970-2016 | 2002-2009, 2011-2013 | 1983-2013 | - |
| International trawl off Chile | 1979-1991 | 2007-2015* | 1970-2016 | China (2001-2015); EU, Korea & Vanuatu (2003-2016); 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, …., 2016} | $I$ | |
| Fleets (f) and surveys (s) | $f,s$ | Identification of information source |
| 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 | $M$ | 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 | $\Gamma$ | 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( $\mu_q^s$ , $\sigma_q^2$ ) |
| Stock-recruitment parameters | $R_0$ | Unfished equilibrium recruitment |
| | $h$ | Stock-recruitment steepness |
| | $\sigma_R^2$ | Recruitment variance |
| Unfished biomass | $\varphi$ | 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. The symbol $\Delta^s$ 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 fleet (f=1,2,3,4), year(i) and age (j) /length (l) | $\hat{C}_{il}, \hat{C}_{ij}, \hat{Y}_i$ | $\hat{C}^f_{i,j}, = N_{i,j}\frac{F^f{}_{i,j}}{Z^f{}_{i,j}}\left(1 - e^{-Z^f{}_{i,j}}\right)$ <br> $\hat{Y}^f{}_i = \sum_{j=1}^{12+} \hat{C}^f_{i,j} w^f_{i,j}$ |
| | (transformation from age to length composition. Fleet 3, FarNorth) | | $\hat{C}_{il} = \Gamma \ \hat{C}_{ij}$ <br> $\Gamma_{l,j} = \int_j^{j+1} e^{-\frac{1}{2\sigma_j^2}(l-L_j)^2} dl$ <br> $L_j = L_{00}(1-e^{-k}) + e^{-k} L_{j-1}$ <br> $\sigma_j = cv\, L_j$ |
| 3) | Proportion at age j, in year i | | $p^f_{ij} = \frac{\hat{C}^f_{ij}}{\sum_j \hat{C}^f_{ij}}$ $\quad p^s_{ij} = \frac{N_{ij} S^s_j e^{-\Delta^s Z_{ij}}}{\sum_j N_{ij} S^s_j e^{-\Delta^s Z_{ij}}}$ |
| | Proportion at length l, in year i | | $P_{il} = \frac{C_{il}}{\sum_{l=10}^{50} C_{il}}$ |
| 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+ | $N_{1970,12+} = N_{1970,11} e^{-M}(1 - e^{-M})^{-1}$ |
| 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, …, 2016 | $\varepsilon_i, \sum_{i=1958}^{2016} \varepsilon_i = 0$ | $N_{i,1} = e^{\mu_R + \varepsilon_i}$ |
| 11) | Index catchability | $\mu^s, \mu^f$ | $q_i^s = e^{\mu^s}$ |
| | Mean effect | | $s^s_j = e^{\eta^s_j}$ $\quad j \le \text{maxage}$ |
| | Age effect | $\eta^s{}_j, \sum_{j=1958}^{2016} \eta^s{}_j = 0$ | $s^s_j = e^{\eta^s_{\text{maxage}}}$ $\quad j > \text{maxage}$ |
| 12) | Instantaneous fishing mortality | | $F^f_{ij} = e^{\mu^f + \eta^f_j + \phi_i}$ |
| 13) | Mean fishing effect | $\mu^f$ | |
| 14) | Annual effect of fishing mortality in year i | $\varphi_i, \sum_{i=1970}^{2016} \varphi_i = 0$ | |

| Eq | Description | Symbol/Constraints | Key Equation(s) |
|---|---|---|---|
| 15) | age effect of fishing (regularized) In year time variation allowed | $\eta^f{}_j, \sum_{j=1958}^{2016} \eta^f{}_j = 0$ | $s_{ij}^f = e^{\eta_j^f}$ $j \leq \text{maxage}$ <br> $s_{ij}^f = e^{\eta_{\text{maxage}}^f}$ $j > \text{maxage}$ |
| | 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) | Recruits (Beverton-Holt form) at age 1. | $R_i$ | $R_i = \frac{\alpha B_t}{\beta + B_i},$ <br> $\alpha = \frac{4hR_0}{5h-1} \text{ and } \beta = \frac{B_0(1-h)}{5h-1} \text{ where }$ h=0.8 <br> $B_0 = R_0 \varphi$ <br> $\varphi = \sum_{j=1}^{12} e^{-M(j-1)} W_j p_j + \frac{e^{-12M} W_{12} p_{12}}{1-e^{-M}}$ |

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 | $L_1 = 0.5\sum_s \frac{1}{cv_s^2}\sum_i log\left(\frac{I_i}{\hat{I}_i}\right)^2$ | 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 | $L_3 = \lambda_3 \sum_{i=1958}^{2016} \varepsilon^2{}_i$ <br> $\lambda_3 = \frac{0.5}{\sigma_R^2}$ | Influences estimates where data are lacking (e.g., if no signal of recruitment strength is available, then the recruitment estimate will converge to median value). |
| 22) | Catch biomass likelihood | $L_4 = 0.5\sum_f \frac{1}{cv_f^2}\sum_{i=1970}^{2016} log\left(\frac{Y^f{}_i}{\hat{Y}^f{}_i}\right)^2$ | 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) | Dome-shaped selectivity | $L_6 = \lambda_4 \sum_{j=6}^{12}\left(lnS_{j-1} - lnS_j\right)^2$ <br> $S_{j-1} > S_j$ | (relaxed in final phases of estimation) |
| 25) | Fishing mortality regularity | F values constrained between 0 and 5 | (relaxed in final phases of estimation) |
| 26) | Recruitment curve fit | $L_7 = \lambda_5 \sum_{j=1970}^{2013} log\left(\frac{N_{i,1}}{\tilde{R}_i}\right)^2$ <br> $\lambda_5 = \frac{0.5}{\sigma_R^2}$ | Conditioning on stock-recruitment curve over period 1970-2013. |
| 27) | Priors or assumptions | $R_0$ non-informative | $\sigma_R = 0.6$ |
| 28) | 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). Step change in 2002 |
| **Index series** | | |
| 2) | Acoustic survey in Peru | Assumed to be the same as in fishery 1) |
| 3) | Peruvian fishery CPUE | Assumed to be the same as in fishery 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 1980. |
| **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) |

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; 2005-2009. |
| 6) | Acoustic survey in northern Chile | Estimated from age composition data 2006-2016. Selectivity changes were implemented in 2015 and 2016 |
| 7) | Central and southern fishery CPUE | Assumed to be the same as 2) |
| 8) | Egg production survey | Estimated from age composition data 2001, 2003-2006, 2008. Two time-blocks were considered around 2003. |
| 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, Korea & EU fleets CPUE | Assumed to be the same as 4) |
| 13) | ex-USSR CPUE | Assumed to be the same as 4) |

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 |
|---|---|
| **Models 0.x** | **Data introductions...** |
| mod0.0 | Exact 2015 model and data set through 2015 |
| mod0.1 | Extended to 2016...with revised catches through 2015 and provisional 2016 catch estimates |
| mod0.2 | As 0.1 but with new Chinese CPUE index |
| mod0.3 | As 0.2 but with new Peruvian CPUE index |
| mod0.4 | As 0.3 but with updated Chilean CPUE index |
| mod0.5 | As 0.4 but with 2012 q changed to 2000 on Chilean CPUE index |
| mod0.6 | As 0.5 but with alternative Chilean CPUE index |
| mod0.7 | As 0.5 but with new Offshore nominal CPUE index |
| mod0.8 | As 0.7 but with age composition from all updated |
| mod0.9 | As 0.8 but with selectivity in acoustic N |
| mod0.10 | As 0.9 but with age-error turned off |
| mod0.11 | As 0.10 but with EU only LF for 2015 |
| mod0.12 | As 0.10 but echo-abundance in Far North as an alternative, uses backscatter directly |
| mod0.13 | As 0.12 but Updated Acoustic survey data in N Chile including 2016 biomass estimate |
| **Models 1.x** | **Configuration sensitivities...** |
| mod1.0 | As 0.13 |
| mod1.1 | As 1.0 nominal CPUE removed |
| mod1.2 | As 1.0 discontinued surveys dropped |
| mod1.3 | As 1.0 Use CV according to data workshop |
| mod1.4 | As 1.0 CV according to posteriors |
| mod1.5 | As 1.0 Selectivity in time blocks as Cristian paper |
| mod1.6 | As 1.0 Selectivity in time blocks as in SC02 |
| mod1.7 | As 1.0 Downweight catch-age |
| mod1.8 | As 1.0 Rescale sample size using Francis T1.8 method |
| mod1.9 | As 1.13 Profiles over M |
| mod1.10 | As 1.0 M following Lorenzen age-specific |
| mod1.11 | As 1.0 selectivity change in Chile N acoustic in 2015 and 2016 |
| mod1.12 | As 1.11 and 1.5 |
| mod1.13 | As 1.12 and 1.7 |
| mod1.14 | As 1.11 and 1.3 |
| mod1.15 | As 1.11 but selectivity change in Chile N acoustics in 2014, 2015, and 2016 |
| mod1.16 | As 1.11 but with rescaled Lorenzen curve to have mean of 0.23 |
| mod1.17 | As 1.11 but provisional age-error matrix included |
| mod1.18 | As 1.11 but with time-varying selectivity incremented by one year in the fisheries |
| mod1.19 | As 1.18 but provisional age-error matrix included |
| **Models 2.x** | **Projection Configuration ... to reflect regime and uncertainty in stock productivity** |
| mod2.0 | As 1.18, steepness=0.80, recruitment from 1970-2013 |
| mod2.1 | As 1.18, steepness=0.80, recruitment from 2000-2013 |
| mod2.2 | As 1.18, steepness=0.65, recruitment from 1970-2013 |
| mod2.3 | As 1.18, steepness=0.65, recruitment from 2000-2013 |

Table A8.27. Estimated begin-year numbers at age (Model 1.18), 1970-2016. Green shading reflects relative level.

