Fisheries New Zealand
Tini a Tangaroa

Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for data up to the 2022–23 fishing year

New Zealand Fisheries Assessment Report 2024/37

I.J. Doonan,
V.L. McGregor,
S.J. Holmes

ISSN 1179-5352 (online)
ISBN 978-1-991308-13-9 (online)

July 2024

Te Kāwanatanga o Aotearoa
New Zealand Government

Disclaimer

Requests for further copies should be directed to:

Fisheries Science Editor
Fisheries New Zealand
Ministry for Primary Industries
PO Box 2526
Wellington 6140
NEW ZEALAND

Email: Fisheries-Science.Editor@mpi.govt.nz
Telephone: 0800 00 83 33

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

Please cite this report as:

Doonan, I.J.; McGregor V.L.; Holmes, S.J. (2024). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for data up to the 2022–23 fishing year. *New Zealand Fisheries Assessment Report 2024/37.* 45 p.

TABLE OF CONTENTS

Plain language summary

Southern blue whiting (*Micromesistius australis*) is a fish species which, in New Zealand waters, is almost entirely restricted in distribution to sub-Antarctic waters.

They are dispersed over the Campbell Plateau and Bounty Plateau for much of the year, but during August and September they aggregate to spawn near the Campbell Islands, on Pukaki Rise, on Bounty Plateau, and near the Auckland Islands over depths of 250–600 m, where they are targeted by commercial trawl fisheries.

The size and health of the southern blue whiting stock at each spawning location is assessed separately. This report presents an assessment of the Campbell Island Rise stock.

The assessment made use of a statistical model informed by commercial catch history, the age distribution of fish in each year, and biomass estimates obtained from acoustic surveys, up to and including the 2022 fishing season (1 April 2022 to 31 March 2023).

Different assumptions applied to the assessment model were tested. Model outcomes were ‘robust’, i.e. did not change in a way that gave different perceptions of stock health depending on input assumptions made.

The base case assessment model (model judged as most plausible) suggested the spawning biomass of the Campbell Island Rise stock in 2022 was at 63% of pre-fishing levels. The stock is judged in good health if the spawning biomass is at or above 40% of pre-fishing levels.

Projections out to 2028, assuming constant catch equal to the average over the 2020 to 2022 fishing seasons (18 200 t), predicted biomass to decrease to 54% of pre-fishing levels by 2028. The biomass was expected to decline to 29% of pre-fishing levels by 2028 under an assumption of a constant catch equal to the current total allowable commercial catch (TACC) in 2022 (39 200 t).

EXECUTIVE SUMMARY

Doonan, I.J.[1]; McGregor, V.L.; Holmes, S.J. (2024). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for data up to the 2022–23 fishing year.

New Zealand Fisheries Assessment Report 2024/37. **45 p.**

This report documents the assessment of the Campbell Island Rise stock of southern blue whiting, using a statistical model informed by catch history, proportion-at-age, and acoustic survey biomass estimates, up to and including the 2022 fishing season (2022–23 fishing year). This assessment updates the previous assessment for 2019–20. The most important data sources were the relative abundance index from the R.V. *Tangaroa* wide-area acoustic biomass surveys carried out from 1993 to 2022 and commercial trawl fishery proportion-at-age data from 1979 to 2022.

The base case assessment model run suggested the spawning biomass of the Campbell Island Rise stock in 2022 was at 63% B_0 (95% C.I. 47–82%). Projections out to 2028 assumed recruitment that was resampled from the 1960 to 2021 estimates. When using a projected constant catch equal to the average over the 2020 to 2022 fishing seasons (18 200 t), the biomass was expected to decrease to 54% B_0 by 2028. The biomass was expected to decline to 29% B_0 by 2028 under an assumption of a constant catch equal to the current TACC in 2022 (39 200 t).

---

[1] All authors: National Institute of Water and Atmospheric Research Limited (NIWA), New Zealand.

1. INTRODUCTION

In New Zealand waters, southern blue whiting (*Micromesistius australis*) are almost entirely restricted in distribution to sub-Antarctic waters. They are dispersed over the Campbell Plateau and Bounty Plateau for much of the year, but during August and September they aggregate to spawn near the Campbell Islands, on Pukaki Rise, on Bounty Plateau, and near Auckland Islands over depths of 250–600 m, where they are targeted by commercial trawl fisheries (Figure 1). During most years fish in the spawning fishery are 35–50 cm fork length (FL), although occasionally smaller lengths of males (29–32 cm FL) have been observed in the catch (Holmes et al. 2023).

Commercial fishing has been concentrated on the spawning aggregations on Campbell Island Rise and, to a lesser extent, the Bounty Plateau. The Pukaki Rise and Auckland Islands have generally supported smaller fisheries, with much lower annual catches than the Campbell Island Rise and Bounty Plateau fisheries (Holmes et al. 2023).

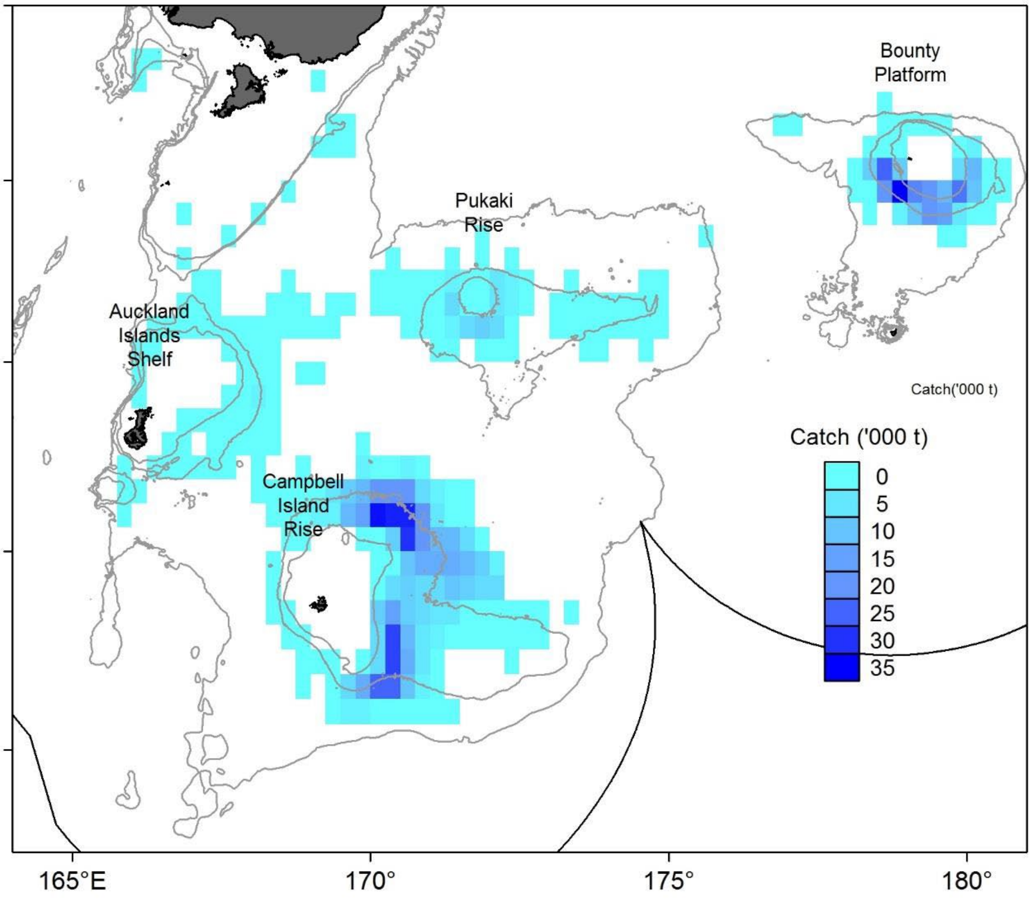


Figure 1: Relative total density of the commercial catch of southern blue whiting by location, TCEPR data 1990–2022 (reproduced from Holmes et al. 2023).

Acoustic biomass surveys of the Campbell Island Rise stock using R.V. *Tangaroa* have been carried out approximately every two to three years since 1993 and the most recent survey was carried out in 2022 (Escobar-Flores et al. 2023). Stock assessments of the Campbell Island Rise stock have generally been carried out every one or two years since 1991 with the most recent assessment completed for the 2017–19 fishing year (Doonan 2020).

The 2017 assessment model (Roberts & Hanchet 2019) was changed to use an initial equilibrium age distribution, with the model starting in 1960, which required estimates of catch history from 1960 to 1978. Previously, the initial age distribution was a non-equilibrium one (*Cinitial*) for 1979 (Dunn & Hanchet 2017), but this model was unstable when natural mortality (*M*) was estimated in the model using Markov chain Monte Carlo (MCMC). However, even with this change in the assumptions over the initial state, the model was still unable to provide an unbiased estimate of M using MCMC, as revealed in simulations by Roberts & Dunn (2017); they recommended that the assessment continue to use an assumed value for M of 0.20 with sensitivity analyses at 0.15 and 0.25.

This report documents the assessment of the Campbell Island Rise stock using data up to and including the 2022–23 fishing year (2022 season), building upon the 2017 assessment model (Roberts & Hanchet 2019). The assessment used the R.V. *Tangaroa* acoustic biomass indices for 1993–2022 and commercial catch proportions-at-age data from the years 1979–2022. A comprehensive summary of available data used for the assessments of southern blue whiting was described by Holmes et al. (2023).

This report is in fulfilment of the Fisheries New Zealand Project SBW2022-01 “To carry out stock assessments of southern blue whiting (*Micromesistius australis*) around Campbell Island (SBW 6I), including estimating biomass and sustainable yields”; Objective 2 “To update the SBW 6I stock assessment including estimating biomass and sustainable yields, the status of the stock in relation to management reference points, and future projections of stock status as required to support management within required timeframes”.

2. METHODS

2.1 Population dynamics

For the current assessment, a two-sex, single-stock, and single-area Bayesian statistical catch-at-age model for the Campbell Island Rise southern blue whiting stock was implemented in Casal2 (Doonan et al. 2016) following a similar approach to that used in previous assessments of this stock (e.g., Dunn & Hanchet 2017, Roberts & Hanchet 2019). The model partitioned the stock into immature and mature fish with two sexes and age groups 2–15, with a plus group at age 15. The model was run for the years 1960 to 2022, with five-year projections run for the years 2023–2028. The annual cycle was partitioned into two time steps (Table 1). In the first time step (nominally the non-spawning season), 90% of natural mortality was assumed to take place. In the second time step (spawning season), fish matured, ages were incremented, and the 2-year-olds were recruited to the population. These were then subjected to fishing mortality and the remaining 10% of natural mortality. A two-sex model was assumed because there are sex-based differences in proportions-at-age in the commercial catch for fish aged 2–4 (Holmes et al. 2023).

Table 1: Annual cycle of the stock model, showing the processes taking place at each step, and the available observations. Fishing mortality (*F*) and natural mortality (*M*) that occur within a time step occur after all other processes. The column headed *M* is the proportion of *M* occurring in that time step.

Period	Process	M	Length-at-age	Observations
1. Nov–Aug	Natural mortality (M)	0.9	–	
2. Sep–Oct	Age, recruitment, fishing mortality (F), and M	0.1	Growth matrix	Proportions at age Acoustic abundance indices

The stock recruitment relationship was assumed to be Beverton-Holt with a steepness of 0.9, with the proportion of males at recruitment (at age two) assumed to be 0.5 of all recruits. Relative year class strengths (YCSs) were parameterised in the model such that the mean was equal to one.

Southern blue whiting on the Campbell Island Rise are assumed to be mature when on the fishing ground, because they are fished when in spawning aggregations (Holmes et al. 2023). Hence, it was assumed that all mature fish were equally selected by fishing. The maximum exploitation rate ($U_{\max}$) was assumed to be 0.99. The proportion of immature fish that mature in each year was a logistic ogive (parameters age A_{50} and A_{to95}). In a sensitivity run, the maturity A_{50} was made time varying.

Southern blue whiting exhibit large inter-annual differences in growth, presumably caused by local environmental factors, closely correlated with the occurrence of strong and weak year classes (Holmes et al. 2023). Hence, a standard von Bertalanffy growth curve was not used to determine the mean length-at-age of fish in the model, but rather an empirical length-at-age matrix. The length-at-age matrix used the empirically estimated mean lengths-at-age from the commercial catch data (Holmes et al. 2023). Missing estimated mean lengths in the matrix were inferred from the relative size of their cohort and the mean growth of similar ages in other years; and cohorts with unusually small or large increments were similarly adjusted.

Lengths-at-age were converted to weights-at-age in the model using the length-weight relationship given by Hanchet (1991), i.e., assuming the relationship weight = $a \times \text{length}^b$ for length in centimetres and weight in kilograms. The parameters a = 0.00515 and 0.00407 and b = 3.092 and 3.152 were assumed for males and females, respectively, for all model years.

Catches for southern blue whiting have been recorded since 1971 (Holmes et al. 2023), with an average of about 25 000 t annual catch between 1971 and 1977. However, the locations of the catches, and, hence, the stock associated with the catch in this period, are not well known. Also, age and length sampling of the population from 1979 showed evidence of a very high proportion (greater than 50% by number in the catch proportions-at-age) of old fish (11+) in the Campbell Island Rise population, with the age data suggesting that there was at least one very strong year class spawned in or around 1965 that remained a significant part of the population until the mid-1980s (see also Hanchet et al. 1998). This required estimation of the catch history in years 1971–1978, described in Section 2.2 below.

2.2 Observations

Available observations for the Campbell Island Rise stock are described by Holmes et al. (2023). They include: a time series of catches from 1979 to 2022; wide-area acoustic biomass estimates; survey age frequency data for immature fish; and proportions-at-age from the commercial catch.

Stock assessments have been run since 1979 and have used catches for the Campbell Island stock taken from Quota Management Reports (QMRs) and Monthly Harvest Returns (MHRs). However, to start the model from 1960, catch estimates were required from the start of the fishery. It is known that the Russian fleet fished throughout the New Zealand EEZ from 1971 to 1977, and estimates of the total annual catch are available, but the proportion of the catch taken from the Campbell Island stock could not be determined (Hanchet 1998). For the purposes of the stock assessment, it was assumed that the proportion of the catch taken from the Campbell Island stock in the period 1971–1977 equalled the proportion of the catch across the period since 1978 following Hanchet (1998) and Roberts & Dunn (2017). For the period 1978 to 2016–2017 this proportion equalled 0.70 and the resulting estimates for 1971–1977 are given in Table 2.

Previous models have also considered catch per unit effort (CPUE) indices and trawl survey biomass indices. Standardised CPUE indices were last updated by Hanchet et al. (2006) but were not considered to be a useful index of abundance by the (then) Middle Depths Working Group. Hence, these data were not used in this assessment.

Dunn & Hanchet (2011) modelled observations from the sub-Antarctic trawl survey biomass and age frequencies time series. They found that, although the model fits suggested some consistency with the summer series biomass estimates, in general the trawl survey underestimated biomass at low stock sizes and overestimated biomass at high stock sizes. They concluded that the time series was not particularly useful for monitoring abundance in its present form. Hence, these data were not used for this assessment.

Table 2: Estimated catches and catch limits (TACCs) (t) of southern blue whiting at the Campbell Island Rise for 1971 to 2022–23 (source: QMRs, MHRs, Roberts & Dunn 2017; italicised catch figures from 1971 to 1977 were estimated by applying the proportion of the catch taken from the Campbell Island stock between 1978 and 2016–17 to the period 1971–1977, following Hanchet 1998 and Roberts & Dunn 2017 ; '–' denotes no catch limit in place).

Fishing year*	Estimated catch (t)[2]	Limit (t)	Fishing year*	Estimated catch (t)†	Limit (t)
1971	*7 260*	–	1996–97	15 685	30 100
1972	*18 010*	–	1997–98	24 273	35 460
1973	*33 856*	–	1998–00	30 386	35 460
1974	*29 458*	–	2000–01	18 049	20 000
1975	*1 660*	–	2001–02	29 999	30 000
1976	*11 929*	–	2002–03	33 445	30 000
1977	*18 453*	–	2003–04	23 718	25 000
1978	*6 403*	–	2004–05	19 799	25 000
1978–79	25 305	–	2005–06	26 190	25 000
1979–80	12 828	–	2006–07	19 763	20 000
1980–81	5 989	–	2007–08	20 996	20 000
1981–82	7 915	–	2008–09	20 483	20 000
1982–83	12 803	–	2009–10	19 040	20 000
1983–84	10 777	–	2010–11	20 224	23 000
1984–85	7 490	–	2011–12	30 982	29 400
1985–86	15 252	–	2012–13	21 321	29 400
1986–87	12 804	–	2013–14	28 606	29 400
1987–88	17 422	–	2014–15	23 397	39 200
1988–89	26 611	–	2015–16	22 100	39 200
1989–90	16 542	–	2016–17	19 875	39 200
1990–91	21 314	–	2017–18	18 334	39 200
1991–92	14 208	–	2018–19	15 147	39 200
1992–93	9 316	11 000	2019–20	26 517	39 200
1993–94	11 668	11 000	2020–21	11 982	39 200
1994–95	9 492	11 000	2021–22	19 514	39 200
1995–96	14 959	21 000	2022–23	22 985	39 200

* Fishing years defined as 1 April to 30 September for 1978; 1 October to 30 September for 1978–79 to 1997–98; 1 October 1998 to 31 March 2000 for 1998–2000; 1 April to 31 March for 2000–01 to current.

† Estimated catch. Estimates for 1971 to 1977 are taken from Roberts & Dunn (2017).

