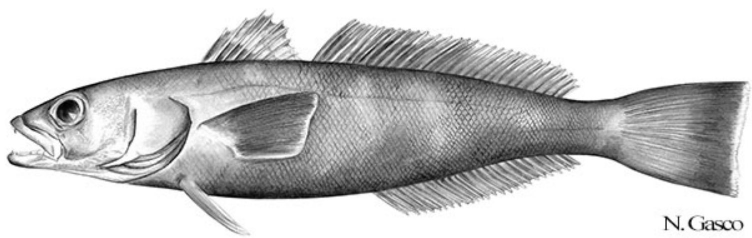
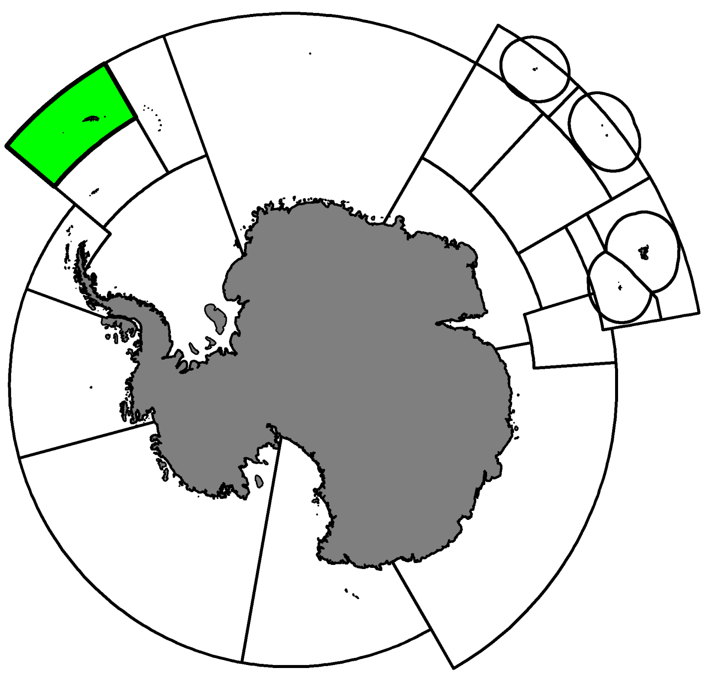
Stock Assessment Report 2021: *Dissostichus eleginoides* in Subarea 48.3

CCAMLR Secretariat

26 April 2022



Patagonian toothfish *Dissostichus eleginoides* Smitt, 1898.



Map of the management areas within the CAMLR Convention Area. The region discussed in this report is shaded in green.

CCAMLR

Commission for the Conservation of Antarctic Marine Living Resources
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Комиссия по сохранению морских живых ресурсов Антарктики
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Assessment of Patagonian toothfish (Dissostichus eleginoides) in Subarea 48.3

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Assessment of Patagonian Toothfish (*Dissostichus eleginoides*) in Subarea 48.3

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Abstract

Assessment of the Patagonian toothfish (*D. eleginoides*) in Subarea 48.3 indicates that the current status of the stock is at 47% of B_0. Projections indicate that a constant catch of 2,072 tonnes in the 2022[1] and 2023 seasons would be consistent with the CCAMLR decision rule after accounting for recent mammal depredation rates.

The assessment would lead to a recommendation from Working Group FSA to Scientific Committee that the catch limit for *D. eleginoides* in Subarea 48.3 should be set at 2 072 tonnes for 2021/22 and 2022/23.

1. Introduction

The fishery for Patagonian toothfish (*D. eleginoides*) in Subarea 48.3 began in the late 1980's and expanded rapidly during the 1990's. Reported catches peaked in 2003 at 7,500 tonnes when as many as 19 vessels operated in the fishery (Table 1). Both the number of vessels and catch limits have reduced in subsequent years. The stock was initially assessed in the mid-nineties with a generalised yield model (Constable and de la Mare, 1996), which was used until 2004. Since 2005 the stock has been assessed with the integrated model implemented in CASAL (C++ Algorithmic Stock Assessment Laboratory, https://www.niwa.co.nz/fisheries/tools-resources/casal) and assessed biannually since 2007 based on the recommendation of WG-FSA (CCAMLR, 2006). IUU fishing has been considered to be zero since 2006.