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1970 | 7,933 | 4,839 | 3,327 | 2,346 | 1,570 | 1,224 | 905 | 800 | 708 | 626 | 551 | 5,287 |
| 1971 | 8,270 | 6,302 | 3,843 | 2,638 | 1,857 | 1,237 | 953 | 692 | 612 | 554 | 492 | 4,584 |
| 1972 | 8,995 | 6,568 | 5,003 | 3,043 | 2,084 | 1,455 | 952 | 713 | 517 | 474 | 432 | 3,959 |
| 1973 | 9,690 | 7,143 | 5,211 | 3,954 | 2,406 | 1,641 | 1,133 | 727 | 543 | 403 | 373 | 3,450 |
| 1974 | 12,268 | 7,690 | 5,659 | 4,098 | 3,116 | 1,886 | 1,266 | 851 | 544 | 419 | 316 | 2,992 |
| 1975 | 17,739 | 9,714 | 6,061 | 4,367 | 3,192 | 2,419 | 1,432 | 925 | 621 | 417 | 324 | 2,559 |
| 1976 | 21,694 | 14,078 | 7,697 | 4,767 | 3,427 | 2,472 | 1,815 | 1,019 | 656 | 470 | 321 | 2,220 |
| 1977 | 21,625 | 17,214 | 11,149 | 6,043 | 3,733 | 2,640 | 1,832 | 1,260 | 705 | 490 | 359 | 1,943 |
| 1978 | 21,504 | 17,018 | 13,376 | 8,171 | 4,580 | 2,842 | 1,944 | 1,265 | 862 | 520 | 373 | 1,753 |
| 1979 | 22,219 | 16,977 | 13,318 | 10,058 | 6,223 | 3,419 | 1,978 | 1,193 | 761 | 603 | 382 | 1,562 |
| 1980 | 24,309 | 17,563 | 13,324 | 10,121 | 7,698 | 4,637 | 2,334 | 1,135 | 642 | 504 | 425 | 1,369 |
| 1981 | 30,352 | 19,197 | 13,755 | 10,047 | 7,745 | 5,786 | 3,245 | 1,429 | 668 | 439 | 364 | 1,294 |
| 1982 | 33,349 | 23,996 | 15,035 | 10,344 | 7,629 | 5,671 | 3,790 | 1,733 | 712 | 417 | 305 | 1,152 |
| 1983 | 28,311 | 26,409 | 18,944 | 11,669 | 7,857 | 5,351 | 3,288 | 1,545 | 618 | 375 | 254 | 886 |
| 1984 | 46,187 | 22,467 | 20,897 | 14,788 | 9,005 | 5,733 | 3,380 | 1,595 | 660 | 339 | 231 | 703 |
| 1985 | 55,581 | 36,637 | 17,721 | 16,122 | 11,096 | 6,340 | 3,376 | 1,362 | 507 | 298 | 174 | 478 |
| 1986 | 29,153 | 44,104 | 28,964 | 13,810 | 12,212 | 7,904 | 3,860 | 1,471 | 479 | 228 | 155 | 340 |
| 1987 | 22,101 | 23,147 | 34,951 | 22,807 | 10,694 | 9,061 | 5,305 | 1,990 | 575 | 218 | 119 | 259 |
| 1988 | 26,023 | 17,538 | 18,277 | 27,214 | 17,336 | 7,845 | 6,033 | 2,676 | 731 | 223 | 96 | 166 |
| 1989 | 25,669 | 20,622 | 13,716 | 14,074 | 20,284 | 12,259 | 5,189 | 3,294 | 1,049 | 239 | 75 | 89 |
| 1990 | 27,928 | 20,339 | 16,135 | 10,520 | 10,594 | 14,368 | 7,893 | 2,986 | 1,587 | 393 | 76 | 52 |
| 1991 | 20,307 | 22,130 | 15,980 | 12,345 | 7,885 | 7,635 | 9,512 | 4,632 | 1,534 | 663 | 125 | 40 |
| 1992 | 20,539 | 16,095 | 17,404 | 12,264 | 9,229 | 5,725 | 5,155 | 5,538 | 2,204 | 613 | 195 | 48 |
| 1993 | 16,573 | 16,279 | 12,647 | 13,306 | 9,117 | 6,558 | 3,819 | 3,147 | 2,659 | 784 | 137 | 54 |
| 1994 | 17,918 | 13,125 | 12,677 | 9,348 | 9,555 | 6,258 | 4,239 | 2,288 | 1,696 | 1,106 | 176 | 43 |
| 1995 | 22,594 | 14,182 | 10,196 | 9,296 | 6,403 | 6,060 | 3,639 | 2,279 | 1,059 | 533 | 209 | 41 |
| 1996 | 25,139 | 17,809 | 10,744 | 6,808 | 5,367 | 3,275 | 2,624 | 1,447 | 819 | 278 | 88 | 41 |
| 1997 | 31,336 | 19,750 | 13,215 | 6,856 | 3,481 | 2,100 | 1,149 | 903 | 473 | 229 | 65 | 30 |
| 1998 | 27,841 | 24,563 | 14,451 | 8,005 | 2,790 | 1,020 | 621 | 408 | 314 | 139 | 61 | 25 |
| 1999 | 31,910 | 21,856 | 18,127 | 9,592 | 3,996 | 1,249 | 469 | 306 | 203 | 144 | 58 | 36 |
| 2000 | 31,838 | 25,186 | 16,663 | 12,685 | 5,803 | 2,243 | 704 | 278 | 184 | 116 | 76 | 50 |
| 2001 | 21,116 | 25,030 | 19,041 | 12,175 | 8,189 | 3,445 | 1,354 | 453 | 182 | 118 | 71 | 77 |
| 2002 | 14,288 | 16,328 | 17,564 | 12,989 | 7,767 | 4,549 | 1,911 | 822 | 284 | 111 | 68 | 85 |
| 2003 | 8,146 | 11,257 | 12,608 | 12,968 | 8,839 | 4,774 | 2,700 | 1,180 | 514 | 167 | 60 | 82 |
| 2004 | 7,854 | 6,385 | 8,516 | 9,195 | 8,951 | 5,619 | 2,890 | 1,679 | 741 | 295 | 87 | 74 |
| 2005 | 5,349 | 6,161 | 4,888 | 6,194 | 6,347 | 5,805 | 3,331 | 1,732 | 1,022 | 406 | 149 | 81 |
| 2006 | 7,107 | 4,195 | 4,678 | 3,513 | 4,312 | 4,265 | 3,441 | 1,967 | 1,040 | 564 | 209 | 118 |
| 2007 | 6,693 | 5,544 | 3,045 | 3,163 | 2,313 | 2,872 | 2,574 | 1,865 | 1,086 | 529 | 275 | 160 |
| 2008 | 6,077 | 5,232 | 4,064 | 1,888 | 1,902 | 1,429 | 1,721 | 1,380 | 881 | 479 | 220 | 181 |
| 2009 | 6,643 | 4,748 | 3,805 | 2,599 | 1,125 | 1,161 | 807 | 918 | 664 | 396 | 200 | 168 |
| 2010 | 8,099 | 5,204 | 3,565 | 2,627 | 1,522 | 638 | 562 | 357 | 358 | 246 | 137 | 127 |
| 2011 | 4,310 | 6,317 | 3,760 | 2,494 | 1,614 | 907 | 362 | 312 | 186 | 152 | 103 | 111 |
| 2012 | 8,480 | 3,381 | 4,527 | 2,540 | 1,782 | 1,140 | 572 | 228 | 202 | 110 | 93 | 131 |
| 2013 | 11,596 | 6,708 | 2,621 | 3,260 | 1,879 | 1,253 | 733 | 369 | 155 | 135 | 75 | 151 |
| 2014 | 11,281 | 9,184 | 5,226 | 1,990 | 2,426 | 1,338 | 847 | 503 | 261 | 108 | 94 | 157 |
| 2015 | 16,013 | 8,934 | 7,162 | 3,973 | 1,480 | 1,743 | 950 | 602 | 361 | 181 | 73 | 169 |
| 2016 | 27,363 | 12,691 | 7,044 | 5,579 | 2,993 | 1,101 | 1,311 | 709 | 444 | 259 | 126 | 168 |

Table A8.28. Estimated total fishing mortality at age (Model 1.18), 1970-2016. 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 | 0.004 | 0.009 | 0.020 | 0.039 | 0.038 | 0.015 | 0.012 | 0.012 | 0.012 |
| 1971 | 0.000 | 0.001 | 0.003 | 0.006 | 0.014 | 0.032 | 0.061 | 0.060 | 0.024 | 0.018 | 0.018 | 0.018 |
| 1972 | 0.001 | 0.001 | 0.005 | 0.005 | 0.009 | 0.020 | 0.040 | 0.043 | 0.020 | 0.011 | 0.011 | 0.011 |
| 1973 | 0.001 | 0.003 | 0.010 | 0.008 | 0.013 | 0.029 | 0.056 | 0.060 | 0.029 | 0.015 | 0.015 | 0.015 |
| 1974 | 0.003 | 0.008 | 0.029 | 0.020 | 0.023 | 0.045 | 0.085 | 0.085 | 0.037 | 0.027 | 0.027 | 0.027 |
| 1975 | 0.001 | 0.003 | 0.010 | 0.012 | 0.026 | 0.057 | 0.111 | 0.114 | 0.049 | 0.032 | 0.032 | 0.032 |
| 1976 | 0.001 | 0.003 | 0.012 | 0.015 | 0.031 | 0.070 | 0.135 | 0.139 | 0.060 | 0.038 | 0.038 | 0.038 |
| 1977 | 0.010 | 0.022 | 0.081 | 0.047 | 0.043 | 0.076 | 0.141 | 0.150 | 0.073 | 0.042 | 0.042 | 0.042 |
| 1978 | 0.006 | 0.015 | 0.055 | 0.042 | 0.062 | 0.133 | 0.259 | 0.278 | 0.127 | 0.078 | 0.078 | 0.078 |
| 1979 | 0.005 | 0.012 | 0.045 | 0.037 | 0.064 | 0.152 | 0.325 | 0.389 | 0.182 | 0.121 | 0.121 | 0.121 |
| 1980 | 0.006 | 0.014 | 0.052 | 0.038 | 0.056 | 0.127 | 0.261 | 0.301 | 0.150 | 0.096 | 0.096 | 0.096 |
| 1981 | 0.005 | 0.014 | 0.055 | 0.045 | 0.082 | 0.193 | 0.398 | 0.467 | 0.239 | 0.134 | 0.134 | 0.134 |
| 1982 | 0.003 | 0.006 | 0.023 | 0.045 | 0.125 | 0.315 | 0.668 | 0.801 | 0.411 | 0.268 | 0.268 | 0.268 |
| 1983 | 0.001 | 0.004 | 0.018 | 0.029 | 0.085 | 0.229 | 0.493 | 0.621 | 0.369 | 0.253 | 0.253 | 0.253 |
| 1984 | 0.002 | 0.007 | 0.029 | 0.057 | 0.121 | 0.299 | 0.679 | 0.917 | 0.564 | 0.440 | 0.440 | 0.440 |
| 1985 | 0.001 | 0.005 | 0.019 | 0.048 | 0.109 | 0.266 | 0.601 | 0.815 | 0.566 | 0.421 | 0.421 | 0.421 |
| 1986 | 0.001 | 0.003 | 0.009 | 0.026 | 0.068 | 0.169 | 0.432 | 0.710 | 0.559 | 0.419 | 0.419 | 0.419 |
| 1987 | 0.001 | 0.006 | 0.020 | 0.044 | 0.080 | 0.177 | 0.454 | 0.771 | 0.719 | 0.594 | 0.594 | 0.594 |
| 1988 | 0.003 | 0.016 | 0.031 | 0.064 | 0.117 | 0.183 | 0.375 | 0.707 | 0.890 | 0.853 | 0.853 | 0.853 |
| 1989 | 0.003 | 0.015 | 0.035 | 0.054 | 0.115 | 0.210 | 0.322 | 0.500 | 0.751 | 0.918 | 0.918 | 0.918 |
| 1990 | 0.003 | 0.011 | 0.038 | 0.058 | 0.098 | 0.182 | 0.303 | 0.436 | 0.642 | 0.920 | 0.920 | 0.920 |
| 1991 | 0.002 | 0.010 | 0.035 | 0.061 | 0.090 | 0.163 | 0.311 | 0.513 | 0.687 | 0.996 | 0.996 | 0.996 |
| 1992 | 0.002 | 0.011 | 0.038 | 0.066 | 0.112 | 0.175 | 0.263 | 0.504 | 0.804 | 1.267 | 1.267 | 1.267 |
| 1993 | 0.003 | 0.020 | 0.072 | 0.101 | 0.146 | 0.206 | 0.282 | 0.389 | 0.647 | 1.265 | 1.265 | 1.265 |
| 1994 | 0.004 | 0.023 | 0.080 | 0.148 | 0.225 | 0.312 | 0.391 | 0.540 | 0.927 | 1.438 | 1.438 | 1.438 |
| 1995 | 0.008 | 0.048 | 0.174 | 0.319 | 0.440 | 0.607 | 0.692 | 0.793 | 1.109 | 1.571 | 1.571 | 1.571 |
| 1996 | 0.011 | 0.068 | 0.219 | 0.441 | 0.708 | 0.817 | 0.837 | 0.888 | 1.043 | 1.217 | 1.217 | 1.217 |
| 1997 | 0.014 | 0.082 | 0.271 | 0.669 | 0.998 | 0.988 | 0.805 | 0.825 | 0.992 | 1.102 | 1.102 | 1.102 |
| 1998 | 0.012 | 0.074 | 0.180 | 0.465 | 0.574 | 0.548 | 0.477 | 0.470 | 0.553 | 0.642 | 0.642 | 0.642 |
| 1999 | 0.007 | 0.041 | 0.127 | 0.273 | 0.348 | 0.343 | 0.293 | 0.281 | 0.328 | 0.407 | 0.407 | 0.407 |
| 2000 | 0.011 | 0.050 | 0.084 | 0.208 | 0.291 | 0.275 | 0.212 | 0.190 | 0.217 | 0.262 | 0.262 | 0.262 |
| 2001 | 0.027 | 0.124 | 0.152 | 0.219 | 0.358 | 0.359 | 0.269 | 0.235 | 0.267 | 0.323 | 0.323 | 0.323 |
| 2002 | 0.008 | 0.029 | 0.073 | 0.155 | 0.257 | 0.292 | 0.252 | 0.240 | 0.299 | 0.389 | 0.389 | 0.389 |
| 2003 | 0.014 | 0.049 | 0.086 | 0.141 | 0.223 | 0.272 | 0.245 | 0.236 | 0.324 | 0.428 | 0.428 | 0.428 |
| 2004 | 0.013 | 0.037 | 0.088 | 0.141 | 0.203 | 0.293 | 0.282 | 0.266 | 0.372 | 0.457 | 0.457 | 0.457 |
| 2005 | 0.013 | 0.045 | 0.100 | 0.132 | 0.168 | 0.293 | 0.297 | 0.280 | 0.366 | 0.433 | 0.433 | 0.433 |
| 2006 | 0.018 | 0.090 | 0.162 | 0.188 | 0.176 | 0.275 | 0.383 | 0.364 | 0.446 | 0.486 | 0.486 | 0.486 |
| 2007 | 0.016 | 0.081 | 0.248 | 0.278 | 0.252 | 0.282 | 0.394 | 0.520 | 0.587 | 0.645 | 0.645 | 0.645 |
| 2008 | 0.017 | 0.089 | 0.217 | 0.288 | 0.264 | 0.341 | 0.399 | 0.502 | 0.569 | 0.642 | 0.642 | 0.642 |
| 2009 | 0.014 | 0.057 | 0.140 | 0.305 | 0.337 | 0.496 | 0.585 | 0.712 | 0.761 | 0.832 | 0.832 | 0.832 |
| 2010 | 0.018 | 0.095 | 0.127 | 0.257 | 0.288 | 0.337 | 0.358 | 0.424 | 0.627 | 0.639 | 0.639 | 0.639 |
| 2011 | 0.013 | 0.103 | 0.162 | 0.106 | 0.118 | 0.231 | 0.230 | 0.203 | 0.292 | 0.263 | 0.263 | 0.263 |
| 2012 | 0.004 | 0.025 | 0.098 | 0.071 | 0.122 | 0.212 | 0.208 | 0.157 | 0.171 | 0.160 | 0.160 | 0.160 |
| 2013 | 0.003 | 0.020 | 0.045 | 0.066 | 0.109 | 0.162 | 0.146 | 0.116 | 0.130 | 0.136 | 0.136 | 0.136 |
| 2014 | 0.003 | 0.019 | 0.044 | 0.066 | 0.100 | 0.112 | 0.111 | 0.101 | 0.133 | 0.164 | 0.164 | 0.164 |
| 2015 | 0.002 | 0.008 | 0.020 | 0.053 | 0.066 | 0.055 | 0.063 | 0.076 | 0.101 | 0.133 | 0.133 | 0.133 |
| 2016 | 0.001 | 0.005 | 0.014 | 0.042 | 0.067 | 0.068 | 0.066 | 0.078 | 0.107 | 0.144 | 0.144 | 0.144 |