Wide-area acoustic surveys

Acoustic biomass estimates of southern blue whiting available on Campbell Island Rise during the fishing season were available from a wide-area survey series conducted by the R.V. *Tangaroa* from 1993 to 2022 (see Table 3 and Holmes et al. 2023 for details). The primary objective of the acoustic surveys has been to estimate the relative biomass of the adult spawning stock by year. A secondary objective has been to provide biomass estimates of pre-recruit fish and therefore the survey transects extend into 300 m depths where the younger fish live.

Southern blue whiting acoustic marks were identified as one of three categories of fish: juvenile, immature, or adult. The categories were broadly defined as adult (also known as mature) which consisted mainly of adult fish that were going to spawn that year; immature which consisted mainly of two-year-olds; and juvenile which consisted mainly of one-year-olds. Identification of each mark to a category was typically made at the time based on the results of research tows, the acoustic 'shape' of the mark, and its depth and location.

Only the survey estimates of immature and mature southern blue whiting were used in this analysis and they were assumed to be relative estimates of mid-season biomass (i.e., after half the catch for that fishing season has been removed), with a coefficient of variation (CV) equal to the sampling CV estimated from the survey. We ignored the juvenile category in the assessment because biomass estimates of the juvenile category (mainly two-year-olds) were generally low and inconsistent with subsequent estimates of those year classes, and so were unlikely to be a good index of abundance (Dunn & Hanchet 2011).

The acoustic biomass observations were fitted using a lognormal likelihood (Bull et al. 2012).

Table 3: R.V. *Tangaroa* juvenile, immature, and mature acoustic biomass estimates (t) and CV for the Campbell Island Rise 1993–2022 using the revised target strength derived by O'Driscoll et al. (2013).

	Juvenile		Immature		Mature		Total	Source
Year	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	
1993	0	0.00	35 208	0.25	16 060	0.24	51 268	(Fu et al. 2013)
1994	0	0.00	5 523	0.38	72 168	0.34	77 691	(Fu et al. 2013)
1995	0	0.00	15 507	0.29	53 608	0.30	69 114	(Fu et al. 2013)
1998	322	0.45	6 759	0.20	91 639	0.14	98 720	(Fu et al. 2013)
2000	423	0.39	1 864	0.24	71 749	0.17	74 035	(Fu et al. 2013)
2002	1 969	0.39	247	0.76	66 034	0.68	68 250	(Fu et al. 2013)
2004	639	0.67	5 617	0.16	42 236	0.35	48 492	(Fu et al. 2013)
2006	504	0.38	3 423	0.24	43 843	0.32	47 770	(Fu et al. 2013)
2009	0	–	24 479	0.26	99 521	0.27	124 000	(Fu et al. 2013)
2011	0	–	14 454	0.17	53 299	0.22	67 753	(Fu et al. 2013)
2013	0	–	8 004	0.55	65 801	0.25	73 805	(O'Driscoll et al. 2014)
2016	775	0.37	4 456	0.19	97 117	0.16	102 348	(O'Driscoll et al. 2018)
2019	0	–	4 060	0.18	91 145	0.27	95 205	(Ladroit et al. 2020)
2022	12 764	0.14	5 356	0.22	91 968	0.20	110 088	(Escobar-Flores et al. 2023)

Proportions-at-age in the commercial catch

Catch-at-age observations by sex were available from the commercial fishery for 1979 to 2022 from observer data, excluding 1987 (Figure 2).

Although length data were available for 1987, there were no otoliths aged for 1987, so the age-length key was estimated using the length-at-age keys from 1986 and 1988, and adding or subtracting 1 year of growth, respectively, following Hanchet & Ingerson (1995). Commercial catch-at-age data were fitted to the model as proportions-at-age by sex, where associated CVs by age were estimated by bootstrap resampling implemented in the NIWA catch-at-age software (Bull & Dunn 2002). The catch proportions-at-age data were fitted to the modelled proportions-at-age composition using a multinomial likelihood (Casal2 Development Team 2022).

A robustifying function was used to avoid division by zero errors (see Casal2 Development Team 2022 for more details). Proportions-at-age data were derived from the aged otoliths collected by observers and the length frequency of the catch. Holmes et al. (2023) described the catch-at-age data available for the assessment models from 1990, and data before 1990 were described by Hanchet et al. (2006). The derivation of the assumed multinomial sample sizes for the proportions-at-age data is described below.

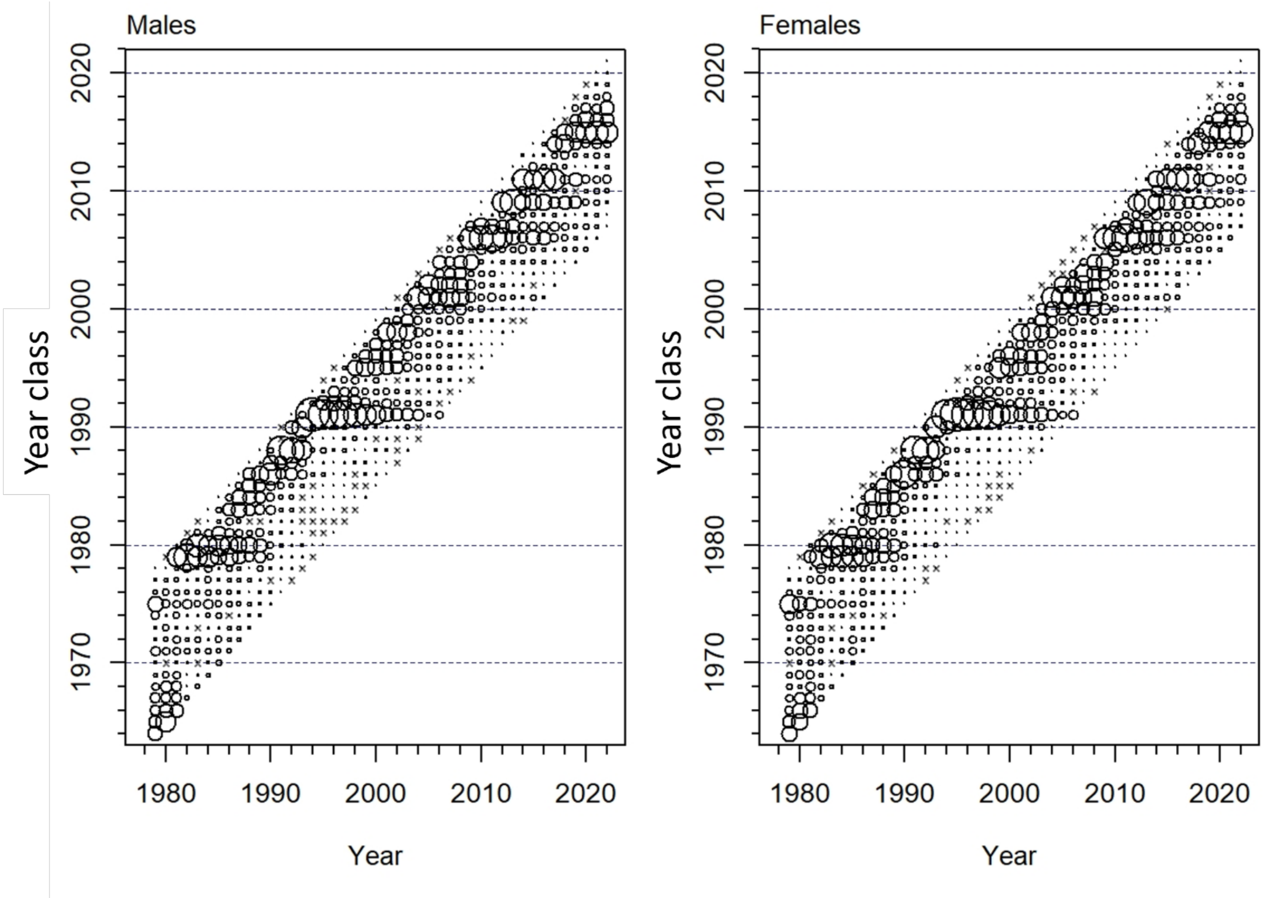


Figure 2: Commercial catch proportions-at-age for the Campbell Island stock by sex and year class, 1979–2022 for ages 1–15+. Symbol area is proportional to the proportions-at-age within the sampling event.

2.3 Model estimation

The previous assessments used CASAL (Bull et al. 2012), but here, we have converted the model to use Casal2 (Casal2 Development Team 2022). Initial model fits were evaluated at the maximum of the posterior density (MPD) by visually inspecting the fits and residuals. The MPD results were used to select models to take to a Markov chain Monte Carlo (MCMC) analysis which estimates the joint posterior distribution of the parameters in a Bayesian analysis.

An initial MCMC chain was estimated using a burn-in length of 50 000 iterations, with every 1000th sample taken from the next 3 million iterations (i.e., a final sample of length 3000 was taken from the Bayesian posterior). To improve mixing at MCMC (following the approach of Roberts & Doonan 2016) the covariance matrix was recalculated empirically from the 3000 samples obtained from the initial MCMC chain and the chain started afresh with the new covariance matrix out to a length 3.0×10^6 iterations (no burn-in). The initial chain was discarded. Two further chains were started independent of the first kept chain, but with random jumps from the MPD to start the chain.

Prior distributions and penalties

With the exception of natural mortality (assumed lognormal with mean 0.2 and CV 0.2) and time varying A_{50}, the assumed prior distributions used in the assessment were intended to be non-informative with wide bounds (Table 4). The prior assumed for the relative year class strengths was lognormal, with mean 1.0 and CV 1.3, for all year classes.

Table 4: The parameters, number of degrees of freedom (N), priors (including distributions, and means and CVs for the lognormal), and bounds assumed for estimated parameters for the models.

		Distribution	Values			Bounds	
Parameter	N		Mean	CV	S.D.	Lower	Upper
B_0	1	Uniform-log	–	–	–	30 Kt	800 Kt
Male maturation ogive A_{50}	1	Uniform	–	–	–	0.01	4
Female maturation ogive A_{50}	1	Uniform	–	–	–	0.01	4
Male maturation ogive A_{to95}	1	Uniform	–	–	–	0.01	4
Female maturation ogive A_{to95}	1	Uniform	–	–	–	0.01	4
Year class strength	62	Lognormal	1.00	1.30	–	0.001	100
Acoustic catchability q							
Mature	1	Lognormal	0.54	0.44	–	0.01	1.5
Immature	1	Uniform	–	–	–	0.01	1.5
*Natural mortality (average)	1	Lognormal	0.20	0.20	–	0.075	0.325
*Natural mortality (difference)	1	Normal	0.00	–	0.05	-0.05	0.05
*Time varying A_{50} maturation							
Male	33	Normal	3.00	–	1.50	0	6
Female	33	Normal	3.23	–	1.50	0	6

* Estimated in sensitivity runs

For assessments before 2016, the log-normal prior for the wide-area acoustic survey catchability coefficient had a mean of 0.87 and a CV of 0.30. The adoption of a new target strength-length relationship for southern blue whiting (O'Driscoll et al. 2013) led to a revised prior with a mean of 0.54 and CV of 0.44 for the 2016 assessment (Roberts & Hanchet 2019). Details of the factors and values used are shown in Table 5. The revised prior was used in this assessment.

Table 5: Best and lower and upper bounds for the factors for the acoustic catchability prior. A lognormal prior with mean 0.54 and CV 0.44 was used for the assessment.

Factor	Lower	Best	Upper
Target strength: Uncertainty	0.80	1.00	1.20
Target strength: Tilt angle	0.25	0.70	1.00
Target identification	0.85	1.00	1.15
Vertical availability	0.90	0.95	1.00
Areal availability	0.80	0.90	1.00
System calibration	0.90	1.00	1.10
Combined	0.11	0.60	1.52

Natural mortality was estimated to be 0.2 y^{-1} by Hanchet (1991). When estimated in the current model (as a sensitivity run), natural mortality was parameterised by the average of male and female, with the difference estimated with an associated normal prior with a mean of zero and standard deviation of 0.05 y^{-1}.

Penalty functions were used to constrain the model so that any combinations of parameters that did not allow the historical catch to be taken were strongly penalised. A small penalty was applied to encourage the estimates of year class strengths to have mean equal to one.

Process error and data weighting

In addition to sampling error, additional variance assumed to arise from differences between model simplifications and real-world variation was added to the sampling variance. The additional variance, here termed "process error", was estimated in each of the initial runs (MPDs) using all the available data. Process errors were estimated separately for the proportions-at-age data and for the acoustic estimates from the wide-area surveys.

The proportions-at-age had a multinomial distribution where the sampling error for a year is indexed by the sampling size, N_j. Estimates of the effective sample size, N_j', which incorporated process error, were obtained by adding additional process error, *NPE,* to *Nj* using Method TA1.8 of Francis (2011); i.e., from an initial MPD model fit, an estimate of the additional process error was made such that the standardised residuals from the mean observed age and mean expected age in each year had mean equal to one.

Estimates of the process error CV for the biomass observations were made by fitting the process error within each MPD run, where the applied CV c_i' was determined from the process error c_{PE} and the observed CVs c_i by,

$$c_i' = \sqrt{c_i^2 + c_{PE}^2}$$

Model runs

Five model runs were considered: a base case and four sensitivity tests (Table 6). As recommended by the Deepwater Working Group (DWWG), the base case run had an equilibrium age distribution in the year 1960, YCSs were estimated from 1960 to 2021, the 1971 to 2022 catch history was used, and natural mortality was assumed equal to 0.20. The first three sensitivity tests considered the influence of uncertainty in natural mortality in the model: the first two assumed natural mortality equal to 0.15 or 0.25; and the third allowed for the estimation of the natural mortality rate for males and females. The last sensitivity run investigated the influence of time varying maturity.

Table 6: Model run labels and descriptions for the model runs.

Model type	Model label	MCMC	Description
Base case	Base	Yes	Model with equilibrium age distribution for the year 1960, YCSs estimated for years 1960–2021, catch history for years 1971–2022, natural mortality equal to 0.20.
Sensitivity	M0.15	No	Base Model, but with natural mortality set to 0.15
Sensitivity	M0.25	No	Base Model, but with natural mortality set to 0.25
Sensitivity	Mfree	Yes	Base Model, but with natural mortality estimated.
Sensitivity	Tvary	Yes	Base Model, but with time varying adjustment to maturity from 1990 to 2022.

2.4 Assessment automation code

To allow a cost-effective updated assessment between survey years (currently every 3 years) when just new catch and age date would be available, R scripts were developed to automate a base SBW stock assessment. Under an automated assessment no exploration of model runs would be undertaken, and the model input files used in the last assessment year would be updated, i.e., the previous model assumptions retained. This allows an efficient (i.e., cheap) update to be made with minimal analyst intervention. The final product is a MS Word document with figures and tables automatically generated.

The auto-assessment update consists of 9 steps, each of which has its own R function. These are summarised in Table 7. The last step produces a report as a MS Word document including key outputs from the updated assessment. The data can be quite slow to load and process, so this code was made separate to the code for creating the report. This made it possible to create the data once, then create different versions of the report; i.e., only particular sections, (e.g., only MPD outputs). It also allows for newly developed report formats to be produced without the need to re-load data.

To again improve efficiency, the function used to create a data file for model projections creates a new report rather than collating reports generated from previous steps. The reports from previous steps contain detail, e.g., fits to all observations, useful for detailed analysis of the performance of the model but unnecessary for projections.

The update assessment functions were tested first against the 2019 model, updated with 2020 data, and then with the new 2020 model, updated with 2021 data. The script the analyst uses to update the assessment is given in Appendix 1. Apart from setting parameters and getting the age data and catch, the script requires little intervention from the analyst (assuming no run-time errors), e.g., Casal2 runs are set off automatically with no analyst intervention. An example of the report produced from updating the 2019 assessment with 2020 data and running one set of projections is given in Appendix 2.

Table 7: Overview of assessment automation code written in R for the SBW 6I assessment. (Continued on next page)

Model step	Function	Description
1	checkNewData()	Based on updateData() but rather than updating data, only run checks on it. Takes in definitions for existing model, path for new data, and path for new model. Creates a log file with descriptions of the data checks that includes ‘pass’, ‘warning’, and ‘error’ messages.
2	updateData()	Copies existing model to new model location, then updates with new data. Takes in definitions for existing model, path for new data, and path for new model. Has the option to run an MPD estimation at the same time.
3	runMPD()	Runs MPD estimation. Takes path for model and path for Casal2 executable files. Optionally, also defines filenames for output and log files. If user has Casal2 as a system variable and OK to not specify the version of Casal2 to use, the path for Casal2 can be left blank.
4	reweightCompositionData()	Applies Francis (2011) re-weighting method to composition data. Takes in model directory and number of iterations. Creates a folder within the model directory for the reweighted models. Creates a reweighting log file that summarises re-weighting scalars at each iteration.
5	runMCMC()	Runs MCMCs. Takes in path for the model and path for Casal2 executable files. Defaults to 3 chains with random seeds (1,2,3), but these can be specified using the *nchains* and *random_seeds* variables. If user has Casal2 as a system variable and OK to not specify the version of Casal2 to use, the path for Casal2 can be left blank. MCMC runs are expected to take place after re-weighting, but (useReweighted=FALSE) gives the option to use base model without re-weighting.