Over the past ten years the CASAL assessment has been refined periodically. In 2009 the assessment moved from using catch-at-length proportions to using catch-at-age proportions, derived from random otolith sampling of the catch. Data from the UK demersal survey (e.g. Collins *et al*., 2021) was included to estimate juvenile toothfish abundance and cetacean depredation corrections to CPUE were incorporated for catches from 2003 onwards (Agnew and Peatman, 2009). In 2011 the use of a 'three-fleet model' in addition to the established 'two-fleet-model' was explored to account for changing fishing behaviour, which was continued until and including 2013 (Peatman *et al.,* 2011, Scott, 2013), and in addition the tag loss rate was revised (Peatman *et al.,* 2011). The assessment in 2013 made no further changes to the biological parameters but investigated the two- vs three-fleet model scenarios, following which WG-FSA recommended the use of the two-fleet model for future assessments (CCAMLR, 2013) WG-FSA-13 § 4.19).

[1] The seasons are labelled according to calendar year in which the season finishes *e.g.* the 2020 season refers to the season from 1st December 2019 to 30th November 2020.

This assessment provides an update to the 2013-2019 assessments with data from the 2019 and 2020 fishing seasons without changes to biological parameters.

2. Input data

In WG-FSA-17, Paragraph 3.20 (CCAMLR, 2017) the Working Group recommended that:

"…where some data series are incomplete at the time of assessment, the assessment presented to the Working Group should be based on data that have been through data quality assurance processing rather than placing an emphasis on including the most recent data. It further recommended that toothfish stock assessments should be carried out up to, and including, the current season and include the reported catch data where fishing has been completed, or the anticipated catch for the current season."

As a result, data are included in this assessment up to the end of the 2020 season, with an assumption that catch in 2021 will reach the catch limit of 2,327 tonnes. The following data sources are used in the updated assessment:

- **Catch tonnage corrected for depredation:** Catch tonnage for the 2019 and 2020 seasons was added, the depredation factors since 2003 were recalculated as part of the CPUE standardisation. Catch in 2021 was assumed to be equal to the CCAMLR TAC of 2,327t, as the fishing season was still ongoing at the time of assessment
- **Scanned length distribution:** Data for the 2019 and 2020 seasons were added.
- **Observer data on orca and sperm whale sightings:** Data for the 2019 and 2020 seasons were added.
- **Catch per unit effort data:** Data for the 2019 and 2020 seasons were added. The GLM was refitted including all data from 2003 onwards.
- **Tag release data:** Data for the 2018 and 2019 seasons was added. The tags released in 2018 are not used because the only recaptures are in-year recaptures
- **Tag recapture data:** Recapture data for the 2019 and 2020 seasons were added.
- **Survey biomass and length distributions:** Data from the survey in May 2021 were added.
- **Otolith aging data from a sample of the catch:** Data from the 2019 and 2020 seasons were added.

*Table 1: Catch history for Dissostichus eleginoides in Subarea 48.3. SGSR: South Georgia–Shag Rocks stock; West: area outside the SGSR stock area. (Source: CCAMLR fishery reports for past seasons, and vessel catch and effort reports for current season, past CCAMLR reports for IUU catch). *indicates data for the current season which is incomplete (only catch up to 31st July) and not used in the assessment.*

Season	Regulated fishery			Depredation Correction Factor	Estimated IUU catch (tonnes)	Total removals (tonnes)		
	Effort (no. vessels)	*D. eleginoides* catch (tonnes)				SGSR Used in assessment	West	Subarea
		Limit	Reported					
1985	1	-	521		0	517	4	521
1986	1	-	733		0	733	0	732

1987	1	-	1954		0	1954	0	1954
1988	2	-	876		0	876	0	876
1989	3	-	7060		144	6962	241	7204
1990	2	-	6785		437	6838	384	7222
1991	1	2500	1756	1.007	1775	3555	0	3531
1992	23	3500	3809	1.007	3066	6910	11	6875
1993	18	3350	3020	1.007	4019	7086	0	7039
1994	4	1300	658	1.006	4780	5280	191	5438
1995	13	2800	3371	1.010	1674	5021	73	5045
1996	13	4000	3602	1.022	0	3607	72	3602
1997	10	5000	3812	1.021	0	3888	4	3812
1998	9	3300	3201	1.019	146	3410	0	3347
1999	12	3500	3627	1.022	667	4387	0	4293
2000	17	5310	4904	1.030	1015	6087	9	5919
2001	18	4500	4047	1.030	196	4358	11	4243
2002	17	5820	5742	1.030	3	5887	29	5745
2003	19	7810	7496	1.015	0	7616	18	7634
2004	17	4420	4462	1.016	0	4532	37	4532
2005	8	3050	3032	1.024	23	3105	0	3105
2006	11	3556	3522	1.022	0	3601	0	3601
2007	11	3554	3527	1.019	0	3594	2	3594
2008	12	3920	3807	1.019	0	3879	0	3879
2009	11	3920	3382	1.023	0	3459	0	3459
2010	9	3000	2518	1.046	0	2633	0	2633
2011	6	3000	1732	1.029	0	1783	0	1783
2012	6	2600	1846	1.030	0	1902	0	1902
2013	6	2600	2094	1.040	0	2177	0	2177
2014	6	2400	2180	1.039	0	2265	0	2265
2015	6	2400	2195	1.033	0	2267	0	2267
2016	6	2750	2196	1.037	0	2278	0	2278
2017	6	2750	2195	1.023	0	2246	0	2246
2018	6	2600	1950	1.056	0	2060	0	2060
2019	6	2600	2124	1.041	0	2211	0	2211
2020	5	2327	1884	1.061	0	1999	0	1999
2021	5	2327	1344*					

