SPRFMO SC10-Report
Annex 10. Jack Mackerel Technical Annex

1. Introduction

1. This document and content are based on discussions and analyses conducted at the 10th SPRFMO Scientific Committee (SC) meeting in 2022. The analyses updated the model and assumptions from the jack mackerel benchmark meeting (SCW14) and the report can be found on the meeting link (here). During SC10, the model was updated with new data, and subsequently accepted by the SC. Discussions at SC10 focused on the following topics:

- Review and update of data sets;
- Corrections to an error in the length metrics of the growth model used;
- Change to the handling of selectivity and weight of the catch at age data for the offshore fleet in 2022.

2. A benchmark workshop for the jack mackerel stock assessment was completed in 2022 (SCW14). The main objective of the SCW14 workshop was to update the assessment with new data based on the updated aging criteria developed by Chile. These data included age compositions and weight-at-age in the catches of Chile and the offshore fleets, and in the acoustic surveys of Central and North of Chile. As a consequence of this update, a new maturity-at-age vector was estimated and a new value of natural mortality was derived (M=0.28). Overall, the changes caused by the new aging criteria led to the understanding of a faster-growing species that is earlier to mature.

3. In addition, CPUE indices were updated to include a factor for increases in the efficiency of fishing effort ("effort creep"). The efficiency factor for the offshore CPUE index was estimated to be approximately 2.5% per year, whereas the factor was set at a very preliminary value of 1% per year for the Chilean and Peruvian CPUE indices (not based on a quantitative analysis). Reference points were also updated from previously-set interim levels. In addition, for the single-stock hypothesis, a new reference point has been derived for a limit biomass, B_{lim}, which was estimated at 8% of unfished spawning biomass. Compared to the most recent assessment using the 'old' age composition data, the perception of stock is relatively unchanged and is estimated to be well above B_{MSY}, with fishing mortality is well below F_{MSY}.

Scientific Name and General Distribution

4. The Chilean jack mackerel (*Trachurus murphyi*, Nichols 1920) is widespread throughout the South Pacific. It is found 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

5. 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 the 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 incidental catches are very small.

Stock Structure

6. 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 exists 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.

7. 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 hypotheses already identified. That is: jack mackerel caught off the coasts of Peru and Chile constitute a single shared stock which straddles the high seas (hypothesis 1); or that jack mackerel caught off the coasts of Peru and Chile each constitute separate stocks (the Peruvian or northern and the Chilean or southern stock) which straddle the high seas (hypothesis 2). In following up on the SWG-11 recommendations, the SPRFMO Commission at its 1st Commission Meeting requested the newly established Scientific Commission (SC) 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 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 SC10.

Fishery

8. 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.

9. The fishery by the coastal states is conducted by purse seiners. The largest fishery exists in Chile, where the fish are used for fish meal. In Peru, the fishery is variable from year to year. Here the fish are 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 (70,000 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.

10. 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, Poland 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 EEZs of the coastal states.

11. The jack mackerel fishery in Chilean and offshore waters is mono-specific. In the offshore fishery, the catch consists of 90 – 98% 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 by Member are shown in Table A10.1 with the catch summarised by fleets in Figure A10.1.

Management

12. 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 to limit the number of fishing vessels was introduced in 2010. Catch limits for jack mackerel were established for the south-eastern Pacific starting from 2011.

Information on the environment in relation to the fisheries

13. Important environmental events such as the El Niño effect of 2016 affect oceanographic dynamics. During such events, the depth of the 15ºC isotherm and oxycline change significantly affecting the spatial distribution of jack mackerel and their availability in different regions (see for example the work of the Habitat Monitoring Working Group of the Scientific Committee as reported in previous meetings of the Scientific Committee). The extent that such changes affect the overall population productivity is unclear.

Reproductive Biology

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

2. Data used in the assessment

Fishery Data

15. The catch data for the model represents a summation of catch values from various Members (Table A10.1) to form four "fleets", which are intended to be consistent with the gear and general areas of fishing (Figure A10.1). The summarised catches from each of these fleets are presented in Table A10.2.

16. 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 were converted to age compositions by applying Chilean age-length keys as compiled by quarter of the year and then aggregated (Table A10.3, Table A10.4, and Table A10.5). The EU provided age-length keys which were used to convert EU length distribution data to age. For Peruvian and Ecuadorian fisheries, length frequency data (Table A10.6) were used directly and fit within the model according to the specified growth curve.

17. In the benchmark workshop prior to SC10 (SCW14), a new Chilean ageing method was included into the assessment. This resulted in revisions to age composition data for both Chilean fleets, as well as the offshore fleet. In addition, several biological variables (weight, maturity, natural mortality) were re-estimated and updated. Some detail on the revisions to the historical data and the validation approach can be found in the SCW11 report.

18. In the benchmark workshop SCW14, it was further agreed that a protocol should be developed to include self-sampling data from the Offshore fleet into the assessment. As introduced in meeting documents SC10-JM03 and SC10-JM04, the protocol stipulates that length-distributions from quarters that are not sampled in the observer program but that are covered in the self-sampling, will be included

into the assessment. For SC10 this meant that self-sampling data for 2021_Q2, 2022_Q2 and 2022_Q3 were included in the assessment data.

19. Several CPUE data series are used in the model, with changes in methodology to calculate the series introduced during SC4, SC6, SC7, SC9 and SC10. From SC10 onwards, the CPUE series include a factor that compensates for efficiency increases of fishing operations as estimated in global effort analysis (e.g. Rousseau et al 2019).

20. For the Chilean purse seiner fleet in the southern-central area, a "Generalized Linear Model" (GLM; McCullagh & Nelder, 1989) approach has been used to standardise the CPUE. Here trip-based CPUE has been modelled as a linear combination of explanatory variables, with the goal of estimating a year-effect that is proportional to jack mackerel biomass. 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 SC4 to exclude trips with no jack mackerel catches. This was preferred because it better reflected changes in management over time (particularly the introduction of 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 with a catchability change in year 2000. In addition, an overall increase of technical efficiency of 1% per year has been included during SC10.

21. Prior to the 2018 assessment (SC6), Peru presented a CPUE abundance index derived from the industrial purse seine fleet. This fishery has a strong focus on anchoveta and other stocks such as chub mackerel (*Scomber japonicus*) and bonito (*Sarda chiliensis*). With increasing catch rates in those fisheries, the focus on jack mackerel shifted, and the CPUE index was deemed to be no longer indicative of jack mackerel biomass. This resulted in a lack of CPUE data between 2015 and 2017. Thus, for the 2018 assessment CPUE indicators were calculated based on artisanal and small-scale fleets. These fleets are and have been targeting jack mackerel on a regular basis, operating at a closer distance to the coast than the industrial fleets. Historical data on catch by haul capacity for the artisanal fleets were recovered beginning in 2000. A Generalised Additive Model, in which the dependent variable (catch per trip) is gamma-distributed using a log-link function, was applied by removing the operational (holding capacity) and temporal effects (year, month). The GAM combined data from both artisanal and industrial fleets, although concerns were raised about the accuracy of the historical data (e.g., from missing fleet identifiers) and thus there is a need for continued development. In addition, an overall increase of technical efficiency of 1% per year has been included during SC10.

22. Up to the 2017 assessment (SC5), the European Union CPUE index (un-standardised), the Russian CPUE index (un-standardised) and the Chinese CPUE index (standardised with a GLM) were included as separate indices of exploitable biomass for the offshore fleet. However, it was noted that these fleets shared similar temporal and spatial dynamics and the European Union and Russian data were incorporated into a combined standardised offshore CPUE index in 2018 (SC6), with the Chinese CPUE kept separate. In 2019 (SC7), haul-by-haul data of China, EU, Korea, Vanuatu, and Russia were combined and standardised into a single Offshore CPUE time series (SC7-JM06 rev1). The standardisation procedure followed what had previously been done during SCW6. A GAM was fit to catch data with an offset of log(effort) assuming a negative binomial distribution. Vessel, month of the year, year, and El Niño effect (sea surface temperature anomaly) were taken as linear effects while two-dimensional smoothers were applied to correct for spatial effects. In SC9, the vessel explanatory variable was replaced by vessel contracting party, which resulted in CPUE indices that were similar in trend (SC9-JM02). Note that the start year of the various offshore CPUE indices has varied over time. Originally, when the European Union CPUE index was separate from the Chinese and Russian CPUE indices (SC5), the index began in 2003. In SC6, when the Russian CPUE data was incorporated into the combined Offshore index, this index was taken as beginning in 2006. From 2019 (SC7), the combined Offshore CPUE index has been included in the stock assessment as an index for the period from 2008 to the

present. In addition, an overall increase of technical efficiency of 2.5% per year has been included during SC10.

23. In all standardised CPUE series (Table A10.7), no explicit correction for search time has been incorporated. In some products, such as the offshore CPUE, effort in weeks is taken rather than effort by day (of positive registrations) to account for searching time. However, the inability to consistently define and accurately measure searching time remains an issue.

24. In SCW14, advances in fishing technological efficiency (also termed "effort creep") were explicitly incorporated in the CPUE standardization process. As mentioned previously, annual effort creep value of 2.5% was thus applied to CPUE for the offshore fleet (details in SCW14-WD01). For the other CPUE series from Chile and Peru, no formal evaluations of technological advances had been conducted. As such, an interim level of 1% efficiency improvement was applied to each series. It was agreed that further analyses would be required to understand the model reaction to the effort creep factor and noted that at this stage this factor does not appear to have an important effect on model results. SCW14 further recommended specific studies to evaluate the potential efficiency improvements for these fleets, including the technical equipment (e.g., those under consideration by the SPRFMO Scientific Committee's Habitat Monitoring Working Group), and any other factors that could influence effective fishing effort.

25. Further, the lack of a defined protocol for CPUE standardisation has been noted. Development of CPUE standardisation guidelines has thus been identified as a priority to improve the quality of the assessment.

Fisheries Independent Data

26. The Chilean jack mackerel research programme has included surveys using hydro-acoustics and the daily egg production method (DEPM). Acoustic estimates have been used as relative abundance indices. For the northern region (N-Chile), data on acoustic biomass and numbers, and weights at age are available from 1984-1988, 1991, and 2006-2021. 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 that the survey age composition data indicate that it catches younger ages than the fishing fleet, the SC6 considered it more appropriate to assign the survey its own selectivity.

27. Egg surveys (using DEPM) were conducted on an annual basis from 1999 to 2008 along the central zone of the Chilean coast in order to assess the biomass of the spawning stock. In addition, there are estimates of abundance and numbers-at-age for the central-southern regions based on DEPM for the years 2001, 2003, 2004, 2005, 2006, 2008. Egg survey results have been used as relative abundance indices in the models. Age composition data from the acoustic and DEPM Chilean surveys are shown in Table A10.8, Table A10.9, and Table A10.10.

28. In SC10, as mentioned previously, changes were made to the Chilean ageing methods. These resulted in updated historical age composition data for both Chilean surveys and the commercial catches.

29. 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 beginning in 1966. Acoustic biomass estimates of jack mackerel were available beginning in 1983. As these surveys had Peruvian anchoveta as the target species, the data only covered 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 made using an environmental index describing the potential habitat of this species based on available monthly data on SST, Sea Surface Salinity (SSS), water masses (WM), oxycline depth (OD) and chlorophyll (CHL). An alternative acoustic index for Peru was presented at SC3. This was constructed using backscatter information without converting the information to biomass estimates

using length-frequency data. This method was proposed to address the reduced quality of the available length-frequency data in recent years. This alternative series was included in the jack mackerel assessment in SC4, 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 is needed to standardise and analyse the survey data to develop a reasonable index from the later data. The index has been retained in the current assessment and extends from 1985 to 2013.

30. 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, using scientific vessels. Additionally, comprehensive acoustic surveys have been conducted from the Chilean commercial fleet. The time series of available acoustic estimates extends from 1984 to present day (intermittently, depending on the area). All abundance indices (fishery CPUE and survey) series used in the model are presented in Table A10.7.

Biological Parameters

31. The maturity-at-age for jack mackerel in Chile was estimated by Leal et al. (2013) and has been updated by applying the new ageing criteria (SCW14-WD04) to the otoliths and histological maturity data collected between September 2011 and January 2012. Overall, the changes caused by the new aging criteria led to the understanding of a faster-growing species that is earlier to mature. Maturity-at-length was consistently observed with L_{50} at about 22-23 cm fork length (FL). The maturity-at-age values, for the single/Southern stock and those for the far-north stock, are shown in Table A10.11.

32. 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 A10.12. It was noted in SC10 that the growth parameters reflected fish Total Length, whereas the data were in Fork Length. The parameters were since corrected. Ageing imprecision was previously acknowledged using an age-error matrix, as shown in Table A10.13. However, because this matrix is based on expert judgement instead of empirical data, the discussions during SC4 led to selecting the final assessment model with this ageing error option turned off.

33. 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 Table A10.14, Table A10.15, Table A10.16, and Table A10.17.

34. For the Chilean fleets, the mean weight-at-age is calculated by year by taking the mean length-at-age in the catch and a length-weight relationship derived for the year. Before SC3, the same weight-at-age matrix was used for the Northern Chilean Fleet (Fleet 1) and the Southern Chilean Fleet (Fleet 2). Beginning in SC3, 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 programme of the Chilean fisheries. The information was separated into 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, resulting in the weights-at-ages seen in Table A10.14 and Table A10.15. The information covers the period 1974-2021; for earlier years the weight-at-age from 1974 was used.

35. For the far north fleet, mean weight-at-age is fixed for all years and was initially calculated from the time-invariant mean length-at-age estimated from the growth function (Table A10.12). The information covers the period from 1970 to present year (Table A10.16).

36. The weights-at-age for the offshore fleet are derived from EU age-length keys as well as age-length keys from the Chilean South-Central fleet. The EU reported both age, length, and weight data, allowing for weight-at-age to be reported for their catches based on observer programme data compiled in 2019. For China, Vanuatu, Russia and Korea, length-weight information is transformed using the Chilean fleet-2 quarter-specific age-length keys (Table A10.17). Note that for most countries weight-at-length information is available. In some years however, including 2018, weight-at-length data from the Chinese fleet were missing, which resulted in using the length-weight relationship from the Chilean fleet 2. As of SCW14, due to the update in the Chilean ageing criteria, these weight-at-age data were updated for the time series beginning in 2015.

37. Historically, missing weight-at-age data were replaced with data from the previous year. In SCW14, it was recommended that those missing data be replaced with appropriate mean values by fleet instead. However, this has not been done during the SC10 assessment.

38. In SCW14, the Natural Mortality Tool (https://connect.fisheries.noaa.gov/natural-mortality-tool/) was used to derive values of M range from roughly 0.1 to 0.35 with a mode at 0.28. The L_∞ was assumed to be 80.4cm, k was assumed at 0.16 and t0 at –0.356. The value of 0.28 was used for the assessment in SC10. The estimated M values are assumed to be the same for all ages and all years within the given stock (see Table A10.12).

Data Sets

39. A full description of data sets used for the assessment of jack mackerel is in Annex 3 of the SC Data workshop 2015. Summaries of all data available for the assessment are provided in Table A10.18 and Figure A10.2.

3. The Assessment Model

40. A statistical catch-at-age model was used to evaluate the jack mackerel stocks. The JJM ("Joint Jack Mackerel Model") is implemented in AD Model Builder (ADMB) and considers different types of information, which correspond to the available data on the jack mackerel fishery in the South Pacific area from 1970 to 2021 (Table A10.18).

41. The JJM model is an explicitly 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 & Archibald (1982), Hilborn & Walters (1992) and Schnute & Richards (1995). This model was adopted as the assessment method in 2010 after several technical meetings.

JJM Developments

42. Since its adoption, the JJM model has been improved by participating scientists. The most notable changes have been options to include length composition data (and specifying or estimating growth) and the capability to estimate natural mortality by age and time (although this capability is not used). The model is flexible and permits the use of catch information either at age or size for any fleet, and explicitly incorporates regime shifts in population productivity.

43. The model consists 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).

44. A JM modelling workshop was held from 7/8 – 9/10 June 2022, attended by 33 people, with the aim of building capacity for utilization of the existing JJM model but also identifying several ways in which it could be improved to enhance transparency and ease of use. These ideas were subsequently fed into the JM Benchmark Workshop in July (SCW14).

45. Stock dynamics: recruitment is assumed to occur in January while the spawning season is assumed to be an instantaneous process occurring in mid-November. The population's age composition considers individuals from 1 to 12+ years old. In all cases a stochastic Beverton-Holt relationship (Beverton & Holt 1957) between stock and recruitment is included. Each cohort survives an age-specific mortality composed of fishing mortalities at-age by fleet and natural mortality (assumed to be constant over time and age). The model is not spatially-explicit, although the fisheries operate in geographically distinct areas. The initial population is based on an equilibrium condition and occurs in 1958 (12 years prior to the model start in 1970).

46. 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 fleet), 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 pattern is non-parametric and assumed to be fishery-specific and time-variant. Catchability is specific to each of the seven abundance indices. The model includes temporal variation in both fishery and index selectivity patterns at the annual and regime scales, depending on the index and the stock structure hypothesis. More detail is included in the subsequent section.

47. Observation models for the data: There are four data components that contribute to the log-likelihood function: the total catch data, the age-frequency data, the length-frequency data and the abundance indices.

48. The probability distributions for the age and length-frequency proportions are assumed to be approximated by multinomial distributions. Sample size is specified to be gear-specific but mostly constant over years. For the total catch by fishery (4) and the abundance indices (7), a log-normal assumption has been assumed with constant CV; the CV for the fisheries being 0.05 whereas the CV for the abundance indices depends on the index. Beginning in 2018, as discussed in SC4 and agreed upon in SCW6, the Francis T1.8 weighting method (Francis 2011) is used to assign weighted sample sizes for age-frequency data. The data weights have been updated during the JM 2022 benchmark (SCW14).

49. Parameter estimation: The model parameters are estimated by maximising 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 its characteristics can be consulted in Fournier et al. (2012).

Model Details

50. Parameters estimated conditionally are listed in Table A10.19. The most numerous of these involve estimates of annual and age-specific components of fishing mortality for each year and for 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+) were the second most numerous type of parameter.

51. Equations and specifications for the assessment model are given in Table A10.20 and Table A10.21. Table A10.22 contains the initial variance assumptions for the indices and the age and length compositions.

52. The treatment of selectivity patterns and how they are shared among fisheries and indices are given in Table A10.23 and Table A10.24 for the two stocks under the two-stock model configurations

(hypothesis 2), and Table A10.25 for the single-stock hypothesis (hypothesis 1). Selectivity for the Far North fleet was specified with a regime shift in 2002 under the two-stock hypothesis, while annual variations beginning in 1981 were specified for the same fleet under the single-stock hypothesis. 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.

53. Equilibrium-based reference points are calculated within the jjm model. The model estimates values of MSY and F_{MSY} using a Newton-Raphson minimization routine that finds the value of fishing mortality, given the terminal year relative catches (and selectivities-at-age) by fleet, and the terminal year weights-at-ages for each fleet, that maximizes catch. Since weights-at-age and "effective" selectivity change each year, these values can vary. MSY is thus defined as the maximum amount of catch that allows the remaining stock to generate sufficient recruitment to maintain the population at the same level. B_{MSY} is taken as the long-term average of biomass fished under MSY. Between 2013 and 2021, a provisional B_{MSY} level of 5.5 million tons was applied. In SCW14, the interim management reference point for B_{MSY} was revised to a ten-year average of the model-estimated B_{MSY}. A limit reference point B_{lim} (where B refers to spawning biomass) for the single-stock hypothesis was also developed during SCW14. B_{lim} was defined as the spawning biomass level below which recruitment would likely be impaired. As such, there should be no fishing when the current spawning biomass is estimated to be below B_{lim}. For jack mackerel, B_{lim} was computed from the lowest ratio of historical spawning biomass relative to the most-recently-estimated unfished spawning biomass. In SCW14, this ratio was estimated to be 8% of the unfished spawning biomass.

Models for Stock Structure Hypothesis

54. During SWG 11, two types of population structure were evaluated, and this was continued for subsequent evaluations. Beginning in 2020 (SC8), models under the one-stock hypothesis carry "h1" in front of the model number, models under the two-stock hypotheses carry "h2" in front of the model number.

Description of Model Explorations

55. As SC10 was an update assessment, after the benchmark of SCW14, the main model explorations involved incrementally adding new data components relative to the model and data adopted from SCW14. These are labelled "*h1_0.x*" and "*h2_0.x*. where *h1* and *h2* represent the stock structure hypothesis and *x* represents the number when a component was added (Table A10.26).

56. The rationale for the main updates and data revisions occurring through model configurations 0.00 to 0.10 has been explained in the "Data used in the assessment" section, earlier in this Annex.

57. Thereafter, Model 0.10 was renamed as Model *1.00*. with an updated control file to reflect changes in selectivity for the current year, as was done in previous years.

58. During SC10, attention was brought to an analysis in the Peruvian National Report (SC10-Doc27). The analysis noted a mistake in the assessment, where growth parameters reflecting fish Total Length were applied to Fork Length data. The model was thus updated to correct the growth parameters (L_∞=73.56; L_0=13.56; SC10-Doc27) in Model 1.01.

59. In the most recent years of the fishery, there has been a notable northward shift in the distribution of fishing effort by the offshore fleet. This geographical shift has been associated with catches of smaller and younger fish. As a result, the model fit to the age composition data in these terminal years was poor. To address this, a second sensitivity was developed (Model 1.02). Age composition data in the terminal year has traditionally been down-weighted to reflect uncertainty in those data points. To better fit to the offshore data in the final year, the sample size was increased to be the same as that of earlier years. It should be noted that the overall weight of the offshore age composition data is quite

low relative to other data sources. In addition, more flexibility was added to the selectivity of the offshore fleet in 2022.

60. The final model used the Francis weights agreed upon by SCW14 for the multinomial age composition sample sizes, and these weights were not updated in this assessment. Also, the model took a precautionary approach to assessment and advice. It assumed low steepness (h=0.65) and used the most recent recruitment time-series (2001-2015), similar to assessments prior to SC5. Recruitment used in the forecast was taken directly from the assessment.

61. Beginning in SC9, efforts have been made to increase the reproducibility and transparency of the assessment process. A centralised repository for data submissions was created on Teams to facilitate ease of access. R scripts were developed to document the assessment update process. These scripts included code to 1) read in, analyse, and raise catch at age/length data, 2) incrementally update data files for the bridging exercise from the previous year's assessment to the new assessment, 3) update model files for model sensitivity runs, 4) conduct projections with the final model, and 5) create an HTML document for result presentation. Scripts for processing the data (1) are found in the jjmData repository, whereas the assessment scripts can be found on the jjm repository, in the assessment folder.

4. Results

62. Results from incrementally updating the data (Models 0.00 to 0.10) indicated a slight increase in biomass for recent years, with the largest change driven by the update to Peruvian CPUE data. Correcting the growth parameters (Model 1.01) had negligible impacts on the stock status. Similarly, adding flexibility to selectivity estimates in the offshore fleet (Model 1.02) improved fits to recent age composition data, but had negligible impact on stock status. Overall, the stock (or stocks; depending on the stock structure hypothesis used) shows continued increasing trends in biomass, similar to previous years.

63. An analytical retrospective analysis involves running the model multiple times, each time removing the final year of data (for five years). The retrospective analysis shows that Model h1_1.02 tended to slightly under-estimate SSB, with a Mohn's rho of -0.13 (Figure A10.3). Recruitment tended to be under-estimated, with a Mohn's rho of -0.34 (Figure A10.4). The negative bias in recruitment is likely due to the fact that recruitment in recent years has been very high, and estimated recruitment in the final year reverts to a mean. Model h2_1.02 had a slight tendency to over-estimate SSB (Mohn's rho of 0.12 (south) and 0.21 (north); Figure A10.5) and under-estimate recruitment for the south (Mohn's rho of -0.11) and over-estimate the same for the north (Mohn's rho of 0.24; Figure A10.6).

64. An alternative to the analytical retrospective analysis, which is based on the current model formulation, the "historical retrospective analysis" instead compares quantities derived from assessments previously adopted by the SC. This indicates the year-to-year changes in estimates of stock trends and reference points. This analysis was only conducted on Model h1_1.02 (raw values for biomass found in Table A10.27; graphically visualised in Figure A10.7 and Figure A10.8). The results indicate that the current model formulation has a higher estimate of biomass relative to estimates from previous years. This was likely due to the revision in Chilean age data. Estimates of fishing mortality in recent years remain similar to those from previous SCs, although the current model estimates fishing mortality to be higher for historical years. Recruitment estimates appear mostly in line with those of previous models, with peaks in recruitment shifting by approximately two years. Overall, the trends appear consistent over time. Another interesting comparison to make is that of the management reference points (biomass (B) at maximum sustainable yield (MSY) and fishing mortality (F) at MSY; B_{MSY} and F_{MSY} respectively) estimated over the years. The updates to the age data in 2022, and subsequently the biological parameters, likely resulted in large changes to the reference points, B_{MSY} in particular (Figure A10.8). Despite that, it is to be noted that stock status relative to those changed reference points remained largely the same for

recent years. Also, the stock has consistently been estimated as rebuilt since 2018, and not subject to overfishing since 2013, relative to the dynamically-estimated MSY reference points.

65. Fishery mean weights-at-age assumed for all models are shown in Figure A10.9, and those for the surveys are shown in Figure A10.10. Estimates of numbers-at-age from Model h1_1.02 are given in Table A10.28, and Model h2_1.02 results are in Table A10.29 (southern stock) and Table A10.30 (northern stock). Both models show similar good fits to the composition data (Figure A10.11, Figure A10.12, Figure A10.13, Figure A10.14, Figure A10.15, Figure A10.16, Figure A10.17, and Figure A10.18). The fits to age composition data from the surveys are given in Figure A10.19, Figure A10.20, Figure A10.21, Figure A10.22, Figure A10.23, and Figure A10.24. Models h1_1.02 and h2_1.02 fit the indices similarly (Figure A10.25 (h1), Figure A10.26 (h2 south), and Figure A10.27 (h2 north); they both fit well to the Chilean CPUE data and poorly to recent years of the offshore and Peruvian CPUE data, although the relative abundance estimates remained within the uncertainty bounds of the data. Whereas the models predicted higher relative abundance than was shown in the offshore CPUE data, they predicted lower relative abundance than was shown in the Peruvian CPUE data. Estimates of fishery mean age compositions are shown in Figure A10.28 (h1_1.02) and Figure A10.29 (h2_1.02), and survey mean age compositions are shown in Figure A10.30 (h1_1.02) and Figure A10.31 (h2_1.02). Both models fit poorly to data from the Central-South Chilean acoustic survey. Both models seem to estimate mean length composition data for the Far North fleet relatively poorly in recent years, as shown in Figure A10.32 and Figure A10.33. Selectivity estimates for the fishery and indices are shown over time in Figure A10.34, Figure A10.35, Figure A10.36, and Figure A10.37.

66. For SC10, B_{MSY} was estimated to be approximately 7.8 million t under the single-stock hypothesis (h1_1.02), and 7.0 and 0.96 million t for the south and far north stocks respectively under the two-stock hypothesis (h2_1.02). B_{lim} was estimated to be approximately 1.24 million t, or 8% of the unfished spawning biomass, during SC10. More details on this reference point and the associated harvest control rule can be found in the SCW14 report.

67. A summary of the time series stock status (spawning biomass, F, recruitment, total biomass) for the single-stock hypothesis (h1_1.02) is shown in Figure A10.38. It is noted that the biomass has been steadily increasing over the last decade, and is now above the B_{MSY} management reference point. For the jack mackerel stock, with the current level at around 54% of what is estimated to have occurred had there been no fishing (Figure A10.41).

68. Under the 2-stock hypothesis (h2_1.02), conditions of the jack mackerel stock in its entire distribution range in the southeast Pacific shows a continued recovery since the time-series low in 2010. It is noted that under the two-stock model, the southern unit shows an increasing trend in biomass over the last decade (Figure A10.39), while the northern unit only shows an increase in biomass beginning in the middle of the last decade (Figure A10.40). The southern unit showed similar results to that of the single-stock hypothesis, although SSB was estimated slightly higher under the former scenario. Estimates of exploitation rate for the northern stock were comparable to recent years, remaining at relatively low levels (Figure A10.40). Figure A10.42 and Figure A10.43 show the current total biomass to be approximately 55% and 61% of unfished total biomass for the southern and the far north stocks respectively.

69. Fishing mortality rates at age (combined fleets) were high starting in about 1992 across the entire jack mackerel population, but have declined in the past years, regardless of stock structure hypothesis or designation (Table A10.31, Table A10.32, Table A10.33, Figure A10.38, Figure A10.39, and Figure A10.40). It should be noted that the low probability of B_{2032} being greater than B_{MSY} under the F_{MSY} projection for model h1_1.05 is likely due to B_{MSY} being set at the interim level, and not the model-estimated B_{MSY}. Within the period 2001-2015, the level of expected recruitment was lower than the alternatives although recruitment has increased in recent years to about the long-term average mean. The aforementioned period was used for projections but Model 1.02 uses the period 2001 to 2019 to

fit the stock recruitment curve for the southern/single stock. Time series of quantities derived by Model h1_1.02 are presented in Table A10.34, whereas those of Model h2_1.02 are in Table A10.35 (southern stock) and Table A10.36 (far north stock). Short, medium and long-term predictions for the stock(s) under different fishing mortalities are found under Table A10.37 (h1_1.02) and Table A10.38 (h2_1.02).

5. Management Advice

70. New data and indicators on the status of the jack mackerel stock suggest that conditions evaluated in detail from the last benchmark assessment (completed in 2022) 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, better catch rates apparent in all fisheries for which data are available, and increase in average age in the Chilean fisheries) drive the increase.

71. Historical fishing mortality rates and patterns relative to the provisional biomass target are shown in Figure A10.38 for Model h1_1.02. Near-term spawning biomass is expected to increase from 14.3 million t in 2022 to 15.5 million t in 2023 (with approximate 90% confidence bounds of 12.0 – 20.1 million t). Under the two-stock hypothesis, historical fishing mortality rates and patterns relative to the biomass targets estimated by Model h2_1.02 are shown in Figure A10.39 and Figure A10.40. Near-term spawning biomass is expected to increase from the 2022 estimate of 12.7 million t to 13.8 million t in 2023 for the southern stock (with approximate 90% confidence bounds of 10.0 – 19.2 million t), and decrease from 1.5 million t to 1.4 million t for the far north stock (with approximate 90% confidence bounds of .98 – 2.1 million t).

72. Recent increases in the model-calculated B_{MSY} values (which is different from the constant B_{MSY}) that are likely due to changes in selectivity of all fisheries combined, would imply an estimate of SSB at well over 50% over B_{MSY} for both the single-stock and the two-stock hypotheses.

73. Given current stock status, the fourth tier of the jack mackerel rebuilding plan (as defined in the SCW14 report) should be applied. This means that F_{MSY} would be used as the basis for catch advice. However, this would result in a potential increase of over three times of last year's recommended catch. In line with the "adjusted Annex K" rebuilding plan (SC2), catch advice relative to the previous year can only increase by a maximum of 15%. This results in advice of a 2023 catch level for jack mackerel within the entire jack mackerel range to be at or below 1,035,000t t.

74. Projections show a high likelihood of the biomass being above B_{MSY} in 2024 even under the most conservative recruitment productivity scenario evaluated (h1_1.02.ls and h2_1.02.ls; Table A10.37 and Table A10.38). A re-evaluation of the rebuilding plan is recommended to analyse sustainable exploitation rates of the re-built jack mackerel stock.

6. Assessment Issues

75. Based on results from the 2022 benchmark workshop, assessment plans for the next benchmark should be developed several months prior 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. Another priority for consideration is the development of guidelines for standardisation of CPUE indices and the collection of relevant data. In particular, evaluations of efficiency improvements for the Peruvian and Chilean fishing fleets were noted. Results of the data weighting and the retrospective pattern analysis also warrant further investigation.

76. 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. Residual patterns in the age composition for the North Chilean fleet remain unresolved, and warrant further investigation as well.

77. The need for a closer evaluation comparing the performance of the model under the single-stock and two-stock hypotheses was noted, likely conducted using simulation and MSE.

7. References

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8. Tables

Table A10.1. Sources and values of catch (t) compiled for the four fleets used for the assessment (note that data for 2021 are not official figures, and 2022 are predictions).

