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Tini a Tangaroa

The 2026 stock assessment of ling (*Genypterus blacodes*) off the west coast South Island (LIN 7WC)

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PLAIN LANGUAGE SUMMARY

Ling (*Genypterus blacodes*) is an important commercial fish species in New Zealand middle depths waters and is caught mainly by bottom trawls, bottom longlines, and increasingly by potting.

This report summarises the 2026 stock assessment of one of the five main ling stocks managed under the Quota Management System: the ling stock off the west coast of the South Island (LIN 7WC).

A stock assessment model was carried out, informed by commercial catches, commercial age compositions, commercial standardised catch per unit effort (CPUE) for both bottom longlines and bottom trawl, and information from the west coast South Island trawl survey biomass series.

The initial spawning stock biomass was at 54 144 t and status in 2026 was at 34% of initial biomass, with a downward trend in recruitment since 2003 and lower than average recruitment since 2008.

Five-year projections indicated that, under recent or a continued decline in recruitment, the spawning stock biomass would continue to decline even with a 30% reduction in recent catches and would most likely breach the limit reference point in 2031 at that level of catch.

EXECUTIVE SUMMARY

Mormede, S.[1]; Dunn, A.[2]; Webber, D.N.[3] (2026). The 2026 stock assessment of ling (*Genypterus blacodes*) off the west coast South Island (LIN 7WC).

***New Zealand Fisheries Assessment Report 2026/26.* 25 p.**

Ling (*Genypterus blacodes*) is an important species commercially caught mainly by bottom trawls and bottom longlines, and, increasingly, by pots. They are found throughout the middle depths of New Zealand waters. Ling are managed as eight administrative Quota Management Areas with five of those reporting about 95% of the landings. This report summarises the 2026 stock assessment of the west coast South Island ling stock (LIN 7WC) using data up to and including the 2025 calendar year.

The indices of abundance provided to the model included the west coast South Island trawl surveys, as well as the bottom longline and bottom trawl standardised catch per unit effort (CPUE) series. Sensitivity analyses were carried out, including evaluating the effect of various data weighting, the exclusion of the commercial trawl index, and different selectivity assumptions.

The 2023 assessment for west coast South Island ling (LIN 7WC) estimated the initial spawning stock biomass at about 62 200 t, and status in 2023 at about 51% of initial biomass. The stock size had been declining since 2013, and year class strengths were estimated below average since 2010. The present updated assessment estimated the initial spawning stock biomass at 54 144 t and status in 2026 at 34% of initial biomass, with continued lower than average recruitment since 2008.

The reduction in the estimate of initial biomass and current stock status was driven by continued recent low recruitment, as indicated by the retrospective analysis. Because recruitment is assumed to average 1 over the time of the assessment, continued lower than average recruitment results in a reduction of the estimated initial biomass, as seen in the retrospective analysis. Results indicated that this stock might have been in a period of low productivity since about 2008.

Agreed reference points for west coast South Island ling include a management target of 40% B_0, a soft limit of 20% B_0, and a hard limit of 10% B_0. B_{2026} was estimated to be very likely to be below the target for the base case model and very unlikely to be below the soft or hard limit and overfishing was likely to be occurring. This conclusion was also sensitive to the assumed natural mortality, with 2026 status ranging from 29.9% to 38.4% of B_0 across the sensitivity runs.

Five-year projections indicated that, under recent or a continued decline in recruitment, the spawning stock biomass would continue to decline even with a 30% reduction in recent catches and would be likely to breach the limit reference point in 2031 at that level of catch. This probability was higher under continued declining recruitment (ARIMA-based projections) than under recent recruitment levels.

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1. INTRODUCTION

Ling (*Genypterus blacodes*) is an important commercial species with adults found throughout the middle depths of the New Zealand Exclusive Economic Zone (EEZ) typically in depths of 100 m to 800 m (Mormede et al. 2021, 2022, 2023a). Ling are caught mainly by deepwater trawlers, often as bycatch in hoki (*Macruronus novaezelandiae*) target fisheries, by demersal longliners, and more recently by potting.

Ling are managed as eight administrative Quota Management Areas (QMAs), with five of these QMAs (LIN 3, 4, 5, 6, and 7) reporting about 95% of landings. There are at least four major biological stocks of ling in New Zealand waters (Horn 2005)—the Chatham Rise (LIN 3&4), the Sub-Antarctic (including the Stewart-Snares shelf and Puysegur Bank – LIN 5&6, and the Bounty Platform – LIN 6B), the west coast of the South Island (LIN 7WC), and Cook Strait (LIN 7CK). LIN 5&6 contributes the highest ling catches, followed by LIN 3&4 then LIN 7WC.

In this analysis, catches from Statistical Area 032 were included in the west coast of the South Island based on the continuity of catches along the depth contour along Statistical Areas 032, 033, and 034 (Mormede et al. 2023a). Based on the difference in ling growth between LIN 7WC and LIN 5&6, this stock boundary was corroborated (Mormede et al. 2024a).

The last assessment for LIN 7WC was carried out by Mormede et al. (2024b), who reported that the base case initial spawning stock biomass was about 62 200 t, and current status was about 51% of initial biomass. The stock size had been declining from about 75% of initial biomass in 2013, and recruitment multipliers had been below average since 2010.

This report fulfils Specific Objective 2 of Project LIN2025-01 funded by Fisheries New Zealand. The Overall Objective was 'To carry out a stock assessment of ling (*Genypterus blacodes*) from the west coast of the South Island including estimating biomass and sustainable yields.' Specific Objective 2 was 'To complete a stock assessment for LIN 7 including estimates of current biomass and yields, the status of the stock in relation to management reference points, and future projections of stock status as required to support management.'

2. METHODS

2.1 Model structure

An age-based statistical catch-at-age stock assessment was carried out for west coast South Island ling using the stock assessment program Casal2 v24.02 (2024-02-21) (Casal2 Development Team 2024). The stock assessment model assumed a Beverton-Holt stock-recruit relationship with ages 1–28, with the oldest age a plus group. The model was a two-sex model with a maturity ogive. The model structure was incrementally changed from the previous assessment model.

In this document, 'year' always refers to the model year unless specifically otherwise stated. The model time steps were modified to the new model year. The model's annual cycle is described in Table 1.

Table 1: LIN 7WC annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	*M**	Age†	Description	%*Z*‡
1	Jan-Dec	Recruitment	1.0	0.0		
		Spawning				
		Fishery (longline)			Longline catch-at-age	0.5
					Longline CPUE	
		Fishery (trawl)			Trawl catch-at-age	0.5
					Trawl CPUE	
					Tangaroa Trawl survey biomass and catch-at-age	
2	End of Dec	Increment ages	0.0	1.0		

* *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
† Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
‡ %*Z* is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

2.2 Inputs

The updated catch histories, commercial bottom trawl and bottom longline fishery CPUE series, age compositions, and estimates of biological parameters are described by Mormede et al. (2026). The commercial CPUE series were assumed to include a 1% annual learning rate. Although potting is becoming an important part of this fishery, there are no age data available for potting in LIN 7WC and potting was assumed to have the same selectivity as bottom longline, as assumed in the other ling stocks that include potting catches (Mormede et al. 2023b).

The west coast South Island *Tangaroa* trawl survey index and age compositions were used in all model runs. This survey covered the northern part of LIN 7WC where the majority of the commercial bottom trawl fishing for ling occurs, but does not cover the area where the bottom longline fishing occurs as well (Mormede et al. in prep). All age composition series were provided to the model as sexed observations with ages 1 to 28 (with 28 as a plus group).

A summary of all observations used in the assessment models and the associated time series is given in Table 2. The input parameters used are summarised in Table 3 and Table 4. A lognormal distribution was assumed for all relative biomass observations (i.e., the trawl survey and CPUE indices). The coefficients of variation (CVs) available for the observations of relative abundance allowed for sampling error only. Process error, assumed to arise from differences between model simplifications and real-world variation, was added to the sampling variance and estimated during the Maximum Posterior Density (MPD) estimation. Multinomial errors were assumed for all age composition observations. The effective sample sizes for the composition samples were estimated following the method TA1.8 described in Appendix A of Francis (2011).

Table 2: Observations used in the west coast South Island ling stock assessment model

Data series	Model years
Trawl survey biomass (*Tangaroa*)	2000, 2012–13, 2016, 2018, 2021, 2024
Trawl survey proportion at age (*Tangaroa*)	2000, 2012–13, 2016, 2018, 2021, 2024
LIN 7WC CPUE (bottom longline)	1990–2025
LIN 7WC CPUE (bottom trawl)	1997–2025
LIN 7WC commercial longline proportion-at-age	2012, 2015–18, 2020, 2021, 2024
LIN 7WC commercial trawl proportion-at-age	1994–03, 2005–08, 2012–18, 2020–21, 2023–25

Table 3: **Input parameters used in the ling stock models for the west coast of the South Island (LIN 7WC).**

Relationship	Reference	Parameter (units)	Value Both	Male	Female
von Bertalanffy growth	(Mormede et al. 2026)	t_0 (y)		-0.1	-0.1
		k (y^{-1})		0.13	0.11
		L_∞ (cm)		126.1	148.9
		CV		0.09	0.09
Length-weight	(Mormede et al. 2023a)	a ($g.cm^{-1}$)		$1.31e^{-6}$	$0.98e^{-6}$
		b		3.292	3.362
Stock recruitment relationship					
Stock recruitment steepness	(Kienzle 2021)	h	0.84		
Recruitment variability	(Fisheries New Zealand 2025)	σ_R	0.6		
Ageing error	(Fisheries New Zealand 2025)	CV	0.05		
Proportion male at birth			0.5		
Proportion of mature that spawn			1.0		
Maximum exploitation rate (U_{max})			0.6		

Table 4: **Maturity-at-age used in the ling stock models for the west coast of the South Island (LIN 7WC) (from Horn 2005).**

Age	3	4	5	6	7	8	9	10	11	12
Male	0.0	0.015	0.095	0.39	0.77	0.94	1.00	1.00	1.00	1.00
Female	0.0	0.004	0.017	0.06	0.18	0.39	0.65	0.85	0.94	1.00

2.3 Estimation of parameters

The logarithm of initial spawning stock biomass (B_0) was estimated in the model. All selectivity ogives were estimated and assumed to be logistic curves. A sensitivity run in which the trawl selectivities were estimated as a double normal showed that this parameterisation had little effect. Estimated parameters are summarised in Table 5.

Because no potting trips have been observed in LIN 7WC, the potting fishery was assumed to have the same selectivity as the longline fishery following the analysis carried out for LIN 3&4 (Mormede et al. 2022). Selectivities were assumed constant across all years in each of the fisheries and for the survey. Instantaneous natural mortality (M) was assumed at 0.18 y^{-1} for both sexes and to be constant at age in the model (Horn 2008). An attempt to estimate natural mortality for this stock was unsuccessful in 2023, with the estimation being both highly uncertain and biased (Mormede et al. 2024b).