Table 7—*continued*

Model step	Function	Description
6	runPostMCMC()	After MCMCs, reads in all samples, removes burn-in from each, and combines them into one file ('samples.all'). Runs post-MCMC (-r -t) on the combined samples to get quantities of interest (e.g., *SSB*, selectivity proportions, true YCS). Creates a new report.csl2 file that can be used for projections.
7	runProjection()	Runs a projection. Takes in model path, future catches, YCS sampling, and path for Casal2 executable files. If YCS sampling is left blank, defaults to sampling from all standardised year classes.
8	prepDataForReport()	Takes in model path, projection specifications (for comparing multiple projections), and data to include. Sub-sections of the report can be specified e.g., *data2include = c("MPD")* only works up the data for MPD comparisons.
9	createReport()	Produces report as a Microsoft Word document. Takes in model name, model path, data name, and author name.

3. RESULTS

3.1 MPD results

The spawning stock biomass (*SSB*) trajectories for the MPD fits are shown for the Base model in Figure 3, along with the relative year class strengths and fits to the acoustic indices. Fits to the acoustic indices were generally good. For the acoustic biomass indices, the estimated processes error CV was zero for the mature biomass, but 63% for the immature acoustic biomass meaning the latter did not have a good fit in the model.

The fits to the mature biomass acoustic indices and the age data looked very similar for the sensitivity runs (not shown). Average M was estimated to be 0.16 (0.19 for males and 0.17 for females) in model run Mfree. The time varying maturation A_{50} from model Tvary showed most years had an A_{50} around age 3 and that changes in A_{50} were correlated between the sexes, but not perfectly. There was a small number of years where the A_{50} was close to age 2 or close to age 4. However, model Tvary did estimate the process error CV on the immature (mostly age 2 fish) acoustic estimate to be close to zero (0.0001) which meant that the immature biomass estimate could be fitted using just its sampling error in contrast to the other runs where this process error CV was estimated at 60 to 66%.

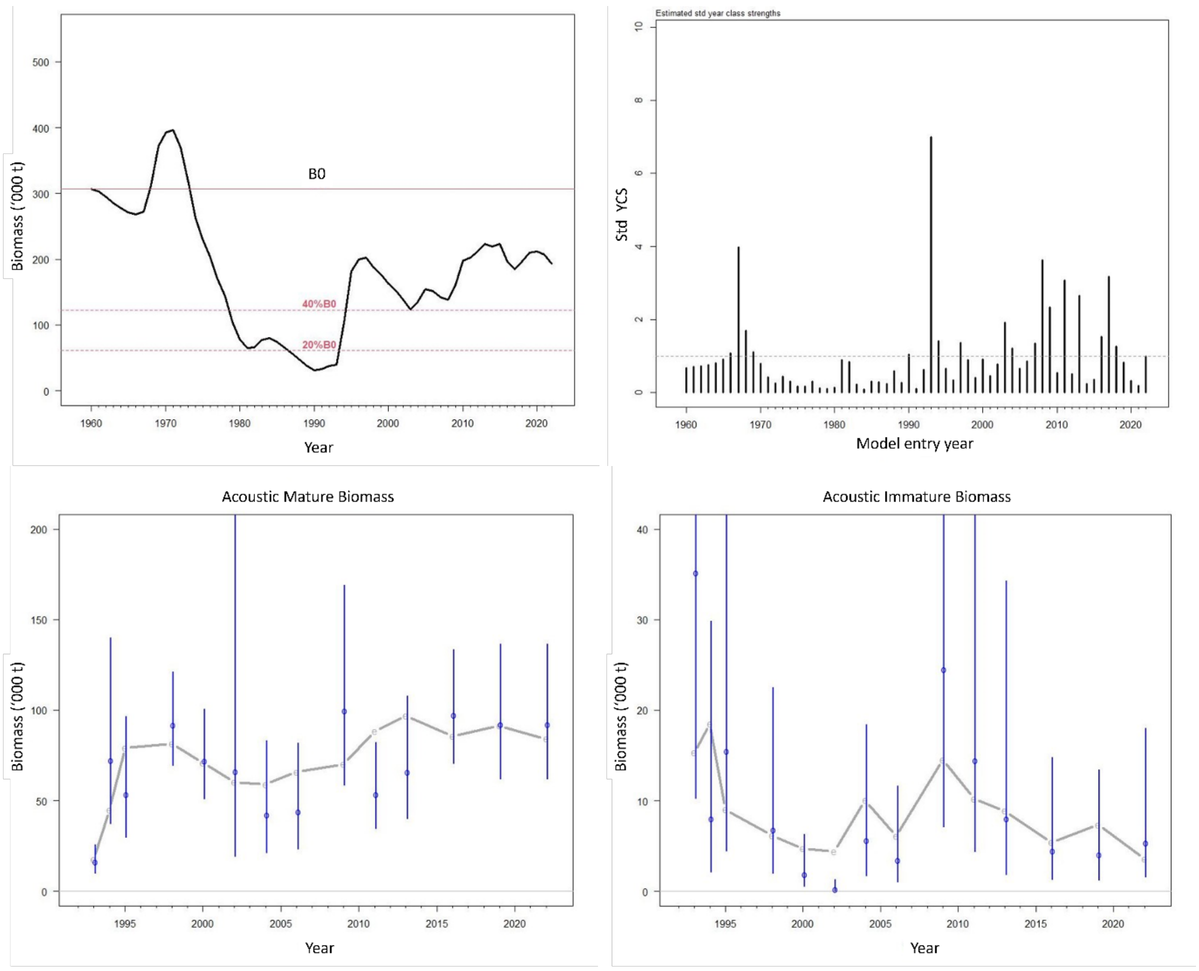


Figure 3: Results of MPD fits for Base model showing (top left panel) estimated *SSB* trajectory (with B_0 shown as a solid line and 20% B_0 and 40% B_0 shown as a dashed lines) 1960–2022; (top right panel) estimated relative year class strength (with the average of one shown as a dashed line); (bottom left panel) observed (o) and expected (e) mature acoustic biomass index (±2 s.d.); and (bottom right panel) immature acoustic observed (o) and expected (e) biomass indices (±2 s.d. including process error).

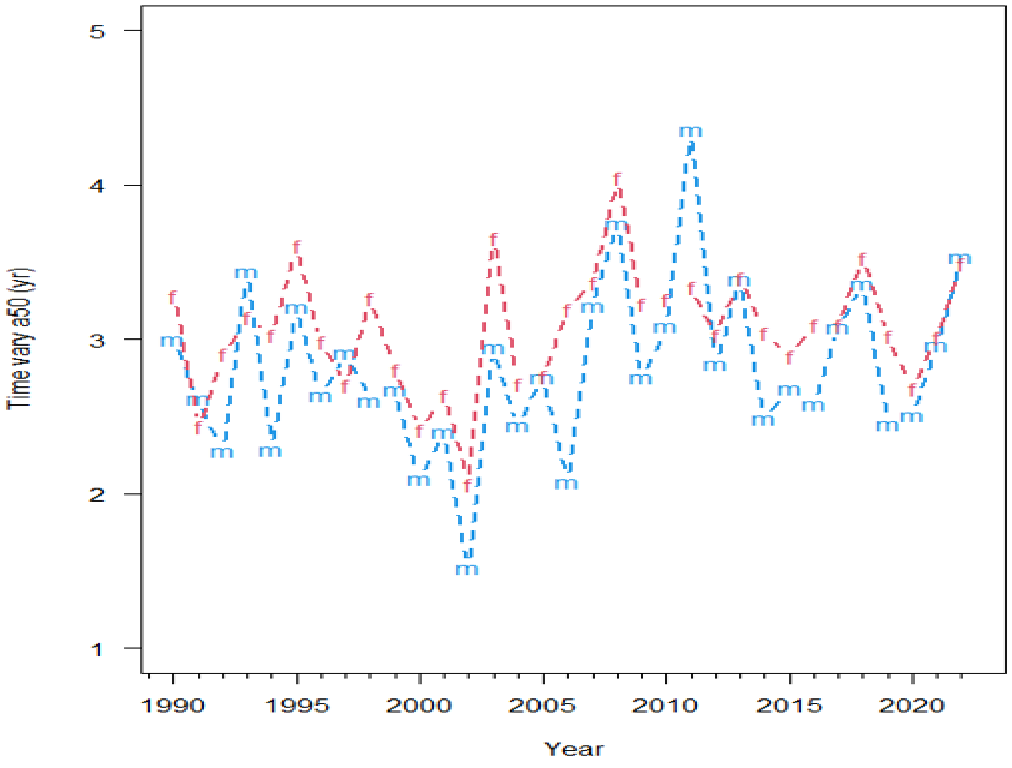


Figure 4: Mean age of mature fish (A_{50}) by year by sex ('m' male, 'f' female) from model Tvary.

For the Base model and the sensitivities, the MPD estimated virgin biomass and current spawning biomass in 2022 are given in Table 8.

Table 8: For the Base model and sensitivities, MPD estimates of B_0 and B_{2022}.

Model	B_0 (`000 t)	B_{2022} (% B_0)
Base	308	63
M0.15	313	49
M0.25	355	71
Mfree	308	51
Tvary	330	68

3.2 MCMC results

MCMC diagnostics

MCMC diagnostics were reasonably good for B_0 and for B_{2022} (% B_0) for the Base model (Figure 5) and also for the maturation rates at ages 3 and 4, which are the main ages at which fish mature (Figures 6 and 7). The sensitivity model runs had similar results (not shown).

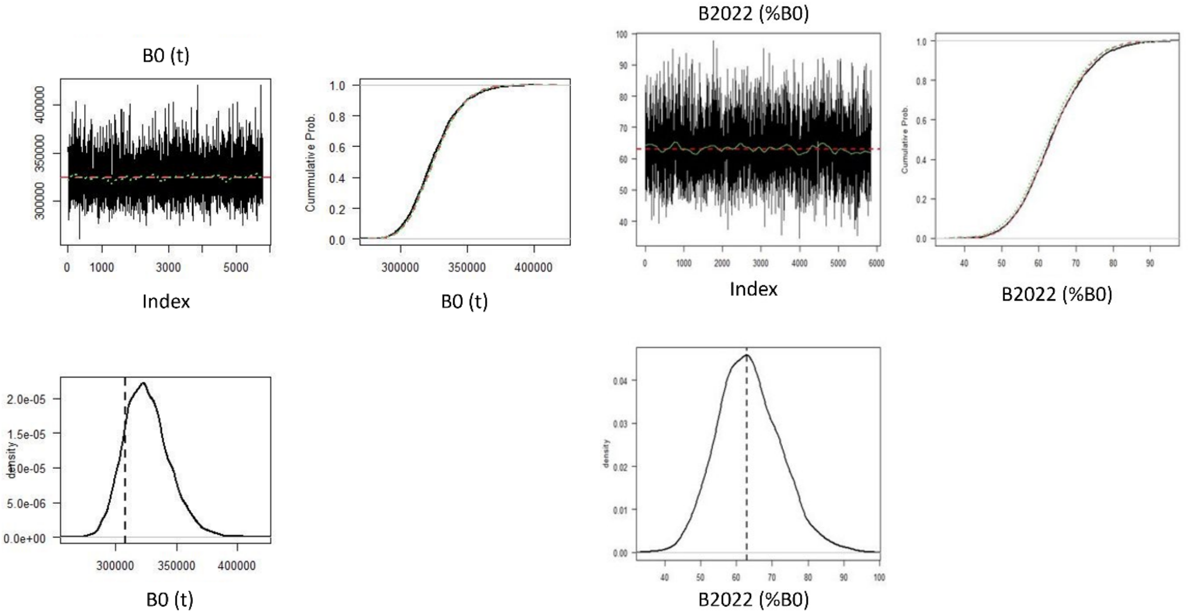


Figure 5: MCMC diagnostic plots for the Base model: left panel set, B_0; right panel set, current status, B_{2022} (% B_0). Each panel set shows posterior trace plots (top left), the three cumulative distributions from splitting the chain into three consecutive parts (black, red, and green) (top right), and the posterior distribution (vertical dotted line is the MPD estimate) (lower left).

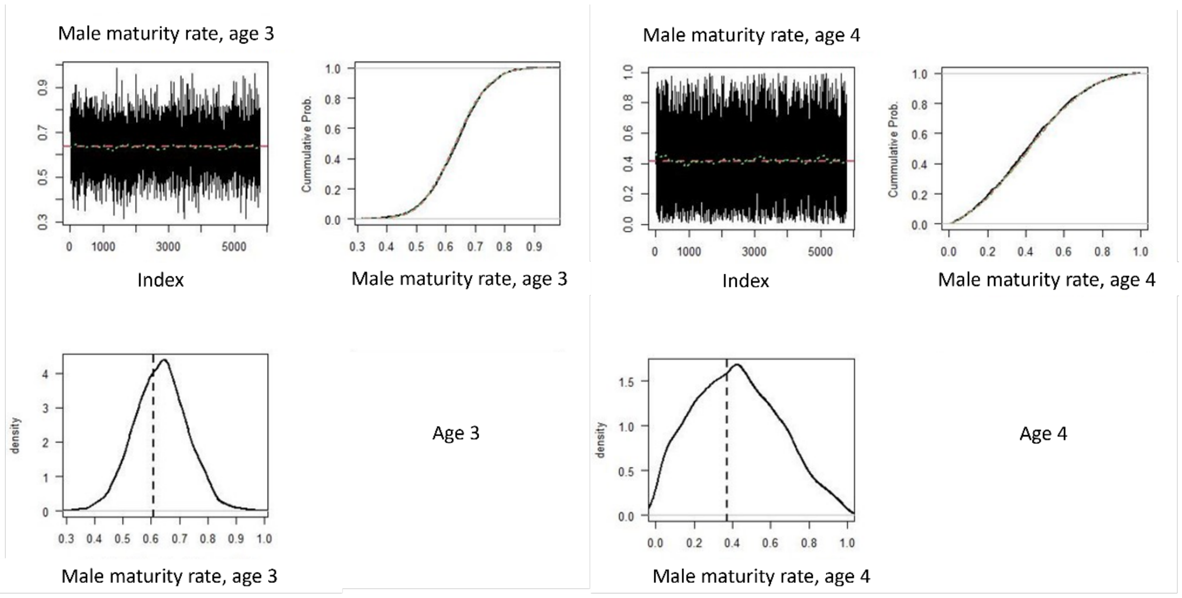


Figure 6: MCMC diagnostic plots for the Base model: left panel set, maturity rate for age 3 male; right panel set, maturity rate for age 4 male. Each panel set shows posterior trace plots (top left), the three cumulative distributions from splitting the chain into three consecutive parts (black, red, and green) (top right), and the posterior distribution (vertical dotted line is the MPD estimate) (lower left).

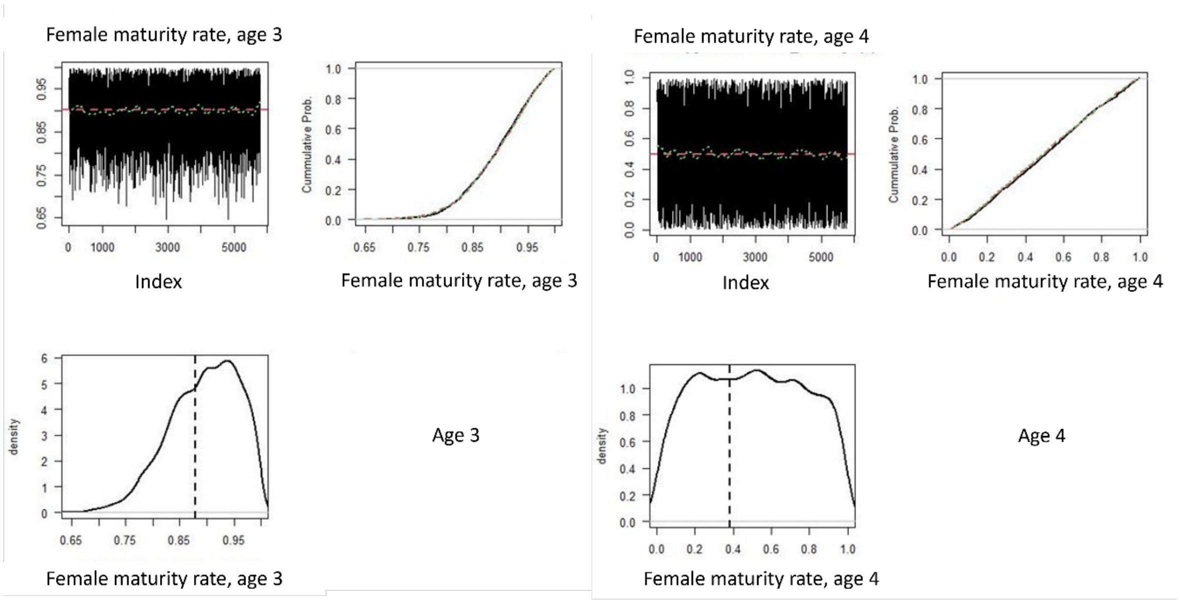


Figure 7: MCMC diagnostic plots for the Base model: left panel set, maturity rate for age 3 female; right panel set, maturity rate for age 4 female. Each panel set shows posterior trace plots (top left), the three cumulative distributions from splitting the chain into three consecutive parts (black, red, and green) (top right), and the posterior distribution (vertical dotted line is the MPD estimate) (lower left).

Model Mfree estimated *M* and had good diagnostics (Figure 8). For the annual adjustments in maturity model (model Tvary), there were 33 estimates of A_{50} for each sex. For males, 29 years had good diagnostics and four estimates were adequate. For females, 30 years had good diagnostics and three estimates were adequate. Figure 9 shows one set of the least good diagnostics for maturity. With the Tvary model, some diagnostics for YCS were also only adequate (Figure 10).