Assigned Fleet	Fleet 1	Fleet 2	Fleet 3 (Far North)						Fleet 4 (Offshore Trawl)												Grand Total
Year	N Chile	Chile CS	Cook Islands	Cuba	Ecuador (ANJ)	Peru (ANJ)	USSR	Subtotal	Belize	China	Cuba	European Union	Faroe Islands	Japan	Korea	Peru	Russia / USSR	Ukraine	Vanuatu	Subtotal	
1970	101 685	10 309				4 711		4 711												0	116 705
1971	143 454	14 988				9 189		9 189												0	167 631
1972	64 457	22 546				18 782		18 782									5 500			5 500	111 285
1973	83 204	38 391				42 781		42 781												0	164 376
1974	164 762	28 750				129 211		129 211												0	322 723
1975	207 327	53 878				37 899		37 899												0	299 104
1976	257 698	84 571				54 154		54 154						35						35	396 458
1977	226 234	114 572				504 992		504 992						2 273						2 273	848 071
1978	398 414	188 267				386 793	0	386 793						1 667	403		49 220			51 290	1 024 764
1979	344 051	253 460		6 281		151 591	175 938	333 810			12 719	1 180		120			356 271			370 290	1 301 611
1980	288 809	273 453		38 841		123 380	252 078	414 299			45 130	1 780					292 892			339 802	1 316 363
1981	474 817	586 092		35 783		37 875	371 981	445 638			38 444			29			399 649			438 123	1 944 670
1982	789 912	704 771		9 589		50 013	84 122	143 724			74 292	7 136					651 776			733 204	2 371 611
1983	301 934	563 338		2 096		76 825	31 769	110 690			52 779	39 943		1 694			799 884			894 300	1 870 262
1984	727 000	699 301		560		184 333	15 781	200 674			33 448	80 129		3 871			942 479			1 059 927	2 686 902
1985	511 150	945 839		1 067		87 466	26 089	114 622			31 191			5 229			762 903			799 323	2 370 934
1986	55 210	1 129 107		66		49 863	1 100	51 029			46 767			6 835			783 900			837 502	2 072 848
1987	313 310	1 456 727		0		46 304	0	46 304			35 980			8 815			818 628			863 423	2 679 764
1988	325 462	1 812 793		5 676		118 076	120 476	244 229			38 533			6 871			817 812			863 215	3 245 699
1989	338 600	2 051 517		3 386	0	140 720	137 033	281 139			21 100			701			854 020			875 821	3 547 077
1990	323 089	2 148 786		6 904	4 144	191 139	168 636	370 823			34 293			157			837 609			872 059	3 714 757
1991	346 245	2 674 267		1 703	45 313	136 337	30 094	213 447			29 125						514 534			543 659	3 777 618
1992	304 243	2 907 817		0	15 022	96 660	0	111 682			3 196						32 000	2 736		37 932	3 361 674
1993	379 467	2 856 777			2 673	130 681		133 354												0	3 369 598
1994	222 254	3 819 193			36 575	196 771		233 346												0	4 274 793
1995	230 177	4 174 016			174 393	376 600		550 993												0	4 955 186
1996	278 439	3 604 887			56 782	438 736		495 518												0	4 378 844
1997	104 198	2 812 866			30 302	649 751		680 053												0	3 597 117
1998	30 273	1 582 639			25 900	386 946		412 846												0	2 025 758
1999	55 654	1 164 035			19 072	184 679		203 751						7						7	1 423 447
2000	118 734	1 115 565			7 122	296 579		303 701		2 318										2 318	1 540 318
2001	248 097	1 401 836			133 969	723 733		857 702		20 090										20 090	2 527 725
2002	108 727	1 410 266			604	154 219		154 823		76 261										76 261	1 750 077
2003	143 277	1 278 019			0	217 734		217 734		94 690					2 010		7 540		53 959	158 199	1 797 229
2004	158 656	1 292 943			0	187 369		187 369		131 020					7 438		62 300		94 685	295 443	1 934 411
2005	165 626	1 264 808			0	80 663		80 663	867	143 000		6 187			9 126		7 040		77 356	243 576	1 754 673
2006	155 256	1 224 685			0	277 568		277 568	481	160 000		62 137			10 474		0		129 535	362 627	2 020 136
2007	172 701	1 130 083	7		927	254 426		255 360	12 585	140 582		123 523	38 700		10 940		0		112 501	438 831	1 996 975
2008	167 258	728 850	0		0	169 537		169 537	15 245	143 182		108 174	22 919		12 600		4 800		100 066	406 986	1 472 631
2009	134 022	700 905	0		1 934	74 694		76 628	5 681	117 963		111 921	20 213	0	13 759	13 326	9 113		79 942	371 918	1 283 473
2010	169 012	295 796	0		4 613	17 559		22 172	2 240	63 606		67 497	11 643	0	8 183	40 516			45 908	239 593	726 573
2011	30 825	216 470	0		69 373	257 240		326 613	0	32 862	8	2 248	0	0	9 253	674	8 229		7 617	60 891	634 799
2012	13 256	214 204	0		77	187 292		187 369		13 012	0	0	0	0	5 492	5 346	0		16 068	39 917	454 746
2013	16361	214999	0		3563	79441		83004		8329		10101	0		5267	2670			14809	41175	355539
2014	18219	254295	0		9	79191		79200		21155		20539	0		4078	2557			15324	63652	415366
2015	34886	250327			289	23036		23325		29180		27955	0		5749	0	2561		21227	86672	395210
2016	24657	295160			0	15121		15121		20208		11962	0		6430	0	0		15563	54163	389101
2017	35002	311863			54	10094		10148		16802		27887	0		1235	0	3188		0	49113	406126
2018	11551	415149			23	58356		58379		24366		9691	0		3717	0	4685		0	42460	527539
2019	11875	432447			0	139811		139811		22699		11870	0		7444	0	9423		0	51436	635569
2020	44155	517665			0	158880		158880		0		0	0		0	0	5245		0	5245	725945
2021	61359	567267			8	123628		123636				43111					12193			55304	807566
2022	83000	601000			8	180069		180077				45095					19680			64775	928852

Table A10.2. Input catch (kilo tonnes) by fleet (combined) for the stock assessment model. Note that the final year's data are predictions.

Year	Fleet 1	Fleet 2	Fleet 3	Fleet 4
1970	101.69	10.31	4.71	1
1971	143.45	14.99	9.19	1
1972	64.46	22.55	18.78	5.5
1973	83.2	38.39	42.78	1
1974	164.76	28.75	129.21	1
1975	207.33	53.88	37.9	1
1976	257.7	84.57	54.15	1.04
1977	226.23	114.57	504.99	2.27
1978	398.41	188.27	386.79	51.29
1979	344.05	253.46	333.81	370.29
1980	288.81	273.45	414.3	339.8
1981	474.82	586.09	445.64	438.12
1982	789.91	704.77	143.72	733.2
1983	301.93	563.34	110.69	894.3
1984	727	699.3	200.67	1059.93
1985	511.15	945.84	114.62	799.32
1986	55.21	1129.11	51.03	837.5
1987	313.31	1456.73	46.3	863.42
1988	325.46	1812.79	244.23	863.22
1989	338.6	2051.52	316.25	875.82
1990	323.09	2148.79	370.82	872.06
1991	346.25	2674.27	213.45	543.66
1992	304.24	2907.82	111.68	37.93
1993	379.47	2856.78	133.35	1
1994	222.25	3819.19	233.35	1
1995	230.18	4174.02	550.99	1
1996	278.44	3604.89	495.52	1
1997	104.2	2812.87	680.05	1
1998	30.27	1582.64	412.85	1
1999	55.65	1164.04	203.75	1.01
2000	118.73	1115.57	303.7	2.32
2001	248.1	1401.84	857.74	20.09
2002	108.73	1410.27	154.82	76.26
2003	143.28	1278.02	217.73	158.2
2004	158.66	1292.94	187.37	295.44
2005	165.63	1264.81	80.66	243.58
2006	155.26	1224.69	277.57	362.63
2007	172.7	1130.08	255.36	438.83
2008	167.26	728.85	169.54	406.99
2009	134.02	700.9	76.63	371.92
2010	169.01	295.8	22.17	239.59
2011	30.82	216.47	326.39	60.89
2012	13.26	214.2	187.4	39.92
2013	16.36	215	80.59	41.18
2014	18.22	254.29	74.53	63.65
2015	34.89	250.33	22.45	86.67
2016	24.66	295.16	15.09	54.16
2017	35	311.86	8.87	49.11
2018	11.55	415.15	57.16	42.46
2019	11.88	432.45	135.78	51.44
2020	44.16	517.66	140.12	4.74
2021	61.36	567.27	123.64	55.3
2022	83	601	180.08	64.78

Table A10.3. Catch at age for Fleet 1. Units are relative value (they are normalised to sum to 100 for each year in the model).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1980	0	5	14	24	31	22	4	0	0	0	0	0
1981	1	7	13	21	33	19	5	1	0	0	0	0
1982	0	15	15	21	26	16	6	1	0	0	0	0
1983	1	9	17	27	28	15	3	0	0	0	0	0
1984	2	34	12	14	18	16	4	0	0	0	0	0
1985	1	18	26	30	18	5	1	0	0	0	0	0
1986	8	11	9	18	32	18	5	0	0	0	0	0
1987	15	68	11	3	2	1	0	0	0	0	0	0
1988	1	17	54	26	2	0	0	0	0	0	0	0
1989	0	9	42	39	8	1	0	0	0	0	0	0
1990	9	3	28	49	10	1	0	0	0	0	0	0
1991	11	33	8	18	24	6	1	0	0	0	0	0
1992	11	30	21	21	12	5	1	0	0	0	0	0
1993	15	72	8	4	1	0	0	0	0	0	0	0
1994	27	32	25	13	2	1	0	0	0	0	0	0
1995	5	69	18	6	2	0	0	0	0	0	0	0
1996	29	57	11	3	0	0	0	0	0	0	0	0
1997	36	60	3	0	0	0	0	0	0	0	0	0
1998	8	79	11	3	0	0	0	0	0	0	0	0
1999	9	84	5	2	0	0	0	0	0	0	0	0
2000	36	47	16	1	0	0	0	0	0	0	0	0
2001	51	48	1	0	0	0	0	0	0	0	0	0
2002	21	58	17	3	1	0	0	0	0	0	0	0
2003	21	72	4	2	1	0	0	0	0	0	0	0
2004	13	63	23	1	0	0	0	0	0	0	0	0
2005	40	44	11	4	1	0	0	0	0	0	0	0
2006	8	83	6	2	1	0	0	0	0	0	0	0
2007	12	69	13	3	2	0	0	0	0	0	0	0
2008	56	27	9	7	1	0	0	0	0	0	0	0
2009	20	68	4	8	0	0	0	0	0	0	0	0
2010	9	74	13	3	1	0	0	0	0	0	0	0
2011	77	20	2	1	0	0	0	0	0	0	0	0
2012	34	58	7	0	0	0	0	0	0	0	0	0
2013	31	66	1	1	1	0	0	0	0	0	0	0
2014	59	40	2	0	0	0	0	0	0	0	0	0
2015	14	60	15	6	4	1	0	0	0	0	0	0
2016	10	20	13	19	19	7	10	1	0	0	0	0
2017	31	61	6	1	1	0	0	0	0	0	0	0
2018	100	0	0	0	0	0	0	0	0	0	0	0
2019	20	19	9	14	13	6	7	4	3	3	1	2
2020	0	27	25	23	15	8	2	0	0	0	0	0
2021	18	3	4	14	22	18	12	7	3	1	1	0
2022	0	0	0	3	26	32	30	7	2	1	0	0

Table A10.4. Catch at age for fleet 2. Units are relative value (they are normalised to sum to 100 in the model).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1980	2	23	40	26	8	1	0	0	0	0	0	0
1981	2	20	32	31	12	3	0	0	0	0	0	0
1982	2	27	37	25	8	1	0	0	0	0	0	0
1983	15	28	24	20	11	2	0	0	0	0	0	0
1984	7	50	8	14	12	6	2	0	0	0	0	0
1985	3	27	26	20	17	7	2	0	0	0	0	0
1986	4	11	24	27	21	12	2	0	0	0	0	0
1987	8	46	7	10	17	10	2	0	0	0	0	0
1988	12	38	29	7	8	6	1	0	0	0	0	0
1989	1	12	42	30	9	5	2	0	0	0	0	0
1990	0	1	6	26	33	18	12	3	0	0	0	0
1991	1	3	0	6	27	29	18	10	4	1	0	0
1992	1	7	6	6	8	21	22	16	9	4	0	0
1993	1	16	17	14	12	10	14	12	4	1	0	0
1994	0	6	17	18	13	11	17	13	4	1	0	0
1995	1	19	17	22	20	8	7	4	1	0	0	0
1996	4	22	19	17	15	10	6	3	1	0	0	0
1997	8	42	21	10	6	5	5	2	1	1	0	0
1998	9	58	14	6	3	3	4	2	1	0	0	0
1999	20	52	15	6	2	1	1	1	1	0	0	0
2000	10	49	24	10	3	1	1	1	1	0	0	0
2001	6	41	28	12	4	2	2	2	1	1	1	0
2002	7	34	23	16	6	4	3	2	2	2	1	0
2003	4	31	28	21	8	3	2	2	1	1	0	0
2004	2	22	29	26	11	5	3	2	1	0	0	0
2005	2	8	20	33	19	9	5	2	1	1	0	0
2006	1	6	9	20	25	14	11	7	3	2	1	1
2007	0	13	17	11	15	15	12	9	4	2	1	1
2008	3	1	6	22	20	16	11	9	5	3	2	2
2009	2	15	2	19	21	16	10	7	4	2	1	1
2010	1	32	20	10	11	6	9	6	2	1	1	0
2011	2	11	14	36	11	8	13	2	1	0	0	0
2012	0	8	25	27	29	7	3	1	0	0	0	0
2013	2	18	31	33	14	2	0	0	0	0	0	0
2014	1	13	24	26	21	12	3	1	0	0	0	0
2015	10	45	14	10	10	7	3	1	0	0	0	0
2016	0	23	26	22	14	8	4	2	1	0	0	0
2017	3	21	16	16	16	11	7	4	3	1	0	1
2018	2	18	24	20	17	9	5	3	1	1	1	0
2019	0	9	17	22	24	14	8	4	1	0	0	0
2020	0	9	10	15	22	20	14	8	3	0	1	0
2021	0	4	15	18	24	18	11	6	2	1	0	0
2022	0	1	6	26	37	21	7	2	0	0	0	0

Table A10.5. Catch at age for Fleet 4. Units are relative value (they are normalised to sum to 100 for each year in the model).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
2015	17	26	10	7	11	11	8	5	3	1	1	0
2016	6	14	17	25	22	7	3	2	1	1	0	0
2017	65	14	12	5	2	1	1	0	0	0	0	0
2018	15	21	7	12	18	15	8	3	1	0	0	0
2019	19	32	8	8	8	8	8	6	2	0	1	0
2020	14	53	24	4	1	1	1	0	0	0	0	0
2021	6	21	50	13	7	2	0	0	0	0	0	0
2022	14	79	3	2	1	0	0	0	0	0	0	0

Table A10.6. Catch at length for Fleet 3. Units are relative value (they are normalised to sum to 100 for each year in the model).

Total length (cm)

Year	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	1	2	5	6	6	7	8	7	8	8	8	8	7	6	5	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	1	2	3	4	5	6	8	8	7	7	8	8	7	5	5	3	3	3	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	1	1	1	1	2	3	7	11	15	18	15	7	5	4	3	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3	5	8	12	16	17	13	8	5	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3	4	6	9	13	16	15	11	7	4	2	1	1	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	5	6	8	9	9	12	11	11	8	6	3	2	1	1	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	4	6	7	7	7	6	7	8	8	8	8	6	4	2	2	1	1

Table A10.7. Abundance indices used within the assessment model.

Year	Chile (1)	Chile (2)	Chile (3)	Chile (4)	Peru(2)	Peru(3)	Offshore
1970	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-
1983	-	-	0.837	-	-	-	-
1984	-	99	0.77	-	-	-	-
1985	-	324	0.673	-	94.316	-	-
1986	-	123	0.567	-	108.116	-	-
1987	-	213	0.666	-	109.789	-	-
1988	-	134	0.585	-	114.18	-	-
1989	-	-	0.569	-	157.394	-	-
1990	-	-	0.487	-	229.757	-	-
1991	-	242	0.537	-	231.672	-	-
1992	-	-	0.492	-	180.355	-	-
1993	-	-	0.441	-	145.726	-	-
1994	-	-	0.473	-	95.245	-	-
1995	-	-	0.423	-	54.257	-	-
1996	-	-	0.418	-	29.967	-	-
1997	3530	-	0.343	-	31.664	-	-
1998	3200	-	0.291	-	43.994	-	-
1999	4100	-	0.296	5724	52.681	-	-
2000	5600	-	0.286	4688	105.784	-	-
2001	5950	-	0.341	5627	131.586	-	-
2002	3700	-	0.295	-	96.661	4.066	-
2003	2640	-	0.26	1388	67.471	4.754	-
2004	2640	-	0.281	3287	51.853	5.184	-
2005	4110	-	0.255	1043	75.171	4.069	-
2006	3192	112	0.276	3283	111.259	5.357	-
2007	3140	275	0.207	626	79.75	7.43	-
2008	487	259	0.136	1935	24.251	3.77	1683.82
2009	328	18	0.113	-	-	1.338	1171.55
2010	-	440	0.087	-	7.247	2.487	823.909
2011	-	432	0.048	-	35.283	6.324	733.503
2012	-	230	0.147	-	50.332	5.52	622.273
2013	-	144	0.129	-	64.504	2.439	707.994
2014	-	87	0.102	-	-	3.318	741.39
2015	-	459	0.083	-	-	2.649	1009.29
2016	-	587.244	0.15	-	-	2.276	728.148
2017	-	610.47	0.178	-	-	2.919	935.778
2018	-	374.11	0.179	-	-	8.17	800.295
2019	-	1487.07	0.197	-	-	13.703	972.161
2020	-	1728.27	0.258	-	-	14.988	-
2021	-	1870.36	0.271	-	-	18.067	1555.91
2022	-	-	0.323	-	-	20.371	-

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 fishery CPUE in Fleet 3
Offshore: Combined CPUE for China, EU, South Korea, Russia, and Vanuatu in Fleet 4

Table A10.8. Catch at age for acoustic surveys in southern Chile. Units are relative value (they are normalised to sum to 100 for each year in the model).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
2001	1	56	10	17	6	4	2	1	1	1	0	0
2002	2	45	27	13	5	5	2	1	0	0	0	0
2003	1	29	32	22	7	4	2	1	1	1	0	0
2004	1	13	19	25	17	10	9	4	1	0	0	0
2005	1	12	20	41	16	5	2	1	1	0	0	0
2006	0	0	13	34	32	8	6	4	2	1	0	0
2007	0	0	2	14	19	21	18	13	8	2	2	1
2008	0	0	0	12	33	25	13	9	4	2	1	2
2009	0	0	0	0	1	30	24	16	17	6	3	3

Table A10.9. Catch at age for acoustic surveys in northern Chile. Units are relative value (they are normalised to sum to 100 for each year in the model).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
2006	30	69	1	0	0	0	0	0	0	0	0	0
2007	8	60	23	8	2	0	0	0	0	0	0	0
2009	68	31	1	0	0	0	0	0	0	0	0	0
2013	45	13	21	15	5	1	0	0	0	0	0	0
2014	95	2	0	1	1	0	0	0	0	0	0	0
2015	72	21	4	2	1	0	0	0	0	0	0	0
2016	73	19	4	2	1	0	0	0	0	0	0	0
2017	66	23	8	2	1	0	0	0	0	0	0	0
2018	92	6	1	0	0	0	0	0	0	0	0	0
2019	16	59	20	4	1	0	0	0	0	0	0	0
2020	23	8	25	31	11	2	0	0	0	0	0	0
2021	62	5	13	12	6	2	0	0	0	0	0	0

Table A10.10. Catch at age for DEPM surveys in the southern area of Chile. Units are relative value (they are normalised to sum to one for each year in the model). Green shading reflects relative level with a darker green indicating a stronger cohort.

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

Table A10.11. 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 / Southern Stock	0.520	1.000	1.000	1.000	1.000	1.000	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 A10.12. Jack mackerel growth (von Bertalanffy) and natural mortality parameters used in JJM models.

Parameter	Far North stock	Single / South stock
L_∞ (cm) (Total length)	73.56	73.56
k	0.16	0.16
L0 (cm)	13.56	13.56
M (year-1)	0.33	0.28

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

Table A10.13. Ageing error matrix of jack mackerel. Columns represent the observed ages, while the rows represent the true age. These data are not used in the stock assessment.

	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 A10.14. Input mean body mass (kg) at age over time assumed for Fleet 1 (northern Chile).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1971	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1972	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1973	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1974	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1975	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1976	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1977	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1978	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1979	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1980	0.203	0.201	0.237	0.275	0.328	0.375	0.504	0.861	0.995	1.159	1.397	1.534
1981	0.164	0.187	0.238	0.268	0.308	0.368	0.464	0.796	0.995	1.159	1.397	1.534
1982	0.183	0.201	0.233	0.261	0.295	0.344	0.402	0.447	0.995	1.159	1.397	1.534
1983	0.12	0.166	0.249	0.284	0.33	0.418	0.497	0.606	0.995	1.159	1.397	1.534
1984	0.151	0.148	0.243	0.289	0.342	0.421	0.499	0.567	0.995	1.159	1.397	1.534
1985	0.192	0.204	0.233	0.299	0.366	0.452	0.537	0.627	0.695	1.159	1.397	1.534
1986	0.136	0.212	0.273	0.313	0.408	0.475	0.55	0.687	1	1.159	1.397	1.534
1987	0.126	0.137	0.218	0.335	0.407	0.455	0.492	0.564	0.824	1.159	1.397	1.534
1988	0.182	0.197	0.221	0.34	0.444	0.49	0.539	0.801	1.108	1.159	1.397	1.534
1989	0.211	0.224	0.257	0.31	0.436	0.536	0.579	0.625	0.948	1.159	1.397	1.534
1990	0.11	0.271	0.318	0.38	0.457	0.572	0.675	0.752	0.797	1.485	1.397	1.534
1991	0.17	0.136	0.295	0.418	0.469	0.538	0.657	0.761	0.829	0.921	0.966	1.211
1992	0.147	0.186	0.23	0.296	0.47	0.545	0.605	0.712	0.844	0.968	1.334	1.534
1993	0.162	0.177	0.246	0.32	0.389	0.533	0.684	0.82	0.925	1.117	1.827	1.534
1994	0.195	0.226	0.287	0.347	0.454	0.614	0.783	0.884	1.014	1.178	1.581	1.534
1995	0.174	0.19	0.266	0.339	0.425	0.563	0.797	1.012	1.187	1.425	1.797	1.534
1996	0.189	0.193	0.281	0.362	0.512	0.704	0.954	1.182	1.356	1.445	2.008	1.534
1997	0.174	0.196	0.266	0.36	0.518	0.699	0.887	1.084	1.287	1.529	1.786	1.779
1998	0.151	0.165	0.251	0.343	0.539	0.794	1.025	1.218	1.404	1.584	1.933	2.526
1999	0.161	0.167	0.259	0.338	0.494	0.789	1.039	1.235	1.397	1.654	1.841	1.952
2000	0.188	0.199	0.262	0.357	0.486	0.801	1.058	1.159	1.31	1.454	1.656	2.052
2001	0.183	0.202	0.266	0.336	0.455	0.614	0.868	1.119	1.395	1.568	1.813	1.929
2002	0.182	0.201	0.265	0.33	0.449	0.638	0.86	1.093	1.312	1.499	1.665	2.073
2003	0.174	0.192	0.249	0.305	0.403	0.588	0.786	1.026	1.261	1.504	1.734	1.861
2004	0.195	0.204	0.259	0.311	0.396	0.52	0.685	0.857	1.065	1.395	1.517	1.772
2005	0.083	0.234	0.28	0.318	0.396	0.506	0.642	0.751	0.92	1.16	1.324	1.606
2006	0.114	0.186	0.289	0.349	0.413	0.512	0.618	0.76	0.938	1.041	1.312	1.725
2007	0.124	0.187	0.23	0.333	0.431	0.513	0.625	0.777	0.909	1.056	1.228	1.542
2008	0.033	0.215	0.287	0.336	0.421	0.525	0.62	0.726	0.88	1.016	1.16	1.479
2009	0.138	0.139	0.273	0.346	0.418	0.539	0.624	0.759	0.892	1.007	1.138	1.398
2010	0.095	0.182	0.236	0.321	0.414	0.539	0.651	0.796	1.056	1.374	1.56	1.778
2011	0.198	0.202	0.296	0.36	0.478	0.64	0.806	1.025	1.261	1.45	1.874	1.981
2012	0.201	0.213	0.297	0.349	0.491	0.65	0.827	1.062	0.968	1.835	2.222	2.796
2013	0.218	0.245	0.312	0.381	0.448	0.58	0.714	0.926	1.292	1.751	2.082	2.512
2014	0.192	0.265	0.418	0.544	0.643	0.785	0.913	1.002	1.345	1.592	2.407	2.971
2015	0.214	0.214	0.282	0.48	0.61	0.746	0.884	0.99	1.049	1.239	1.13	1.483
2016	0.236	0.258	0.316	0.377	0.483	0.584	0.791	0.872	1.132	1.284	1.544	2.045
2017	0.182	0.226	0.295	0.368	0.444	0.549	0.676	0.922	1.096	1.391	1.741	1.583
2018	0.105	0.241	0.304	0.376	0.493	0.594	0.771	0.922	1.342	1.627	1.792	2.549
2019	0.019	0.268	0.305	0.393	0.482	0.578	0.683	0.759	0.888	1.339	1.978	2.906
2020	0.062	0.23	0.302	0.424	0.56	0.686	0.813	1.014	1.204	1.366	1.408	2.801
2021	0.231	0.272	0.318	0.405	0.562	0.695	0.809	0.956	1.115	1.404	1.484	1.693
2022	0.231	0.227	0.361	0.412	0.458	0.496	0.582	0.629	0.947	1.404	1.484	1.693

Table A10.15. Input mean body mass (kg) at age over time assumed for Fleet 2 (central-south Chile).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1971	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1972	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1973	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1974	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1975	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1976	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1977	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1978	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1979	0.157	0.202	0.271	0.346	0.444	0.57	0.709	0.867	1.076	1.313	1.579	1.826
1980	0.203	0.201	0.237	0.275	0.328	0.375	0.504	0.861	0.995	1.159	1.397	1.534
1981	0.164	0.187	0.238	0.268	0.308	0.368	0.464	0.796	0.995	1.159	1.397	1.534
1982	0.183	0.201	0.233	0.261	0.295	0.344	0.402	0.447	0.995	1.159	1.397	1.534
1983	0.12	0.166	0.249	0.284	0.33	0.418	0.497	0.606	0.995	1.159	1.397	1.534
1984	0.151	0.148	0.243	0.289	0.342	0.421	0.499	0.567	0.995	1.159	1.397	1.534
1985	0.192	0.204	0.233	0.299	0.366	0.452	0.537	0.627	0.695	1.159	1.397	1.534
1986	0.136	0.212	0.273	0.313	0.408	0.475	0.55	0.687	1	1.159	1.397	1.534
1987	0.126	0.137	0.218	0.335	0.407	0.455	0.492	0.564	0.824	1.159	1.397	1.534
1988	0.182	0.197	0.221	0.34	0.444	0.49	0.539	0.801	1.108	1.159	1.397	1.534
1989	0.211	0.224	0.257	0.31	0.436	0.536	0.579	0.625	0.948	1.159	1.397	1.534
1990	0.11	0.271	0.318	0.38	0.457	0.572	0.675	0.752	0.797	1.485	1.397	1.534
1991	0.17	0.136	0.295	0.418	0.469	0.538	0.657	0.761	0.829	0.921	0.966	1.211
1992	0.147	0.186	0.23	0.296	0.47	0.545	0.605	0.712	0.844	0.968	1.334	1.534
1993	0.162	0.177	0.246	0.32	0.389	0.533	0.684	0.82	0.925	1.117	1.827	1.534
1994	0.195	0.226	0.287	0.347	0.454	0.614	0.783	0.884	1.014	1.178	1.581	1.534
1995	0.174	0.19	0.266	0.339	0.425	0.563	0.797	1.012	1.187	1.425	1.797	1.534
1996	0.189	0.193	0.281	0.362	0.512	0.704	0.954	1.182	1.356	1.445	2.008	1.534
1997	0.174	0.196	0.266	0.36	0.518	0.699	0.887	1.084	1.287	1.529	1.786	1.779
1998	0.151	0.165	0.251	0.343	0.539	0.794	1.025	1.218	1.404	1.584	1.933	2.526
1999	0.161	0.167	0.259	0.338	0.494	0.789	1.039	1.235	1.397	1.654	1.841	1.952
2000	0.188	0.199	0.262	0.357	0.486	0.801	1.058	1.159	1.31	1.454	1.656	2.052
2001	0.183	0.202	0.266	0.336	0.455	0.614	0.868	1.119	1.395	1.568	1.813	1.929
2002	0.182	0.201	0.265	0.33	0.449	0.638	0.86	1.093	1.312	1.499	1.665	2.073
2003	0.174	0.192	0.249	0.305	0.403	0.588	0.786	1.026	1.261	1.504	1.734	1.861
2004	0.195	0.204	0.259	0.311	0.396	0.52	0.685	0.857	1.065	1.395	1.517	1.772
2005	0.083	0.234	0.28	0.318	0.396	0.506	0.642	0.751	0.92	1.16	1.324	1.606
2006	0.114	0.186	0.289	0.349	0.413	0.512	0.618	0.76	0.938	1.041	1.312	1.725
2007	0.124	0.187	0.23	0.333	0.431	0.513	0.625	0.777	0.909	1.056	1.228	1.542
2008	0.033	0.215	0.287	0.336	0.421	0.525	0.62	0.726	0.88	1.016	1.16	1.479
2009	0.138	0.139	0.273	0.346	0.418	0.539	0.624	0.759	0.892	1.007	1.138	1.398
2010	0.095	0.182	0.236	0.321	0.414	0.539	0.651	0.796	1.056	1.374	1.56	1.778
2011	0.198	0.202	0.296	0.36	0.478	0.64	0.806	1.025	1.261	1.45	1.874	1.981
2012	0.201	0.213	0.297	0.349	0.491	0.65	0.827	1.062	0.968	1.835	2.222	2.796
2013	0.218	0.245	0.312	0.381	0.448	0.58	0.714	0.926	1.292	1.751	2.082	2.512
2014	0.192	0.265	0.418	0.544	0.643	0.785	0.913	1.002	1.345	1.592	2.407	2.971
2015	0.214	0.214	0.282	0.48	0.61	0.746	0.884	0.99	1.049	1.239	1.13	1.483
2016	0.236	0.258	0.316	0.377	0.483	0.584	0.791	0.872	1.132	1.284	1.544	2.045
2017	0.182	0.226	0.295	0.368	0.444	0.549	0.676	0.922	1.096	1.391	1.741	1.583
2018	0.105	0.241	0.304	0.376	0.493	0.594	0.771	0.922	1.342	1.627	1.792	2.549
2019	0.019	0.268	0.305	0.393	0.482	0.578	0.683	0.759	0.888	1.339	1.978	2.906
2020	0.062	0.23	0.302	0.424	0.56	0.686	0.813	1.014	1.204	1.366	1.408	2.801
2021	0.231	0.272	0.318	0.405	0.562	0.695	0.809	0.956	1.115	1.404	1.484	1.693
2022	0.231	0.227	0.361	0.412	0.458	0.496	0.582	0.629	0.947	1.404	1.484	1.693

Table A10.16. Input mean body mass (kg) at age over time assumed for Fleet 3 (far north).

	Age group (years)											
Year	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	1.9	2.196	2.47	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	0.03	0.13	0.306	0.548	0.835	1.148	1.47	1.789	2.095	2.382	2.647	2.887
1973	0.037	0.147	0.33	0.568	0.842	1.134	1.43	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	0.31	0.54	0.808	1.095	1.387	1.674	1.946	2.201	2.434	2.645
1976	0.044	0.16	0.34	0.567	0.822	1.087	1.351	1.606	1.845	2.065	2.266	2.446
1977	0.032	0.13	0.294	0.51	0.76	1.028	1.3	1.566	1.818	2.054	2.27	2.465
1978	0.032	0.129	0.295	0.516	0.774	1.05	1.332	1.608	1.872	2.117	2.343	2.547
1979	0.036	0.138	0.304	0.518	0.762	1.02	1.28	1.532	1.77	1.991	2.193	2.375
1980	0.036	0.136	0.298	0.506	0.743	0.994	1.245	1.49	1.721	1.934	2.13	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	1.92	2.108	2.278
1983	0.042	0.138	0.28	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	0.04	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	1.26	1.512	1.751	1.973	2.176	2.359
1988	0.038	0.145	0.315	0.533	0.78	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	0.15	0.32	0.532	0.769	1.017	1.263	1.499	1.722	1.927	2.113	2.28
1991	0.039	0.142	0.305	0.511	0.743	0.985	1.227	1.461	1.68	1.883	2.068	2.234
1992	0.04	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	1.08	1.354	1.62	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	0.54	0.792	1.058	1.325	1.583	1.827	2.053	2.26	2.446
1996	0.038	0.145	0.317	0.537	0.788	1.053	1.318	1.576	1.82	2.045	2.251	2.436
1997	0.045	0.152	0.312	0.506	0.72	0.94	1.155	1.361	1.553	1.729	1.889	2.031
1998	0.04	0.14	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	1.55	1.877	2.189	2.481	2.75	2.994
2001	0.033	0.139	0.324	0.572	0.864	1.18	1.504	1.822	2.127	2.412	2.674	2.912
2002	0.036	0.145	0.33	0.576	0.861	1.167	1.478	1.783	2.074	2.344	2.593	2.817
2003	0.04	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	1.74	2.017	2.275	2.511	2.724
2005	0.037	0.15	0.341	0.595	0.89	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	1.23	1.558	1.88	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	1.19	1.51	1.823	2.122	2.4	2.656	2.888
2009	0.038	0.15	0.337	0.582	0.865	1.167	1.474	1.773	2.057	2.321	2.563	2.782
2010	0.039	0.15	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	1.395	1.806	2.217	2.614	2.99	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	0.95	1.31	1.682	2.051	2.405	2.739	3.047	3.327
2016	0.033	0.146	0.346	0.621	0.95	1.31	1.682	2.051	2.405	2.739	3.047	3.327
2017	0.033	0.146	0.346	0.621	0.95	1.31	1.682	2.051	2.405	2.739	3.047	3.327
2018	0.033	0.146	0.346	0.621	0.95	1.31	1.682	2.051	2.405	2.739	3.047	3.327
2019	0.033	0.146	0.346	0.621	0.95	1.31	1.682	2.051	2.405	2.739	3.047	3.327
2020	0.033	0.146	0.346	0.621	0.95	1.31	1.682	2.051	2.405	2.739	3.047	3.327
2021	0.033	0.146	0.346	0.621	0.95	1.31	1.682	2.051	2.405	2.739	3.047	3.327
2022	0.033	0.146	0.346	0.621	0.95	1.31	1.682	2.051	2.405	2.739	3.047	3.327

Table A10.17. Input mean body mass (kg) at age over time assumed for Fleet 4 (offshore trawl). Weight-at-age 1970-2013 were assumed to be the same as Fleet 2.