Most of the priors were assumed to be relatively uninformative (i.e., uniform or uniform-log) and were specified with wide bounds. In all models, the catchability coefficients (qs) for either the survey or the CPUE index were estimated as free parameters (Table 5).

Annual recruitments were modelled as a recruitment multiplier (i.e., year class strengths) with a lognormal distribution using the simplex method (also known as a broken stick approach: the sum of the parameters equals 1). The simplex method rescales n parameters as n-1 parameters with the constraint that they average one, making it a natural transformation for the estimation of annual recruitment multipliers with the constraint that they have mean one over some year range.

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was penalised. In the models that did not use the simplex method to constrain annual recruitment multipliers, a small penalty was applied to the estimates to encourage estimates that averaged one.

MPD estimates were used to compare diagnostics and fits between models. For final runs, the full posterior distribution was sampled using Markov chain Monte Carlo (MCMC), based on the Metropolis-Hastings algorithm. Three MCMC chains with a total length of 3×10^6 iterations each were constructed. A burn-in length of 1×10^6 iterations was used, with every 1000th sample taken from the final 2×10^6 iterations (i.e., a final sample of length 2000 was sampled from the posterior for each of the three independent chains).

Table 5: Parameters estimated in the ling stock models for the west coast of the South Island (LIN 7WC).

Parameter description	Distribution	Initial value	Parameters		Bounds	
B_0	uniform-log	200 000	–	–	10 000	500 000
Year class strength multipliers	lognormal	1	1.0	0.6	0.01	100
Tangaroa survey q	lognormal	0.3	0.07	0.70	0.001	1
Trawl CPUE q	uniform-log	0.5	–	–	0.4	3
Longline CPUE q	uniform-log	0.5	–	–	0.01	3
Trawl fishery selectivity a_{50} (logistic)	uniform	13	–	–	1	30
Trawl fishery selectivity a_{to95} (logistic)	uniform	7	–	–	1	30
Trawl survey selectivity a_{50} (logistic)	uniform	13	–	–	1	50
Trawl survey selectivity a_{to95} (logistic)	uniform	7	–	–	1	100
Longline fishery selectivity a_{50} (logistic)	uniform	13	–	–	1	60
Longline fishery selectivity a_{to95} (logistic)	uniform	4			1	200

* A range of maximum values was used for the upper bound.

3. RESULTS

3.1 Update of the 2023 model

The 2023 base case (Mormede et al. 2024b) was used as the starting point for model development. The 2026 initial model was developed by making incremental changes to the 2023 base case, including providing sex-disaggregated age composition data, updating catches, biological parameters, and observations. Reweighting of the data was only done once the final data and model structure had been updated, to allow comparison of the models throughout this process. This excludes estimates of process errors, which were still estimated within the model. Details of the steps are given in Table 6.

Updating the observations to sex-specific age-composition observations had the greatest influence on the model. The update of the growth curve and catches had little effect on the model. Once the data were re-weighted, the 2026 initial case had lower estimates of initial biomass and status in 2023 (Table 7).

An initial investigation into this initial model indicated that the survey catchability priors (q) had an undue influence on the model outcomes. The priors were modified from a logistic prior to a uniform prior. This resulted in a slight drop in initial biomass and stock status, due to a slight drop in the estimated survey catchability coefficients q (Table 7).

The updated model suggested a continued decline in the year class strengths in recent years. The model was updated to estimate recruitment up to 2020 instead of 2018, to capture this continued decline better. MCMCs indicated that the last two years of estimates were still below average, and well estimated (see below). Finally, the final model included bottom longlines and bottom trawl CPUE indices, resulting in a slight increase in initial biomass and status in 2026 (Table 7).

Table 6: Incremental model build from the 2023 base case to the 2026 initial model run at MPD level. The data were not re-weighted between models. Objective function values that are not comparable due to changes in data inputs are given in grey.

Run	Model description	Objective function	B_0 (t)	SSB_{2023} (t)	SSB_{2023} (% B_0)
R6.4_2023	base 2023	879	62 968	35 167	55.8
R0.1	update biological parameters	878	61 007	35 210	57.7
R0.2	update catches	878	60 506	34 457	56.9
R0.3	update observations	1 960	56 615	28 208	49.8
R0.4	update to 2026	2 740	53 571	22 882	42.7

Table 7: 2023 base and 2026 main models MPD estimates, once data were re-weighted.

Run	Model description	B_0 (t)	SSB_{2023} (t)	SSB_{2023} (% B_0)	SSB_{2026} (t)	SSB_{2026} (% B_0)
R6.4_2023	base 2023	62 968	35 167	55.8		
R1.0	initial	58 918	28 248	47.9	24 510	41.6
R2.0	uniform q priors	49 743	17 927	36.0	14 360	28.9
R3.0	YCS to 2020	52 297	22 201	42.5	17 086	32.7
R4.0	Base case	54 241	24 341	44.9	18 621	34.3

3.2 Additional sensitivity runs

A range of sensitivity runs were carried out to investigate different parts of the model. A summary of the main sensitivity runs is detailed below.

The bottom longline age compositions were deemed unreliable due to the paucity of lengths (Mormede et al. in prep). The effect of this time series on the model was investigated by arbitrarily reducing its data weight to half or a quarter of its calculated weight. The outcomes remained unchanged.

The last and lowest point of the bottom longline CPUE and survey biomass series could not be fitted by the models, with the expected value higher than the observed value. The removal of the trawl CPUE index, deemed less reliable, did not improve the fits. Neither did down weighting the two CPUE series. Removing the 1% learning rate from the CPUE series improved the fit to the survey biomass marginally but reduced the fit to the bottom longline CPUE series. Increasing the number of year class strengths estimated (R3.0, see above) did not improve the fits to the last point of the survey.

The process error of the biomass indices was estimated at MPD level, at values of 0.02 for the survey, 0.12 for the bottom longline CPUE and 0.09 for the bottom trawl CPUE in the base case model. An alternative approach used in some other stock assessments is to arbitrarily set these at 0.2 for CPUE series and 0.1 for survey series. This option was tested and yielded almost identical results.

The use of cohort-based age compositions developed for ling in LIN 7WC (Mormede et al. in prep) was tested as alternative data series. Results were similar to the base case model at the population level, but the fits to the age composition data presented some residuals that require further investigations. It is proposed that this method continues to be developed and tested alongside current methodologies.

Sensitivity runs were carried out with regard to the commercial trawl selectivity. For the base case, the commercial trawl selectivity was assumed logistic as per previous analyses (Mormede et al. 2024b). This assumption was once again tested, by running a model with a double normal selectivity. The resulting trawl selectivity was estimated as very slightly domed, resulting in a slightly higher initial biomass at MPD level. As in 2023, the logistic selectivity was retained for the base case model.

As in previous assessments (Kienzle 2021; Mormede et al. 2024b), the survey trawl selectivity was estimated well to the right of other survey selectivities for ling, such as that of the Chatham Rise for example (Mormede et al. 2023b). A sensitivity run was carried out whereby the survey selectivity was assumed equal to that estimated for the Chatham Rise survey. This resulted in poor fits to the survey age composition data (Figure 1) and was deemed unacceptable. Although the gear selectivity of ling in both surveys is expected to be identical given that the fishing gear is identical, the availability of ling at age is clearly different in those two surveys, with younger ling not as well represented in the west coast trawl survey as they are on the Chatham Rise.

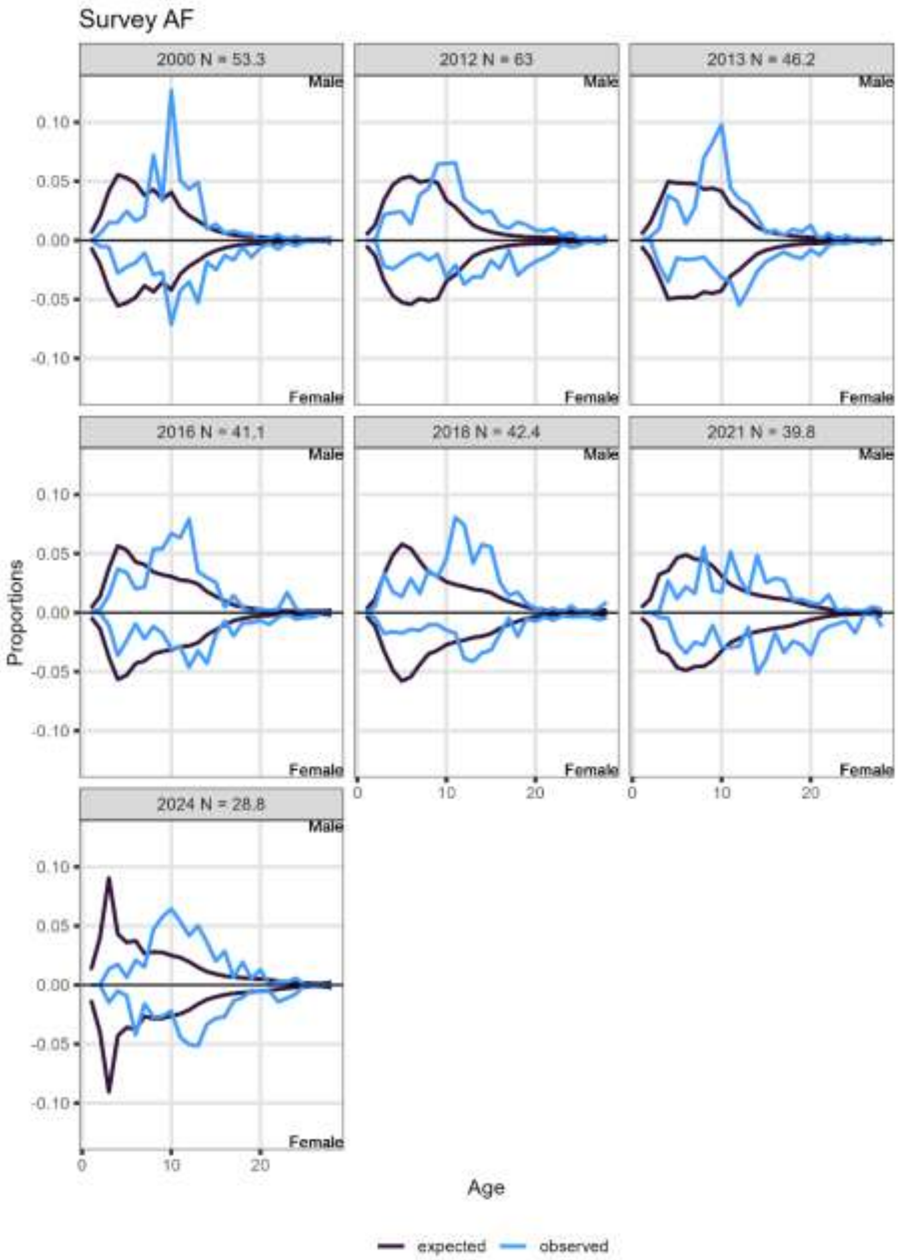

Figure 1: MPD fits to the trawl survey age composition data when assuming that the survey trawl selectivity is identical to that estimated for the Chatham Rise trawl survey (Mormede et al. 2023b). The effective sample size after reweighting is also provided for each year.