Table A8.29. Spawning biomass of jack mackerel obtained in last four SPRFMO scientific Committee (SC) meetings.

| | SC01 | SC02 | SC03 | SC04 |
|---|---|---|---|---|
| 1971 | 8,761 | 6,629 | 10,082 | 9770 |
| 1971 | 8,112 | 6,303 | 9,164 | 8872 |
| 1972 | 7,818 | 6,105 | 8,527 | 8289 |
| 1973 | 7,726 | 5,958 | 8,042 | 7911 |
| 1974 | 7,676 | 5,861 | 7,673 | 7633 |
| 1975 | 7,763 | 5,852 | 7,446 | 7511 |
| 1976 | 8,141 | 6,039 | 7,454 | 7638 |
| 1977 | 8,810 | 6,558 | 7,808 | 8027 |
| 1978 | 9,551 | 7,124 | 8,224 | 8445 |
| 1979 | 10,189 | 7,590 | 8,553 | 8810 |
| 1980 | 10,854 | 8,256 | 9,085 | 9349 |
| 1981 | 11,171 | 8,505 | 9,213 | 9561 |
| 1982 | 10,806 | 8,110 | 8,679 | 9137 |
| 1983 | 11,092 | 8,494 | 8,926 | 9487 |
| 1984 | 11,122 | 8,629 | 8,942 | 9653 |
| 1985 | 11,554 | 9,338 | 9,557 | 10297 |
| 1986 | 13,159 | 11,352 | 11,531 | 11890 |
| 1987 | 14,919 | 13,281 | 13,459 | 13371 |
| 1988 | 15,496 | 13,714 | 13,895 | 13801 |
| 1989 | 15,050 | 13,080 | 13,256 | 13389 |
| 1990 | 14,228 | 12,204 | 12,371 | 12701 |
| 1991 | 13,098 | 11,029 | 11,197 | 11792 |
| 1992 | 11,909 | 9,854 | 10,018 | 10772 |
| 1993 | 10,802 | 8,939 | 9,082 | 9800 |
| 1994 | 9,271 | 7,516 | 7,634 | 8165 |
| 1995 | 7,154 | 5,445 | 5,532 | 5901 |
| 1996 | 5,819 | 3,817 | 3,862 | 4174 |
| 1997 | 4,950 | 2,986 | 2,965 | 3254 |
| 1998 | 4,985 | 3,152 | 3,074 | 3539 |
| 1999 | 5,668 | 3,928 | 3,795 | 4475 |
| 2000 | 6,671 | 5,008 | 4,834 | 5616 |
| 2001 | 7,481 | 5,883 | 5,690 | 6368 |
| 2002 | 8,083 | 6,692 | 6,544 | 7010 |
| 2003 | 8,201 | 6,947 | 6,848 | 7274 |
| 2004 | 7,641 | 6,560 | 6,475 | 6908 |
| 2005 | 6,708 | 5,760 | 5,676 | 6159 |
| 2006 | 5,486 | 4,679 | 4,595 | 5102 |
| 2007 | 4,119 | 3,428 | 3,324 | 3846 |
| 2008 | 3,067 | 2,543 | 2,382 | 2890 |
| 2009 | 2,130 | 1,849 | 1,598 | 2070 |
| 2010 | 1,709 | 1,648 | 1,291 | 1775 |
| 2011 | 1,855 | 1,865 | 1,382 | 1868 |
| 2012 | 2,304 | 2,126 | 1,552 | 2065 |
| 2013 | 3,085 | 2,402 | 1,814 | 2308 |
| 2014 | | 2,767 | 2,222 | 2667 |
| 2015 | | | 2,720 | 3273 |
| 2016 | | | | 4116 |

Table A8.30. Summary of results for model 1.18. Note that MSY values are a function of time-varying selectivity and average weight.

| Year | Landings ('000 t) | SSB ('000 t) | Recruitment (age 1, millions) | Fishing mortality (Mean over ages 1-12) | Fmsy | SSBmsy ('000 t) |
|---|---|---|---|---|---|---|
| 1970 | 117 | 9770 | 7933 | 0.014 | 0.228 | 4551 |
| 1971 | 168 | 8872 | 8270 | 0.021 | 0.230 | 4480 |
| 1972 | 111 | 8289 | 8995 | 0.015 | 0.236 | 4124 |
| 1973 | 164 | 7911 | 9690 | 0.021 | 0.236 | 3877 |
| 1974 | 323 | 7633 | 12268 | 0.035 | 0.206 | 3953 |
| 1975 | 299 | 7511 | 17739 | 0.040 | 0.232 | 4310 |
| 1976 | 396 | 7638 | 21694 | 0.048 | 0.234 | 4291 |
| 1977 | 848 | 8027 | 21625 | 0.064 | 0.182 | 4138 |
| 1978 | 1025 | 8445 | 21504 | 0.101 | 0.228 | 3980 |
| 1979 | 1302 | 8810 | 22219 | 0.131 | 0.219 | 4659 |
| 1980 | 1316 | 9349 | 24309 | 0.108 | 0.214 | 4504 |
| 1981 | 1945 | 9561 | 30352 | 0.158 | 0.230 | 4416 |
| 1982 | 2372 | 9137 | 33349 | 0.267 | 0.256 | 4598 |
| 1983 | 1870 | 9487 | 28311 | 0.217 | 0.207 | 5608 |
| 1984 | 2687 | 9653 | 46187 | 0.333 | 0.221 | 5477 |
| 1985 | 2371 | 10297 | 55581 | 0.308 | 0.216 | 5691 |
| 1986 | 2073 | 11890 | 29153 | 0.269 | 0.176 | 6907 |
| 1987 | 2680 | 13371 | 22101 | 0.338 | 0.185 | 6849 |
| 1988 | 3246 | 13801 | 26023 | 0.412 | 0.250 | 6037 |
| 1989 | 3582 | 13389 | 25669 | 0.397 | 0.278 | 5836 |
| 1990 | 3715 | 12701 | 27928 | 0.378 | 0.292 | 5791 |
| 1991 | 3778 | 11792 | 20307 | 0.405 | 0.360 | 5324 |
| 1992 | 3362 | 10772 | 20539 | 0.481 | 0.315 | 5998 |
| 1993 | 3370 | 9800 | 16573 | 0.472 | 0.254 | 6311 |
| 1994 | 4275 | 8165 | 17918 | 0.580 | 0.231 | 6336 |
| 1995 | 4955 | 5901 | 22594 | 0.742 | 0.199 | 6001 |
| 1996 | 4379 | 4174 | 25139 | 0.724 | 0.167 | 5979 |
| 1997 | 3597 | 3254 | 31336 | 0.746 | 0.156 | 5817 |
| 1998 | 2026 | 3539 | 27841 | 0.440 | 0.146 | 6009 |
| 1999 | 1423 | 4475 | 31910 | 0.272 | 0.141 | 6230 |
| 2000 | 1540 | 5616 | 31838 | 0.194 | 0.149 | 5653 |
| 2001 | 2528 | 6368 | 21116 | 0.248 | 0.144 | 5646 |
| 2002 | 1750 | 7010 | 14288 | 0.231 | 0.153 | 6253 |
| 2003 | 1797 | 7274 | 8146 | 0.239 | 0.157 | 6234 |
| 2004 | 1934 | 6908 | 7854 | 0.256 | 0.168 | 6024 |
| 2005 | 1755 | 6159 | 5349 | 0.250 | 0.175 | 5783 |
| 2006 | 2020 | 5102 | 7107 | 0.297 | 0.184 | 5276 |
| 2007 | 1997 | 3846 | 6693 | 0.383 | 0.193 | 5104 |
| 2008 | 1473 | 2890 | 6077 | 0.384 | 0.183 | 5315 |
| 2009 | 1283 | 2070 | 6643 | 0.492 | 0.187 | 5615 |
| 2010 | 727 | 1775 | 8099 | 0.371 | 0.154 | 6354 |
| 2011 | 635 | 1868 | 4310 | 0.187 | 0.180 | 4815 |
| 2012 | 455 | 2065 | 8480 | 0.129 | 0.189 | 4597 |
| 2013 | 353 | 2308 | 11596 | 0.100 | 0.188 | 4782 |
| 2014 | 411 | 2667 | 11281 | 0.099 | 0.179 | 5368 |
| 2015 | 394 | 3273 | 16013 | 0.070 | 0.218 | 4918 |
| 2016 | 360 | 4116 | 27363 | 0.073 | 0.191 | 5795 |