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1971	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1972	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1973	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1974	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1975	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1976	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1977	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1978	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1979	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1980	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1981	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1982	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1983	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1984	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1985	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1986	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1987	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1988	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1989	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1990	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1991	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1992	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1993	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1994	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1995	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1996	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1997	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1998	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
1999	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2000	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2001	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2002	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2003	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2004	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2005	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2006	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2007	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2008	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2009	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2010	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2011	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2012	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2013	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2014	0.157	0.223	0.329	0.429	0.613	0.741	0.835	0.935	1.049	1.145	1.308	1.543
2015	0.228	0.248	0.295	0.434	0.655	0.818	0.933	1.098	1.214	1.326	1.27	1.823
2016	0.311	0.383	0.399	0.428	0.481	0.61	0.837	0.883	0.985	1.094	1.535	1.265
2017	0.059	0.192	0.47	0.549	0.659	0.703	0.739	0.922	0.962	1.094	1.359	1.543
2018	0.066	0.146	0.305	0.388	0.507	0.606	0.649	0.634	0.778	0.868	1.051	1.68
2019	0.127	0.136	0.244	0.51	0.79	0.927	1.04	1.042	1.128	1.263	1.249	1.405
2020	0.152	0.234	0.259	0.265	0.588	0.778	0.811	1.029	1.228	1.226	1.382	1.543
2021	0.103	0.204	0.251	0.277	0.279	0.343	0.544	0.67	0.617	0.966	1.032	0.979
2022	0.132	0.135	0.223	0.311	0.424	0.554	0.682	0.824	1.011	1.153	1.27	1.42

Table A10.18. Years and types of information used in the JJM assessment models.

Fleet	Catch-at-age	Catch-at-length	Landings	CPUE	Acoustic	DEPM
1 North Chile purse seine	1980-2022	-	1970-2022	-	Index: 1984-1988; 1991; 2006-2021 Age comps: 2006-2021	-
2 South-central Chile purse seine	1980-2022	-	1970-2022	1983-2022	1997-2009 Age comps: 2001-2009	Index: 1999-2001; 2003-2008 Age comps: 2001; 2003-2006; 2008
3 FarNorth	-	1980-2022	1970-2022	2002-2022	1985-2008; 2010-2013	-
4 International trawl off Chile	2015-2022	2015-2022*	1970-2022	China, EU, Korea, Russia, & Vanuatu (2008-2019; 2021)	-	-

(*) Are converted to age using age-length keys of central-southern area off Chile, the EU, and Russia.

Table A10.19. Symbols and definitions used for model equations.

General Definitions	Symbol/Value	Use in Catch at Age Model
Year index: i = {1970, …., 2022}	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 of 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 parameterisation
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	Γ	Transform from age to length
Sample size for proportion in year i	T_i	Scales multinomial assumption about estimates of proportion at age
Survey catchability coefficient	q^s	Prior distribution lognormal(μ_q^s , σ_q^2)
Stock-recruitment parameters	R_0	Unfished equilibrium recruitment
	h	Stock-recruitment steepness
	σ_R^2	Recruitment variance
Unfished biomass	φ	Spawning biomass per recruit when there is no fishing
Estimated parameters		
$\phi_i(\#), R_0, h, \varepsilon_i(\#), \mu^f, \mu^s, M, \eta_j^s(\#), \eta_j^f(\#), q^s(\#)$		

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

Table A10.20. 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 Δ^s represents the fraction of the year when the survey occurs.	I_i^s	$I_i^s = q^s \sum_{j=1}^{12} N_{ij} W_{ij} S_j^s e^{-\Delta^s Z_{ij}}$
2)	Catch biomass by fleet (f=1,2,3,4), year(i) and age (j) /length (l)	$\hat{C}_{il}, \hat{C}_{ij}, \hat{Y}_i$	$\hat{C}^f_{i,j}, = N_{i,j} \frac{F^f{}_{i,j}}{Z^f{}_{i,j}} \left(1 - e^{-Z^f{}_{i,j}}\right)$ $\hat{Y}^f{}_i = \sum_{j=1}^{12+} \hat{C}^f_{i,j} w^f_{i,j}$
	(transformation from age to length composition. Fleet 3, FarNorth)		$\hat{C}_{il} = \Gamma_{lj} \hat{C}_{ij}$ $\Gamma_{l,j} = \int_j^{j+1} e^{-\frac{1}{2\sigma_j^2}(l-L_j)^2} dl$ $L_j = L_{00}(1-e^{-k}) + e^{-k} L_{j-1}$ $\sigma_j = cv\, L_j$
3)	Proportion at age j, in year i		$p_{ij}^f = \frac{\hat{C}_{ij}^f}{\sum_j \hat{C}_{ij}^f} \quad p_{ij}^s = \frac{N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}{\sum_j N_{ij} S_j^s e^{-\Delta^s Z_{ij}}}$
	Proportion at length l, in year i		$P_{il} = \frac{C_{il}}{\sum_{l=10}^{50} C_{il}}$
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, …, 2022	$\varepsilon_i, \sum_{i=1958}^{final\ year} \varepsilon_i = 0$	$N_{i,1} = e^{\mu_R + \varepsilon_i}$

Eq	Description	Symbol/Constraints	Key Equation(s)	
11)	Index catchability		$q_i^s = e^{\mu^s}$	
	Mean effect	μ^s, μ^f	$s_j^s = e^{\eta_j^s}$	$j \le$ maxage
	Age effect	$\eta^s{}_j$, $\sum_{j=1958}^{final\ year} \eta^s{}_j = 0$	$s_j^s = e^{\eta^s_{\mathrm{maxage}}}$	$j >$ maxage
12)	Instantaneous fishing mortality		$F_{ij}^f = e^{\mu^f + \eta_j^f + \phi_i}$	
13)	Mean fishing effect	μ^f		
14)	Annual effect of fishing mortality in year i	φ_i, $\sum_{i=1970}^{final\ year} \varphi_i = 0$		
15)	age effect of fishing (regularised) In year time variation allowed	$\eta^f{}_j$, $\sum_{j=1958}^{final\ year} \eta^f{}_j = 0$	$s_{ij}^f = e^{\eta_j^f}$	$j \le$ maxage
			$s_{ij}^f = e^{\eta^f_{\mathrm{maxage}}}$	$j >$ maxage
	In years where selectivity is constant over time	$\eta^f_{i,j} = \eta^f_{i-1,j}$	$i \ne$ 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.	$\tilde{R}_i$	$\tilde{R}_i = \frac{\alpha B_t}{\beta + B_i}$, $\alpha = \frac{4hR_0}{5h-1}$ and $\beta = \frac{B_0(1-h)}{5h-1}$ where $B_0 = R_0 \varphi$, $\varphi = \sum_{j=1}^{12} e^{-M(j-1)} W_j p_j + \frac{e^{-12M} W_{12} p_{12}}{1-e^{-M}}$, h=0.8	

Table A10.21 Specification of objective function that is minimised (i.e., the penalised negative of the log-likelihood).

Eq	Likelihood /penalty component		Description / noted
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	$L_3 = \lambda_3 \sum_{i=1958}^{final\ year} \varepsilon^2{}_i$ $\lambda_3 = \frac{0.5}{\sigma_R^2}$	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	$L_4 = 0.5\sum_f \frac{1}{cv_f^2}\sum_{i=1970}^{final\ year} log\left(\frac{Y^f{}_i}{\hat{Y}^f{}_i}\right)^2$	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	$L_6 = \lambda_4 \sum_{j=6}^{12}\left(lnS_{j-1} - lnS_j\right)^2$ $S_{j-1} > S_j$	(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	$L_7 = \lambda_5 \sum_{j=1970}^{2015} log\left(\frac{N_{i,1}}{\tilde{R}_i}\right)^2$ $\lambda_5 = \frac{0.5}{\sigma_R^2}$	Conditioning on stock-recruitment curve over period 1970-2015. (Assessment models use the period 1970 to (present year – 3))
27)	Priors or assumptions	R_0 non-informative	$\sigma_R = 0.6$
28)	Overall objective function to be minimised	$\dot{L} = \sum_k L_k$	

Table A10.22. Coefficients of variation and sample sizes used in likelihood functions, with adjustments based on calculated Francis weights. Initial sample sizes are in parentheses.

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 – Offshore	0.20		
Smoothness for selectivities (indexes)	Λ	Proportion at age likelihood (indexes)	n
Acoustic CS-Chile	100	Acoustic CS-Chile	6.8 (150)
Acoustic N-Chile	100	Acoustic N-Chile	12.4 (150)
CPUE – Chile	100	DEPM – Chile	1
CPUE – Offshore	100		
Smoothness for selectivities (fleets)	λ	Proportion at age (or length) likelihood	n
N -Chile	1	N-Chile	23.9 (100)
CS-Chile	25	CS-Chile	64.3 (250)
Farnorth	12.5	Farnorth (length)	30
Offshore	12.5	Offshore	12.6 (150)
Recruitment regularity	λ	S – Recruitment curve fit	cv
	1.4		0.6

Table A10.23. Description of JJM model components and how selectivity was treated (two-stock hypothesis; Far North Stock).

Item	Description	Selectivity assumption
Fisheries		
1)	Peruvian and Ecuadorian area fishery	Selectivity in the model under the two-stock hypothesis was estimated from length composition data (converted to age inside the model). Two regimes were considered – before and after 2002. This is a different assumption from the single-stock hypothesis, which has annual variations in selectivity between 1981 and 2022.
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 A10.24. Description of JJM model components and how selectivity was treated (two-stock hypothesis; Southern 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. Additional flexibility in selectivity was allowed for 2022 to reflect a change in the fishing pattern.
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. Selectivity changes were implemented in 2012 and 2016.
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)	Offshore fleet (China, EU, Korea, Russia, Vanuatu) CPUE	Assumed to be the same as 3)

Table A10.25.Description of JJM model components and how selectivity was treated under the single-stock hypothesis.

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). Annual variations were considered since 1981
4)	Offshore trawl fishery	Estimated from age composition data. Annual variations were considered since 1980. Additional flexibility in selectivity was allowed for 2022 to reflect a change in the fishing pattern.
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)	Offshore fleet (Vanuatu, Russia, Korea, EU & China) CPUE	Assumed to be the same as 4)

Table A10.26. Systematic model progression from the 2021 assessment data to the agreed revised datasets for 2022. Note that the data file names corresponding to each model follow the same naming convention, but with the stock-structure hypothesis denoted as h1 for the single-stock and h2 for the two-stock (e.g., "0.01.dat" with "h1_0.01.ctl" and "h2_0.01.ctl).

Model	Description
Models 0.x	Data introductions
0.00	Exact 2021 (single stock h1 and two-stock h2) model and data set (model 1.14) from benchmark SCW14.
0.01	As 0.00 but with revised catches through 2021 (currently still estimates)
0.02	As 0.01 but with updated 2021 fishery age composition data for N_Chile, SC_Chile, and Offshore_Trawl, and updated 2021 fishery length composition data for FarNorth
0.03	As 0.02 but with updated 2021 weight at age data for all fisheries and their associated CPUE indices
0.04	As 0.03 but replaced offshore CPUE up to 2021
0.05	As 0.04 but with updated AcousN 2021 index, with associated age composition and weight at age
0.06	As 0.05 but with 2022 catch projections
0.07	As 0.06 but with updated 2022 fishery age composition data for N_Chile, SC_Chile, and Offshore_Trawl, and updated 2022 fishery length composition data for FarNorth
0.08	As 0.07 but with updated 2022 weight at age data for N_Chile, SC_Chile, and FarNorth fleets, and for their associated CPUE indices
0.09	As 0.08 but replaced SC_Chile_CPUE index (traditional absolute scaled CPUE by trip)
0.1	As 0.09 but replaced Peru_CPUE index
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Models 1.x	Updated Model and Sensitivities
1.00	As 0.10 but with updated model (selectivity changes, recruitment) to 2022; 0.10 data file
1.01	As 1.00 but with correct growth parameters to reflect FL (Linf=73.56; L0=13.56; SC10-Doc27 Peru National Report - ANJ)
1.02	As 1.01 but with added flexibility for selectivity in the offshore fleet

Table A10.27. Spawning biomass of jack mackerel (base model under the single-stock hypothesis) estimated in previous SPRFMO SC meetings.

Year	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10
1970	8761	6726	10082	9770	9928	10319	10289	10629	11383	14378
1971	8112	6384	9164	8872	9037	10015	9964	10214	10979	13372
1972	7818	6173	8527	8289	8457	9854	9783	9964	10731	12456
1973	7726	6015	8042	7911	8079	9756	9666	9794	10521	11541
1974	7676	5910	7673	7633	7800	9646	9538	9625	10249	10560
1975	7763	5894	7446	7511	7675	9604	9480	9534	9984	9742
1976	8141	6075	7454	7638	7799	9752	9610	9638	9822	9136
1977	8810	6589	7808	8027	8186	10112	9948	9955	9808	8711
1978	9551	7151	8224	8445	8603	10458	10267	10256	9810	8562
1979	10188	7613	8553	8810	8965	10717	10497	10473	9832	8470
1980	10854	8276	9085	9349	9494	11124	10881	10847	10069	8560
1981	11170	8521	9213	9561	9693	11174	10920	10878	9982	8423
1982	10806	8122	8679	9137	9252	10513	10263	10217	9192	8033
1983	11092	8503	8926	9487	9578	10584	10358	10310	9344	9078
1984	11122	8635	8942	9653	9722	10502	10310	10264	9434	9507
1985	11554	9342	9557	10297	10351	10869	10721	10679	10077	10080
1986	13159	11355	11531	11890	11936	12177	12075	12039	11772	13579
1987	14919	13284	13459	13371	13411	13402	13344	13314	13297	18078
1988	15496	13716	13894	13801	13830	13717	13702	13679	13828	19862
1989	15050	13082	13256	13389	13406	13455	13472	13454	13502	18745
1990	14228	12207	12371	12701	12699	13076	13116	13101	13136	17271
1991	13098	11032	11197	11792	11763	12408	12466	12455	12537	16133
1992	11909	9856	10018	10772	10716	11542	11610	11602	11763	15260
1993	10802	8942	9082	9800	9722	10658	10726	10720	10743	13700
1994	9271	7518	7634	8165	8070	9061	9127	9123	9074	11132
1995	7154	5448	5532	5901	5794	6696	6761	6758	6666	8161
1996	5819	3820	3862	4174	4073	4775	4832	4831	4740	6003
1997	4950	2990	2965	3254	3181	3609	3655	3657	3564	4719
1998	4985	3158	3074	3539	3498	3677	3724	3730	3573	4814
1999	5668	3937	3795	4475	4457	4434	4499	4511	4278	5956
2000	6671	5018	4834	5616	5624	5463	5556	5574	5312	7308
2001	7481	5892	5690	6368	6404	6172	6298	6323	6095	7759
2002	8083	6699	6544	7010	7073	6805	6965	6997	6770	8442
2003	8201	6952	6848	7274	7349	7080	7270	7309	7078	8463
2004	7641	6564	6475	6908	6979	6725	6935	6980	6751	7815
2005	6708	5763	5676	6159	6225	5997	6213	6262	6056	7188
2006	5486	4682	4595	5102	5160	4979	5195	5248	5061	6049
2007	4119	3430	3324	3846	3890	3754	3973	4029	3857	4241
2008	3067	2545	2382	2890	2915	2779	2998	3055	2926	2986
2009	2130	1850	1598	2070	2074	1893	2103	2159	2076	2465
2010	1709	1647	1291	1775	1758	1538	1728	1778	1703	2413
2011	1855	1861	1382	1868	1832	1667	1817	1855	1782	2373
2012	2304	2115	1552	2065	2015	1980	2068	2090	2038	2458
2013	3085	2383	1814	2308	2248	2339	2362	2370	2348	2659
2014	-	2738	2222	2667	2572	2725	2687	2691	2719	3127
2015	-	3206	2720	3273	3103	3176	3019	3042	3107	3767
2016	-	-	3174	4116	3885	3606	3390	3456	3567	4857
2017	-	-	-	-	5294	4097	3915	4047	4190	6867
2018	-	-	-	-	-	4777	4821	5078	5264	9747
2019	-	-	-	-	-	-	6188	6673	6956	12041
2020	-	-	-	-	-	-	-	8273	8740	12802
2021	-	-	-	-	-	-	-	-	9960	13547
2022	-	-	-	-	-	-	-	-	-	14289

Table A10.28. Estimated begin-year numbers at age (Model *h_1.02*; single-stock hypothesis).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	5771.73	4671.65	3822.52	3129.81	2546.08	2054.31	1647.14	1311.23	1035.26	811.09	631.2	2543.37
1971	5377.5	4360.77	3525.02	2876.82	2341.76	1882.11	1508.53	1223.52	982.33	778.16	609.7	2386.32
1972	4958.65	4062.13	3287.4	2646.38	2139.98	1710.43	1361.01	1110.27	912.33	736.22	583.25	2245.59
1973	4433.17	3745.56	3062.18	2467.74	1972.27	1583.61	1261.69	1013.22	831.89	685.29	553.09	2125.2
1974	4500.37	3346.95	2817.72	2285.36	1817.97	1442.01	1154.83	932.79	756.18	623.2	513.52	2006.95
1975	5846.29	3393.3	2509.91	2077.7	1633.26	1283.52	1012.33	834.68	687.48	561.59	462.93	1872.29
1976	7300.93	4410.53	2542.53	1854.42	1496.14	1137.53	879.49	720.9	611.15	508.91	415.92	1729.48
1977	10829	5502.41	3288.47	1854.91	1302.21	1004.27	747.68	610.49	520.4	448.07	373.41	1574.17
1978	13584	8092.14	4018.65	2219.42	1095.21	796.58	631.45	504.51	428.73	371.34	320.09	1391.32
1979	14113.3	10149.8	5867.29	2686.09	1290.2	610.21	437.64	390.87	337.44	295.38	256.32	1181.32
1980	14697.2	10534	7330.1	3915.75	1573.8	714.72	328.23	257.39	240.58	209.37	183.7	894.1
1981	17152.4	10962.2	7591.7	4869.21	2288.62	894.2	400.81	196.53	158.02	147.5	128.7	662.56
1982	19827.8	12740.3	7657.37	4665.36	2564.23	1125.8	428.1	210.72	107.2	85.99	80.72	433.03
1983	27563.5	14623.4	8680.55	4571.48	2285.65	975.17	368.3	162.53	84.66	42.47	34.3	204.93
1984	20854.3	20330	10194.5	5501.8	2552.04	1136.19	431.88	151.73	59.09	27.97	14.1	79.43
1985	24765.5	15159.8	13368.2	6326.95	2871.56	977.2	336.61	122.56	39.75	14.46	6.88	23.02
1986	55243.2	18156.9	10321	8453.62	3480.79	1256.77	358.55	118.56	41.25	13.02	4.76	9.85
1987	51806.6	40836.9	12933.7	6864.83	5146.85	1789.98	544.29	150.88	47.51	16.02	5.05	5.67
1988	25731.2	38022.1	27938	8636.12	4261.79	2654.19	753.9	223.46	60.58	18.5	6.13	4.1
1989	15289.8	18773	26112.5	18216.8	5434.29	2482.39	1355.91	339.56	90.35	22.32	6.42	3.55
1990	17285.3	11268.8	13214.4	16778.4	11150.5	3273.84	1396.69	671.4	142.67	32.25	7.14	3.19
1991	22671.6	12793.5	8125.97	9032.83	10538.6	6564.27	1787.15	686.38	296.22	53.36	10.6	3.4
1992	25305.6	16766.1	9151.31	5609.24	5847.1	6193.34	3383.58	786.03	255.54	96.18	16.15	4.24
1993	14500.6	18722.3	11909.5	6218.14	3637.94	3619.62	3293.37	1382.3	211.48	55.43	24.27	5.15
1994	15774.3	10581.4	12653.2	7735.46	3853.49	2157.11	2023.37	1505.43	407.33	44.88	12.56	6.67
1995	14854.3	11526.1	7182.93	7848.01	4440.73	2047.11	1031.07	713.96	365.06	78.78	8.53	3.66
1996	15055.9	10705.4	6812.28	3501.95	3386.18	1772.38	793.91	301.05	144.83	53.49	9.8	1.52
1997	17642.8	10467.7	5680.93	2742.28	1293.59	1259.71	625.8	230.57	67.42	25.01	7.92	1.68
1998	17300.4	12304.2	4641.88	1732.15	939.97	507.55	467.82	184.65	52.45	11.96	3.87	1.49
1999	22025.8	12334	6045.69	1947.11	827.74	492.02	257.23	208.28	70.16	16.99	3.48	1.56
2000	20678.7	15771.5	7122.05	3322.12	1137.29	508	299.71	146.39	107.12	32.14	7.12	2.11
2001	20570.8	14925.4	9714.36	3960.59	2020.95	734.37	329.91	187.77	86.27	59.36	17.04	4.9
2002	18555.1	14381.7	8614.1	4471.56	2155.55	1217.04	448.29	193.2	102.98	44.59	29.78	11.01
2003	11286.6	13427.9	9219.72	5108.04	2610.22	1302.3	736.65	258.17	103.39	52.13	22.12	20.23
2004	10172.5	8093.3	8519.27	5523.73	2967.12	1574.77	794.15	430.45	140.31	53.25	26.33	21.39
2005	10989.1	7300.7	5125.47	5034.86	3111.58	1723.44	927.2	449.72	230.06	71.76	26.75	23.98
2006	6272.8	7752.11	4727.51	3104.08	2761.11	1719.23	981.4	514.34	238.34	118.84	36.92	26.1
2007	2127.24	4410.88	4793.51	2719.9	1649.51	1353	868.44	480.38	244.21	114.91	59.75	31.69
2008	5786.18	1418.69	2511.79	2489.14	1361.05	765.15	584.64	360.27	189.78	103.07	52.64	41.89
2009	9198.5	3648.79	745.1	1264.09	1142.87	596.92	331.16	254.1	153.85	84.37	49.25	45.17
2010	5379.48	6269.99	1980.09	371.33	479.33	381.29	198.19	115.11	93.68	63.56	37.81	42.32
2011	4432.69	3602.71	3524.87	1091.16	183.48	215.12	174.83	84.16	53.96	49.96	35.7	45
2012	4015.22	3172.7	2483.22	1915.14	598.51	96.06	116.95	92.99	49.68	33.74	32.14	51.92
2013	4332.18	2975.76	2276.21	1570.96	1140.86	338.16	57.78	73.67	60.72	33.04	22.6	56.32
2014	7372.45	3207.58	2121.74	1517.72	982.18	742.29	223.64	38.15	48.74	40.19	21.86	52.21
2015	7734.99	5463.35	2303.92	1431.79	989.97	646.23	495.21	148.66	24.82	31.18	25.54	47.06
2016	13846.5	5755.13	3865.62	1597.04	981.22	662.7	429.22	327.72	94.91	15.08	18.54	43.17
2017	21923	10390.1	4198.62	2723.12	1085.4	652.1	439.4	284.91	213.64	59.67	9.27	37.92
2018	27908.7	16412.8	7644.81	3025.3	1908.2	722.89	423.3	283.15	181.67	134.06	37.14	29.37
2019	16711	20956.9	12210.6	5517.65	2126.24	1291.11	472.93	270.3	178.35	113.99	83.92	41.63
2020	6825.92	12575.9	15668.6	8900.14	3935.48	1449.47	853.27	300.36	169.12	113.19	73.16	80.58
2021	15997.1	5142.27	9423.72	11618.8	6464.07	2779.27	967.19	546.9	188.03	108.51	74.21	100.81
2022	9709.52	12021.5	3835.35	6959.25	8485.88	4624.36	1920.77	633.86	347.27	118.29	69.3	111.77

Table A10.29. Estimated begin-year numbers at age (Model *h_2.02*; two-stock hypothesis; southern stock).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	5888.22	4756.58	3876.92	3154.7	2546.28	2037.51	1620.42	1279.65	1002.83	780.55	604.05	2263.64
1971	5480.5	4448.61	3587.55	2915.05	2356.9	1878.61	1496.89	1205.1	959.24	753.96	586.87	2156.11
1972	5064.62	4139.79	3351.6	2690.12	2164.7	1717.23	1360.01	1103.97	899.55	719.27	565.37	2056.88
1973	4507.86	3826.01	3120.07	2516.7	2008.7	1602.75	1268.79	1014.26	828.13	676.21	540.73	1971.36
1974	4410.14	3404.49	2878.29	2333.19	1866.44	1473.17	1173	941.15	758.78	621.52	507.59	1885.69
1975	5600.39	3329.97	2558.74	2146.08	1714.24	1335.21	1045.18	855.1	698.21	566.63	464.19	1787.45
1976	7051.41	4226.12	2493.02	1890.87	1552	1196.02	922.37	750.2	629.06	518.43	420.84	1672.32
1977	9490.49	5316.65	3147.23	1820.07	1338.17	1046.21	796.38	648.06	545.56	463.43	382.11	1542.77
1978	12156.5	7152.36	3946.35	2281.91	1276.96	897.59	695.64	558.72	470.4	401.11	340.95	1416.16
1979	12787.7	9141.88	5243.42	2779.08	1512.99	774.05	532.2	455.12	388.47	334.12	285.19	1249.32
1980	13296.4	9599.65	6665.43	3656.04	1822.7	914.41	455.76	335.53	294.24	249.96	215.26	988.61
1981	14760.1	9979.78	6992.42	4645.03	2414.98	1135.78	560.4	292.54	217.15	188.02	159.95	770.36
1982	16120.9	11013.6	7022.9	4524.13	2744.86	1324.03	616.18	326.68	172.49	125.51	109	539.3
1983	27246.3	11934.8	7507.15	4231.97	2332.66	1175.65	531.14	279.72	149.26	75.01	54.78	282.98
1984	22956.1	20176	8325.95	4809.99	2471.78	1253.99	591.29	249.37	111.69	51.8	26.11	117.57
1985	24039.9	16760.1	13350.4	5263.33	2620.62	1019.6	430.66	191.44	67.21	25.49	11.86	32.89
1986	55124.1	17641.9	11475.3	8500.69	2924.07	1166.4	396.26	157.33	60.67	19.18	7.29	12.8
1987	50004.1	40730	12566.3	7680.62	5217.43	1491.99	508.39	165.1	57.74	20.31	6.4	6.7
1988	22568.7	36653.3	27826.2	8427.92	4814.49	2707.76	629.11	207.59	63.09	20.58	7.12	4.59
1989	13072.4	16430.8	25153.5	18383.7	5429.34	2871.95	1402.94	283.48	82.32	22.43	6.95	3.95
1990	17439.4	9624.65	11562.3	16272	11511.3	3339.33	1637.99	697.73	118.17	29.02	7.2	3.5
1991	21836.8	12905.6	6947.49	7964.69	10513.5	6934.7	1849.83	814.47	308.12	44.09	9.72	3.58
1992	23917.5	16143.2	9237.73	4823.9	5254.81	6291.91	3647.39	828.41	309.85	102.98	14.02	4.23
1993	14378.9	17677.4	11452.8	6305.92	3161.56	3274.31	3403.39	1543.07	235.06	72.91	28.46	5.04
1994	14674.5	10474.5	11917.2	7521.92	3969.79	1887.12	1841.15	1593.5	484.67	55.12	18.49	8.49
1995	11531.2	10691.4	7094.77	7492.25	4427.09	2141.38	902.56	650.49	403.89	103.15	11.77	5.76
1996	13400.5	8261.03	6241.31	3685.45	3507.32	1857.39	859.27	271.78	139.3	65.62	14.68	2.49
1997	14556.7	9215.41	4180.31	2737.2	1547.36	1436.41	712.22	272.34	66.77	26.61	10.74	2.81
1998	15230.2	10088.5	4028.68	1638.71	1185.33	711.08	616.81	247.64	73.53	13.83	4.66	2.37
1999	17216.9	10847.4	5027.22	2123.55	921.21	695.24	402.52	313.54	108.78	27.12	4.44	2.26
2000	19270.7	12246.7	6226.66	2986.68	1319.81	593.74	446.04	244.55	174.1	53.32	11.82	2.92
2001	19863.8	13872.2	7467.63	3749.9	1903.71	880.53	397.42	289.41	149.71	99.39	28.61	7.91
2002	18409.2	13919.6	8294.3	4294.52	2270.31	1217.54	565.53	245.61	167.66	80.92	51.29	18.84
2003	12033	13338.1	8978.26	5118.55	2601	1415.88	759.72	337.21	136.04	86.83	40.34	34.96
2004	7346.12	8641.88	8597.94	5593.8	3103.44	1622.05	889.44	458.35	189.36	71.56	44.11	38.25
2005	8384.09	5248.24	5546.11	5280.5	3294.03	1864.31	980.96	516.82	250.26	97.72	35.74	41.14
2006	5301.28	5836.03	3352.43	3414.18	3000.05	1880.57	1088.34	555.19	277.46	129	49.46	38.92
2007	2435.93	3703.01	3609.91	2071.69	1935.11	1567.97	995.26	550.56	268.61	133.6	63.83	43.73
2008	5876.38	1617.75	2086.47	2041.27	1127.14	956	725.48	437.64	226.19	114.47	60.59	48.77
2009	5038.92	3657.21	863.92	1143.19	1014.6	519.08	436.27	333.83	196.57	103.16	54.89	52.44
2010	3832.12	3327.76	1955.46	447.36	465.83	354.01	180.41	162	133.34	85.44	47.2	49.1
2011	4056.03	2451.4	1616.82	1028.52	220.23	211.34	162.37	76.59	77.47	71.93	47.94	54.03
2012	4184.03	2883.99	1713.37	1091.87	617.5	121.31	116.82	86.59	45.94	49.71	47.37	67.16
2013	4889.8	3102.24	2084.52	1171.47	683.48	351.75	73.4	73.77	56.95	30.97	33.88	78.05
2014	8193.03	3622.18	2218.85	1417.39	740.54	431.47	228.97	48.16	48.92	38.15	20.9	75.51
2015	8490.65	6074.33	2620.79	1556.81	954.4	478.06	278.14	149.45	31.19	31.66	24.86	62.82
2016	11306.1	6314.96	4328.95	1851.24	1078.24	635.24	308.9	177.75	93.51	19.09	19.43	53.81
2017	14976.4	8474.37	4616.12	3083.84	1273.53	719.88	416.45	199.93	112.94	58.65	11.98	45.97
2018	22887.6	11179.9	6210.42	3332.59	2172.77	854.76	467.19	264.4	124.44	69.73	36.67	36.23
2019	16004.1	17167.1	8306.03	4510.82	2358.03	1484.76	564.82	298.72	164.56	76.79	43.39	45.37
2020	6817.61	12043	12843.3	6128.04	3241.2	1620.22	994.87	364.38	188.28	104	48.97	56.6
2021	15853	5136.43	9028.46	9566.44	4486.19	2279.49	1087.4	649.46	232.93	121.98	68.16	69.2
2022	9467.07	11913.7	3831.12	6672.22	7016.09	3184.12	1556.35	718.83	421.1	148.62	77.92	87.75