3.3 Final base case model

The base case of the 2026 stock assessment of west coast South Island ling (LIN 7WC) included catches, the west coast South Island survey biomass indices and sexed age compositions, and the commercial bottom longline and bottom trawl standardised CPUE (with a 1% learning rate) and sexed age compositions. The observation data included in the base case model and their associated error values are detailed in Figure 2. Natural mortality was fixed at 0.18 y^{-1}. Models with alternative natural mortality values of M = 0.16 y^{-1} and M = 0.20 y^{-1} were conducted as per previous stock assessments.

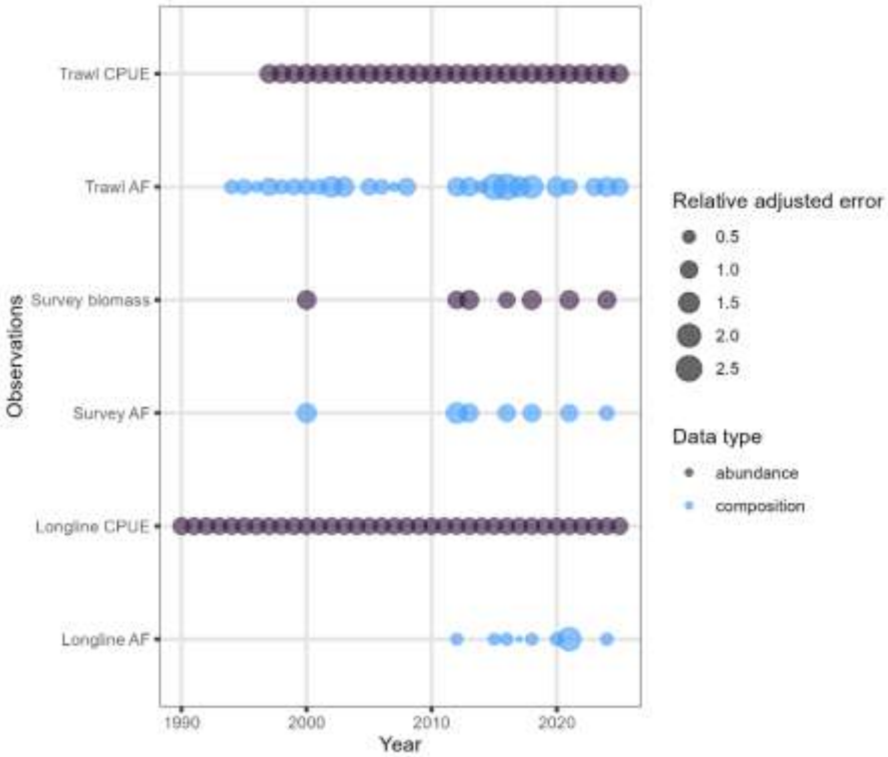

Figure 2: Observations included in the base case model and their relative adjusted error (CV and additional process error combined). The adjusted errors of abundance and age composition data are not comparable and are plotted as different colours. AF represents age compositions.

The base case estimated that B_0 was 54 144 t for this stock, and that biomass for 2026 was 34% of B_0. The 95% credible interval of stock status estimates for 2026 from the base case and all sensitivity runs were in the range of 30–38% of B_0. The probability of the 2026 status being above 40% B_0 was 2.7% for the base case, and the probability of it being below 20% B_0 was 0% in all instances (Table 8).

Table 8: LIN 7WC. Posterior median and 95% credible intervals (in parentheses) of B_0 (in tonnes), and B_{2026} as a percentage of B_0, and the probability that B_{2026} is above 40% and below 20% of B_0 from the base model and sensitivity runs.

Model run	B_0		B_{2026} (% B_0)		P(>40% B_0)	P(<20% B_0)
Base case	54 144	(50 096 – 59 413)	34.0	(28.9 – 40.1)	0.027	0
M = 0.16	51 917	(48 928 – 55 904)	29.9	(25.1 – 35.5)	0.000	0
M = 0.20	58 180	(52 266 – 66 996)	38.4	(32.3 – 45.1)	0.313	0

Biomass estimates for the stock have been variable and generally declining since the start of the model in 1973, with continued sharp decline since 2012 (Figure 3). Posterior distributions of year class strength from the base case model are shown in Figure 4. Year classes were generally more uncertain at the start of the series. They also show continued decline since 2003 and lower than average recent recruitment since 2008. The overall stock exploitation rate showed an increase to 2000, decline to about 2008, and increase again since then, to the highest levels seen in the model (Figure 5).

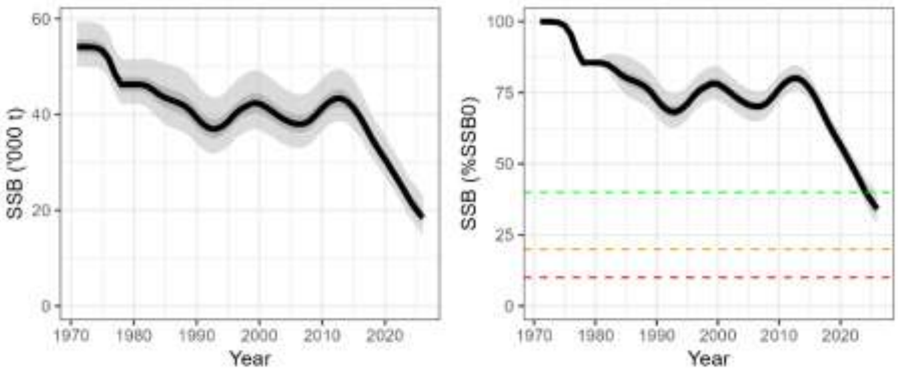

Figure 3: West coast South Island ling estimated posterior distribution of the spawning stock biomass (*SSB* in tonnes, left) and of the proportion of initial spawning biomass (% SSB_0, right) trajectory with estimated initial spawning stock biomass reference points (40%, 20%, and 10% B_0) for the base case model. The solid black line represents the median values, the dark grey shading indicates the interquartile range, and light shading indicates the 95% credible interval.

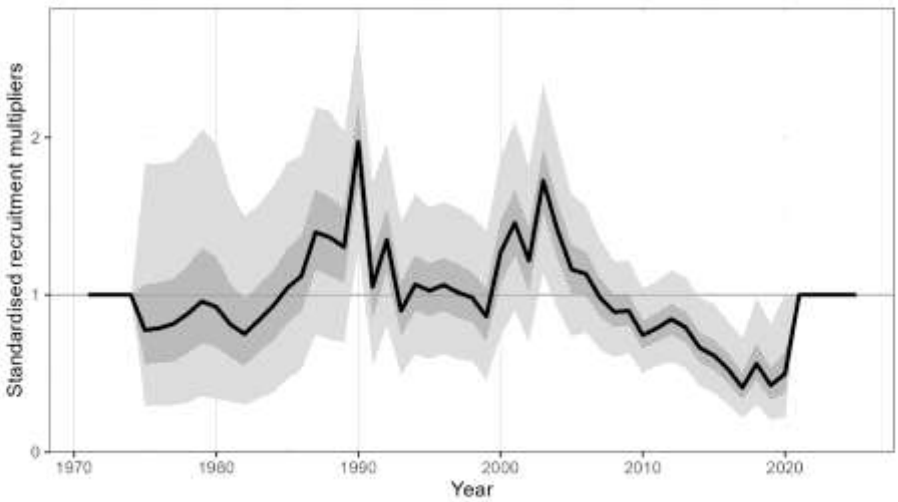

Figure 4: West coast South Island ling estimated posterior distributions for standardised recruitment multipliers from the base case run, with median (line), the interquartile range (dark grey), and 95% credible interval (light grey). The horizontal line indicates a recruitment multiplier value of one.

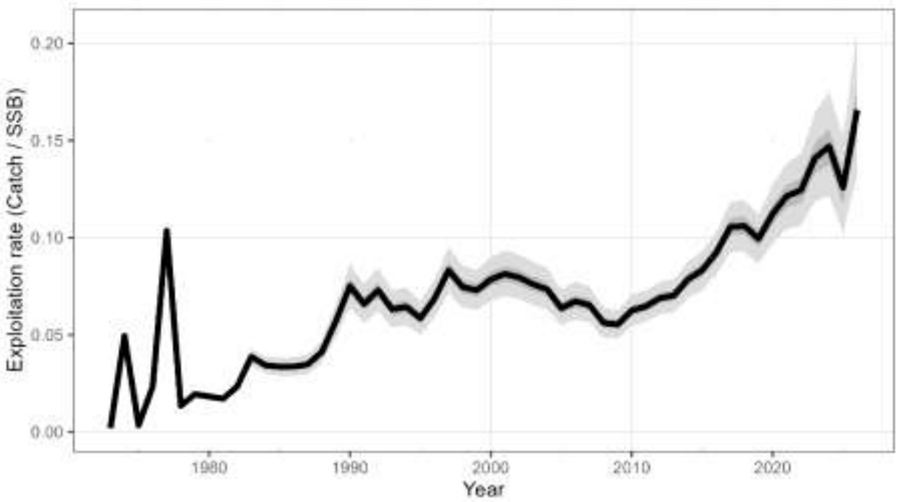

Figure 5: West coast South Island ling base model overall exploitation rate expressed as catch (in tonnes) divided by spawning stock biomass (SSB, in tonnes) with the interquartile range (dark grey) and 95% credible interval (light grey).

Selectivities were estimated with relatively narrow credible intervals (Figure A.1 of Appendix A for the base case) and were virtually identical between model runs. Fits to the age composition data were adequate (Figure A.2 and Figure A.3 for the base case), and almost identical between model runs (not shown). Fits to the abundance indices generally captured the trends over time within the confidence bounds of each series, although the model could not fit to the last longline CPUE and survey biomass data point in the base case or any sensitivity run (Figure A.4 for the base case).

There was no evidence of a lack of convergence of the MCMCs (Figure A.5). Multichain diagnostic using approximate $\hat{r}$ statistics (Vehtari et al. 2017) did not suggest any evidence of non-convergence (Figure A.6). Trace plots also showed no evidence of failure to converge for the base case model (Figure A.7 and Figure A.8) or the sensitivity runs (not shown).

A plot of the stock recruitment relationship indicates that all recent recruitment were below expected values (Figure 6), as seen in the annual year class strength plot (Figure 4), indicating that this stock might have seen a change in productivity since 2010.