3. Standardised CPUE

Commercial catch per unit effort (kg per hook) was standardised following the approach described in Clark and Agnew (2010) and Peatman *et al*., (2011) using a GLM with explanatory variables (season, month, area, vessel nationality, depth class and cetacean presence) included as factors. Standardised CPUE was calculated for the period of 2004 to present (Figure 1) with the effect of the explanatory variables shown in Figure 2. Figure 3 shows the catch corrections derived from the GLM fit by considering the magnitude of the effect of cetacean presence multiplied by the frequency of observation from those hauls with observer data. The average catch correction for the last 10 years was 1.039. The catch correction was particularly high in 2018-2020. The year 2018 was the first year of reporting of mammal observations using new recording protocols and forms. After a time series of data is available for analysis, further work will be necessary to investigate the estimation of cpue trends in order to combine the data recorded under the two protocols.

Estimates of CPUE for the period 1998 to 2003, which do not include cetacean presence, are input to the assessment as a separate block. These values have not been re-estimated and remain unchanged from previous years. Both blocks of CPUE use the same selectivity ogive, but different catchability rates (q) are estimated for the two blocks.

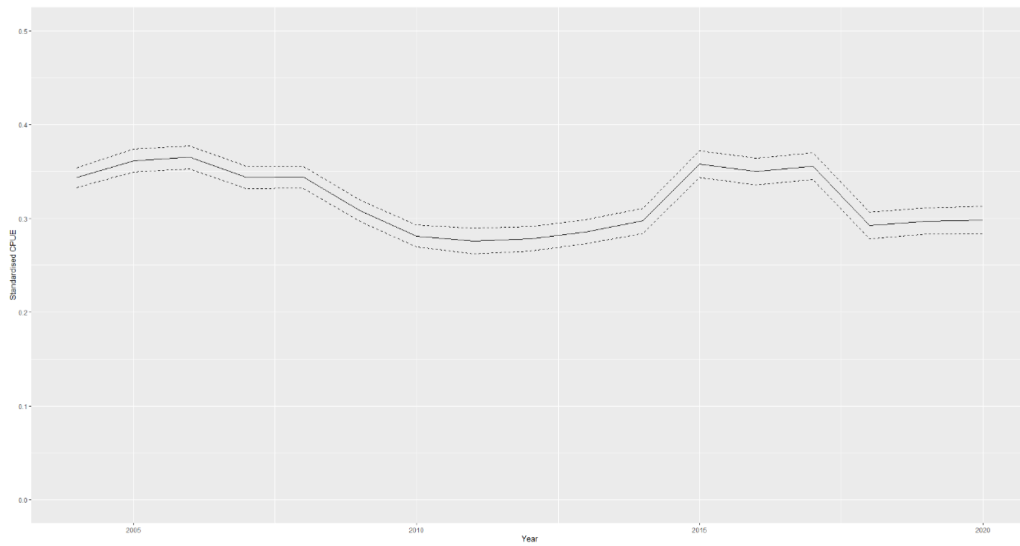

Figure 1: CPUE estimates by year. Bold black line with dashed intervals shows model fit, with 95% confidence intervals.

