SPRFMO SC11-Report
Annex 7. Jack Mackerel Technical Annex

1. Introduction

1. This document and content are based on discussions and analyses conducted at the 11th SPRFMO Scientific Committee (SC) meeting in 2023. During SC11, the model was updated with new data, and subsequently accepted by the SC. Discussions at SC11 focused on the following topics:

- Review and update of data sets;
- Inclusion of varying weights-at-age data for the FarNorth fleet;
- Inclusion of updates to the Acoustic Central-South Chile survey data;

Scientific Name and General Distribution

2. 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

3. 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

4. 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.

5. 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 SC11.

Fishery

6. 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.
7. 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.
8. 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.
9. 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

10. 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

11. Important environmental events such as the El Niño effect of 2016 affect oceanographic dynamics. During such events, the depth of the 15^{o}C 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

12. 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

13. 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.
14. 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 EU, Russian or 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 and Russia 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.

15. 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 for older years. 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.

16. 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. This meant that, beginning in 2021, self-sampling data were included in the assessment data.

17. 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. Since 2022 (SC10), all 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).

18. 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. An overall increase of technical efficiency of 1% per year has been included for this fleet since SC10. In SC11, alternative efficiency factors in the form of time blocks were proposed as a result of interviews with fishers (SC11-JM06). It was noted that inclusion of these proposed time blocks be explored in a benchmark assessment.

19. 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 (SC6) 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 for the entire time series, beginning in SC10.

20. 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 in the time series, beginning in SC10.

21. 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.

22. 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.

23. The lack of a defined protocol for CPUE standardisation was noted during SCW14. Development of CPUE standardisation guidelines has thus been identified as a priority to improve the quality of the assessment.

Fisheries Independent Data

24. 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. The survey resumed in 2020, resulting in data points for 2020, 2022, and 2023. Preliminary analyses during SC11 led to the

recommendation of further investigation during the next benchmark assessment, prior to including these updated data in the assessment. 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.

25. 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.

26. 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.

27. 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.

28. 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

29. 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

30. Table A10.11.

31. 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.

32. 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,

33. Table A10.16, and

34

	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	0.14	0.328	0.584	0.889	1.223	1.568	1.91	2.405	2.739	3.047	3.327
2016	0.037	0.143	0.32	0.553	0.821	1.109	1.402	1.689	2.405	2.739	3.047	3.327
2017	0.029	0.132	0.318	0.578	0.892	1.24	1.602	1.966	2.405	2.739	3.047	3.327
2018	0.031	0.136	0.326	0.591	0.91	1.262	1.628	1.995	2.405	2.739	3.047	3.327
2019	0.03	0.134	0.322	0.586	0.904	1.256	1.623	1.991	2.405	2.739	3.047	3.327
2020	0.029	0.131	0.319	0.584	0.905	1.262	1.637	2.012	2.405	2.739	3.047	3.327
2021	0.031	0.134	0.315	0.564	0.861	1.186	1.523	1.858	2.405	2.739	3.047	3.327
2022	0.031	0.134	0.315	0.562	0.857	1.179	1.512	1.843	2.405	2.739	3.047	3.327
2023	0.04	0.149	0.323	0.547	0.801	1.07	1.341	1.606	2.405	2.739	3.047	3.327

35. Table A10.17.

36. 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.

37. For the far north fleet, mean weight-at-age is calculated from annual weight-at-length data using the growth function (Table A10.12). The information covers the period from 1970 to present year (

38. Table A10.16). Prior to SC11, the weights-at-age from 2015-2022 were fixed to historical mean values, but the time series has been updated since then.

39. The weights-at-age for the offshore fleet are derived from EU and Russian age-length keys as well as age-length keys from the Chilean South-Central fleet. The EU and Russia 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 and Korea, length-weight information is transformed using the EU, Russian and Chilean fleet-2 quarter-specific age-length keys (

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	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

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	1	2	3	4	5	6	7	8	9	10	11	12
2015	0.033	0.14	0.328	0.584	0.889	1.223	1.568	1.91	2.405	2.739	3.047	3.327
2016	0.037	0.143	0.32	0.553	0.821	1.109	1.402	1.689	2.405	2.739	3.047	3.327
2017	0.029	0.132	0.318	0.578	0.892	1.24	1.602	1.966	2.405	2.739	3.047	3.327
2018	0.031	0.136	0.326	0.591	0.91	1.262	1.628	1.995	2.405	2.739	3.047	3.327
2019	0.03	0.134	0.322	0.586	0.904	1.256	1.623	1.991	2.405	2.739	3.047	3.327
2020	0.029	0.131	0.319	0.584	0.905	1.262	1.637	2.012	2.405	2.739	3.047	3.327
2021	0.031	0.134	0.315	0.564	0.861	1.186	1.523	1.858	2.405	2.739	3.047	3.327
2022	0.031	0.134	0.315	0.562	0.857	1.179	1.512	1.843	2.405	2.739	3.047	3.327
2023	0.04	0.149	0.323	0.547	0.801	1.07	1.341	1.606	2.405	2.739	3.047	3.327

41. 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.

42. 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. This procedure was adopted in SC11.

43. 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 beginning 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

44. 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

45. 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 data types. The available data on the jack mackerel fishery in the South Pacific area begin from 1970 to the present year (Table A10.18).

46. 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

47. 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.

48. 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).

49. 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).

50. 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).

51. 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.

52. 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.

53. 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 were updated during the JM 2022 benchmark (SCW14).

54. 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

55. 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.

56. 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.

57. 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. A growth function within the model was specified to convert model-predicted age compositions to length compositions, in order to fit the model to the length composition data.

58. 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 instated based on a analyses executed at SC03. In SCW14, the provisional 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

59. 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

60. As SC11 was an update assessment, the main model explorations involved incrementally adding new data components relative to the model and data adopted from SC10. 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).

61. 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.

62. 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.

63. During the JMWG web meeting in 2023 (G128-2023), it was noted that the Chilean central-south acoustic survey had resumed operations beginning in 2020. Preliminary assessment runs incorporated these updated data points to test their impact on the stock status. Two versions were tested- one with just the data updated (Model 1.01) and a second with a break allowed in selectivity estimates (selectivity change penalty and catchability in 2019) to account for changes since 2009 (Model 1.02).

64. Several updates to the Chilean CPUE indices were proposed in SC11. There was a proposal to test the inclusion of these new time series in the assessment model (Models 1.03-1.05).

65. During SC11, it was noted that annual weight-at-age had not been updated for the FarNorth fleet since 2015, despite the fact that these data were collected annually and show some (minor) temporal variation. These data were included in Model 1.06.

66. 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. As a result, the CPUE value for the offshore fleet for the final year (2022) was unusually high, likely due to reasons unrelated to the stock size. To address this, Model 1.07 down-weighted this final value to reduce its impact on the assessment.

67. In 2023, the Peruvian fleet fished in the SPRFMO Convention Area, amounting to 20,056 tons of catch. The SC decided to incorporate those catches to Fleet 3 due to two factors, namely that 1) the fishery composition data were not separated by area, and 2) the fleet characteristics (e.g., gear) are that of the far-north fleet rather than that of the offshore fleet. A sensitivity was tested to allocate those catch data to the offshore fleet instead (Model 1.08). Doing so had negligible impact on the assessment, showing a barely perceptible difference in the north stock for the two-stock model.

68. 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 update. 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.

69. 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

70. 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. Incorporating the recent central-south acoustic (Models 1.01 and 1.02) led to a decline in the stock biomass in recent years. Questions were raised about how the new data points should be weighted, as the current data weight for the time series had been calculated from data collected over a decade ago. As a result, the inclusion of these data should be examined and discussed in greater detail during the next benchmark assessment. Similarly, the decision was made to investigate the impacts of changing the Chilean CPUE during the next benchmark assessment (Models 1.03-1.05). Incorporating annual variation in the FarNorth mean weight-at-age (Model 1.06) resulted in a slight decrease in stock biomass in recent years. Down-weighting the 2022 value for the offshore CPUE had negligible impact on the outlook of the stock.

71. It was decided that the final model for SC11 was to be Model 1.07, which included the annual variation in FarNorth mean weight-at-age as well as a down-weighted 2022 value for the offshore fleet CPUE. Overall, the stock (or stocks; depending on the stock structure hypothesis used) shows continued increasing trends in biomass, similar to previous years.

72. 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_1.07 tended to slightly under-estimate SSB, with a Mohn's rho of -0.17 (Figure A10.3). Recruitment tended to be under-estimated, with a Mohn's rho of -0.42 (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_1.07 showed little retrospective pattern in SSB for the south stock (Mohn's rho of 0.01), but had a slight tendency to over-estimate SSB for the north stock (Mohn's rho of 0.19; Figure A10.5). The model also tended to under-estimate recruitment for the south (Mohn's rho of -0.29), with better performance for the north stock (Mohn's rho of -0.04; Figure A10.6).

73. 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_1.07 (raw values for biomass found in Table A10.27; graphically visualised in Figure A10.7 and Figure A10.8). The results were mostly in line with the previous year's estimates, albeit with the SC11 model showing a larger increase in biomass for 2022 and 2023 than the previous model. The trends in the CPUE and age composition data were likely driving this change. Estimates of fishing mortality in recent years remain similar to that of the previous SCs, almost following the estimates from SC10 exactly. Recruitment estimates appear mostly in line with those of previous models, similar to SC10. 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. Previously, updates to the ageing methodology in 2022 likely led to a change in the perception of stock biomass, likely resulting in an increase in the estimate of B_{MSY}. The updates to the data for the 2023 resulted in similar estimates of the reference points to the SC10 model (Figure A10.8). 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.

74. 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_1.07 are given in

75.

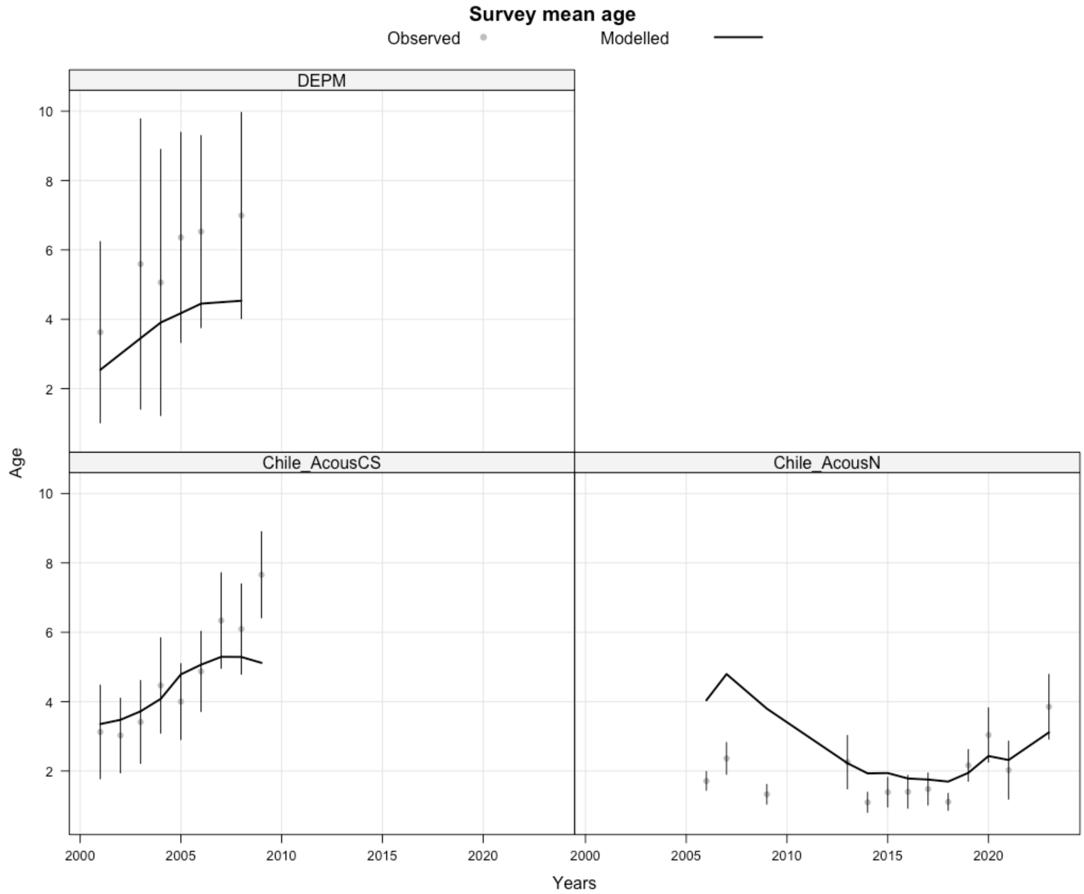
	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11
1970	8761	6726	10082	9770	9928	10319	10289	10629	11383	14378	14403
1971	8112	6384	9164	8872	9037	10015	9964	10214	10979	13372	13368
1972	7818	6173	8527	8289	8457	9854	9783	9964	10731	12456	12431
1973	7726	6015	8042	7911	8079	9756	9666	9794	10521	11541	11499
1974	7676	5910	7673	7633	7800	9646	9538	9625	10249	10560	10505
1975	7763	5894	7446	7511	7675	9604	9480	9534	9984	9742	9675
1976	8141	6075	7454	7638	7799	9752	9610	9638	9822	9136	9057
1977	8810	6589	7808	8027	8186	10112	9948	9955	9808	8711	8623
1978	9551	7151	8224	8445	8603	10458	10267	10256	9810	8562	8469
1979	10188	7613	8553	8810	8965	10717	10497	10473	9832	8470	8374
1980	10854	8276	9085	9349	9494	11124	10881	10847	10069	8560	8464
1981	11170	8521	9213	9561	9693	11174	10920	10878	9982	8423	8325
1982	10806	8122	8679	9137	9252	10513	10263	10217	9192	8033	7933
1983	11092	8503	8926	9487	9578	10584	10358	10310	9344	9078	8976
1984	11122	8635	8942	9653	9722	10502	10310	10264	9434	9507	9404
1985	11554	9342	9557	10297	10351	10869	10721	10679	10077	10080	9980
1986	13159	11355	11531	11890	11936	12177	12075	12039	11772	13579	13487
1987	14919	13284	13459	13371	13411	13402	13344	13314	13297	18078	17988
1988	15496	13716	13894	13801	13830	13717	13702	13679	13828	19862	19768
1989	15050	13082	13256	13389	13406	13455	13472	13454	13502	18745	18646
1990	14228	12207	12371	12701	12699	13076	13116	13101	13136	17271	17171
1991	13098	11032	11197	11792	11763	12408	12466	12455	12537	16133	16034
1992	11909	9856	10018	10772	10716	11542	11610	11602	11763	15260	15170
1993	10802	8942	9082	9800	9722	10658	10726	10720	10743	13700	13621
1994	9271	7518	7634	8165	8070	9061	9127	9123	9074	11132	11064
1995	7154	5448	5532	5901	5794	6696	6761	6758	6666	8161	8100
1996	5819	3820	3862	4174	4073	4775	4832	4831	4740	6003	5942
1997	4950	2990	2965	3254	3181	3609	3655	3657	3564	4719	4645
1998	4985	3158	3074	3539	3498	3677	3724	3730	3573	4814	4718
1999	5668	3937	3795	4475	4457	4434	4499	4511	4278	5956	5839
2000	6671	5018	4834	5616	5624	5463	5556	5574	5312	7308	7182
2001	7481	5892	5690	6368	6404	6172	6298	6323	6095	7759	7642
2002	8083	6699	6544	7010	7073	6805	6965	6997	6770	8442	8342
2003	8201	6952	6848	7274	7349	7080	7270	7309	7078	8463	8373
2004	7641	6564	6475	6908	6979	6725	6935	6980	6751	7815	7725
2005	6708	5763	5676	6159	6225	5997	6213	6262	6056	7188	7095
2006	5486	4682	4595	5102	5160	4979	5195	5248	5061	6049	5957
2007	4119	3430	3324	3846	3890	3754	3973	4029	3857	4241	4157
2008	3067	2545	2382	2890	2915	2779	2998	3055	2926	2986	2904
2009	2130	1850	1598	2070	2074	1893	2103	2159	2076	2465	2363
2010	1709	1647	1291	1775	1758	1538	1728	1778	1703	2413	2277
2011	1855	1861	1382	1868	1832	1667	1817	1855	1782	2373	2203
2012	2304	2115	1552	2065	2015	1980	2068	2090	2038	2458	2257
2013	3085	2383	1814	2308	2248	2339	2362	2370	2348	2659	2433
2014	-	2738	2222	2667	2572	2725	2687	2691	2719	3127	2873
2015	-	3206	2720	3273	3103	3176	3019	3042	3107	3767	3504
2016	-	-	3174	4116	3885	3606	3390	3456	3567	4857	4615
2017	-	-	-	-	5294	4097	3915	4047	4190	6867	6685
2018	-	-	-	-	-	4777	4821	5078	5264	9747	9730
2019	-	-	-	-	-	-	6188	6673	6956	12041	12534
2020	-	-	-	-	-	-	-	8273	8740	12802	14060
2021	-	-	-	-	-	-	-	-	9960	13547	15454

75.

	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11
2022	-	-	-	-	-	-	-	-	-	14289	16482
2023	-	-	-	-	-	-	-	-	-	-	16400

76. Table A10.28, and Model h2_1.07 results are in

Table A10.29 (southern stock) and Table A10.30 (northern stock). Both models show similar good fits to the fishery 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), although both models predicted more older fish than were found in the offshore trawl fleet (Figure A10.15 and Figure A10.16). 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_1.07 and h2_1.07 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_1.07) and Figure A10.29 (h2_1.07), and survey mean age compositions are shown in Figure A10.30 (h1_1.07) and



77. Figure A10.31 (h2_1.07). 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.

78. For SC11, B_{MSY} was estimated to be approximately 8.1 million t under the single-stock hypothesis (h1_1.07), and 6.8 and 0.25 million t for the south and far north stocks respectively under the two-stock hypothesis (h2_1.07).

79. A summary of the time series stock status (spawning biomass, F, recruitment, total biomass) for the single-stock hypothesis (h1_1.07) is shown in Figure A10.38**Error! Reference source not**

found.. 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 56% of what is estimated to have occurred had there been no fishing (Figure A10.39).

80. Under the 2-stock hypothesis (h2_1.07), 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 A10.40), while the northern unit only shows an increase in biomass beginning in the middle of the last decade (Figure A10.41). 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 A10.42 and Figure A10.43 show the current total biomass to be approximately 56% and 62% of unfished total biomass for the southern and the far north stocks respectively.

81. 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, Age group (years)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	0.000361	0.00206	0.00515	0.0116	0.0243	0.0289	0.0166	0.00851	0.00546	0.00542	0.00542	0.00542
1971	0.000551	0.00315	0.00788	0.0177	0.0369	0.0439	0.0252	0.0129	0.00824	0.00818	0.00818	0.00818
1972	0.000454	0.00279	0.00649	0.0121	0.0207	0.0231	0.0137	0.00778	0.00563	0.00553	0.00553	0.00553
1973	0.000727	0.00462	0.0106	0.019	0.0303	0.0328	0.0193	0.0106	0.00731	0.00713	0.00713	0.00713
1974	0.00094	0.00557	0.0136	0.0283	0.0554	0.0645	0.0372	0.0193	0.0125	0.0124	0.0124	0.0124
1975	0.00155	0.00946	0.0225	0.0442	0.0807	0.0917	0.0532	0.028	0.0185	0.0182	0.0182	0.0182
1976	0.00238	0.0148	0.0347	0.066	0.115	0.129	0.0753	0.0401	0.0267	0.0262	0.0262	0.0262
1977	0.00285	0.0181	0.0416	0.0747	0.121	0.131	0.0769	0.0421	0.0288	0.0281	0.0281	0.0281
1978	0.00499	0.0305	0.0709	0.132	0.223	0.248	0.149	0.0868	0.0649	0.0638	0.0638	0.0638
1979	0.00669	0.0359	0.0808	0.143	0.226	0.255	0.187	0.162	0.168	0.167	0.167	0.167
1980	0.00686	0.0369	0.0813	0.135	0.195	0.214	0.169	0.162	0.176	0.175	0.175	0.175
1981	0.0127	0.0713	0.156	0.247	0.324	0.339	0.268	0.26	0.283	0.28	0.28	0.28
1982	0.0205	0.103	0.227	0.384	0.575	0.648	0.53	0.532	0.59	0.586	0.586	0.586
1983	0.0204	0.0802	0.166	0.26	0.346	0.42	0.503	0.687	0.847	0.844	0.844	0.844
1984	0.0347	0.134	0.18	0.331	0.616	0.815	0.898	1.12	1.31	1.31	1.31	1.31
1985	0.0295	0.0993	0.173	0.311	0.538	0.686	0.768	0.937	1.06	1.06	1.06	1.06
1986	0.0225	0.0593	0.122	0.21	0.399	0.566	0.626	0.773	0.877	0.88	0.88	0.88
1987	0.0303	0.101	0.12	0.188	0.38	0.597	0.641	0.72	0.799	0.816	0.816	0.816
1988	0.0371	0.0964	0.135	0.16	0.239	0.385	0.534	0.674	0.793	0.846	0.846	0.846
1989	0.0257	0.071	0.155	0.189	0.207	0.285	0.428	0.616	0.795	0.893	0.893	0.893
1990	0.0206	0.0454	0.0923	0.157	0.228	0.313	0.425	0.552	0.732	0.847	0.847	0.847
1991	0.0217	0.0539	0.0844	0.136	0.234	0.365	0.528	0.699	0.841	0.899	0.899	0.899
1992	0.0223	0.0633	0.102	0.143	0.193	0.336	0.584	0.991	1.19	1.04	1.04	1.04
1993	0.0369	0.114	0.141	0.183	0.237	0.297	0.482	0.888	1.2	1.13	1.13	1.13
1994	0.0367	0.11	0.184	0.25	0.338	0.459	0.763	1.1	1.3	1.31	1.31	1.31
1995	0.0537	0.259	0.376	0.481	0.59	0.635	0.925	1.28	1.58	1.74	1.74	1.74
1996	0.095	0.403	0.547	0.591	0.616	0.682	0.876	1.14	1.41	1.59	1.59	1.59
1997	0.0875	0.553	0.663	0.562	0.501	0.57	0.785	1.05	1.33	1.52	1.52	1.52
1998	0.0601	0.423	0.366	0.3	0.256	0.292	0.402	0.554	0.742	0.897	0.897	0.897
1999	0.0614	0.28	0.245	0.199	0.162	0.166	0.222	0.316	0.45	0.581	0.581	0.581
2000	0.0491	0.217	0.231	0.174	0.128	0.125	0.157	0.219	0.297	0.369	0.369	0.369
2001	0.0759	0.236	0.277	0.226	0.171	0.168	0.209	0.279	0.357	0.414	0.414	0.414
2002	0.0421	0.159	0.205	0.225	0.197	0.199	0.248	0.328	0.405	0.453	0.453	0.453
2003	0.0508	0.159	0.194	0.223	0.197	0.192	0.236	0.316	0.391	0.434	0.434	0.434
2004	0.0558	0.163	0.207	0.251	0.234	0.23	0.276	0.347	0.414	0.453	0.453	0.453
2005	0.082	0.168	0.205	0.286	0.284	0.265	0.302	0.365	0.416	0.439	0.439	0.439
2006	0.0781	0.2	0.201	0.288	0.372	0.364	0.418	0.474	0.489	0.463	0.463	0.463
2007	0.128	0.293	0.29	0.33	0.429	0.5	0.561	0.647	0.62	0.558	0.558	0.558
2008	0.195	0.349	0.323	0.423	0.503	0.515	0.512	0.55	0.549	0.5	0.5	0.5
2009	0.135	0.35	0.384	0.633	0.796	0.801	0.736	0.668	0.596	0.553	0.553	0.553
2010	0.172	0.458	0.375	0.449	0.54	0.53	0.612	0.487	0.364	0.327	0.327	0.327
2011	0.0649	0.0827	0.119	0.244	0.336	0.335	0.375	0.249	0.178	0.152	0.152	0.152
2012	0.0204	0.0481	0.108	0.203	0.305	0.24	0.194	0.15	0.124	0.113	0.113	0.113
2013	0.0215	0.0602	0.117	0.196	0.198	0.164	0.154	0.141	0.131	0.124	0.124	0.124
2014	0.0204	0.0475	0.0828	0.13	0.177	0.178	0.163	0.168	0.168	0.161	0.161	0.161
2015	0.0168	0.0642	0.075	0.0986	0.146	0.18	0.19	0.21	0.231	0.228	0.228	0.228
2016	0.00844	0.0355	0.0656	0.106	0.142	0.165	0.179	0.198	0.21	0.209	0.209	0.209
2017	0.0122	0.0314	0.0487	0.0779	0.135	0.178	0.207	0.232	0.242	0.228	0.228	0.228
2018	0.0074	0.0169	0.0398	0.0685	0.11	0.154	0.203	0.247	0.266	0.263	0.263	0.263
2019	0.00395	0.00977	0.024	0.0523	0.103	0.139	0.188	0.223	0.225	0.218	0.218	0.218
2020	0.00256	0.00712	0.0141	0.0319	0.0748	0.131	0.172	0.204	0.196	0.188	0.188	0.188
2021	0.00445	0.0105	0.0203	0.0298	0.062	0.106	0.15	0.186	0.215	0.234	0.234	0.234
2022	0.00541	0.0126	0.0173	0.0276	0.0441	0.0781	0.114	0.15	0.183	0.234	0.234	0.234
2023	0.00627	0.0116	0.0182	0.032	0.0496	0.0717	0.105	0.151	0.217	0.291	0.291	0.291

82. 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 fixed value as estimated at SWG14, 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_1.07 are presented in

Table A10.34, whereas those of Model h2_1.07 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_1.07) and Table A10.38 (h2_1.07).

5. Management Advice

83. New data and indicators on the status of the jack mackerel stock suggest that conditions evaluated in detail from the last update assessment 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.

84. Historical fishing mortality rates and patterns relative to the provisional biomass target are shown in Figure A10.38 for Model h1_1.07. Near-term spawning biomass is expected to increase from 16.4 million t in 2023 to 17.2 million t in 2024 (with approximate 90% confidence bounds of 13.5 – 21.9 million t). Under the two-stock hypothesis, historical fishing mortality rates and patterns relative to the biomass targets estimated by Model h2_1.07 are shown in Figure A10.39 and Figure A10.40. Near-term spawning biomass is expected to increase from the 2023 estimate of 12.9 million t to 13.7 million t in 2024 for the southern stock (with approximate 90% confidence bounds of 9.9 – 18.8 million t), and decrease from 1.47 million t to 1.44 million t for the far north stock (with approximate 90% confidence bounds of .98 – 2.1 million t).

85. 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.

86. Given current stock status, the third tier of the jack mackerel rebuilding plan (as defined in the SCW14 report, para 62.d) 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 four 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 2024 catch level for jack mackerel within the entire jack mackerel range to be at or below 1,242,000t t.

87. Projections show a high likelihood of the biomass being above B_{MSY} in 2024 even under the most conservative recruitment productivity scenario evaluated (h1_1.07.ls and h2_1.07.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

88. 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.

89. 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.

90. 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 2022 are not official figures, and 2023 are predictions).