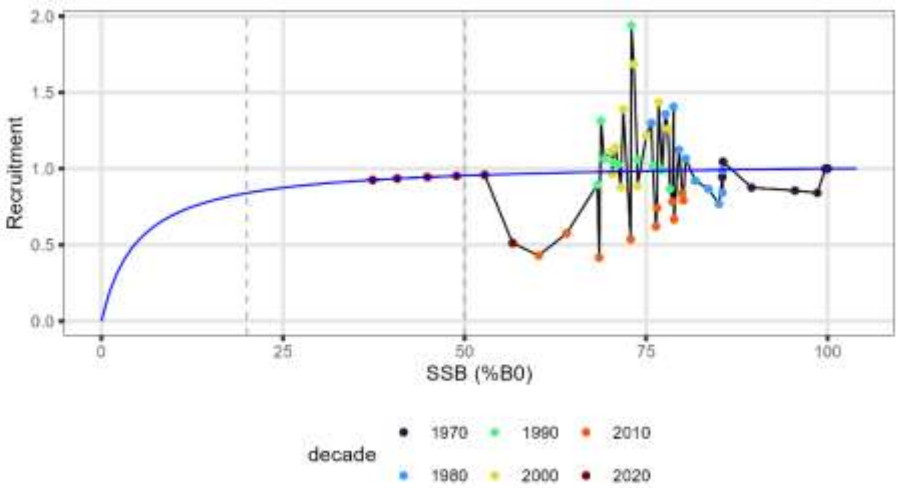

Figure 6: West coast South Island ling stock recruit relationship, with spawning stock biomass (SSB) as a proportion of initial spawning stock biomass (B_0) plotted against recruitment strength for each year of the model. The assumed stock recruit relationship with steepness of 0.84 is plotted as a blue line. The decades are colour coded.

3.4 Retrospective analysis

A retrospective analysis was carried out on the base case model, whereby an increasing number of recent years of data were removed from the model, which was then rerun to MPD level. Results indicated that as more data were available to the model, the initial biomass was re-estimated lower than previously, but the biomass trajectory remained identical (Figure 7). Furthermore, the estimated year class strengths were similar between model runs up to recent years: recent year-class strengths were systematically re-estimated lower as more data were available (Figure 8).

The current assessment is consistent with the 2023 assessment despite resulting in quite a different stock status. In 2023, recruitment had been estimated lower than average since 2010. In this assessment the trend continued, with the most recent year class strength estimated at about half of average recruitment. Because recruitment is assumed to average 1 over the time period of the assessment, continued lower than average recruitment results in a reduction of the estimated initial biomass, as seen in the retrospective analysis.

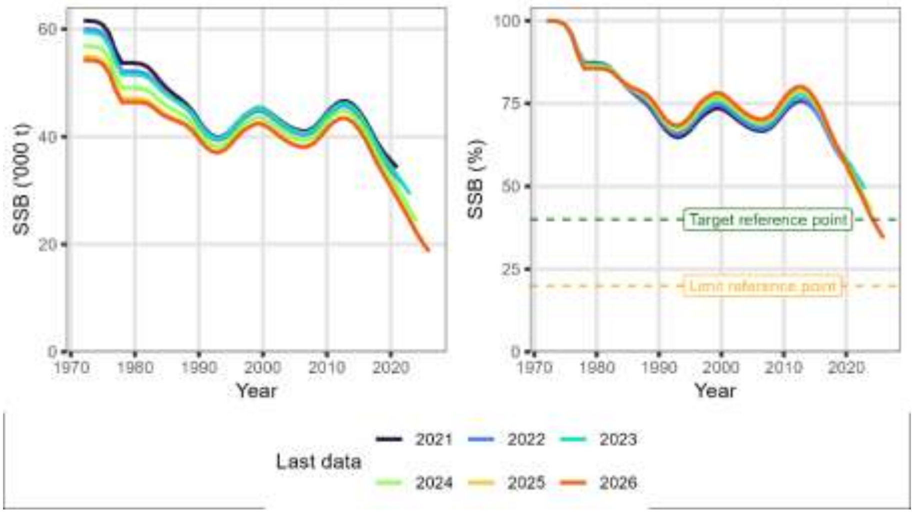

Figure 7: West coast South Island ling retrospective analysis: MPD estimate of the spawning stock biomass (*SSB* in tonnes, left) and of the proportion of initial spawning biomass (% SSB_0, right) trajectory with estimated initial spawning stock biomass reference points (40% and 20%) for the various retrospective model runs, colour coded by the last year of data included in the model.

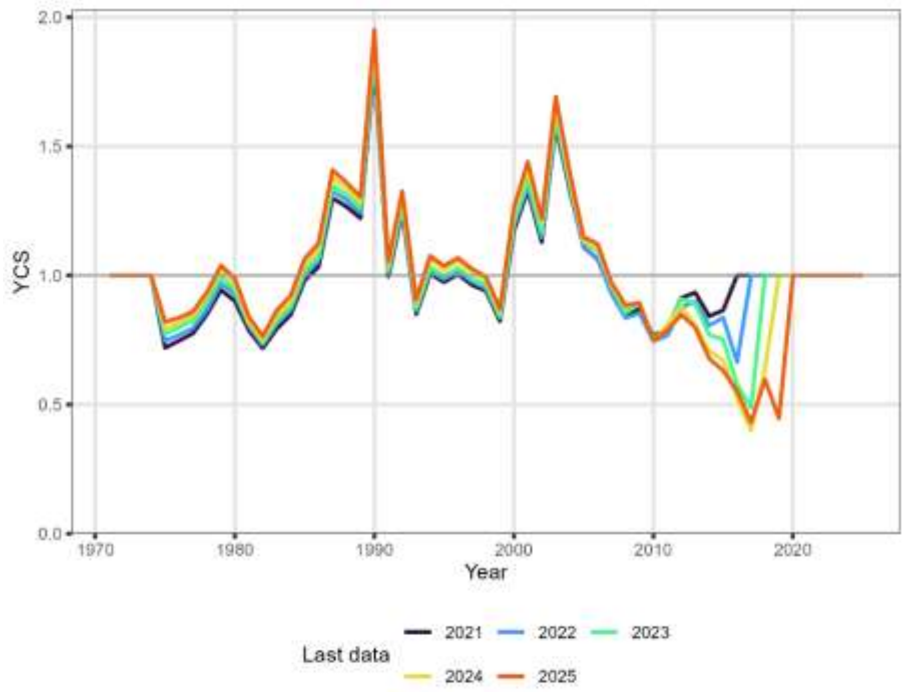

Figure 8: West coast South Island ling retrospective analysis: MPD estimate of the year class strength series for the various retrospective model runs, colour coded by the last year of data included in the model. Values at 1 were not estimated.

3.5 Projections

Projected recruitment

Because recent recruitment has been decreasing since 2003 and lower than average since 2007 (Figure 4), two alternative assumptions for future recruitment were assumed for the projections: that future recruitment will follow the most recent years of recruitment (arbitrarily chosen as the last five years estimated: 2016–2020, with additional sensitivity runs carried out), or that future recruitment will continue to follow the recent trend. This trend was determined by developing an Autoregressive

Integrated Moving Average (ARIMA) model using all the MCMC estimates of recruitment from the base case model. Developed by Box & Jenkins (1976), ARIMA models are designed to understand past data or predict future values by analysing trends, and the autocorrelation inherent in the data.

The ARIMA modelling of the estimated recruitment multipliers was carried out over all MCMC chains separately. Results indicated strong support for a slope (d = 1) and some support for one- and two-year autocorrelation of the year class strengths (p = 1 or 2, Figure 9). The resulting predicted recruitment multipliers were more uncertain that the recruitment multipliers resampled over the 2016–2020 period, and with a small downward trend (Figure 10).

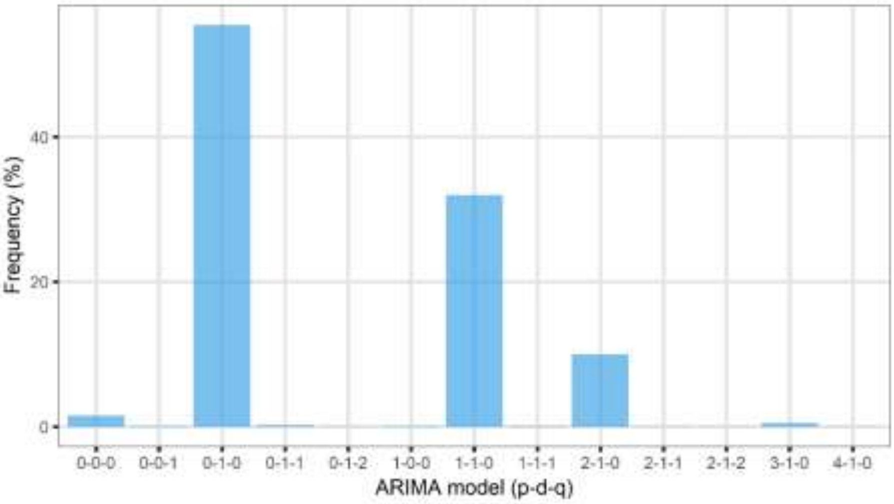

Figure 9: LIN 7WC: frequency of estimation of the ARIMA parameters p (order of the autoregressive component), d (degree of differencing – the slope), and q(order of the moving average) over all MCMC chains.

Future YCS resampled from 2016-2020 estimates

Future YCS estimated using ARIMA model

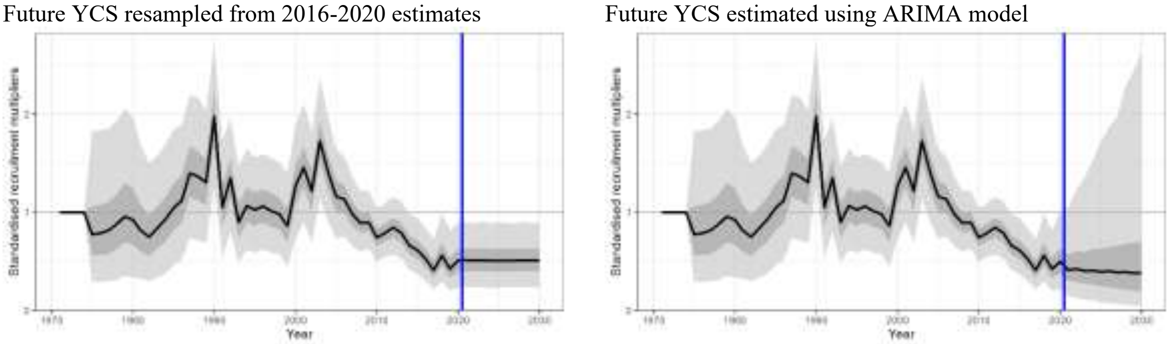

Figure 10: LIN 7WC base model projections: Future recruitment multipliers under the assumption of recent recruitment (left) or continued trend in recruitment (right) with the interquartile range (dark grey) and 95% credible interval (light grey). The blue line represents when recruitment multipliers start being assumed.