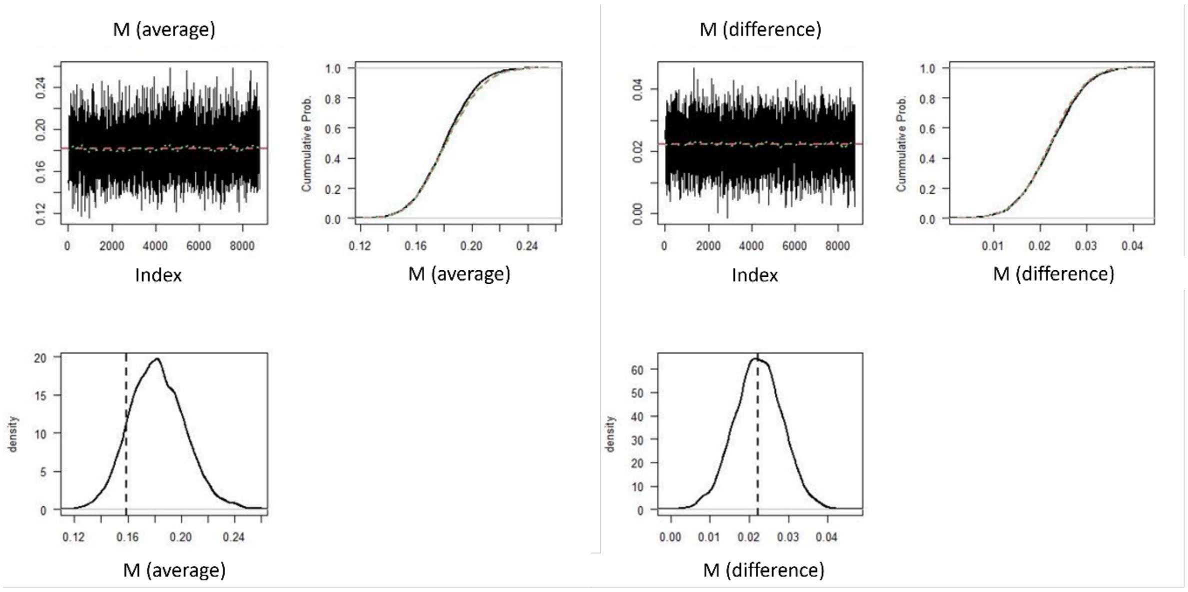


Figure 8: MCMC diagnostic plots for the model Mfree: left panel set, average *M* for females and males combined; right panel set, difference in *M* between sexes. Each panel set shows posterior trace plots (top left), the three cumulative distributions from splitting the chain into three consecutive parts (black, red, and green) (top right), and the posterior distribution (vertical dotted line is the MPD estimate) (lower left).

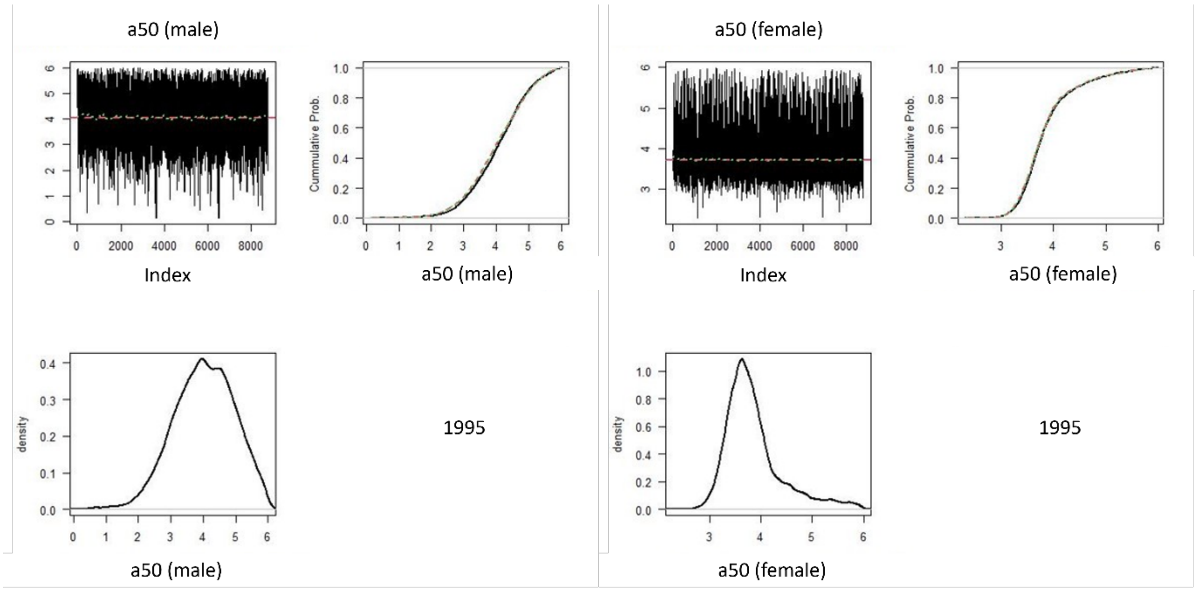


Figure 9: MCMC diagnostic plots for the model Tvary: example plots for annual A_{50} maturation with adequate diagnostics: left panel set, 1995 males; right panel set, 1995 females. Four estimates for males and three for females were considered adequate only. Each panel set shows posterior trace plots (top left), the three cumulative distributions from splitting the chain into three consecutive parts (black, red, and green) (top right), and the posterior distribution (vertical dotted line is the MPD estimate) (lower left).

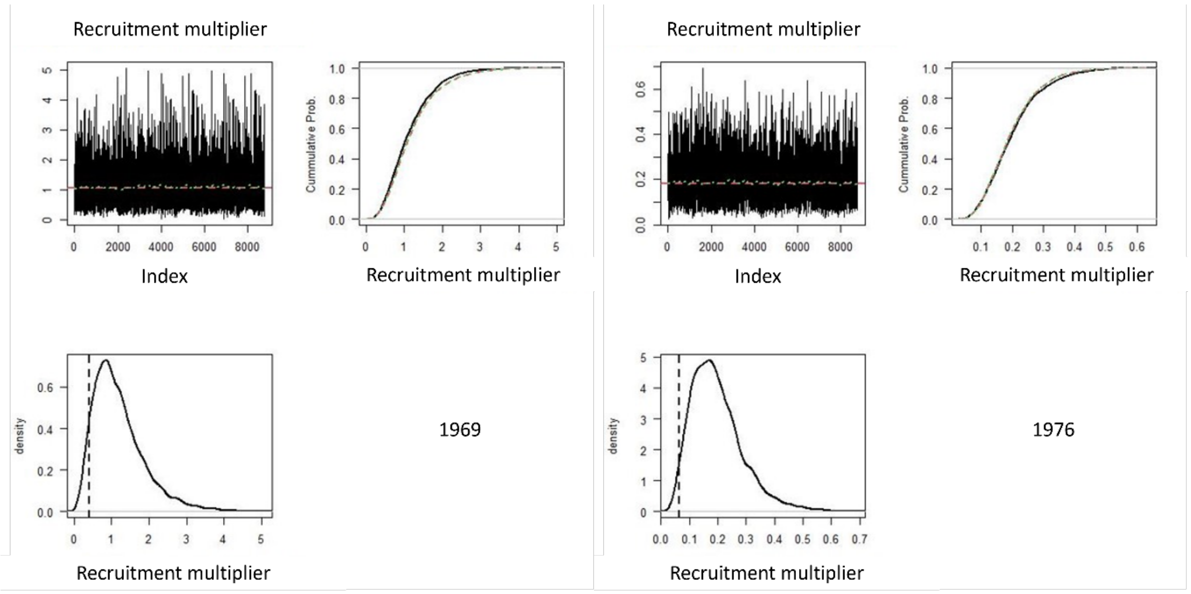


Figure 10: MCMC diagnostic plots for the model Tvary: example plots for YCS (recruitment) multipliers with adequate diagnostics: left panel set, 1969; right panel set, 1976. Each panel set shows posterior trace plots (top left), the three cumulative distributions from splitting the chain into three consecutive parts (black, red, and green) (top right), and the posterior distribution (vertical dotted line is the MPD estimate) (lower left).

MCMC estimates

Base case model run

The estimated MCMC marginal posterior distributions for parameters of interest are shown for the Base model in Figures 11 and 12, and the results are summarised in Table 9 and Table10. The Base model run indicated that the spawning stock biomass increased from 1960 to 1970 as a result of a strong year class and no fishery exploitation. There followed a period of low recruitment and some fishing, in which the SSB steadily declined until 1993, when it rose sharply as the very strong 1991 recruitment matured. Subsequently, the SSB declined steadily from 1997 until 2008, and then showed a moderate increase by 2010, remaining flat to 2015 as the 2006 and 2009 and then 2011 year classes recruited to the fishery. In the recent years, the *SSB* remained at values similar to those for 2010–2015. At the start of fishing in 1971, the spawning stock biomass was estimated to be at about 140% B_0. During the late 1980s and early 1990s the biomass was estimated to have dropped to below 20% B_0 for several years, but since 1994 it has remained above the target level of 40% B_0.

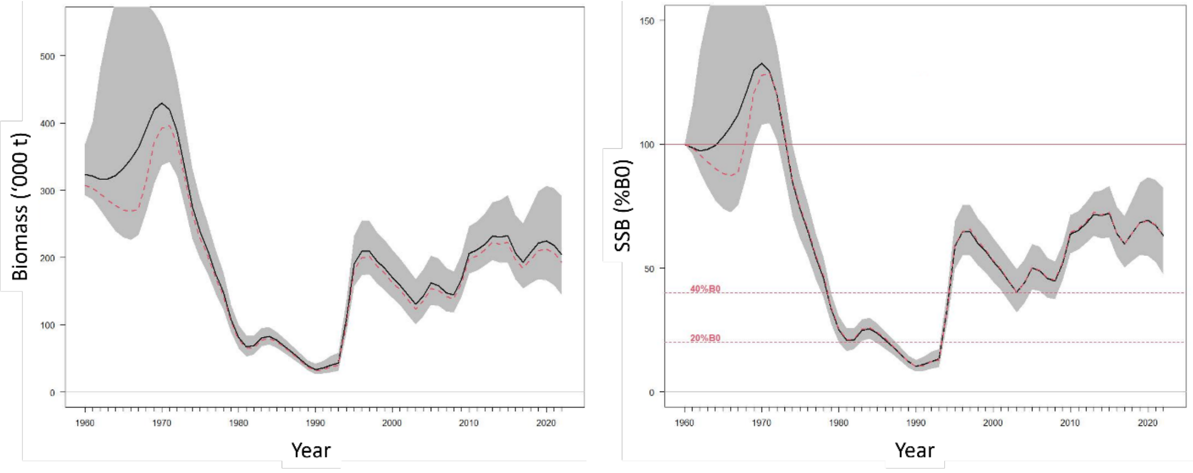


Figure 11: MCMC median and 95% credible intervals of the trajectory of (left) spawning stock biomass and (right) stock status (% B_0) for the Base model. The red dashed line in each plot shows the MPD result.

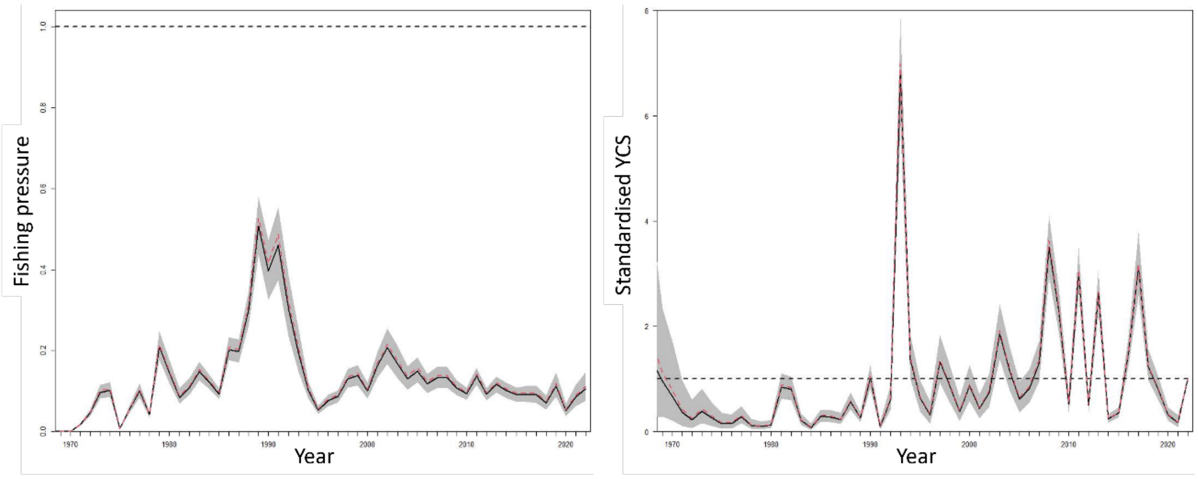


Figure 12: MCMC median and 95% credible intervals for (left) exploitation rates and (right) relative year class strength for the Base model. The red dashed line in each plot shows the MPD result. Year is model year that fish enter the population at age 2.

The estimate of the median mature biomass acoustic q was 0.41 (95% confidence interval of 0.33–0.49), which was less than the prior value of 0.54, meaning the prior was strongly updated by the current data. The estimate was close to that of the previous assessment in 2019 (Doonan 2020) which estimated q to be 0.40. In 2017, Roberts & Hanchet (2019) estimated *q* to be 0.36. The estimate of 0.36 is within the 95% CI of the current assessment. The estimate of the median immature biomass acoustic *q* was 0.23 (95% CI 0.20–0.28), compared with 0.26 from the two preceding assessments.

Table 9: Bayesian median and 95% credible intervals of equilibrium (B_0) and current status (% B_0) for Base model and the sensitivity cases.

Model	B_0 (`000 t)	B_{2022} (% B_0)
Base	323 (292–369)	63 (47–82)
Mfree	319 (291–365)	58 (41–79)
Tvary	345 (310–400)	57 (42–74)

Table10: Bayesian median and 95% credible intervals of the catchability coefficients (*q*) for the wide-area acoustic biomass indices for Base model and the sensitivity cases Mfree and Tvary. Estimates of natural mortality for the sensitivity case, Mfree.

Model	Catchability		Natural mortality	
	Immature	Mature	Male	Female
Base	0.23 (0.20–0.28)	0.41 (0.33–0.49)	–	–
Mfree	0.29 (0.19–0.40)	0.48 (0.34–0.62)	0.19 (0.15–0.24)	0.17 (0.13–0.21)
Tvary	0.30 (0.25–0.37)	0.39 (0.32–0.47)	–	–

Model sensitivity runs

The estimated MCMC marginal posterior distributions for parameters of interest are shown for the sensitivity model runs in Figures 13 and 14, and the results are summarised in Table 9 and Table.

The biomass trajectories for both sensitivity runs showed very similar patterns to the base case. The key difference was in the stock status, but the differences were modest. Model Mfree estimated lower values of *M* than used in the Base model (0.20) at 0.19 for males and 0.17 for females and these were similar to those estimated in the 2020 (0.16–0.17) and 2017 (0.17–0.18) assessments.

For model Tvary, the median female maturation A_{50} stayed between age 2.2 to 3.6, except in 2008 when it reached age 4. The MPD estimates were close to the MCMC median values. However, the male A_{50} median was more extreme than the MPD estimates, and estimated at approximately age 4 at five points in the time series (Figure 15a). The median A_{50} by sex were correlated, but the male values were more extreme than those for females in several years (Figure 15b).

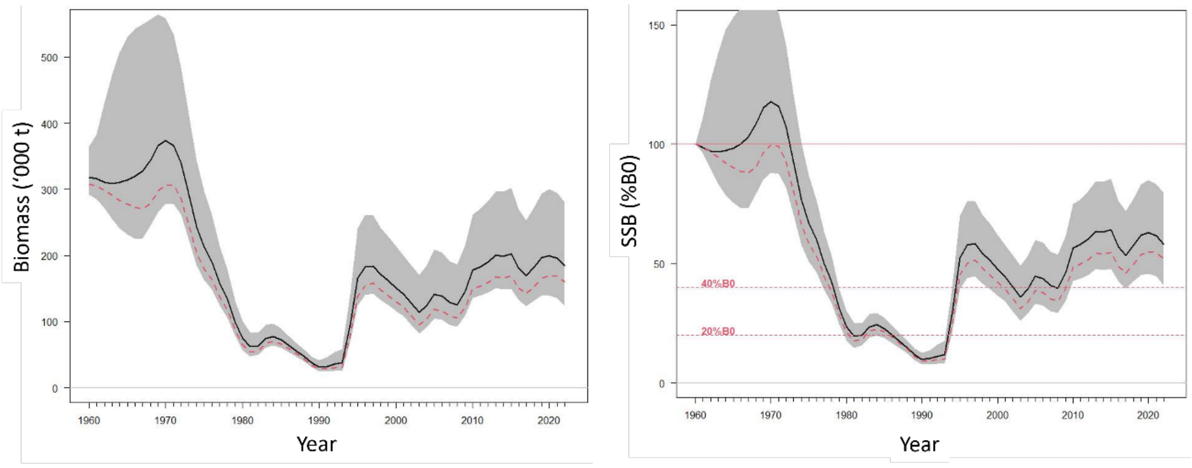


Figure 13: Mfree model: MCMC median and 95% credible intervals of the trajectory of (left) spawning stock biomass and (right) stock status (% B_0). The red dashed line in each plot shows the MPD result.