Assigned Fleet / Year	Fleet 1 N Chile	Fleet 2 Chile CS	Fleet 3 (Far North) Cook Islands	Fleet 3 (Far North) Cuba (2)	Fleet 3 (Far North) Ecuador (ANJ)	Fleet 3 (Far North) Peru (ANJ)	Fleet 3 (Far North) USSR	Fleet 3 (Far North) Subtotal	Fleet 4 (Offshore Trawl) Belize	Fleet 4 (Offshore Trawl) China	Fleet 4 (Offshore Trawl) Cuba	Fleet 4 (Offshore Trawl) European Union	Fleet 4 (Offshore Trawl) Faroe Islands	Fleet 4 (Offshore Trawl) Japan	Fleet 4 (Offshore Trawl) Korea	Fleet 4 (Offshore Trawl) Peru	Fleet 4 (Offshore Trawl) Russia/ USSR	Fleet 4 (Offshore Trawl) Ukraine	Fleet 4 (Offshore Trawl) Vanuatu	Fleet 4 (Offshore Trawl) Subtotal	Grand Total
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	256,566		325,939	0	32,862	8	2,248	0	0	9,253	674	8,229		7,617	60,891	634,125
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	16,361	214,999	0		3,563	79,441		83,004		8,329		10,101	0		5,267	2,670			14,809	41,175	355,539
2014	18,219	254,295	0		9	79,191		79,200		21,155		20,539	0		4,078	2,557			15,324	63,652	415,366
2015	34,886	250,327			289	23,036		23,325		29,180		27,955	0		5,749	0	2,561		21,227	86,672	395,210
2016	24,657	295,160			0	15,121		15,121		20,208		11,962	0		6,430	0	0		15,563	54,163	389,101
2017	35,002	311,863			54	10,094		10,148		16,802		27,887	0		1,235	0	3,188		0	49,113	406,126
2018	11,551	415,149			23	58,356		58,379		24,366		9,691	0		3,717	0	4,685		0	42,460	527,539
2019	11,875	432,447			0	139,811		139,811		22,699		11,870	0		7,444	0	9,423		0	51,436	635,569
2020	44,155	517,665			0	158,880		158,880		0		0	0		0	0	5,245		0	5,245	725,945
2021	61,359	567,267			8	118,096		118,104		0		43,167	0		0	0	12,151		0	55,318	802,048
2022	72,795	655,157			5	159,603		159,608		0		44,425	0		0	0	29,443		0	73,868	961,428
2023	*80,466*	*736,292*	*0*		*5*	*210,000*		*210,005*	*0*	*0*	*0*	*55,144*	*0*		*0*	*20,056*	*32,649*		*0*	*107,849*	*1,134,612*

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	72.8	655.16	159.61	73.87
2023	80.47	736.29	230.06	87.79

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	2	1	1	11	26	29	19	6	3	1	0	0
2023	4	1	4	12	19	32	19	6	1	0	1	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	5	17	24	23	16	9	3	2	0	0
2023	0	2	10	19	28	22	11	5	2	1	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	1	67	8	7	10	3	2	1	1	0	0	0
2023	21	41	18	13	5	2	1	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	1	1	2	3	4	4	5	6	7	8	7	7	6	6	6	6	6	5	4	3	2	1	1	1
2023	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	6	8	8	6	5	4	5	5	6	6	6	5	5	4	3	3	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	-	-	0.833	-	-	-	-
1984	-	99	0.766	-	-	-	-
1985	-	324	0.669	-	94.316	-	-
1986	-	123	0.563	-	108.116	-	-
1987	-	213	0.662	-	109.789	-	-
1988	-	134	0.582	-	114.18	-	-
1989	-	-	0.566	-	157.394	-	-
1990	-	-	0.485	-	229.757	-	-
1991	-	242	0.535	-	231.672	-	-
1992	-	-	0.49	-	180.355	-	-
1993	-	-	0.439	-	145.726	-	-
1994	-	-	0.472	-	95.245	-	-
1995	-	-	0.422	-	54.257	-	-
1996	-	-	0.416	-	29.967	-	-
1997	3530	-	0.341	-	31.664	-	-
1998	3200	-	0.29	-	43.994	-	-
1999	4100	-	0.295	5724	52.681	-	-
2000	5600	-	0.286	4688	105.784	-	-
2001	5950	-	0.34	5627	131.586	-	-
2002	3700	-	0.295	-	96.661	4.07	-
2003	2640	-	0.26	1388	67.471	4.833	-
2004	2640	-	0.281	3287	51.853	5.188	-
2005	4110	-	0.255	1043	75.171	4.103	-
2006	3192	112	0.277	3283	111.259	5.423	-
2007	3140	275	0.207	626	79.75	7.473	-
2008	487	259	0.136	1935	24.251	3.792	1680
2009	328	18	0.113	-	-	1.341	1185
2010	-	440	0.087	-	7.247	2.494	824
2011	-	432	0.048	-	35.283	6.375	732
2012	-	230	0.147	-	50.332	5.559	618
2013	-	144	0.129	-	64.504	2.448	719
2014	-	87	0.102	-	-	3.29	760
2015	-	459	0.084	-	-	2.647	1035
2016	-	587.244	0.15	-	-	2.272	743
2017	-	610.47	0.178	-	-	2.897	916
2018	-	374.11	0.115	-	-	8.258	807
2019	-	1487.07	0.197	-	-	13.756	975
2020	-	1728.27	0.257	-	-	14.943	1373
2021	-	1870.36	0.271	-	-	18.062	1714
2022	-	-	0.276	-	-	22.672	3032
2023	-	2502.16	0.28	-	-	19.127	-

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
2023	5	18	23	22	14	11	6	1	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	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1971	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1972	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1973	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1974	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1975	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1976	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1977	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1978	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1979	0.108	0.155	0.247	0.314	0.388	0.51	0.653	0.78	0.949	1.153	1.349	1.575
1980	0.181	0.209	0.263	0.338	0.434	0.462	0.499	1.062	0.984	1.144	1.35	1.551
1981	0.205	0.235	0.287	0.353	0.424	0.5	0.601	0.735	0.984	1.144	1.35	1.551
1982	0.164	0.192	0.236	0.301	0.354	0.422	0.46	0.49	0.739	1.144	1.35	1.551
1983	0.122	0.191	0.245	0.309	0.376	0.429	0.485	0.486	0.529	1.144	1.35	1.551
1984	0.157	0.174	0.241	0.323	0.387	0.443	0.51	0.559	0.984	1.144	1.35	1.551
1985	0.209	0.206	0.275	0.344	0.406	0.482	0.553	0.595	0.984	1.144	1.35	1.551
1986	0.083	0.166	0.279	0.358	0.432	0.523	0.559	0.716	0.984	1.144	1.35	1.551
1987	0.159	0.163	0.237	0.335	0.432	0.491	0.542	0.545	0.984	1.144	1.35	1.551
1988	0.178	0.214	0.251	0.296	0.382	0.581	0.69	0.852	0.984	1.144	1.35	1.551
1989	0.137	0.194	0.252	0.297	0.354	0.496	0.579	0.547	0.701	1.144	1.35	1.551
1990	0.116	0.238	0.293	0.338	0.386	0.49	0.688	0.677	0.95	1.144	1.35	1.551
1991	0.144	0.165	0.283	0.344	0.388	0.44	0.739	0.855	0.775	1.144	1.35	1.551
1992	0.116	0.159	0.259	0.285	0.342	0.394	0.471	0.673	0.984	1.144	1.35	1.551
1993	0.133	0.13	0.258	0.334	0.379	0.432	0.52	0.638	0.815	0.935	0.96	1.551
1994	0.105	0.132	0.282	0.322	0.379	0.436	0.508	0.584	0.984	1.144	1.35	1.551
1995	0.072	0.147	0.27	0.34	0.394	0.394	0.632	0.852	0.984	1.144	1.35	1.551
1996	0.117	0.151	0.203	0.23	0.284	0.388	1.32	0.852	0.984	1.144	1.35	1.551
1997	0.162	0.15	0.225	0.291	0.425	0.556	0.704	0.852	0.984	1.144	1.35	1.551
1998	0.183	0.124	0.246	0.285	0.339	0.411	0.704	0.852	0.984	1.144	1.35	1.551
1999	0.111	0.095	0.266	0.306	0.37	0.612	0.704	0.852	0.984	1.144	1.35	1.551
2000	0.061	0.173	0.232	0.256	0.456	0.556	0.704	0.852	0.984	1.144	1.35	1.551
2001	0.117	0.116	0.208	0.289	0.4	0.556	0.704	0.852	0.984	1.144	1.35	1.551
2002	0.097	0.133	0.24	0.324	0.389	0.483	0.704	0.852	0.984	1.144	1.35	1.551
2003	0.095	0.112	0.234	0.314	0.422	0.478	0.51	0.852	0.984	1.144	1.35	1.551
2004	0.14	0.182	0.199	0.246	0.36	0.556	0.704	0.852	0.984	1.144	1.35	1.551
2005	0.084	0.134	0.223	0.265	0.294	0.66	0.739	0.852	0.984	1.144	1.35	1.551
2006	0.077	0.127	0.202	0.386	0.457	0.529	0.636	0.852	0.984	1.144	1.35	1.551
2007	0.116	0.14	0.217	0.296	0.401	0.539	0.658	0.852	0.984	1.144	1.35	1.551
2008	0.053	0.1	0.246	0.29	0.389	0.592	0.629	0.761	0.984	1.144	1.35	1.551
2009	0.088	0.126	0.246	0.286	0.334	0.534	0.704	0.852	0.984	1.144	1.35	1.551
2010	0.056	0.102	0.231	0.287	0.401	0.602	0.701	0.852	0.984	1.144	1.35	1.551
2011	0.064	0.109	0.275	0.325	0.382	0.556	0.704	0.852	0.984	1.144	1.35	1.551
2012	0.047	0.179	0.252	0.349	0.361	0.556	0.704	0.852	0.984	1.144	1.35	1.551
2013	0.064	0.064	0.284	0.39	0.441	0.657	0.52	0.852	0.984	1.144	1.35	1.551
2014	0.052	0.105	0.218	0.283	0.43	0.553	0.704	0.852	0.984	1.144	1.35	1.551
2015	0.037	0.185	0.279	0.369	0.437	0.608	0.779	0.852	0.984	1.144	1.35	1.551
2016	0.164	0.175	0.233	0.294	0.366	0.499	0.718	0.86	0.658	1.144	1.35	1.551
2017	0.049	0.158	0.192	0.259	0.332	0.451	0.6	0.528	0.984	1.144	1.35	1.551
2018	0.034	0.129	0.248	0.277	0.279	0.556	0.704	0.852	0.984	1.144	1.35	1.551
2019	0.025	0.179	0.284	0.471	0.501	0.528	0.732	0.853	0.888	1.28	1.695	1.806
2020	0.068	0.211	0.242	0.303	0.397	0.474	0.77	1.066	1.351	1.568	1.35	2.294
2021	0.042	0.147	0.457	0.452	0.536	0.655	0.745	0.923	1.002	1.098	1.193	1.804
2022	0.027	0.244	0.404	0.52	0.606	0.684	0.792	0.816	1.065	1.12	1.193	2.659
2023	0.108	0.196	0.496	0.624	0.742	0.744	0.83	0.779	0.892	1.34	1.231	2.659

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	0.025	0.355	0.437	0.56	0.69	0.806	0.925	1.057	1.231	1.128	1.415	1.62
2023	0.192	0.265	0.437	0.52	0.597	0.699	0.799	0.907	0.916	1.11	1.442	1.674

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	0.14	0.328	0.584	0.889	1.223	1.568	1.91	2.405	2.739	3.047	3.327
2016	0.037	0.143	0.32	0.553	0.821	1.109	1.402	1.689	2.405	2.739	3.047	3.327
2017	0.029	0.132	0.318	0.578	0.892	1.24	1.602	1.966	2.405	2.739	3.047	3.327
2018	0.031	0.136	0.326	0.591	0.91	1.262	1.628	1.995	2.405	2.739	3.047	3.327
2019	0.03	0.134	0.322	0.586	0.904	1.256	1.623	1.991	2.405	2.739	3.047	3.327
2020	0.029	0.131	0.319	0.584	0.905	1.262	1.637	2.012	2.405	2.739	3.047	3.327
2021	0.031	0.134	0.315	0.564	0.861	1.186	1.523	1.858	2.405	2.739	3.047	3.327
2022	0.031	0.134	0.315	0.562	0.857	1.179	1.512	1.843	2.405	2.739	3.047	3.327
2023	0.04	0.149	0.323	0.547	0.801	1.07	1.341	1.606	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	0.154	0.141	0.218	0.251	0.278	0.544	0.785	0.933	1.09	1.252	1.362	1.49
2023	0.206	0.217	0.257	0.315	0.41	0.531	0.641	0.812	0.985	1.075	1.222	1.316

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	1980-2023	-	1970-2023	-	Index: 1984-1988; 1991; 2006-2021, 2023 Age comps: 2006-2007, 2009; 2013-2021, 2023	-
2 South-central Chile purse seine	1980-2023	-	1970-2023	1983-2023	1997-2009 Age comps: 2001-2009	Index: 1999-2001; 2003-2008 Age comps: 2001; 2003-2006, 2008
3 FarNorth	-	1980-2023	1970-2023	2002-2023	1985-2008; 2010-2013	-
4 International trawl off Chile	2015-2023	2015-2023*	1970-2023	China, EU, Korea, Russia, & Vanuatu (2008-2022)	-	-

(*) 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, …., 2023}	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	pj	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, ..., 2023	$\varepsilon_i, \sum_{i=1958}^{final\ year} \varepsilon_i = 0$	$N_{i,1} = e^{\mu_R + \varepsilon_i}$

Eq	Description	Symbol/Constraints	Key Equation(s)	
11)	Index catchability	μ^s, μ^f	$q_i^s = e^{\mu^s}$	
	Mean effect		$s_j^s = e^{\eta_j^s}$	$j \le \text{maxage}$
	Age effect	$\eta^s{}_j, \sum_{j=1958}^{final\ year} \eta^s{}_j = 0$	$s_j^s = e^{\eta_{\text{maxage}}^s}$	$j > \text{maxage}$
12)	Instantaneous fishing mortality		$F_{ij}^f = e^{\mu^f + \eta_j^f + \phi_i}$	
13)	Mean fishing effect	μ^f		
14)	Annual effect of fishing mortality in year i	$\varphi_i, \sum_{i=1970}^{final\ year} \varphi_i = 0$		
15)	age effect of fishing (regularised) In year time variation allowed	$\eta^f{}_j, \sum_{j=1958}^{final\ year} \eta^f{}_j = 0$	$s_{ij}^f = e^{\eta_j^f}$	$j \le \text{maxage}$
			$s_{ij}^f = e^{\eta_{\text{maxage}}^f}$	$j > \text{maxage}$
	In years where selectivity is constant over time	$\eta_{i,j}^f = \eta_{i-1,j}^f$	$i \ne \text{change year}$	
16)	Natural Mortality	M	fixed	
17)	Total mortality		$Z_{ij} = \sum_f F_{ij}^f + M$	
17)	Spawning biomass (note spawning taken to occur at mid of November)	B_i	$B_i = \sum_{j=2}^{12} N_{ij} e^{-\frac{10,5}{12} Z_{ij}} W_{ij} p_j$	
18)	Recruits (Beverton-Holt form) at age 1.	$\tilde{R}_i$	$\tilde{R}_i = \dfrac{\alpha B_t}{\beta + B_i}$,	
			$\alpha = \dfrac{4hR_0}{5h-1}$ and $\beta = \dfrac{B_0(1-h)}{5h-1}$ where	
			$B_0 = R_0 \varphi$	
			$\varphi = \sum_{j=1}^{12} e^{-M(j-1)} W_j p_j + \dfrac{e^{-12M} W_{12} p_{12}}{1-e^{-M}}$	
			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	$L_4 = 0.5 \sum_f \frac{1}{cv_f^2} \sum_{i=1970}^{final\ year} log\left(\frac{Yf_i}{\hat{Y}f_i}\right)^2$	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	$L_6 = \lambda_4 \sum_{j=6}^{12} (lnS_{j-1} - lnS_j)^2$ $S_{j-1} > S_j$	(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 2023.
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 2022 assessment data to the agreed revised datasets for 2023. 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 2022 (single stock h1 and two-stock h2) model and data set (model 1.02) from SC10.
0.01	As 0.00 but with revised catches through 2022 (currently still estimates)
0.02	As 0.01 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
0.03	As 0.02 but with updated 2022 weight at age data for all fisheries and their associated CPUE indices
0.04	As 0.03 but replaced offshore CPUE up to 2022
0.05	As 0.04 but with 2023 catch projections
0.06	As 0.05 but with updated 2023 fishery age composition data for N_Chile, SC_Chile, and Offshore_Trawl, and updated 2023 fishery length composition data for FarNorth
0.07	As 0.06 but with updated 2023 weight at age data for N_Chile, SC_Chile, and FarNorth fleets, and for their associated CPUE indices
0.08	As 0.07 but replaced SC_Chile_CPUE index (traditional absolute scaled CPUE by trip)
0.09	As 0.08 but replaced Peru_CPUE index
0.10	As 0.09 but updated AcousN 2023 index, with associated age composition and weight at age
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Models 1.x	Updated Model and Sensitivities
1.00	As 0.10 but with updated model (selectivity changes, recruitment) to 2023; 0.10 data file
1.01	As 1.00 but with updated Acoustic_CS data (2020, 2021, 2023)
1.02	As 1.01 but with a break in selectivity for Acoustic_CS in 2019
1.03	As 1.00 but with updated ageing error matrix from Chile (SC11-JM05) (NOT RUN)
1.04	As 1.00 but with proposed Chile CPUE index incorporating effort creep based on fisher interviews (SC11-JM06) (NOT RUN; comparison shown in SC11-JM06)
1.05	As 1.00 but with proposed Chile CPUE index from SC11-JM07
1.06	As 1.00 but with updated Peruvian weight-at-age data
1.07	As 1.06 but with downweighted 2022 offshore CPUE index
1.08	As 1.07 but with Peruvian high seas catch allocated to the offshore fleet (f4) instead of the farnorth fleet (f3)
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Models 1.xx.yy	Base Model Projections
1.07.xx	Base model
1.07.ls	As 1.07 but low steepness and short recruitment time series (2000-2015)

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	SC11
1970	8761	6726	10082	9770	9928	10319	10289	10629	11383	14378	14403
1971	8112	6384	9164	8872	9037	10015	9964	10214	10979	13372	13368
1972	7818	6173	8527	8289	8457	9854	9783	9964	10731	12456	12431
1973	7726	6015	8042	7911	8079	9756	9666	9794	10521	11541	11499
1974	7676	5910	7673	7633	7800	9646	9538	9625	10249	10560	10505
1975	7763	5894	7446	7511	7675	9604	9480	9534	9984	9742	9675
1976	8141	6075	7454	7638	7799	9752	9610	9638	9822	9136	9057
1977	8810	6589	7808	8027	8186	10112	9948	9955	9808	8711	8623
1978	9551	7151	8224	8445	8603	10458	10267	10256	9810	8562	8469
1979	10188	7613	8553	8810	8965	10717	10497	10473	9832	8470	8374
1980	10854	8276	9085	9349	9494	11124	10881	10847	10069	8560	8464
1981	11170	8521	9213	9561	9693	11174	10920	10878	9982	8423	8325
1982	10806	8122	8679	9137	9252	10513	10263	10217	9192	8033	7933
1983	11092	8503	8926	9487	9578	10584	10358	10310	9344	9078	8976
1984	11122	8635	8942	9653	9722	10502	10310	10264	9434	9507	9404
1985	11554	9342	9557	10297	10351	10869	10721	10679	10077	10080	9980
1986	13159	11355	11531	11890	11936	12177	12075	12039	11772	13579	13487
1987	14919	13284	13459	13371	13411	13402	13344	13314	13297	18078	17988
1988	15496	13716	13894	13801	13830	13717	13702	13679	13828	19862	19768
1989	15050	13082	13256	13389	13406	13455	13472	13454	13502	18745	18646
1990	14228	12207	12371	12701	12699	13076	13116	13101	13136	17271	17171
1991	13098	11032	11197	11792	11763	12408	12466	12455	12537	16133	16034
1992	11909	9856	10018	10772	10716	11542	11610	11602	11763	15260	15170
1993	10802	8942	9082	9800	9722	10658	10726	10720	10743	13700	13621
1994	9271	7518	7634	8165	8070	9061	9127	9123	9074	11132	11064
1995	7154	5448	5532	5901	5794	6696	6761	6758	6666	8161	8100
1996	5819	3820	3862	4174	4073	4775	4832	4831	4740	6003	5942
1997	4950	2990	2965	3254	3181	3609	3655	3657	3564	4719	4645
1998	4985	3158	3074	3539	3498	3677	3724	3730	3573	4814	4718
1999	5668	3937	3795	4475	4457	4434	4499	4511	4278	5956	5839
2000	6671	5018	4834	5616	5624	5463	5556	5574	5312	7308	7182
2001	7481	5892	5690	6368	6404	6172	6298	6323	6095	7759	7642
2002	8083	6699	6544	7010	7073	6805	6965	6997	6770	8442	8342
2003	8201	6952	6848	7274	7349	7080	7270	7309	7078	8463	8373
2004	7641	6564	6475	6908	6979	6725	6935	6980	6751	7815	7725
2005	6708	5763	5676	6159	6225	5997	6213	6262	6056	7188	7095
2006	5486	4682	4595	5102	5160	4979	5195	5248	5061	6049	5957
2007	4119	3430	3324	3846	3890	3754	3973	4029	3857	4241	4157
2008	3067	2545	2382	2890	2915	2779	2998	3055	2926	2986	2904
2009	2130	1850	1598	2070	2074	1893	2103	2159	2076	2465	2363
2010	1709	1647	1291	1775	1758	1538	1728	1778	1703	2413	2277
2011	1855	1861	1382	1868	1832	1667	1817	1855	1782	2373	2203
2012	2304	2115	1552	2065	2015	1980	2068	2090	2038	2458	2257
2013	3085	2383	1814	2308	2248	2339	2362	2370	2348	2659	2433
2014	-	2738	2222	2667	2572	2725	2687	2691	2719	3127	2873
2015	-	3206	2720	3273	3103	3176	3019	3042	3107	3767	3504
2016	-	-	3174	4116	3885	3606	3390	3456	3567	4857	4615
2017	-	-	-	-	5294	4097	3915	4047	4190	6867	6685
2018	-	-	-	-	-	4777	4821	5078	5264	9747	9730
2019	-	-	-	-	-	-	6188	6673	6956	12041	12534
2020	-	-	-	-	-	-	-	8273	8740	12802	14060
2021	-	-	-	-	-	-	-	-	9960	13547	15454
2022	-	-	-	-	-	-	-	-	-	14289	16482
2023	-	-	-	-	-	-	-	-	-	-	16400

Table A10.28. Estimated begin-year numbers at age (Model *h_1.07*; single-stock hypothesis).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	5708.45	4622.43	3784.58	3101.76	2526.22	2040.67	1638.12	1305.56	1031.91	809.24	630.28	2606
1971	5316.51	4312.99	3487.99	2848.48	2321.13	1867.79	1498.48	1216.65	978	775.6	608.27	2432.6
1972	4898.79	4016.1	3251.52	2618.86	2119.34	1695.77	1350.5	1102.59	907.07	732.9	581.28	2279.02
1973	4375.99	3700.38	3027.6	2441.05	1952.1	1568.53	1250.76	1005.23	826.05	681.28	550.56	2148.67
1974	4434.49	3303.84	2783.93	2259.95	1798.81	1427.45	1143.6	924.43	750.06	618.72	510.44	2022.36
1975	5749.16	3343.75	2477.85	2053.42	1615.96	1270.23	1001.59	826.02	681.02	556.86	459.46	1880.87
1976	7205.71	4337.36	2505.67	1831.21	1479.27	1125.68	869.72	712.6	604.46	503.94	412.27	1732.68
1977	10734.3	5430.83	3234.38	1828.63	1286.54	993.01	738.94	602.85	513.94	442.89	369.56	1572.97
1978	13500.2	8022.26	3967.52	2184.72	1080.84	786.51	622.87	497.38	422.57	366.17	315.93	1385.68
1979	14044.9	10088	5817.72	2653.02	1270.22	601.19	430.05	383.83	331.64	290.44	252.18	1171.89
1980	14636.5	10483.1	7285.67	3882.57	1553.27	701.77	321.49	251.53	235.13	204.79	179.8	881.61
1981	17082.6	10916.7	7554.49	4838.33	2266.34	879.71	391.22	191.39	153.56	143.3	125.16	648.7
1982	19740	12687.5	7623.91	4639.36	2542.5	1109	417.07	203.63	103.34	82.64	77.58	418.94
1983	27469.8	14554.1	8638.46	4544.56	2264.26	956.97	355.48	154.98	79.92	39.84	32.09	192.84
1984	20804.8	20248.2	10135.3	5465.04	2527.89	1117.26	417.89	143.38	54.55	25.31	12.69	71.64
1985	24755.7	15109.3	13289.6	6273.7	2838.34	956.1	322.78	114.6	35.89	12.62	5.9	19.64
1986	55282.9	18137.4	10273.1	8384.66	3437.11	1230.72	344.41	110.88	37.37	11.33	4.01	8.11
1987	51773.7	40846.9	12910.6	6823.83	5091.89	1757.12	526.44	142.5	43.48	14.15	4.29	4.59
1988	25660.8	37982.6	27927.7	8613.41	4229.41	2613.06	731.43	212.62	56.06	16.53	5.29	3.32
1989	15219.3	18713.8	26067.9	18196.6	5414.94	2458.12	1327.14	325.55	84.33	20.14	5.58	2.91
1990	17224.1	11213	13164.7	16734.1	11128.5	3258.28	1379.33	652.58	134.7	29.36	6.25	2.64
1991	22649.7	12744.1	8081.85	8992.41	10501.5	6543.09	1774.75	674.43	284.59	49.27	9.37	2.83
1992	25342.3	16746.1	9112.45	5575.59	5816.4	6162.48	3363.9	776.85	248.31	90.25	14.42	3.57
1993	14525.6	18749	11893.5	6188.95	3613.21	3595.02	3265.99	1365.89	206.13	52.28	21.92	4.37
1994	15785.4	10599.5	12669.8	7721.61	3830.63	2137.63	2002.94	1483.12	396.24	42.35	11.35	5.71
1995	14828.4	11533.6	7193.86	7854.74	4426.5	2027.48	1015.75	698.63	351.36	73.71	7.67	3.09
1996	14991.7	10684.2	6808.81	3501.49	3377.29	1753.26	777.78	291.29	137.28	48.84	8.58	1.25
1997	17487.6	10416.8	5655.04	2729.87	1285.26	1243.62	610.66	221.31	63.22	22.58	6.8	1.37
1998	17118.8	12184.5	4586.09	1707.04	925.22	498.25	454.69	175.91	48.6	10.65	3.28	1.19
1999	21868.2	12194.6	5938.73	1902.1	807.35	479.68	249.67	199.01	65.22	15.22	2.98	1.25
2000	20652.5	15649.8	7008.65	3237.81	1102.8	492.36	290.19	140.72	100.84	29.23	6.21	1.72
2001	20673.4	14904.4	9622.34	3874.65	1956.97	708.01	317.77	180.29	81.93	54.93	15.17	4.12
2002	18646.8	14455.9	8597.62	4404.09	2092.08	1168.41	427.78	183.48	97.07	41.35	26.79	9.4
2003	11294.8	13493.4	9269.09	5093.57	2558.46	1254.26	700.21	242.99	96.36	47.96	19.95	17.46
2004	10091.3	8096.14	8561.55	5556.72	2953.33	1535.54	758.43	403.62	129.51	48.38	23.53	18.35
2005	10874.3	7236.4	5122.61	5061.33	3130.95	1710.41	898.16	424.16	211.6	64.55	23.61	20.43
2006	6221.74	7662.41	4678.4	3099.6	2776.36	1728.42	969.88	493.51	221.02	106.75	32.34	22.06
2007	2110.42	4368.25	4724.05	2687.34	1647.4	1360.92	870.28	469.76	229.88	103.85	52.26	26.63
2008	5691.84	1403	2472.52	2439.4	1342.57	763.11	586.38	357.56	181.36	94.11	46.1	35.02
2009	8897.54	3568.22	729.12	1232.39	1114.11	585.1	327.72	252.46	150.04	78.35	43.62	37.61
2010	5092.68	6035.28	1912.39	358.38	458.48	363.31	189.78	111.67	91.35	60.4	34	35.25
2011	4138.41	3387.12	3342.57	1038.34	173.49	199.95	161.82	78.01	51.15	47.83	33.28	38.16
2012	3760.39	2951.22	2321.04	1776.74	556.42	88.28	105.61	83.5	45.23	31.59	30.44	45.46
2013	4148.1	2783.46	2109.23	1447.28	1033.71	305.3	51.96	65.41	53.88	29.82	21.01	50.48
2014	7115.85	3068.42	1976.68	1390.63	886.54	659.8	198.58	33.81	42.76	35.34	19.58	46.96
2015	7740.7	5270.56	2198.34	1321.73	892.72	572.44	432	129.72	21.64	27	22.23	41.85
2016	14012.6	5759.23	3719.94	1514.84	896.95	587.91	372.45	279.68	80.88	12.87	15.77	37.41
2017	22430.6	10516.3	4200.07	2610.51	1021.27	587.51	382.11	241.58	177.57	49.53	7.72	31.9
2018	29477	16801.1	7742	3024.8	1822.65	673.53	373.92	239.23	148.55	106.96	29.6	23.68
2019	21919.9	22148.8	12508.2	5591.72	2127.44	1230.53	435.12	232.08	144.01	87.94	62.26	31.01
2020	12337.3	16510.4	16575.7	9117.35	3984.93	1447.08	805.62	271.12	140.42	87.33	53.41	56.66
2021	19833.2	9303.62	12394.2	12305.4	6621.68	2813.22	963.21	510.45	165.77	86.61	54.28	68.42
2022	8488.82	14933.9	6969.67	9193.42	8996.78	4743.52	1947.6	631.82	319.6	100.23	51.31	72.69
2023	7406.99	6385.67	11164.1	5177.48	6716.74	6506.64	3377.21	1341.04	414.01	199.96	59.03	73.02

Table A10.29. Estimated begin-year numbers at age (Model *h_2.07*; two-stock hypothesis; southern stock).