Table A10.30. Estimated begin-year numbers at age (Model *h2_1.02*; two-stock hypothesis; far north stock).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	2291.59	1553.02	1121.54	809.21	583.7	420.82	303.23	218.43	157.29	113.23	81.49	225.55
1971	2277.02	1647.44	1116.2	804.26	578.47	418.84	302.43	217.98	157.02	113.07	81.4	220.72
1972	2257.58	1636.93	1183.75	798.47	571.8	414.34	300.91	217.39	156.68	112.86	81.28	217.16
1973	2233.27	1622.86	1175.32	840.94	558.95	407.45	297.39	216.24	156.22	112.59	81.11	214.46
1974	2228.55	1605.19	1163.46	823.31	570.5	394.16	291.88	213.6	155.31	112.2	80.87	212.29
1975	2228.64	1600.99	1143.61	768.97	490.52	385.28	280.11	209.21	153.1	111.32	80.42	210.13
1976	2189.43	1601.86	1147.75	800.92	521.42	345.84	275.99	201.19	150.27	109.97	79.96	208.69
1977	3174.18	1573.56	1147.3	796.88	532.67	365.27	247.45	198.17	144.46	107.9	78.96	207.26
1978	2370.14	2272.51	1074.36	510.52	196.18	268.02	245.85	174.87	140.05	102.09	76.25	202.27
1979	2041.86	1695.8	1539.39	444.28	106.7	93.47	178.59	173.29	123.26	98.71	71.96	196.32
1980	1613.05	1462.12	1160.53	700.04	114.82	54.56	63.1	126.31	122.56	87.18	69.82	189.74
1981	2522.06	1153.98	989.03	473.62	142.06	54.17	36.29	44.46	88.99	86.35	61.42	182.86
1982	2933.83	1799.01	752.74	287.99	45.22	52.14	34.4	25.26	30.95	61.94	60.1	170.04
1983	1674.35	2103.39	1249.81	393.64	101.69	25.65	35.88	24.45	17.96	22	44.03	163.58
1984	817.09	1201.93	1484.37	756.18	192.51	64.3	18.01	25.64	17.47	12.83	15.72	148.34
1985	1939.89	586.55	848.22	898.22	369.94	121.75	45.15	12.87	18.32	12.48	9.17	117.22
1986	3007.03	1393.55	417.65	557.7	528.94	248.86	86.46	32.35	9.22	13.13	8.95	90.57
1987	4342.88	2160.85	996.23	284.93	356.65	365.73	177.63	62.04	23.22	6.62	9.42	71.41
1988	3093.21	3120.52	1543.2	673.32	178.45	244.9	260.71	127.42	44.51	16.65	4.75	57.98
1989	2018.62	2219.48	2190.21	887.6	294.08	108.67	170.75	185.94	90.88	31.74	11.88	44.74
1990	1104.95	1448.7	1561.36	1286.81	406.53	181.95	75.99	121.87	132.72	64.86	22.66	40.41
1991	1904.37	792.86	1017.15	900.88	566.02	248.16	126.92	54.21	86.93	94.67	46.27	44.99
1992	2139.39	1367.15	560.02	620.47	448.73	360.12	174.43	90.71	38.74	62.13	67.66	65.22
1993	1603.98	1536.58	971.18	360.24	347.96	296.99	254.97	124.9	64.95	27.74	44.49	95.15
1994	2111.59	1151.52	1085.56	593.62	180.24	221.71	208.81	182.25	89.28	46.43	19.83	99.81
1995	4290.97	1514.89	806.62	612.94	248.79	108.27	154.19	148.83	129.9	63.63	33.09	85.27
1996	2364.22	3059.44	982.77	223.22	52.23	87.92	68.27	107.13	103.41	90.25	44.21	82.24
1997	2701.34	1674.94	1833.52	130.17	3.67	10.67	50.1	46.2	72.5	69.98	61.08	85.58
1998	2084.76	1897	899.95	88.02	0.22	0.35	5.29	32.7	30.15	47.32	45.67	95.72
1999	4921.81	1449.54	901.09	13.74	0.01	0.01	0.15	3.31	20.49	18.89	29.65	88.58
2000	2202.23	3506.19	930.35	225.7	0.94	0	0.01	0.1	2.29	14.18	13.08	81.85
2001	1610.53	1571.43	2297.23	282.26	23.62	0.35	0	0	0.07	1.6	9.89	66.18
2002	1232.05	1131.94	853.19	121.51	0.6	2.44	0.18	0	0	0.05	1.05	49.81
2003	326.8	882.8	729.71	339.32	44.66	0.29	1.64	0.13	0	0	0.03	36
2004	2093.12	234.1	564.76	278.38	118.99	21.08	0.19	1.16	0.09	0	0	25.48
2005	1748.61	1499.34	149.45	213	96.36	55.72	14.11	0.14	0.82	0.06	0	18.01
2006	885.85	1254.56	1008.43	74.83	101.63	54.47	38.49	10.05	0.1	0.58	0.04	12.83
2007	158.1	633.56	761.08	288.36	18.93	39.59	35.36	27.01	7.05	0.07	0.41	9.03
2008	257.17	113.05	382.18	211.03	70.44	7.22	25.62	24.8	18.94	4.94	0.05	6.62
2009	2775.09	183.91	68.34	107.22	52.24	27.1	4.68	17.97	17.39	13.28	3.47	4.68
2010	1062.39	1984.22	110.6	18.64	25.71	19.72	17.5	3.28	12.6	12.19	9.31	5.71
2011	530.92	762.82	1368.91	63.57	10.4	15.93	13.83	12.51	2.34	9	8.71	10.74
2012	397.92	379.44	452.24	345.48	13.96	3.73	10.2	9.68	8.75	1.64	6.3	13.61
2013	348.6	284.93	239.43	160.12	111.33	6.27	2.48	7.2	6.83	6.17	1.16	14.05
2014	560	250.05	190.37	115.62	73.34	61.44	4.31	1.76	5.12	4.86	4.39	10.82
2015	506.93	401.46	163.83	82.67	46.95	37.71	41.77	3.06	1.25	3.63	3.45	10.79
2016	1947.41	364.09	279.57	99.07	48.86	30.09	26.6	29.9	2.19	0.9	2.6	10.19
2017	4008.36	1399.36	257.67	184.54	64.66	33.19	21.43	19.08	21.44	1.57	0.64	9.17
2018	3646.11	2881.14	999.68	178.98	127.6	45.44	23.77	15.39	13.71	15.4	1.13	7.05
2019	1068.62	2619.66	2029.98	644.18	113.67	85.3	32.27	17.04	11.03	9.82	11.04	5.86
2020	586.02	767.7	1839.38	1283.74	400.48	75.04	60.46	23.12	12.21	7.91	7.04	12.11
2021	800.81	421.08	542.5	1204.44	830.23	270.59	53.39	43.36	16.58	8.76	5.67	13.74
2022	1169.61	575.42	297.59	355.4	779.35	561.12	192.54	38.29	31.1	11.89	6.28	13.92

Table A10.31. Estimated total fishing mortality at age (Model h1_1.02; single-stock hypothesis).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0.002	0.004	0.01	0.022	0.029	0.017	0.009	0.005	0.005	0.005	0.005
1971	0.001	0.003	0.007	0.016	0.034	0.044	0.027	0.013	0.008	0.008	0.008	0.008
1972	0.001	0.003	0.007	0.014	0.021	0.024	0.015	0.009	0.006	0.006	0.006	0.006
1973	0.001	0.005	0.013	0.026	0.033	0.036	0.022	0.013	0.009	0.009	0.009	0.009
1974	0.002	0.008	0.025	0.056	0.068	0.074	0.045	0.025	0.018	0.017	0.017	0.017
1975	0.002	0.009	0.023	0.048	0.082	0.098	0.06	0.032	0.021	0.02	0.02	0.02
1976	0.003	0.014	0.035	0.074	0.119	0.14	0.085	0.046	0.03	0.03	0.03	0.03
1977	0.011	0.034	0.113	0.247	0.211	0.184	0.113	0.073	0.057	0.056	0.056	0.056
1978	0.011	0.042	0.123	0.262	0.305	0.319	0.2	0.122	0.093	0.091	0.091	0.091
1979	0.013	0.045	0.124	0.255	0.311	0.34	0.251	0.205	0.197	0.195	0.195	0.195
1980	0.013	0.048	0.129	0.257	0.285	0.298	0.233	0.208	0.209	0.207	0.207	0.207
1981	0.017	0.079	0.207	0.361	0.429	0.457	0.363	0.326	0.328	0.323	0.323	0.323
1982	0.024	0.104	0.236	0.434	0.687	0.837	0.688	0.632	0.646	0.639	0.639	0.639
1983	0.024	0.081	0.176	0.303	0.419	0.534	0.607	0.732	0.828	0.823	0.823	0.823
1984	0.039	0.139	0.197	0.37	0.68	0.937	0.98	1.059	1.128	1.122	1.122	1.122
1985	0.03	0.104	0.178	0.318	0.546	0.723	0.763	0.809	0.836	0.831	0.831	0.831
1986	0.022	0.059	0.128	0.216	0.385	0.557	0.586	0.634	0.666	0.666	0.666	0.666
1987	0.029	0.1	0.124	0.197	0.382	0.585	0.61	0.632	0.663	0.681	0.681	0.681
1988	0.035	0.096	0.148	0.183	0.26	0.392	0.518	0.626	0.718	0.778	0.778	0.778
1989	0.025	0.071	0.162	0.211	0.227	0.295	0.423	0.587	0.75	0.86	0.86	0.86
1990	0.021	0.047	0.1	0.185	0.25	0.325	0.43	0.538	0.703	0.832	0.832	0.832
1991	0.022	0.055	0.091	0.155	0.252	0.383	0.541	0.708	0.845	0.915	0.915	0.915
1992	0.021	0.062	0.106	0.153	0.2	0.352	0.615	1.033	1.248	1.097	1.097	1.097
1993	0.035	0.112	0.152	0.198	0.243	0.302	0.503	0.942	1.27	1.205	1.205	1.205
1994	0.034	0.107	0.198	0.275	0.353	0.458	0.762	1.137	1.363	1.38	1.38	1.38
1995	0.048	0.246	0.438	0.561	0.638	0.667	0.951	1.315	1.641	1.804	1.804	1.804
1996	0.083	0.354	0.63	0.716	0.709	0.761	0.956	1.216	1.476	1.63	1.63	1.63
1997	0.08	0.533	0.908	0.791	0.656	0.711	0.941	1.201	1.45	1.585	1.585	1.585
1998	0.058	0.431	0.589	0.458	0.367	0.4	0.529	0.688	0.847	0.954	0.954	0.954
1999	0.054	0.269	0.319	0.258	0.208	0.216	0.284	0.385	0.501	0.589	0.589	0.589
2000	0.046	0.205	0.307	0.217	0.157	0.152	0.188	0.249	0.31	0.354	0.354	0.354
2001	0.078	0.27	0.496	0.328	0.227	0.214	0.255	0.321	0.38	0.41	0.41	0.41
2002	0.043	0.165	0.243	0.258	0.224	0.222	0.272	0.345	0.401	0.421	0.421	0.421
2003	0.053	0.175	0.232	0.263	0.225	0.215	0.257	0.33	0.384	0.403	0.403	0.403
2004	0.052	0.177	0.246	0.294	0.263	0.25	0.289	0.346	0.391	0.408	0.408	0.408
2005	0.069	0.155	0.222	0.321	0.313	0.283	0.309	0.355	0.381	0.384	0.384	0.384
2006	0.072	0.201	0.273	0.352	0.433	0.403	0.434	0.465	0.45	0.408	0.408	0.408
2007	0.125	0.283	0.375	0.412	0.488	0.559	0.6	0.649	0.583	0.501	0.501	0.501
2008	0.181	0.364	0.407	0.498	0.544	0.557	0.553	0.571	0.531	0.458	0.458	0.458
2009	0.103	0.331	0.416	0.69	0.818	0.823	0.777	0.718	0.604	0.523	0.523	0.523
2010	0.121	0.296	0.316	0.425	0.521	0.5	0.577	0.478	0.349	0.297	0.297	0.297
2011	0.054	0.092	0.33	0.321	0.367	0.329	0.351	0.247	0.19	0.161	0.161	0.161
2012	0.02	0.052	0.178	0.238	0.291	0.228	0.182	0.146	0.128	0.12	0.12	0.12
2013	0.021	0.058	0.125	0.19	0.15	0.133	0.135	0.133	0.133	0.133	0.133	0.133
2014	0.02	0.051	0.113	0.147	0.139	0.125	0.128	0.15	0.167	0.174	0.174	0.174
2015	0.016	0.066	0.086	0.098	0.121	0.129	0.133	0.169	0.218	0.24	0.24	0.24
2016	0.007	0.035	0.07	0.106	0.129	0.131	0.13	0.148	0.184	0.207	0.207	0.207
2017	0.009	0.027	0.048	0.076	0.126	0.152	0.159	0.17	0.186	0.194	0.194	0.194
2018	0.006	0.016	0.046	0.073	0.111	0.144	0.169	0.182	0.186	0.188	0.188	0.188
2019	0.004	0.011	0.036	0.058	0.103	0.134	0.174	0.189	0.175	0.163	0.163	0.163
2020	0.003	0.009	0.019	0.04	0.068	0.125	0.165	0.188	0.164	0.142	0.142	0.142
2021	0.006	0.013	0.023	0.034	0.055	0.089	0.143	0.174	0.183	0.168	0.168	0.168
2022	0.008	0.018	0.023	0.042	0.063	0.084	0.125	0.166	0.184	0.179	0.179	0.179

Table A10.32. Estimated total fishing mortality at age (Model *h2_1.02*; two-stock hypothesis; southern stock).

Age group (years)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	0.000361	0.00206	0.00515	0.0115	0.0241	0.0283	0.0161	0.0082	0.00524	0.0052	0.0052	0.0052
1971	0.000552	0.00315	0.00788	0.0176	0.0366	0.043	0.0245	0.0124	0.00791	0.00785	0.00785	0.00785
1972	0.000455	0.00279	0.00649	0.0121	0.0206	0.0226	0.0133	0.0075	0.0054	0.00531	0.00531	0.00531
1973	0.000728	0.00463	0.0106	0.0189	0.0301	0.0322	0.0187	0.0102	0.00699	0.00682	0.00682	0.00682
1974	0.000942	0.00558	0.0136	0.0283	0.0549	0.0632	0.0361	0.0186	0.012	0.0119	0.0119	0.0119
1975	0.00155	0.00947	0.0225	0.0441	0.08	0.0899	0.0516	0.027	0.0177	0.0174	0.0174	0.0174
1976	0.00238	0.0148	0.0346	0.0657	0.114	0.127	0.073	0.0385	0.0256	0.0251	0.0251	0.0251
1977	0.00285	0.0181	0.0415	0.0744	0.119	0.128	0.0744	0.0404	0.0276	0.0269	0.0269	0.0269
1978	0.005	0.0305	0.0707	0.131	0.221	0.243	0.144	0.0834	0.0621	0.0611	0.0611	0.0611
1979	0.00676	0.0359	0.0806	0.142	0.224	0.25	0.181	0.156	0.161	0.16	0.16	0.16
1980	0.00693	0.0369	0.0811	0.135	0.193	0.21	0.163	0.155	0.168	0.166	0.166	0.166
1981	0.0128	0.0714	0.155	0.246	0.321	0.332	0.26	0.248	0.268	0.265	0.265	0.265
1982	0.0207	0.103	0.227	0.382	0.568	0.633	0.51	0.503	0.553	0.549	0.549	0.549
1983	0.0204	0.0801	0.165	0.258	0.341	0.407	0.476	0.638	0.778	0.775	0.775	0.775
1984	0.0346	0.133	0.179	0.327	0.606	0.789	0.848	1.03	1.2	1.19	1.19	1.19
1985	0.0294	0.0988	0.171	0.308	0.529	0.665	0.727	0.869	0.974	0.972	0.972	0.972
1986	0.0226	0.0593	0.121	0.208	0.393	0.55	0.596	0.722	0.815	0.817	0.817	0.817
1987	0.0306	0.101	0.119	0.187	0.376	0.584	0.616	0.682	0.752	0.768	0.768	0.768
1988	0.0374	0.0965	0.135	0.16	0.237	0.378	0.517	0.645	0.754	0.806	0.806	0.806
1989	0.0262	0.0714	0.156	0.188	0.206	0.282	0.418	0.595	0.763	0.857	0.857	0.857
1990	0.0211	0.0459	0.0927	0.157	0.227	0.311	0.419	0.537	0.706	0.814	0.814	0.814
1991	0.0221	0.0544	0.0848	0.136	0.233	0.363	0.523	0.686	0.816	0.866	0.866	0.866
1992	0.0223	0.0633	0.102	0.143	0.193	0.334	0.58	0.98	1.17	1.01	1.01	1.01
1993	0.0368	0.114	0.14	0.183	0.236	0.296	0.479	0.878	1.17	1.09	1.09	1.09
1994	0.0367	0.11	0.184	0.25	0.337	0.458	0.76	1.09	1.27	1.26	1.26	1.26
1995	0.0535	0.258	0.375	0.479	0.589	0.633	0.92	1.26	1.54	1.67	1.67	1.67
1996	0.0944	0.401	0.544	0.588	0.613	0.679	0.869	1.12	1.38	1.53	1.53	1.53
1997	0.0866	0.547	0.656	0.557	0.498	0.565	0.776	1.03	1.29	1.46	1.46	1.46
1998	0.0594	0.417	0.36	0.296	0.254	0.289	0.397	0.543	0.717	0.857	0.857	0.857
1999	0.0606	0.275	0.241	0.196	0.159	0.164	0.218	0.308	0.433	0.551	0.551	0.551
2000	0.0487	0.215	0.227	0.17	0.125	0.121	0.153	0.211	0.281	0.343	0.343	0.343
2001	0.0756	0.234	0.273	0.222	0.167	0.163	0.201	0.266	0.335	0.382	0.382	0.382
2002	0.0422	0.158	0.203	0.221	0.192	0.192	0.237	0.311	0.378	0.416	0.416	0.416
2003	0.051	0.159	0.193	0.22	0.192	0.185	0.225	0.297	0.362	0.397	0.397	0.397
2004	0.0563	0.164	0.208	0.25	0.23	0.223	0.263	0.325	0.382	0.414	0.414	0.414
2005	0.0823	0.168	0.205	0.285	0.281	0.258	0.289	0.342	0.383	0.401	0.401	0.401
2006	0.0788	0.2	0.201	0.288	0.369	0.356	0.401	0.446	0.451	0.424	0.424	0.424
2007	0.129	0.294	0.29	0.329	0.425	0.491	0.542	0.61	0.573	0.511	0.511	0.511
2008	0.194	0.347	0.322	0.419	0.495	0.505	0.496	0.52	0.505	0.455	0.455	0.455
2009	0.135	0.346	0.378	0.618	0.773	0.777	0.711	0.638	0.553	0.502	0.502	0.502
2010	0.167	0.442	0.363	0.429	0.51	0.499	0.577	0.458	0.337	0.298	0.298	0.298
2011	0.061	0.0782	0.113	0.23	0.316	0.313	0.349	0.231	0.164	0.138	0.138	0.138
2012	0.0192	0.0446	0.1	0.188	0.283	0.222	0.18	0.139	0.114	0.104	0.104	0.104
2013	0.0201	0.0551	0.106	0.179	0.18	0.149	0.142	0.131	0.121	0.114	0.114	0.114
2014	0.0192	0.0436	0.0743	0.115	0.158	0.159	0.147	0.154	0.155	0.148	0.148	0.148
2015	0.016	0.0587	0.0676	0.0873	0.127	0.157	0.168	0.189	0.211	0.208	0.208	0.208
2016	0.00829	0.0334	0.0591	0.0941	0.124	0.142	0.155	0.174	0.186	0.186	0.186	0.186
2017	0.0124	0.0308	0.0458	0.0702	0.119	0.152	0.174	0.194	0.202	0.19	0.19	0.19
2018	0.0076	0.0171	0.0398	0.0659	0.101	0.134	0.167	0.194	0.203	0.194	0.194	0.194
2019	0.00436	0.0102	0.0241	0.0505	0.0953	0.12	0.158	0.182	0.179	0.17	0.17	0.17
2020	0.00315	0.00811	0.0146	0.0319	0.072	0.119	0.146	0.167	0.154	0.142	0.142	0.142
2021	0.00567	0.0132	0.0224	0.0301	0.0628	0.102	0.134	0.153	0.169	0.168	0.168	0.168
2022	0.00781	0.0177	0.0218	0.0356	0.0649	0.0997	0.128	0.15	0.168	0.174	0.174	0.174

Table A10.33. Estimated total fishing mortality at age (Model *h2_1.02*; two-stock hypothesis; far north stock).

Age group (years)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	2.2e-05	0.000273	0.00254	0.00567	0.00189	0.000349	9.07e-05	9.07e-05	9.07e-05	9.07e-05	9.07e-05	9.07e-05
1971	4.32e-05	0.000536	0.00498	0.0111	0.00371	0.000685	0.000178	0.000178	0.000178	0.000178	0.000178	0.000178
1972	0.000103	0.00128	0.0119	0.0266	0.00887	0.00164	0.000426	0.000426	0.000426	0.000426	0.000426	0.000426
1973	0.000225	0.00279	0.026	0.058	0.0193	0.00357	0.000928	0.000928	0.000928	0.000928	0.000928	0.000928
1974	0.000729	0.00905	0.0841	0.188	0.0626	0.0116	0.00301	0.00301	0.00301	0.00301	0.00301	0.00301
1975	0.000227	0.00282	0.0262	0.0585	0.0195	0.0036	0.000936	0.000936	0.000936	0.000936	0.000936	0.000936
1976	0.000302	0.00375	0.0349	0.0779	0.0259	0.00479	0.00125	0.00125	0.00125	0.00125	0.00125	0.00125
1977	0.00416	0.0516	0.48	1.07	0.357	0.0659	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171
1978	0.0048	0.0595	0.553	1.24	0.411	0.076	0.0198	0.0198	0.0198	0.0198	0.0198	0.0198
1979	0.00397	0.0493	0.458	1.02	0.341	0.0629	0.0164	0.0164	0.0164	0.0164	0.0164	0.0164
1980	0.00491	0.0609	0.566	1.26	0.421	0.0778	0.0202	0.0202	0.0202	0.0202	0.0202	0.0202
1981	0.00784	0.0972	0.904	2.02	0.672	0.124	0.0323	0.0323	0.0323	0.0323	0.0323	0.0323
1982	0.00276	0.0342	0.318	0.711	0.237	0.0437	0.0114	0.0114	0.0114	0.0114	0.0114	0.0114
1983	0.0015	0.0186	0.172	0.385	0.128	0.0237	0.00616	0.00616	0.00616	0.00616	0.00616	0.00616
1984	0.00149	0.0185	0.172	0.385	0.128	0.0237	0.00616	0.00616	0.00616	0.00616	0.00616	0.00616
1985	0.000775	0.00961	0.0893	0.2	0.0664	0.0123	0.00319	0.00319	0.00319	0.00319	0.00319	0.00319
1986	0.000454	0.00564	0.0524	0.117	0.039	0.0072	0.00187	0.00187	0.00187	0.00187	0.00187	0.00187
1987	0.000536	0.00664	0.0618	0.138	0.0459	0.00848	0.00221	0.00221	0.00221	0.00221	0.00221	0.00221
1988	0.00193	0.024	0.223	0.498	0.166	0.0306	0.00797	0.00797	0.00797	0.00797	0.00797	0.00797
1989	0.00175	0.0217	0.202	0.451	0.15	0.0277	0.00721	0.00721	0.00721	0.00721	0.00721	0.00721
1990	0.00191	0.0237	0.22	0.491	0.164	0.0302	0.00786	0.00786	0.00786	0.00786	0.00786	0.00786
1991	0.00142	0.0177	0.164	0.367	0.122	0.0226	0.00587	0.00587	0.00587	0.00587	0.00587	0.00587
1992	0.000964	0.012	0.111	0.248	0.0827	0.0153	0.00397	0.00397	0.00397	0.00397	0.00397	0.00397
1993	0.00141	0.0175	0.162	0.362	0.121	0.0223	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058
1994	0.0021	0.026	0.242	0.54	0.18	0.0332	0.00863	0.00863	0.00863	0.00863	0.00863	0.00863
1995	0.00828	0.103	0.955	2.13	0.71	0.131	0.0341	0.0341	0.0341	0.0341	0.0341	0.0341
1996	0.0147	0.182	1.69	3.78	1.26	0.232	0.0604	0.0604	0.0604	0.0604	0.0604	0.0604
1997	0.0235	0.291	2.71	6.05	2.01	0.372	0.0967	0.0967	0.0967	0.0967	0.0967	0.0967
1998	0.0334	0.414	3.85	8.6	2.87	0.529	0.138	0.138	0.138	0.138	0.138	0.138
1999	0.00915	0.113	1.05	2.36	0.784	0.145	0.0377	0.0377	0.0377	0.0377	0.0377	0.0377
2000	0.00748	0.0928	0.863	1.93	0.642	0.119	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308
2001	0.0226	0.281	2.61	5.83	1.94	0.358	0.0932	0.0932	0.0932	0.0932	0.0932	0.0932
2002	0.00333	0.109	0.592	0.671	0.393	0.0655	0.0155	0.0155	0.0155	0.0155	0.0155	0.0155
2003	0.00357	0.117	0.634	0.718	0.421	0.0701	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166
2004	0.00363	0.119	0.645	0.731	0.429	0.0713	0.0169	0.0169	0.0169	0.0169	0.0169	0.0169
2005	0.00204	0.0666	0.362	0.41	0.24	0.04	0.00947	0.00947	0.00947	0.00947	0.00947	0.00947
2006	0.00519	0.17	0.922	1.04	0.613	0.102	0.0241	0.0241	0.0241	0.0241	0.0241	0.0241
2007	0.00537	0.175	0.953	1.08	0.633	0.105	0.0249	0.0249	0.0249	0.0249	0.0249	0.0249
2008	0.0053	0.173	0.941	1.07	0.625	0.104	0.0246	0.0246	0.0246	0.0246	0.0246	0.0246
2009	0.00546	0.179	0.969	1.1	0.644	0.107	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254
2010	0.00126	0.0412	0.224	0.254	0.149	0.0247	0.00586	0.00586	0.00586	0.00586	0.00586	0.00586
2011	0.00589	0.193	1.05	1.19	0.696	0.116	0.0274	0.0274	0.0274	0.0274	0.0274	0.0274
2012	0.00399	0.13	0.708	0.802	0.471	0.0783	0.0185	0.0185	0.0185	0.0185	0.0185	0.0185
2013	0.00224	0.0733	0.398	0.451	0.264	0.044	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104
2014	0.00284	0.0928	0.504	0.571	0.335	0.0558	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132
2015	0.000974	0.0319	0.173	0.196	0.115	0.0191	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453
2016	0.000481	0.0157	0.0854	0.0967	0.0567	0.00944	0.00223	0.00223	0.00223	0.00223	0.00223	0.00223
2017	0.000194	0.00633	0.0344	0.039	0.0229	0.0038	9e-04	9e-04	9e-04	9e-04	9e-04	9e-04
2018	0.000616	0.0202	0.109	0.124	0.0727	0.0121	0.00287	0.00287	0.00287	0.00287	0.00287	0.00287
2019	0.000722	0.0236	0.128	0.145	0.0852	0.0142	0.00336	0.00336	0.00336	0.00336	0.00336	0.00336
2020	0.000526	0.0172	0.0934	0.106	0.0621	0.0103	0.00244	0.00244	0.00244	0.00244	0.00244	0.00244
2021	0.000523	0.0171	0.093	0.105	0.0618	0.0103	0.00243	0.00243	0.00243	0.00243	0.00243	0.00243
2022	0.00135	0.0442	0.24	0.272	0.16	0.0265	0.00628	0.00628	0.00628	0.00628	0.00628	0.00628

Table A10.34. Summary of results for Model *h1_1.02* (single-stock hypothesis). 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)	F_{MSY}	SSB_{MSY} ('000 t)
1970	118	14378	5772	0.01	0.2	7095
1971	169	13372	5378	0.01	0.2	7065
1972	111	12456	4959	0.01	0.18	7063
1973	165	11541	4433	0.02	0.18	6978
1974	324	10560	4500	0.03	0.18	6952
1975	300	9742	5846	0.04	0.19	7023
1976	397	9136	7301	0.05	0.19	6970
1977	848	8711	10829	0.1	0.16	7162
1978	1025	8562	13584	0.15	0.17	7086
1979	1302	8470	14113	0.19	0.2	7288
1980	1316	8560	14697	0.19	0.2	7327
1981	1945	8423	17152	0.29	0.2	7364
1982	2372	8033	19828	0.52	0.23	7669
1983	1870	9078	27564	0.51	0.27	8050
1984	2687	9507	20854	0.74	0.27	7948
1985	2371	10080	24766	0.57	0.27	7745
1986	2073	13579	55243	0.44	0.29	7755
1987	2680	18078	51807	0.45	0.27	7859
1988	3246	19862	25731	0.44	0.3	7994
1989	3582	18745	15290	0.44	0.34	7790
1990	3715	17271	17285	0.42	0.38	7615
1991	3778	16133	22672	0.48	0.44	7232
1992	3362	15260	25306	0.59	0.44	7998
1993	3371	13700	14501	0.61	0.32	8907
1994	4276	11132	15774	0.74	0.34	8248
1995	4956	8161	14854	0.99	0.25	8617
1996	4380	6003	15056	0.98	0.22	8349
1997	3598	4719	17643	1	0.2	8159
1998	2027	4814	17300	0.6	0.18	8752
1999	1424	5956	22026	0.36	0.19	8545
2000	1540	7308	20679	0.24	0.17	8081
2001	2528	7759	20571	0.32	0.16	7952
2002	1750	8442	18555	0.29	0.19	8268
2003	1797	8463	11287	0.28	0.18	8262
2004	1934	7815	10172	0.29	0.19	7781
2005	1755	7188	10989	0.3	0.19	7657
2006	2020	6049	6273	0.36	0.19	7517
2007	1997	4241	2127	0.46	0.19	7418
2008	1473	2986	5786	0.47	0.17	7524
2009	1283	2465	9198	0.57	0.19	7216
2010	727	2413	5379	0.37	0.16	7614
2011	635	2373	4433	0.23	0.16	7321
2012	455	2458	4015	0.15	0.17	7399
2013	353	2659	4332	0.12	0.17	7699
2014	411	3127	7372	0.13	0.19	7797
2015	394	3767	7735	0.15	0.24	7544
2016	389	4857	13846	0.13	0.25	7602
2017	405	6867	21923	0.13	0.25	7982
2018	526	9747	27909	0.12	0.24	8455
2019	632	12041	16711	0.11	0.28	7860
2020	707	12802	6826	0.1	0.31	8083
2021	808	13547	15997	0.1	0.36	7712
2022	929	14289	9710	0.1	0.36	7453

Table A10.35. Summary of results for Model *h2_1.02* (two-stock hypothesis; southern stock). 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)	F_{MSY}	SSB_{MSY} ('000 t)
1970	118	13851	5888	0.01	0.19	6215
1971	169	12985	5480	0.01	0.19	6211
1972	111	12191	5065	0.01	0.18	6181
1973	165	11388	4508	0.01	0.18	6114
1974	324	10535	4410	0.02	0.19	6180
1975	300	9766	5600	0.03	0.18	6153
1976	397	9181	7051	0.05	0.18	6138
1977	848	8950	9490	0.05	0.18	6115
1978	1025	8892	12156	0.1	0.18	6202
1979	1302	8824	12788	0.14	0.21	6585
1980	1316	8973	13296	0.14	0.21	6665
1981	1945	8825	14760	0.23	0.2	6630
1982	2372	8048	16121	0.43	0.22	6797
1983	1870	8817	27246	0.46	0.27	7245
1984	2687	9441	22956	0.73	0.28	7239
1985	2371	10146	24040	0.61	0.28	6998
1986	2073	13604	55124	0.49	0.31	6966
1987	2680	17988	50004	0.48	0.28	7027
1988	3246	19603	22569	0.45	0.3	7126
1989	3582	18341	13072	0.44	0.34	6937
1990	3715	16981	17439	0.41	0.38	6769
1991	3778	15951	21837	0.46	0.44	6431
1992	3362	14980	23918	0.55	0.41	7135
1993	3371	13381	14379	0.57	0.31	7857
1994	4276	10860	14674	0.69	0.33	7283
1995	4956	7930	11531	0.93	0.25	7663
1996	4380	5790	13400	0.91	0.22	7389
1997	3598	4686	14557	0.87	0.21	7305
1998	2027	4844	15230	0.49	0.18	7912
1999	1424	5695	17217	0.31	0.18	7612
2000	1540	6880	19271	0.21	0.18	7174
2001	2528	7828	19864	0.26	0.17	7199
2002	1750	8654	18409	0.27	0.19	7346
2003	1797	8858	12033	0.26	0.19	7375
2004	1934	8140	7346	0.28	0.2	6904
2005	1755	7170	8384	0.29	0.19	6800
2006	2020	5939	5301	0.34	0.2	6775
2007	1997	4271	2436	0.43	0.19	6647
2008	1473	3130	5876	0.43	0.17	6706
2009	1283	2305	5039	0.54	0.18	6387
2010	727	1893	3832	0.39	0.15	6683
2011	635	1933	4056	0.19	0.17	6678
2012	455	2157	4184	0.13	0.17	6654
2013	353	2464	4890	0.12	0.17	6693
2014	411	3057	8193	0.12	0.2	6716
2015	394	3824	8491	0.14	0.24	6596
2016	389	4794	11306	0.13	0.25	6627
2017	405	6140	14976	0.13	0.25	7043
2018	526	8257	22888	0.13	0.25	7590
2019	632	10307	16004	0.11	0.28	7244
2020	707	11149	6818	0.1	0.29	7427
2021	808	11927	15853	0.1	0.34	6892
2022	929	12681	9467	0.1	0.33	6859

Table A10.36. Summary of results for Model *h2_1.05* (two-stock hypothesis; far north stock). 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)	F_{MSY}	SSB_{MSY} ('000 t)
1970	118	3030	2292	0	0.1	958
1971	169	3011	2277	0	0.1	958
1972	111	2998	2258	0	0.1	968
1973	165	2971	2233	0.01	0.1	960
1974	324	2878	2229	0.03	0.1	959
1975	300	2828	2229	0.01	0.1	962
1976	397	2794	2189	0.01	0.1	953
1977	848	2397	3174	0.18	0.1	961
1978	1025	2029	2370	0.2	0.1	963
1979	1302	1807	2042	0.17	0.1	958
1980	1316	1490	1613	0.21	0.1	957
1981	1945	1125	2522	0.33	0.1	953
1982	2372	1014	2934	0.12	0.1	955
1983	1870	1093	1674	0.06	0.1	946
1984	2687	1189	817	0.06	0.1	951
1985	2371	1231	1940	0.03	0.1	955
1986	2073	1271	3007	0.02	0.1	953
1987	2680	1428	4343	0.02	0.1	959
1988	3246	1593	3093	0.08	0.1	956
1989	3582	1781	2019	0.07	0.1	953
1990	3715	1788	1105	0.08	0.1	953
1991	3778	1732	1904	0.06	0.1	954
1992	3362	1681	2139	0.04	0.1	954
1993	3371	1675	1604	0.06	0.1	957
1994	4276	1608	2112	0.09	0.1	962
1995	4956	1231	4291	0.35	0.1	957
1996	4380	975	2364	0.63	0.1	957
1997	3598	689	2701	1	0.1	948
1998	2027	467	2085	1.43	0.1	950
1999	1424	440	4922	0.39	0.15	267
2000	1540	481	2202	0.32	0.15	270
2001	2528	270	1611	0.97	0.15	271
2002	1750	307	1232	0.16	0.14	276
2003	1797	317	327	0.17	0.14	274
2004	1934	281	2093	0.17	0.14	274
2005	1755	300	1749	0.1	0.14	276
2006	2020	340	886	0.25	0.14	276
2007	1997	301	158	0.26	0.14	275
2008	1473	226	257	0.26	0.14	276
2009	1283	164	2775	0.26	0.14	275
2010	727	230	1062	0.06	0.14	273
2011	635	285	531	0.28	0.14	283
2012	455	241	398	0.19	0.14	281
2013	353	226	349	0.11	0.14	281
2014	411	209	560	0.14	0.14	281
2015	394	224	507	0.05	0.14	280
2016	389	269	1947	0.02	0.14	280
2017	405	365	4008	0.01	0.14	280
2018	526	632	3646	0.03	0.14	280
2019	632	1060	1069	0.03	0.14	280
2020	707	1419	586	0.03	0.14	280
2021	808	1529	801	0.03	0.14	280
2022	929	1462	1170	0.07	0.14	280

Table A10.37. Summary results for the short, medium, and long-term predictions for Model *h1_1.02.ls* (single-stock hypothesis, low steepness, short timeseries). Note that "B" in all cases represents thousands of tonnes of spawning stock biomass, "P" represents probability as a percentage and B_{MSY} is taken to be the average B_{MSY} estimated over the last ten years.