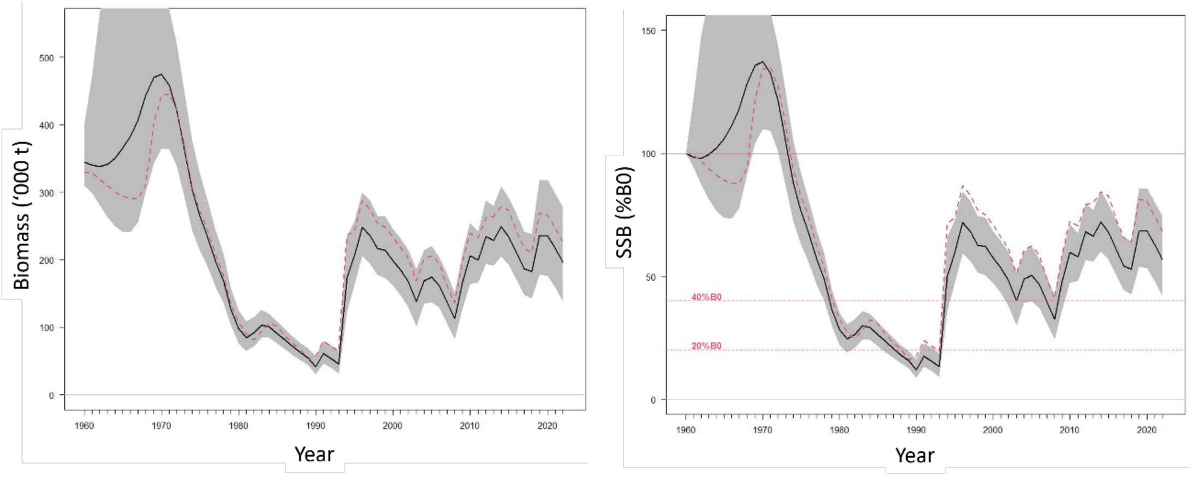


Figure 14: Tvary model: MCMC median and 95% credible intervals of the trajectory of (left) spawning stock biomass and (right) stock status (% B_0). The red dashed line in each plot shows the MPD result.

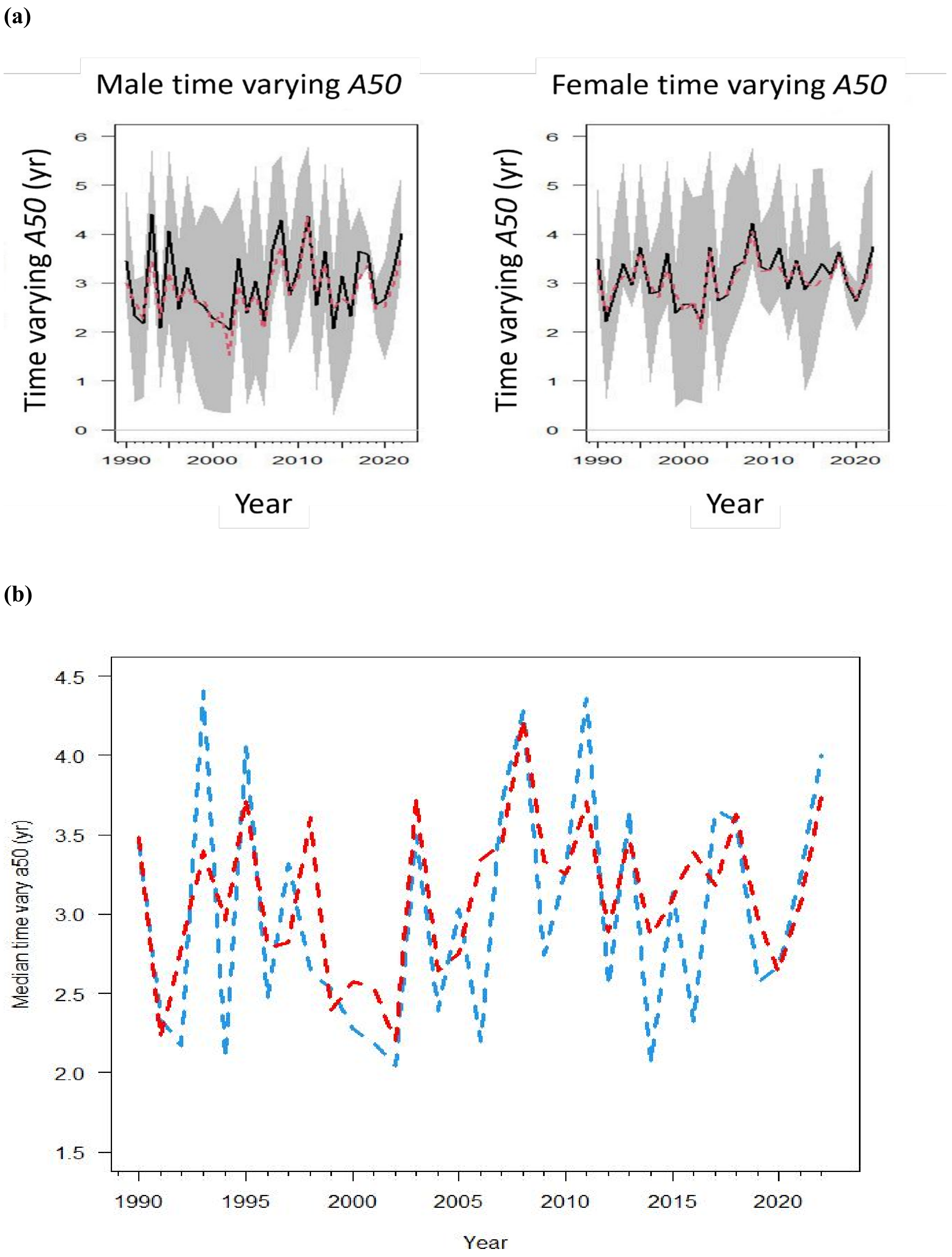


Figure 15: Tvary model: (a) MCMC median and 95% credible intervals of the maturity A_{50} for (left) males and (right) females. The red dashed line in each plot shows the MPD result. (b) MCMC median maturity A_{50} for (blue) males and (red) females.

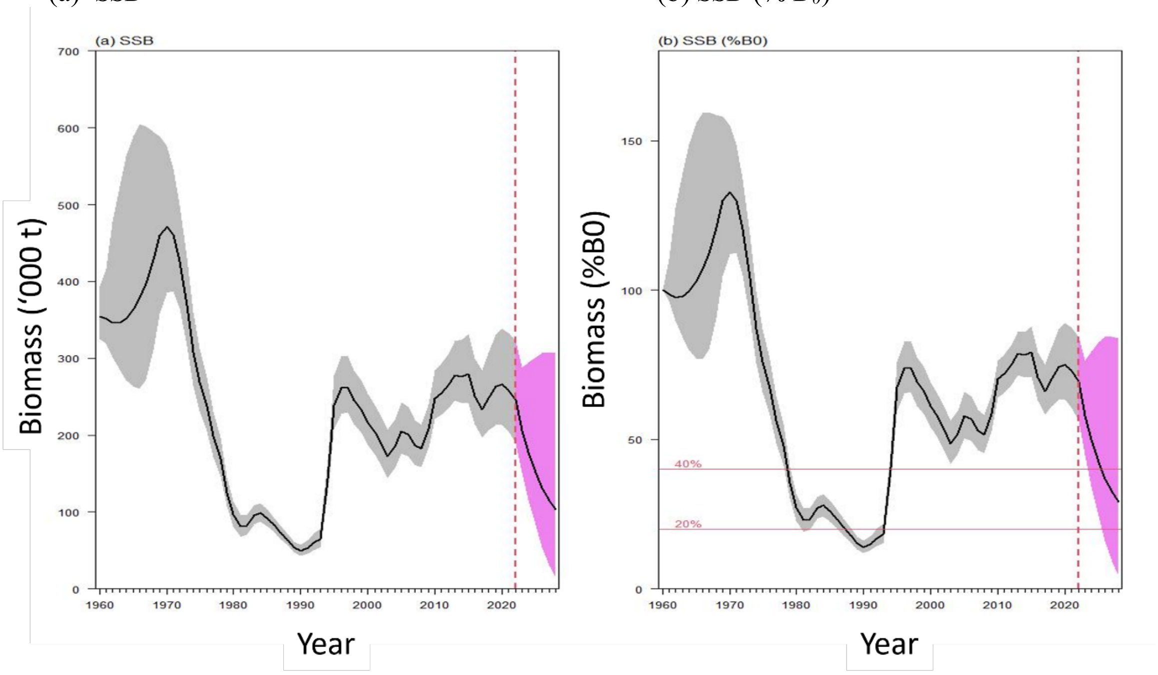
3.3 Projections

Projections were made for the Base model and the sensitivity models assuming fixed catch levels of 39 200 t (2022 TACC) for the years 2023 to 2028 (Figure 16 top panels). Projections were made using the MCMC samples, with recruitments drawn randomly from the distribution of year class strengths as estimated for the period 1960–2021 and applied from 2022 onwards (in model runs, recruitment for 2022 was ill-determined and was set to one). Because of the link between mean size-at-age of fish in the population and the population density, projections used the mean size-at-age from the final year of estimates (2022), rather than return to the average size-at-age that might be expected at lower abundances. An alternative projection was run using the estimated year class strengths for the period 2012–2021 (i.e., the last 10 estimated YCS).

For all three models, another projection was made using a fixed catch of 18 200 t, the average annual catch over 2020–2022 (Figure 16 bottom panels). For model Tvary, the projected A_{50} to maturity-by-age were drawn randomly from the estimated values for 2013–2022.

For each scenario, the probabilities that the mid-season biomass for the specified year will be greater than or equal to 40% B_0, less than 20% B_0, and less than 10% B_0 are given in Table , Table , and Table . For the Base model, the probability of being below 20% B_0 at catch levels of 18 200 t was no greater than 1% for both recruitment distributions over all the years. The probability of dropping below the 20% B_0 threshold biomass at catch levels of 39 200 t exceeded 10% by 2025–26 for the Mfree model for both recruitment distributions and Base model when distributions were sampled from all years; the probability exceeded 10% for all models by 2026–27. Under the TACC catch scenario the biomass was expected to steadily decline under both recruitment conditions. Under the 18 200 t catch scenario, the biomass was expected to steadily decline to 2026–27 but flatten or increase again in 2027–28 under both recruitment conditions.

(a) *SSB* (b) *SSB* (% B_0)



(a) *SSB* (b) *SSB* (% B_0)

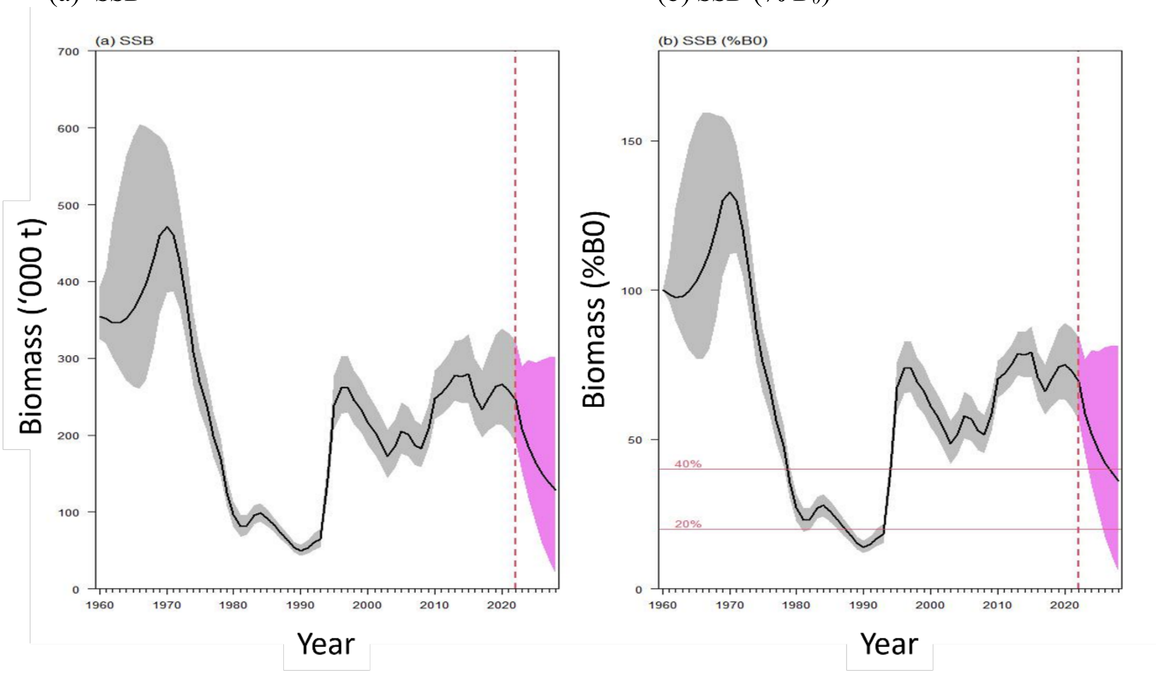


Figure 16: MCMC posterior plots for the median (solid line) and 95% credible intervals for (a) spawning stock biomass and (b) stock status (% B_0) using a catch of 39 200 t for the base case assuming (top panels) average recruitment and (bottom panels) the last 10 estimated recruitments. Horizontal lines indicate 40% and 20% B_0, and the vertical dotted line represents the beginning of the projection period (2023–2028).

Table 11: Base model: probability (%) that the projected mid-season spawning stock biomass for 2023–2028 will be greater than or equal to 40% $\boldsymbol{B_0}$, less than 20% $\boldsymbol{B_0}$, and less than 10% $\boldsymbol{B_0}$, at a projected catch of 18 200 t and 39 200 t.

	Fishing year					
	2022–23	2023–24	2024–25	2025–26	2026–27	2027–28
Catch 39 200 t + YCS 1960–2021						
Median *SSB* (% $\boldsymbol{B_0}$)	58	50	42	37	32	29
%[*SSB* >= 40% $\boldsymbol{B_0}$]	99	83	57	43	36	33
%[*SSB* < 20% $\boldsymbol{B_0}$]	0	0	1	11	24	33
%[*SSB* < 10% $\boldsymbol{B_0}$]	0	0	0	1	6	15
Catch 39 200 t + YCS 2012–2021						
Median SSB (% $\boldsymbol{B_0}$)	59	52	46	42	39	36
%[SSB >= 40% $\boldsymbol{B_0}$]	99	86	65	54	48	43
%[SSB < 20% $\boldsymbol{B_0}$]	0	0	1	8	16	22
%[SSB < 10% $\boldsymbol{B_0}$]	0	0	0	1	4	9
Catch 18 200 t + YCS 1960–2021						
Median SSB (% $\boldsymbol{B_0}$)	61	58	55	53	53	54
%[SSB >= 40% $\boldsymbol{B_0}$]	100	98	92	83	78	77
%[SSB < 20% $\boldsymbol{B_0}$]	0	0	0	0	0	1
%[SSB < 10% $\boldsymbol{B_0}$]	0	0	0	0	0	0
Catch 18 200 t + YCS 2012–2021						
Median SSB (% $\boldsymbol{B_0}$)	62	60	59	59	59	61
%[SSB >= 40% $\boldsymbol{B_0}$]	100	98	93	88	85	85
%[SSB < 20% $\boldsymbol{B_0}$]	0	0	0	0	0	0
%[SSB < 10% $\boldsymbol{B_0}$]	0	0	0	0	0	0

Table 12: Mfree model: probability (%) that the projected mid-season spawning stock biomass for 2023–2028 will be greater than or equal to 40% $\boldsymbol{B_0}$, less than 20% $\boldsymbol{B_0}$, and less than 10% $\boldsymbol{B_0}$, at a projected catch of 18 200 t and 39 200 t.

	Fishing year					
	2022–23	2023–24	2024–25	2025–26	2026–27	2027–28
Catch 39 200 t + YCS 1960–2021						
Median SSB (%B_0)	55	47	39	32	27	23
%[SSB >= 40 %B_0]	97	73	46	33	28	24
%[SSB < 20 %B_0]	0	0	3	18	34	44
%[SSB < 10 %B_0]	0	0	0	3	12	24
Catch 39 200 t + YCS 2012–2021						
Median SSB (%B_0)	55	49	42	37	33	30
%[SSB >= 40 %B_0]	97	77	56	44	37	33
%[SSB < 20 %B_0]	0	0	3	13	23	32
%[SSB < 10 %B_0]	0	0	0	2	8	15
Catch 18 200 t + YCS 1960–2021						
Median SSB (%B0)	66	62	58	56	55	57
%[SSB >= 40 %B0]	100	100	98	92	86	84
%[SSB < 20 %B0]	0	0	0	0	0	0
%[SSB < 10 %B0]	0	0	0	0	0	0
Catch 18 200 t + YCS 2012–2021						
Median SSB (%B0)	58	57	56	56	56	58
%[SSB >= 40 %B0]	99	96	90	84	81	81
%[SSB < 20 %B0]	0	0	0	0	0	1
%[SSB < 10 %B0]	0	0	0	0	0	0

Table 8: Tvary model: probability (%) that the projected mid-season spawning stock biomass for 2023–2028 will be greater than or equal to 40% B_0, less than 20% B_0, and less than 10% B_0, at a projected catch of 18 200 t and 39 200 t.