Age group (years)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	5756.95	4647.88	3786.98	3081.46	2487.51	1990.8	1583.63	1250.95	980.62	763.47	590.97	2219.56
1971	5361.53	4349.44	3505.57	2847.43	2302.12	1834.9	1461.78	1177.16	937.44	737.1	573.9	2112.67
1972	4956.62	4049.92	3276.9	2628.65	2114.39	1676.81	1327.26	1077.27	878.28	702.68	552.55	2013.91
1973	4412.71	3744.43	3052.34	2460.59	1962.73	1565.23	1238.38	989.44	807.87	660.07	528.15	1928.99
1974	4319.06	3332.63	2816.92	2282.53	1824.72	1439.08	1144.82	918.06	739.91	606.13	495.32	1843.87
1975	5497.79	3261.21	2504.75	2100.32	1676.89	1304.76	1019.74	833.62	680.59	552.25	452.46	1746.16
1976	6959.76	4148.71	2441.55	1850.96	1518.71	1169.16	899.74	730.77	612.62	504.95	409.85	1631.71
1977	9414.3	5247.57	3089.59	1782.44	1309.62	1022.71	776.52	630.71	530.6	450.8	371.76	1503.05
1978	12096.5	7094.95	3895.02	2239.94	1250.15	877.4	678.2	543.46	457.05	389.62	331.25	1377.62
1979	12747.6	9096.83	5201.13	2742.42	1484.14	755.97	517.48	441.61	376.59	323.73	276.27	1211.71
1980	13271	9570.22	6632.69	3625.98	1797.36	894.76	442.74	324.46	283.83	240.61	207.11	951.96
1981	14744.6	9961.4	6971.18	4621.6	2393.57	1117.64	545.89	282.72	208.63	179.87	152.71	735.63
1982	16111.6	11003.1	7010.31	4509.44	2728.07	1307.93	602.04	315.44	164.78	118.8	102.74	507.41
1983	27246	11929.4	7500	4222.38	2320.35	1160.66	516.83	267.88	140.09	69.04	49.97	256.64
1984	22949	20176.5	8321.04	4802.39	2461.39	1240.79	576.26	236.3	101.82	45.39	22.44	99.64
1985	24035.1	16752.3	13340.9	5252.54	2607.52	1004.79	415.02	177.46	58.43	20.72	9.27	24.92
1986	55140.1	17637.8	11464.2	8483.65	2909.49	1151.04	382.26	145.49	52.57	15.31	5.44	8.98
1987	49997.6	40748.7	12562.5	7668.34	5197.17	1476.03	493.86	154.43	50.77	16.53	4.8	4.52
1988	22541.2	36658.2	27840.6	8423.46	4801.32	2685.12	614.09	196.62	56.78	17.26	5.52	3.12
1989	13042.2	16415.6	25159.9	18391.5	5422.94	2857.5	1381.21	272.05	75.72	19.43	5.6	2.8
1990	17408.8	9606.57	11555.7	16277.3	11511.6	3331.03	1623.83	680.22	111.07	25.85	6.01	2.6
1991	21820.9	12889.6	6938.18	7963.51	10516.6	6927.74	1840.5	802.27	296.04	40.38	8.38	2.79
1992	23912.9	16137.7	9230.2	4819.22	5254.62	6289.7	3636.19	820.17	301.45	96.51	12.43	3.44
1993	14363.3	17674.4	11448.9	6300.49	3158.05	3272.7	3397.25	1532.24	230	69	25.74	4.23
1994	14645.7	10462.7	11913.7	7517.64	3964.78	1883.84	1838.4	1586.29	476.4	52.45	16.8	7.3
1995	11491.4	10669.6	7085.49	7487.99	4422.77	2137.26	900.05	647.53	397.35	98.27	10.68	4.91
1996	13324.7	8230.76	6222.93	3676.06	3499.64	1852.06	855.78	269.77	136.55	62	13.09	2.08
1997	14412.7	9158.06	4155.82	2720.42	1538.59	1428.58	707.54	269.47	65.2	25.1	9.53	2.33
1998	15033.8	9980.06	3980.94	1618.4	1171.88	704.27	610.63	244.01	71.44	12.98	4.13	1.95
1999	16998.7	10699.4	4940.65	2086.26	906.11	685.33	397.42	308.71	105.94	25.72	4	1.88
2000	19079.3	12082.8	6114.41	2921.44	1292.19	582.59	438.59	240.5	170.02	51.03	10.88	2.49
2001	19766	13728.9	7350.64	3668.52	1855.37	859.56	388.74	283.27	145.97	95.49	26.67	6.98
2002	18410.1	13846.9	8194.11	4212.27	2210.83	1181.32	549.25	238.43	161.97	77.16	47.72	16.82
2003	12044.8	13340.2	8927.44	5047.16	2541.16	1371.5	732.07	324.09	129.78	81.61	37.09	31.01
2004	7348.31	8652.69	8600.66	5557.49	3050.92	1577.23	855.7	436.78	178.61	66.34	39.96	33.34
2005	8379.29	5252.55	5555.98	5282.82	3266.31	1824.25	946.67	490.72	233.3	89.26	31.86	35.2
2006	5285.11	5834.49	3356.21	3421.29	2999.6	1858.08	1057.36	528.87	257.49	116.35	43.49	32.67
2007	2412.69	3694.47	3611.11	2074.99	1938.1	1563.03	975.68	526.16	248.83	119.39	55.36	36.23
2008	5767.07	1603.62	2082.19	2042.25	1127.34	953.4	716.79	420.82	208.14	101.14	51.63	39.61
2009	4884.71	3586.16	854.93	1139.63	1010.97	515.28	430.51	324.67	183.57	90.83	46.35	41.81
2010	3624.46	3226.35	1909.28	440.01	457.26	344.76	174.77	155.87	125.77	76.42	39.48	38.32
2011	3746.47	2305.61	1541.68	991.31	212.35	201.46	153.4	71.65	72.38	66.05	41.65	42.4
2012	3810.26	2653.51	1604.29	1033.99	586.83	114.64	108.87	79.69	42.22	45.79	42.88	54.57
2013	4471.38	2821.64	1911.33	1088.12	637.72	326.85	68.14	67.75	51.84	28.19	30.9	65.76
2014	7465.58	3307.62	2007.99	1285.52	676.03	395.57	209.64	44.14	44.45	34.38	18.83	64.56
2015	8024.8	5528.25	2383.83	1397.05	853.32	428.04	250.15	134.65	28.19	28.41	22.11	53.63
2016	11098.5	5963.99	3918.33	1671.46	956.72	557.57	270.34	156.28	82.47	16.91	17.09	45.55
2017	15189.5	8317.62	4350.39	2773.35	1136.4	627.23	357.23	170.75	96.86	50.51	10.37	38.41
2018	22757.7	11341	6092.18	3131.82	1938.94	750.75	396.87	219.47	102.35	57.49	30.39	29.35
2019	17490.8	17073.1	8427.93	4424.92	2210.19	1313.19	486.2	244.84	129.55	59.28	33.4	34.7
2020	8890.56	13167.1	12778.1	6218.81	3174.02	1506.34	863.74	304.5	148.09	78.21	36.03	41.39
2021	16416.4	6702.13	9880.87	9522.55	4552.49	2226.08	999.05	549.46	187.73	92.05	48.96	48.48
2022	7842.14	12352.2	5012.49	7317.66	6985.83	3233.7	1513.63	649.72	344.91	114.43	55.05	58.27
2023	6501.42	5894.96	9218.39	3723.52	5380.08	5051.97	2260.46	1020.22	422.75	217.03	68.42	67.76

Table A10.30. Estimated begin-year numbers at age (Model *h2_1.07*; two-stock hypothesis; far north stock).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	2103.07	1407.77	1020.56	738.49	533.99	385.76	278.41	200.82	144.76	104.3	75.11	211.04
1971	2081.43	1511.92	1011.81	731.85	527.72	383.08	277.2	200.13	144.35	104.06	74.97	205.69
1972	2052.91	1496.33	1086.39	723.8	519.92	377.8	275.14	199.23	143.84	103.75	74.79	201.72
1973	2021.5	1475.74	1074.41	771.79	505.79	370.06	271	197.67	143.13	103.33	74.53	198.65
1974	2021.58	1453	1058.07	752.66	521.59	355.77	264.73	194.53	141.9	102.74	74.18	196.1
1975	2030.53	1452.36	1035.44	699.24	442.59	349.3	251.71	189.39	139.17	101.51	73.5	193.36
1976	2019.76	1459.48	1041.27	725.07	472.11	311.21	249.87	180.68	135.95	99.9	72.87	191.56
1977	3008.07	1451.63	1045.39	722.65	479.2	329.48	222.24	179.27	129.63	97.54	71.67	189.72
1978	2262.55	2153.89	991.47	460.31	161.24	227.93	215.75	155.28	125.26	90.57	68.15	182.64
1979	1907.71	1618.98	1458.58	402.24	84.47	71.58	146.95	150.03	107.98	87.1	62.98	174.4
1980	1457.36	1366.14	1107.38	651.25	92.78	40.65	47	102.76	104.92	75.51	60.91	166
1981	2241.61	1042.69	923.63	442.34	115.16	40.65	26.13	32.65	71.39	72.89	52.46	157.64
1982	2593.81	1598.74	677.19	251.21	31.26	36.5	24.29	17.75	22.18	48.5	49.52	142.75
1983	1479.64	1859.34	1107.65	341.82	77.65	16.68	24.53	17.11	12.5	15.62	34.16	135.41
1984	723.24	1062.07	1310.02	656.52	155.02	47.44	11.56	17.44	12.16	8.89	11.11	120.55
1985	1735.97	519.14	748.32	776.78	298.03	94.75	32.88	8.22	12.4	8.64	6.32	93.6
1986	2735.82	1247.02	369.4	487.6	441.62	197.22	66.85	23.5	5.87	8.86	6.18	71.42
1987	3934.34	1965.94	891.27	251.08	306.62	302.83	140.28	47.91	16.84	4.21	6.35	55.61
1988	2751.66	2826.97	1403.75	600.26	154.47	208.64	215.02	100.47	34.31	12.06	3.01	44.37
1989	1792.15	1974.35	1982.15	794.34	243.72	90.76	143.31	152.45	71.23	24.33	8.55	33.6
1990	982.27	1286.11	1387.35	1145.32	339.01	145.76	62.59	101.73	108.21	50.56	17.27	29.92
1991	1738.33	704.79	901.76	785	464.94	199.19	100.11	44.38	72.12	76.72	35.85	33.45
1992	2019.32	1247.88	497.26	541.63	367.48	287.28	138.38	71.23	31.57	51.31	54.58	49.31
1993	1542.91	1450.31	885.98	317.18	292.68	238.86	201.88	98.8	50.85	22.54	36.63	74.17
1994	2042.99	1107.67	1024.09	536.32	151.27	182.03	166.19	143.69	70.32	36.19	16.04	78.87
1995	4245.32	1465.72	775.63	572.26	211.33	87.95	124.74	117.74	101.8	49.82	25.64	67.24
1996	2322.88	3027	948.67	204.15	37.39	65.16	52.22	84.58	79.84	69.03	33.78	62.98
1997	2657.57	1645.66	1805.34	114.2	2.06	5.96	33.33	33.83	54.81	51.73	44.73	62.7
1998	2012.5	1866.87	880.99	77.33	0.1	0.14	2.51	20.34	20.64	33.44	31.56	65.55
1999	5005.12	1398.91	873.92	10.46	0	0	0.05	1.42	11.52	11.69	18.94	54.99
2000	2098.5	3565.39	894.64	205.1	0.52	0	0	0.03	0.96	7.76	7.87	49.8
2001	1509.74	1497.15	2325.08	253.05	15.91	0.17	0	0	0.02	0.65	5.28	39.27
2002	1160.48	1060.77	803.65	102.19	0.23	1.09	0.07	0	0	0.01	0.4	27.22
2003	313.89	831.31	679.35	303.73	30.48	0.1	0.7	0.05	0	0	0.01	19.28
2004	2031.17	224.82	529.42	248.87	86.82	12.83	0.06	0.49	0.03	0	0	13.44
2005	1626.29	1454.63	142.72	190.54	69.43	36.03	8.16	0.04	0.34	0.02	0	9.36
2006	895.59	1166.74	977.69	70.56	82.08	37.08	24.24	5.77	0.03	0.24	0.02	6.61
2007	156.18	640.38	704.25	265.82	13.41	27.26	22.45	16.66	3.96	0.02	0.16	4.56
2008	253.42	111.65	383.72	183.83	47.79	4.31	16.38	15.4	11.43	2.72	0.01	3.24
2009	2647.23	181.16	66.88	99.98	32.97	15.35	2.59	11.24	10.57	7.84	1.87	2.23
2010	988.53	1891.77	107.33	16.39	16.49	10.09	9.12	1.77	7.69	7.23	5.37	2.8
2011	502.39	709.72	1302.21	60.6	8.47	9.79	6.95	6.48	1.26	5.47	5.14	5.81
2012	359.79	358.9	416.19	301.48	9.25	2.48	5.76	4.74	4.42	0.86	3.73	7.47
2013	329.81	257.57	224.98	139.64	76.41	3.63	1.56	4	3.29	3.07	0.6	7.78
2014	524.57	236.53	171.18	104.5	55.23	38.83	2.41	1.1	2.82	2.32	2.16	5.9
2015	489.06	375.99	154.33	71.75	35.92	25.87	25.38	1.69	0.77	1.98	1.63	5.65
2016	1868.82	351.22	261.19	91.67	39.73	22.19	17.98	18.08	1.21	0.55	1.41	5.19
2017	3854.16	1342.83	248.24	170.81	57.9	26.49	15.69	12.87	12.94	0.86	0.39	4.72
2018	3193.02	2770.3	959.24	172.23	116.97	40.46	18.93	11.26	9.24	9.29	0.62	3.67
2019	1871.14	2294.08	1951.19	615.25	105.92	76.8	28.51	13.54	8.05	6.61	6.64	3.07
2020	1755.57	1344.21	1610.18	1227.59	368.54	68.5	53.93	20.37	9.67	5.75	4.72	6.94
2021	998.59	1261.46	950.03	1052.8	775.1	245.72	48.42	38.6	14.58	6.92	4.12	8.35
2022	885.73	717.56	892.83	626.16	672.05	520.08	173.96	34.67	27.64	10.44	4.96	8.92
2023	1258.8	636.25	502.56	555.04	368.98	430.48	364.41	124.23	24.76	19.74	7.46	9.91

Table A10.31. Estimated total fishing mortality at age (Model h1_1.07; 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	0.006	0.005	0.005	0.005
1971	0.001	0.003	0.007	0.016	0.034	0.044	0.027	0.014	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	0.012	0.025	0.033	0.036	0.022	0.013	0.009	0.009	0.009	0.009
1974	0.002	0.008	0.024	0.055	0.068	0.074	0.045	0.026	0.018	0.018	0.018	0.018
1975	0.002	0.009	0.022	0.048	0.082	0.099	0.06	0.032	0.021	0.021	0.021	0.021
1976	0.003	0.013	0.035	0.073	0.119	0.141	0.087	0.047	0.031	0.03	0.03	0.03
1977	0.011	0.034	0.112	0.246	0.212	0.186	0.116	0.075	0.059	0.058	0.058	0.058
1978	0.011	0.041	0.122	0.262	0.307	0.324	0.204	0.125	0.095	0.093	0.093	0.093
1979	0.012	0.045	0.124	0.255	0.313	0.346	0.256	0.21	0.202	0.2	0.2	0.2
1980	0.013	0.048	0.129	0.258	0.289	0.304	0.239	0.213	0.215	0.212	0.212	0.212
1981	0.017	0.079	0.208	0.363	0.435	0.466	0.373	0.336	0.34	0.334	0.334	0.334
1982	0.025	0.104	0.237	0.437	0.697	0.858	0.71	0.655	0.673	0.666	0.666	0.666
1983	0.025	0.082	0.178	0.307	0.426	0.549	0.628	0.764	0.87	0.864	0.864	0.864
1984	0.04	0.141	0.2	0.375	0.692	0.962	1.014	1.105	1.184	1.177	1.177	1.177
1985	0.031	0.106	0.181	0.322	0.556	0.741	0.789	0.841	0.873	0.867	0.867	0.867
1986	0.023	0.06	0.129	0.219	0.391	0.569	0.602	0.656	0.691	0.691	0.691	0.691
1987	0.03	0.1	0.125	0.198	0.387	0.596	0.627	0.653	0.687	0.705	0.705	0.705
1988	0.036	0.096	0.148	0.184	0.263	0.397	0.529	0.645	0.744	0.805	0.805	0.805
1989	0.025	0.072	0.163	0.212	0.228	0.298	0.43	0.602	0.775	0.89	0.89	0.89
1990	0.021	0.047	0.101	0.186	0.251	0.328	0.435	0.55	0.726	0.863	0.863	0.863
1991	0.022	0.055	0.091	0.156	0.253	0.385	0.546	0.719	0.868	0.949	0.949	0.949
1992	0.021	0.062	0.107	0.154	0.201	0.355	0.621	1.047	1.278	1.135	1.135	1.135
1993	0.035	0.112	0.152	0.2	0.245	0.305	0.509	0.958	1.303	1.248	1.248	1.248
1994	0.034	0.108	0.198	0.276	0.356	0.464	0.773	1.16	1.402	1.429	1.429	1.429
1995	0.048	0.247	0.44	0.564	0.646	0.678	0.969	1.347	1.693	1.871	1.871	1.871
1996	0.084	0.356	0.634	0.722	0.719	0.775	0.977	1.248	1.525	1.692	1.692	1.692
1997	0.081	0.54	0.918	0.802	0.668	0.726	0.965	1.236	1.501	1.648	1.648	1.648
1998	0.059	0.439	0.6	0.469	0.377	0.411	0.546	0.712	0.881	0.995	0.995	0.995
1999	0.055	0.274	0.327	0.265	0.215	0.223	0.293	0.4	0.523	0.617	0.617	0.617
2000	0.046	0.206	0.313	0.224	0.163	0.158	0.196	0.261	0.327	0.376	0.376	0.376
2001	0.078	0.27	0.502	0.336	0.236	0.224	0.269	0.339	0.404	0.438	0.438	0.438
2002	0.043	0.164	0.244	0.263	0.232	0.232	0.286	0.364	0.425	0.449	0.449	0.449
2003	0.053	0.175	0.232	0.265	0.231	0.223	0.271	0.349	0.409	0.432	0.432	0.432
2004	0.053	0.178	0.246	0.294	0.266	0.256	0.301	0.366	0.416	0.438	0.438	0.438
2005	0.07	0.156	0.222	0.32	0.314	0.287	0.319	0.372	0.404	0.411	0.411	0.411
2006	0.074	0.204	0.274	0.352	0.433	0.406	0.445	0.484	0.475	0.434	0.434	0.434
2007	0.128	0.289	0.381	0.414	0.49	0.562	0.609	0.672	0.613	0.532	0.532	0.532
2008	0.187	0.375	0.416	0.504	0.551	0.565	0.563	0.588	0.559	0.489	0.489	0.489
2009	0.108	0.344	0.43	0.709	0.841	0.846	0.797	0.737	0.63	0.555	0.555	0.555
2010	0.128	0.311	0.331	0.445	0.55	0.529	0.609	0.501	0.367	0.316	0.316	0.316
2011	0.058	0.098	0.352	0.344	0.396	0.358	0.382	0.265	0.202	0.172	0.172	0.172
2012	0.021	0.056	0.192	0.262	0.32	0.25	0.199	0.158	0.137	0.128	0.128	0.128
2013	0.021	0.062	0.137	0.21	0.169	0.15	0.15	0.145	0.142	0.14	0.14	0.14
2014	0.02	0.053	0.122	0.163	0.157	0.143	0.146	0.166	0.18	0.184	0.184	0.184
2015	0.016	0.068	0.092	0.108	0.138	0.15	0.155	0.192	0.24	0.258	0.258	0.258
2016	0.007	0.036	0.074	0.114	0.143	0.151	0.153	0.174	0.21	0.231	0.231	0.231
2017	0.009	0.026	0.048	0.079	0.136	0.172	0.188	0.206	0.227	0.235	0.235	0.235
2018	0.006	0.015	0.045	0.072	0.113	0.157	0.197	0.228	0.244	0.261	0.261	0.261
2019	0.003	0.01	0.036	0.059	0.105	0.144	0.193	0.222	0.22	0.219	0.219	0.219
2020	0.002	0.007	0.018	0.04	0.068	0.127	0.176	0.212	0.203	0.195	0.195	0.195
2021	0.004	0.009	0.019	0.033	0.054	0.088	0.142	0.188	0.223	0.244	0.244	0.244
2022	0.005	0.011	0.017	0.034	0.044	0.06	0.093	0.143	0.189	0.249	0.249	0.249
2023	0.005	0.011	0.021	0.047	0.056	0.058	0.081	0.132	0.216	0.311	0.311	0.311

Table A10.32. Estimated total fishing mortality at age (Model *h2_1.07*; 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	0.0116	0.0243	0.0289	0.0166	0.00851	0.00546	0.00542	0.00542	0.00542
1971	0.000551	0.00315	0.00788	0.0177	0.0369	0.0439	0.0252	0.0129	0.00824	0.00818	0.00818	0.00818
1972	0.000454	0.00279	0.00649	0.0121	0.0207	0.0231	0.0137	0.00778	0.00563	0.00553	0.00553	0.00553
1973	0.000727	0.00462	0.0106	0.019	0.0303	0.0328	0.0193	0.0106	0.00731	0.00713	0.00713	0.00713
1974	0.00094	0.00557	0.0136	0.0283	0.0554	0.0645	0.0372	0.0193	0.0125	0.0124	0.0124	0.0124
1975	0.00155	0.00946	0.0225	0.0442	0.0807	0.0917	0.0532	0.028	0.0185	0.0182	0.0182	0.0182
1976	0.00238	0.0148	0.0347	0.066	0.115	0.129	0.0753	0.0401	0.0267	0.0262	0.0262	0.0262
1977	0.00285	0.0181	0.0416	0.0747	0.121	0.131	0.0769	0.0421	0.0288	0.0281	0.0281	0.0281
1978	0.00499	0.0305	0.0709	0.132	0.223	0.248	0.149	0.0868	0.0649	0.0638	0.0638	0.0638
1979	0.00669	0.0359	0.0808	0.143	0.226	0.255	0.187	0.162	0.168	0.167	0.167	0.167
1980	0.00686	0.0369	0.0813	0.135	0.195	0.214	0.169	0.162	0.176	0.175	0.175	0.175
1981	0.0127	0.0713	0.156	0.247	0.324	0.339	0.268	0.26	0.283	0.28	0.28	0.28
1982	0.0205	0.103	0.227	0.384	0.575	0.648	0.53	0.532	0.59	0.586	0.586	0.586
1983	0.0204	0.0802	0.166	0.26	0.346	0.42	0.503	0.687	0.847	0.844	0.844	0.844
1984	0.0347	0.134	0.18	0.331	0.616	0.815	0.898	1.12	1.31	1.31	1.31	1.31
1985	0.0295	0.0993	0.173	0.311	0.538	0.686	0.768	0.937	1.06	1.06	1.06	1.06
1986	0.0225	0.0593	0.122	0.21	0.399	0.566	0.626	0.773	0.877	0.88	0.88	0.88
1987	0.0303	0.101	0.12	0.188	0.38	0.597	0.641	0.72	0.799	0.816	0.816	0.816
1988	0.0371	0.0964	0.135	0.16	0.239	0.385	0.534	0.674	0.793	0.846	0.846	0.846
1989	0.0257	0.071	0.155	0.189	0.207	0.285	0.428	0.616	0.795	0.893	0.893	0.893
1990	0.0206	0.0454	0.0923	0.157	0.228	0.313	0.425	0.552	0.732	0.847	0.847	0.847
1991	0.0217	0.0539	0.0844	0.136	0.234	0.365	0.528	0.699	0.841	0.899	0.899	0.899
1992	0.0223	0.0633	0.102	0.143	0.193	0.336	0.584	0.991	1.19	1.04	1.04	1.04
1993	0.0369	0.114	0.141	0.183	0.237	0.297	0.482	0.888	1.2	1.13	1.13	1.13
1994	0.0367	0.11	0.184	0.25	0.338	0.459	0.763	1.1	1.3	1.31	1.31	1.31
1995	0.0537	0.259	0.376	0.481	0.59	0.635	0.925	1.28	1.58	1.74	1.74	1.74
1996	0.095	0.403	0.547	0.591	0.616	0.682	0.876	1.14	1.41	1.59	1.59	1.59
1997	0.0875	0.553	0.663	0.562	0.501	0.57	0.785	1.05	1.33	1.52	1.52	1.52
1998	0.0601	0.423	0.366	0.3	0.256	0.292	0.402	0.554	0.742	0.897	0.897	0.897
1999	0.0614	0.28	0.245	0.199	0.162	0.166	0.222	0.316	0.45	0.581	0.581	0.581
2000	0.0491	0.217	0.231	0.174	0.128	0.125	0.157	0.219	0.297	0.369	0.369	0.369
2001	0.0759	0.236	0.277	0.226	0.171	0.168	0.209	0.279	0.357	0.414	0.414	0.414
2002	0.0421	0.159	0.205	0.225	0.197	0.199	0.248	0.328	0.405	0.453	0.453	0.453
2003	0.0508	0.159	0.194	0.223	0.197	0.192	0.236	0.316	0.391	0.434	0.434	0.434
2004	0.0558	0.163	0.207	0.251	0.234	0.23	0.276	0.347	0.414	0.453	0.453	0.453
2005	0.082	0.168	0.205	0.286	0.284	0.265	0.302	0.365	0.416	0.439	0.439	0.439
2006	0.0781	0.2	0.201	0.288	0.372	0.364	0.418	0.474	0.489	0.463	0.463	0.463
2007	0.128	0.293	0.29	0.33	0.429	0.5	0.561	0.647	0.62	0.558	0.558	0.558
2008	0.195	0.349	0.323	0.423	0.503	0.515	0.512	0.55	0.549	0.5	0.5	0.5
2009	0.135	0.35	0.384	0.633	0.796	0.801	0.736	0.668	0.596	0.553	0.553	0.553
2010	0.172	0.458	0.375	0.449	0.54	0.53	0.612	0.487	0.364	0.327	0.327	0.327
2011	0.0649	0.0827	0.119	0.244	0.336	0.335	0.375	0.249	0.178	0.152	0.152	0.152
2012	0.0204	0.0481	0.108	0.203	0.305	0.24	0.194	0.15	0.124	0.113	0.113	0.113
2013	0.0215	0.0602	0.117	0.196	0.198	0.164	0.154	0.141	0.131	0.124	0.124	0.124
2014	0.0204	0.0475	0.0828	0.13	0.177	0.178	0.163	0.168	0.168	0.161	0.161	0.161
2015	0.0168	0.0642	0.075	0.0986	0.146	0.18	0.19	0.21	0.231	0.228	0.228	0.228
2016	0.00844	0.0355	0.0656	0.106	0.142	0.165	0.179	0.198	0.21	0.209	0.209	0.209
2017	0.0122	0.0314	0.0487	0.0779	0.135	0.178	0.207	0.232	0.242	0.228	0.228	0.228
2018	0.0074	0.0169	0.0398	0.0685	0.11	0.154	0.203	0.247	0.266	0.263	0.263	0.263
2019	0.00395	0.00977	0.024	0.0523	0.103	0.139	0.188	0.223	0.225	0.218	0.218	0.218
2020	0.00256	0.00712	0.0141	0.0319	0.0748	0.131	0.172	0.204	0.196	0.188	0.188	0.188
2021	0.00445	0.0105	0.0203	0.0298	0.062	0.106	0.15	0.186	0.215	0.234	0.234	0.234
2022	0.00541	0.0126	0.0173	0.0276	0.0441	0.0781	0.114	0.15	0.183	0.234	0.234	0.234
2023	0.00627	0.0116	0.0182	0.032	0.0496	0.0717	0.105	0.151	0.217	0.291	0.291	0.291

Table A10.33. Estimated total fishing mortality at age (Model *h2_1.07*; two-stock hypothesis; far north stock).

	Age group (years)											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1970	0.000	0.000	0.003	0.006	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.001	0.005	0.012	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1972	0.000	0.001	0.012	0.028	0.010	0.002	0.001	0.001	0.001	0.001	0.001	0.001
1973	0.000	0.003	0.026	0.062	0.022	0.005	0.002	0.002	0.002	0.002	0.002	0.002
1974	0.001	0.009	0.084	0.201	0.071	0.016	0.005	0.005	0.005	0.005	0.005	0.005
1975	0.000	0.003	0.026	0.063	0.022	0.005	0.002	0.002	0.002	0.002	0.002	0.002
1976	0.000	0.004	0.035	0.084	0.030	0.007	0.002	0.002	0.002	0.002	0.002	0.002
1977	0.004	0.051	0.490	1.170	0.413	0.093	0.029	0.029	0.029	0.029	0.029	0.029
1978	0.005	0.060	0.572	1.370	0.482	0.109	0.033	0.033	0.033	0.033	0.033	0.033
1979	0.004	0.050	0.476	1.140	0.401	0.091	0.028	0.028	0.028	0.028	0.028	0.028
1980	0.005	0.061	0.588	1.400	0.495	0.112	0.034	0.034	0.034	0.034	0.034	0.034
1981	0.008	0.102	0.972	2.320	0.819	0.185	0.057	0.057	0.057	0.057	0.057	0.057
1982	0.003	0.037	0.354	0.844	0.298	0.067	0.021	0.021	0.021	0.021	0.021	0.021
1983	0.002	0.020	0.193	0.461	0.163	0.037	0.011	0.011	0.011	0.011	0.011	0.011
1984	0.002	0.020	0.193	0.460	0.162	0.037	0.011	0.011	0.011	0.011	0.011	0.011
1985	0.001	0.010	0.098	0.235	0.083	0.019	0.006	0.006	0.006	0.006	0.006	0.006
1986	0.000	0.006	0.056	0.134	0.047	0.011	0.003	0.003	0.003	0.003	0.003	0.003
1987	0.001	0.007	0.065	0.156	0.055	0.012	0.004	0.004	0.004	0.004	0.004	0.004
1988	0.002	0.025	0.239	0.571	0.202	0.046	0.014	0.014	0.014	0.014	0.014	0.014
1989	0.002	0.023	0.218	0.521	0.184	0.042	0.013	0.013	0.013	0.013	0.013	0.013
1990	0.002	0.025	0.239	0.572	0.202	0.046	0.014	0.014	0.014	0.014	0.014	0.014
1991	0.001	0.019	0.180	0.429	0.151	0.034	0.011	0.011	0.011	0.011	0.011	0.011
1992	0.001	0.013	0.120	0.286	0.101	0.023	0.007	0.007	0.007	0.007	0.007	0.007
1993	0.001	0.018	0.172	0.410	0.145	0.033	0.010	0.010	0.010	0.010	0.010	0.010
1994	0.002	0.026	0.252	0.601	0.212	0.048	0.015	0.015	0.015	0.015	0.015	0.015
1995	0.008	0.105	1.000	2.400	0.847	0.191	0.058	0.058	0.058	0.058	0.058	0.058
1996	0.015	0.187	1.790	4.270	1.510	0.340	0.104	0.104	0.104	0.104	0.104	0.104
1997	0.023	0.295	2.820	6.730	2.380	0.537	0.164	0.164	0.164	0.164	0.164	0.164
1998	0.034	0.429	4.100	9.790	3.460	0.782	0.239	0.239	0.239	0.239	0.239	0.239
1999	0.009	0.117	1.120	2.670	0.943	0.213	0.065	0.065	0.065	0.065	0.065	0.065
2000	0.008	0.098	0.933	2.230	0.786	0.178	0.054	0.054	0.054	0.054	0.054	0.054
2001	0.023	0.292	2.790	6.670	2.350	0.532	0.163	0.163	0.163	0.163	0.163	0.163
2002	0.004	0.116	0.643	0.880	0.511	0.114	0.030	0.030	0.030	0.030	0.030	0.030
2003	0.004	0.121	0.674	0.922	0.535	0.119	0.031	0.031	0.031	0.031	0.031	0.031
2004	0.004	0.124	0.692	0.947	0.549	0.122	0.032	0.032	0.032	0.032	0.032	0.032
2005	0.002	0.067	0.374	0.512	0.297	0.066	0.017	0.017	0.017	0.017	0.017	0.017
2006	0.005	0.175	0.972	1.330	0.772	0.172	0.045	0.045	0.045	0.045	0.045	0.045
2007	0.006	0.182	1.010	1.390	0.805	0.179	0.047	0.047	0.047	0.047	0.047	0.047
2008	0.006	0.182	1.010	1.390	0.806	0.180	0.047	0.047	0.047	0.047	0.047	0.047
2009	0.006	0.193	1.080	1.470	0.854	0.190	0.050	0.050	0.050	0.050	0.050	0.050
2010	0.001	0.043	0.242	0.331	0.192	0.043	0.011	0.011	0.011	0.011	0.011	0.011
2011	0.006	0.204	1.130	1.550	0.900	0.200	0.052	0.052	0.052	0.052	0.052	0.052
2012	0.004	0.137	0.762	1.040	0.605	0.135	0.035	0.035	0.035	0.035	0.035	0.035
2013	0.002	0.079	0.437	0.598	0.347	0.077	0.020	0.020	0.020	0.020	0.020	0.020
2014	0.003	0.097	0.539	0.738	0.428	0.095	0.025	0.025	0.025	0.025	0.025	0.025
2015	0.001	0.034	0.191	0.261	0.152	0.034	0.009	0.009	0.009	0.009	0.009	0.009
2016	0.001	0.017	0.095	0.130	0.075	0.017	0.004	0.004	0.004	0.004	0.004	0.004
2017	0.000	0.006	0.036	0.049	0.028	0.006	0.002	0.002	0.002	0.002	0.002	0.002
2018	0.001	0.021	0.114	0.156	0.091	0.020	0.005	0.005	0.005	0.005	0.005	0.005
2019	0.001	0.024	0.133	0.182	0.106	0.024	0.006	0.006	0.006	0.006	0.006	0.006
2020	0.001	0.017	0.095	0.130	0.075	0.017	0.004	0.004	0.004	0.004	0.004	0.004
2021	0.000	0.016	0.087	0.119	0.069	0.015	0.004	0.004	0.004	0.004	0.004	0.004
2022	0.001	0.026	0.145	0.199	0.115	0.026	0.007	0.007	0.007	0.007	0.007	0.007
2023	0.002	0.059	0.328	0.449	0.261	0.058	0.015	0.015	0.015	0.015	0.015	0.015