F	B_{2024}	$P(B_{2024}>B_{MSY})$	B_{2028}	$P(B_{2028}>B_{MSY})$	B_{2032}	$P(B_{2032}>B_{MSY})$	Catch 2023 (kt)	Catch 2024 (kt)
0	16447	100	17978	100	17868	100	0	0
0.75 × F_{2021}	14813	100	13485	100	12541	97	764	844
F_{2021}	14323	100	12409	99	11404	96	1006	1083
1.25 × F_{2021}	13856	100	11484	98	10462	93	1243	1305
F_{MSY}	10568	100	6908	68	6112	53	3120	2659

Table A10.38. Summary results for the short, medium, and long-term predictions for Model *h2_1.02.ls* (two-stock hypothesis). Note that "B" in all cases represents thousands of tonnes of spawning stock biomass, "P" represents probability as a percentage, and B_{MSY} is estimated dynamically within the model.

Southern Stock:

F	B_{2024}	$P(B_{2024}>B_{MSY})$	B_{2028}	$P(B_{2028}>B_{MSY})$	B_{2032}	$P(B_{2032}>B_{MSY})$	Catch 2023 (kt)	Catch 2024 (kt)
0	14976	100	16498	100	16371	100	0	0
0.75 × F_{2021}	13556	100	12531	99	11594	98	645	705
F_{2021}	13128	100	11563	99	10558	96	849	905
1.25 × F_{2021}	12721	100	10724	98	9696	93	1048	1091
F_{MSY}	9994	100	6680	74	5865	58	2528	2175

Far North Stock:

F	B_{2024}	$P(B_{2024}>B_{MSY})$	B_{2028}	$P(B_{2028}>B_{MSY})$	B_{2032}	$P(B_{2032}>B_{MSY})$	Catch 2023 (kt)	Catch 2024 (kt)
0	1460	100	1374	100	1290	99	0	0
0.75 × F_{2021}	1352	99	1031	95	840	82	72	72
F_{2021}	1321	99	947	92	734	67	94	91
1.25 × F_{2021}	1292	99	874	86	644	49	116	108
F_{MSY}	1202	99	682	59	417	1	187	154

9. Figures

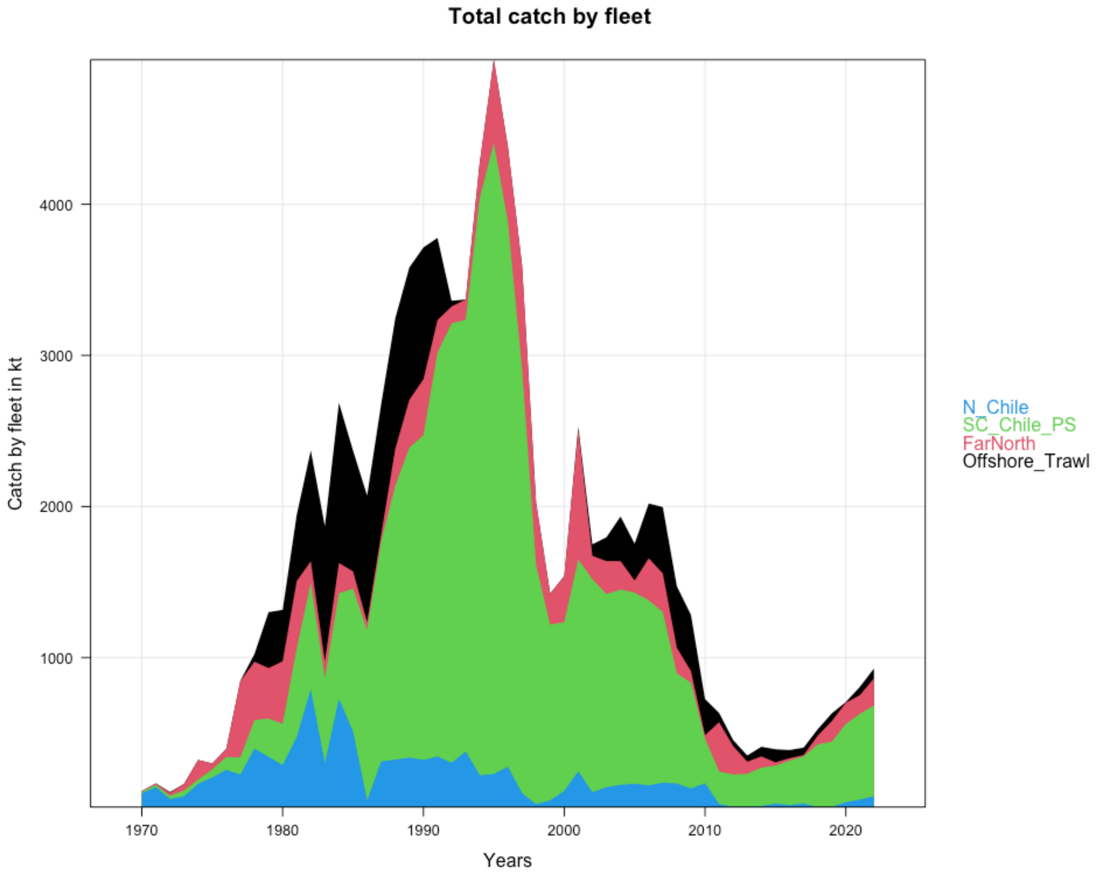


Figure A10.1: Catch of jack mackerel by fleet. Blue is the northern Chilean fleet, green is the south-central Chilean fleet, red is the far north fleet, and black is the offshore trawl fleet.

Figure A10.2: Years and types of information used in the jack mackerel assessment models.

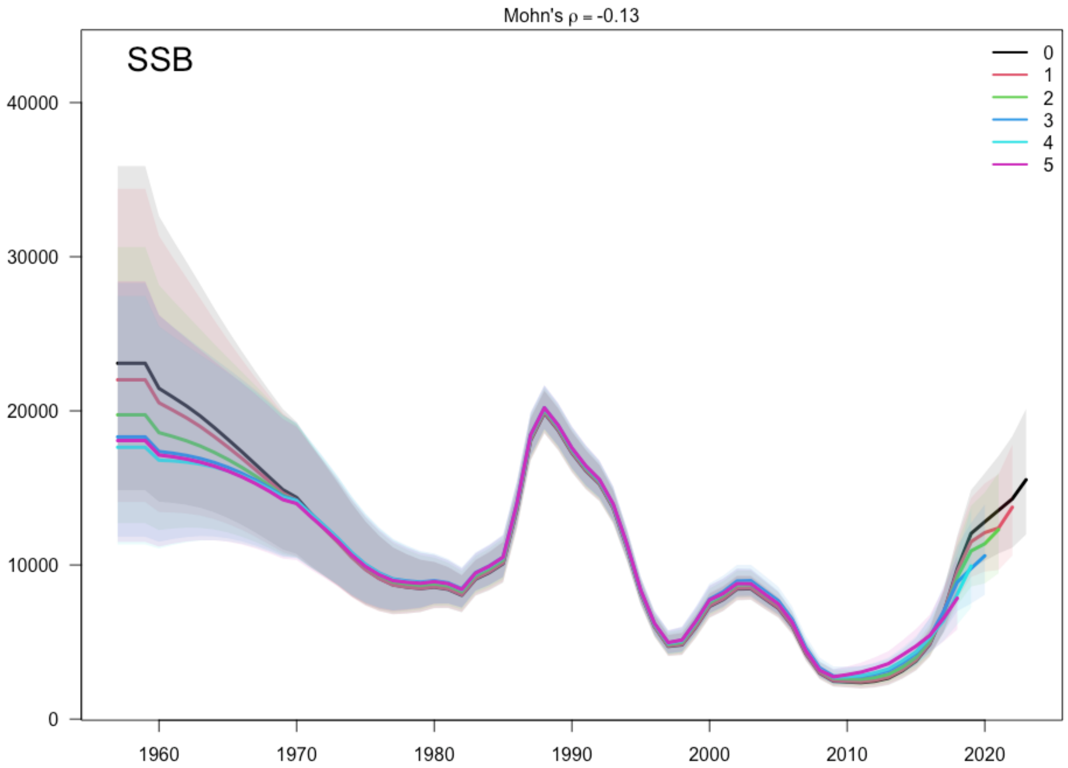


Figure A10.3: Model retrospective of spawning biomass from 5 separate model runs, based on Model h1_1.02 (single-stock hypothesis).

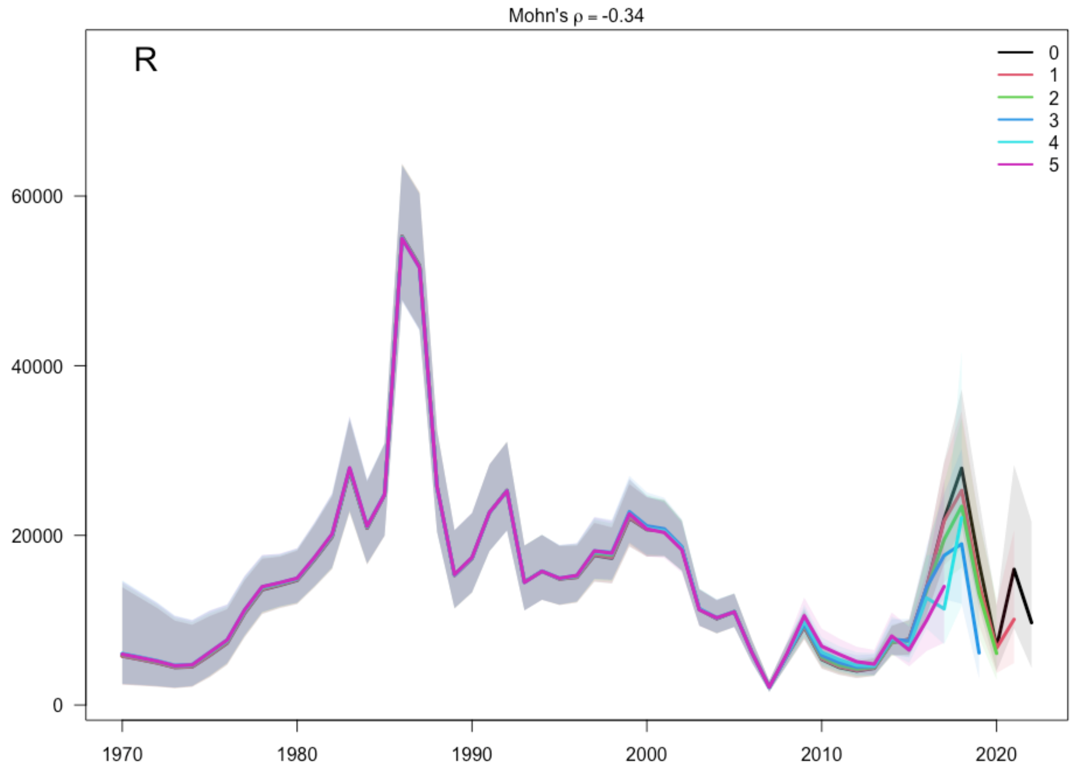
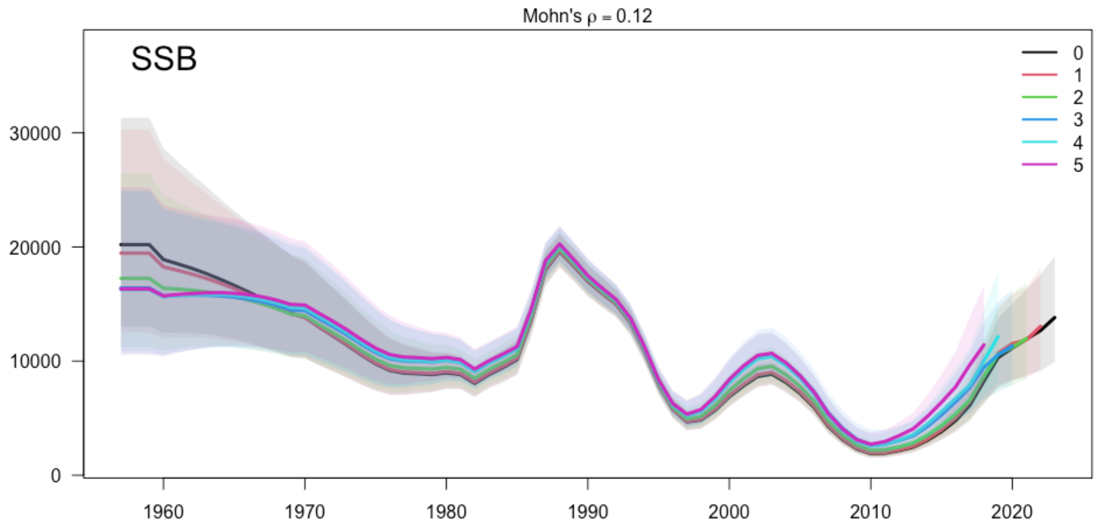


Figure A10.4: Model retrospective of recruitment from 5 separate model runs, based on Model h1_1.02 (single-stock hypothesis).



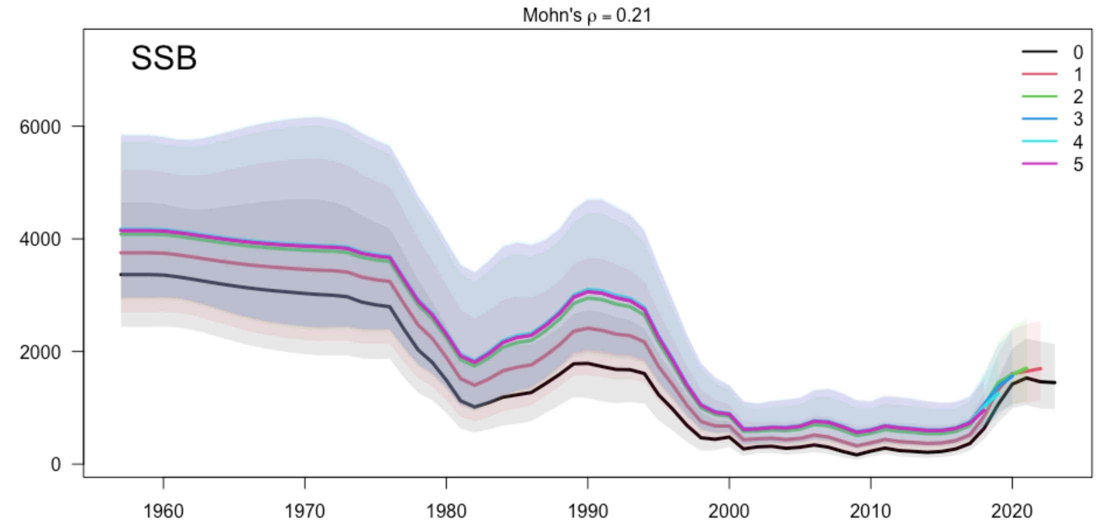


Figure A10.5: Model retrospective of spawning biomass from 5 separate model runs for the southern stock (top) and far north stock (bottom), based on Model h2_1.02 (two-stock hypothesis).

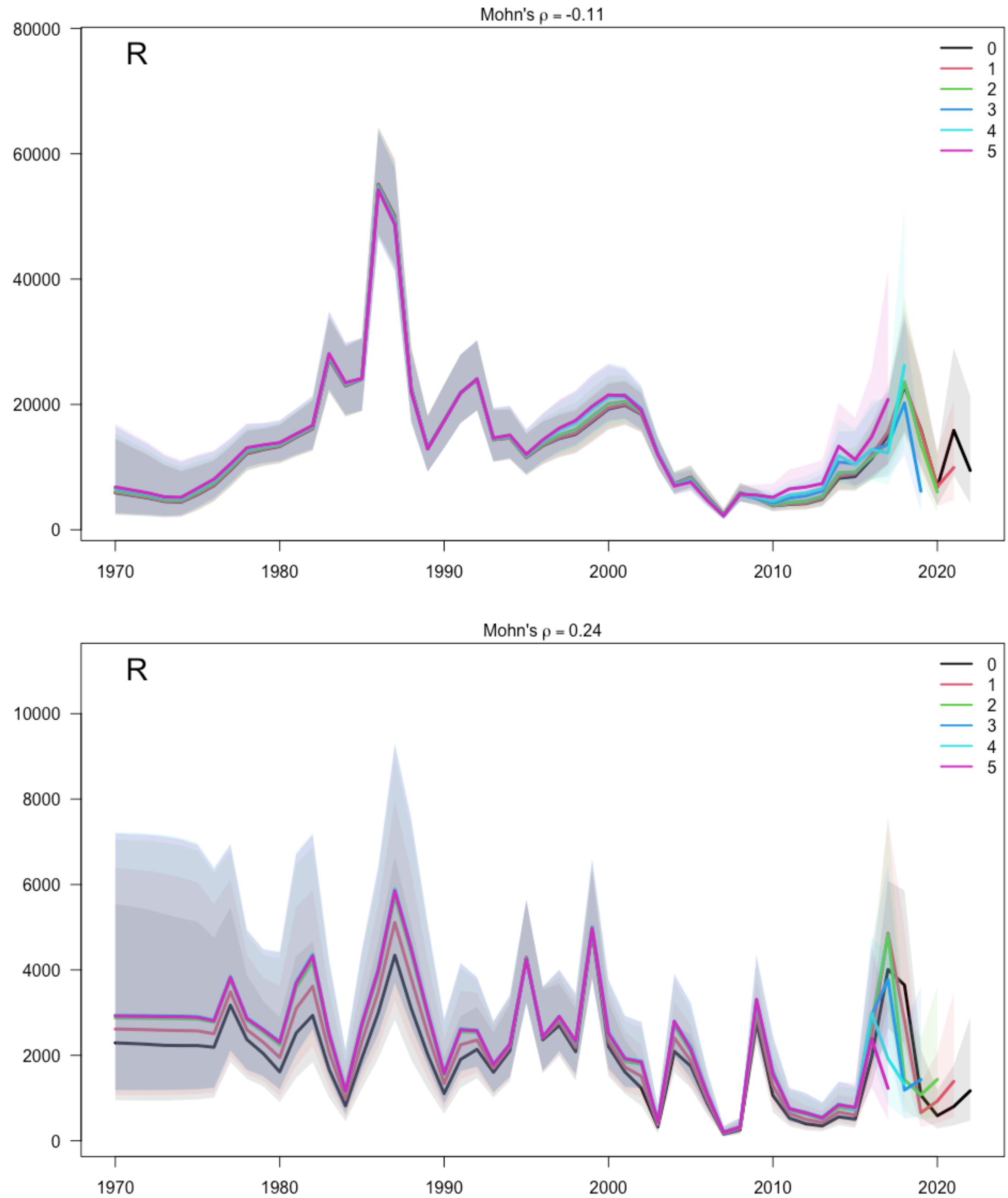


Figure A10.6: Model retrospective of southern stock recruitment from 5 separate model runs for the southern stock (top) and far north stock (bottom), based on Model h2_1.02 (two-stock hypothesis).

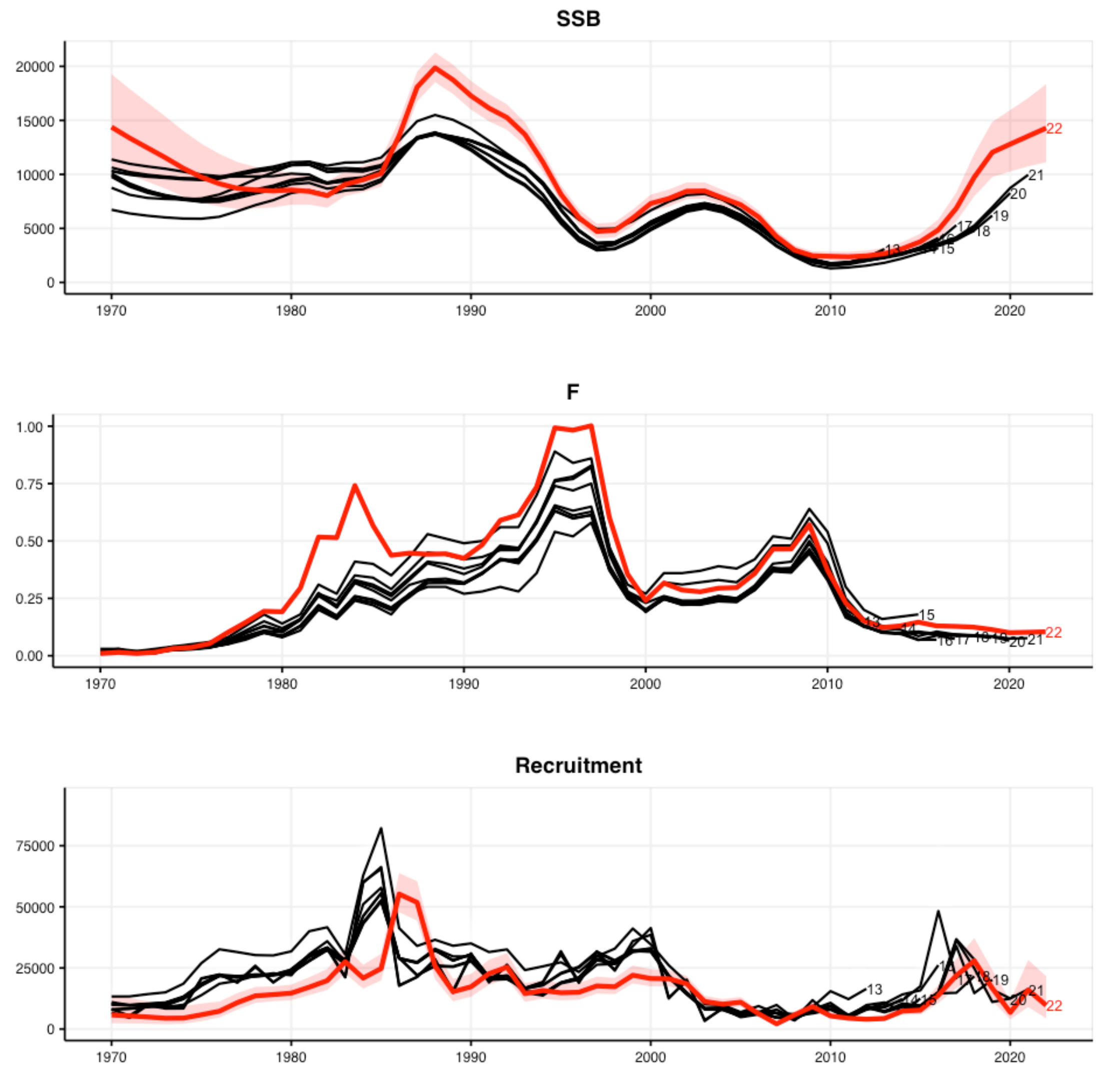


Figure A10.7: Historical retrospective of spawning stock biomass, fishing mortality, and recruitment estimated from Model h1_1.02 (single-stock hypothesis), as estimated and used for advice from SPFRMO Scientific Committees 2013-2022

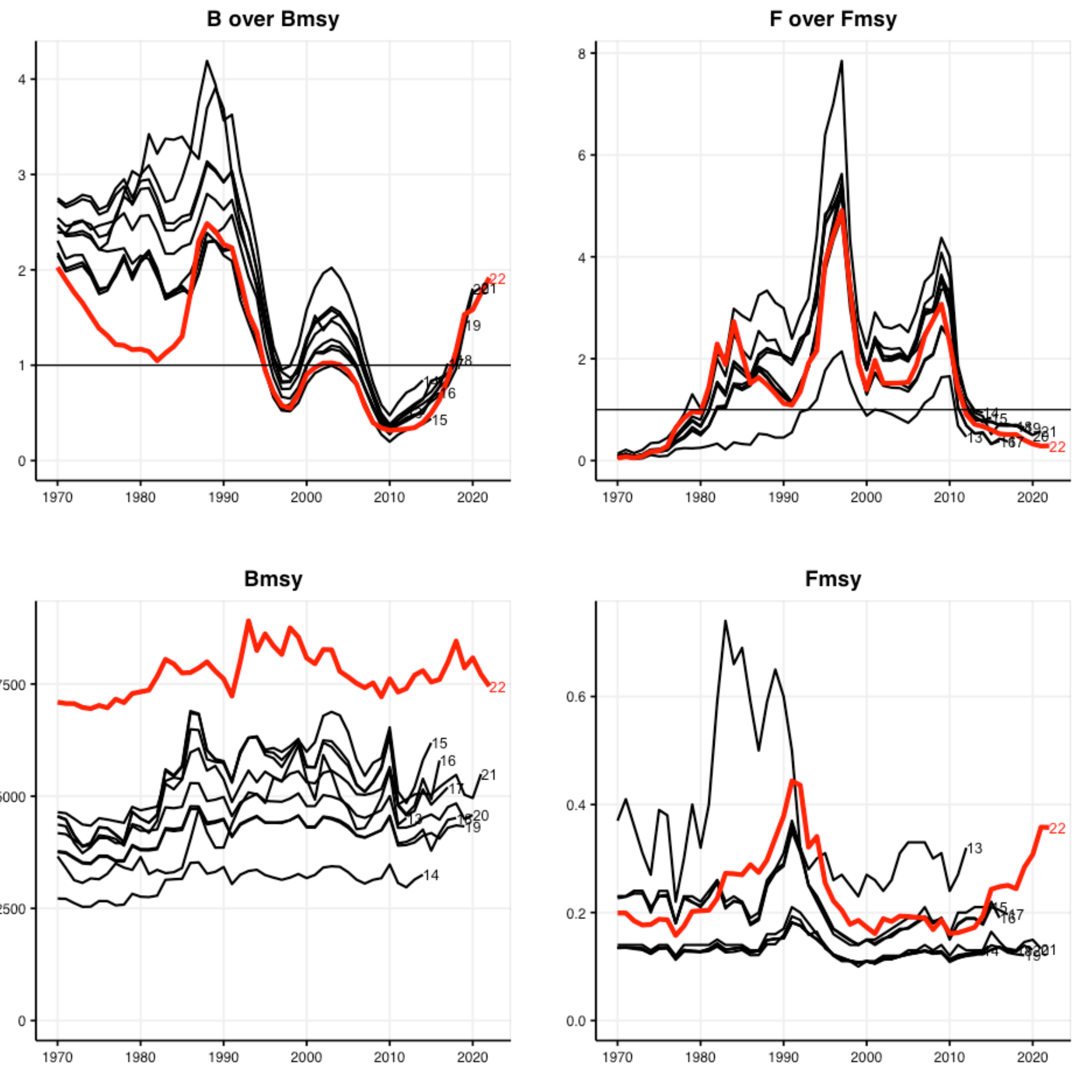


Figure A10.8: Historical retrospective of management reference points estimated from Model h1_1.02 (single-stock hypothesis), as estimated and used for advice from past (and present) SPRFMO scientific committees.

Figure A10.9: Mean weights-at-age (kg) over time used for the fisheries in the JJM models. Each line represents an age from 1 to 12.

Figure A10.10: Mean weights-at-age (kg) over time used for the surveys in the JJM models. Each line represents an age from 1 to 12.

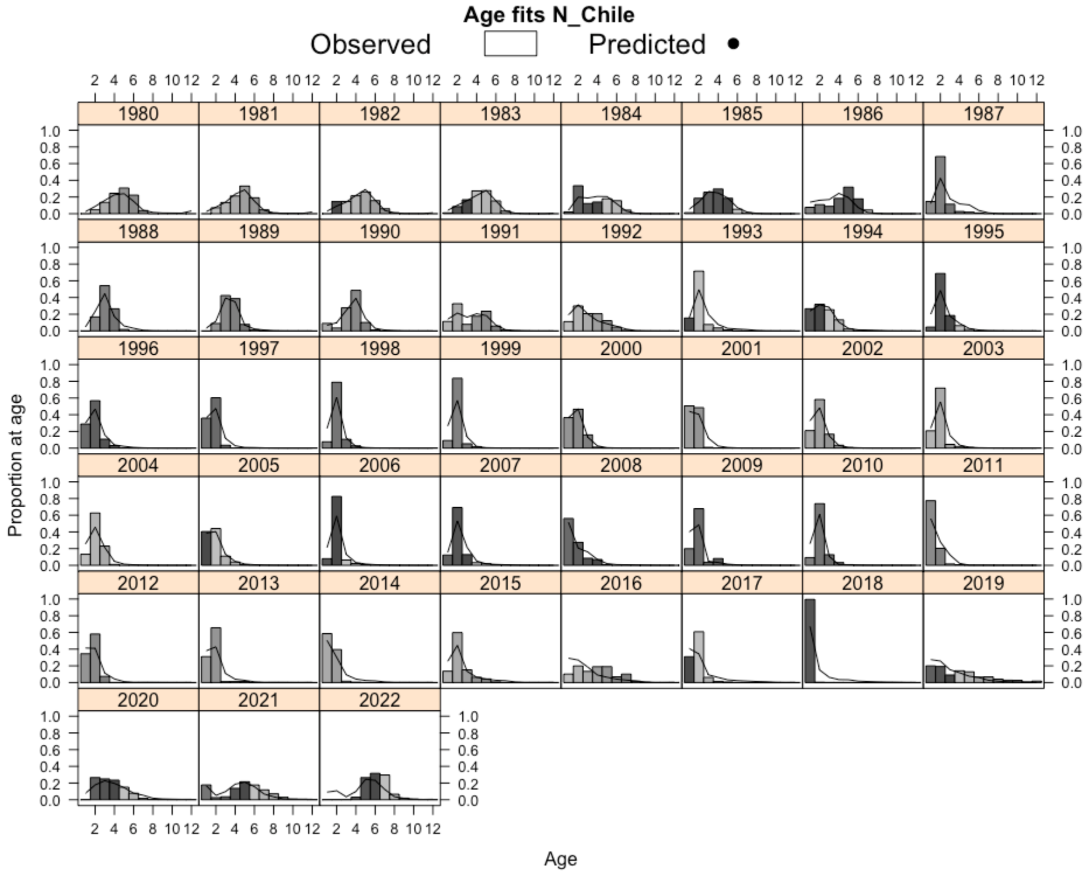


Figure A10.11: Model h1_1.02 (single-stock hypothesis) fit to the age compositions for the Chilean northern zone fishery (Fleet 1). Bars represent the observed data and lines represent the model predictions.