	Fishing year					
	2022–23	2023–24	2024–25	2025–26	2026–27	2027–28
Catch 39 200 t + YCS 1960–2021						
Median SSB (% B_0)	64	54	46	40	36	33
%[SSB >= 40 % B_0]	100	95	71	50	42	38
%[SSB < 20 % B_0]	0	0	0	3	13	23
%[SSB < 10 % B_0]	0	0	0	0	2	6
Catch 39 200 t + YCS 2012–2021						
Median SSB (% B_0)	64	55	48	44	42	40
%[SSB >= 40% B_0]	100	95	74	60	53	49
%[SSB < 20% B_0]	0	0	0	3	10	16
%[SSB < 10% B_0]	0	0	0	0	1	5
Catch 18 200 t + YCS 1960–2021						
Median SSB (% B_0)	66	62	58	56	55	57
%[SSB >= 40% B_0]	100	100	98	92	86	84
%[SSB < 20% B_0]	0	0	0	0	0	0
%[SSB < 10% B_0]	0	0	0	0	0	0
Catch 18 200 t + YCS 2012–2021						
Median SSB (% B_0)	67	63	60	60	61	63
%[SSB >= 40% B_0]	100	100	98	93	88	88
%[SSB < 20% B_0]	0	0	0	0	0	0
%[SSB < 10% B_0]	0	0	0	0	0	0

4. DISCUSSION

The results of the base case assessment suggested that the spawning stock biomass of the Campbell Island Rise in 2022 was 204 000 t (95% CI 144 000–291 000 t), and it was at 63% B_0 (95% CI 47–82%). Projections with an annual catch of 39 200 t (the current TACC) suggested that the spawning stock biomass is expected to decline steadily to 29% or 36% B_0 by 2028 depending on whether future recruitment is drawn from the historical series or from just the last 10 estimates (2012 to 2021). The Mfree model sensitivity gave a more pessimistic prediction for *SSB* in 2028, down to 23% or 30% B_0. The Tvary model sensitivity gave a more optimistic prediction than the Base model, *SSB* dropping but only to 33 to 40% B_0. However, if the future catch is maintained at about the average for the last three years, 18 200 t, then the Base model estimates that the *SSB* would be at 54% B_0 in 2028 if recruitment follows the historical distribution, and at 61% B_0 if recruitment is similar to the later period, 2012–2021.

The last strong year classes were for 2010, 2012, 2016 (age 0 year) and these were well determined. After 2016, there was an average recruitment year followed by two poor years, all moderately determined. Overall, this assessment did not suggest any sustainability concerns at the current catch level.

As of June 2024 the report output from the assessment automation code has not been presented to a Working Group, and additional content might be requested when this happens. This should be a relatively minor task given the modular format of the functions, as additional outputs can be written into the report code without the need to re-run the earlier steps of the model update.

5. POTENTIAL RESEARCH

The assessment automation update code was tested and confirmed to work as expected by adding past data to the 2019 assessment. Age composition data will be collected in the 2023 and 2024 fishing seasons so the auto-update code should be used to update this assessment when these data are ready. These updates are not part of this contract.

6. FULFILLMENT OF BROADER OUTCOMES

This project delivered against the following aspect of broader outcomes.

Building capacity and capability in the research sector

Extracting, grooming, and summarising the southern blue whiting commercial and observer data was overseen by a researcher with considerable experience of southern blue whiting but conducted by two researchers new to the stock and the established grooming techniques. In this way NIWA was able to share expertise and grow institutional knowledge of New Zealand fisheries and stock assessments.

7. ACKNOWLEDGEMENTS

This work was completed under Objective 2 of Fisheries New Zealand project SBW2022-01. The assessment benefited from discussions with members of the Deepwater Working Group. We thank Matt Dunn for reviewing this report.

8. REFERENCES

Bull, B.; Dunn, A. (2002). Catch-at-age: User manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. National Institute of Water and Atmospheric Research. (Unpublished report held by NIWA library, Wellington.)

Bull, B.; Francis, R.I.C.C.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H.; Bian, R.; Fu, D. (2012). CASAL (C++ algorithmic stock assessment laboratory): CASAL user manual v2.30-2012/03/21. *NIWA Technical Report 135.* 280 p.

Casal2 Development Team (2022). Casal2 user manual for age-based models, v22.07 (2022-07-20). National Institute of Water & Atmospheric Research Ltd. *NIWA Technical Report 139.* 252 p.

Doonan, I.J. (2020). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for data up to 2018–19. *New Zealand Fisheries Assessment Report 2020/43.* 20 p.

Doonan, I.J.; Large. K.; Dunn. A.; Rasmussen. S.; Marsh. C.; Mormede. S. (2016). Casal2: New Zealand's integrated population modelling tool. *Fisheries Research 183*: 498–505.

Dunn, A.; Hanchet, S.M. (2011). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise, 2009–10. *New Zealand Fisheries Assessment Report 2011/40.* 37 p.

Dunn, A.; Hanchet, S.M. (2017). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2016. *New Zealand Fisheries Assessment Report 2017/38.* 20 p.

Escobar-Flores, P.C.; Ladroit, Y.; Holmes, S. (2023). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August-September 2022 (TAN2210). *New Zealand Fisheries Assessment Report 2023/37.* 58 p.

Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences 68(6)*: 1124–1138.

Fu, D.; Hanchet, S.M.; O'Driscoll, R.L. (2013). Estimates of biomass and c.v.s of southern blue whiting from previous acoustic surveys from 1993 to 2012 using a new target strength – fish length relationship. Final Research Report to the Ministry of Fisheries. Project DEE201002SBWB. 52 p. (Unpublished report held by Fisheries New Zealand.)

Hanchet, S.M. (1991). Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 91/7. 32 p. (Unpublished report held by NIWA library, Wellington.)

Hanchet, S.M. (1998). Documentation of the separable Sequential Population Analysis used in the assessments of southern blue whiting, and a comparison with other models. New Zealand Fisheries Assessment Research Document 98/33. 22 p. (Unpublished report held by NIWA Library, Wellington.)

Hanchet, S.M.; Blackwell, R.G.; Stevenson, M.L. (2006). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2006. *New Zealand Fisheries Assessment Report 2006/41.* 45 p.

Hanchet, S.M.; Haist, V.; Fournier, D. (1998). An integrated assessment of southern blue whiting (*Micromesistius australis*) from New Zealand waters using separable Sequential Population Analysis. *In:* Funk, F.; Quinn II, T.J.; Heifetz, J.; Ianelli, J.N.; Powers, J.E.; Schweigert, J.F.; Sullivan, P.J.; Zhang, C.-I. (eds.). *Fishery Stock Assessment Models*. University of Alaska Sea Grant AK-SG-98-01, Fairbanks, Alaska.

Hanchet, S.M.; Ingerson, J.K.V. (1995). Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1995–96 fishing year. Fisheries Assessment Research Document 95/20. (Unpublished report held by NIWA library, Wellington.) 37 p

Holmes, S.J.; Bian, R.; Doonan, I.J. (2023). Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2022 season. *New Zealand Fisheries Assessment Report 2023/63*. 75 p

Ladroit, Y.; O'Driscoll, R.L.; Large, K. (2020). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August-September 2019 (TAN1905). *New Zealand Fisheries Assessment Report 2020/26*. 56 p.

O'Driscoll, R.L.; Dunford, A.J.; Ladroit, Y. (2014). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August-September 2013. *New Zealand Fisheries Assessment Report 2014/22*. 46 p.

O'Driscoll, R.L.; Large, K.; Marriott, P. (2018). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August-September 2016. *New Zealand Fisheries Assessment Report 2018/56*. 62 p.

O'Driscoll, R.L.; Oeffner, J.; Dunford, A.J. (2013). In situ target strength estimates of optically verified southern blue whiting (*Micromesistius australis*). *ICES Journal of Marine Science 70:* 431–439.

Roberts, J.; Dunn, A. (2017). Investigation of alternative model structures for the estimation of natural mortality in the Campbell Island Rise southern blue whiting (*Micromesistius australis*) stock assessment (SBW 6I). *New Zealand Fisheries Assessment Report 2017/26*. 14 p.

Roberts, J.; Hanchet, S.M. (2019). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2017. *New Zealand Fisheries Assessment Report 2019/44*. 21 p.

APPENDIX 1: CODE FOR CALLING AUTOMATTED ASSESSMENT FUNCTIONS

```
# read in functions, set path for new data, path for existing model, and then update
# functions are for each step of the process (data check, update data, re-weight, MPD, MCMC, projections,
report)
# report can be produced for any subset of steps

# set Casal2 path here rather than relying on system variables, so it's explicit which compiled version is used
# (and also easy to change it here if you want to)
casal2Path <- file.path("C:/Projects","AssessmentSourceCode","CASAL2_workshop","CASAL2",
"BuildSystem", "Casal2")

baseFunctionsPath <- file.path(DIR$R, "RunCasal2AssessmentUpdateFunctions")
source(file.path(baseFunctionsPath, "checkNewData.R"))
source(file.path(baseFunctionsPath, "updateData.R"))
source(file.path(baseFunctionsPath, "runMPD.R"))
source(file.path(baseFunctionsPath, "reweightCompositionData.R"))
source(file.path(baseFunctionsPath, "runMCMC.R"))
source(file.path(baseFunctionsPath, "runPostMCMC.R"))
source(file.path(baseFunctionsPath, "runProjection.R"))
source(file.path(baseFunctionsPath, "prepDataForReport.R"))
source(file.path(baseFunctionsPath, "createReport.R"))

#########################################################################
## model update needs these inputs
##############################################################################
## updating 2019 model with 2020 data
baseModelPath <- DIR$Models
baseDataPath <- DIR$Data
modelFilenames <- list("Population_file" = "Population.csl2",
             "Estimation_file" = "Estimation.csl2",
             "Observation_file" = "Observation.csl2")
new_final_year <- 2020; new_projection_final_year <- 2025
last_YCSestimated <- 2020
new_data_filenames <- list("Male_length_at_age" = "new.Male.length.at.age.txt",
               "Female_length_at_age" = "new.Female.length.at.age.txt",
               "Proportions_at_age" = "ObsProportions.at.age.txt",
               "Final_year_catch" = "final.year.catch.txt",
               "Error_obs_proprtions" = "error.obs.Proportions.txt")
# new model
newModel <- "updateWith2020data_VMtestingFns"
newModelPath <- file.path(baseModelPath, newModel)
# existing model
existingModel <- "base2019_VMrun"
existingModelPath <- file.path(baseModelPath, existingModel)
## new data
newDataPath <- file.path(baseDataPath, "Get.data","Data","Data.2020")
newDataDescription <- "Data_for_2020"
#############################################
## updating 2020 model with 2021 data
#######################################################
baseModelPath <- DIR$Models
baseDataPath <- DIR$Data
modelFilenames <- list("Population_file" = "Population.csl2",
             "Estimation_file" = "Estimation.csl2",
             "Observation_file" = "Observation.csl2")
new_final_year <- 2021; new_projection_final_year <- 2026
last_YCSestimated <- 2021
new_data_filenames <- list("Male_length_at_age" = "new.Male.length.at.age.txt",
```

```
                    "Female_length_at_age" = "new.Female.length.at.age.txt",
                    "Proportions_at_age" = "ObsProportions.at.age.txt",
                    "Final_year_catch" = "final.year.catch.txt",
                    "Error_obs_proprtions" = "error.obs.Proportions.txt")
# new model
newModel <- "updateWith2021data_VMtestingFns"
newModelPath <- file.path(baseModelPath, newModel)
# existing model
existingModel <- "updateWith2020data_VMtestingFns"
existingModelPath <- file.path(baseModelPath, existingModel)
## new data
newDataPath <- file.path(baseDataPath, "Get.data","Data","Data.2021")
newDataDescription <- "Data_for_2021"

###############################################################

#optionally, run a data check first
checkNewData(baseModelPath = baseModelPath,
        baseDataPath = baseDataPath,
        new_final_year = new_final_year,
        new_projection_final_year = new_projection_final_year,
        last_YCSestimated = last_YCS_estimated,
        existingModel = existingModel,
        newDataPath = newDataPath,
        newDataDescription = newDataDescription,
        new_data_filenames = new_data_filenames,
        modelFilenames = modelFilenames)

# can run MPD as part of updateData(), or run MPD separately using runMPD()
updateData(baseModelPath = baseModelPath,
       baseDataPath = baseDataPath,
       new_final_year = new_final_year,
       new_projection_final_year = new_projection_final_year,
       last_YCSestimated = last_YCS_estimated,
       newModel = newModel,
       existingModel = existingModel,
       newDataPath = newDataPath,
       new_data_filenames = new_data_filenames,
       modelFilenames = modelFilenames)

# run MPD if didn't do it as part of updating the data. Need run MPD before reweighthing
runMPD(config_dir = newModelPath, casal2Path = casal2Path, wait = TRUE)

reweightCompositionData(config_dir = newModelPath, baseFunctionsPath = baseFunctionsPath,
              casal2Path = casal2Path,
              n_loops=3, mpd_file_name ="MPD.log",
              logFile = "reweighting_log.txt",
              verbose=FALSE)

runMCMC(config_dir=newModelPath, nchains=3, random_seeds="", useReweighted=TRUE,
    reweightFolder = "Reweight")

runPostMCMC(config_dir=newModelPath, samples=c(1,2,3), remove_burnin=TRUE, burnin = 500,
              est_pars_filename = "est_pars.par")

runProjection(config_dir = newModelPath, casal2Path = casal2Path, future_catches=10000)

projection_specs <- tibble(future_catch = c(10000),
                    YCS_sampling = "1960_2021")
prepDataForReport(baseModelPath = DIR$Models,
```

```
                functionsPath = file.path(DIR$R,"Functions"),
                newModel=newModel,
                existingModel = existingModel,
          # data2include =  c("Projections"),
                data2include = c("MPD","Reweight","MCMC","Projections"),
                projection_specs = projection_specs)
# for testing, can read the data back in here
# load(file =  file.path(newModelPath, "data_out-MPD-Reweight-MCMC-Projections"))


createReport(modelName=newModel, thisModelPath = newModelPath,
       dataName="data_out-MPD-Reweight-MCMC-Projections",
       authorName = "V L McGregor", functionsPath=file.path(DIR$R,"Functions"))

 ######################
## alt with more than one projection
projection_specs <- tibble(future_catch = c(10000, 12000),
               YCS_sampling = "1960_2020")
prepDataForReport(baseModelPath = DIR$Models,
          functionsPath = file.path(DIR$R,"Functions"),
          newModel=newModel,
          existingModel = existingModel,
          # data2include =  c("Projections"),
          data2include = c("MPD","Reweight","MCMC","Projections"),
          projection_specs = projection_specs)

createReport(modelName=newModel, thisModelPath = newModelPath,
       dataName="data_out-MPD-Reweight-MCMC-Projections",
       authorName = "V L McGregor", functionsPath=file.path(DIR$R,"Functions"))
```

APPENDIX 2: AUTOMATED ASSESSMENT REPORT

The following is an example report output available when using the automated assessment code. It is reproduced verbatim such that section numbering and formatting is as seen in the automated assessment report.

SBW assessment report

2023-10-20

Table of contents

Report compiled by: V L McGregor

1. Introduction

This report documents an automated update of the stock assessment for the Campbell Island Rise stock of southern blue whiting, using a model informed by catch history, proportion-at-age, and acoustic survey biomass estimates up to and including the 2020 fishing year. This update should be read along-side the most recent full stock assessment, documented by (Doonan 2023).

The 2019 model was updated with data from the 2020 fishing year. New data consists of observed proportions-at-age from the fishery, updated length-at-age for males and females in the most recent six years (2015 to 2020), and catches from the 2020 fishing year.

The automated model process consists of the following steps:

- Checking the data
- Updating previous assessment with new data
- Re-weighting the composition data following (Francis 2011)
- MPD estimation
- MPD parameter sensitivities

The model was re-weighted following (Francis 2011).