Table A10.34. Summary of results for Model *h1_1.07* (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	14403	5708	0.01	0.2	7321
1971	169	13368	5317	0.01	0.2	7291
1972	111	12431	4899	0.01	0.19	7289
1973	165	11499	4376	0.02	0.18	7201
1974	324	10505	4434	0.03	0.18	7174
1975	300	9675	5749	0.04	0.19	7248
1976	397	9057	7206	0.05	0.19	7193
1977	848	8623	10734	0.1	0.16	7392
1978	1025	8469	13500	0.15	0.18	7313
1979	1302	8374	14045	0.2	0.2	7520
1980	1316	8464	14636	0.2	0.2	7562
1981	1945	8325	17083	0.3	0.21	7603
1982	2372	7933	19740	0.53	0.23	7926
1983	1870	8976	27470	0.54	0.28	8315
1984	2687	9404	20805	0.77	0.27	8209
1985	2371	9980	24756	0.59	0.27	7996
1986	2073	13487	55283	0.45	0.29	8004
1987	2680	17988	51774	0.46	0.28	8107
1988	3246	19768	25661	0.45	0.3	8257
1989	3582	18646	15219	0.46	0.34	8041
1990	3715	17171	17224	0.44	0.38	7861
1991	3778	16034	22650	0.5	0.45	7458
1992	3362	15170	25342	0.6	0.44	8247
1993	3371	13621	14526	0.63	0.32	9202
1994	4276	11064	15785	0.75	0.35	8516
1995	4956	8100	14828	1.02	0.26	8909
1996	4380	5942	14992	1.01	0.22	8628
1997	3598	4645	17488	1.03	0.21	8429
1998	2027	4718	17119	0.62	0.18	9039
1999	1424	5839	21868	0.37	0.19	8827
2000	1540	7182	20652	0.25	0.17	8359
2001	2528	7642	20673	0.33	0.16	8241
2002	1750	8342	18647	0.3	0.19	8569
2003	1797	8373	11295	0.29	0.19	8577
2004	1934	7725	10091	0.31	0.2	8076
2005	1755	7095	10874	0.31	0.2	7934
2006	2020	5957	6222	0.37	0.19	7786
2007	1997	4157	2110	0.48	0.19	7672
2008	1473	2904	5692	0.48	0.17	7777
2009	1283	2363	8898	0.59	0.19	7450
2010	727	2277	5093	0.39	0.16	7852
2011	635	2203	4138	0.25	0.16	7546
2012	455	2257	3760	0.16	0.17	7608
2013	353	2433	4148	0.13	0.17	7892
2014	411	2873	7116	0.14	0.19	7984
2015	394	3504	7741	0.16	0.24	7771
2016	389	4615	14013	0.15	0.25	7876
2017	405	6685	22431	0.15	0.26	8324
2018	526	9730	29477	0.16	0.26	9047
2019	632	12534	21920	0.14	0.31	8270
2020	707	14060	12337	0.12	0.35	8468
2021	808	15454	19833	0.12	0.45	8087
2022	961	16482	8489	0.11	0.49	7886
2023	1135	16400	7407	0.13	0.59	7164

Table A10.35. Summary of results for Model *h2_1.07* (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	13546	5757	0.01	0.19	6110
1971	169	12693	5362	0.02	0.19	6106
1972	111	11914	4957	0.01	0.18	6077
1973	165	11127	4413	0.01	0.18	6011
1974	324	10290	4319	0.02	0.19	6076
1975	300	9535	5498	0.03	0.18	6049
1976	397	8963	6960	0.05	0.18	6034
1977	848	8747	9414	0.05	0.18	6012
1978	1025	8705	12096	0.1	0.18	6098
1979	1302	8653	12748	0.15	0.21	6479
1980	1316	8820	13271	0.14	0.21	6565
1981	1945	8689	14745	0.23	0.21	6535
1982	2372	7927	16112	0.45	0.22	6711
1983	1870	8714	27246	0.49	0.28	7150
1984	2687	9354	22949	0.78	0.28	7145
1985	2371	10073	24035	0.65	0.29	6903
1986	2073	13540	55140	0.52	0.32	6863
1987	2680	17932	49998	0.5	0.29	6920
1988	3246	19549	22541	0.47	0.31	7014
1989	3582	18290	13042	0.45	0.35	6821
1990	3715	16930	17409	0.43	0.39	6649
1991	3778	15904	21821	0.47	0.45	6315
1992	3362	14940	23913	0.56	0.42	7006
1993	3371	13345	14363	0.58	0.31	7732
1994	4276	10826	14646	0.71	0.33	7161
1995	4956	7895	11491	0.95	0.25	7545
1996	4380	5751	13325	0.93	0.22	7271
1997	3598	4632	14413	0.89	0.21	7188
1998	2027	4769	15034	0.51	0.18	7789
1999	1424	5592	16999	0.32	0.19	7496
2000	1540	6752	19079	0.23	0.18	7077
2001	2528	7684	19766	0.27	0.17	7114
2002	1750	8508	18410	0.28	0.2	7260
2003	1797	8718	12045	0.27	0.19	7298
2004	1934	8008	7348	0.29	0.2	6832
2005	1755	7047	8379	0.31	0.2	6719
2006	2020	5826	5285	0.36	0.2	6689
2007	1997	4171	2413	0.46	0.2	6561
2008	1473	3035	5767	0.45	0.17	6619
2009	1283	2205	4885	0.56	0.18	6292
2010	727	1780	3624	0.41	0.15	6581
2011	635	1795	3746	0.2	0.17	6567
2012	455	1979	3810	0.14	0.17	6535
2013	353	2239	4471	0.13	0.17	6558
2014	411	2758	7466	0.13	0.2	6566
2015	394	3451	8025	0.16	0.24	6457
2016	389	4384	11098	0.14	0.25	6508
2017	405	5744	15190	0.15	0.26	6946
2018	526	7878	22758	0.16	0.26	7662
2019	632	10048	17491	0.14	0.31	7153
2020	707	11165	8891	0.12	0.32	7356
2021	808	12152	16416	0.12	0.4	6887
2022	961	12972	7842	0.11	0.45	6654
2023	1135	12954	6501	0.13	0.59	6031

Table A10.36. Summary of results for Model *h2_1.07* (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	2785	2103	0	0.11	903
1971	169	2761	2081	0	0.11	903
1972	111	2745	2053	0	0.1	913
1973	165	2715	2022	0.01	0.1	905
1974	324	2619	2022	0.03	0.1	904
1975	300	2566	2031	0.01	0.1	908
1976	397	2530	2020	0.01	0.11	899
1977	848	2132	3008	0.2	0.1	907
1978	1025	1774	2263	0.23	0.1	909
1979	1302	1567	1908	0.19	0.11	903
1980	1316	1268	1457	0.24	0.11	903
1981	1945	919	2242	0.4	0.11	899
1982	2372	819	2594	0.14	0.11	900
1983	1870	888	1480	0.08	0.11	892
1984	2687	964	723	0.08	0.11	897
1985	2371	997	1736	0.04	0.11	900
1986	2073	1037	2736	0.02	0.11	899
1987	2680	1186	3934	0.03	0.1	904
1988	3246	1333	2752	0.1	0.11	902
1989	3582	1491	1792	0.09	0.11	898
1990	3715	1473	982	0.1	0.11	898
1991	3778	1410	1738	0.07	0.11	900
1992	3362	1366	2019	0.05	0.11	900
1993	3371	1372	1543	0.07	0.11	903
1994	4276	1325	2043	0.1	0.1	908
1995	4956	977	4245	0.41	0.11	902
1996	4380	756	2323	0.73	0.11	902
1997	3598	503	2658	1.15	0.11	893
1998	2027	315	2012	1.67	0.11	896
1999	1424	315	5005	0.46	0.17	232
2000	1540	380	2098	0.38	0.17	235
2001	2528	192	1510	1.14	0.17	236
2002	1750	235	1160	0.2	0.16	242
2003	1797	242	314	0.21	0.17	239
2004	1934	206	2031	0.22	0.16	240
2005	1755	229	1626	0.12	0.16	242
2006	2020	264	896	0.31	0.16	242
2007	1997	221	156	0.32	0.16	240
2008	1473	154	253	0.32	0.16	242
2009	1283	100	2647	0.34	0.16	240
2010	727	171	989	0.08	0.17	239
2011	635	218	502	0.36	0.16	249
2012	455	172	360	0.24	0.16	247
2013	353	159	330	0.14	0.16	247
2014	411	144	525	0.17	0.16	247
2015	394	162	489	0.06	0.16	245
2016	389	209	1869	0.03	0.16	241
2017	405	307	3854	0.01	0.16	248
2018	526	567	3193	0.04	0.16	248
2019	632	964	1871	0.04	0.16	248
2020	707	1300	1756	0.03	0.16	249
2021	808	1505	999	0.03	0.16	246
2022	961	1584	886	0.05	0.16	246
2023	1135	1466	1259	0.1	0.17	239

Table A10.37. Summary results for the short, medium, and long-term predictions for Model *h1_1.07.ls* (single-stock hypothesis, low steepness, short time series). 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_{2025}	$P(B_{2025}>B_{MSY})$	B_{2029}	$P(B_{2029}>B_{MSY})$	B_{2033}	$P(B_{2033}>B_{MSY})$	Catch 2024 (kt)	Catch 2025 (kt)
0	17758	100	17851	100	16774	100	0	0
0.75 x F_{2023}	15938	100	12768	100	11369	97	974	1100
1 x F_{2023}	15402	100	11692	99	10401	95	1282	1406
1.25 x F_{2023}	14895	100	10804	98	9629	93	1581	1685
F_{MSY}	10167	100	5790	58	5166	44	4934	3823
$F_{TAC2023}$	15752	100	12377	100	11013	96	1080	1207
1.15 x $F_{TAC2023}$	15470	100	11821	99	10515	95	1242	1367
1.2 x $F_{TAC2023}$	15377	100	11646	99	10361	95	1296	1419

Table A10.38. Summary results for the short, medium, and long-term predictions for Model *h2_1.07.ls* (two-stock hypothesis, low steepness, short time series). 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.

Southern Stock:

F	B_{2025}	$P(B_{2025}>B_{MSY})$	B_{2029}	$P(B_{2029}>B_{MSY})$	B_{2033}	$P(B_{2033}>B_{MSY})$	Catch 2024 (kt)	Catch 2025 (kt)
0	14583	100	15181	100	14664	100	0	0
0.75 x F_{2023}	13086	100	11078	99	10138	97	780	870
1 x F_{2023}	12647	100	10194	99	9301	95	1024	1110
1.25 x F_{2023}	12233	100	9462	98	8631	93	1262	1328
F_{MSY}	8215	99	5119	55	4623	43	4064	3012
$F_{TAC2023}$	12938	100	10767	99	9840	96	861	952
1.15 x $F_{TAC2023}$	12707	100	10309	99	9408	95	990	1077
1.2 x $F_{TAC2023}$	12631	100	10165	98	9274	95	1033	1118

Far North Stock:

F	B_{2025}	$P(B_{2025}>B_{MSY})$	B_{2029}	$P(B_{2029}>B_{MSY})$	B_{2033}	$P(B_{2033}>B_{MSY})$	Catch 2024 (kt)	Catch 2025 (kt)
0	1457	100	1350	100	1253	100	0	0
0.75 x F_{2023}	1269	100	855	100	648	99	116	108
1 x F_{2023}	1219	100	752	100	531	96	150	132
1.25 x F_{2023}	1175	100	669	99	440	91	182	152
F_{MSY}	1121	100	581	99	347	86	222	175
$F_{TAC2023}$	1125	100	587	97	353	78	219	173
1.15 x $F_{TAC2023}$	1083	100	525	95	291	64	252	189
1.2 x $F_{TAC2023}$	1069	100	507	94	273	59	263	194

9. Figures

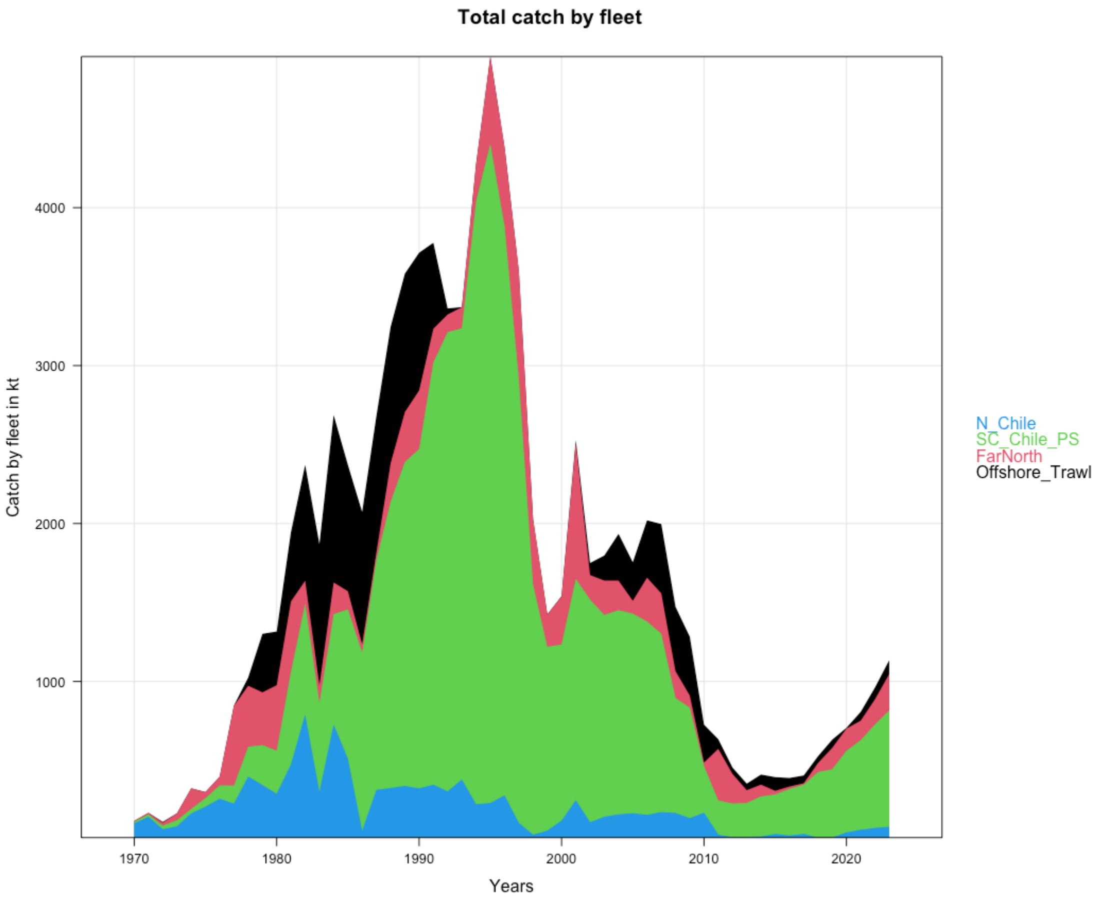

Figure A10.1: Catch of jack mackerel by fleet. Blue is the northern Chilean fleet, green is the south-central Chilean fleet, red is the far north fleet, and black is the offshore trawl fleet.

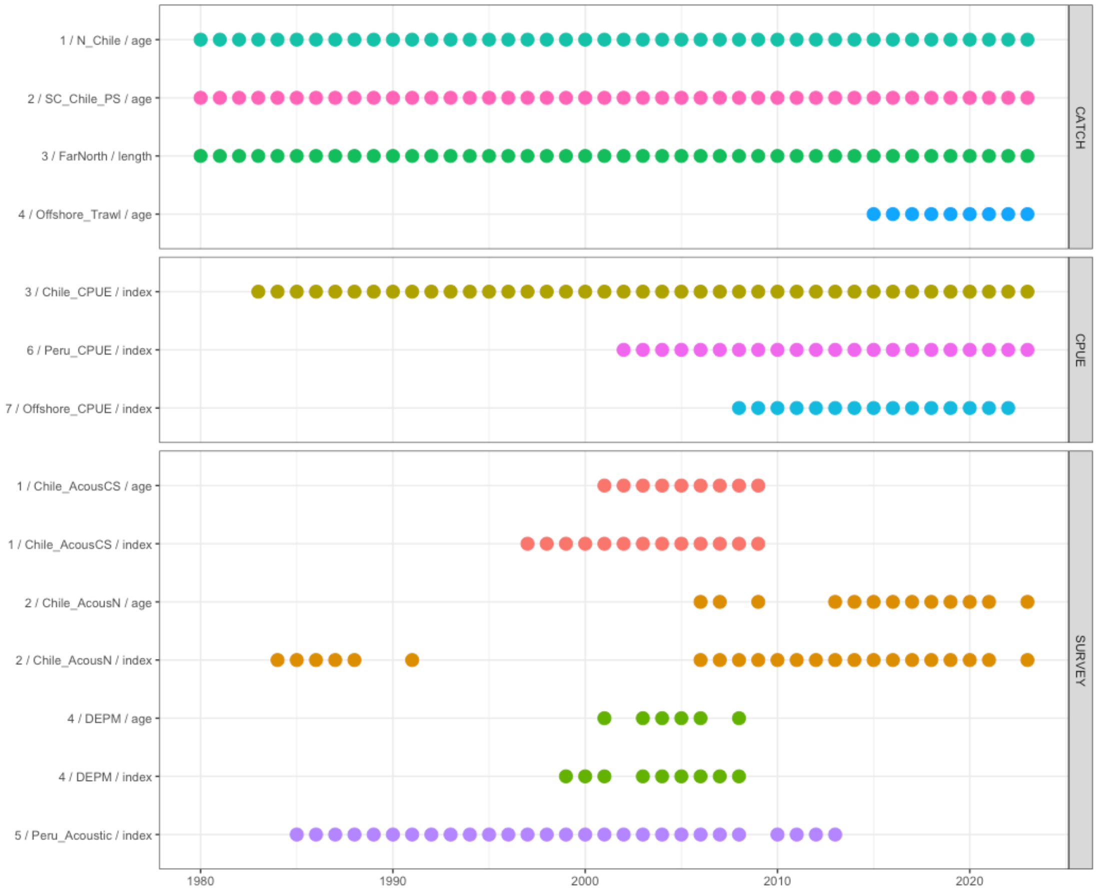

Figure A10.2: Years and types of information used in the jack mackerel assessment models.

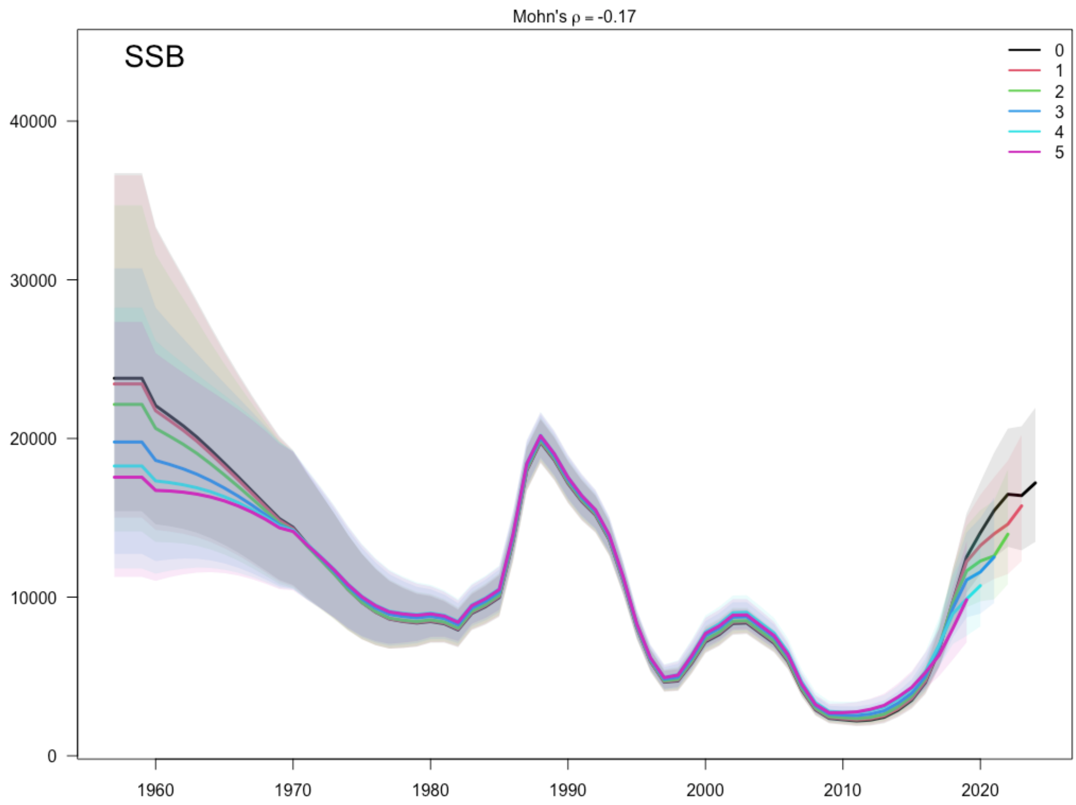

Figure A10.3: Model retrospective of spawning biomass from 5 separate model runs, based on Model h1_1.07 (single-stock hypothesis).

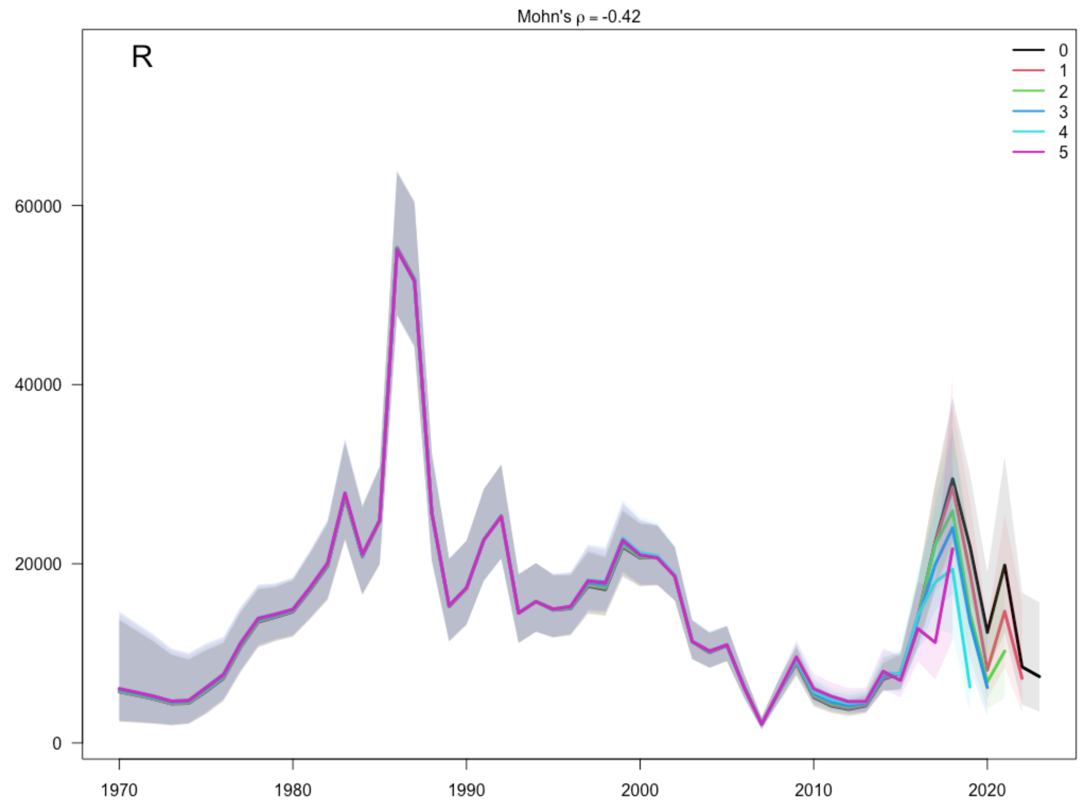

Figure A10.4: Model retrospective of recruitment from 5 separate model runs, based on Model h1_1.07 (single-stock hypothesis).

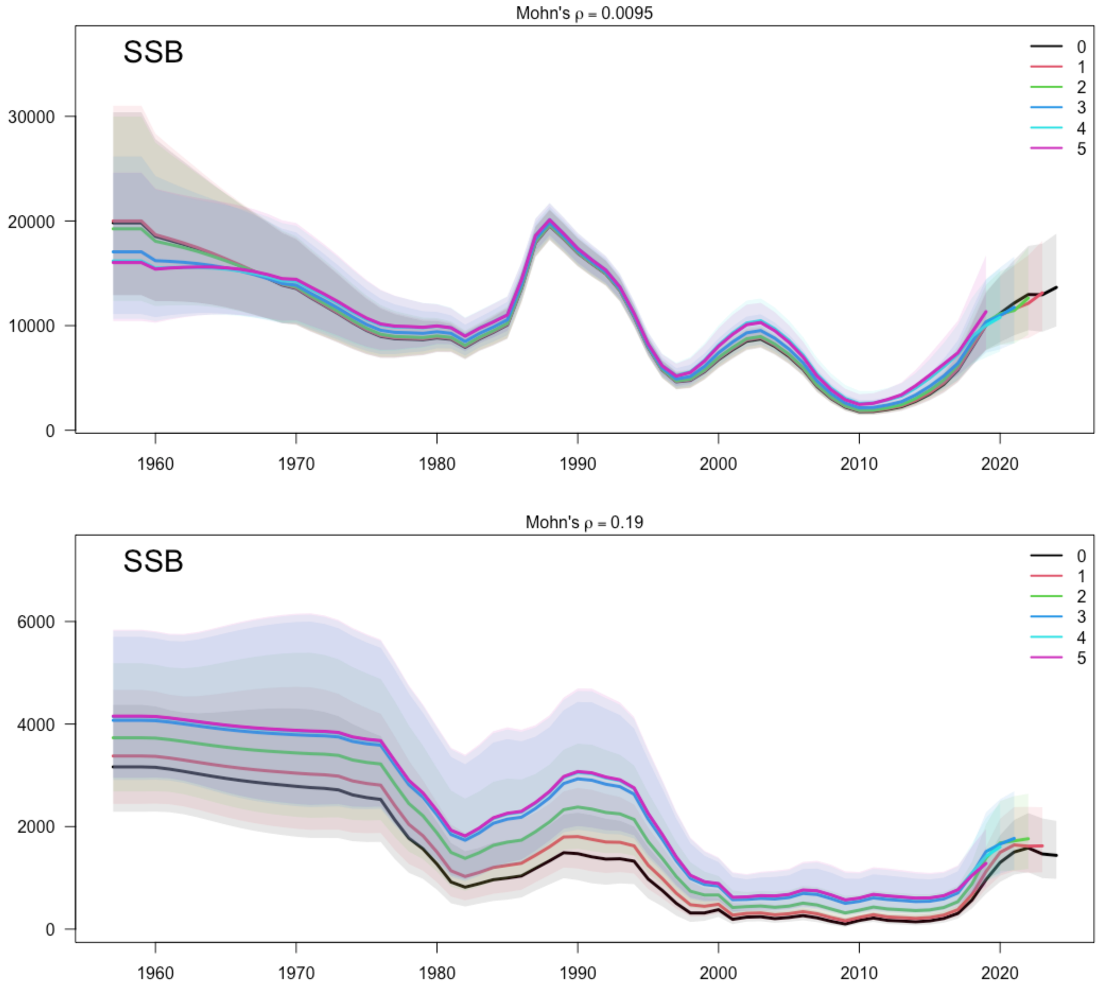

Figure A10.5: Model retrospective of spawning biomass from 5 separate model runs for the southern stock (top) and far north stock (bottom), based on Model h2_1.07 (two-stock hypothesis).

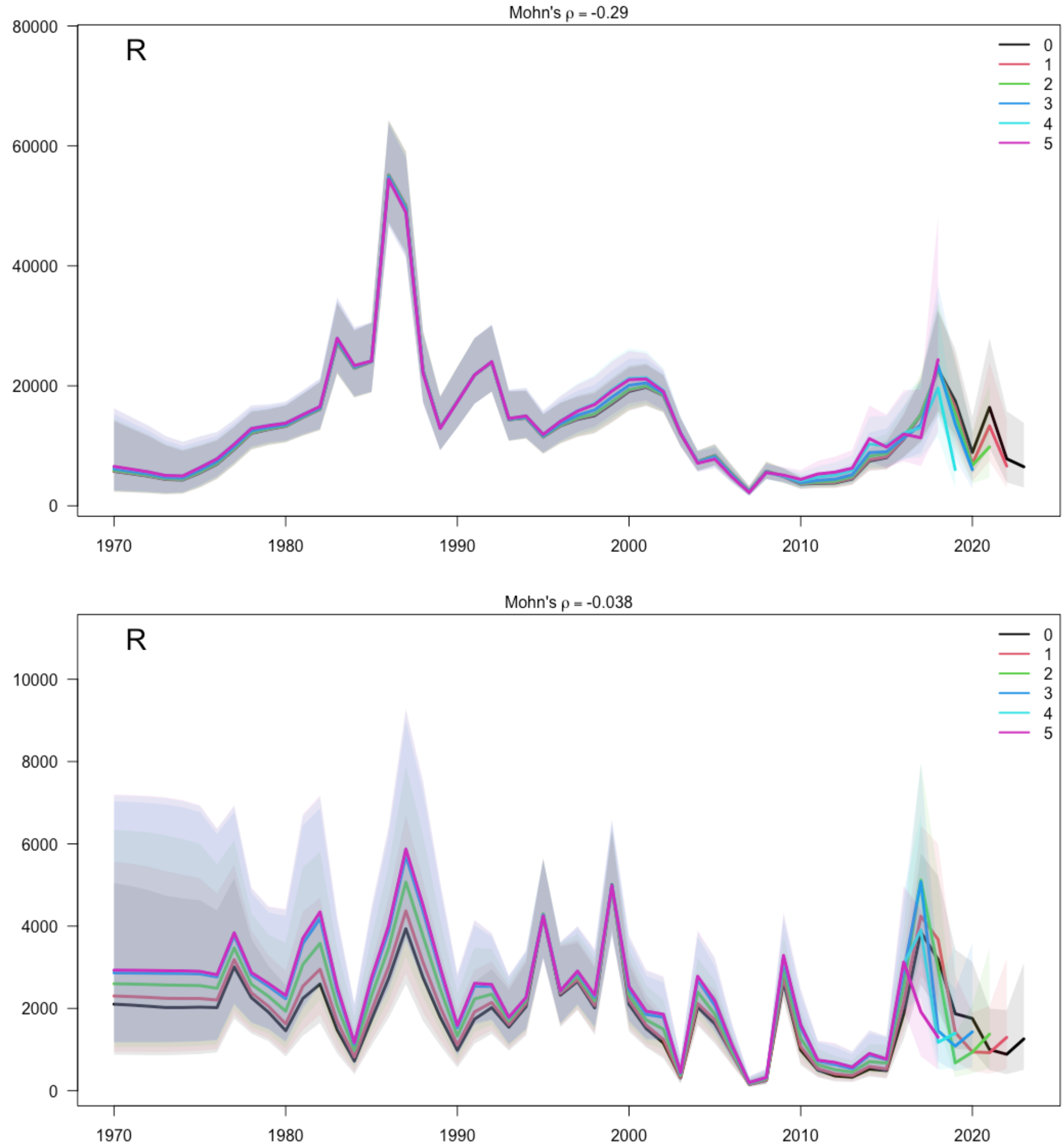

Figure A10.6: Model retrospective of southern stock recruitment from 5 separate model runs for the southern stock (top) and far north stock (bottom), based on Model h2_1.07 (two-stock hypothesis).