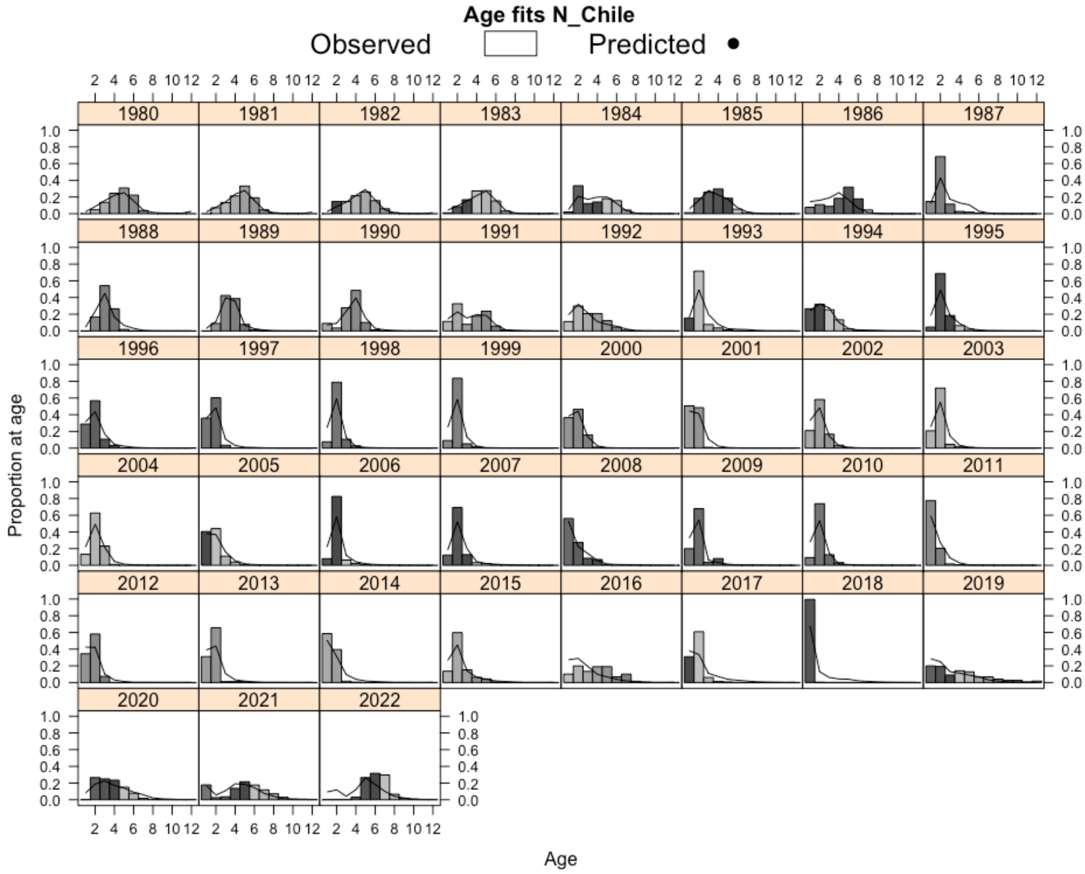


Figure A10.12: Model h2_1.02 (two-stock hypothesis) fit to the age compositions for the Chilean northern zone fishery (Fleet 1). Bars represent the observed data and lines represent the model predictions.

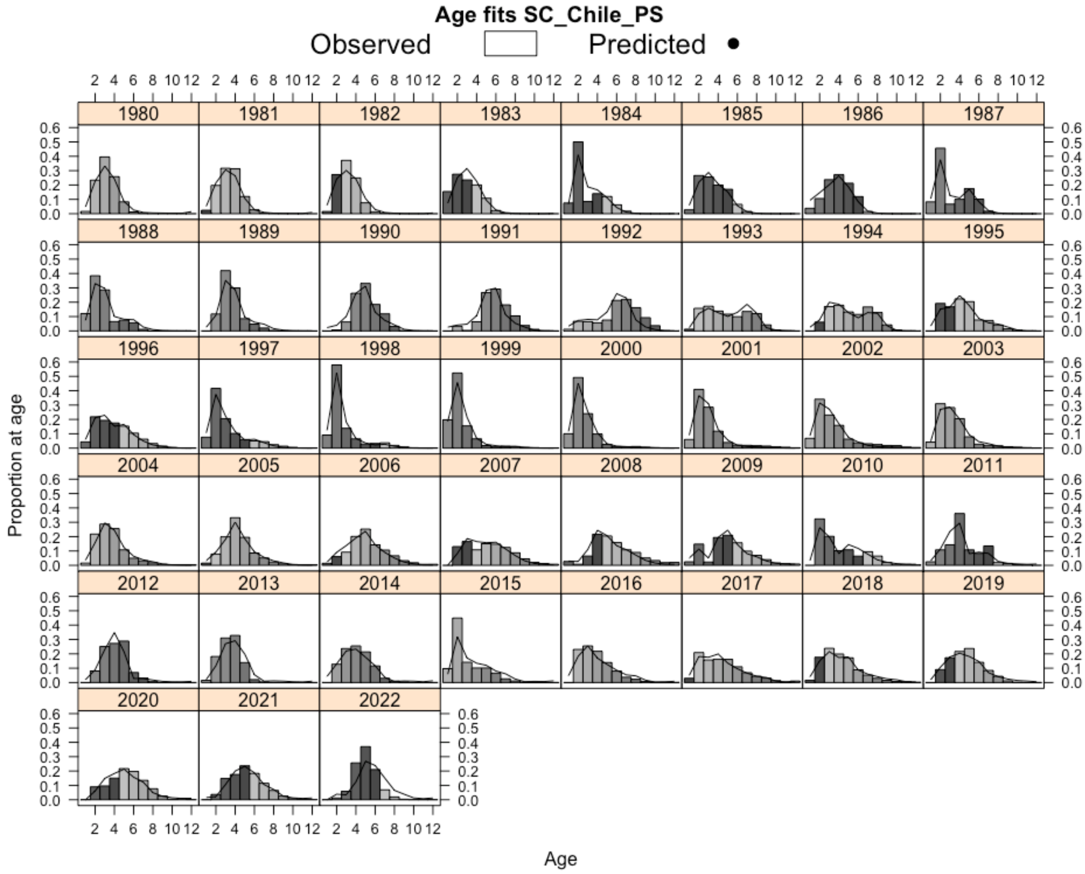


Figure A10.13: Model h1_1.02 (single-stock hypothesis) fit to the age compositions for the South-Central Chilean purse seine fishery (Fleet 2). Bars represent the observed data and lines represent the model predictions.

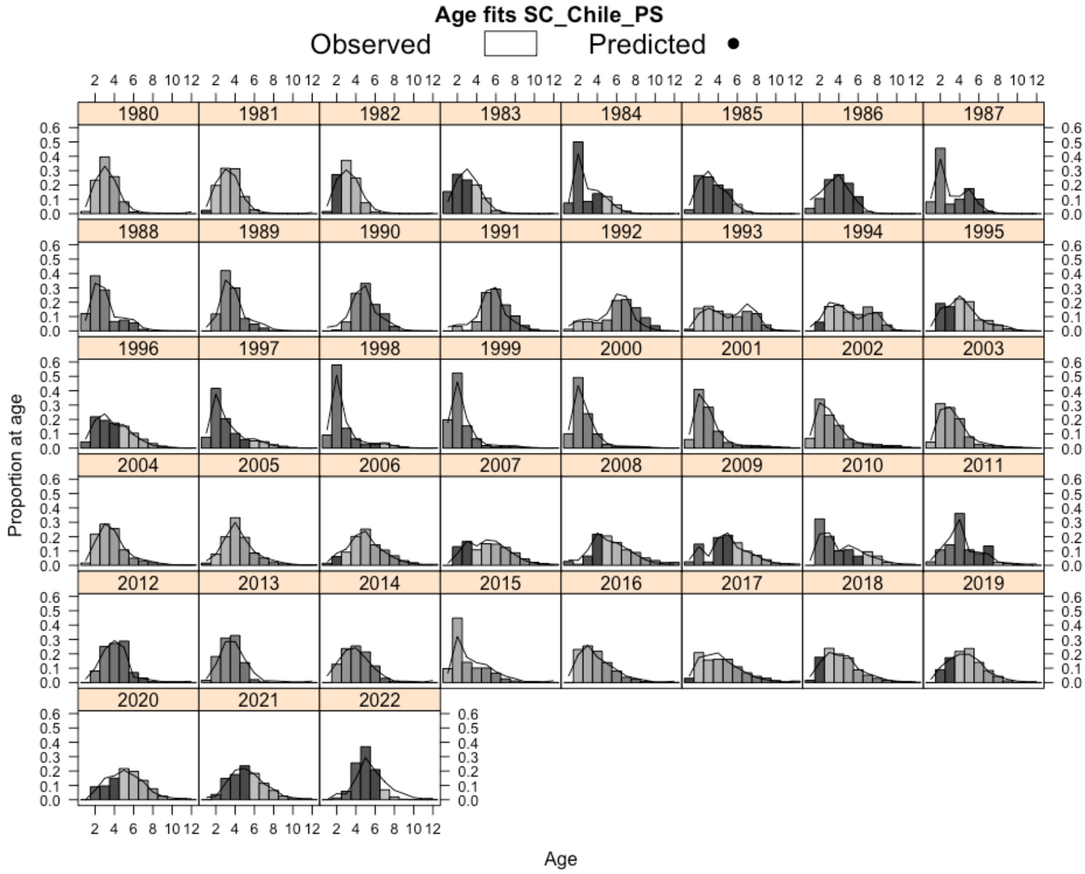


Figure A10.14: Model h2_1.02 (two-stock hypothesis) fit to the age compositions for the South-Central Chilean purse seine fishery (Fleet 2). Bars represent the observed data and lines represent the model predictions.

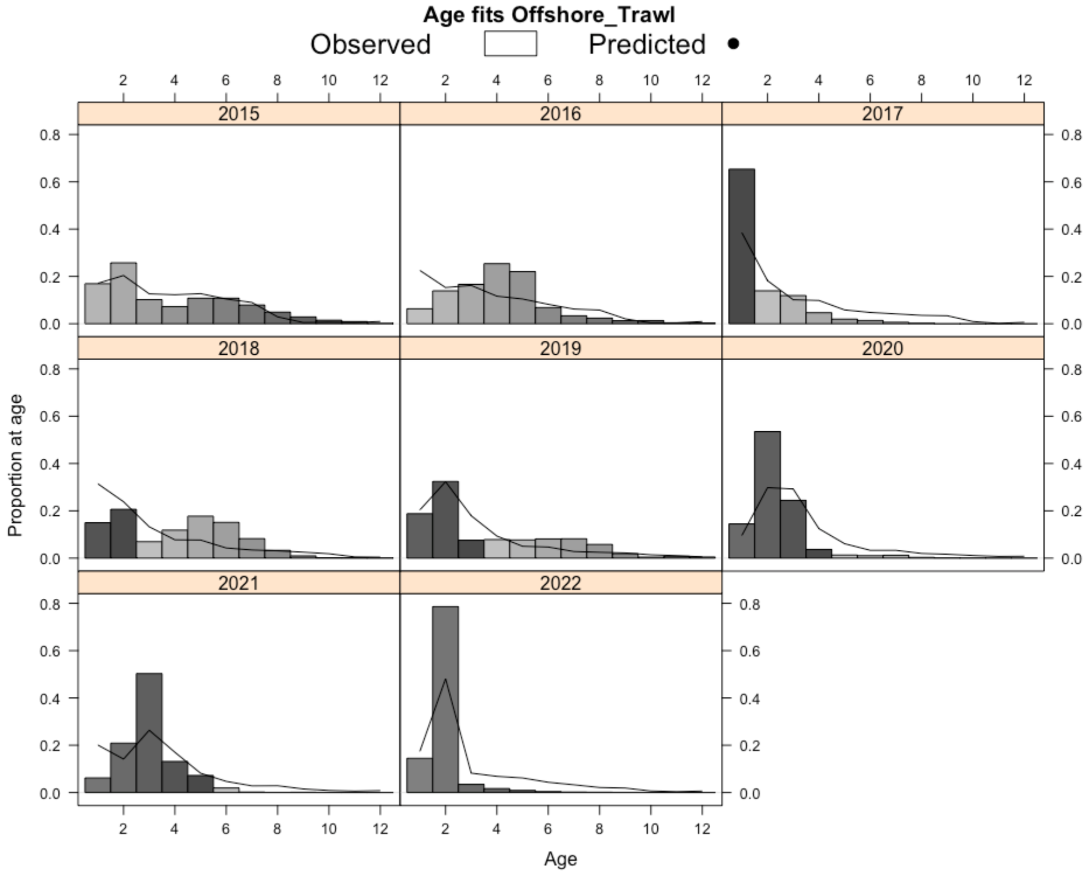


Figure A10.15: Model h1_1.02 (single-stock hypothesis) fit to the age compositions for the offshore trawl fishery (Fleet 4). Bars represent the observed data and lines represent the model predictions.

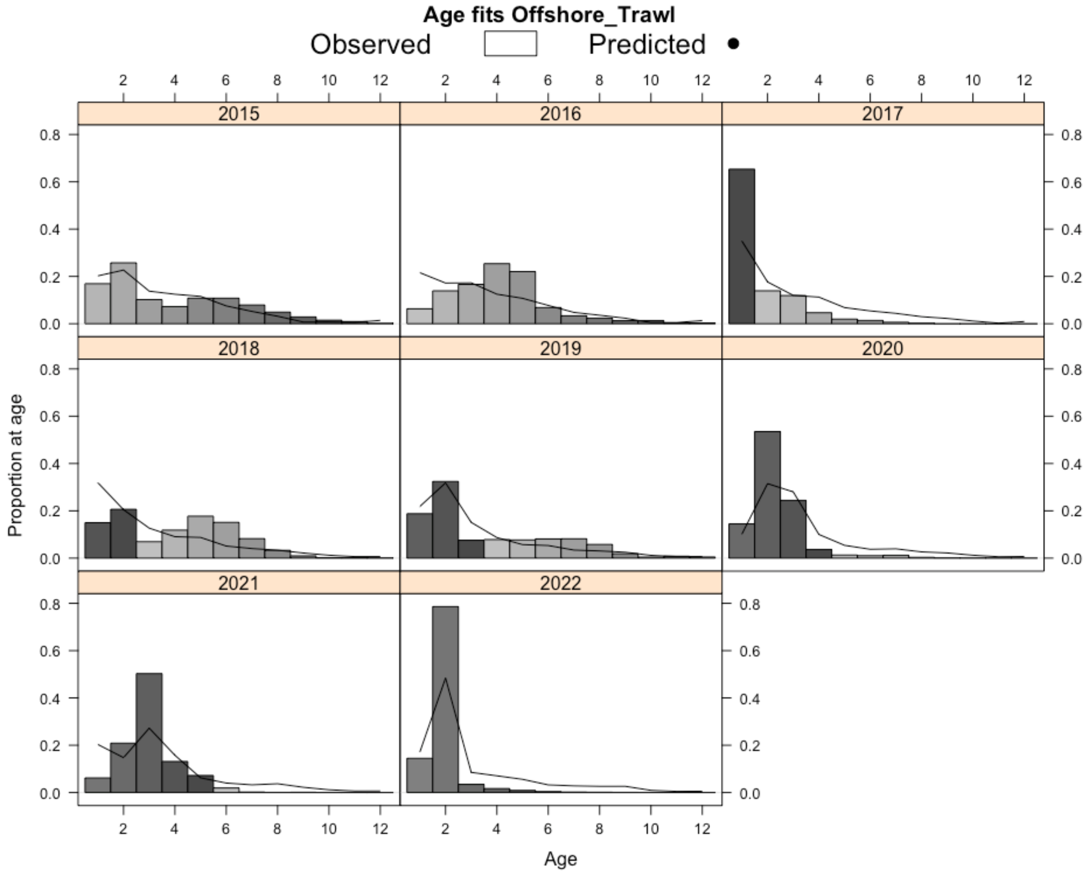


Figure A10.16: Model h2_1.02 (two-stock hypothesis) fit to the age compositions for the offshore trawl fishery (Fleet 4). Bars represent the observed data and lines represent the model predictions.

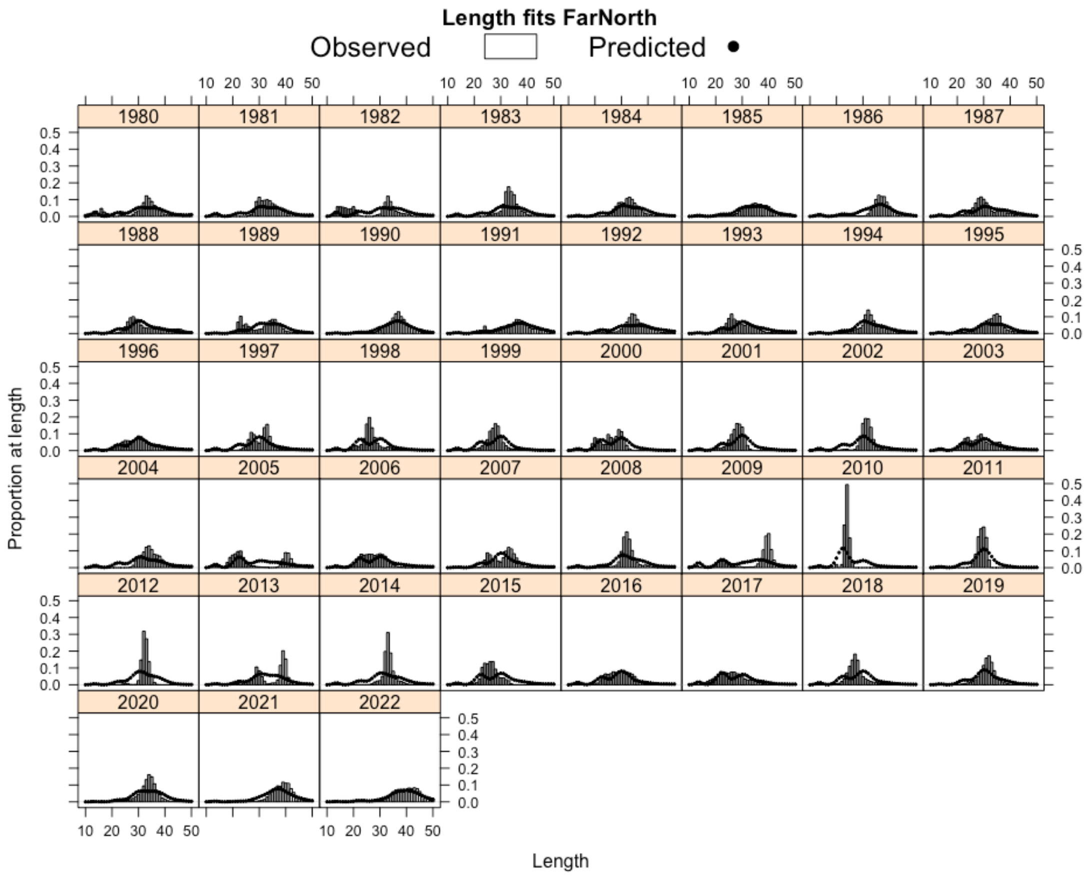


Figure A10.17: Model h1_1.02 (single-stock hypothesis) fit to the length compositions for the far north fishery (Fleet 3). Bars represent the observed data and lines represent the model predictions.

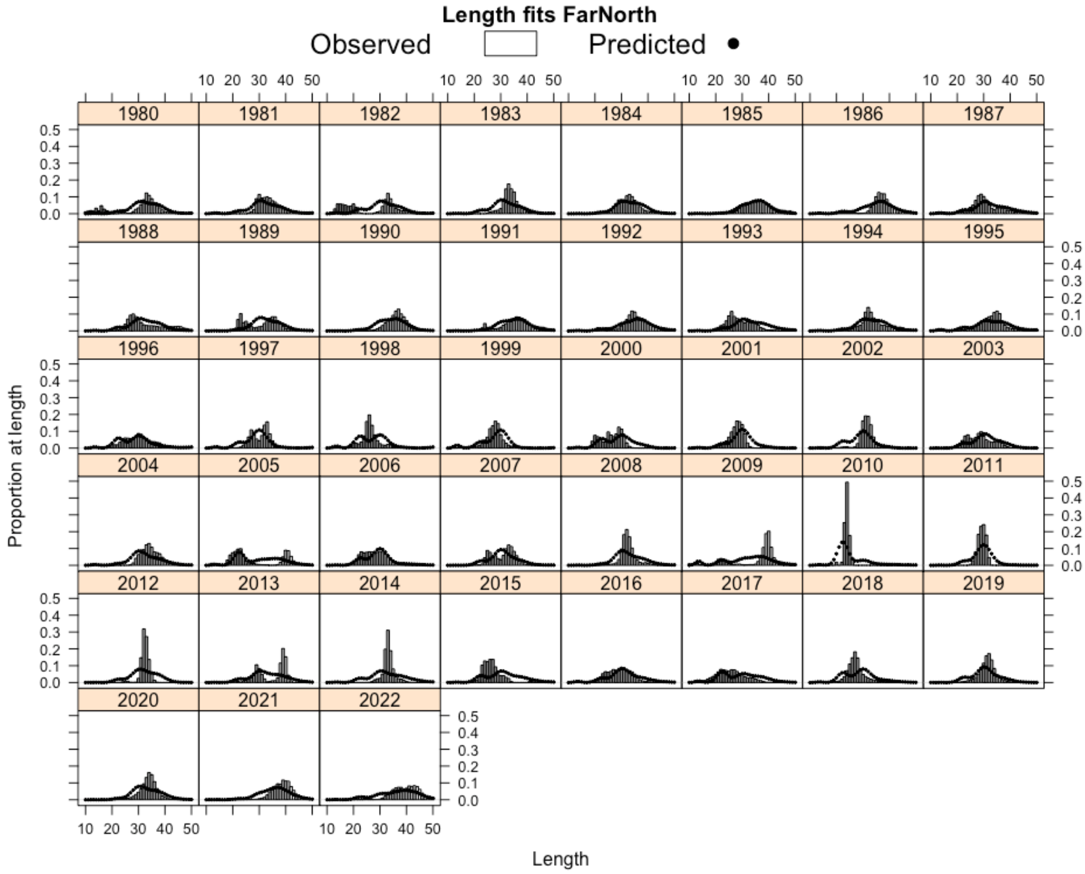


Figure A10.18: Model h2_1.02 (two-stock hypothesis) fit to the length compositions for the far north fishery (Fleet 3). Bars represent the observed data and lines represent the model predictions.

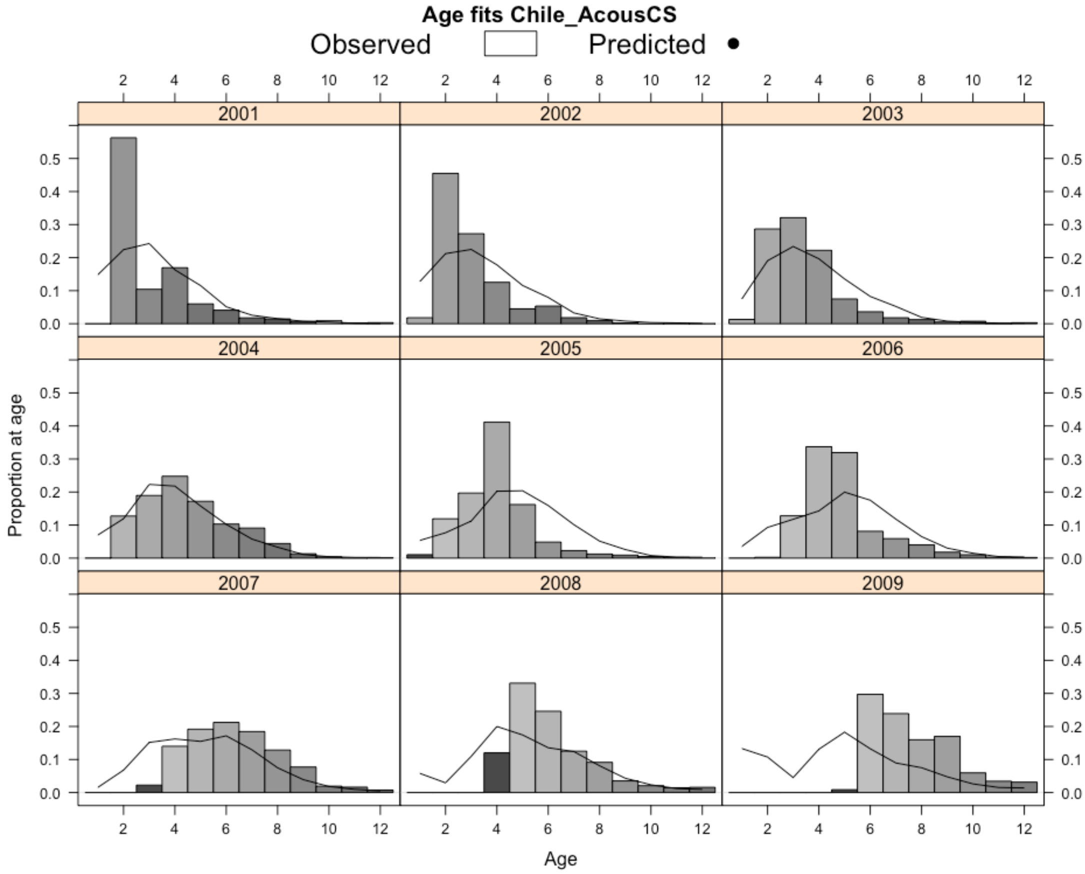


Figure A10.19: Model h1_1.02 (single-stock hypothesis) fit to the age compositions for the South-Central Acoustic survey. Bars represent the observed data and lines represent the model predictions.

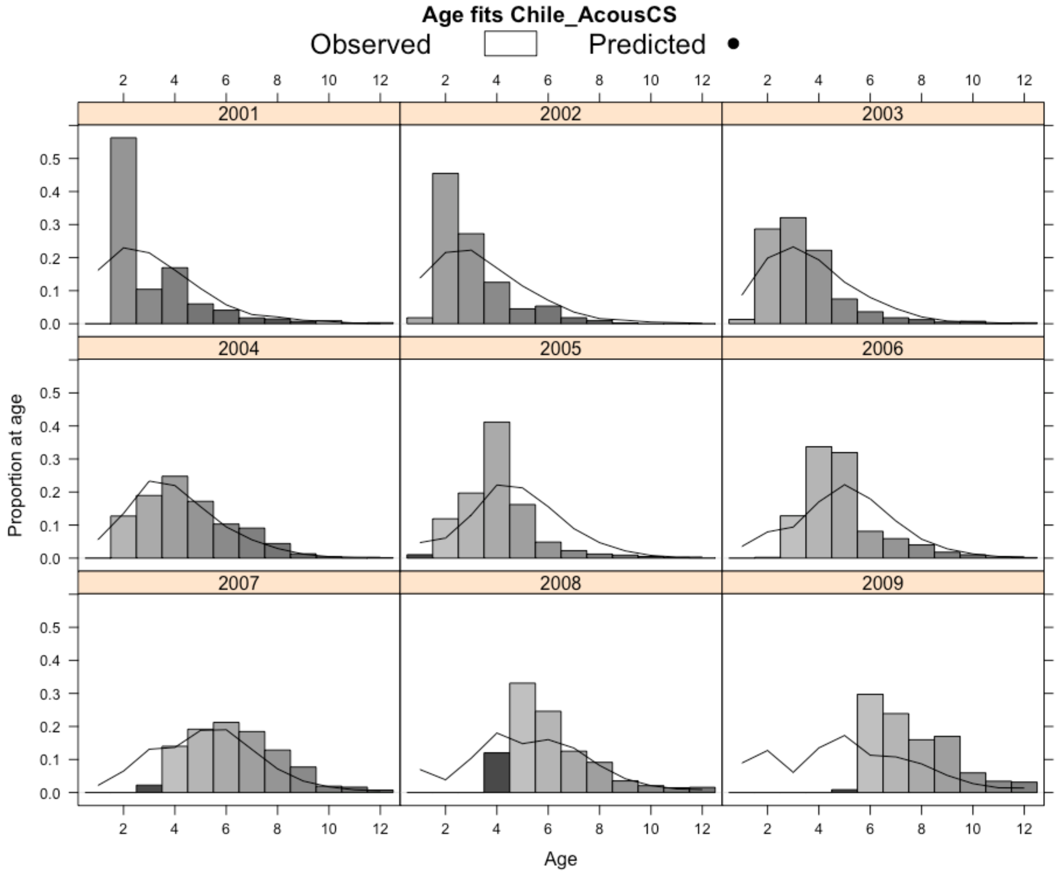


Figure A10.20: Model h2_1.02 (two-stock hypothesis) fit to the age compositions for the South-Central Acoustic survey. Bars represent the observed data and lines represent the model predictions.

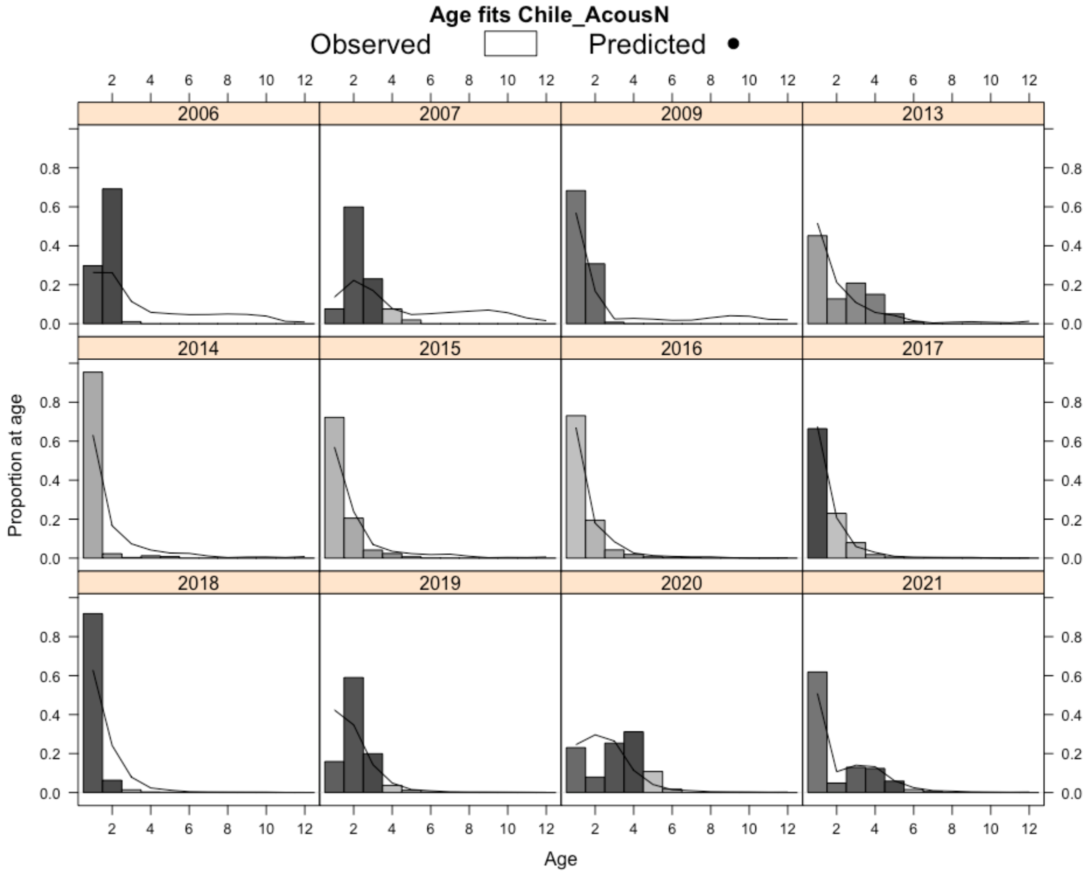


Figure A10.21: Model h1_1.02 (single-stock hypothesis) fit to the age compositions for the North Chilean acoustic survey. Bars represent the observed data and lines represent the model predictions.