Model structure for model updateWith2020data_VMtestingFns

With data from C:/Projects/2022/SBW/Models/updateWith2020data_VMtestingFns

```
[1] "category_names" "fisheryData"    "model_specs"    "MPD_outs"
[5] "reweight_outs"  "MCMC_outs"      "PROJ_outs"
```

2. Model structure

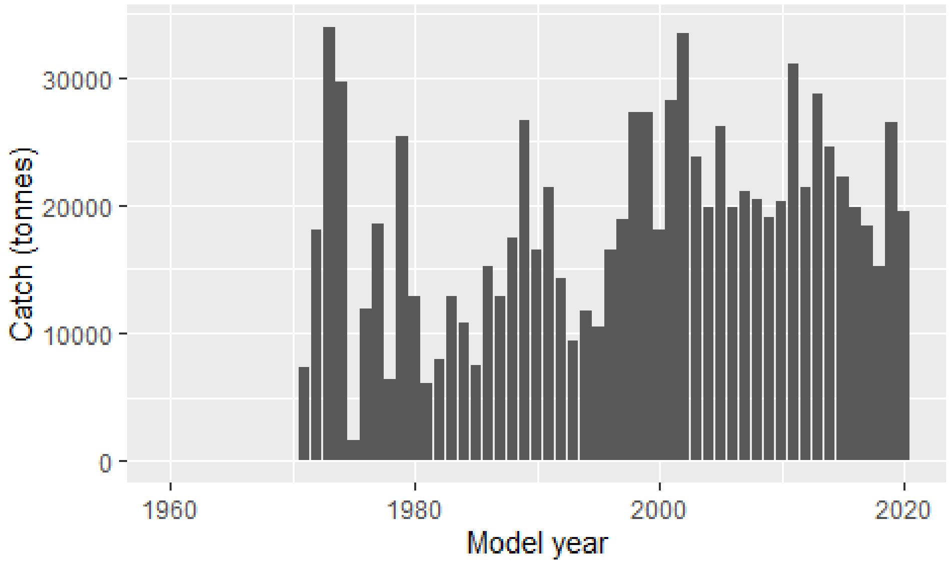
2.1 Categories defined:

sex, maturity

2.2 Year and age specified:

start_year	final_year	projection_final_year	min_age	max_age
1960	2020	2025	2	15

2.3 Catch history:



Year	Trawl
1960	0
1961	0
1962	0
1963	0
1964	0
1965	0
1966	0
1967	0
1968	0
1969	0
1970	0
1971	7280
1972	18060
1973	33950
1974	29540
1975	1665
1976	11962
1977	18505
1978	6403
1979	25305
1980	12828

1981	5989
1982	7915
1983	12803
1984	10777
1985	7490
1986	15252
1987	12804
1988	17422
1989	26611
1990	16542

Year	Trawl
1991	21314
1992	14208
1993	9316
1994	11668
1995	10436
1996	16504
1997	18923
1998	27164
1999	27205
2000	18052
2001	28232
2002	33445
2003	23718
2004	19799
2005	26190
2006	19763
2007	20996
2008	20483
2009	19040
2010	20224
2011	30971
2012	21321
2013	28607
2014	24592
2015	22100
2016	19875
2017	18334
2018	15147

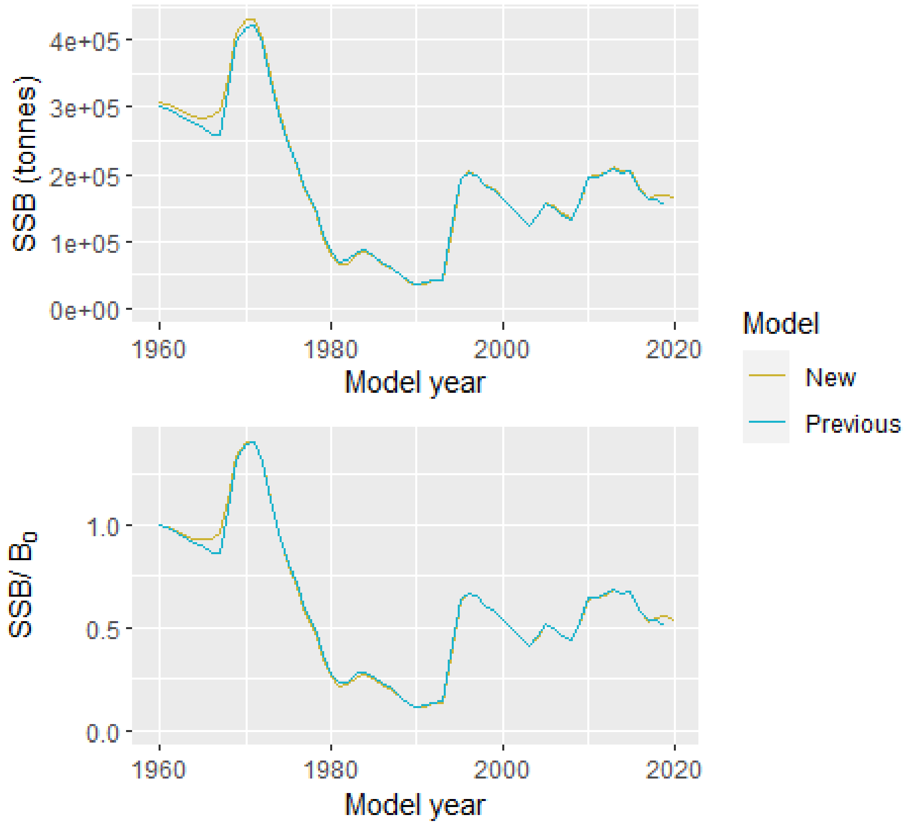
2019	26517
2020	19514

SBW catch history for fishing years 1960-- 2020

.