Projected stock status

Because recruitment has been below average since 2008 and declining since 2003, projections indicated that the spawning stock biomass would continue to decline even with a 30% reduction in recent catches and would most likely breach the limit reference point in 2031 at that level of catch (Table 9). Although both recent recruitment and continued recruitment trends provided similar projections over five years on average, the projected recruitment using ARIMA predictions were more uncertain, leading to a higher probability of breaching the soft limit.

A large range of potential future recruitment and future catch scenarios were carried out and are summarised in Figure 11 for stock status at the end of the projections in 2031 and Figure 12 for the probability of being below 20% of initial stock biomass in 2031.

Table 9: LIN 7WC. Bayesian median and 95% credible intervals (in parentheses) of projected B_{2031} as a percentage of B_0, and B_{2028}/B_{2026} (%) for the base case model run. The probability of B_{2031} being above 40% B_0 (p_{40}) and of B_{2031} being below 20%B_0 (p_{20}) are also reported. Two assumptions of future recruitment are presented: as per the 2016–2020 YCS (top) or continuing trend as estimated using ARIMA models (bottom).

Catch range	Future catch (t) Trawl	Line/Pot	B_{2031} (t)		B_{2031} (%B_0)		B_{2031} (%B_{2026})		p_{40}	p_{20}
Future YCS continued trend estimated using ARIMA model										
2024–2025	1 009	1 875	10 136	(4 830 – 22 010)	19	(9-40)	55	(30-113)	0.02	0.57
80%	807	1 500	12 146	(5 958 – 24 061)	22	(11-43)	66	(38-123)	0.04	0.36
70%	707	1 312	13 158	(6 955 – 25 086)	24	(13-45)	71	(43-128)	0.05	0.25
No catch	0	0	20 330	(14 152 – 32 254)	38	(27-58)	110	(86-167)	0.37	0.00
Future YCS resampled from the 2016–2020 estimates										
2024–2025	1 009	1 875	11 165	(6 923 – 18 188)	21	(13-32)	61	(44- 83)	0.001	0.45
80%	807	1 500	13 205	(8 112 – 20 252)	24	(16-36)	72	(52-93)	0.004	0.18
70%	707	1 312	14 224	(9 083 – 21 280)	26	(18- 38)	77	(59-98)	0.010	0.09
No catch	0	0	21 388	(1 6262 – 28 443)	39	(31-50)	117	(100-136)	0.454	0.00

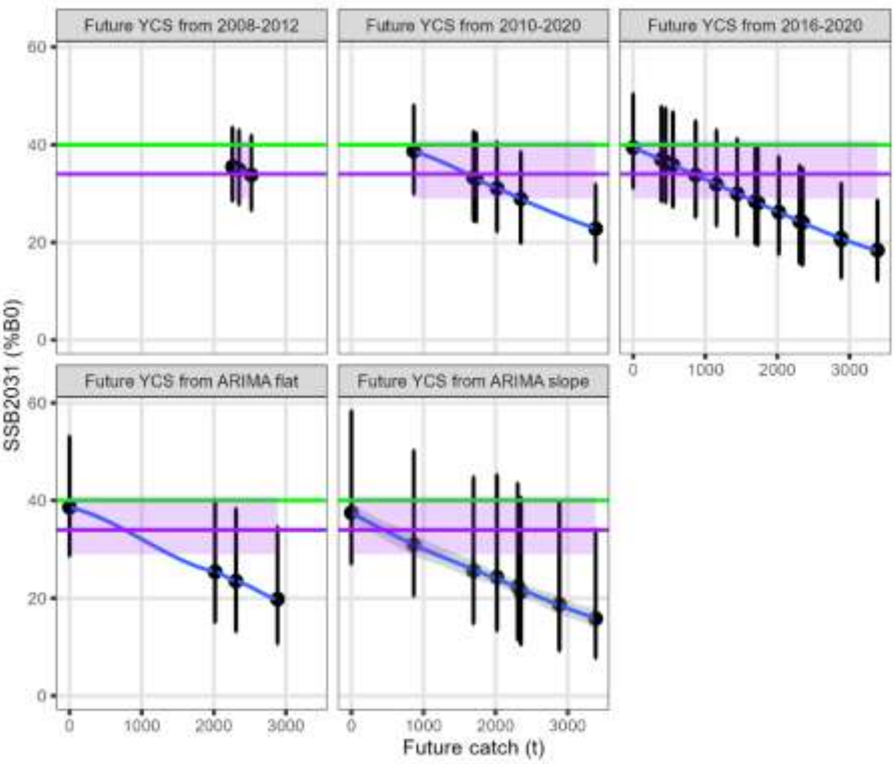

Figure 11: LIN 7WC base model projections: Median and 95% credible interval of spawning stock biomass in 2031 as a percentage of initial biomass (y axis) as a function of future recruitment assumptions (panels) and future constant catch (x axis). The purple line and shading represent the median spawning stock biomass in 2026 and 95% credible interval. The green line represents 40% B0. The blue lines are smoothers between the estimated points to aid interpretation. ARIMA flat assumes that there is no trend in the future projected recruitments (ARIMA d = 0).

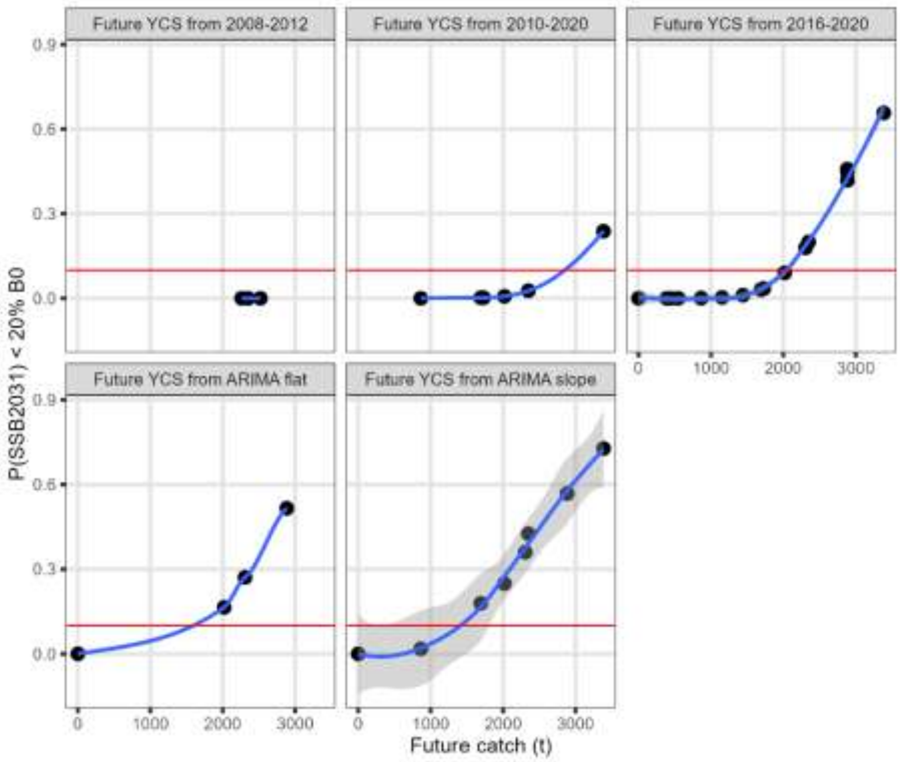

Figure 12: LIN 7WC base model projections: Probability that the spawning stock biomass in 2031 will be below 20% of initial biomass based on various assumptions of future recruitment (panels) and constant catch (x-axis). The red line represents the soft limit: the 10% probability of being below 20% B_0. The blue lines are smoothers between the estimated points to aid interpretation. ARIMA flat assumes that there is no trend in the future projected recruitments (ARIMA d = 0).

3.6 Monitoring of changes that may be due to climate change and environmental variability

A qualitative evaluation of potential effects of environmental or climate change on the stock assessment where productivity may have changed due to environmental fluctuations or climate change is given in Table 10.

Table 10: Summary of the changes that may be due to climate change and environmental variability for west coast South Island ling.

Parameter	Summary
Recruitment	There is evidence of an extended recent period of low recent recruitment with a downwards trend
Age-at-maturity	The survey and observer data indicate a possible increase in the age at maturity of ling in LIN 7WC in the 2021–2025 period, and / or a change in the timing of maturation
Stock recruitment steepness and variability	It is not known if there have been changes in the stock-recruit steepness parameter (*h*). Variability in recruitment has remained relatively constant.
Natural mortality	There was no information to determine if there have been changes in natural mortality over time
Growth	Growth model (von Bertalanffy) residuals by year of observation and year indicates some annual variability in growth, but there was no clear trend over time
Length-weight	There was no evidence of change in length-weight relationship over time

Spatial distribution	Based on the trawl survey distributions, there was no evidence of spatial distribution changes over time
Stock structure	The stock structure does not seem to have changed: Horn (2022) and Mormede et al (2024a) vs Horn(2005)
Locations of spawning and site fidelity	Unknown, as there were few data from which to draw conclusions

4. DISCUSSION

The 2023 assessment for west coast South Island ling (LIN 7WC) estimated the initial spawning stock biomass at about 62 200 t, and status in 2023 at about 51% of initial biomass. The stock size had been declining since 2013, and year class strengths were estimated below average since 2010 (Mormede et al. 2024b). The present updated assessment estimated the initial spawning stock biomass at 54 144 t and status in 2026 at 34% of initial biomass, with continued lower than average recruitment since 2008.

The reduction in the estimate of initial biomass and current stock status was driven by continued recent low recruitment, as indicated by the retrospective analysis. Because recruitment is assumed to average 1 over the time of the assessment, continued lower than average recruitment results in a reduction of the estimated initial biomass, as seen in the retrospective analysis. Results indicated that this stock might have been in a period of low productivity since about 2008. This period coincides with a possible increase in age-at-maturity observed in survey and observer data since 2021 (Table 10), consistent with a broader shift in productivity that should continue to be monitored.

The model trajectory was generally consistent with the survey biomass indices and the commercial CPUE indices, although the last point of the survey biomass series and bottom longline CPUE were both over-estimated. Investigations to the model using sensitivity runs, including excluding or down-weighting the trawl CPUE index and removing the CPUE learning rate assumption, did not resolve this misfit, so the terminal-year status estimate should be treated with some caution pending additional data. The potting fishery is also assumed to share bottom longline selectivity in the absence of age data specific to potting; as potting continues to account for a growing share of total catch, this assumption represents an increasing source of structural uncertainty in the model.

Agreed reference points for west coast South Island ling include a management target of 40% B_0, a soft limit of 20% B_0, and a hard limit of 10% B_0. B_{2026} was estimated to be very likely to be below the target for the base case model and very unlikely to be below the soft or hard limit, and overfishing was likely to be occurring (Figure 13). This conclusion was sensitive to the assumed natural mortality: 2026 status ranged from 29.9% B_0 under M = 0.16 y^{-1} to 38.4% B_0 under M = 0.20 y^{-1} (Table 8), spanning the soft limit under the lower mortality assumption.