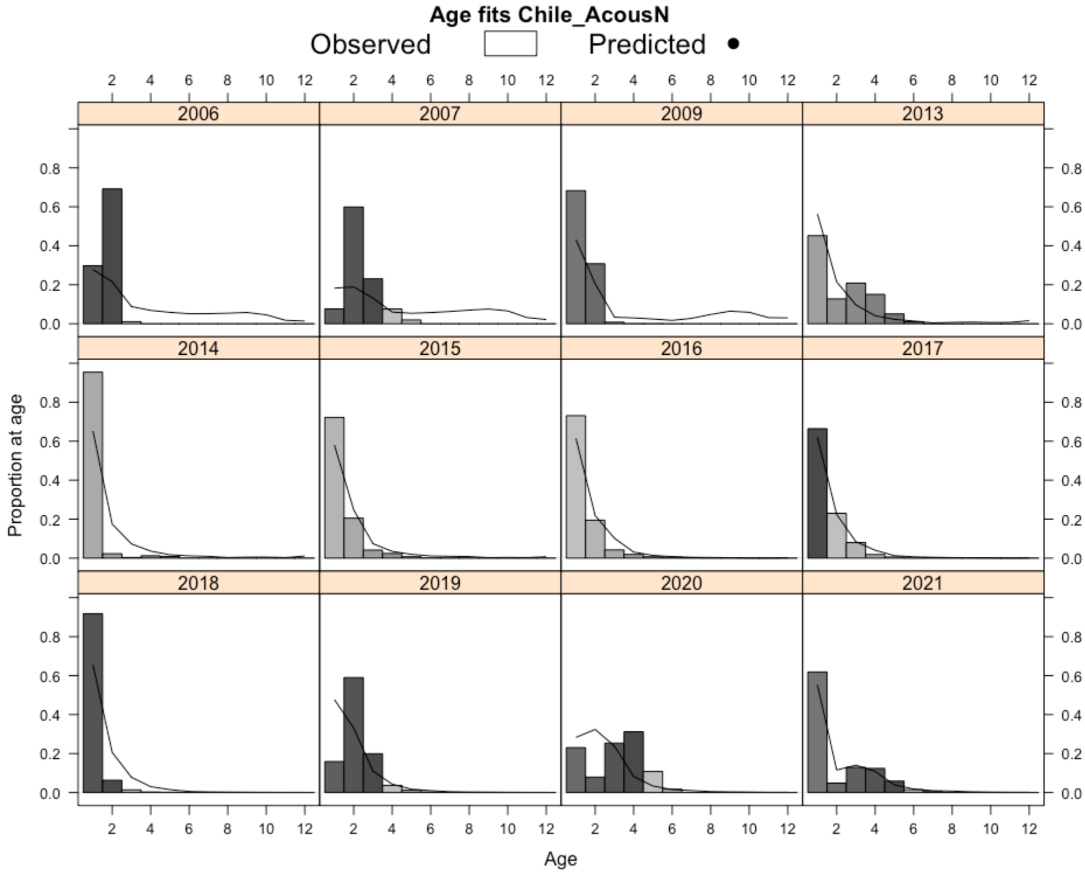


Figure A10.22: Model h2_1.02 (two-stock hypothesis) fit to the age compositions for the North Chilean acoustic survey. Bars represent the observed data and lines represent the model predictions.

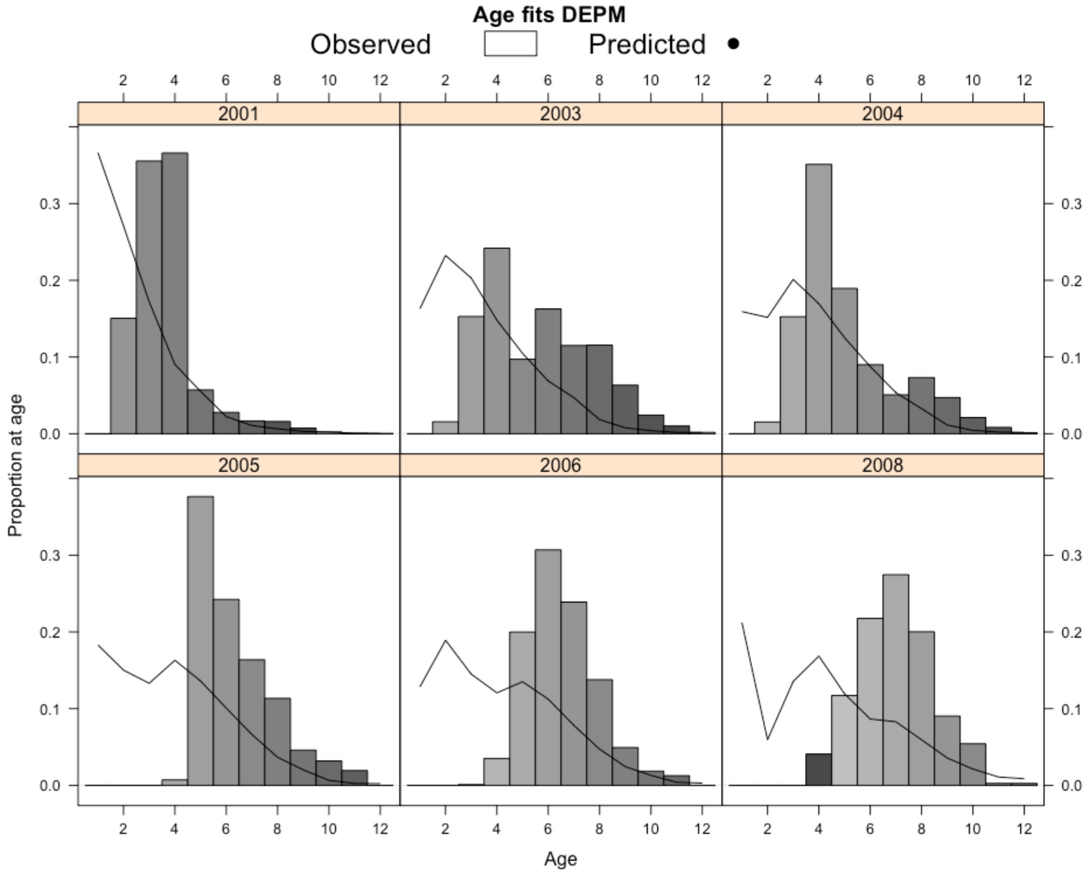


Figure A10.23: Model h1_1.02 (single-stock hypothesis) fit to the age compositions for the Daily Egg Production Method (DEPM) survey. Bars represent the observed data and lines represent the model predictions.

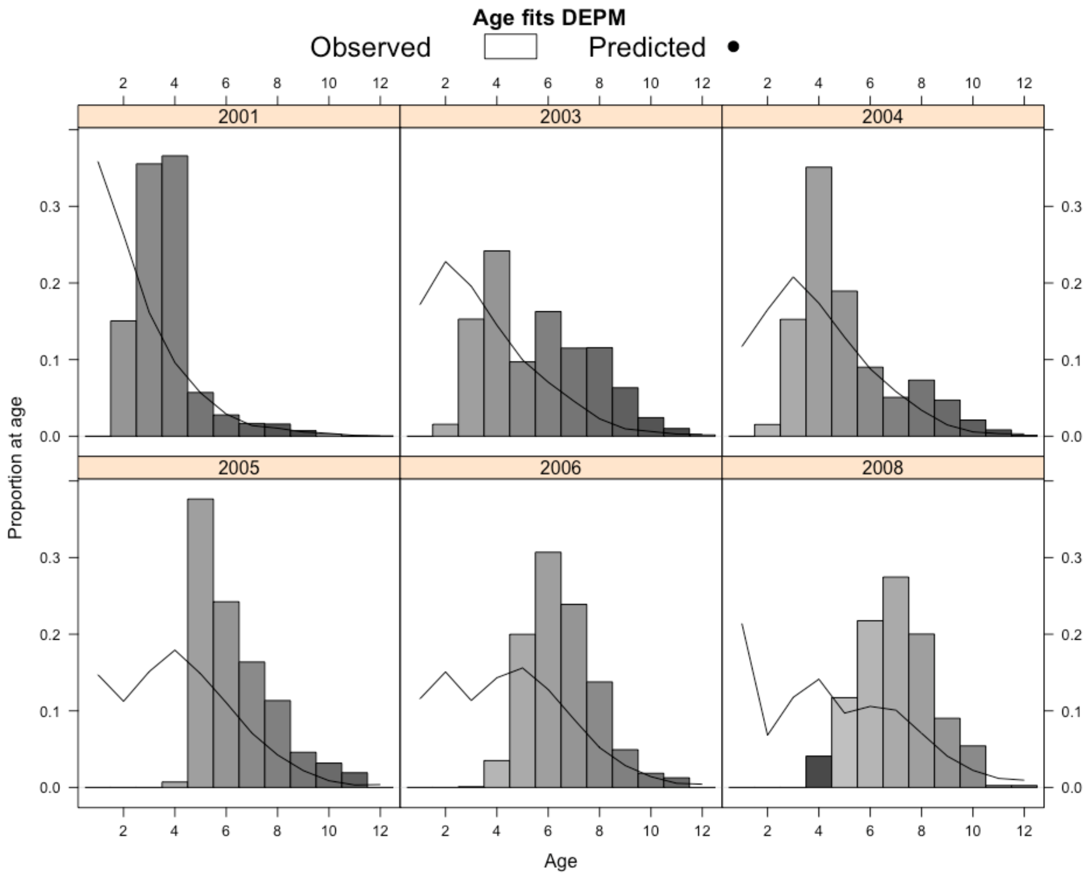


Figure A10.24: Model h2_1.02 (two-stock hypothesis) fit to the age compositions for the Daily Egg Production Method (DEPM) survey. Bars represent the observed data and lines represent the model predictions.

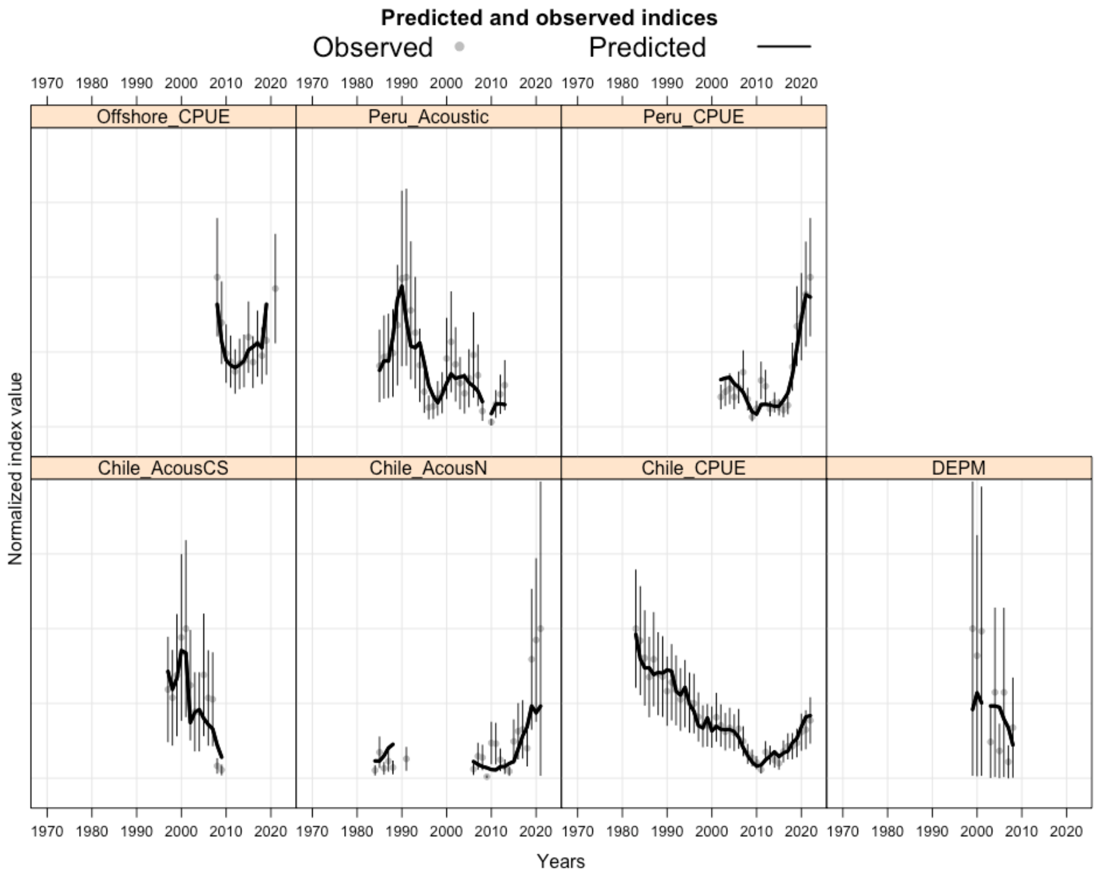


Figure A10.25: Model h1_1.02 (single-stock hypothesis) fit to different indices. Vertical bars represent 2 standard deviations around the observations.

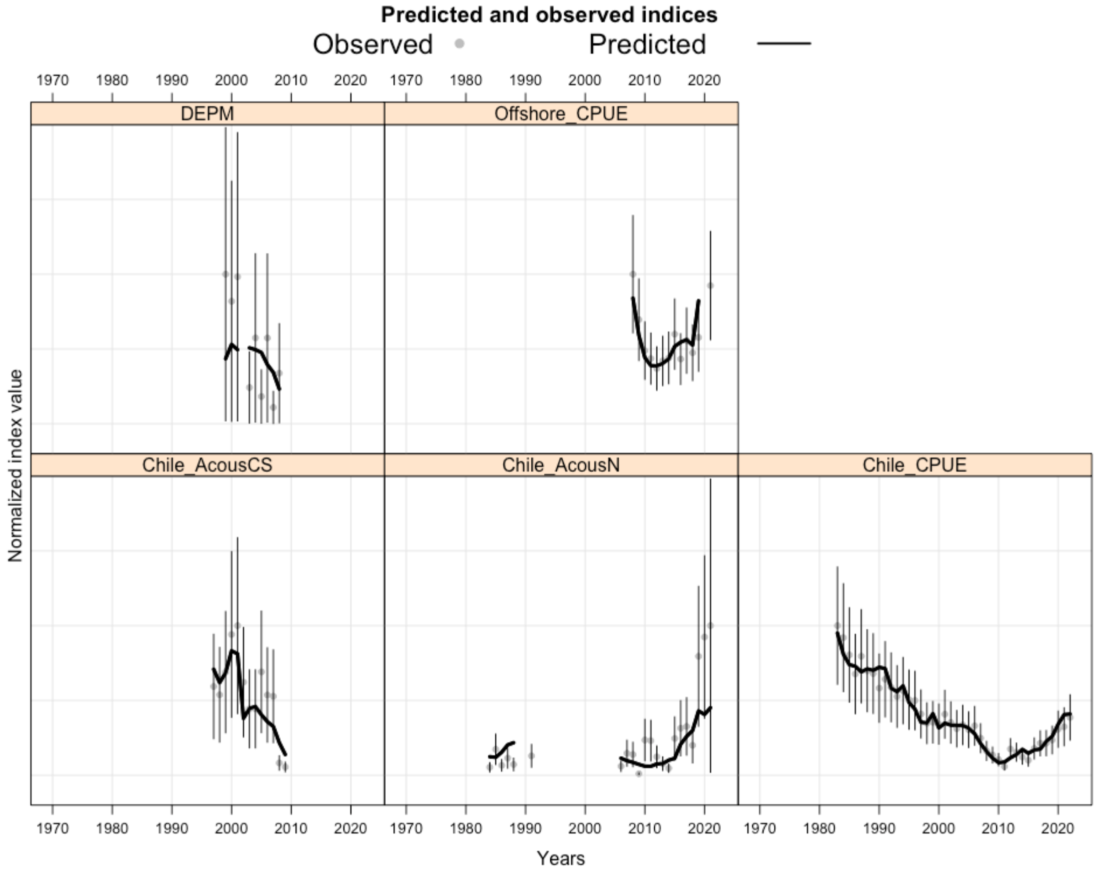


Figure A10.26: Model h2_1.02 (two-stock hypothesis) fit to indices for the south stock. Vertical bars represent 2 standard deviations around the observations.

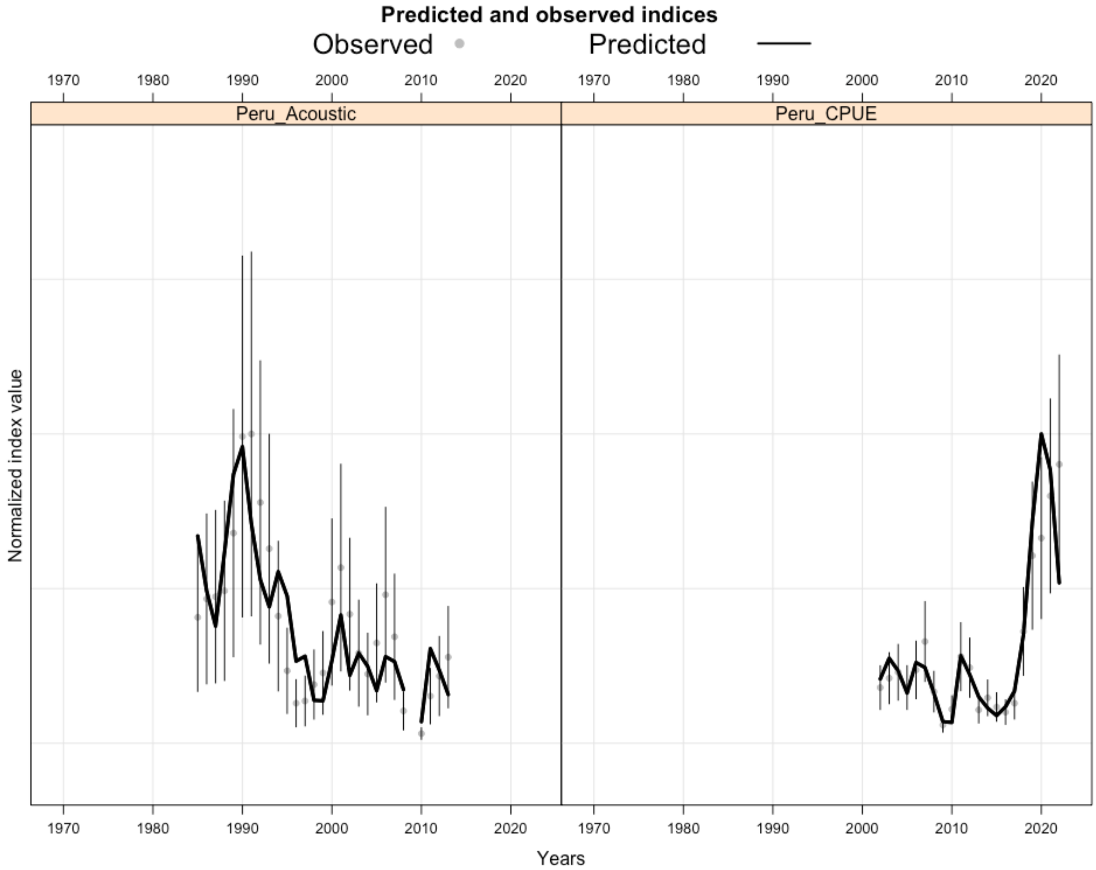


Figure A10.27: Model h2_1.02 (two-stock hypothesis) fit to indices for the north stock. Vertical bars represent 2 standard deviations around the observations.

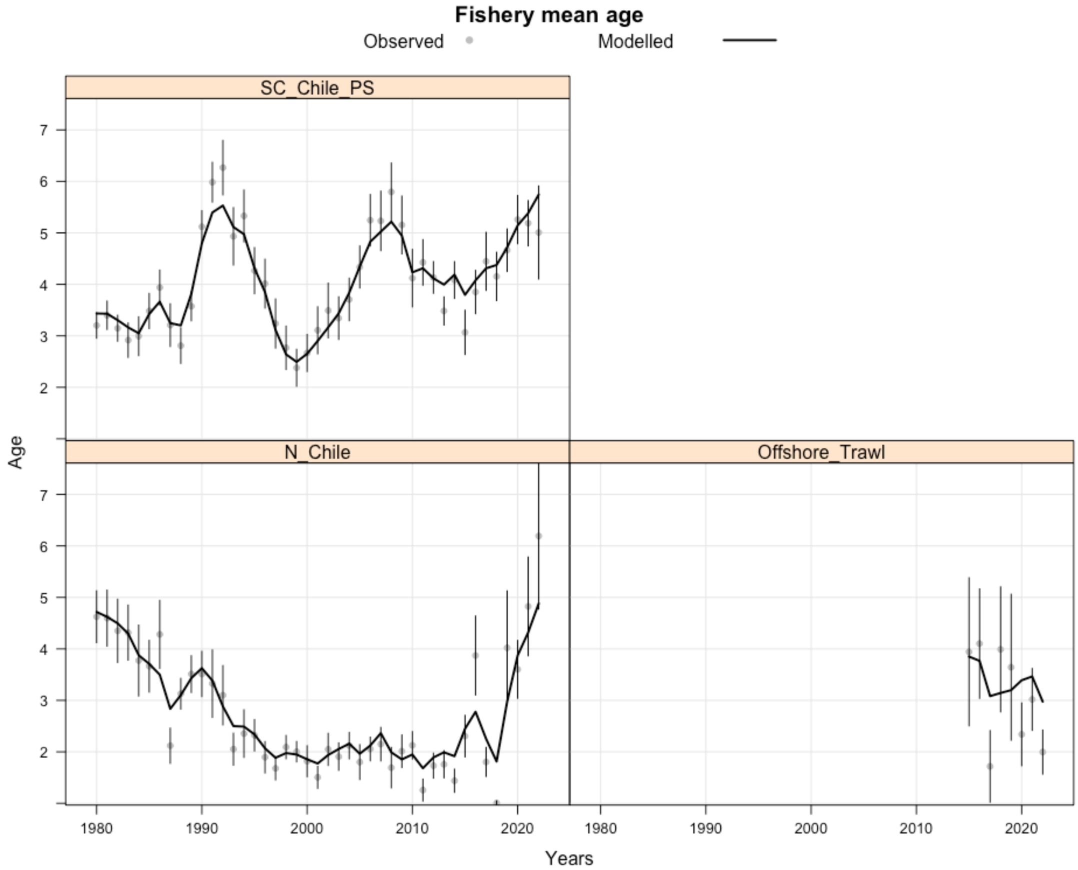


Figure A10.28: Mean age by year and fishery. Line represents the Model h1_1.02 (single-stock hypothesis) predictions and dots observed values with implied input error bars.

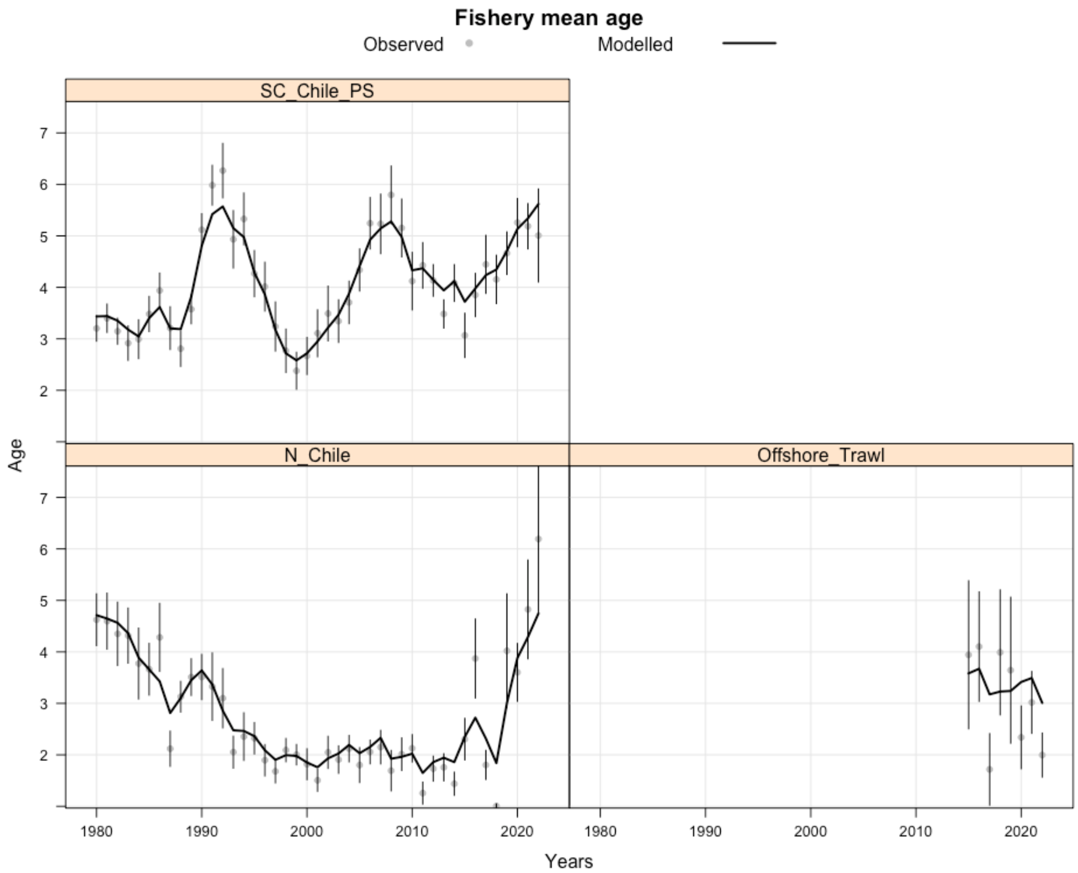


Figure A10.29: Mean age by year and fishery. Line represents the Model h2_1.02 (two-stock hypothesis) predictions and dots observed values with implied input error bars.

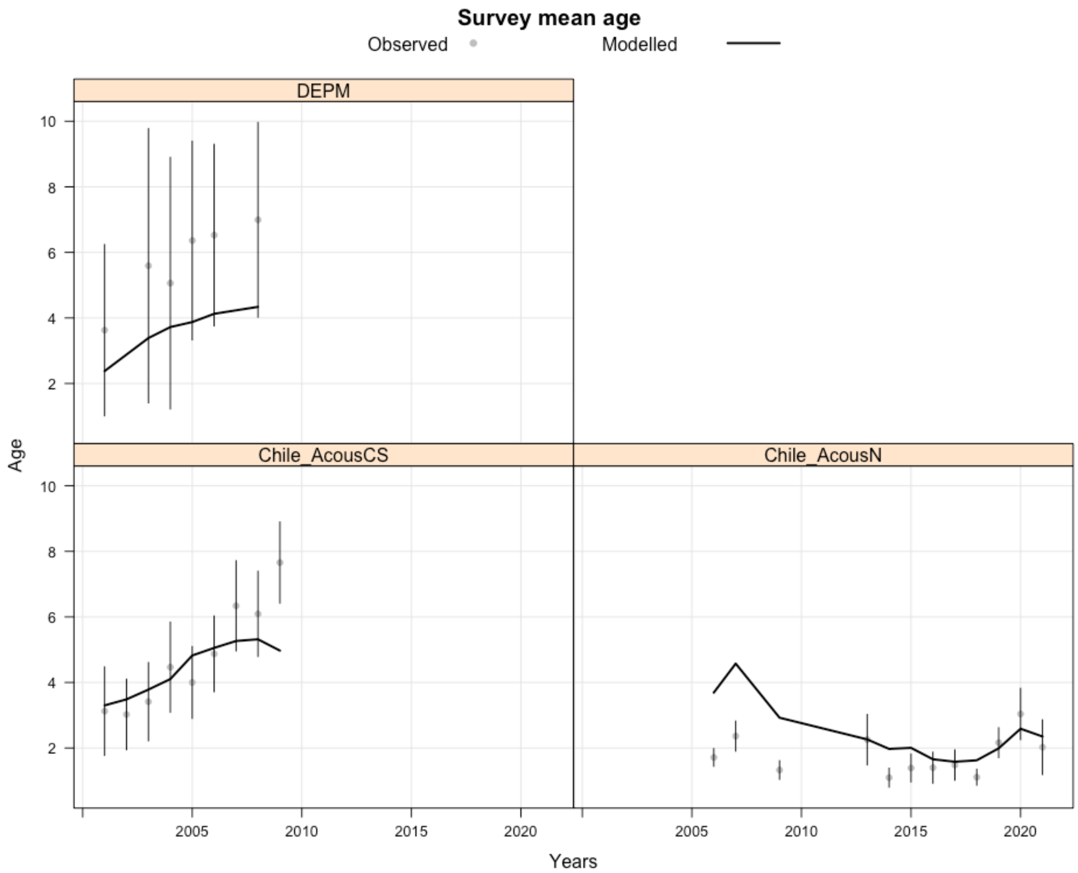


Figure A10.30: Mean age by year and survey. Line represents the Model h1_1.02 (single-stock hypothesis) predictions and dots observed values with implied input error bars.

Figure A10.31: Mean age by year and survey. Line represents the Model h2_1.02 (two-stock hypothesis) predictions and dots observed values with implied input error bars.

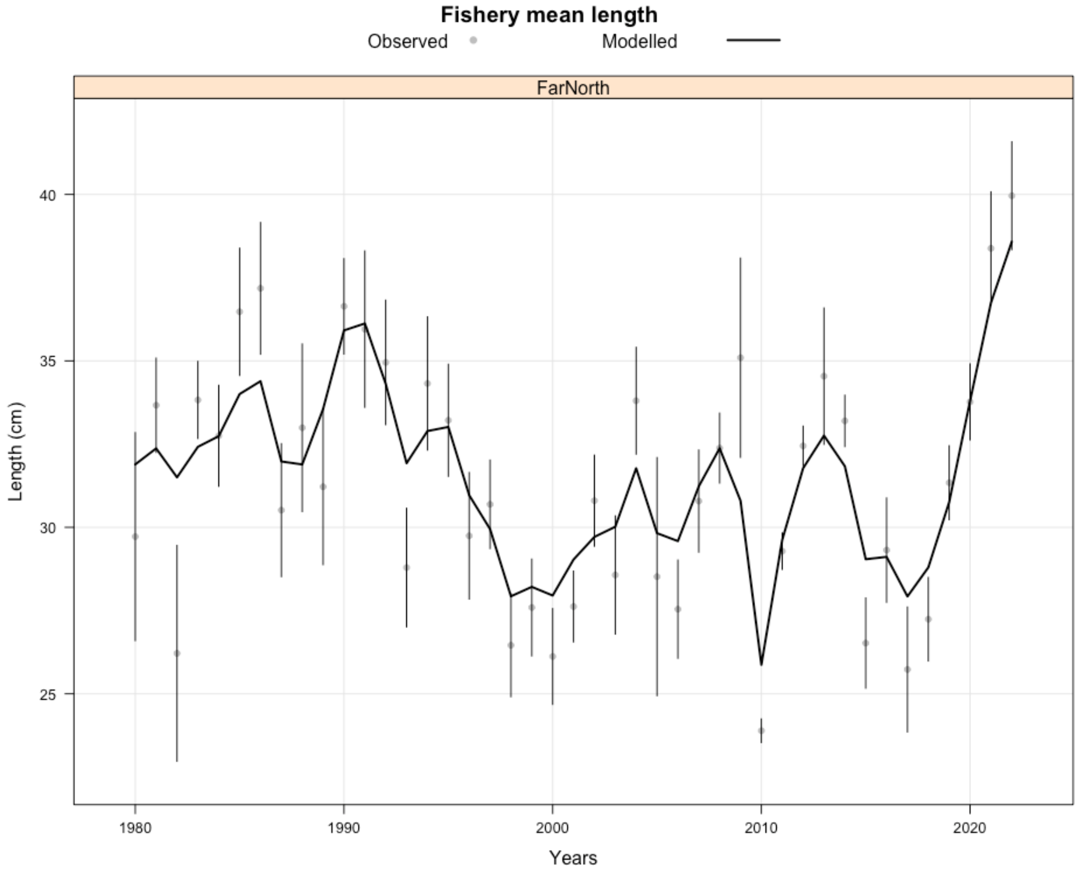


Figure A10.32: Mean length by year in Fleet 3 (Far North). Line represents the Model h1_1.02 (single-stock hypothesis) predictions and dots observed values with implied input error bars.

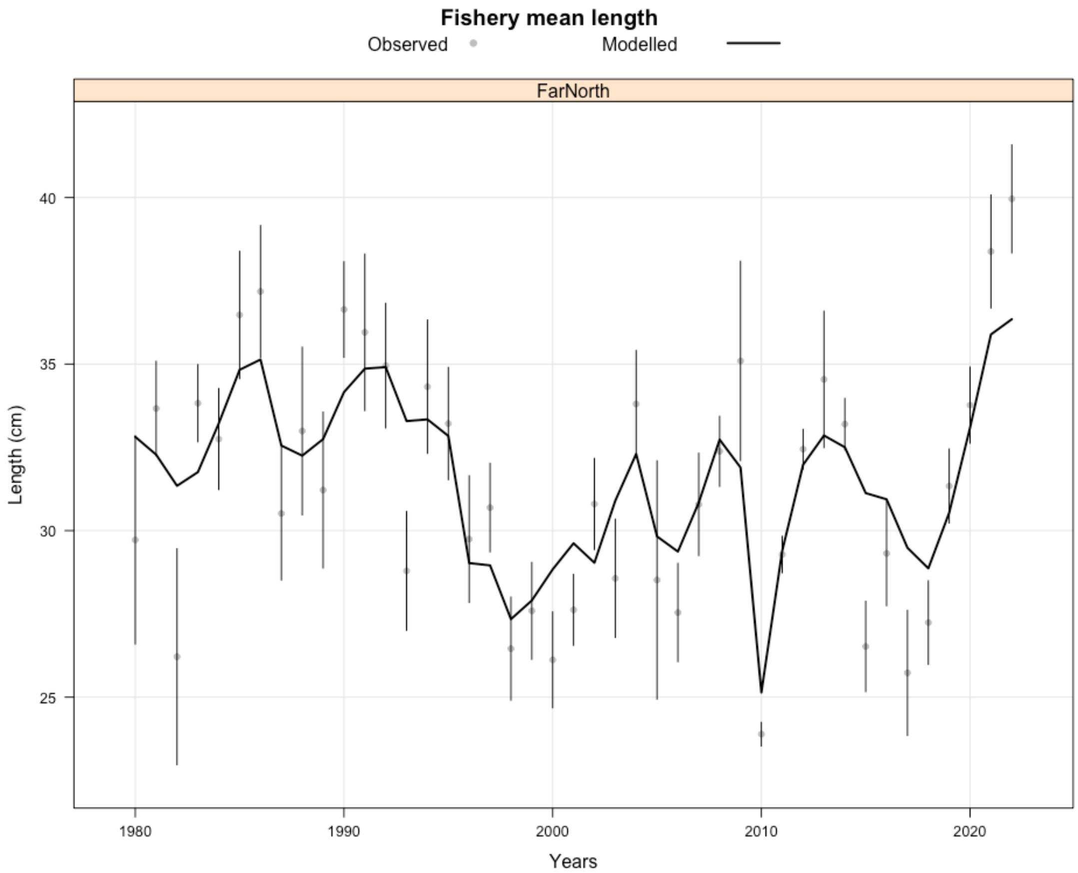


Figure A10.33: Mean length by year in Fleet 3 (Far North). Line represents the Model h2_1.02 (two-stock hypothesis) predictions and dots observed values with implied input error bars.