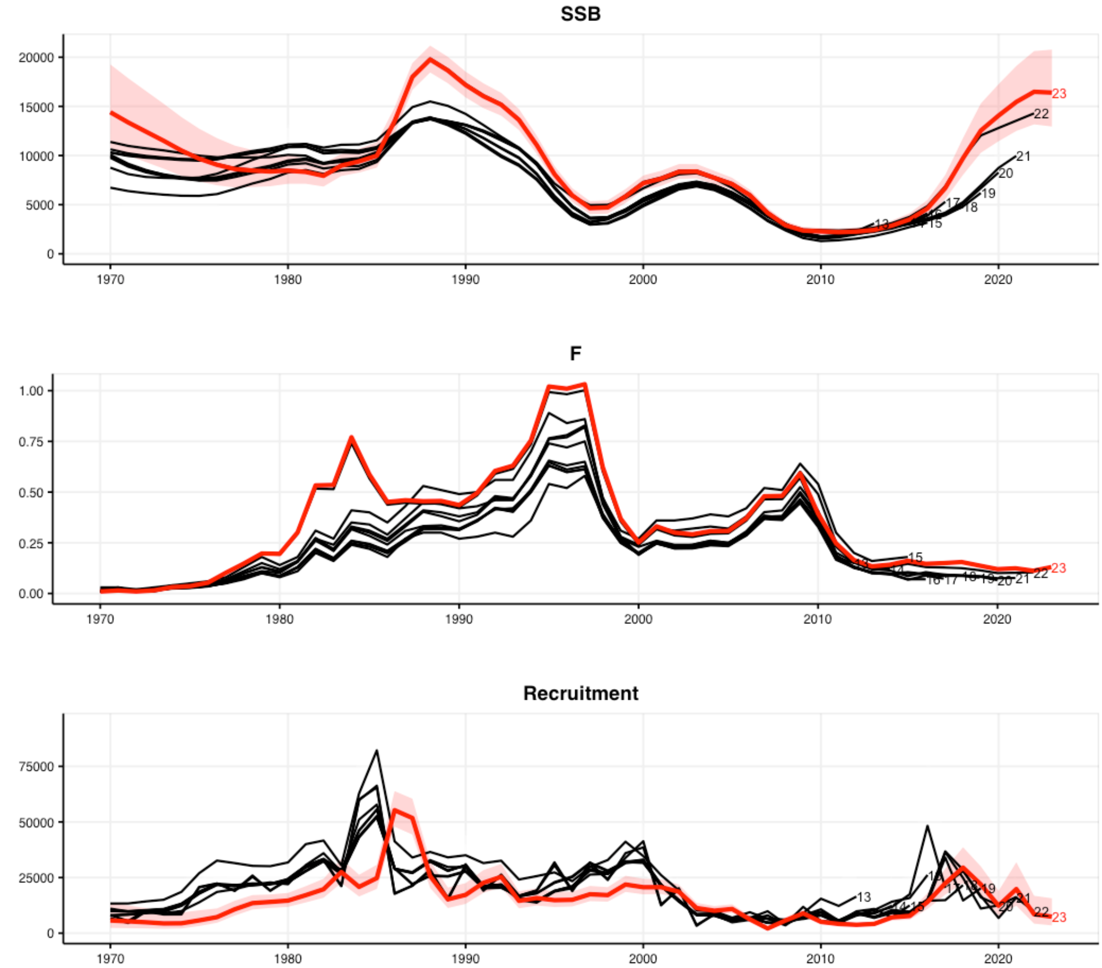

Figure A10.7: Historical retrospective of spawning stock biomass, fishing mortality, and recruitment estimated from Model h1_1.07 (single-stock hypothesis), as estimated and used for advice from SPFRMO Scientific Committees 2013-2023.

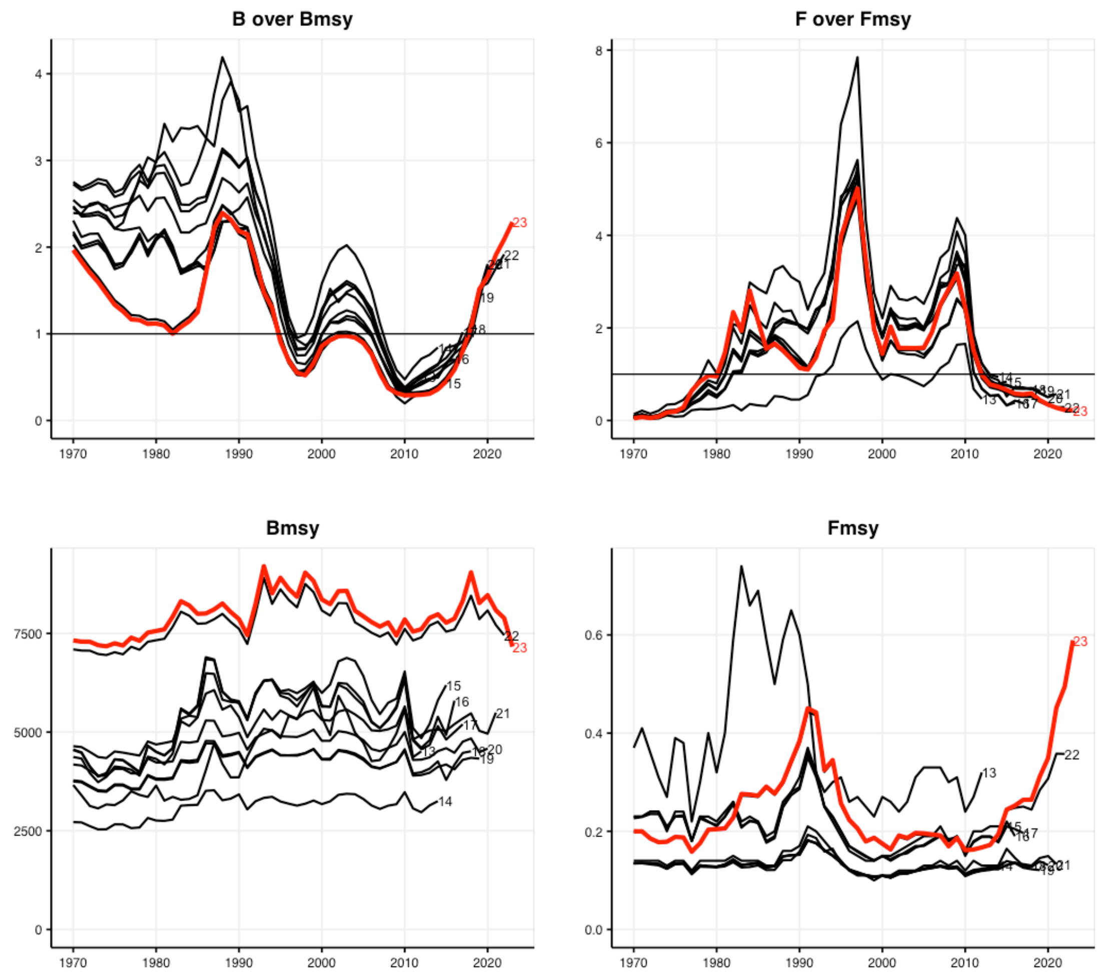

Figure A10.8: Historical retrospective of management reference points estimated from Model h1_1.07 (single-stock hypothesis), as estimated and used for advice from past (and present) SPRFMO scientific committees.

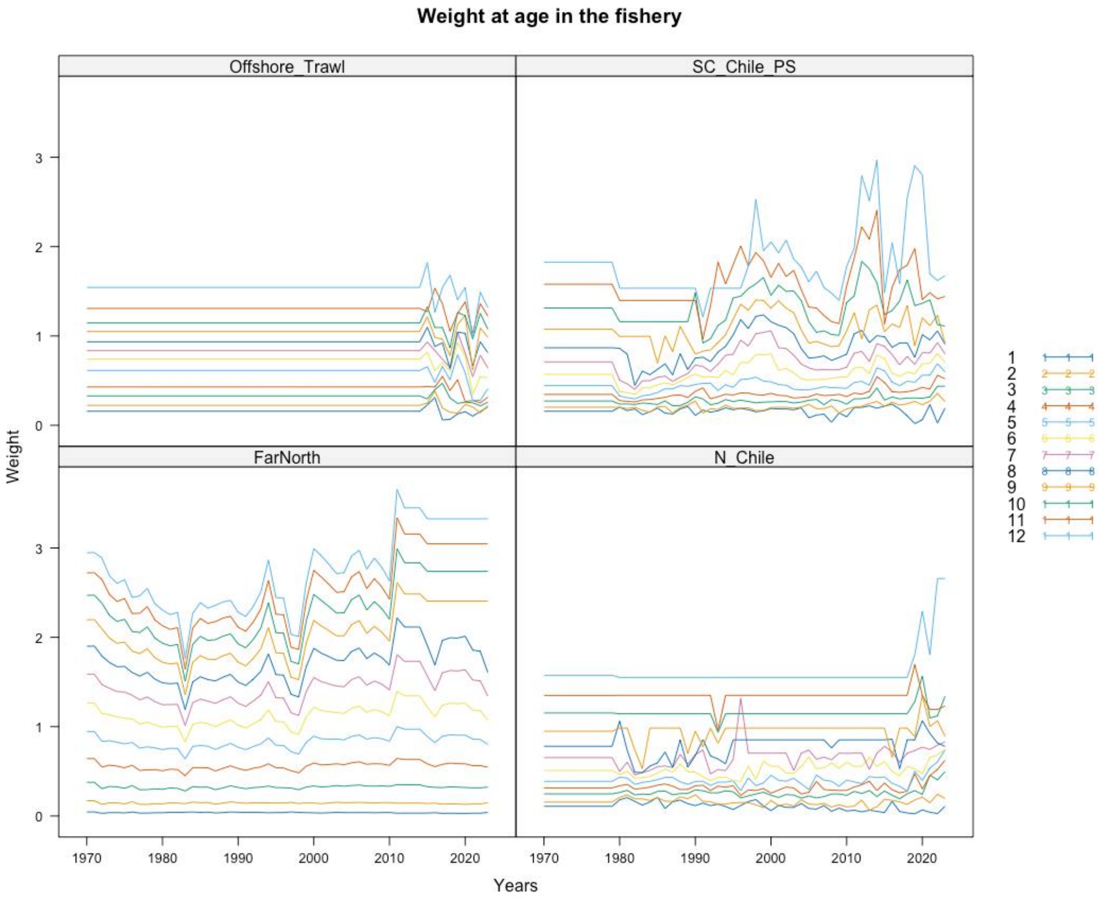

Figure A10.9: Mean weights-at-age (kg) over time used for the fisheries in the JJM models. Each line represents an age from 1 to 12.

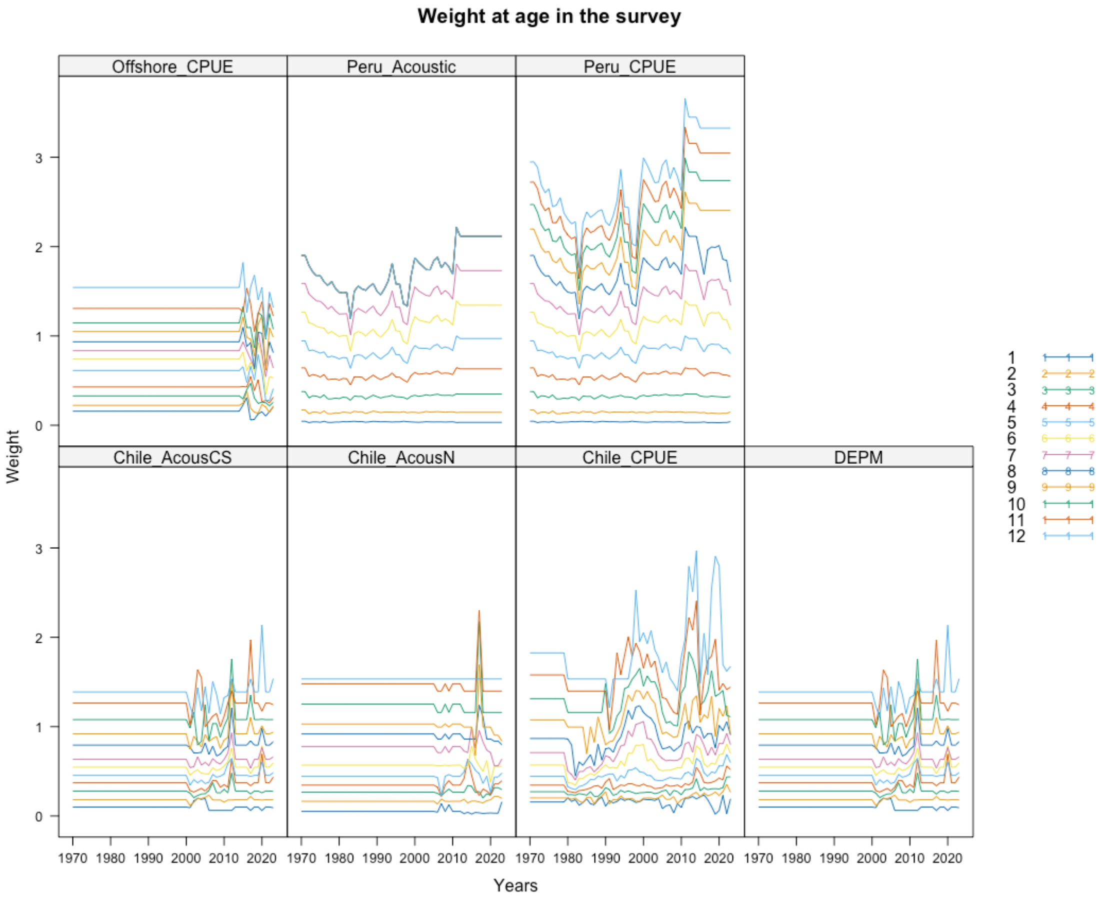

Figure A10.10: Mean weights-at-age (kg) over time used for the surveys in the JJM models. Each line represents an age from 1 to 12.

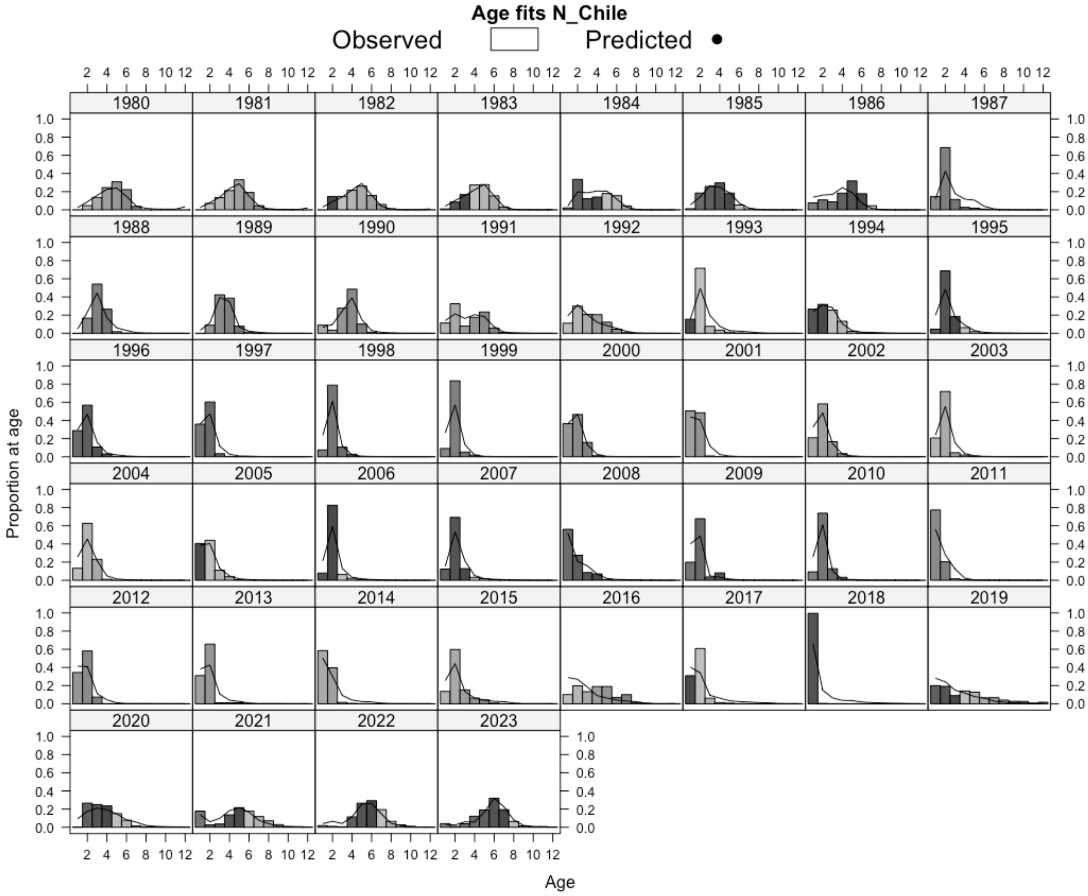

Figure A10.11: Model h1_1.07 (single-stock hypothesis) fit to the age compositions for the Chilean northern zone fishery (Fleet 1). Bars represent the observed data and lines represent the model predictions.

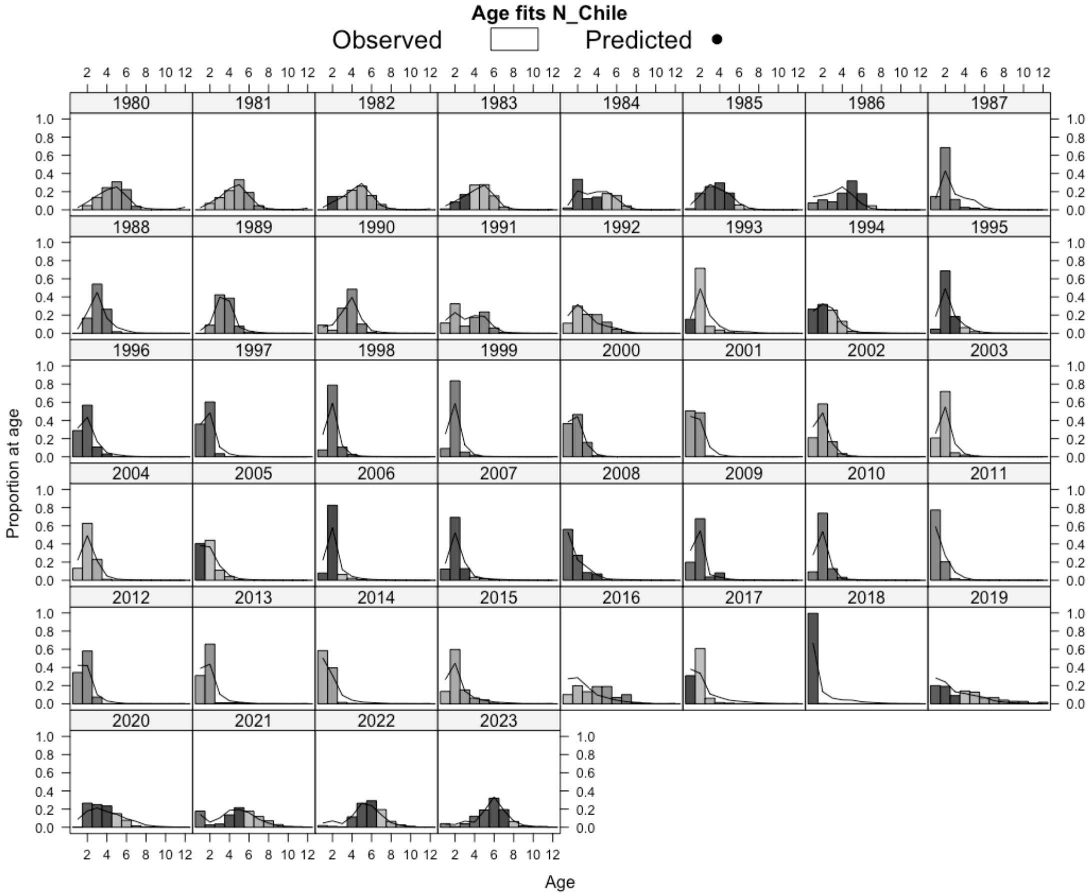

Figure A10.12: Model h2_1.07 (two-stock hypothesis) fit to the age compositions for the Chilean northern zone fishery (Fleet 1). Bars represent the observed data and lines represent the model predictions.

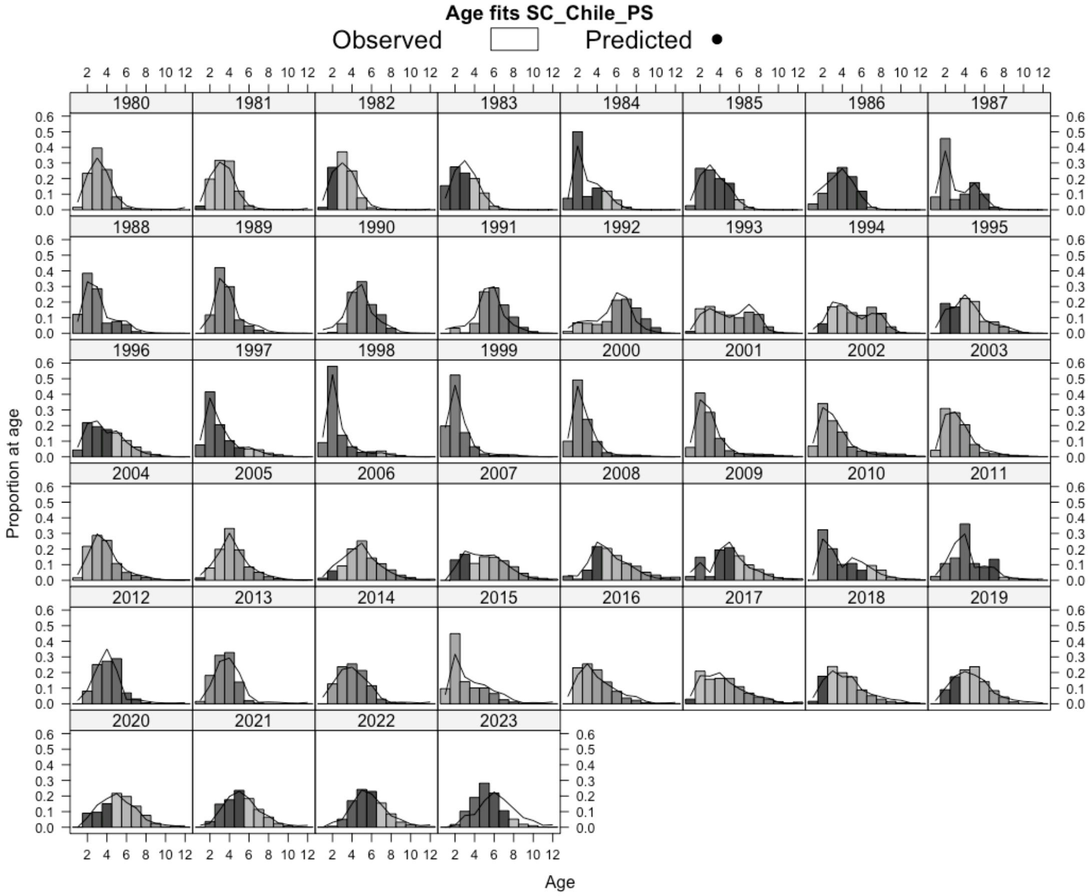

Figure A10.13: Model h1_1.07 (single-stock hypothesis) fit to the age compositions for the South-Central Chilean purse seine fishery (Fleet 2). Bars represent the observed data and lines represent the model predictions.

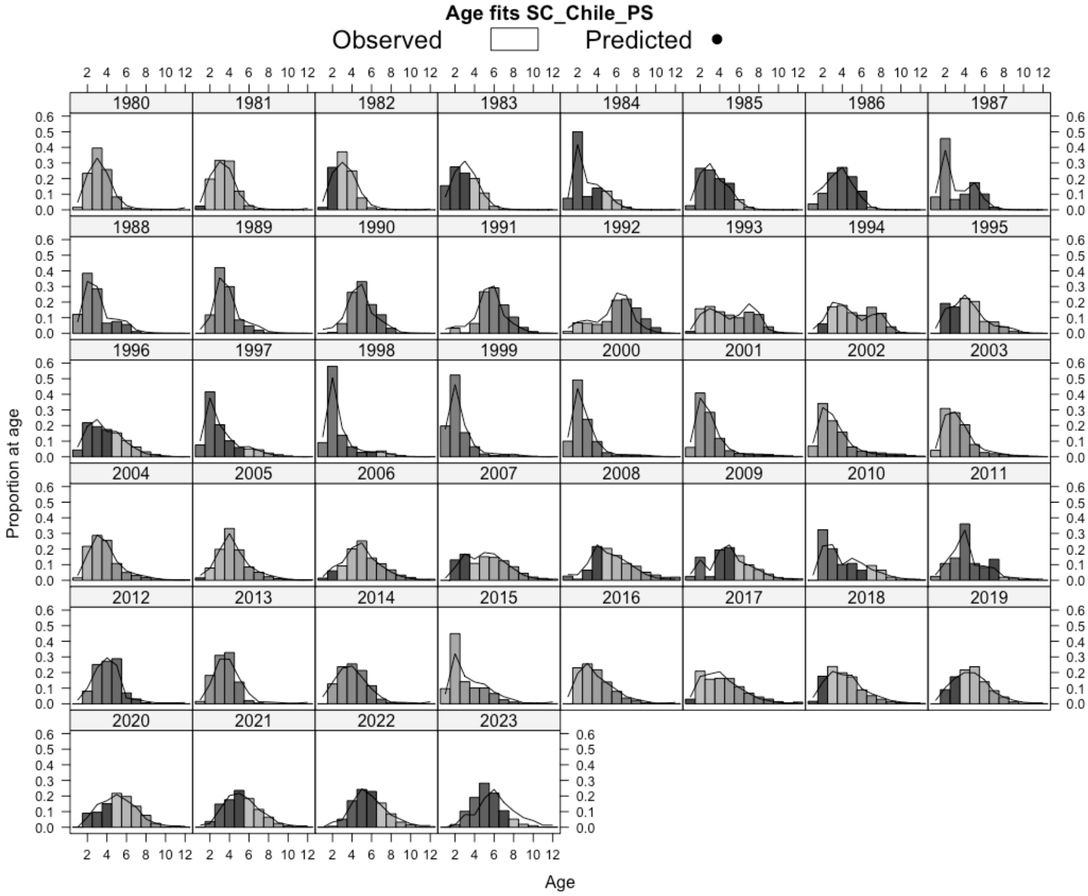

Figure A10.14: Model h2_1.07 (two-stock hypothesis) fit to the age compositions for the South-Central Chilean purse seine fishery (Fleet 2). Bars represent the observed data and lines represent the model predictions.

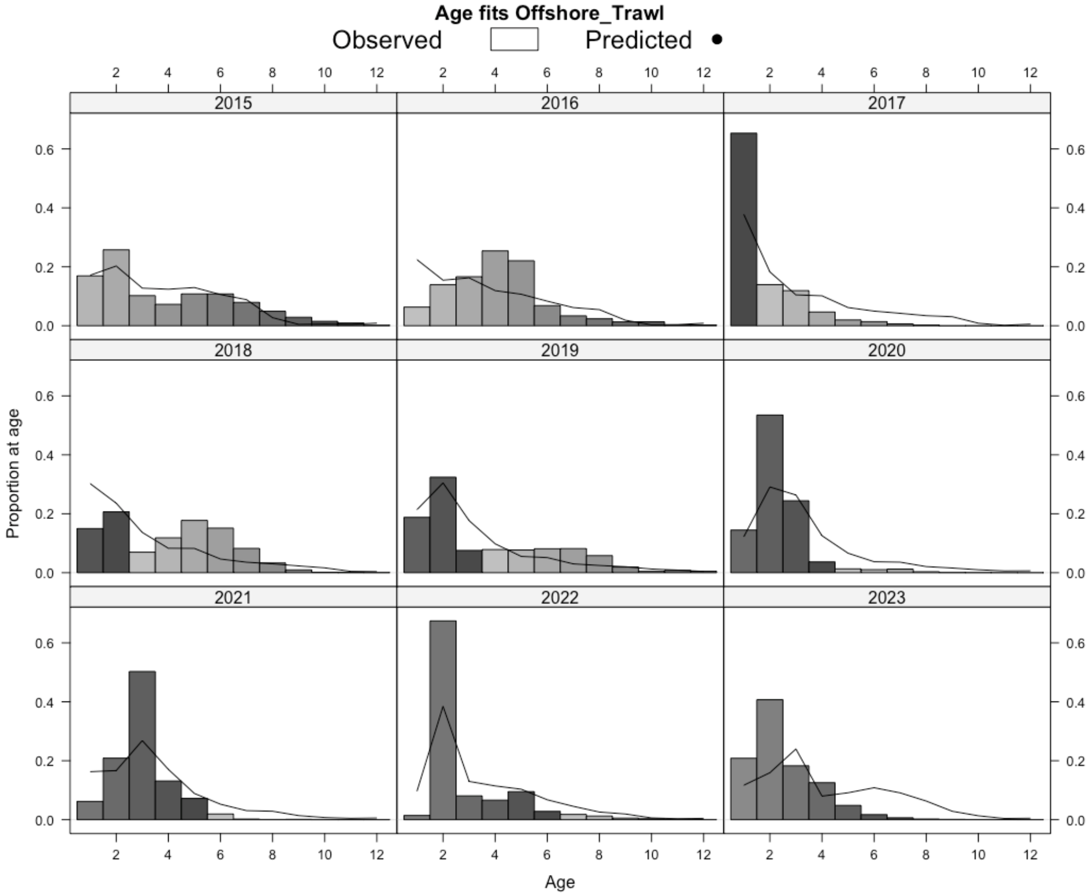

Figure A10.15: Model h1_1.07 (single-stock hypothesis) fit to the age compositions for the offshore trawl fishery (Fleet 4). Bars represent the observed data and lines represent the model predictions.