Projections indicated that, under recent or a continued decline in recruitment, the spawning stock biomass would continue to decline even with a 30% reduction in recent catches and would most likely breach the limit reference point in 2031 at that level of catch. Projections based on the ARIMA-estimated recruitment trend were more uncertain and carried a higher probability of breaching the soft limit than those based on resampling the 2016–2020 year classes, reflecting the additional uncertainty in extrapolating the recent downward trend.

Several analyses would help reduce uncertainty in future assessments of this stock:
- Length and age sampling of the potting fishery would help to evaluate the assumption that it shares longline selectivity, particularly as potting continues to account for a growing share of the catch.

- Continued development and validation of the cohort-based age composition method would help make better use of the available length frequency data, particularly for the bottom longline fishery.
- Continued monitoring of recruitment and age-at-maturity trends is also recommended, to track whether the apparent shift in productivity since 2008 is persisting.
- As the stock status is going down and recent recruitment has been low, this stock could benefit from an increased rate of monitoring and assessment.

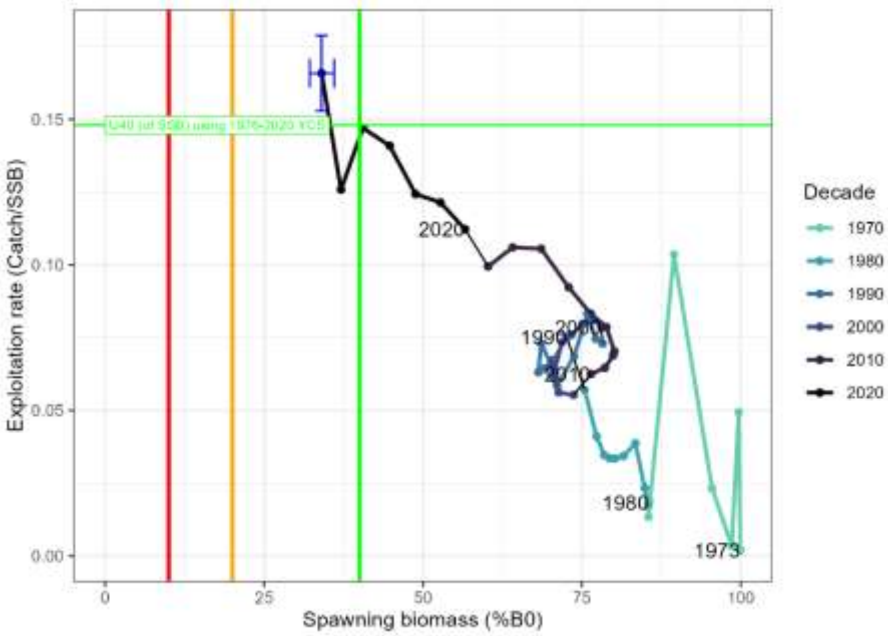

Figure 13: Trajectory over time of exploitation rate (catch/SSB) and spawning biomass (% B_0), for the west coast South Island ling base model from the start of the assessment period in 1973 to 2026. The red vertical line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green lines are the % B_0 target (40% B_0) and the corresponding exploitation rate (catch divided by SSB U_{40} = 0.148 under average recruitment assumptions). Biomass and exploitation rate estimates are medians from posterior distributions for the base model. The blue cross represents the limits of the 95% credible intervals of the estimated ratio of the SSB to B_0 and exploitation rate in 2026.

5. FULFILMENT OF BROADER OUTCOMES

As required under Government Procurement rules[4], Fisheries New Zealand considered broader outcomes (secondary benefits such as environmental, social, economic or cultural benefits) that would be generated by this project. The following broader outcomes were delivered.

Whakapapa links all people back to the land, sea, and sky, and our obligations to respect the physical world. This research aims to ensure the long-term sustainability of ling stocks, for the good of the wider community (including stakeholders and the public) and the marine ecosystems that ling inhabit. This project supports Māori and regional businesses, diversity and inclusion, and our research is inextricably linked to the moana from the work it carries out and the tangata whenua it supports.

[4] https://www.procurement.govt.nz/procurement/principles-charter-and-rules/government-procurement-rules/planning-your-procurement/broader-outcomes/

As part of this project, the team has continued to build capacity and capability in fisheries science and stock assessment, its commitment to zero waste and carbon neutrality, environmental stewardship and social responsibility.

6. ACKNOWLEDGEMENTS

We thank Gretchen Skea (Fisheries New Zealand Deepwater WG Chair), Ian Tuck and Ian Blixt (Fisheries New Zealand reviewers) and members of the Deepwater Fisheries Assessment Working Group for their discussions on this work. We thank the Fisheries New Zealand Data Management Team for the data extracts used in these analyses and the additional assistance and information on interpretation. This work was funded by Fisheries New Zealand under Objective 2 of project LIN2025-01.

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8. Appendix A – Model and diagnostic plots for the base case model

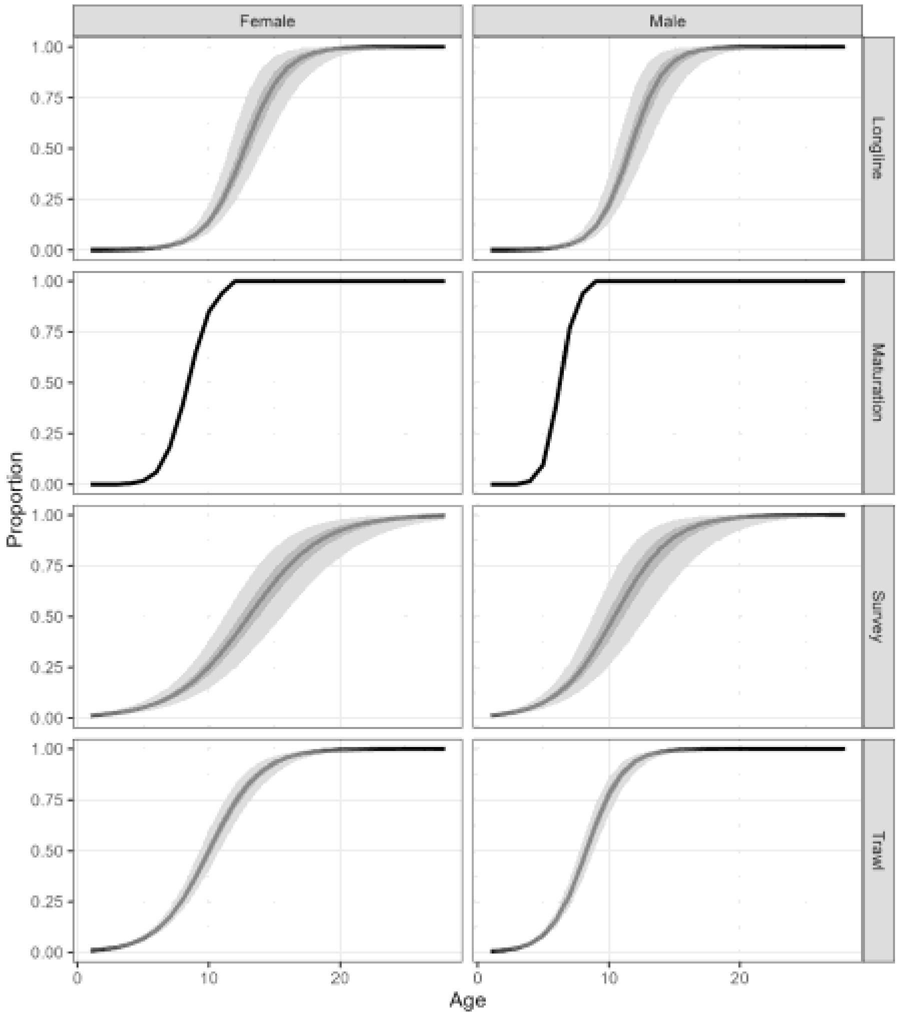

Figure A.1: Selectivity estimates with the interquartile range (dark grey) and 95% credible interval (light grey). Maturation was fixed in the model and is plotted for comparison.

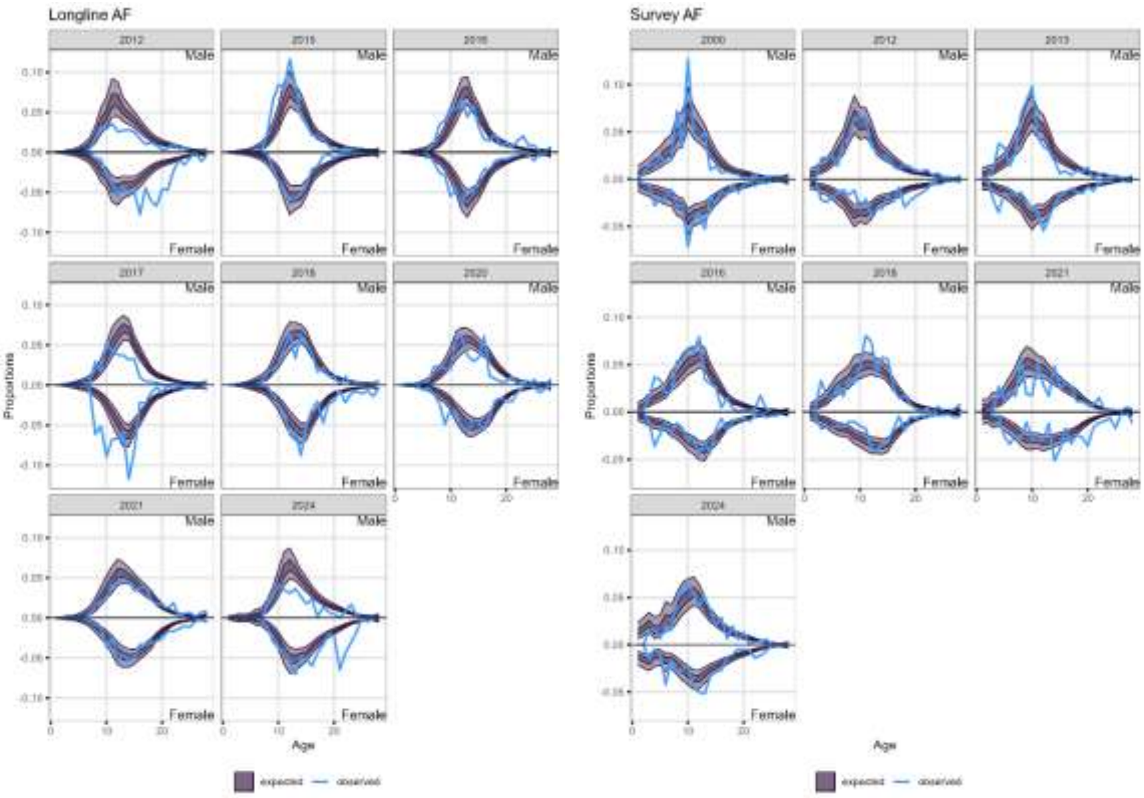

Figure A.2: Fits to the age composition (AF) data for the LIN 7WC bottom longline fishery (left) and the LIN 7WC trawl survey (right) with the interquartile range (dark purple) and 95% credible interval (light purple).