## Figures

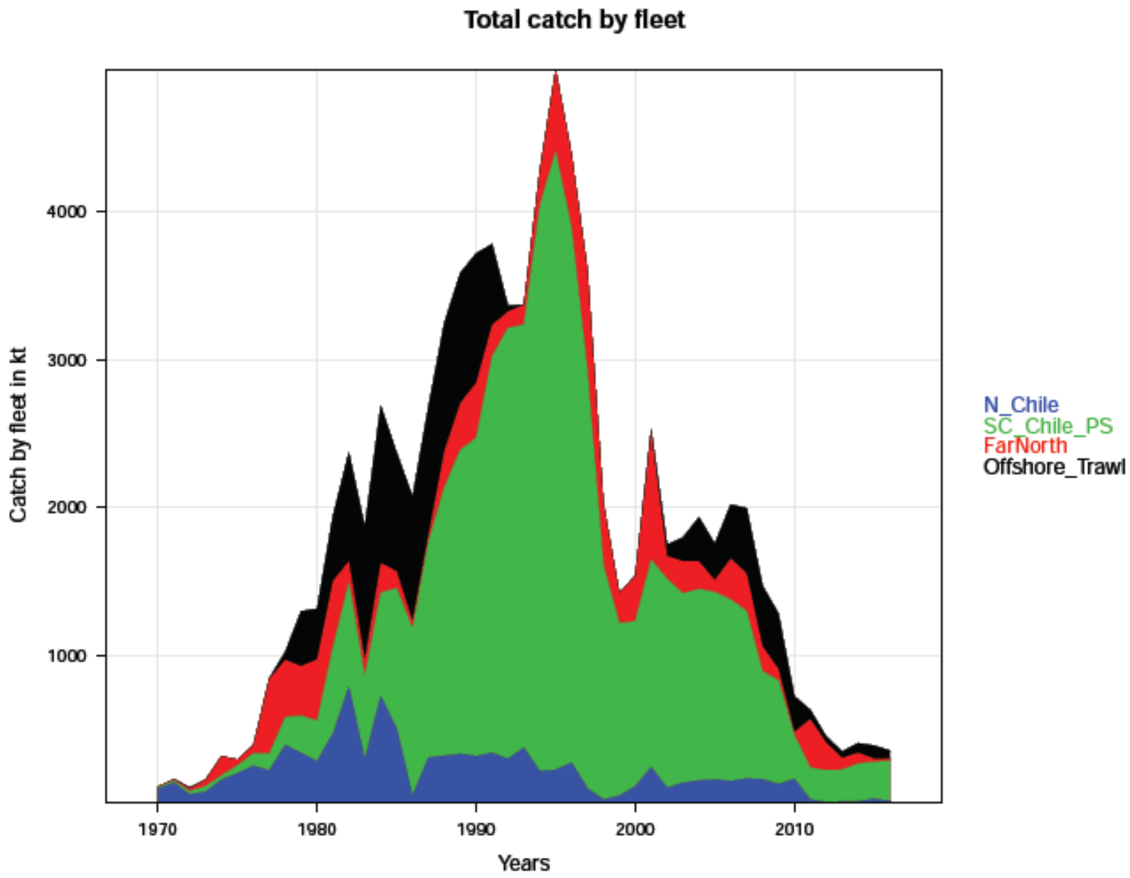



Figure A8.1. Catch of jack mackerel by fleet. Green is the SC Chilean fleet, black is the offshore trawl fleet, red is the far-north fleet, and blue in the northern Chilean fleet.

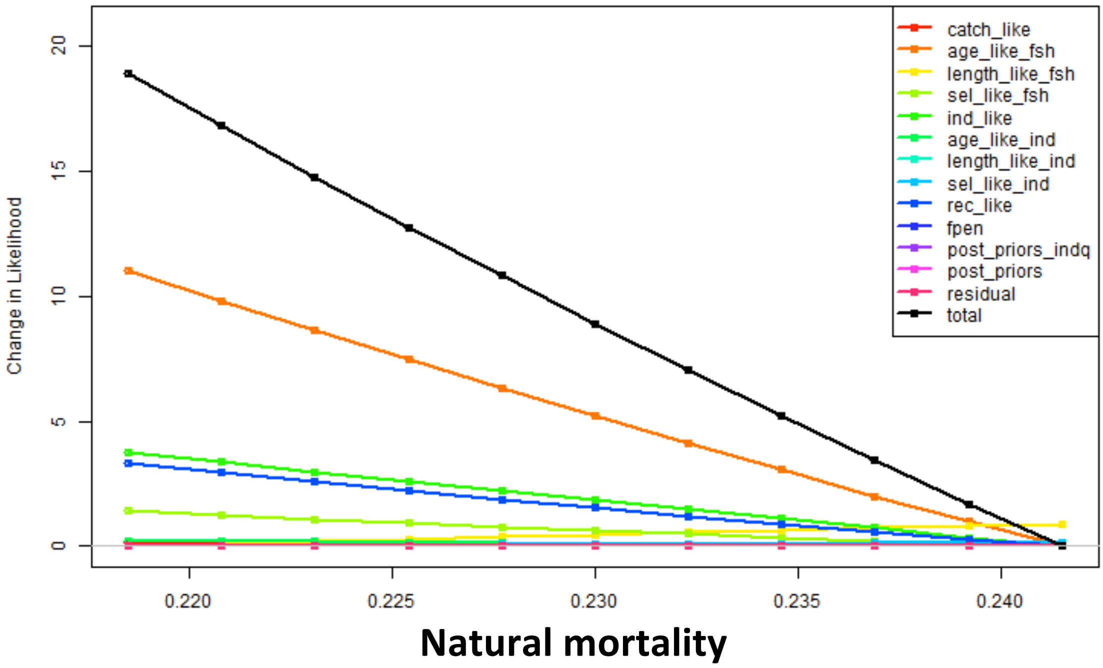



Figure A8.2. Exploratory profile likelihood of alternative fixed values of natural mortality assumed for jack mackerel. The vertical scale is the difference (in log-likelihood units) from the minimum (where the minimum represents the best model fit).

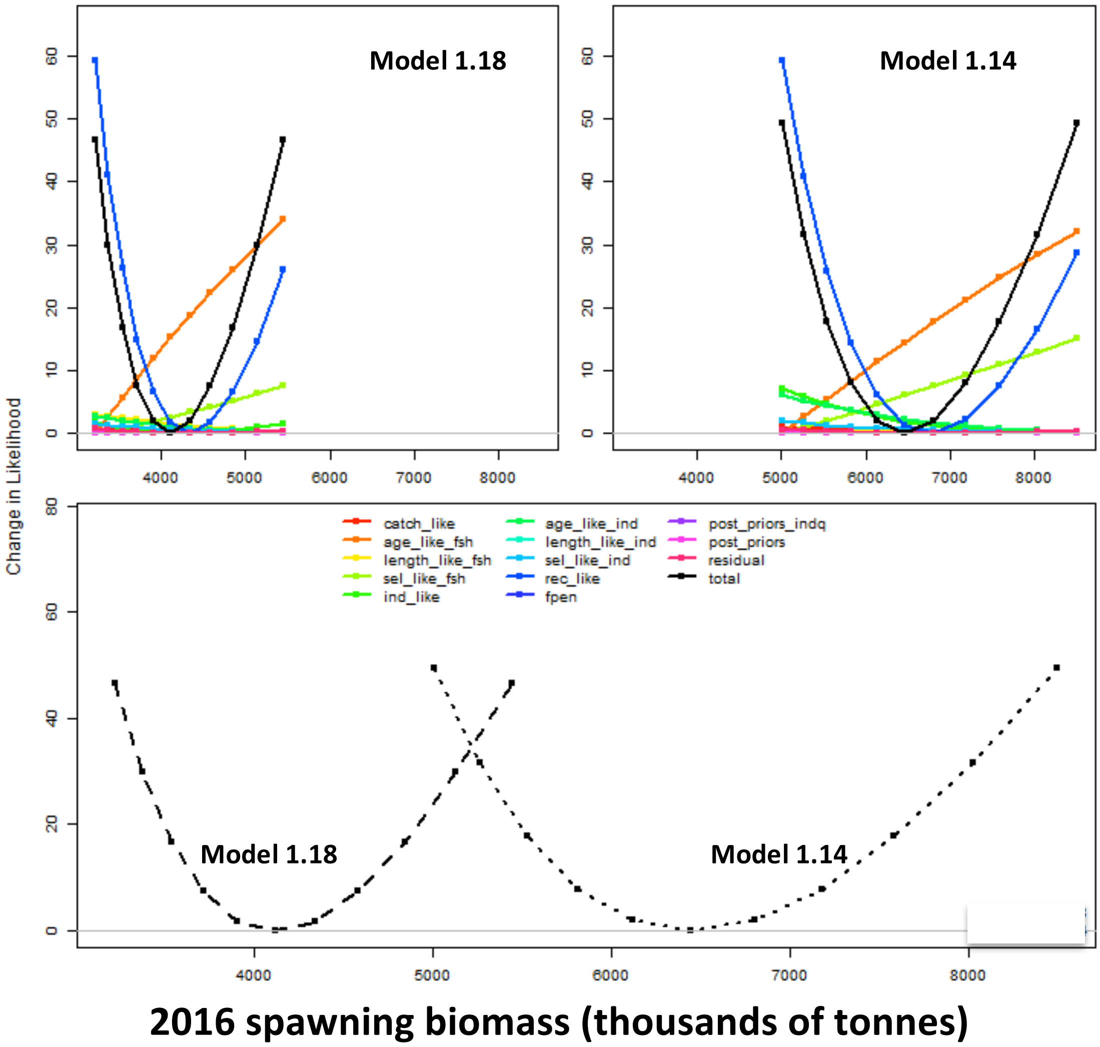



Figure A8.3. Change in likelihood components (top) and totals (bottom) when profiling over fixed mean recruitment values for two model alternatives (1.14 and 1.18). The contrast is manifested in the 2016 spawning biomass (horizontal scale).

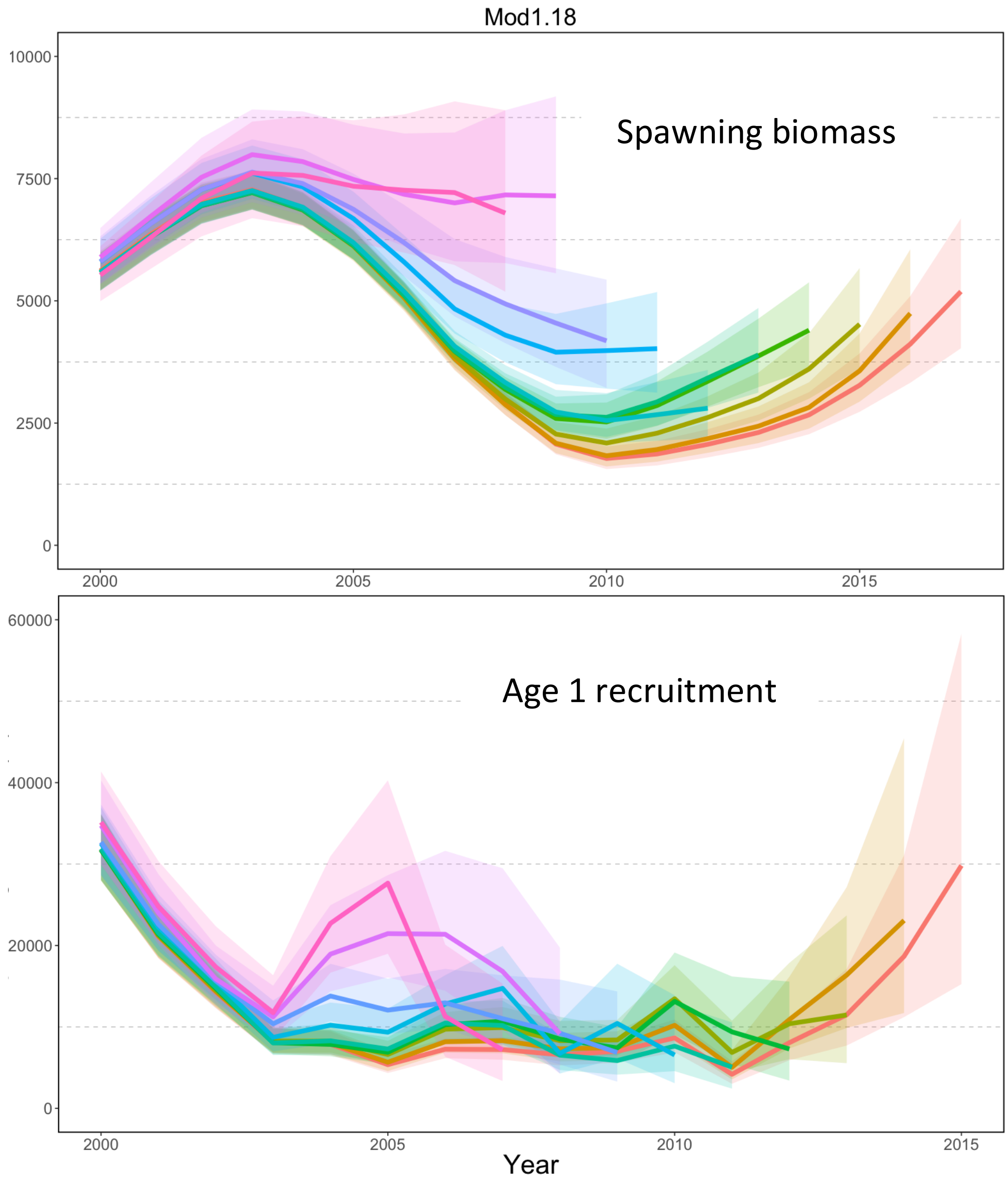



Figure A8.4. Model retrospective of spawning biomass (top) and recruitment (bottom) from 10 separate model runs.