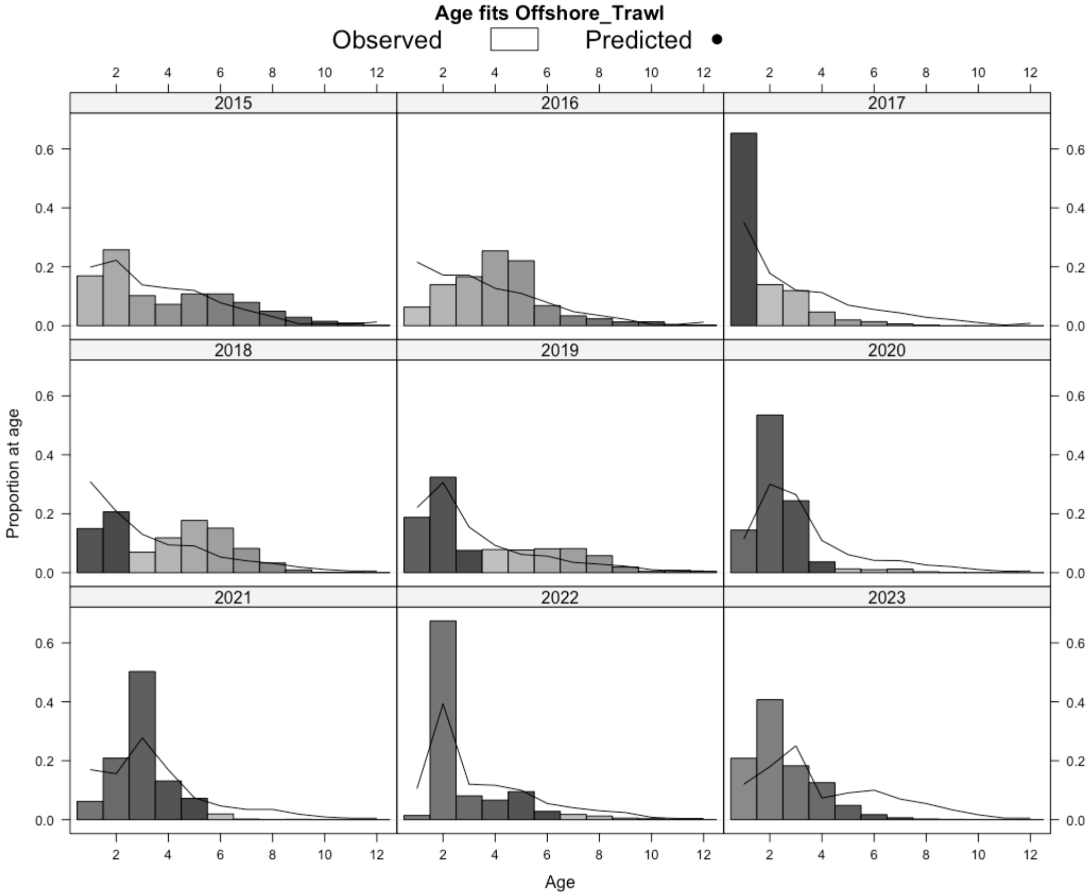

Figure A10.16: Model h2_1.07 (two-stock hypothesis) fit to the age compositions for the offshore trawl fishery (Fleet 4). Bars represent the observed data and lines represent the model predictions.

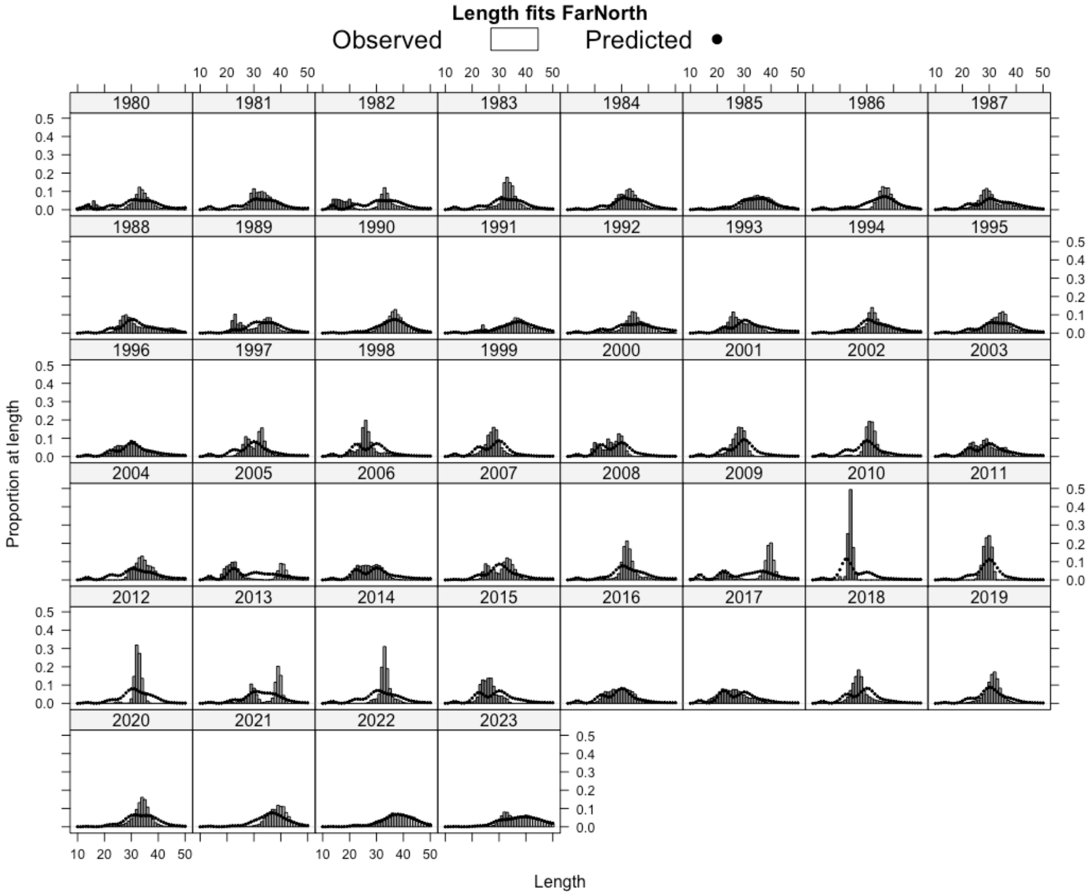

Figure A10.17: Model h1_1.07 (single-stock hypothesis) fit to the length compositions for the far north fishery (Fleet 3). Bars represent the observed data and lines represent the model predictions.

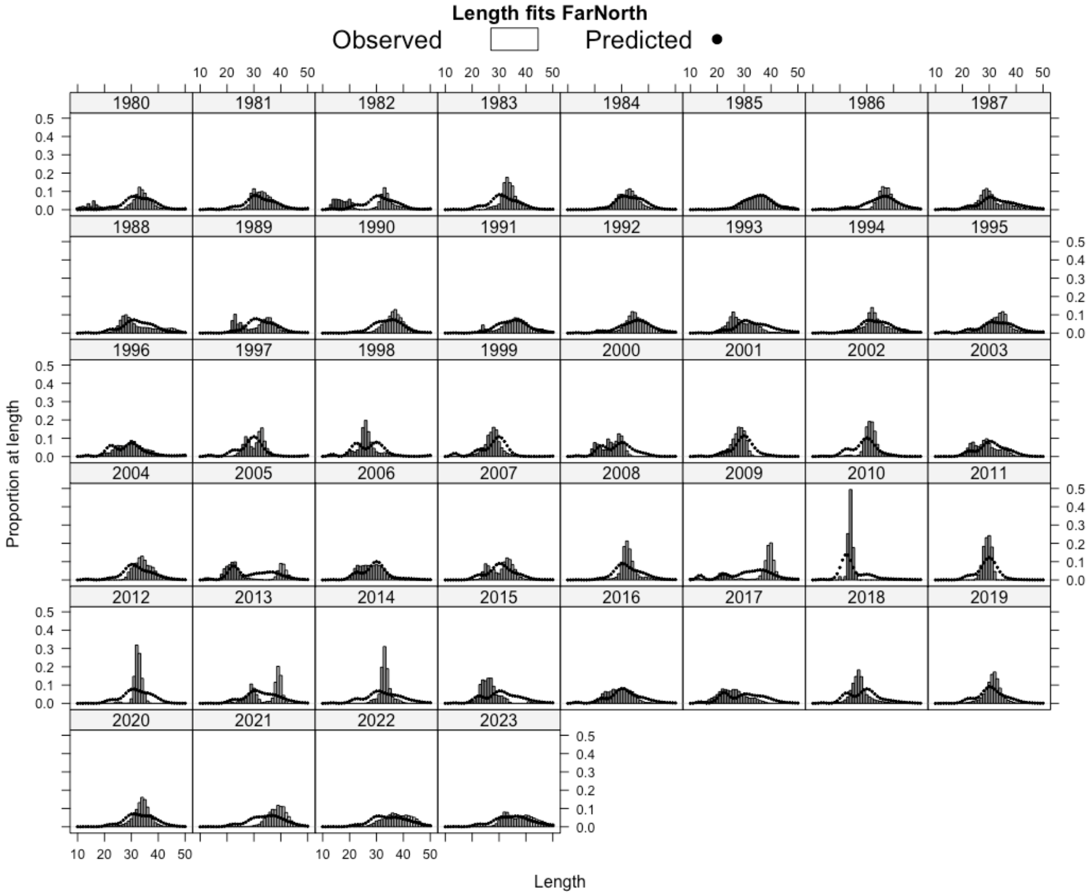

Figure A10.18: Model h2_1.07 (two-stock hypothesis) fit to the length compositions for the far north fishery (Fleet 3). Bars represent the observed data and lines represent the model predictions.

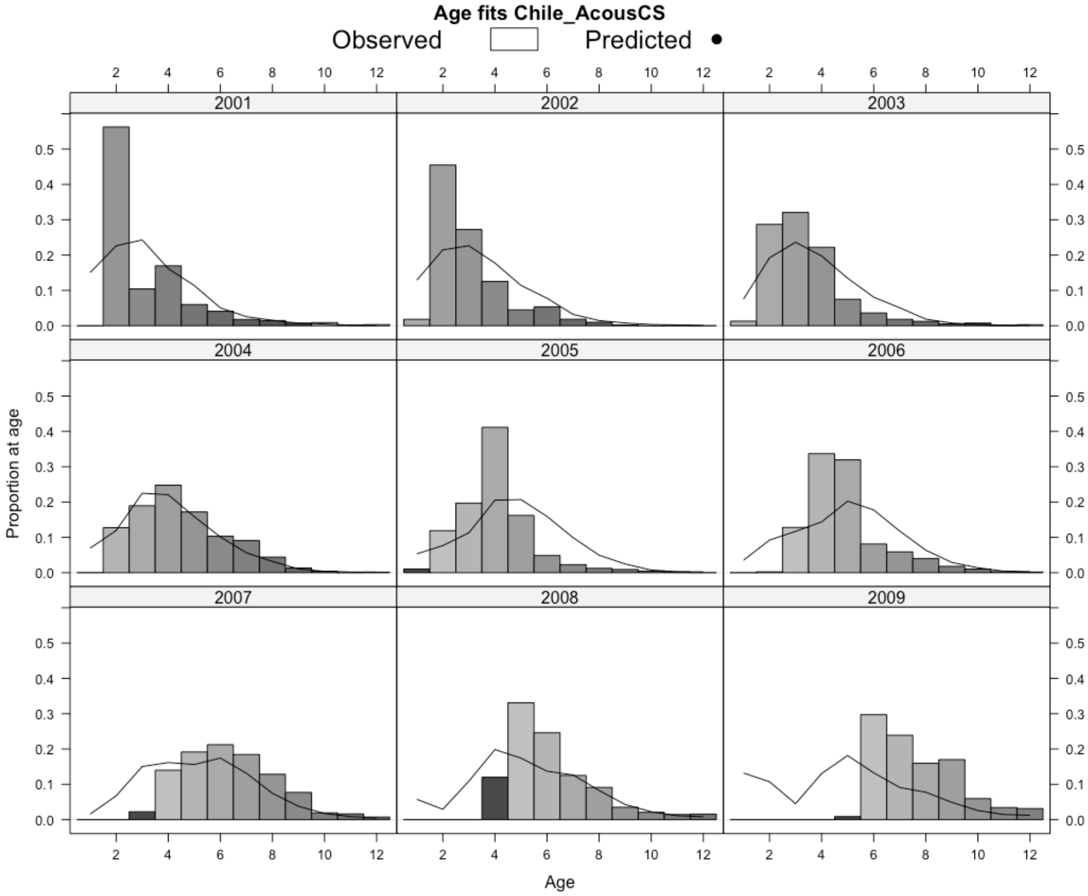

Figure A10.19: Model h1_1.07 (single-stock hypothesis) fit to the age compositions for the South-Central Acoustic survey. Bars represent the observed data and lines represent the model predictions.

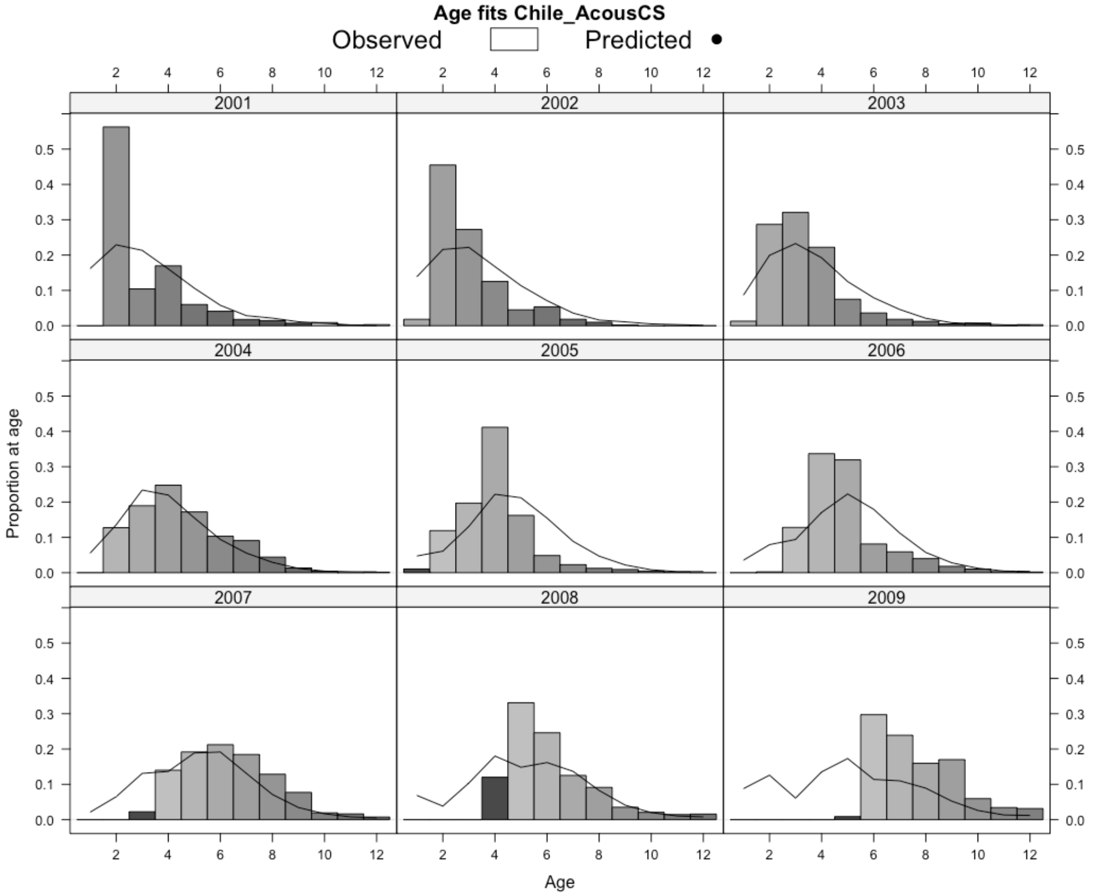

Figure A10.20: Model h2_1.07 (two-stock hypothesis) fit to the age compositions for the South-Central Acoustic survey. Bars represent the observed data and lines represent the model predictions.

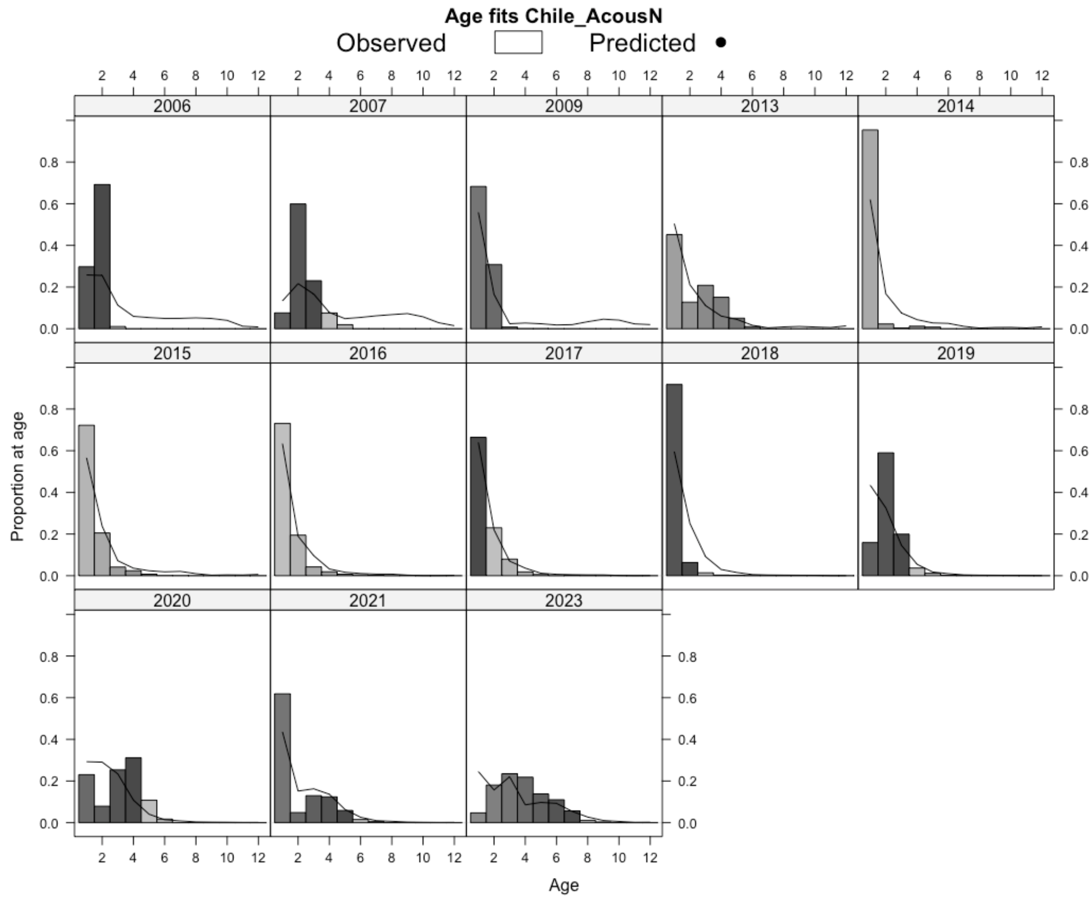

Figure A10.21: Model h1_1.07 (single-stock hypothesis) fit to the age compositions for the North Chilean acoustic survey. Bars represent the observed data and lines represent the model predictions.

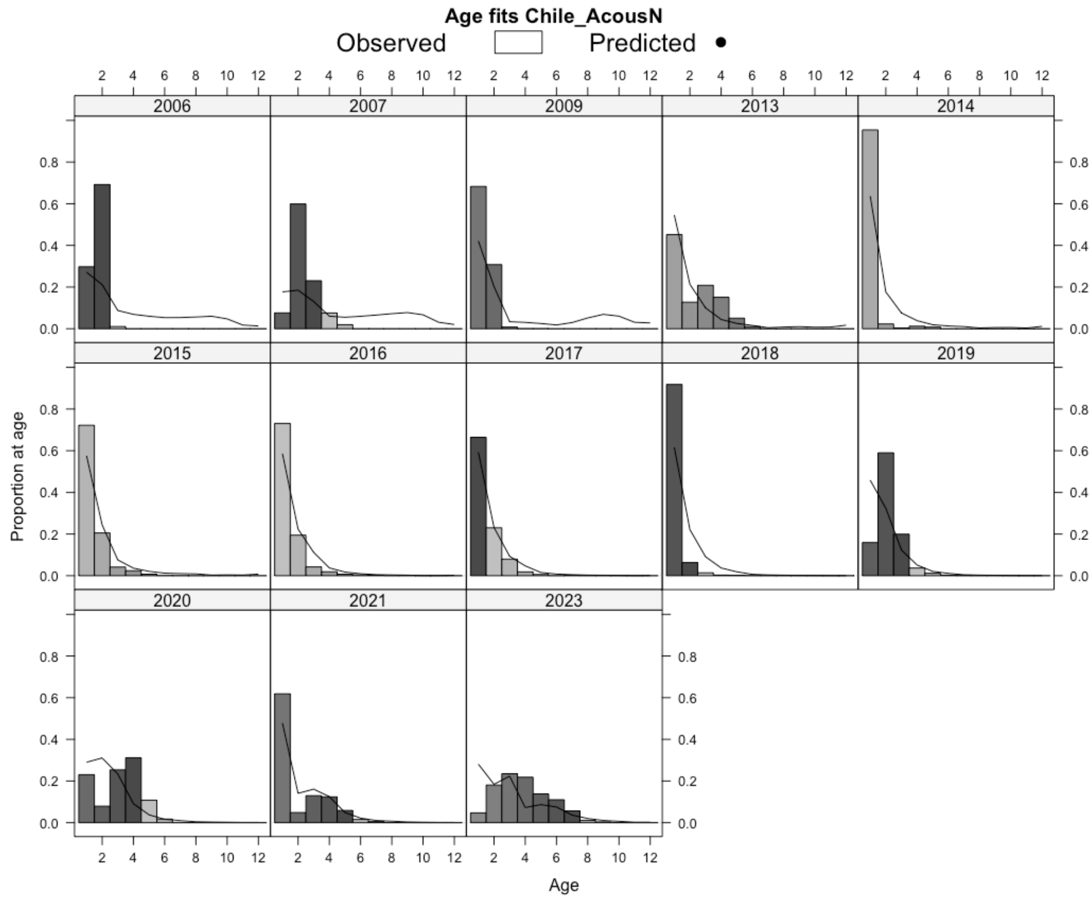

Figure A10.22: Model h2_1.07 (two-stock hypothesis) fit to the age compositions for the North Chilean acoustic survey. Bars represent the observed data and lines represent the model predictions.

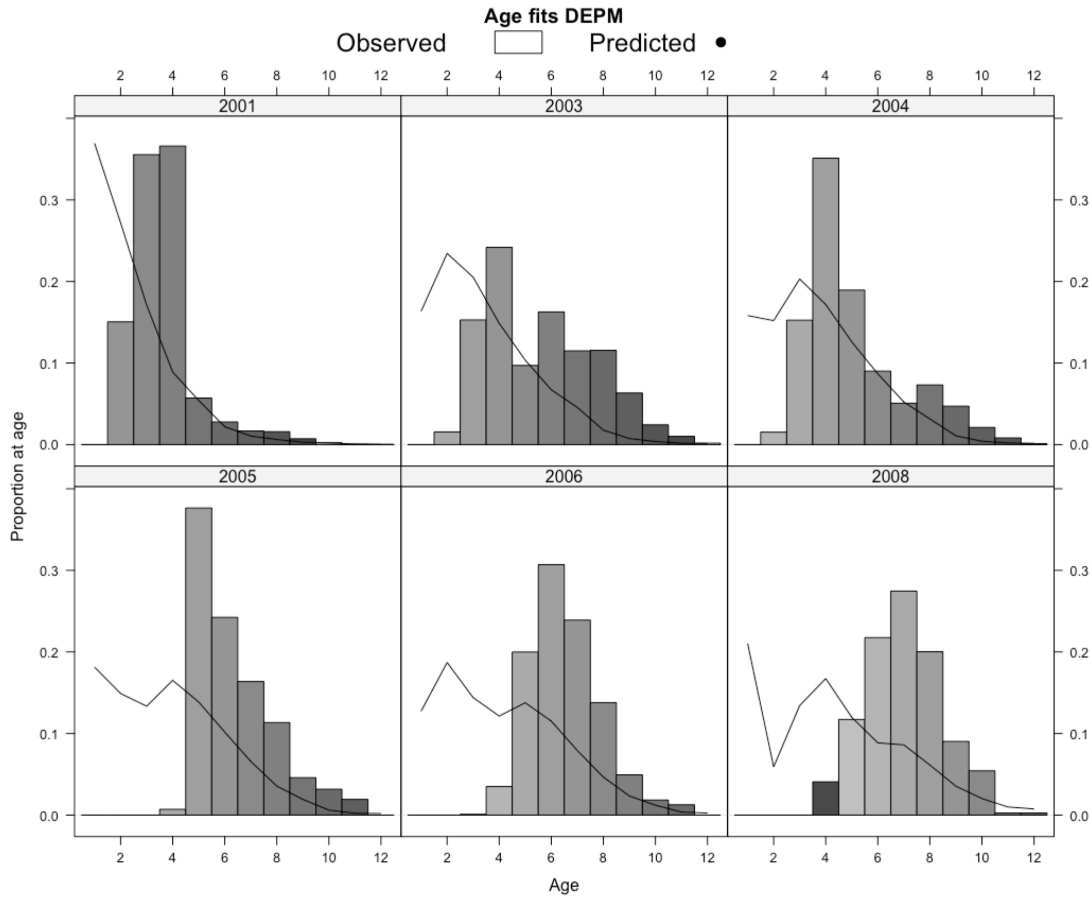

Figure A10.23: Model h1_1.07 (single-stock hypothesis) fit to the age compositions for the Daily Egg Production Method (DEPM) survey. Bars represent the observed data and lines represent the model predictions.

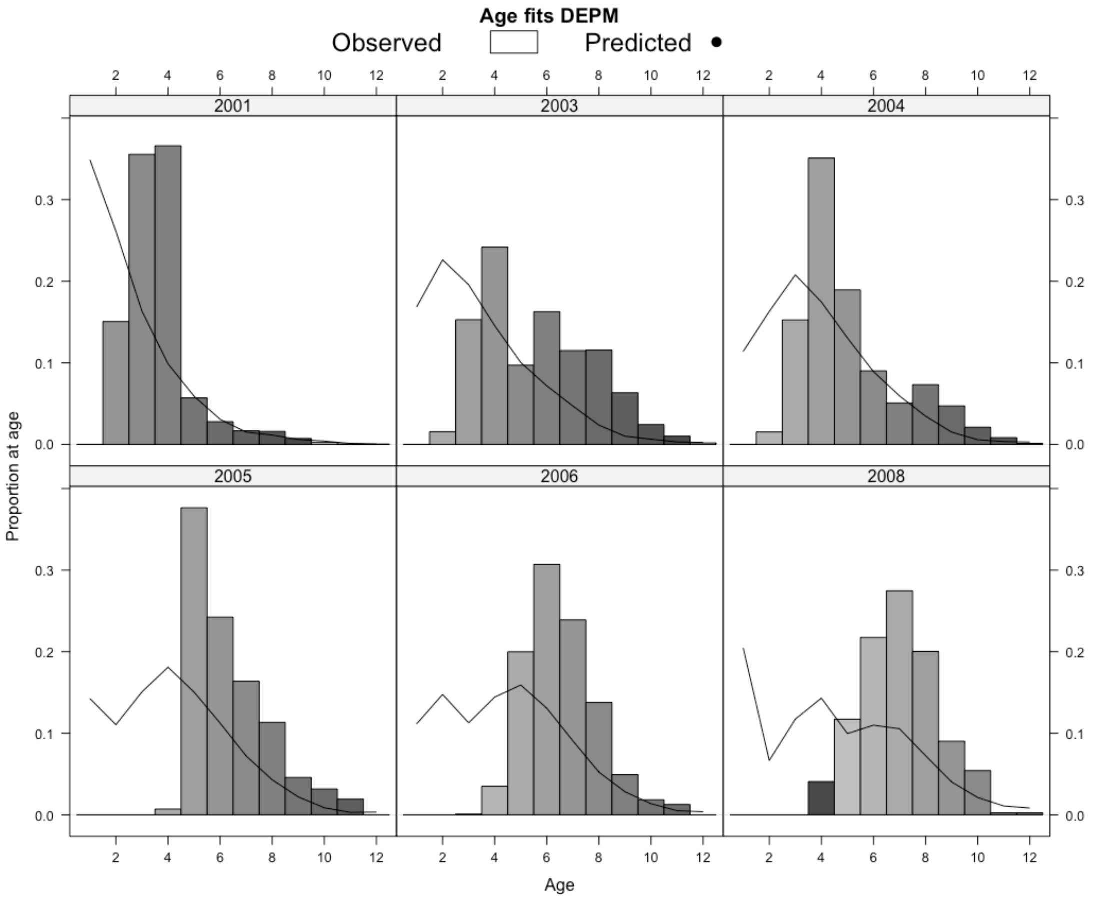

Figure A10.24: Model h2_1.07 (two-stock hypothesis) fit to the age compositions for the Daily Egg Production Method (DEPM) survey. Bars represent the observed data and lines represent the model predictions.