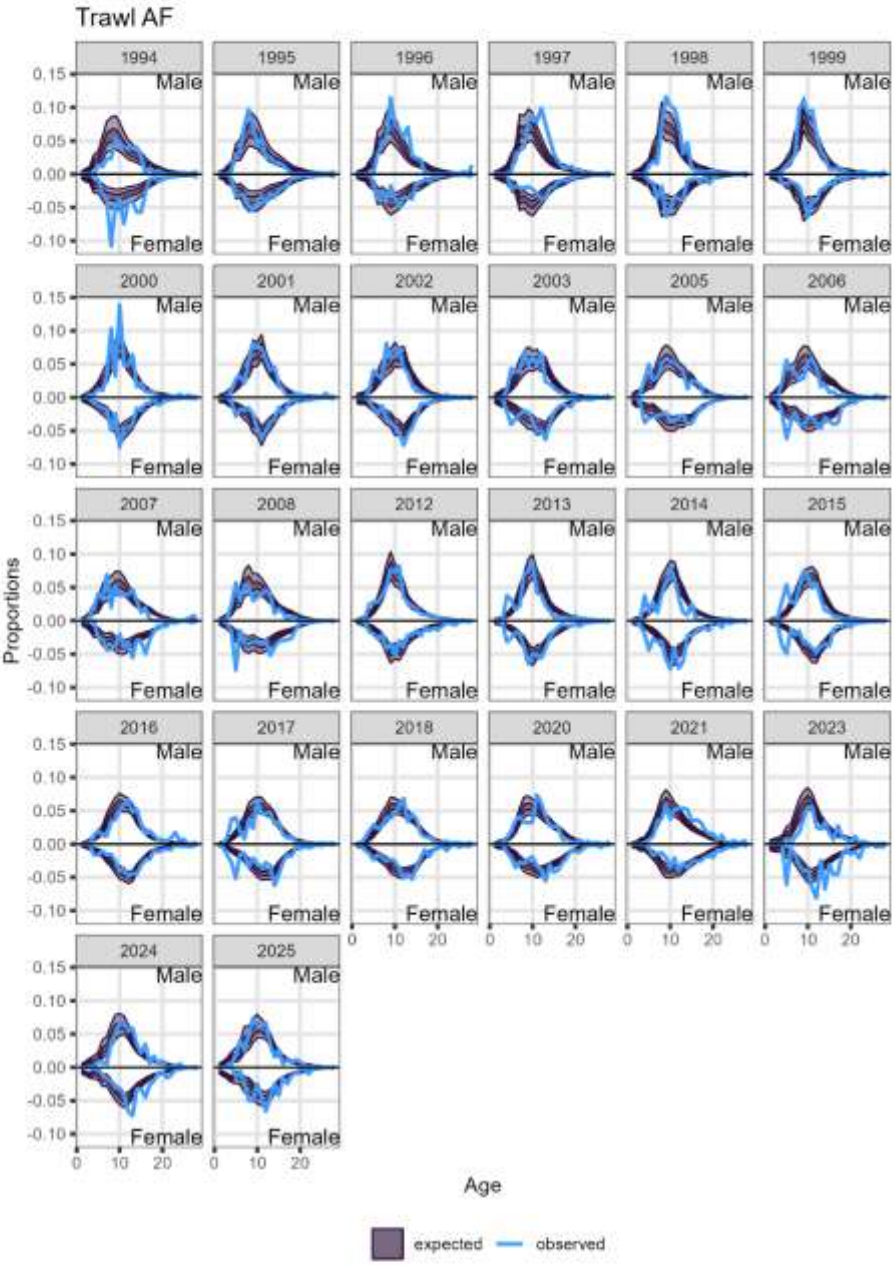

Figure A.3: Fits to the age composition (AF) data for the LIN 7WC bottom trawl fishery with the interquartile range (dark purple) and 95% credible interval (light purple).

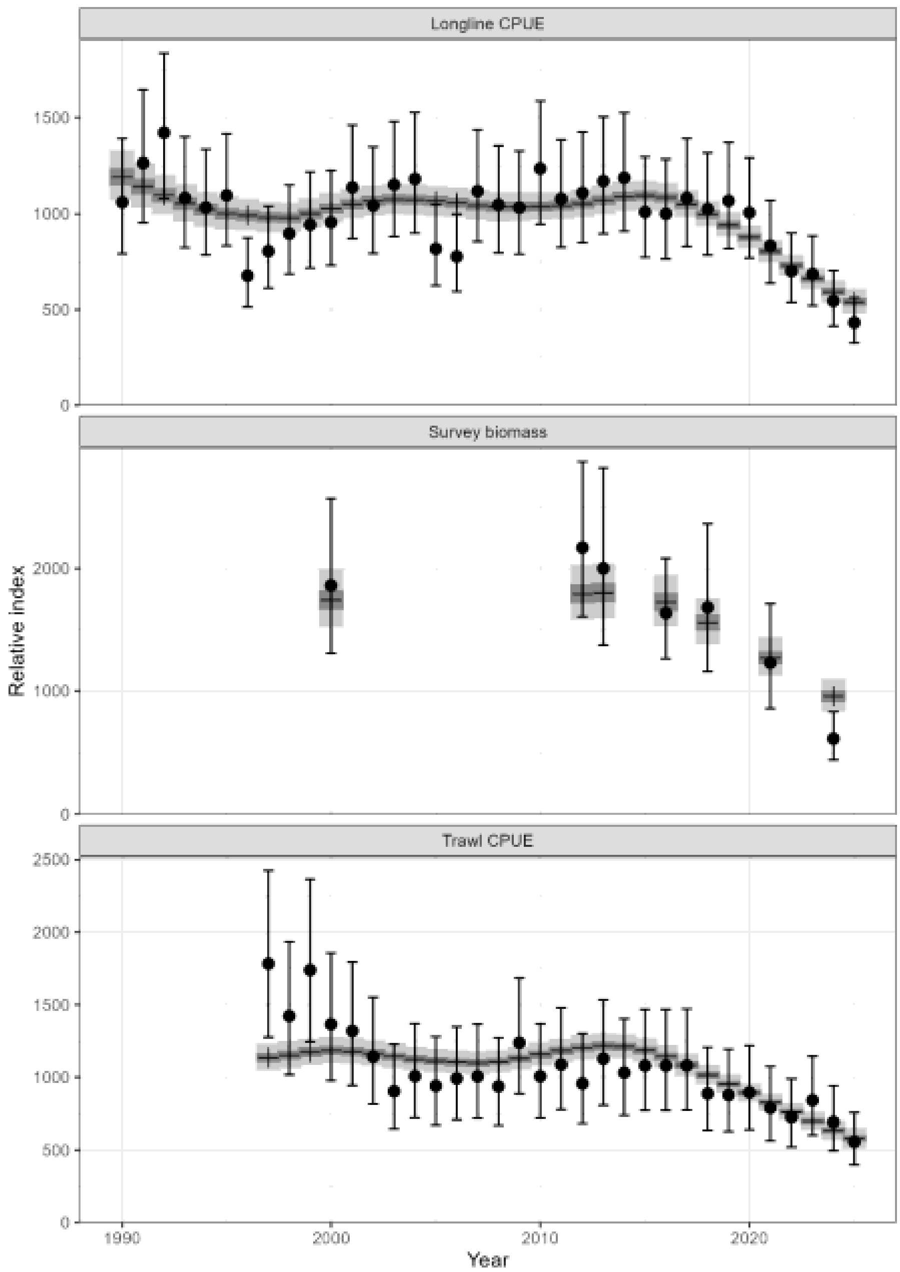

Figure A.4: Fits to the abundance indices with the interquartile range (dark grey) and 95% credible interval (light grey).

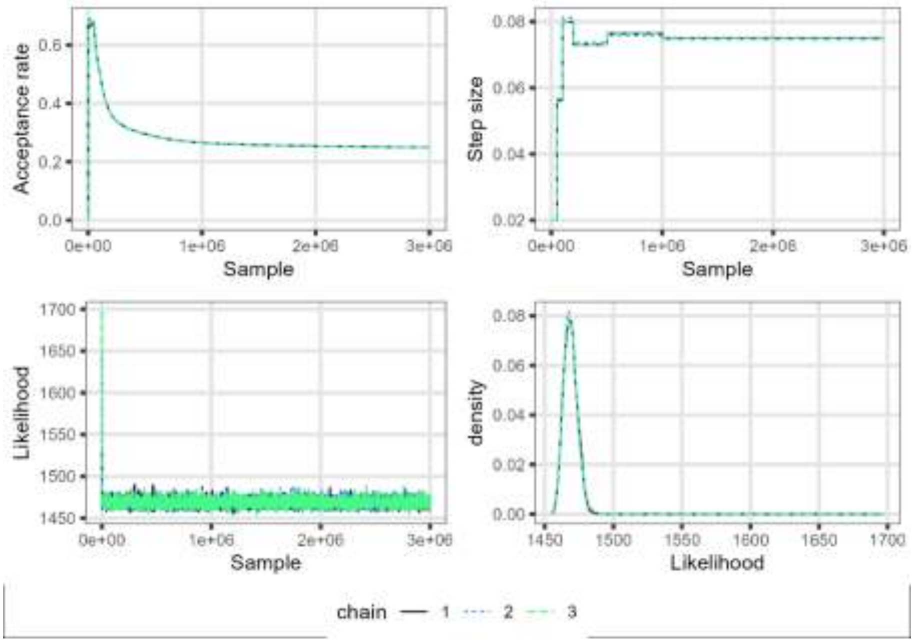

Figure A.5: MCMC diagnostic plots, showing the acceptance rate for each chain (top left), the adaptive step size for each chain (top right), the likelihood of the objective function as a function of the chain number (bottom left) and as a density distribution (bottom right).