Figure A8.5. Mean weights-at-age (kg) over time used for all data types in the JJM models. Different lines represent ages 1 to 12.

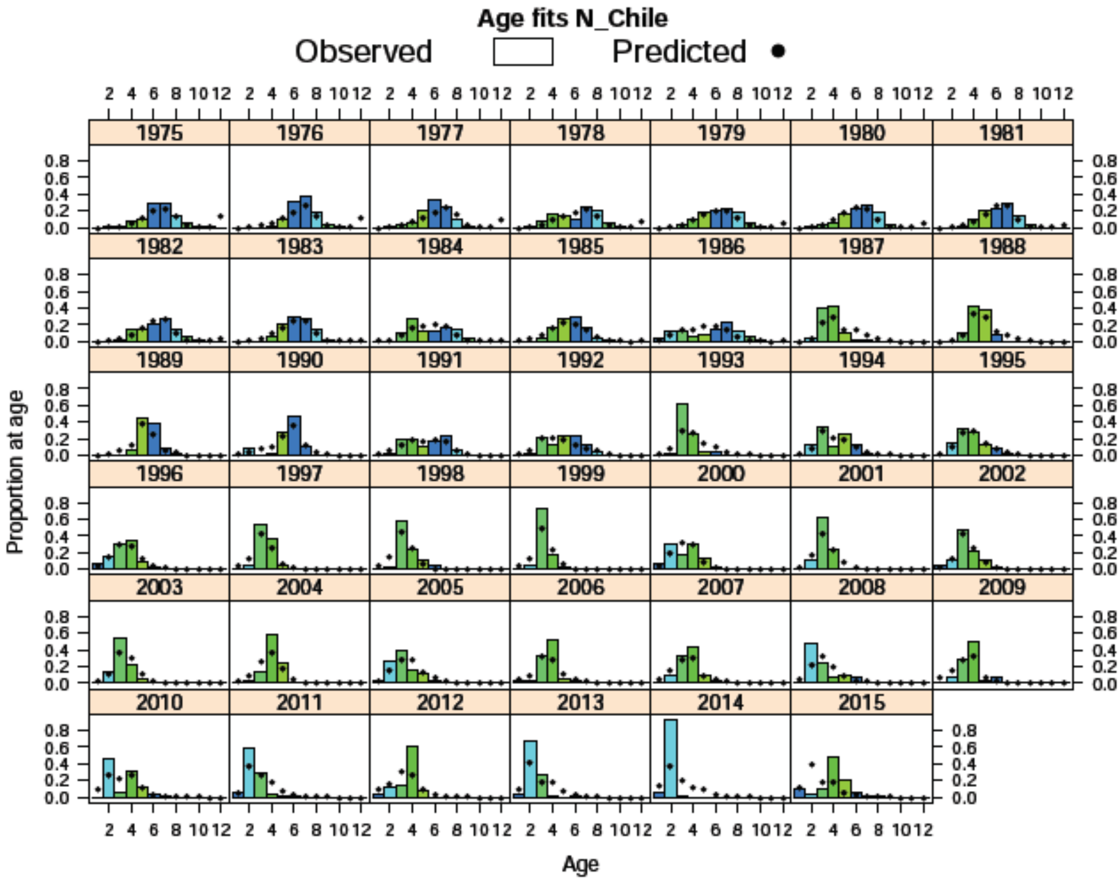



Figure A8.6. Model 1.18 fit to the age compositions for the **Chilean northern zone fishery (Fleet 1)**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

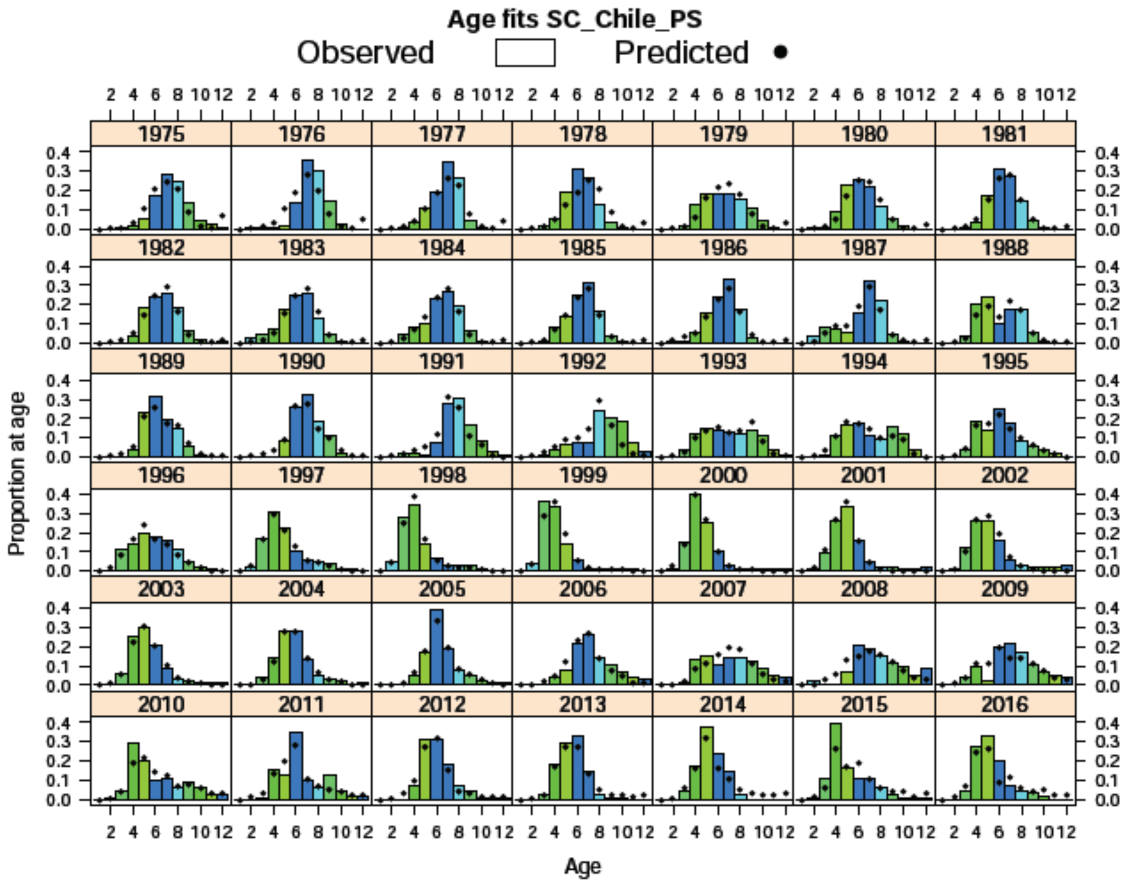



Figure A8.7. Model 1.18 fit to the age compositions for the **South-Central Chilean purse seine** fishery (Fleet 2). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

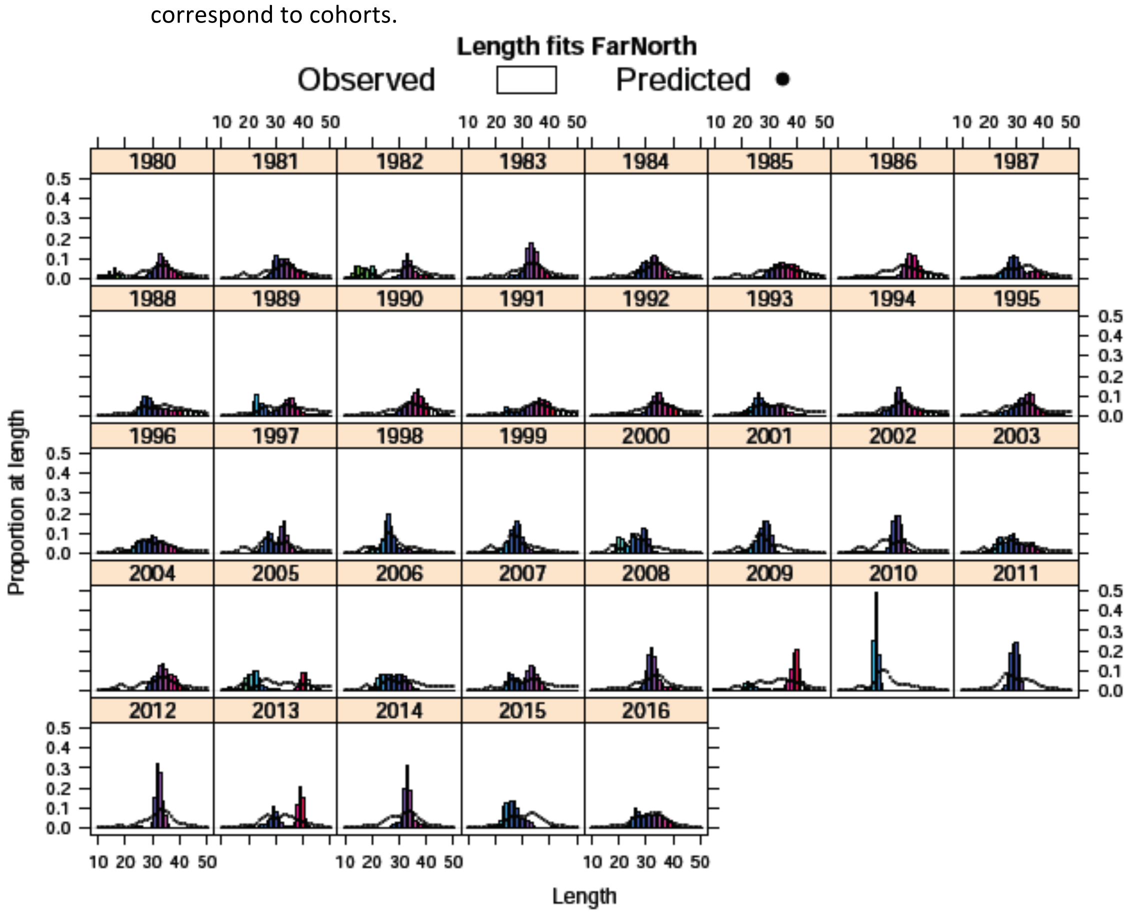



Figure A8.8. Model 1.18 fit to the length compositions for the far north fishery (Fleet 3). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