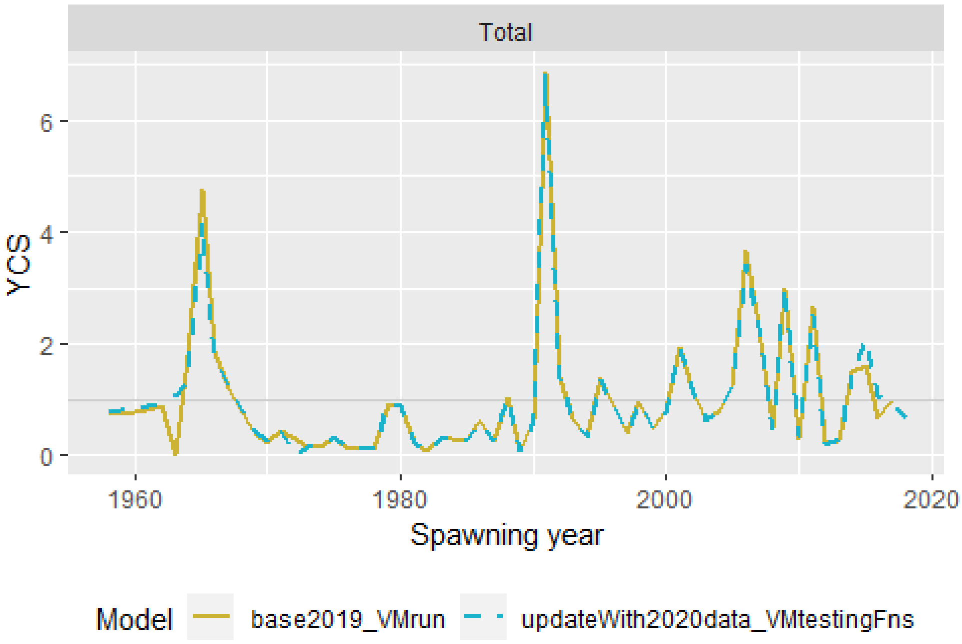
3. MPD outputs

3.1 SSB



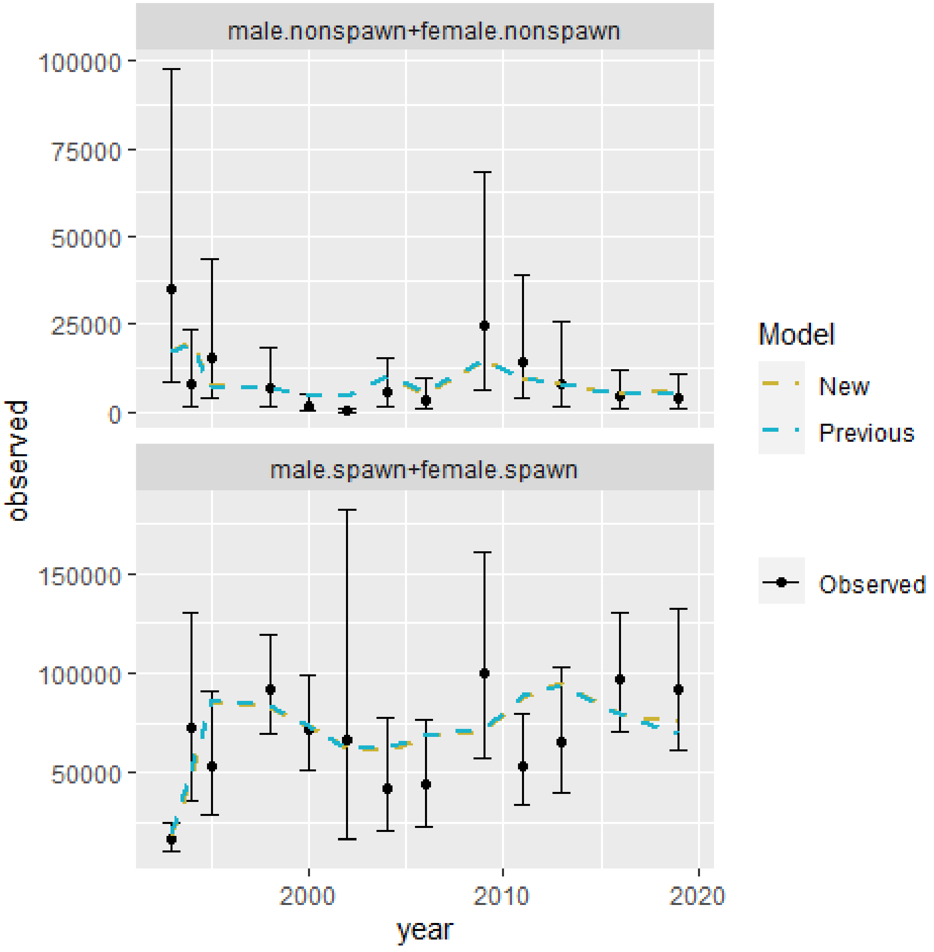
MPD SSB estimates

3.2 Recruitment

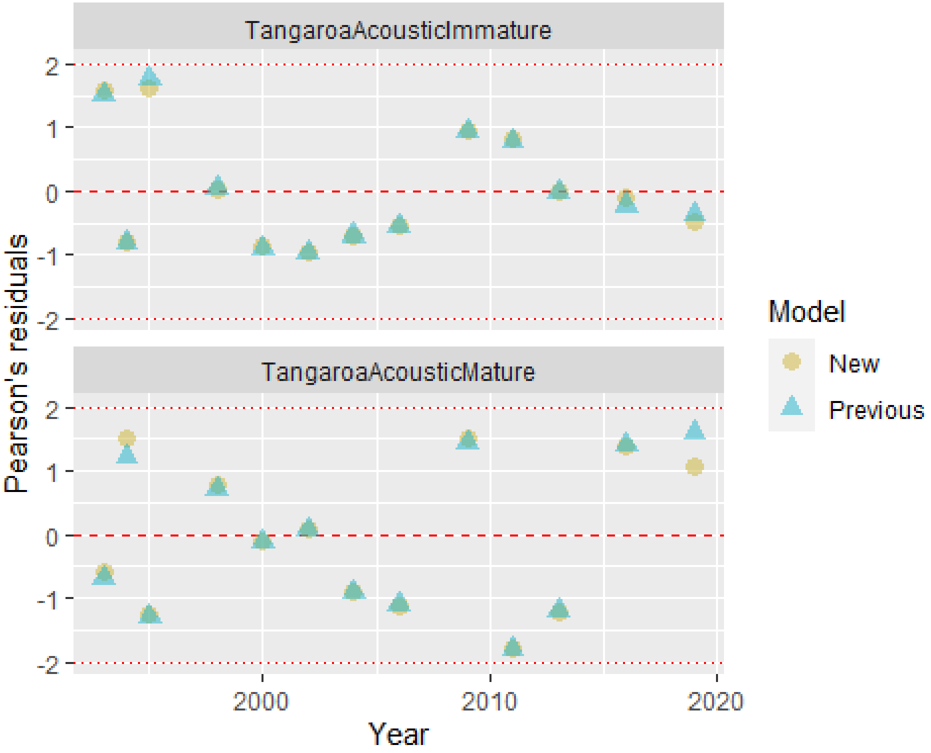


MPD estimated year class strengths

3.3 Abundance fits

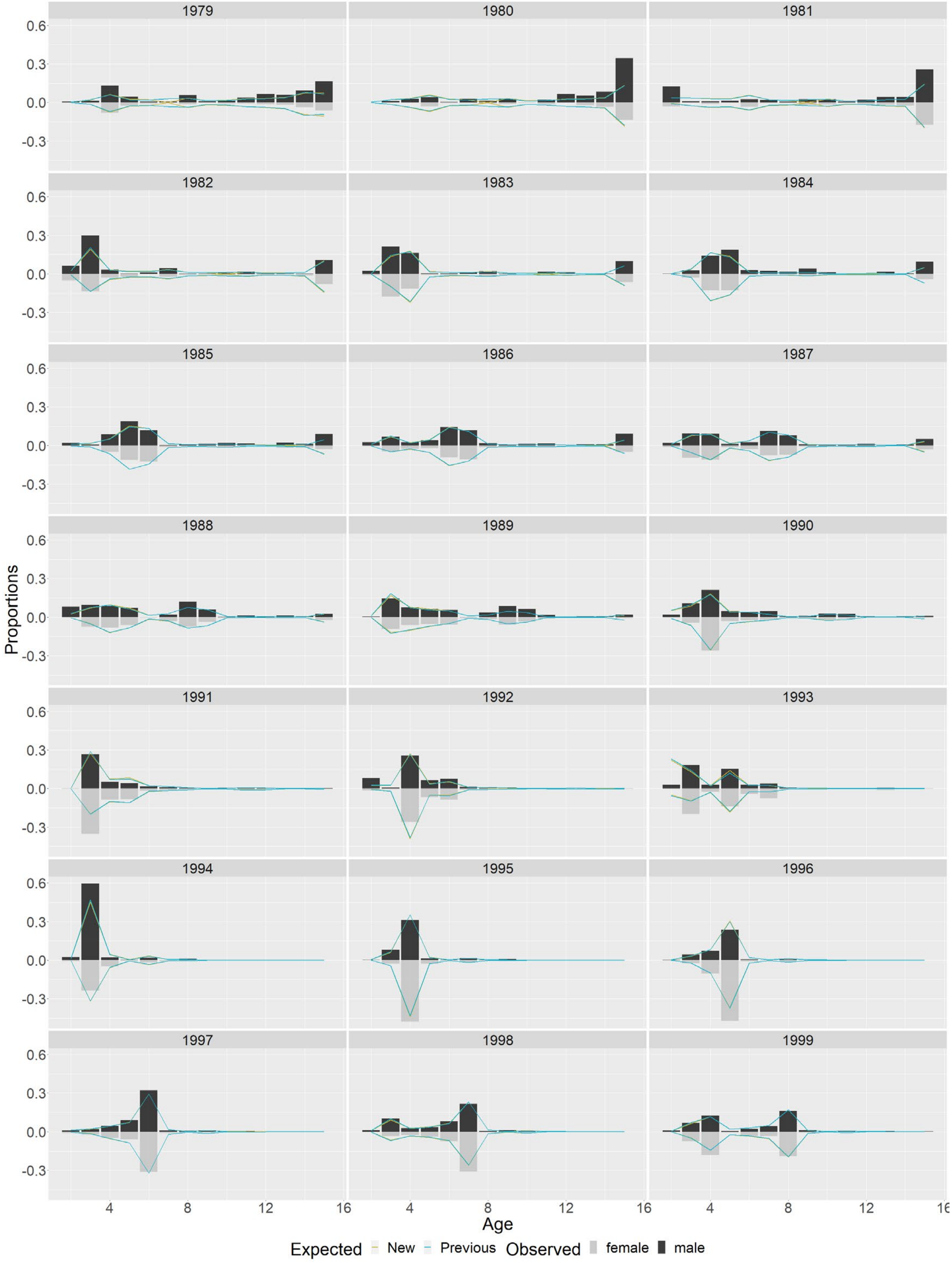


MPD Abundance fits

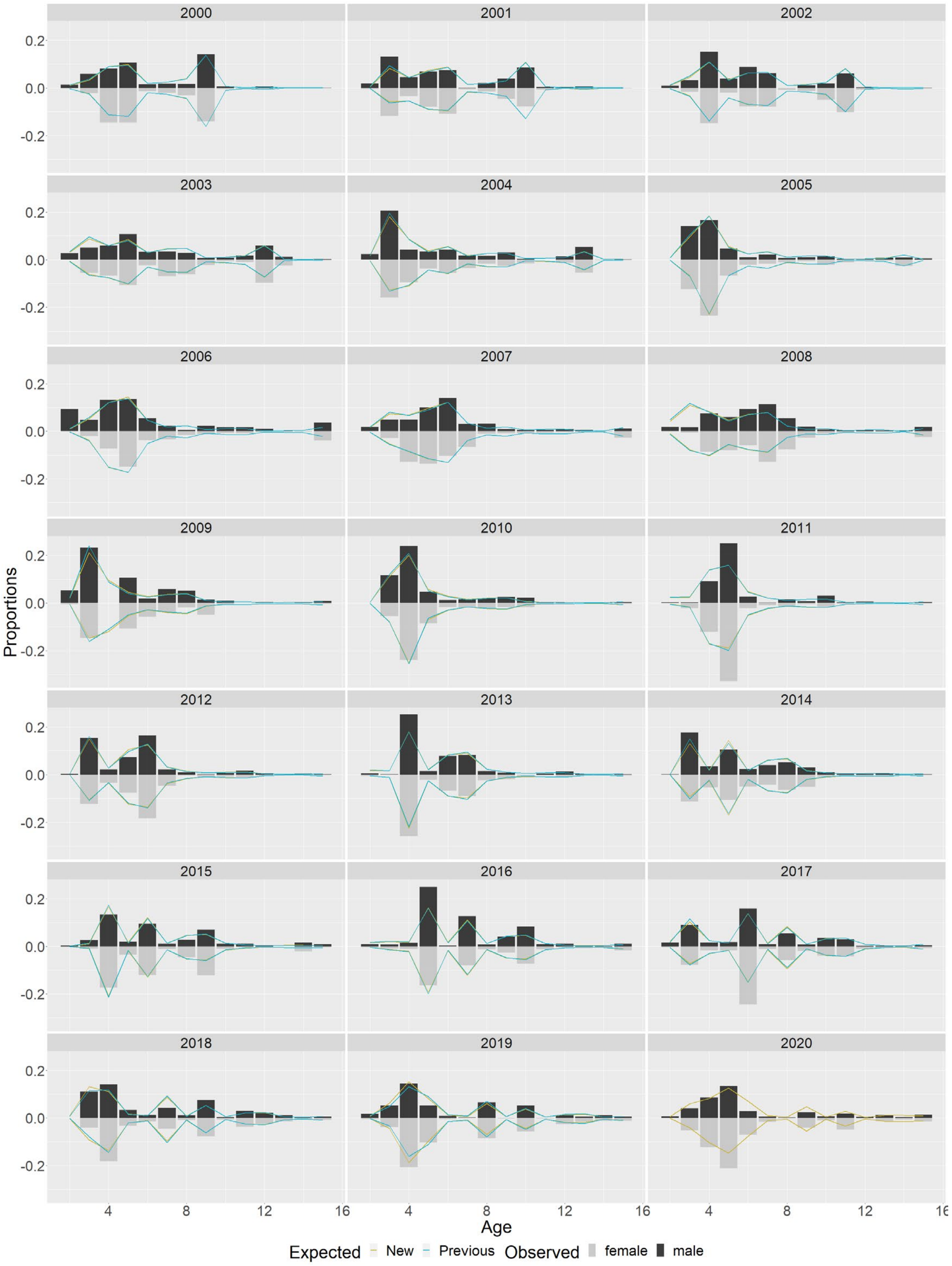


MPD Abundance residuals

3.4 Composition fits



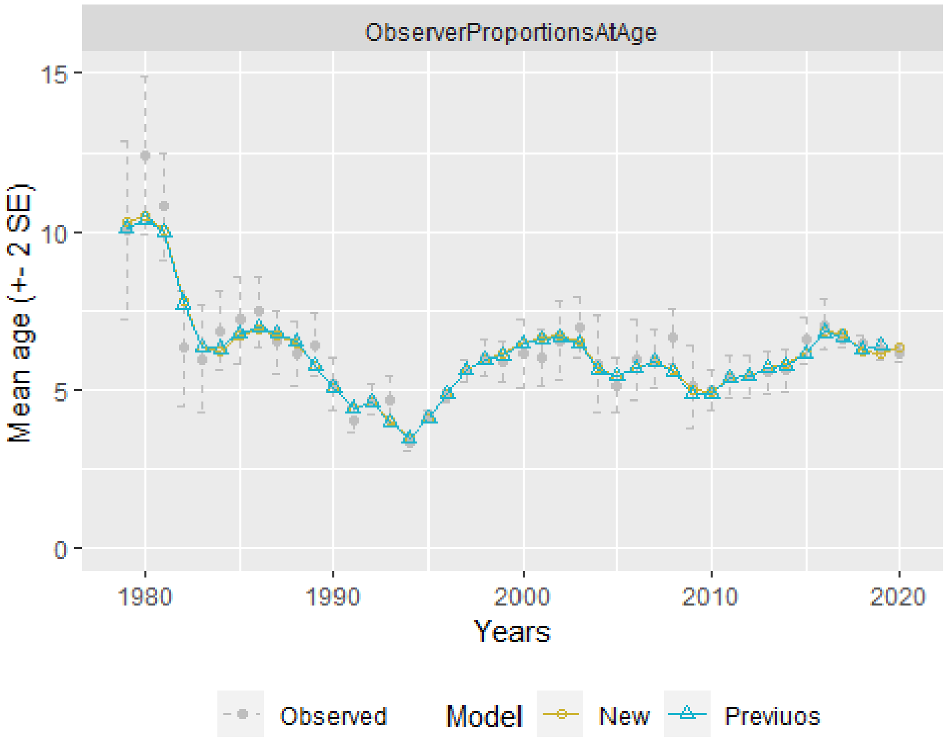
MPD Composition fits



MPD Composition fits

MPD Composition residuals

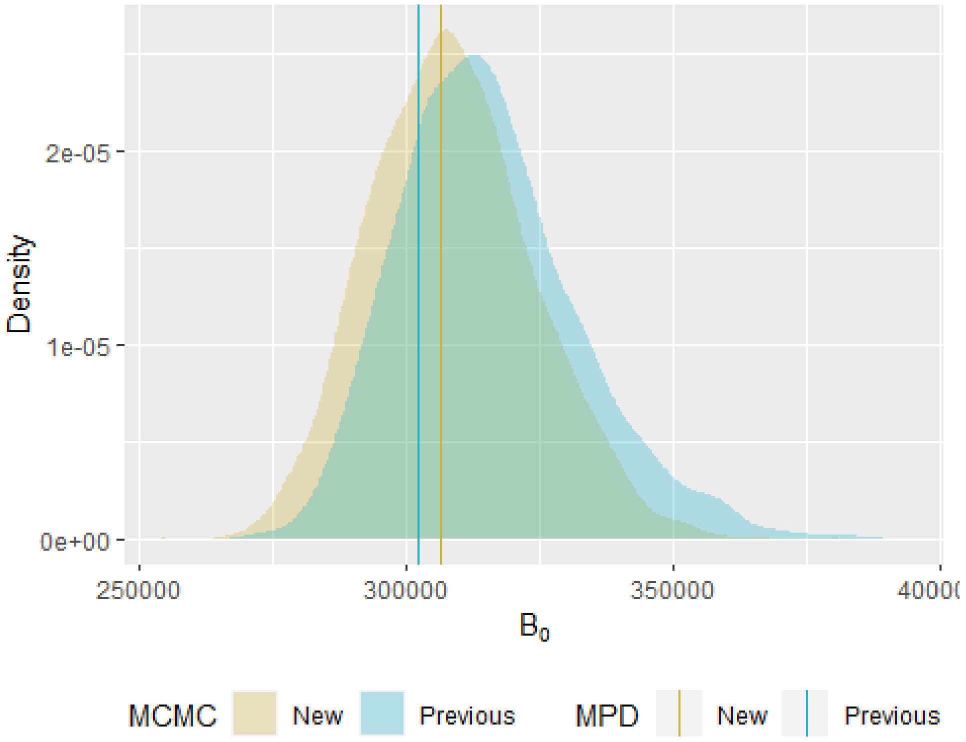
3.5 MPD mean age



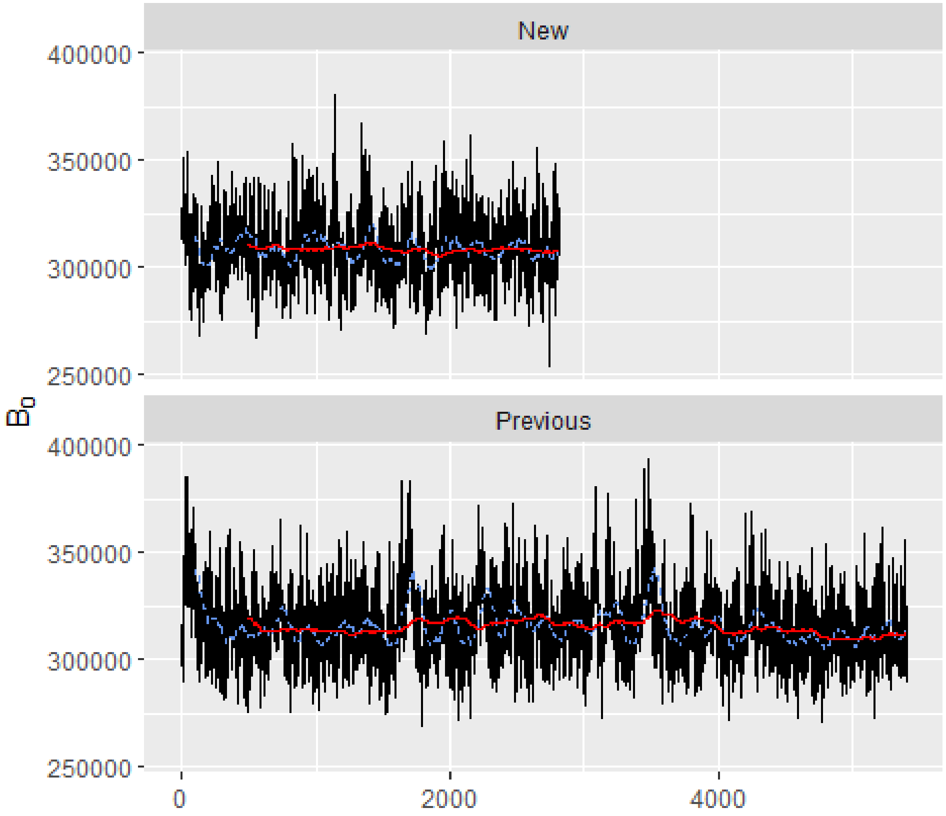
MPD mean age fits

4. MCMC

4.1 B0

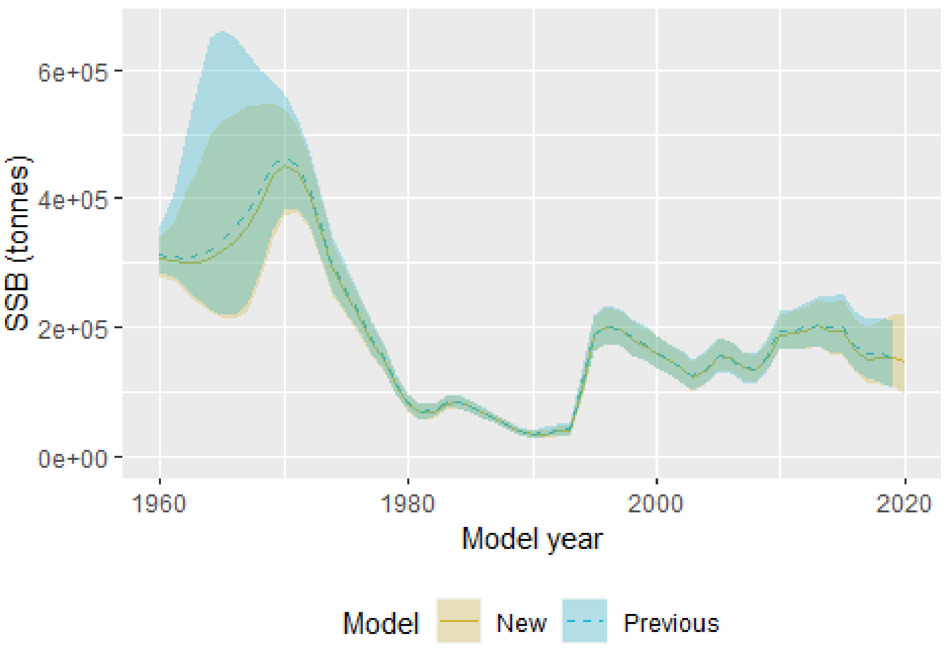


MCMC B0 posterior distribution (grey bars) and MPD estimate (red vertical line).



MCMC B0 trace.

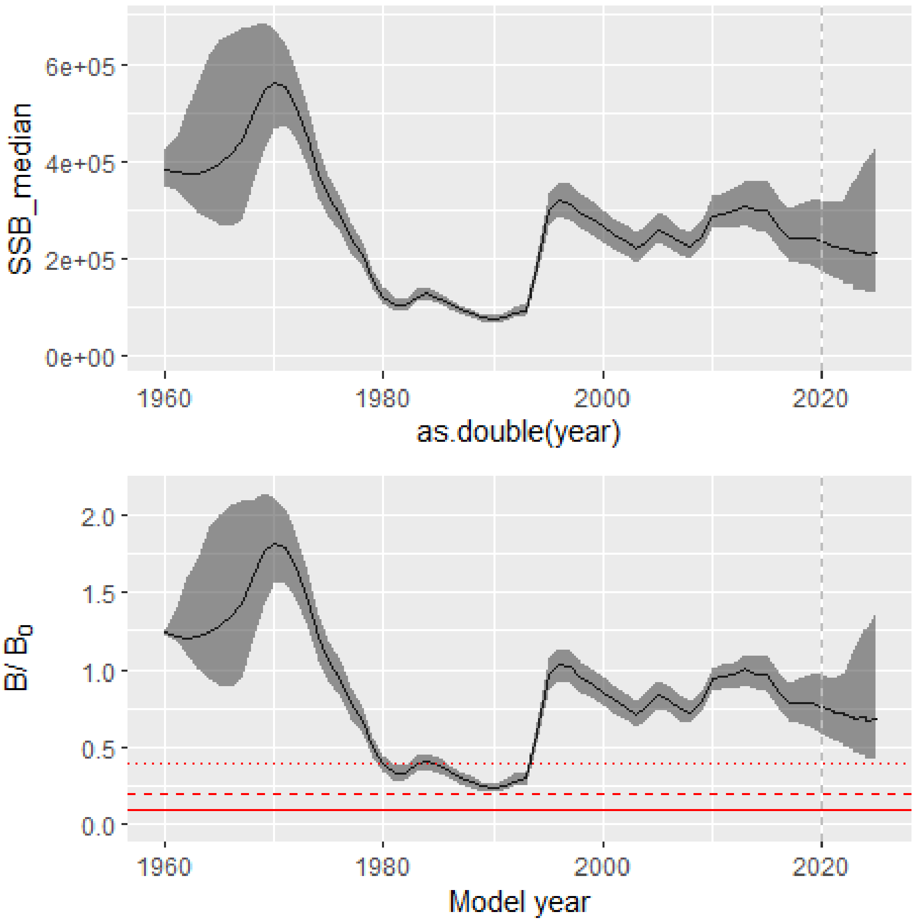
4.2 SSB



MCMC SSB.

5. Projections

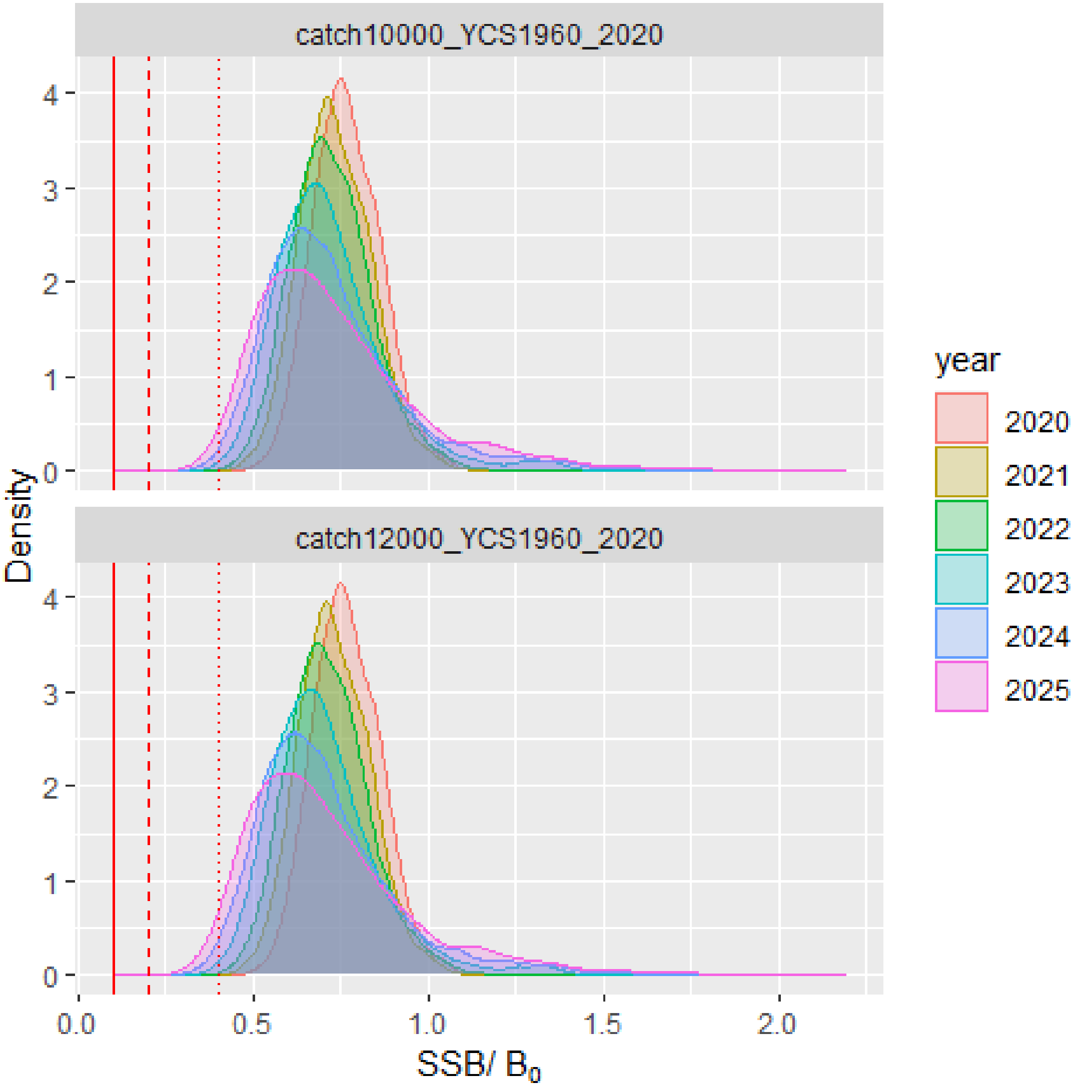
5.1 Summary



5.2 Status probabilities

Projection probabilities

Projection	Reference point	2020	2021	2022	2023	2024	2025
catch10000_YCS1960_2020	>=40%	1	1	1	1	0.99	0.99
catch12000_YCS1960_2020	>=40%	1	1	1	1	0.99	0.98



Projection probabilities

6. References

Doonan, I. J. 2023. “Southern Blue Whiting (*Micromesistius Australis*) Stock Assessment for the Campbell Island Rise for Data up to 2020–23. *New Zealand Fisheries Assessment Report 2023/XX*” XX p.

Francis, R I C C. 2011. “Data Weighting in Statistical Fisheries Stock Assessment Models” *Canadian Journal of Fisheries and Aquatic Sciences 68(6):* 1124–1138.