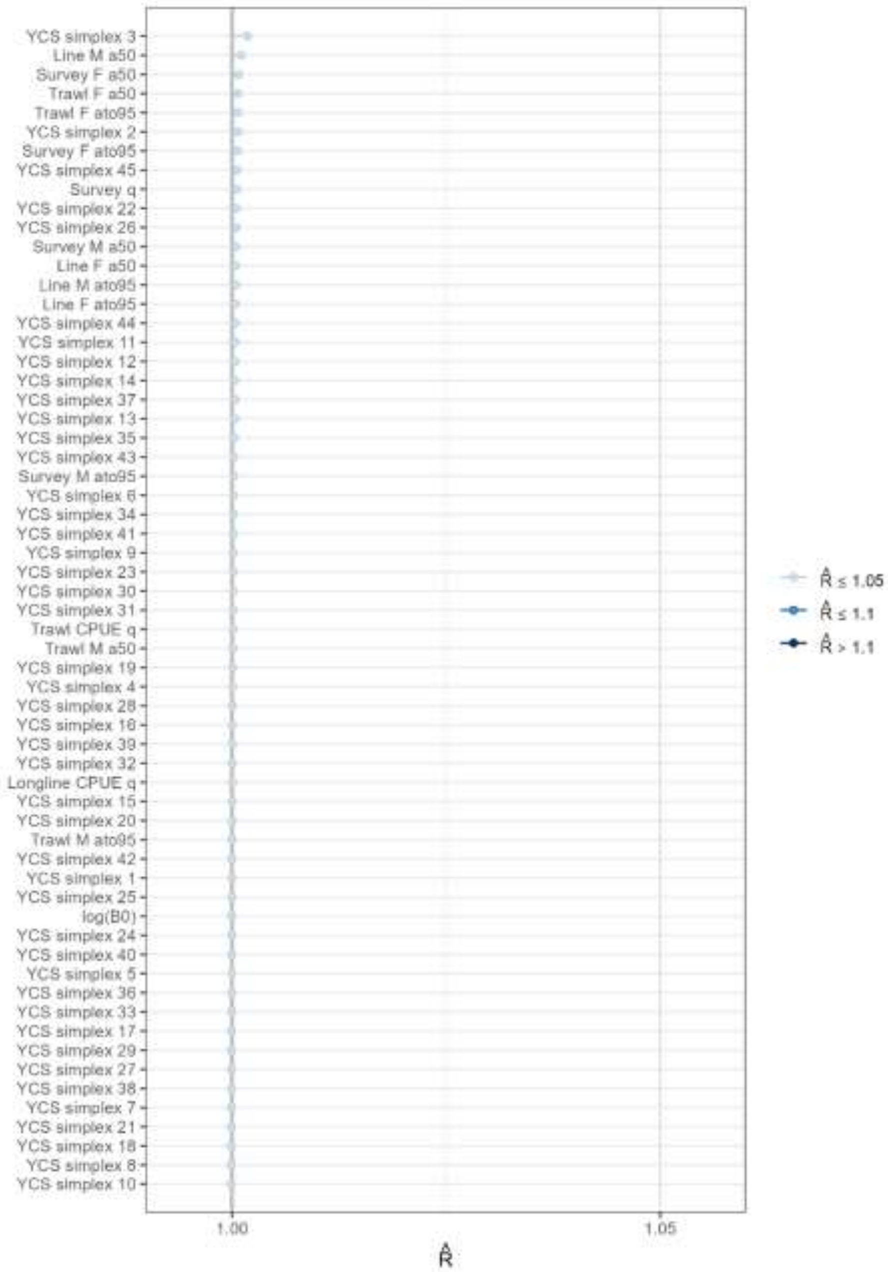

Figure A.6: MCMC r̂ values for all parameters, ordered from highest to lowest value.

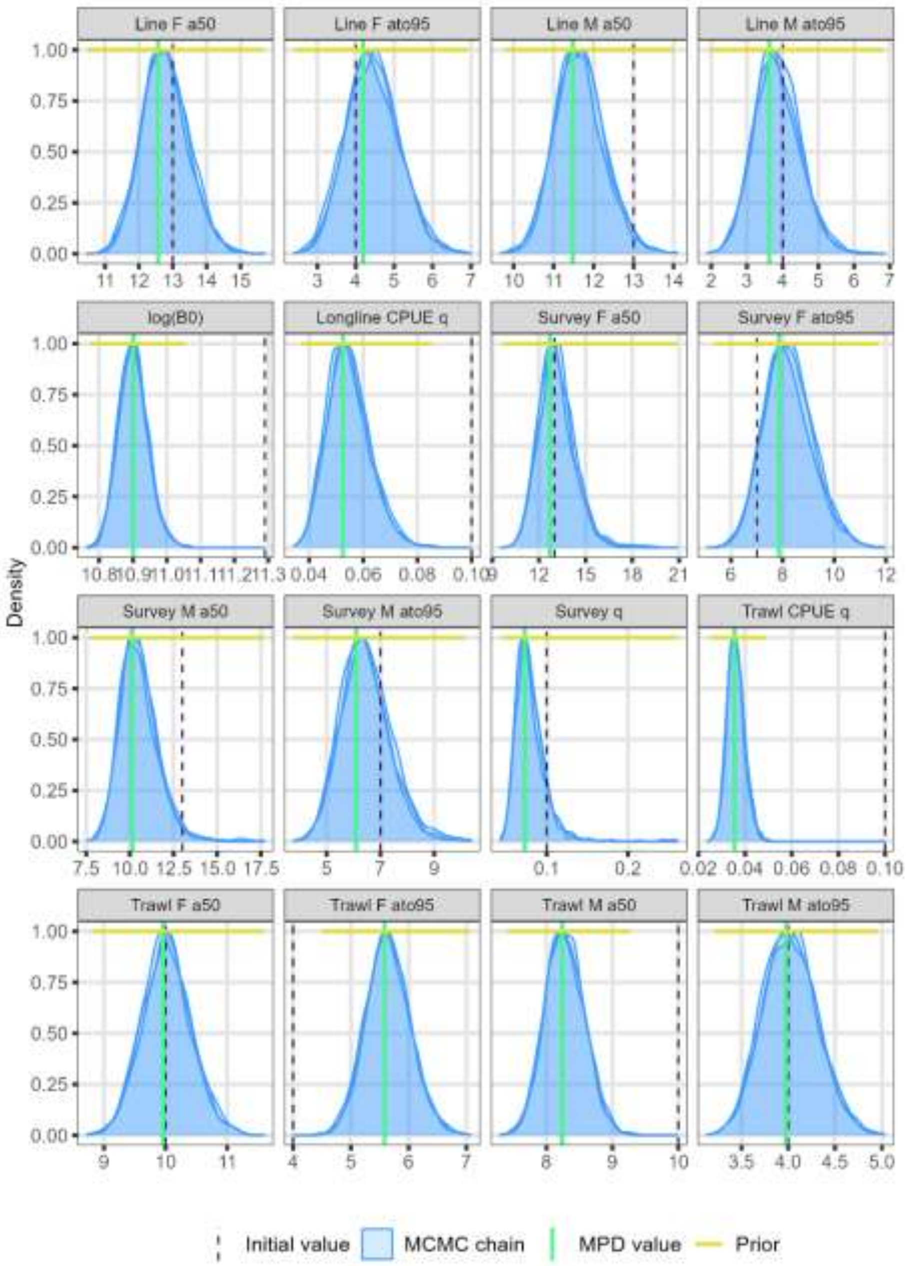

Figure A.7: Posterior density plots for the estimated parameters (excluding year class strength), plotted separately for each chain. The prior, initial value, and MPD value are also plotted.

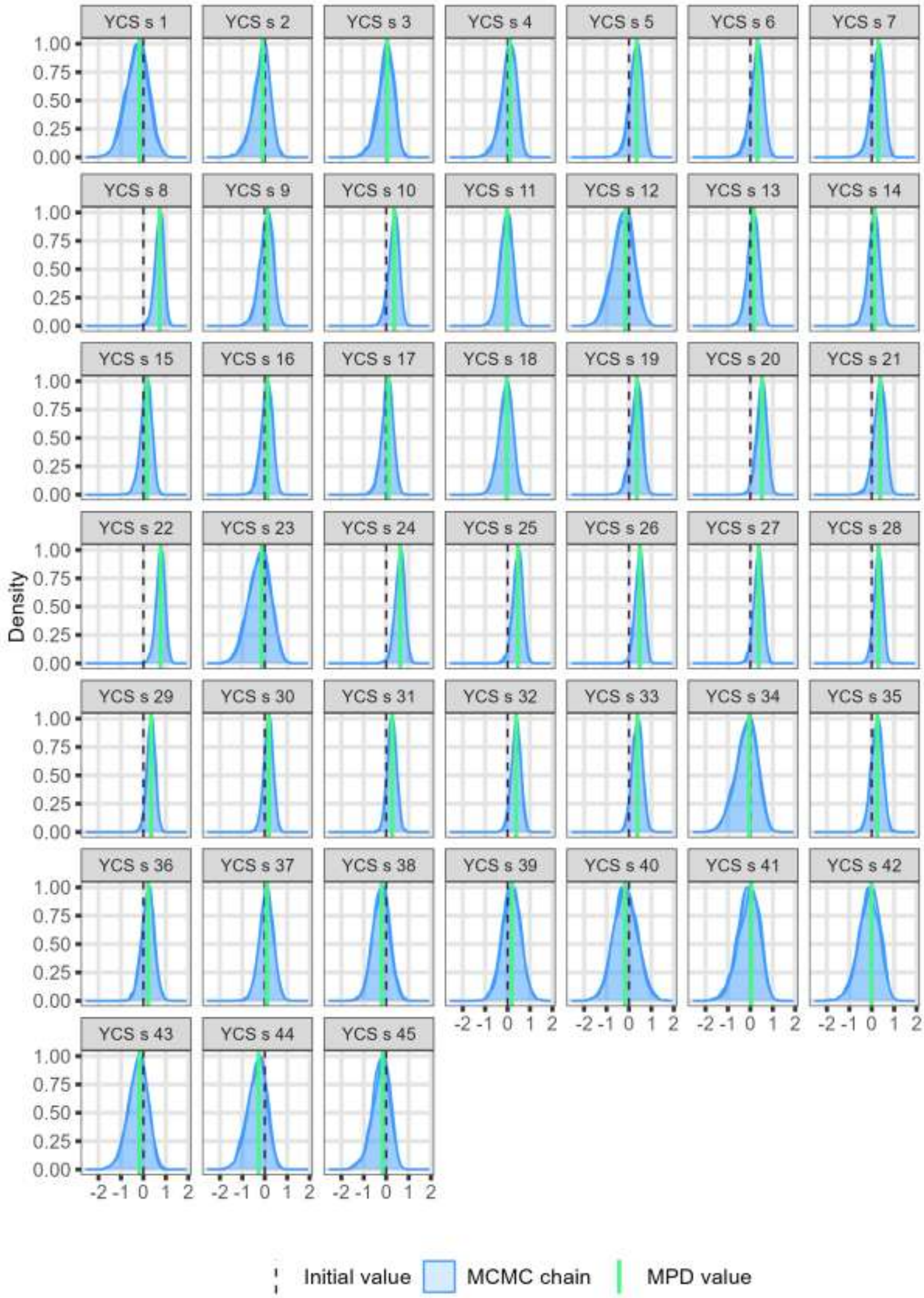

Figure A.8: MCMC chains density plots for the estimated year class strength parameters, plotted separately for each chain. The initial value, and MPD value are also plotted.