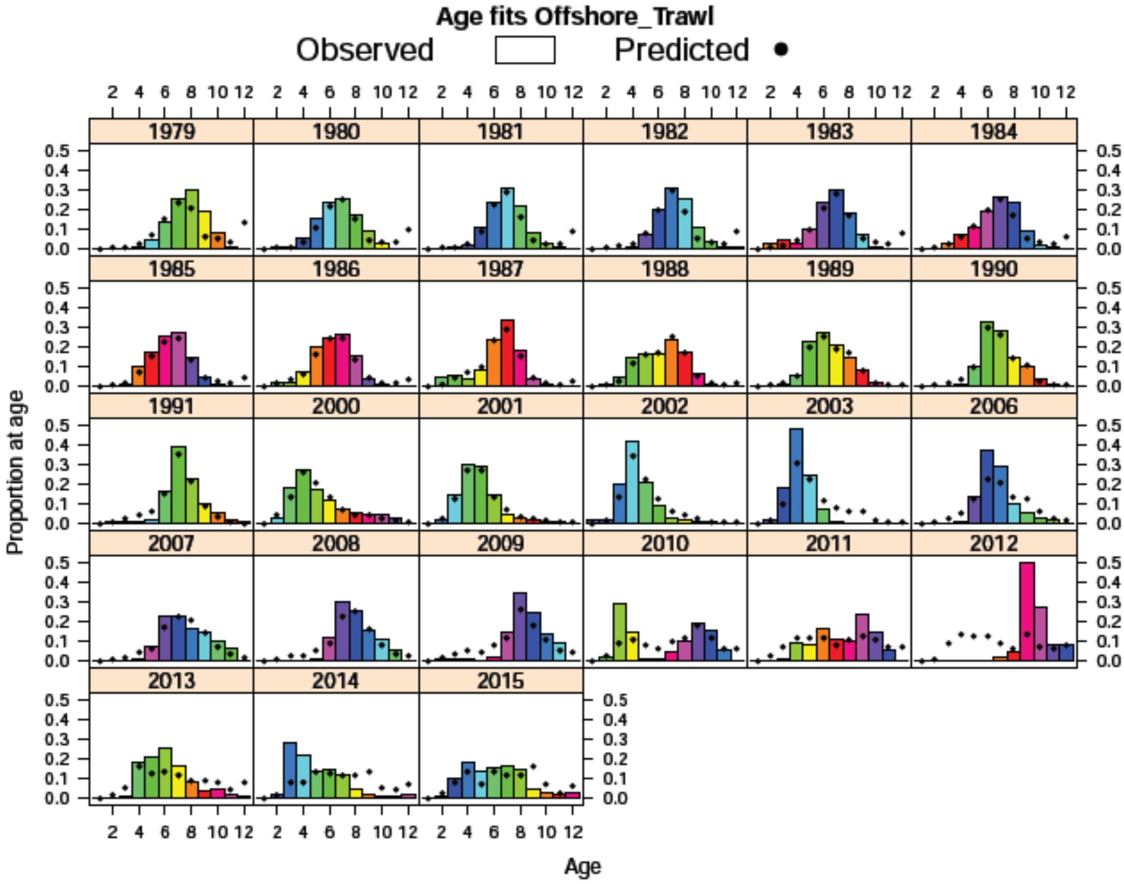
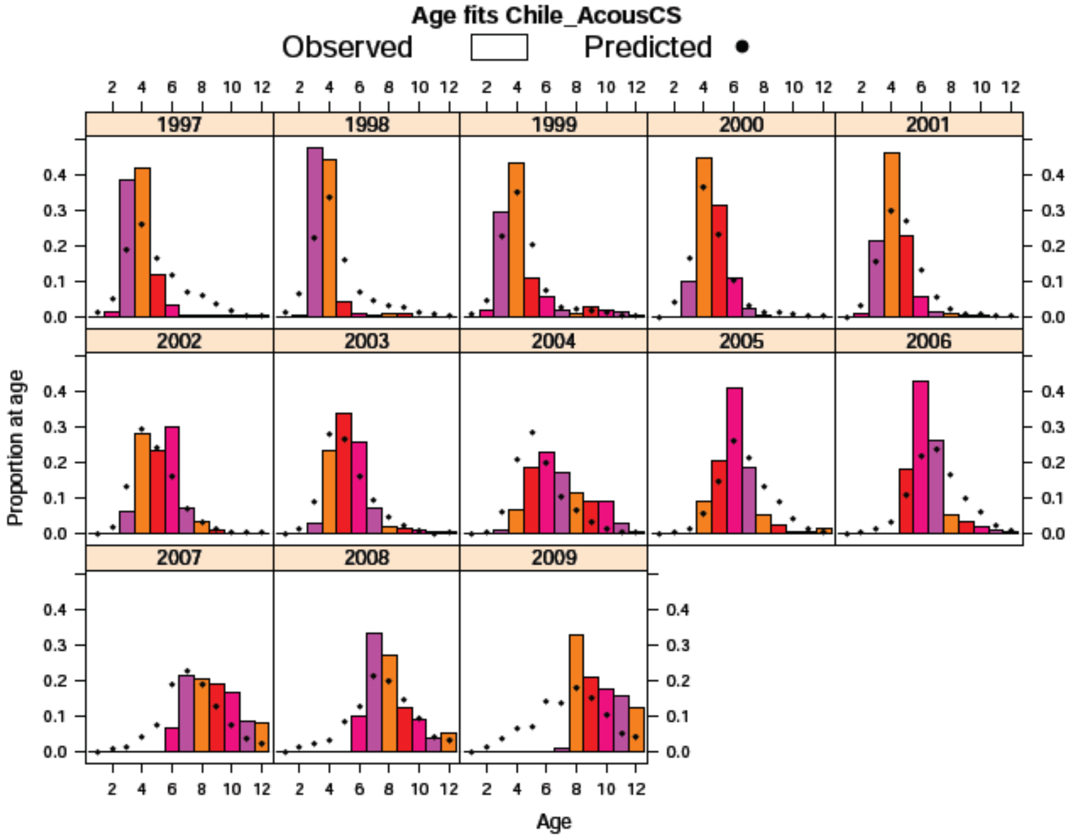



Figure A8.9. Model 1.18 fit to the age compositions for the **offshore trawl** fishery (Fleet 4). Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.



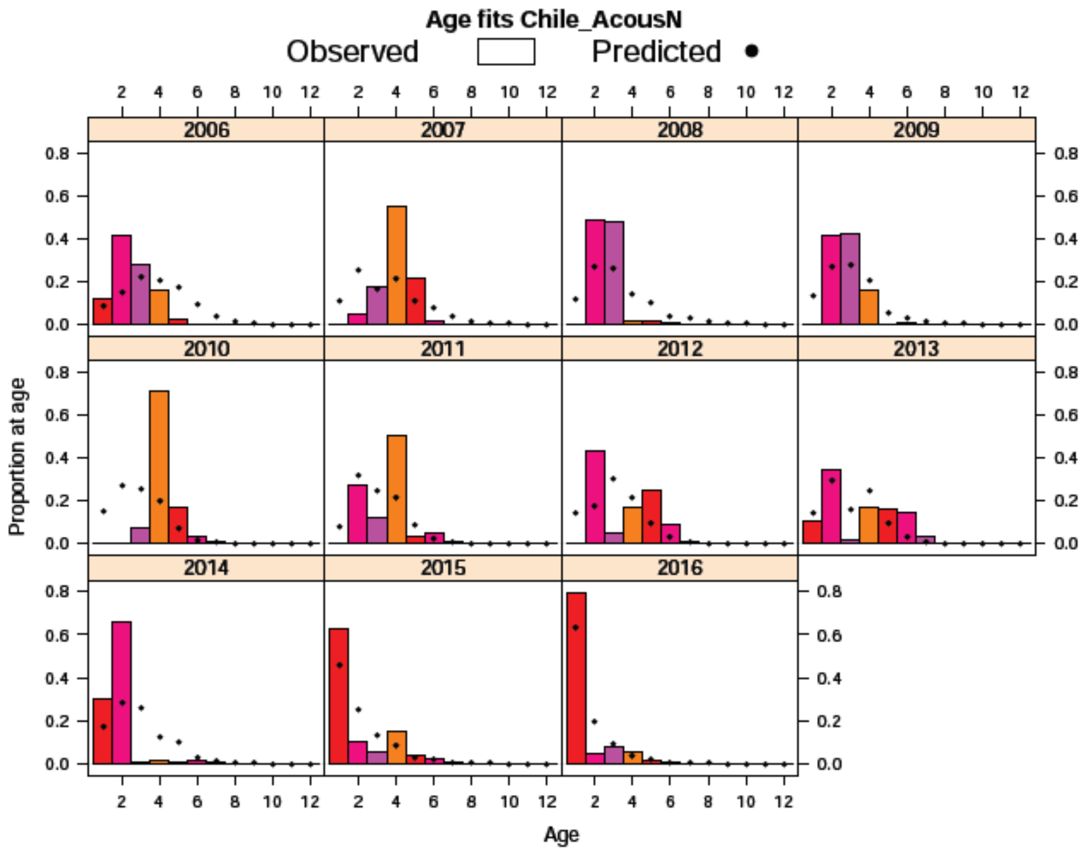




Figure A8.10. Model 1.18 fit to the age compositions for the **S-Central Acoustic survey (top) and N Chilean acoustic survey (bottom)**. Bars represent the observed data and dots represent the model fit and color codes correspond to cohorts.

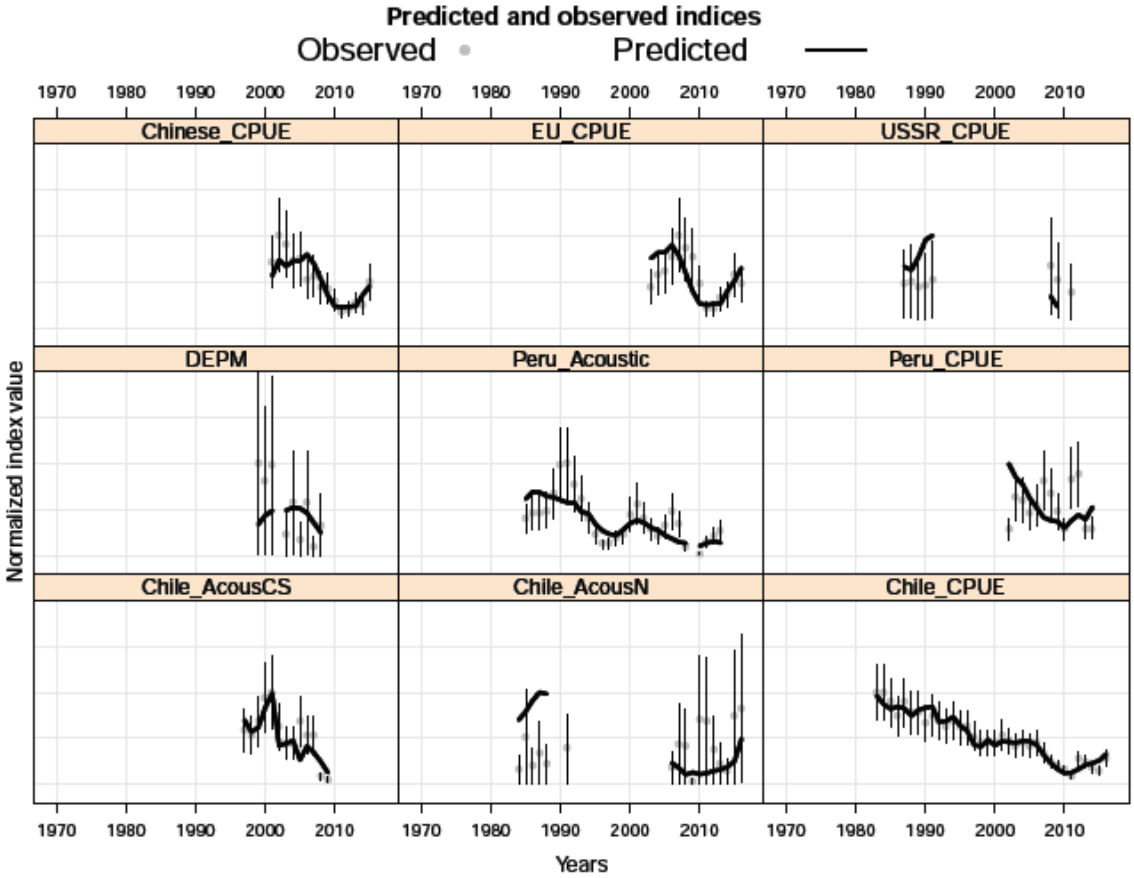



Figure A8.11. Model 1.18 fit to different indices. Vertical bars represent 2 standard deviations around the observations.