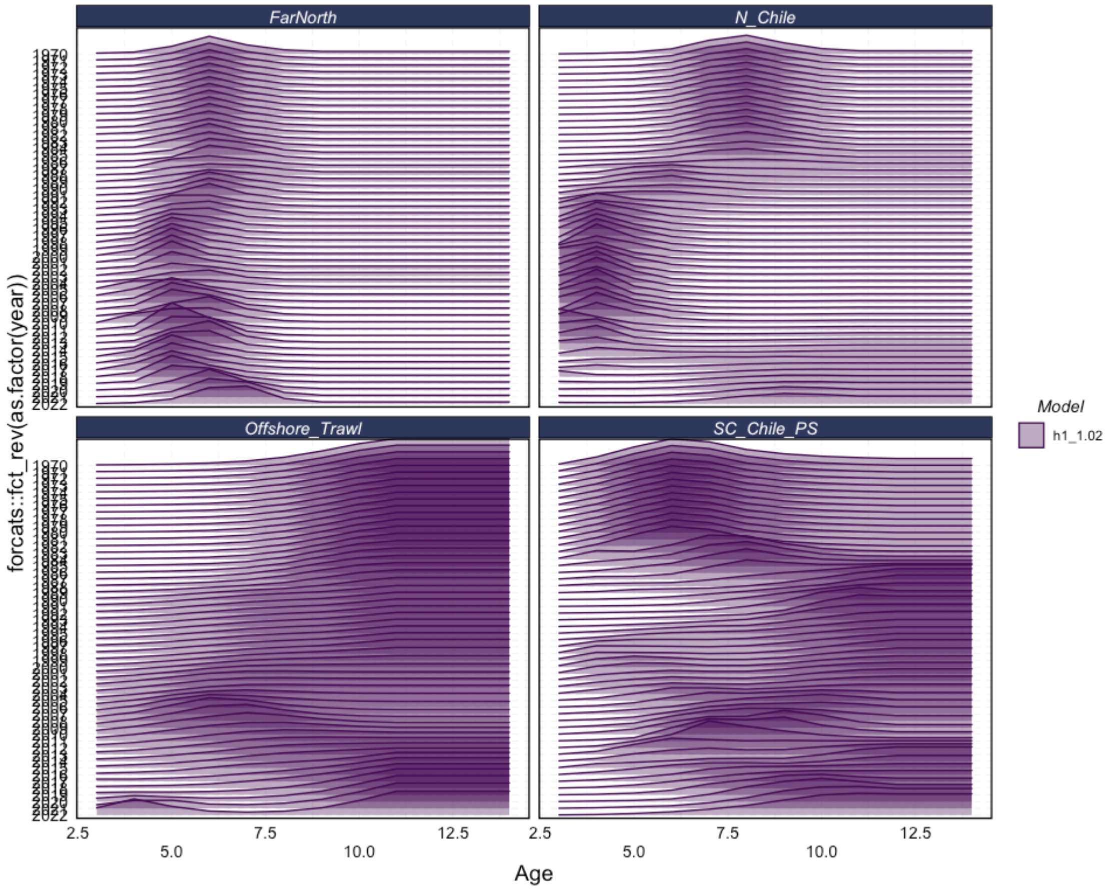


Figure A10.34: Estimates of selectivity by fishery over time for Model h1_1.02 (single-stock hypothesis).

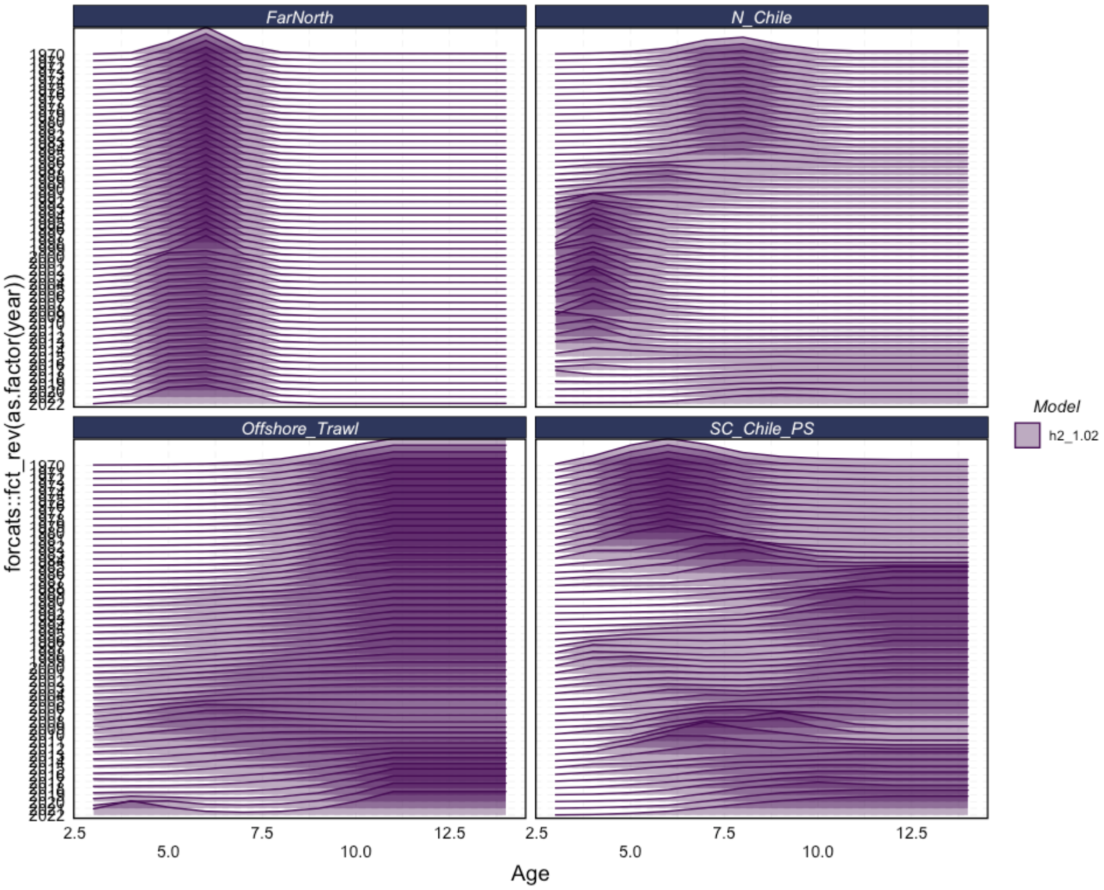


Figure A10.35: Estimates of selectivity by fishery over time for Model h2_1.02 (two-stock hypothesis).

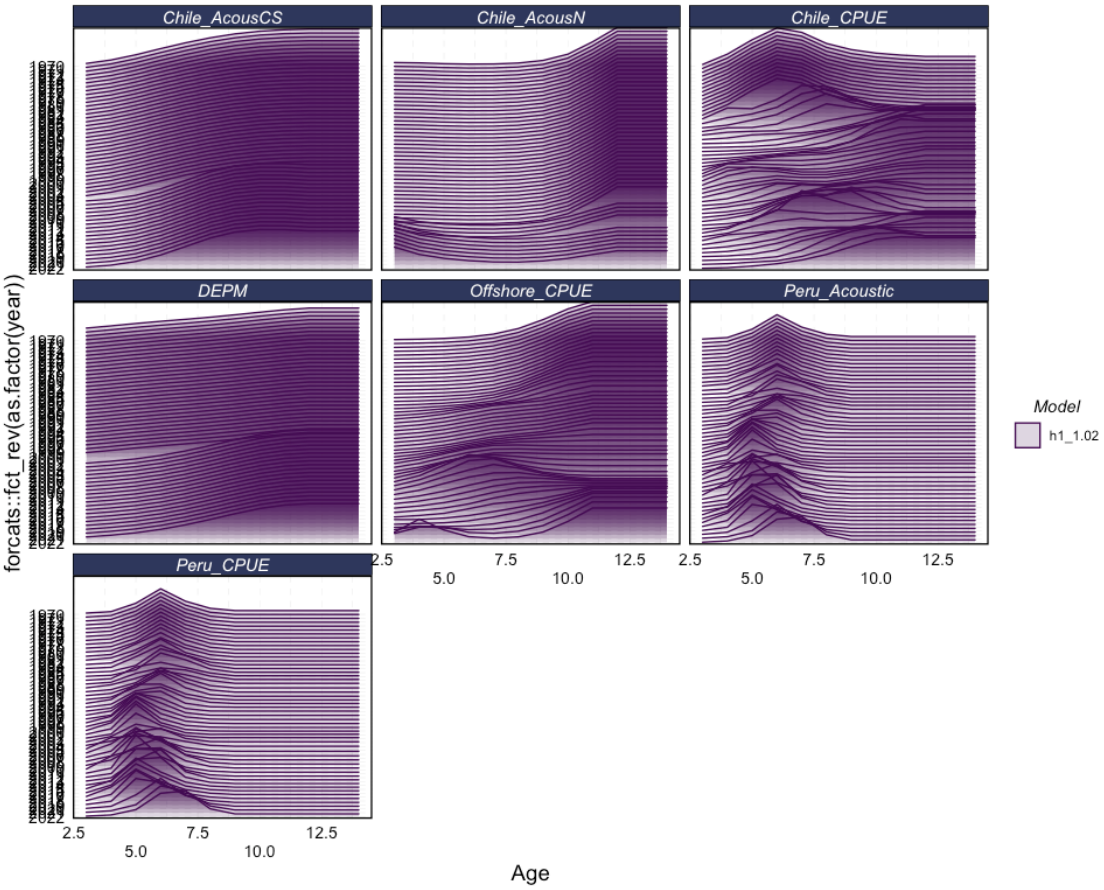


Figure A10.36: Estimates of selectivity by survey over time for Model h1_1.02 (single-stock hypothesis).

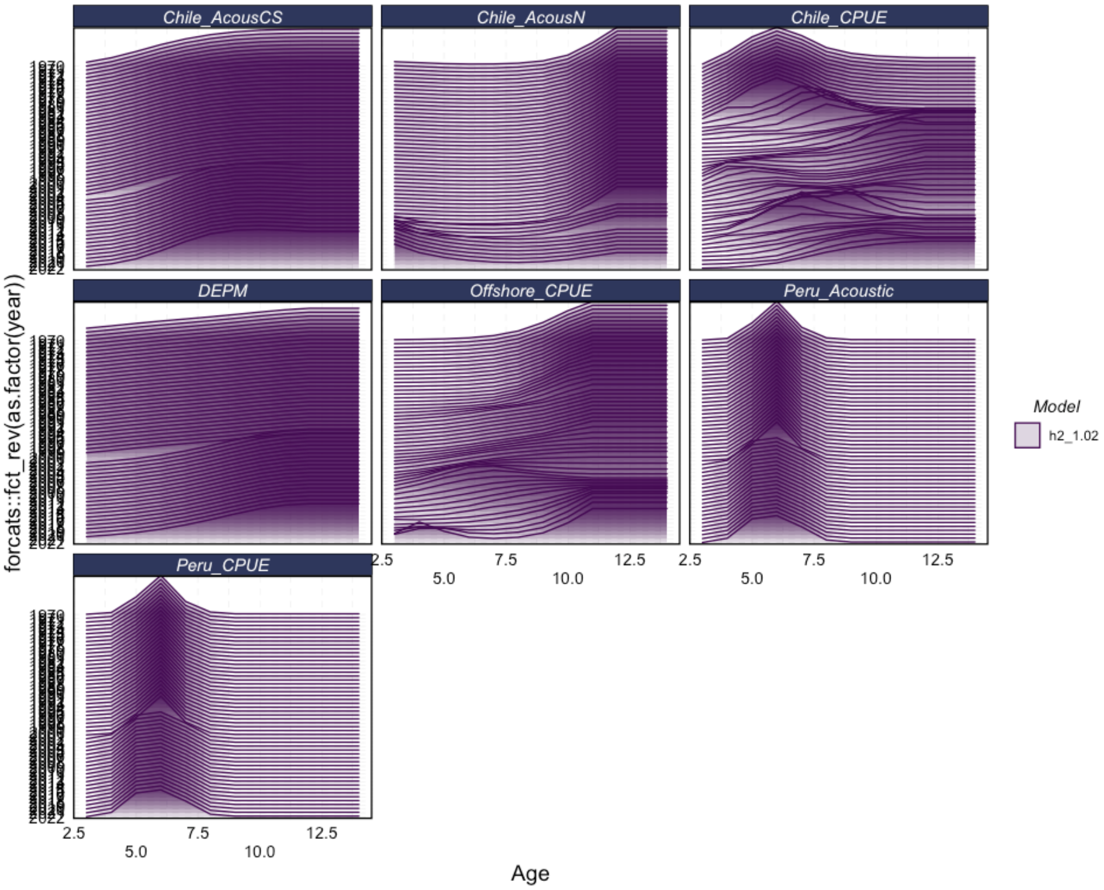


Figure A10.37: Estimates of selectivity by survey over time for Model h2_1.02 (two-stock hypothesis).

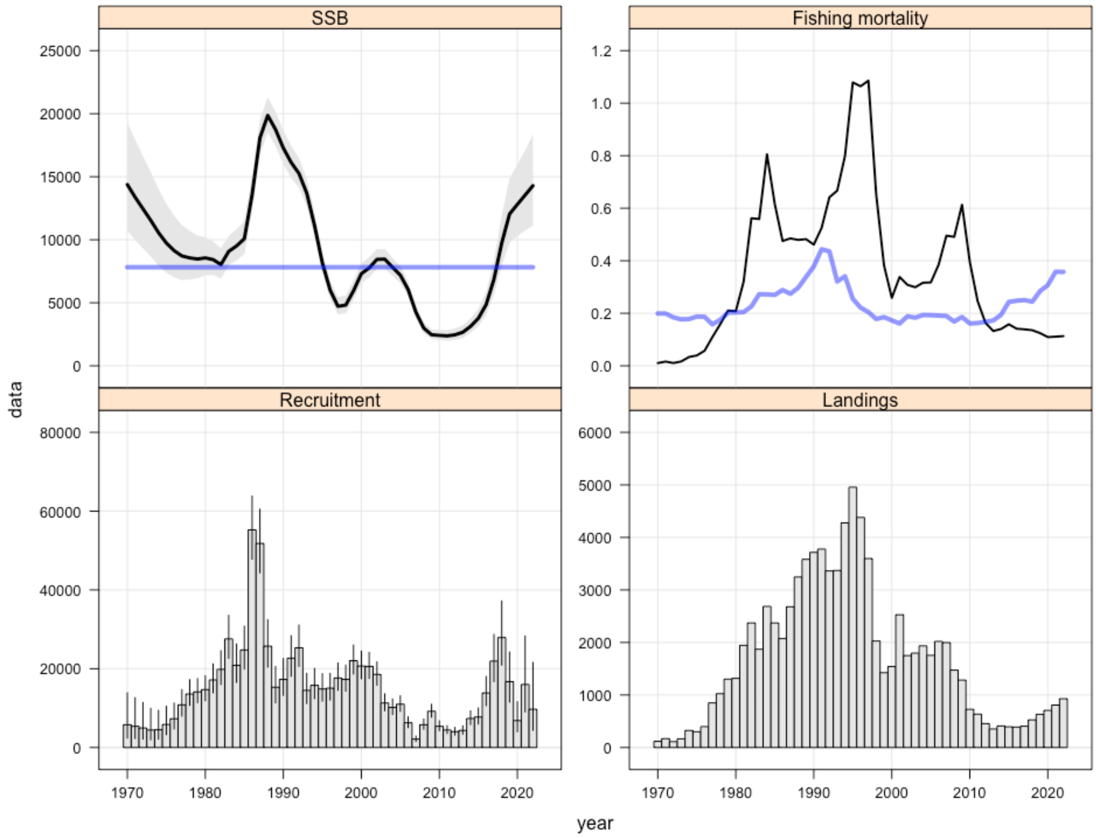


Figure A10.38: Model h1_1.02 (single-stock hypothesis) summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left), total fishing mortality (top right), and total catch (kt; bottom right). Blue lines represent the average B_{MSY} over the most recent ten years (upper left) and dynamic estimates of F_{MSY} (upper right).

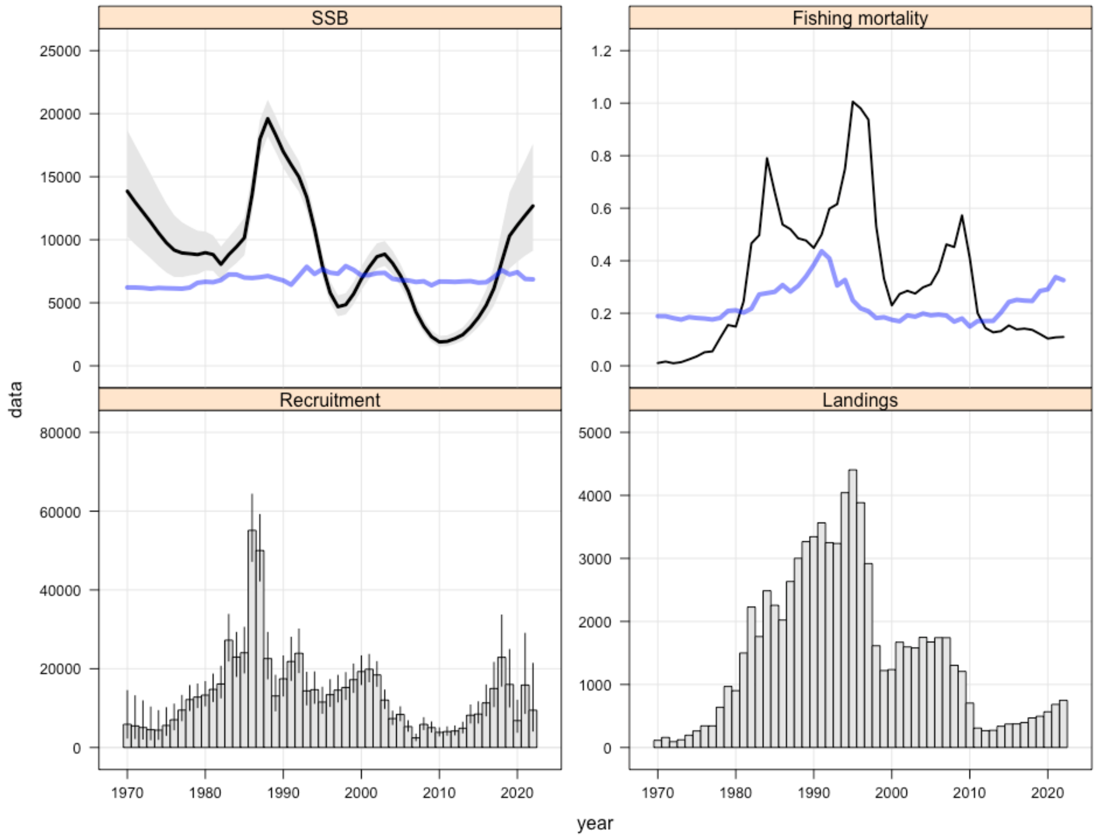


Figure A10.39: Model h2_1.02 (two-stock hypothesis) summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left), total fishing mortality (top right), and total catch (kt; bottom right) for the south stock. Blue lines represent dynamic estimates of B_{MSY} (upper left) and of F_{MSY} (upper right).

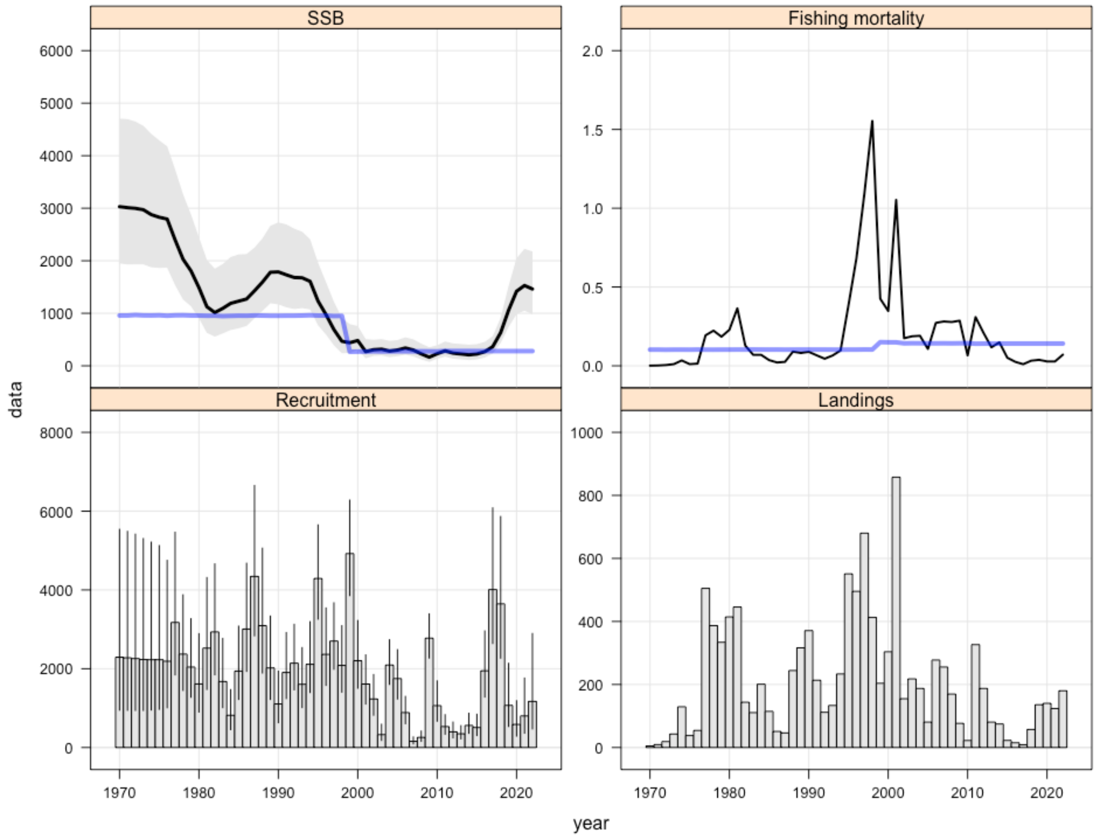


Figure A10.40: Model h2_1.02 (two-stock hypothesis) summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left), total fishing mortality (top right), and total catch (kt; bottom right) for the far north stock. Blue lines represent dynamic estimates of B_{MSY} (upper left) and of F_{MSY} (upper right).

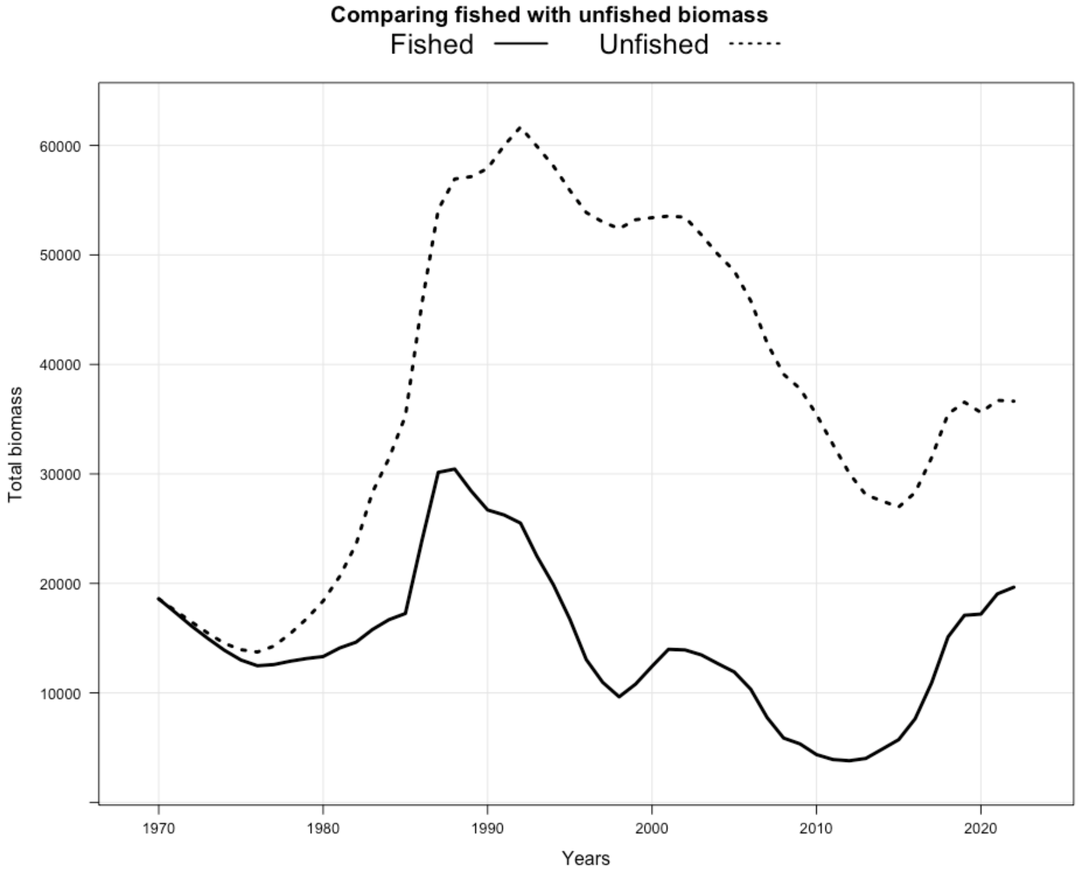


Figure A10.41: Model h1_1.02 (single-stock hypothesis) results for the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place (dotted line), beginning in 1970.

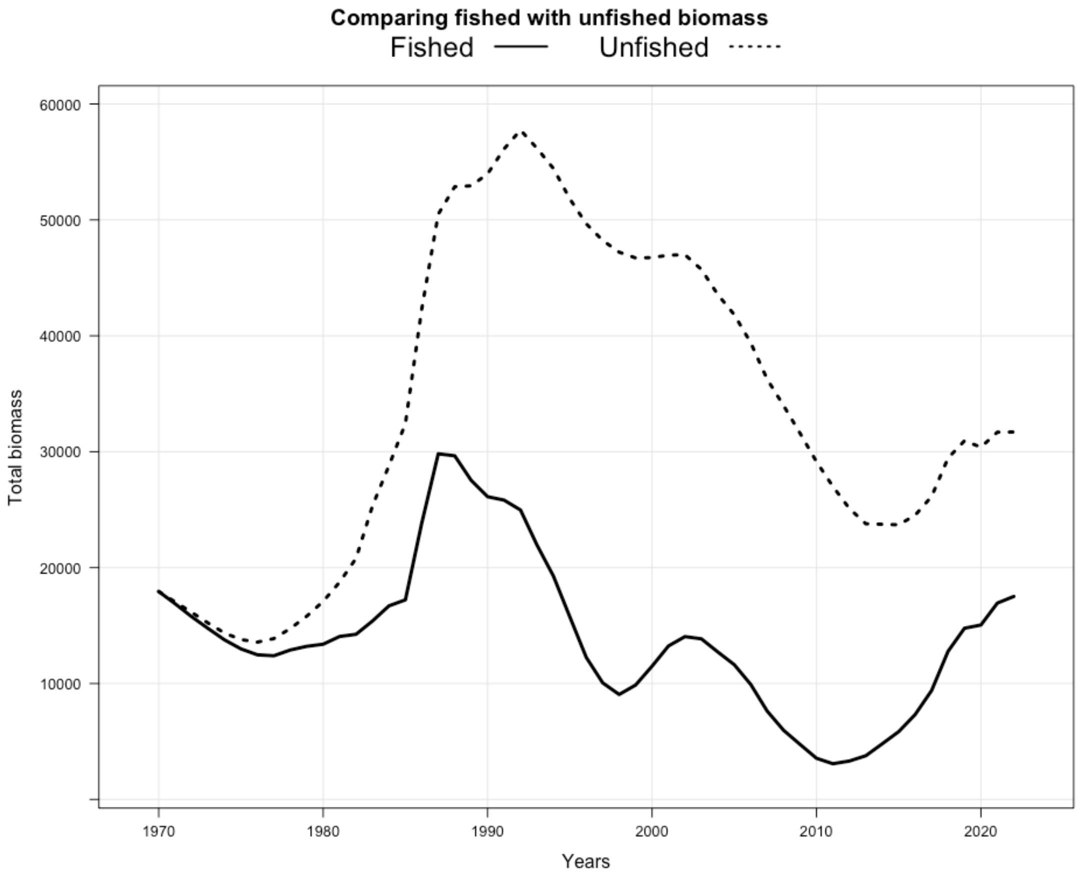


Figure A10.42: Model h2_1.02 (two-stock hypothesis) results for the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place (dotted line) for the south stock, beginning in 1970.

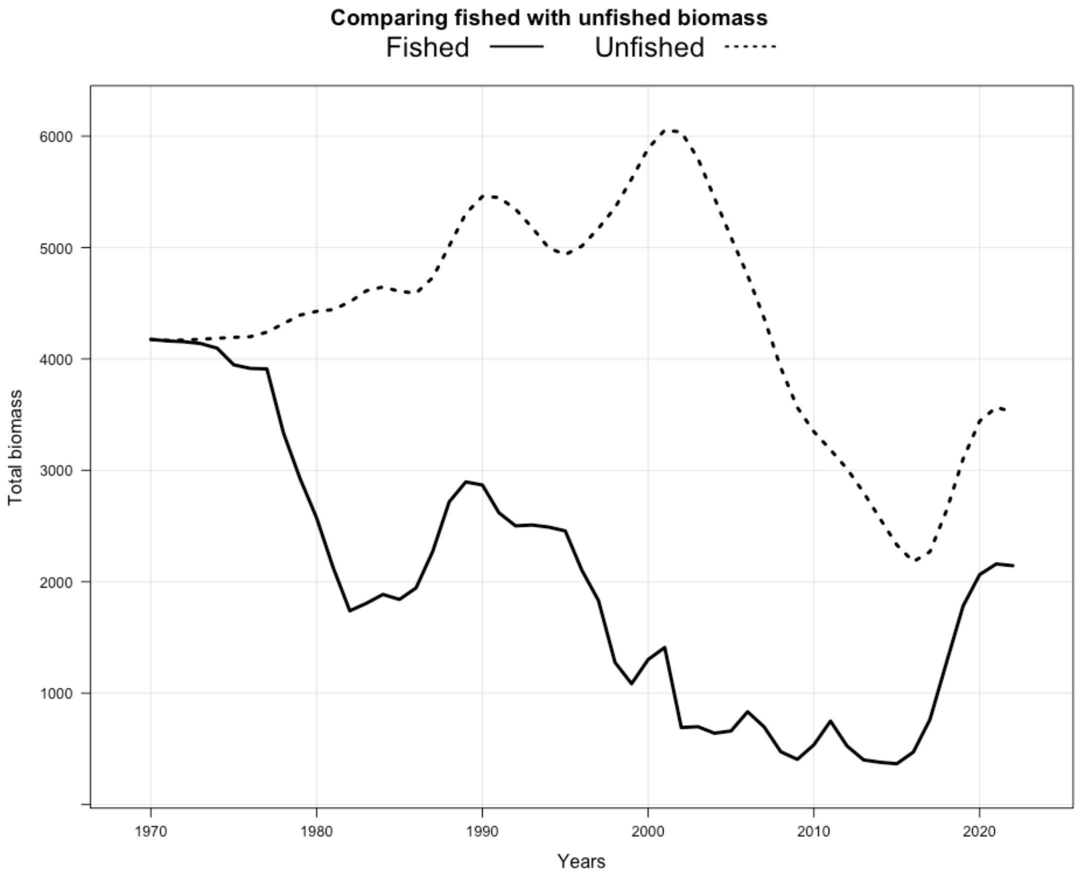


Figure A10.43: Model h2_1.02 (two-stock hypothesis) results for the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place (dotted line) for the far north stock, beginning in 1970.