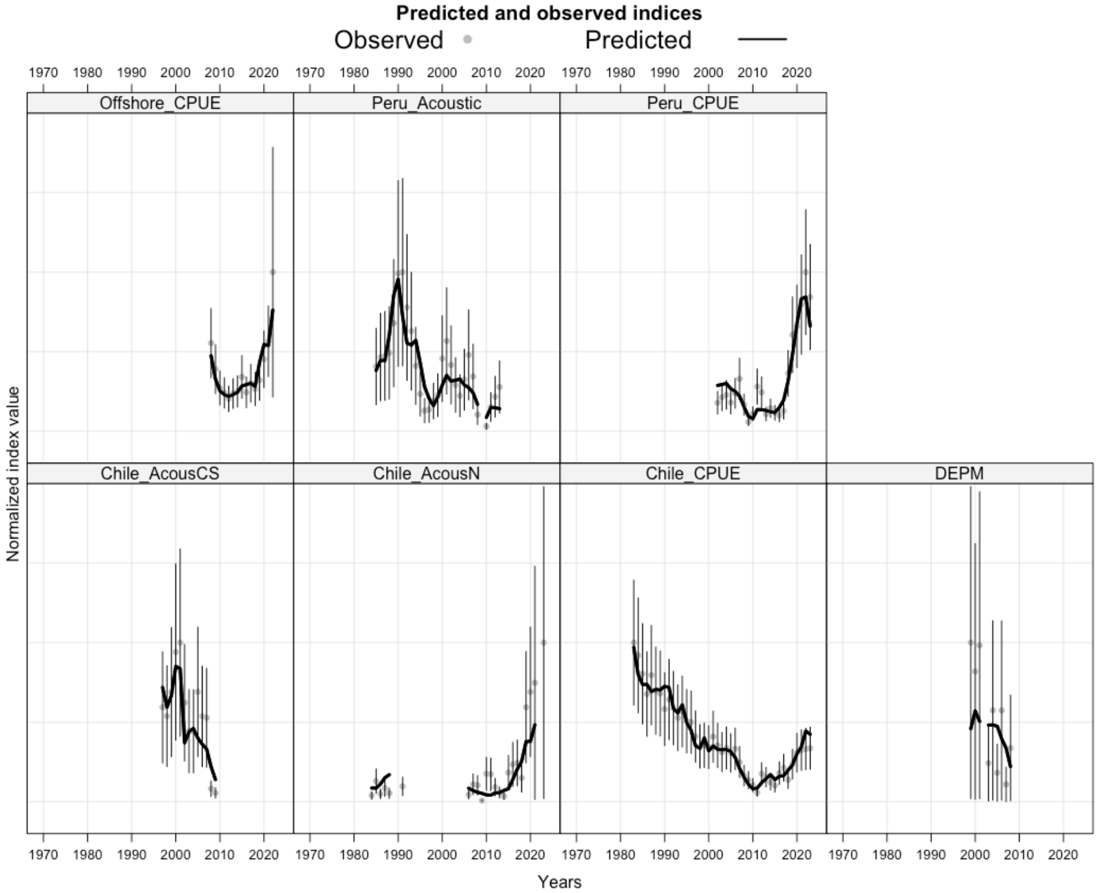

Figure A10.25: Model h1_1.07 (single-stock hypothesis) fit to different indices. Vertical bars represent 2 standard deviations around the observations.

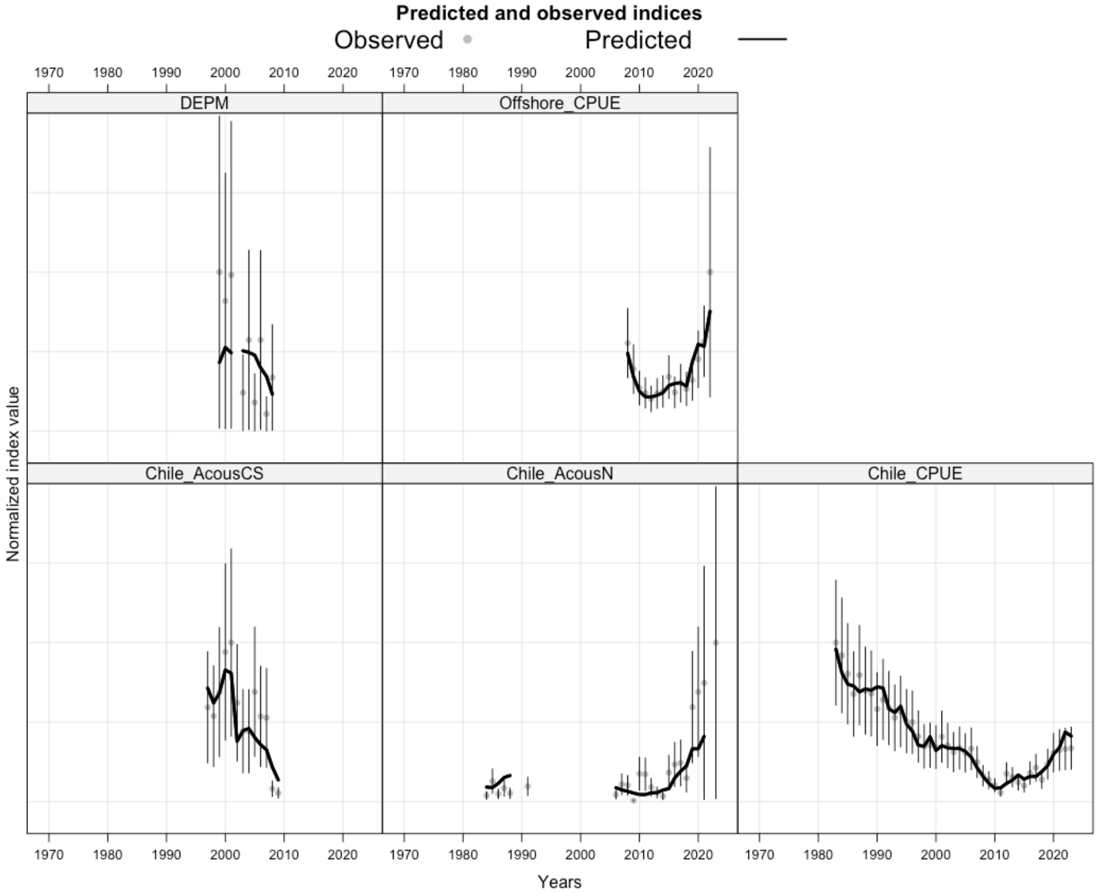

Figure A10.26: Model h2_1.07 (two-stock hypothesis) fit to indices for the south stock. Vertical bars represent 2 standard deviations around the observations.

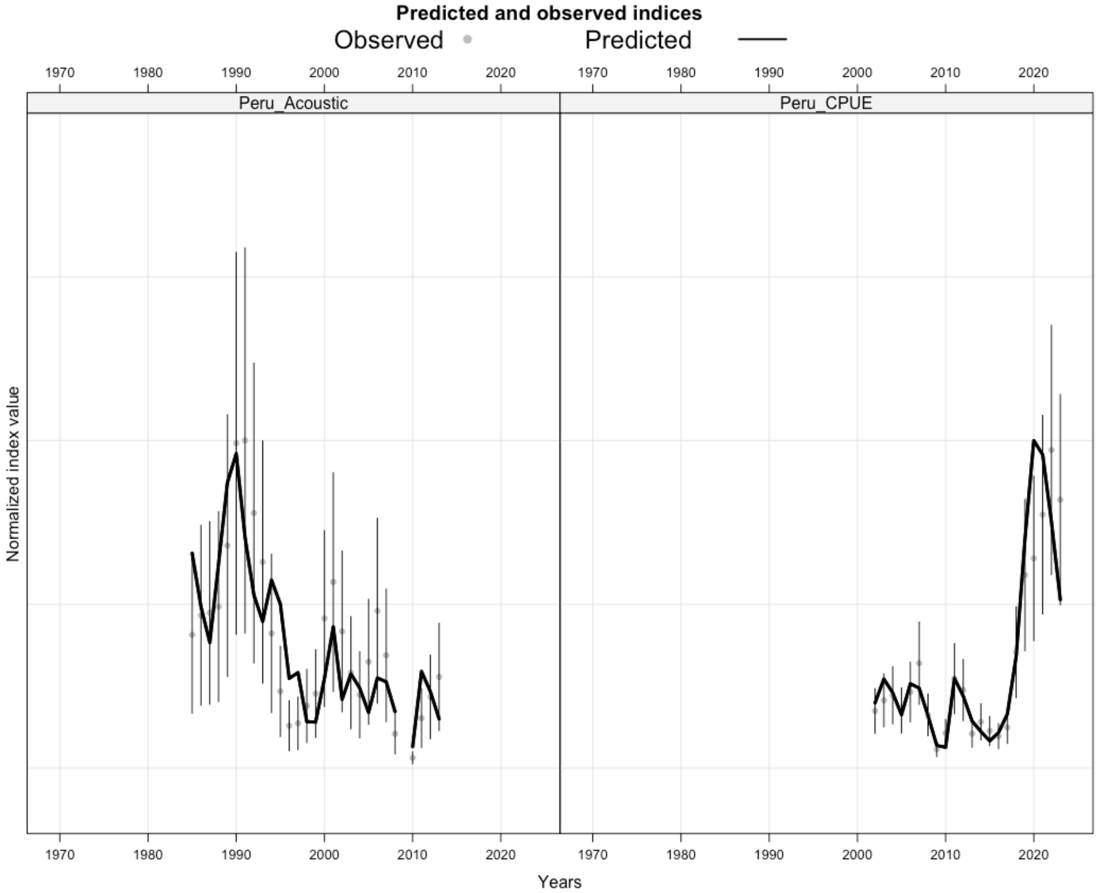

Figure A10.27: Model h2_1.07 (two-stock hypothesis) fit to indices for the north stock. Vertical bars represent 2 standard deviations around the observations.

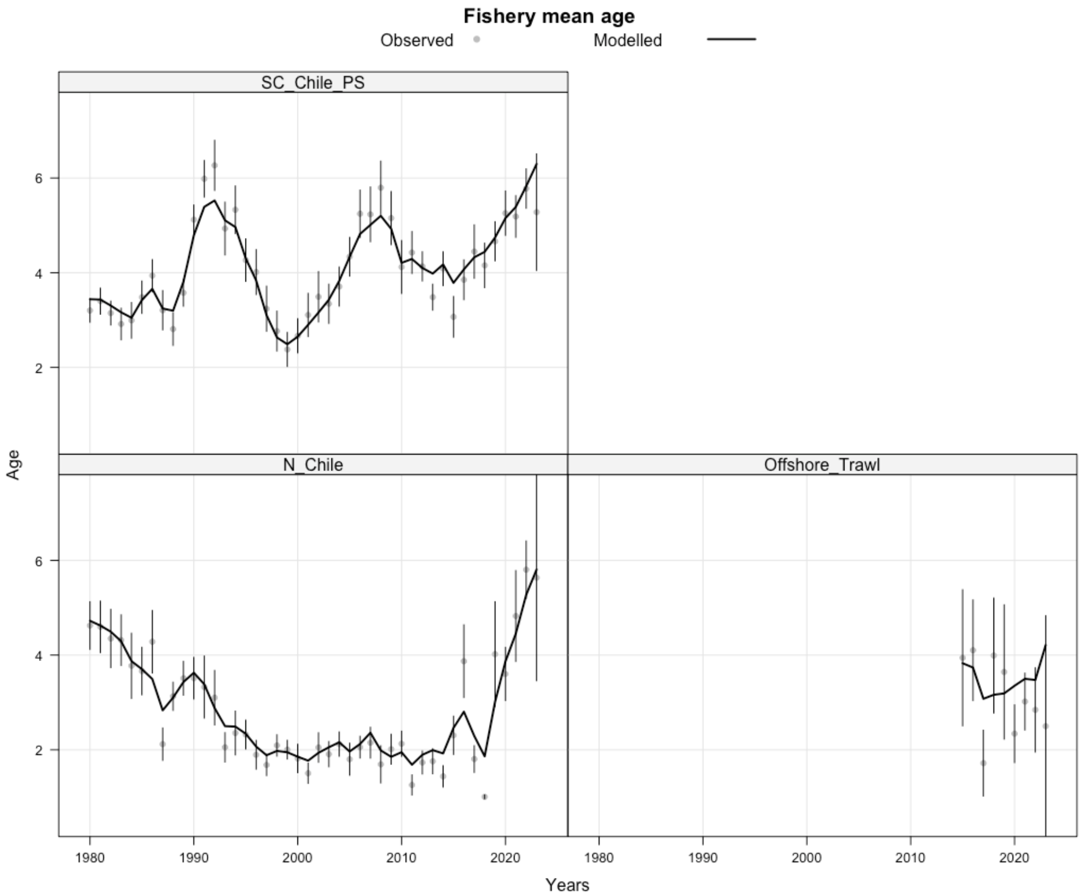

Figure A10.28: Mean age by year and fishery. Line represents the Model h1_1.07 (single-stock hypothesis) predictions and dots observed values with implied input error bars.

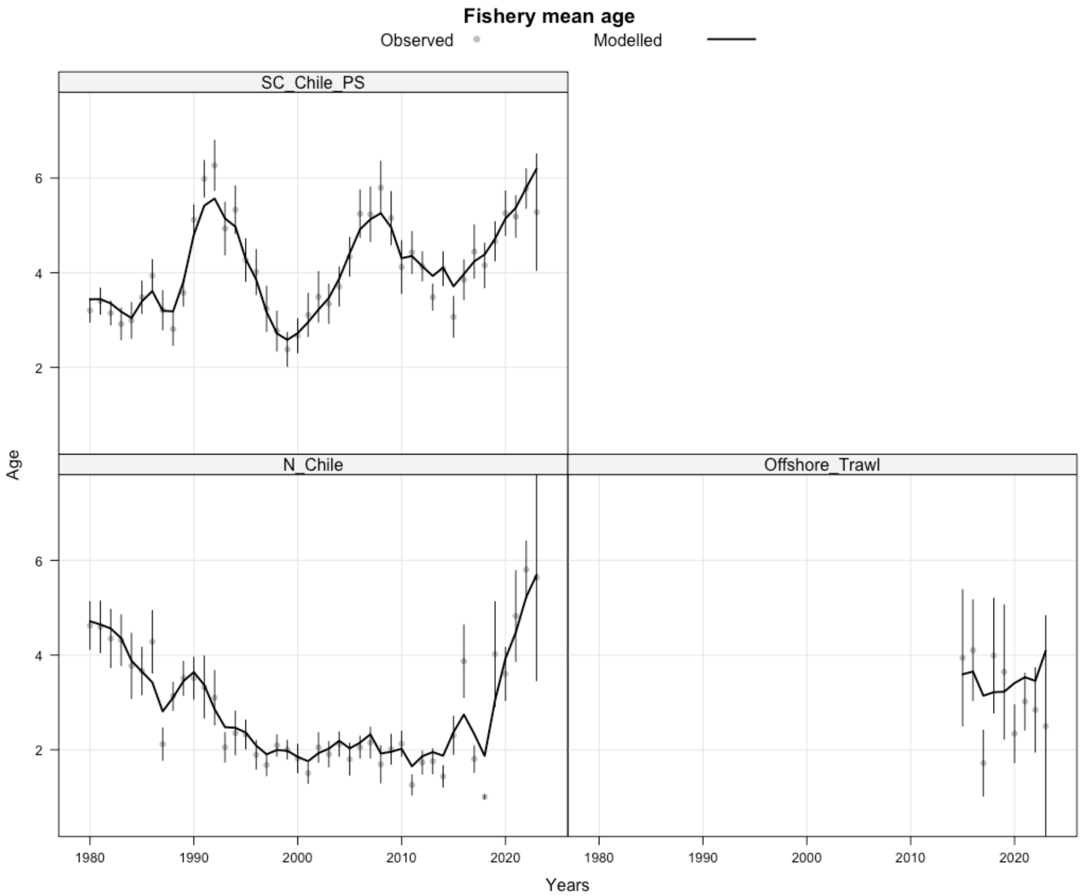

Figure A10.29: Mean age by year and fishery. Line represents the Model h2_1.07 (two-stock hypothesis) predictions and dots observed values with implied input error bars.

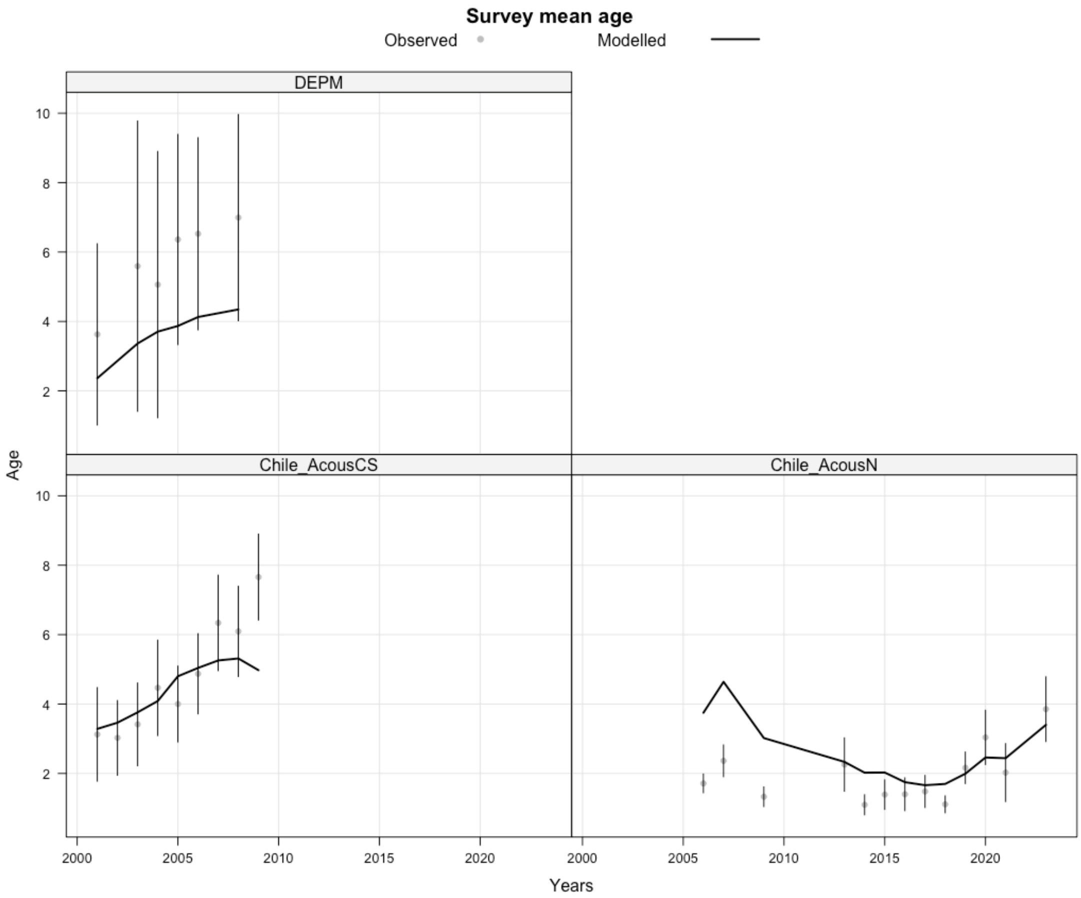

Figure A10.30: Mean age by year and survey. Line represents the Model h1_1.07 (single-stock hypothesis) predictions and dots observed values with implied input error bars.

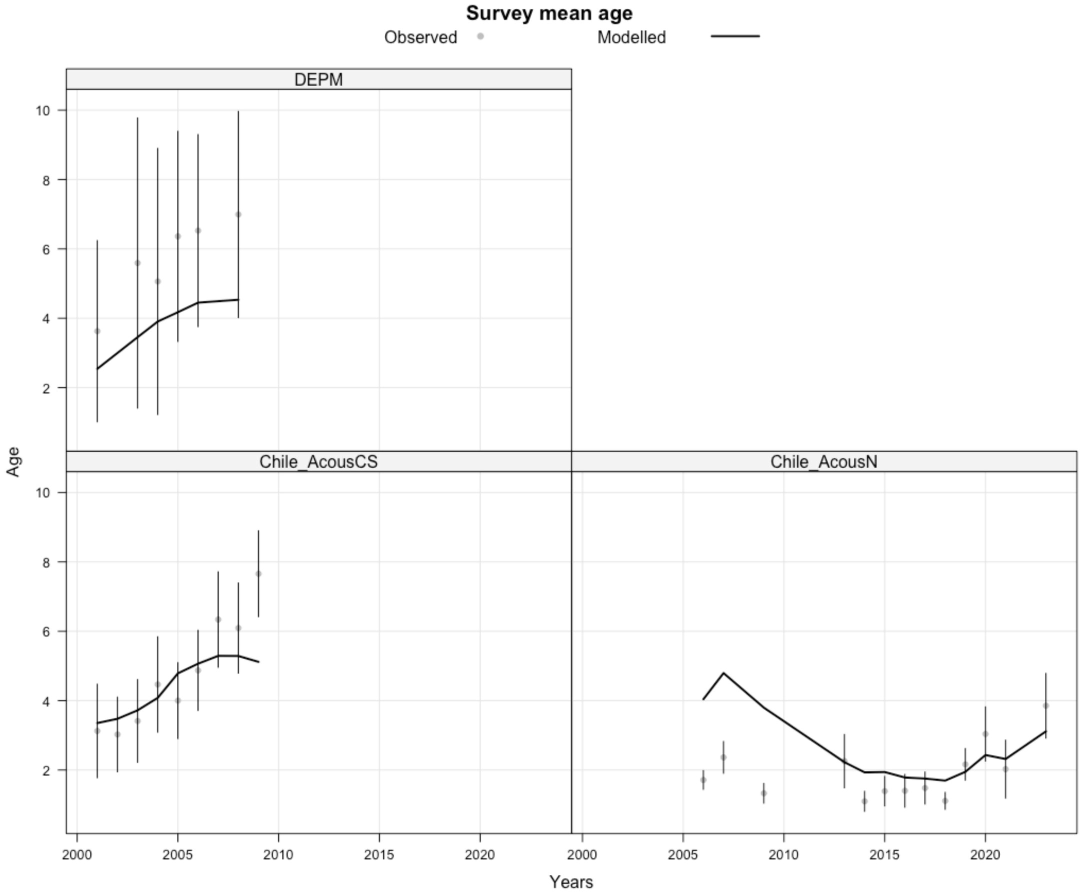

Figure A10.31: Mean age by year and survey. Line represents the Model h2_1.07 (two-stock hypothesis) predictions and dots observed values with implied input error bars.

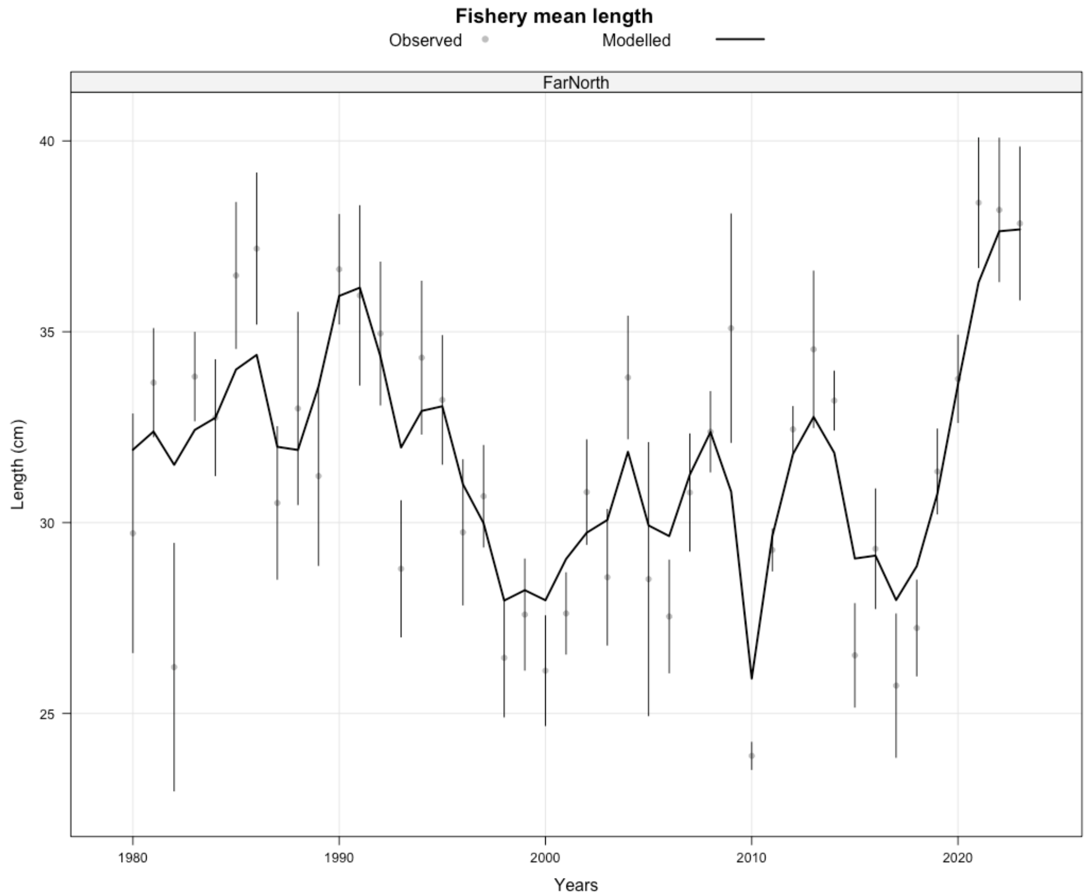

Figure A10.32: Mean length by year in Fleet 3 (Far North). Line represents the Model h1_1.07 (single-stock hypothesis) predictions and dots observed values with implied input error bars.

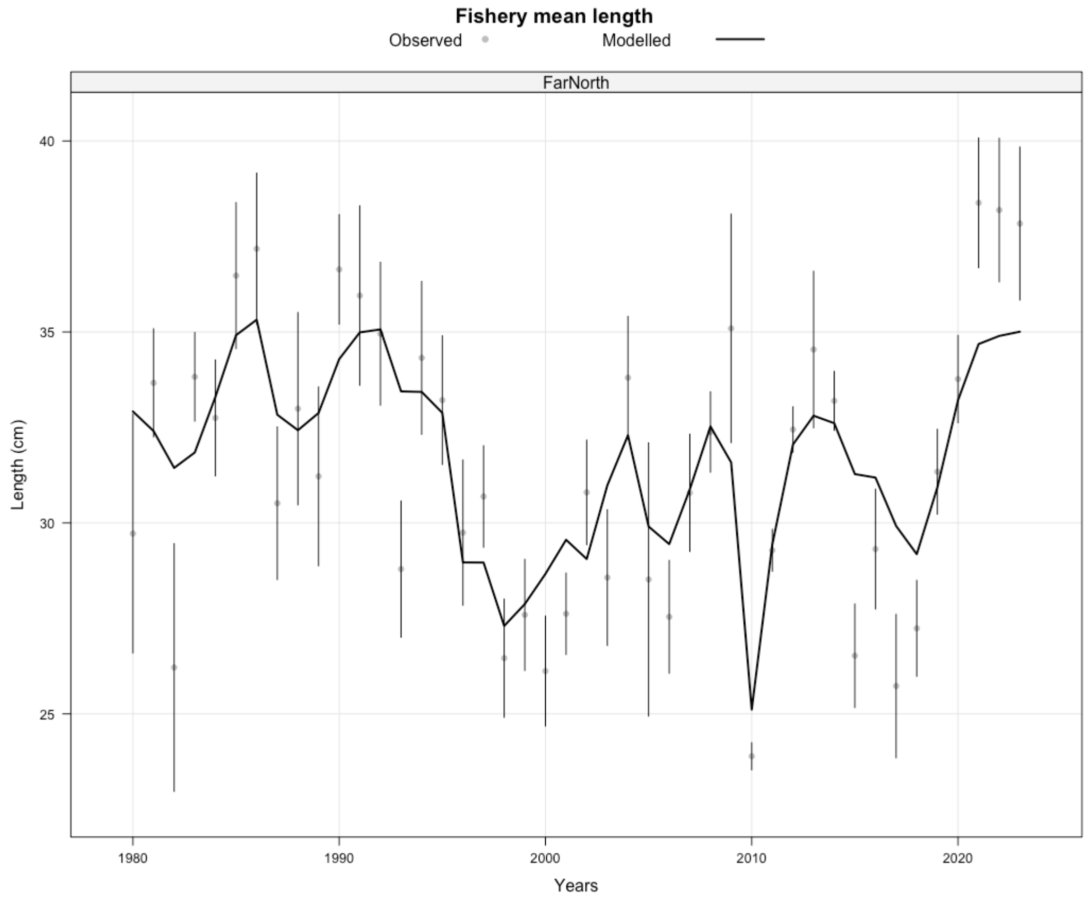

Figure A10.33: Mean length by year in Fleet 3 (Far North). Line represents the Model h2_1.07 (two-stock hypothesis) predictions and dots observed values with implied input error bars.

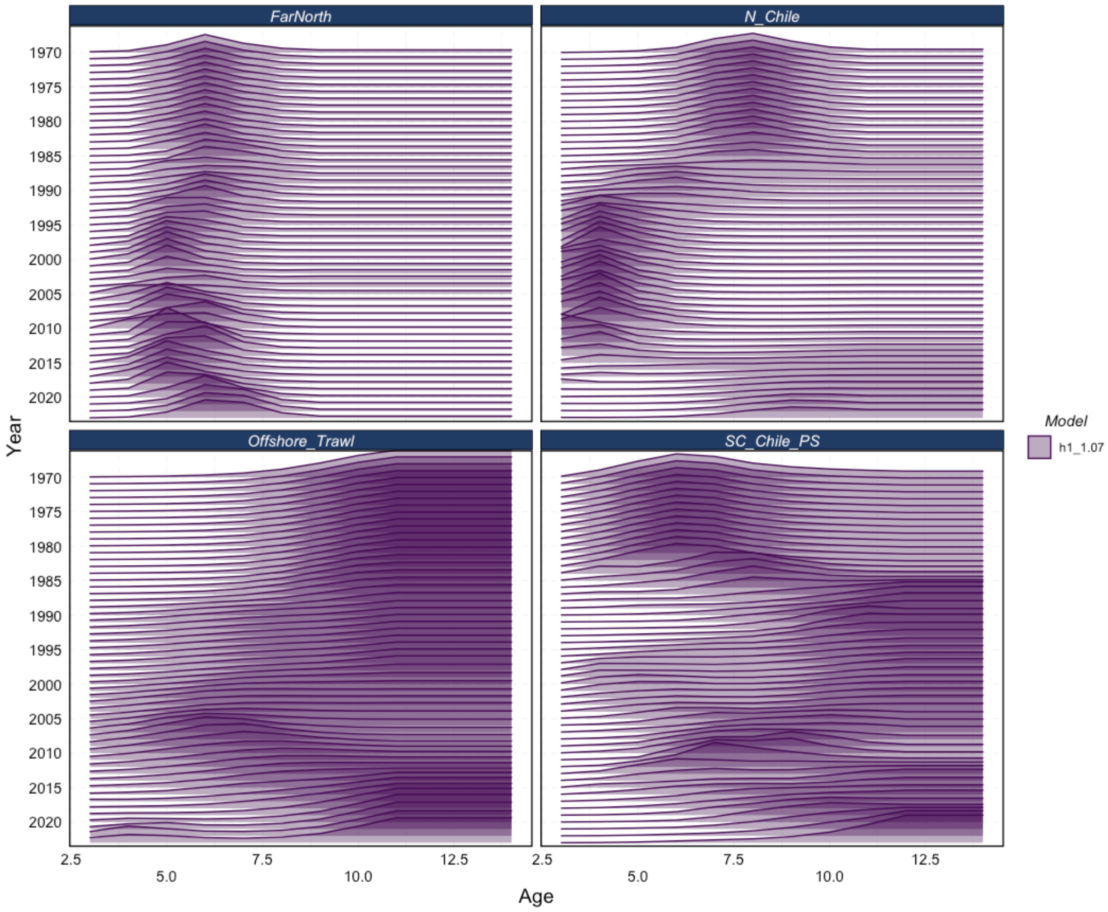

Figure A10.34: Estimates of selectivity by fishery over time for Model h1_1.07 (single-stock hypothesis).