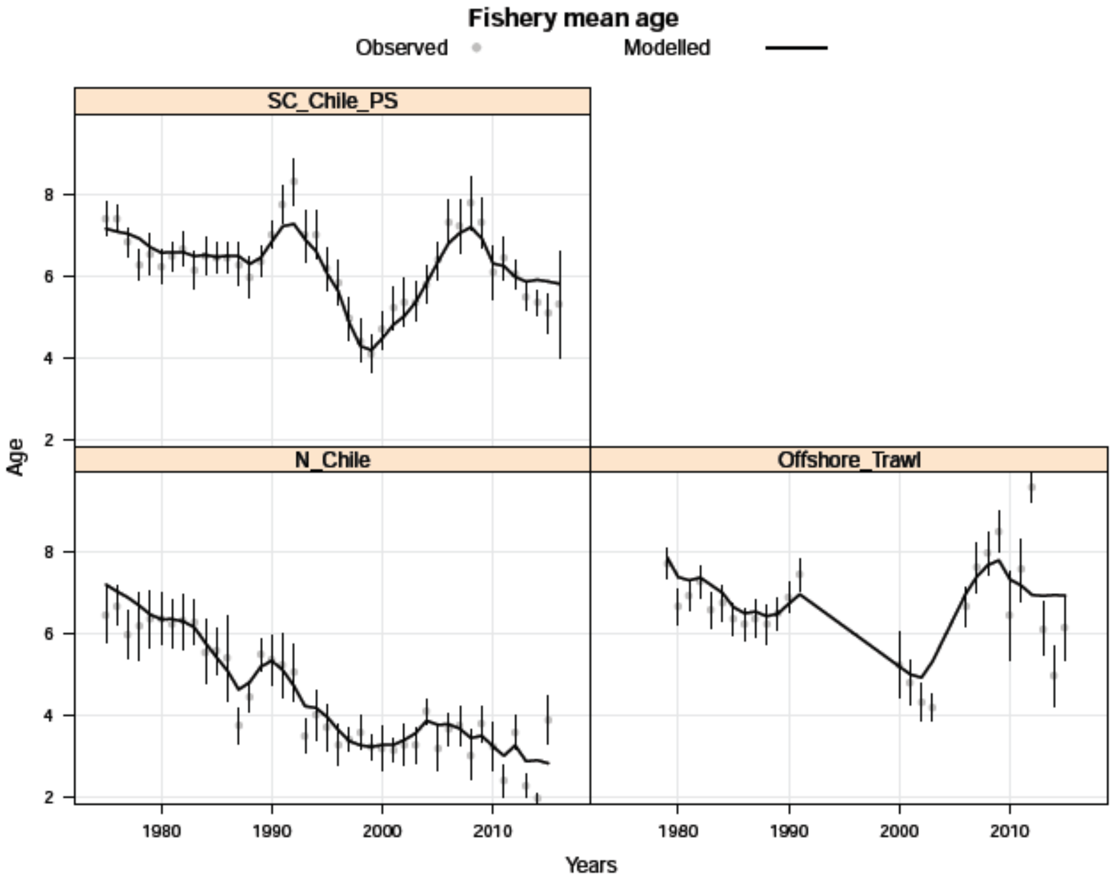



Figure A8.12. Mean age by year and fishery. Line represents the model 1.18 predictions and dots observed values with implied input error bars.

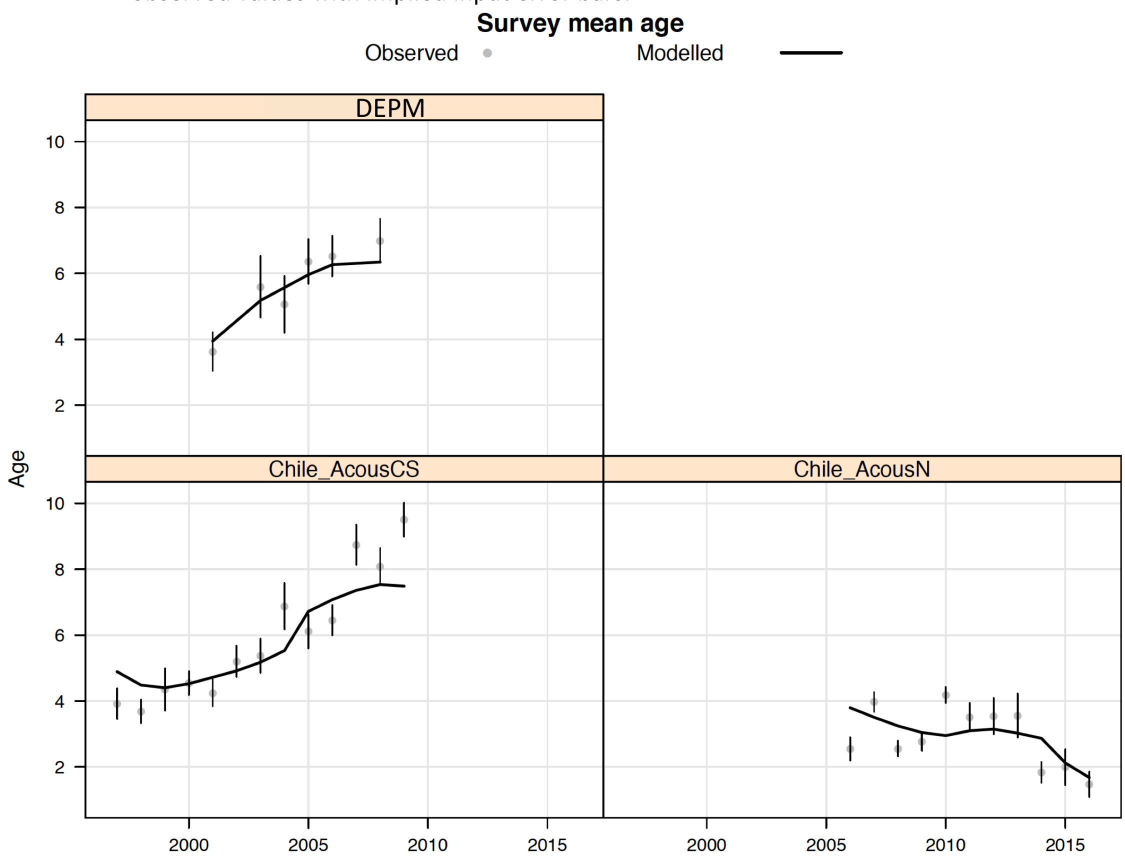



Figure A8.13. Mean age by year and survey. Line represents the model 1.18 predictions and dots observed values with implied input error bars.

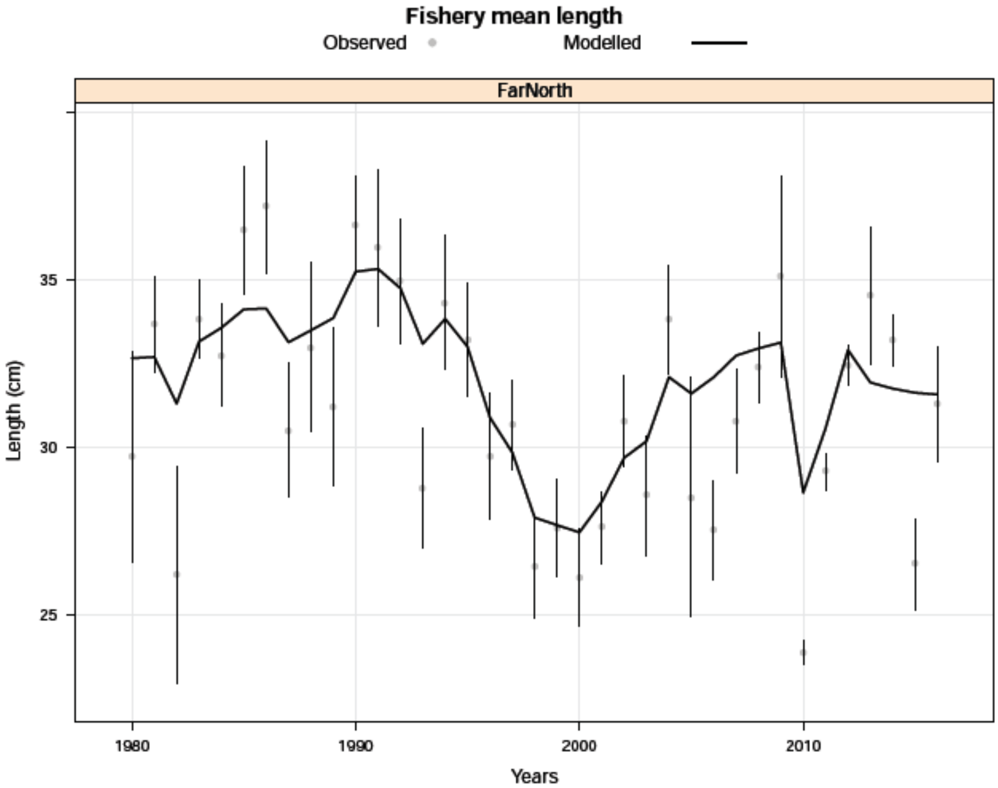



Figure A8.14. Mean length by year in fleet 3 (Far North). Line represents the the model 1.18 predictions and dots observed values with implied input error bars.

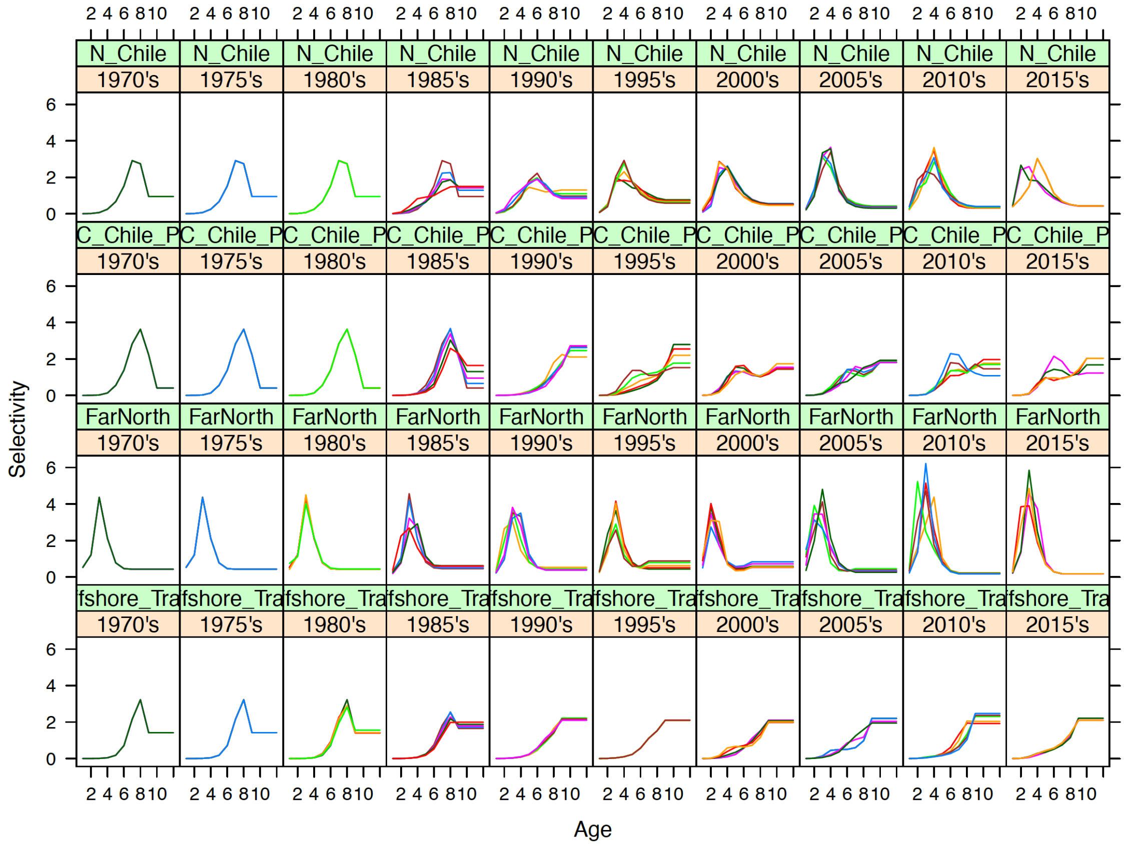



Figure A8.15. Estimates of selectivity by fishery over time for Model 1.18. Each cell represents a 5-year period).

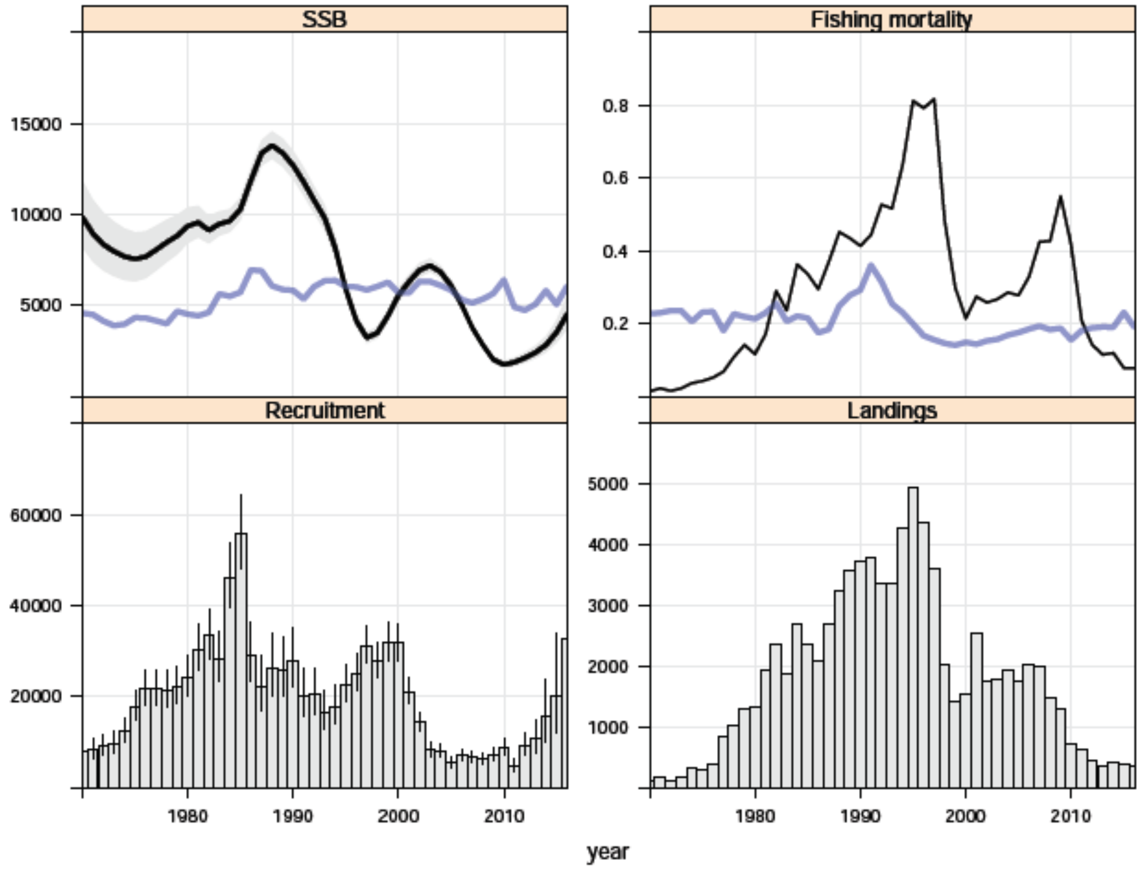



Figure A8.16. Model 1.18—single-stock hypothesis—summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left) total fishing mortality (top right) and total catch (kt; bottom right). Blue lines represent dynamic estimates of $B_{msy}$ (upper left) and $F_{msy}$ (upper right).

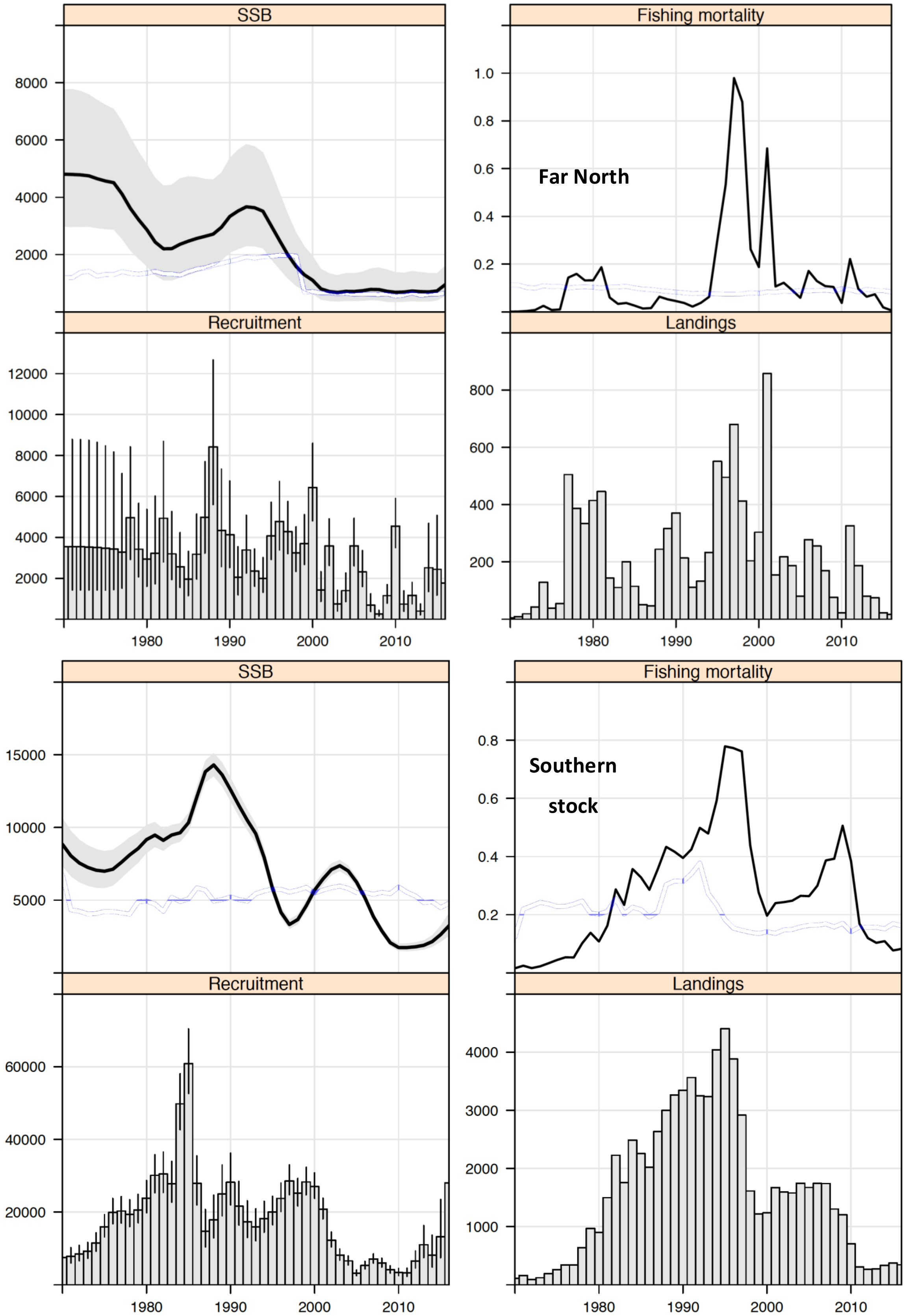



Figure A8.17. Two-stock hypothesis summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left) total fishing mortality (top right) and total catch (kt; bottom right) for Models 1.6 (for the "Far North" stock, top set) and 1.18 (for the "Southern" stock.

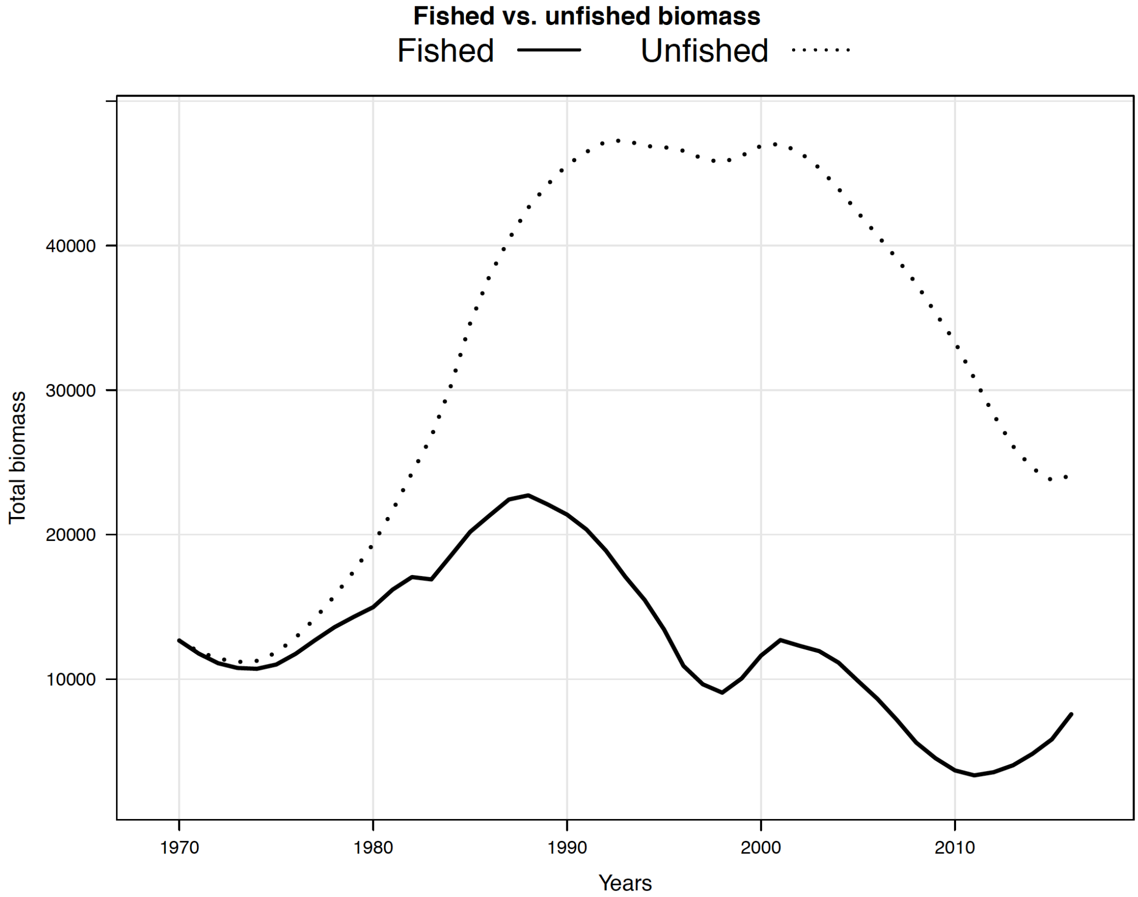



Figure A8.18. Model 1.18 results the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place, 1970-2016.

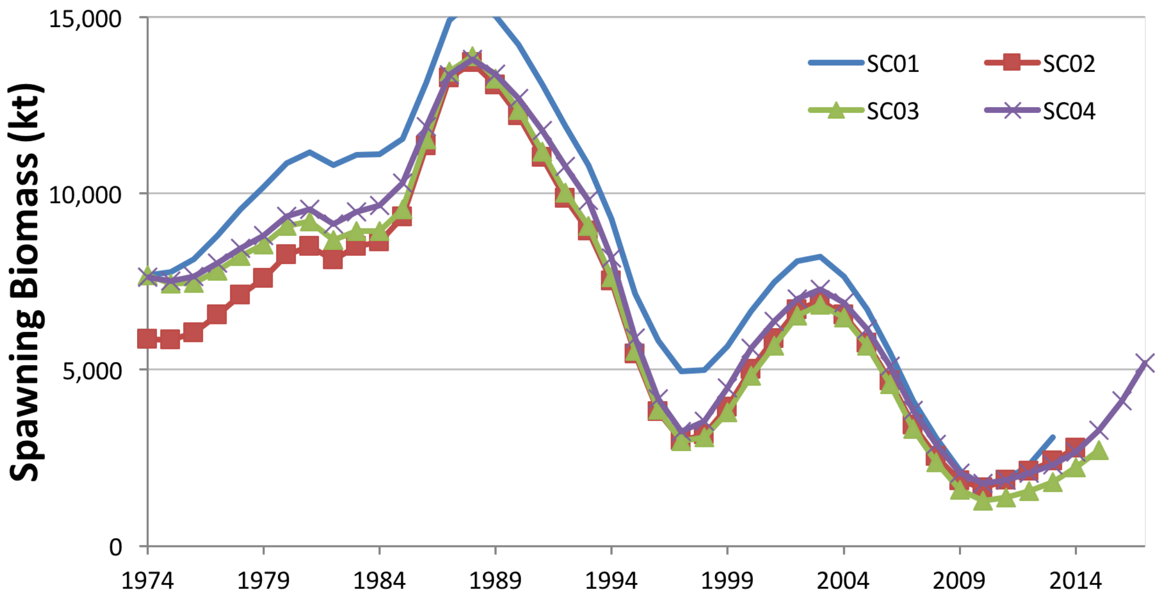



Figure A8.19. Historical retrospective of female spawning biomass (single-stock hypothesis) as estimated and used for advice from past (and present) SPFRMO scientific committees.