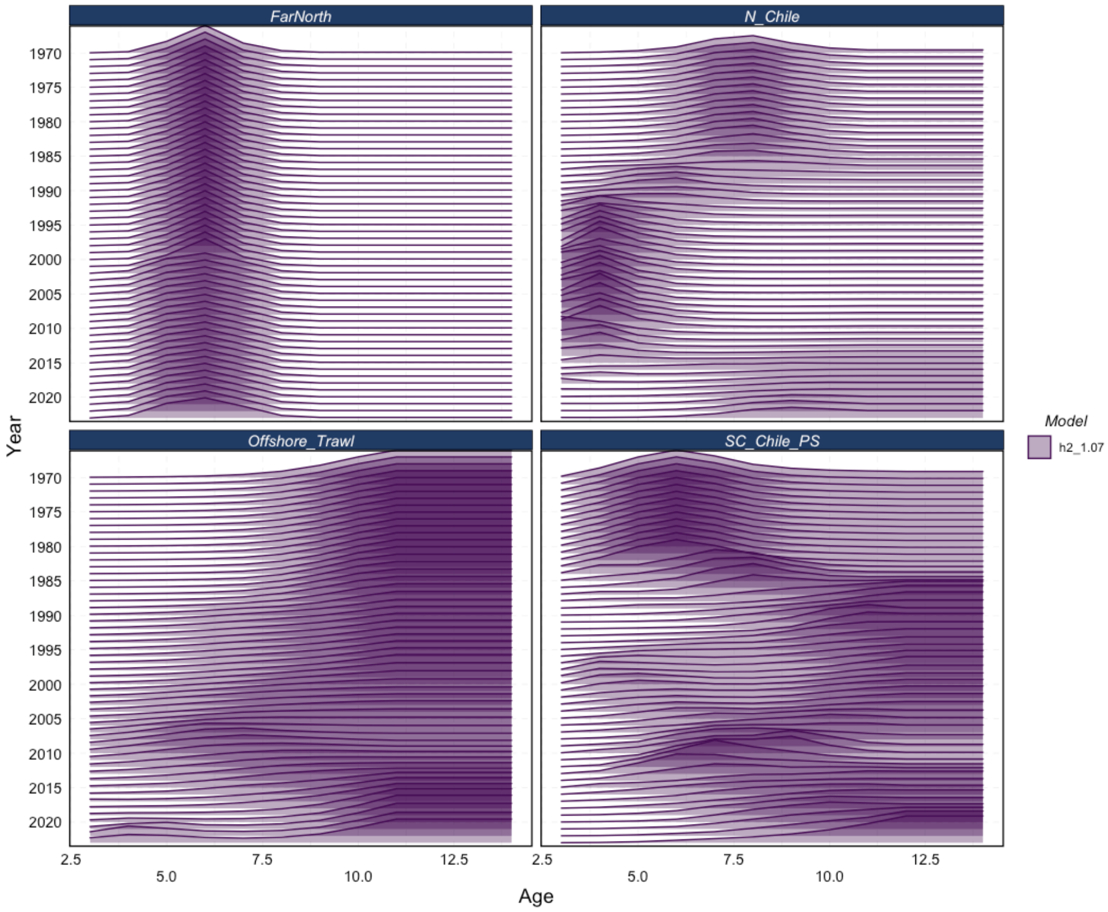

Figure A10.35: Estimates of selectivity by fishery over time for Model h2_1.07 (two-stock hypothesis).

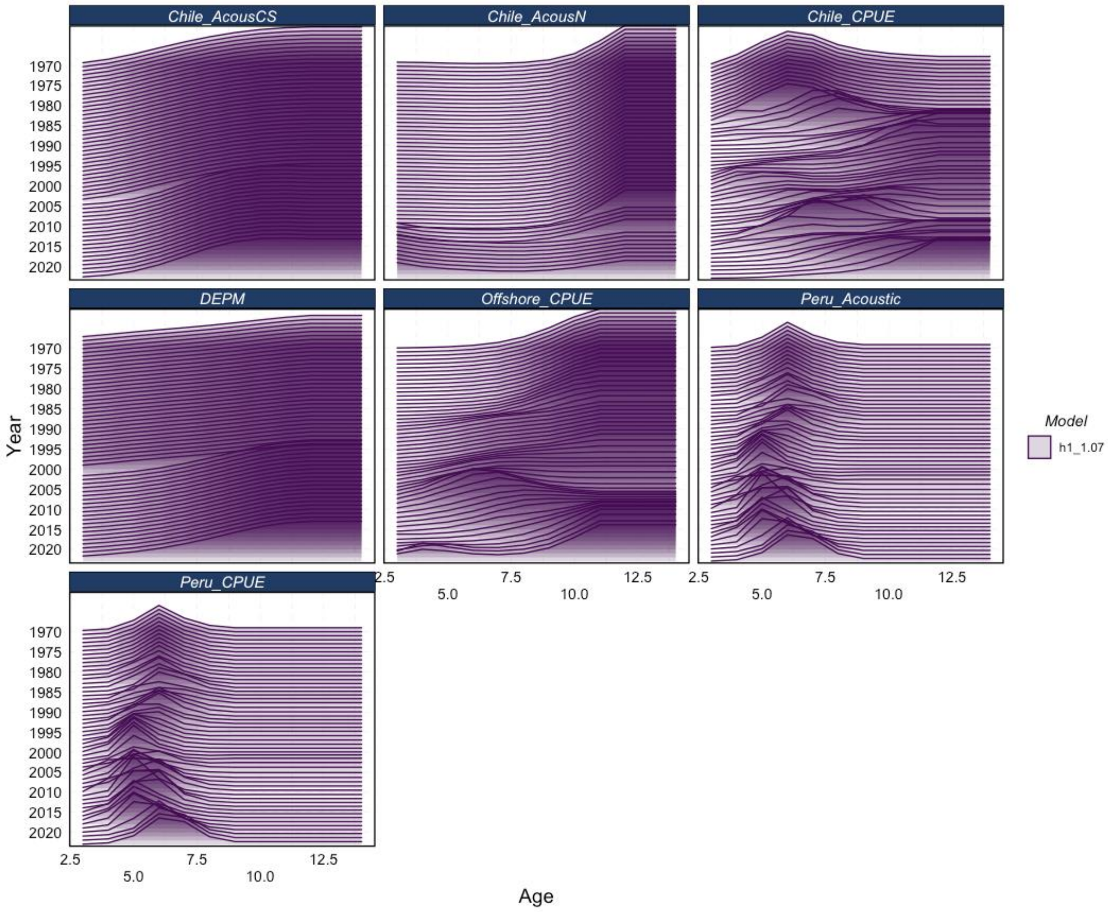

Figure A10.36: Estimates of selectivity by survey over time for Model h1_1.07 (single-stock hypothesis).

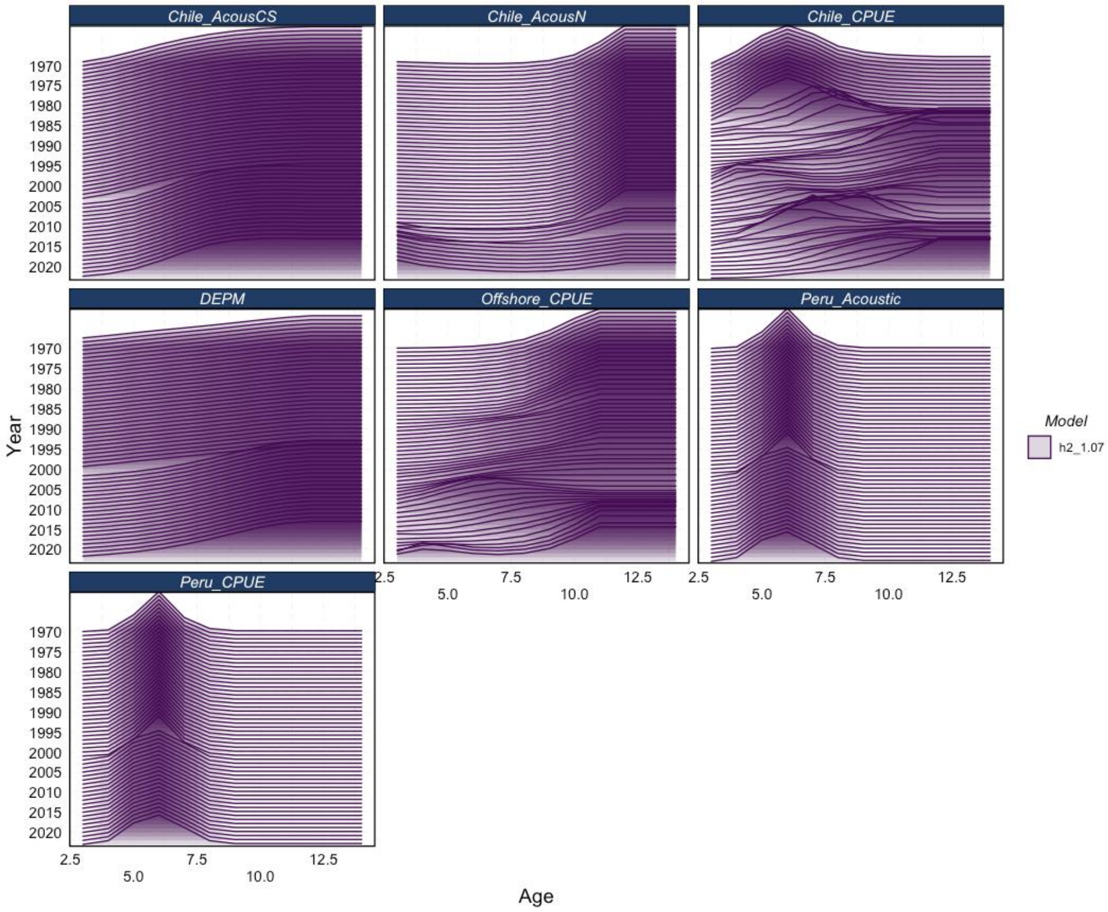

Figure A10.37: Estimates of selectivity by survey over time for Model h2_1.07 (two-stock hypothesis).

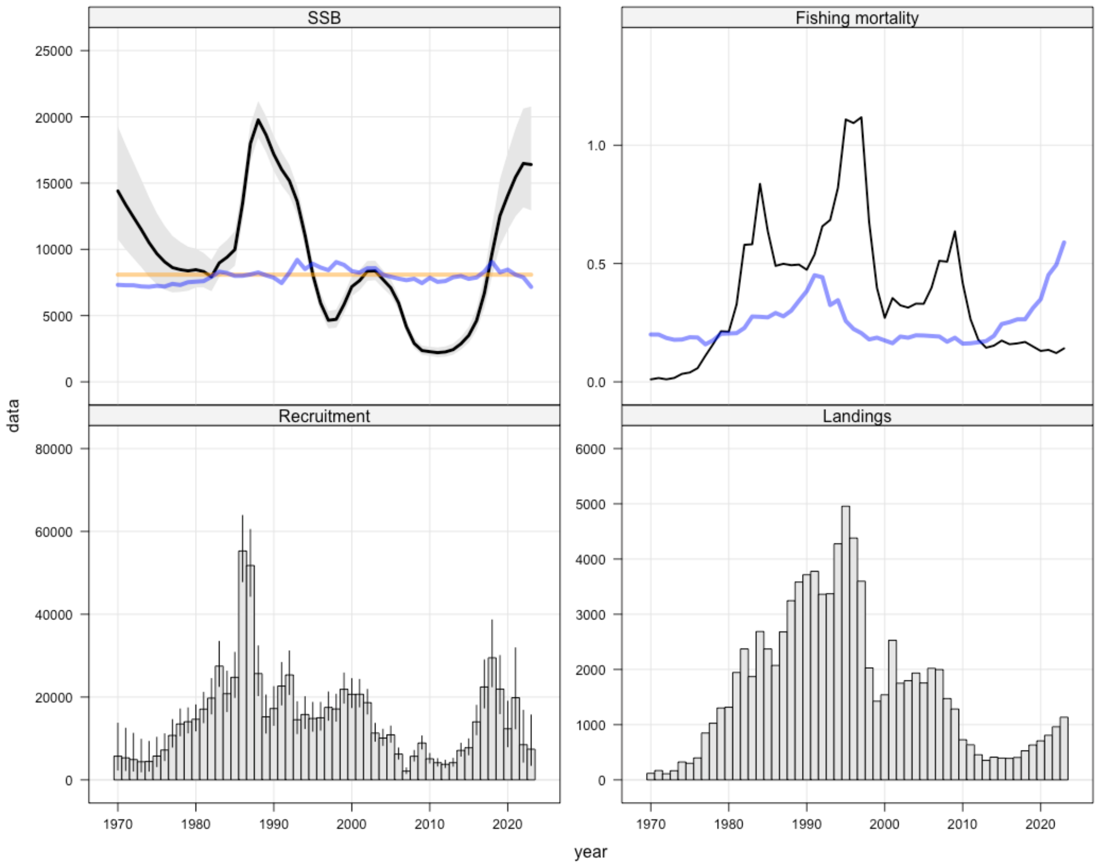

Figure A10.38: Model h1_1.07 (single-stock hypothesis) summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left), total fishing mortality (top right), and total catch (kt; bottom right). Blue lines represent dynamic estimates of B_{MSY} (upper left) and dynamic estimates of F_{MSY} (upper right). The orange line represents the average B_{MSY} over the most recent ten years.

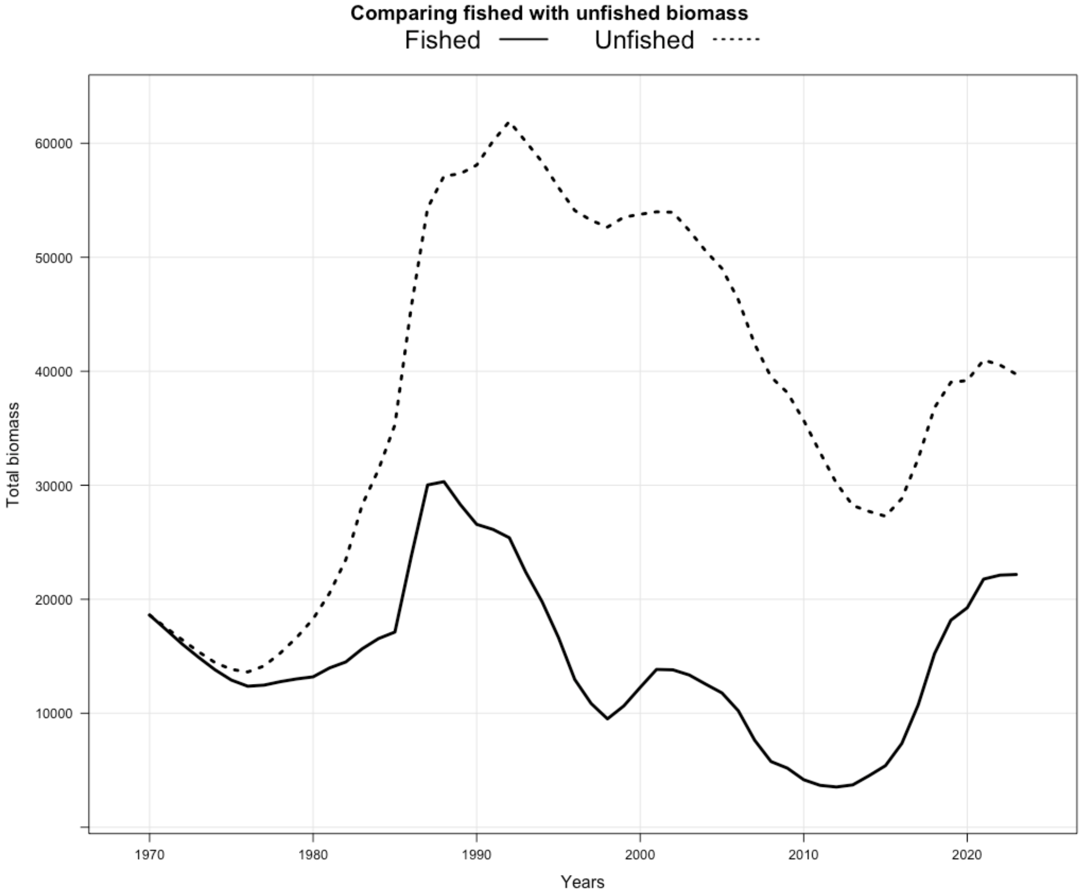

Figure A10.39: Model h1_1.07 (single-stock hypothesis) results for the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place (dotted line), beginning in 1970. This year, the ratio of total biomass to total biomass without fishing is 0.56.

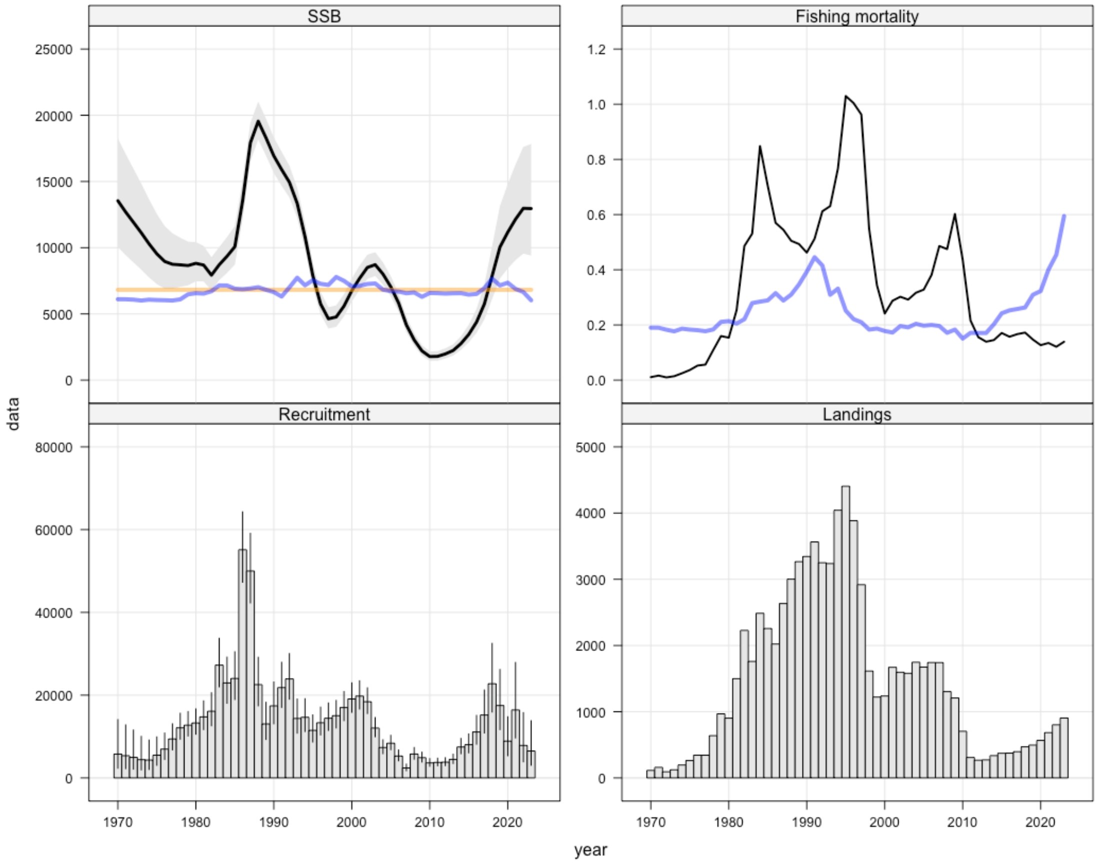

Figure A10.40: Model h2_1.07 (two-stock hypothesis) summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left), total fishing mortality (top right), and total catch (kt; bottom right) for the south stock. Blue lines represent dynamic estimates of B_{MSY} (upper left) and of F_{MSY} (upper right). The orange line represents the average B_{MSY} over the most recent ten years.

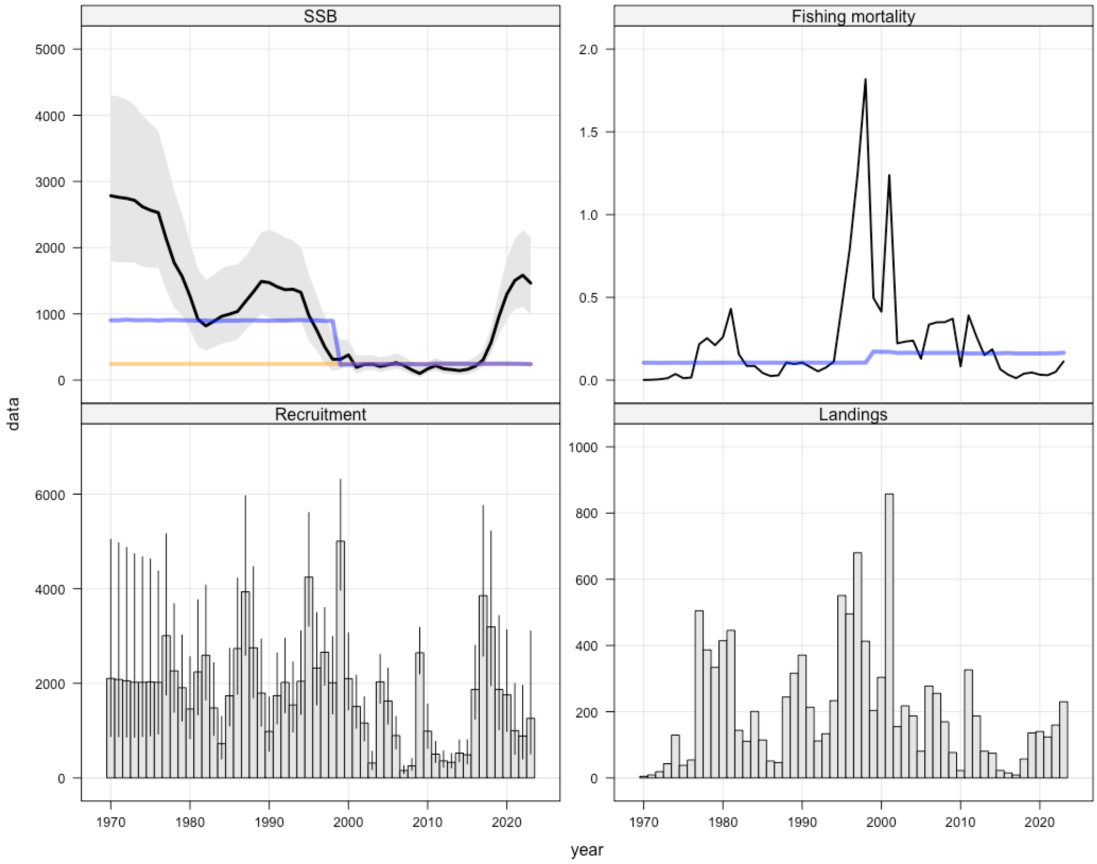

Figure A10.41: Model h2_1.07 (two-stock hypothesis) summary estimates over time showing spawning biomass (kt; top left), recruitment at age 1 (millions; lower left), total fishing mortality (top right), and total catch (kt; bottom right) for the far north stock. Blue lines represent dynamic estimates of B_{MSY} (upper left) and of F_{MSY} (upper right). The orange line represents the average B_{MSY} over the most recent ten years.

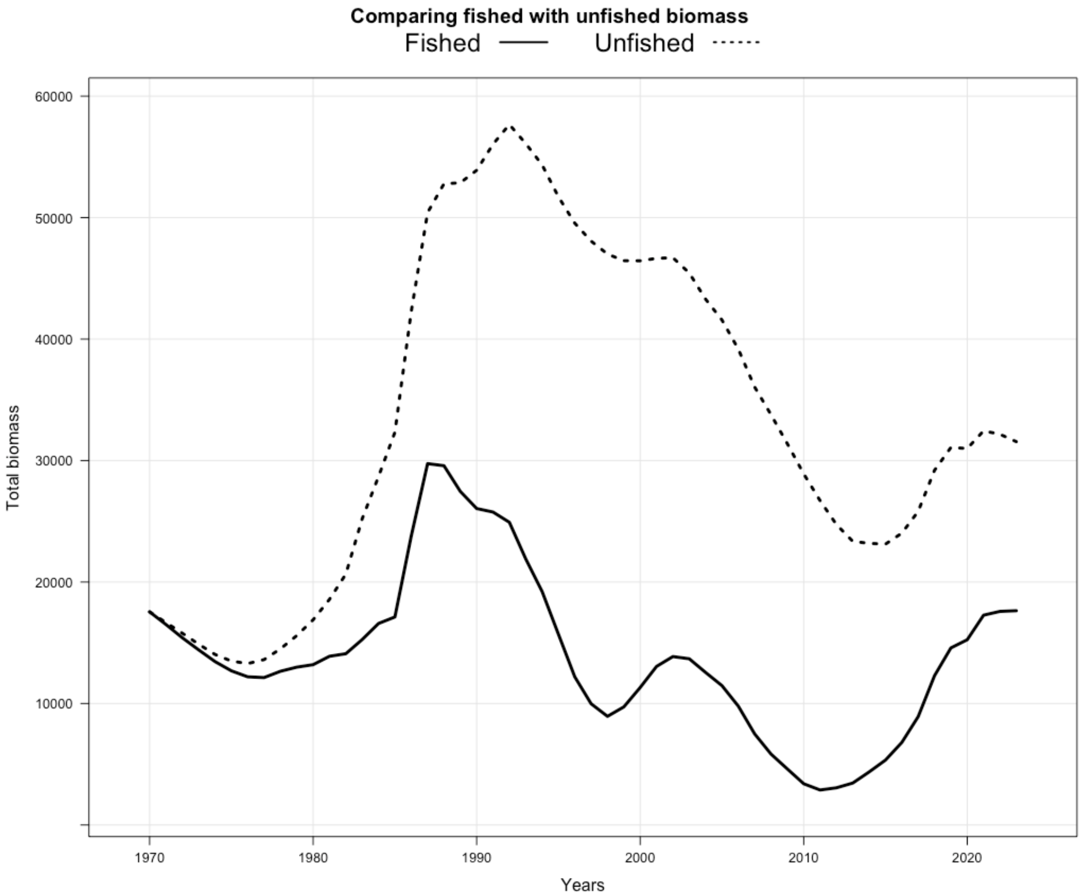

Figure A10.42: Model h2_1.07 (two-stock hypothesis) results for the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place (dotted line) for the south stock, beginning in 1970. This year, the ratio of total biomass to total biomass without fishing is 0.56.

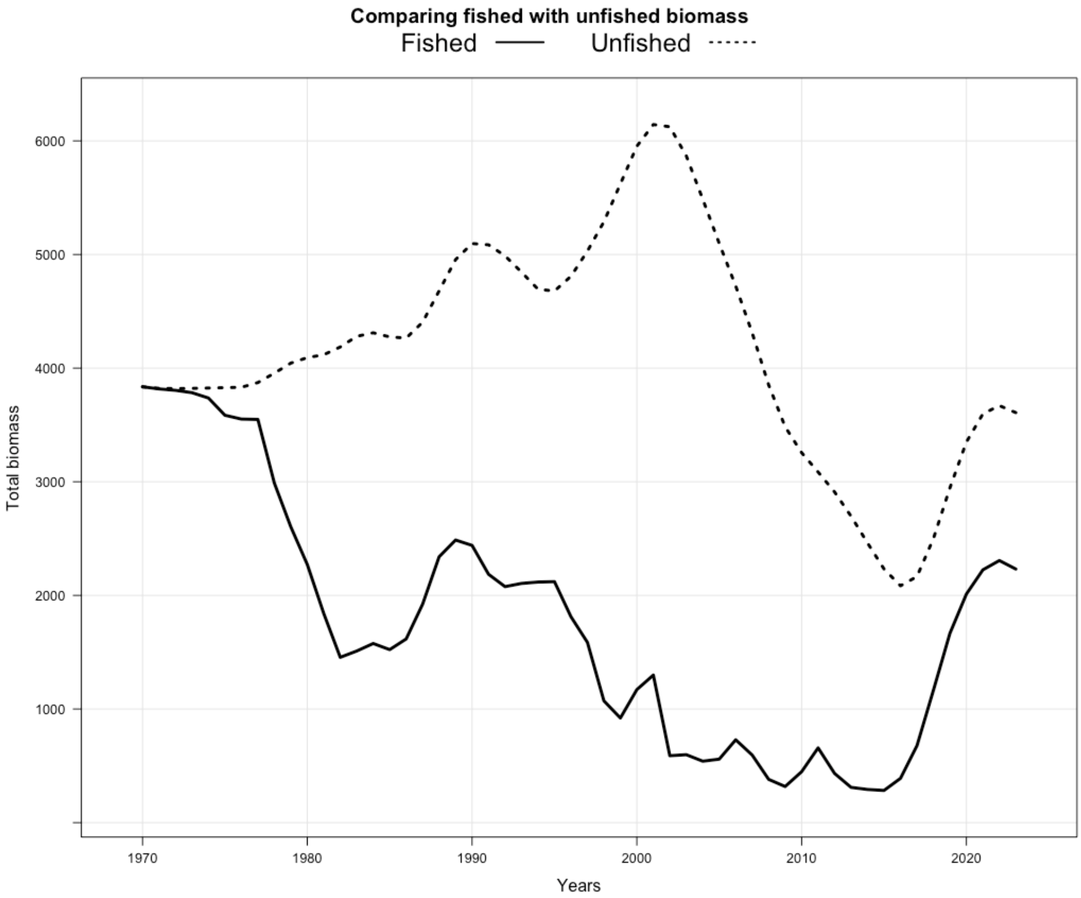

Figure A10.43: Model h2_1.07 (two-stock hypothesis) results for the estimated total biomass (solid line) and the estimated total biomass that would have occurred if no fishing had taken place (dotted line) for the far north stock, beginning in 1970. This year, the ratio of total biomass to total biomass without fishing is 0.62.