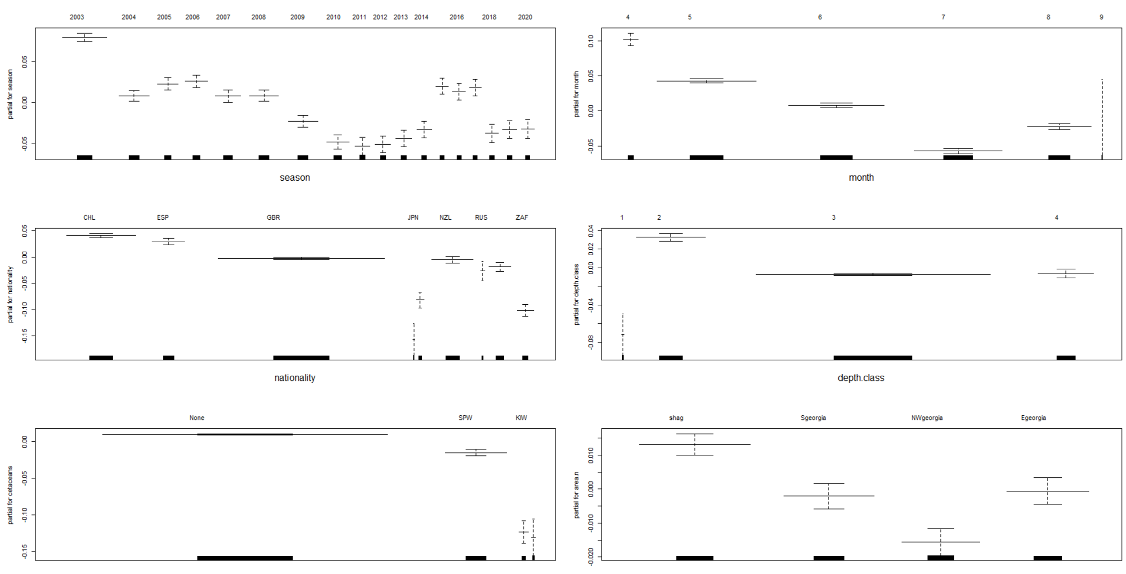

Figure 2: Magnitude of the effects on CPUE of the factors included within the GLM described in the text. Countries: CHL-Chile, ESP-Spain, GBR-Great Britain, JPN-Japan, Korea, New Zealand, RUS-Russia, Uruguay, ZAF-South Africa.

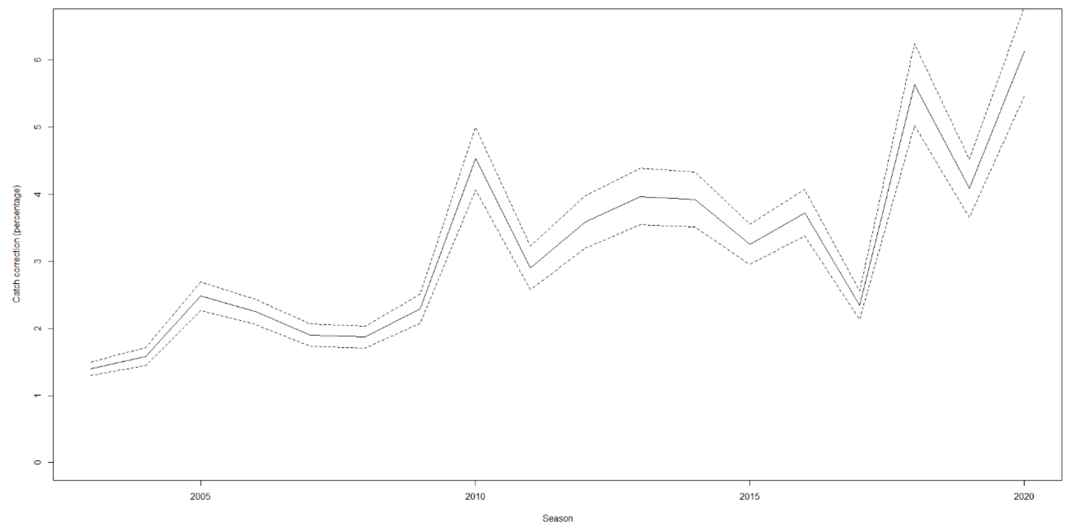

Figure 3: Correction factor applied to the catch to account for depredation, estimated from the frequency of sightings, and the effect of cetacean presence on CPUE as estimated by the GLM described in the text.

4. Catch

Within the CASAL model, catch is split into two periods, each with a separate selectivity ogive. The period prior to 1998-2002 covers a period where ageing data is not available, and so catch composition is specified as proportions at length. During this period, no estimates of cetacean depredation are available (Agnew and Peatman 2009).

5. Catch age and length distribution

The length distribution of the catches has been determined annually since 1998 by simple random sampling of the catch. This is combined with ageing data to calculate the age structure of the catch from 1998 to present (discussed below), and is used within the CASAL model as the numbers at length of fish scanned for tags within 10cm length bins (Figure 4). Average lengths in the catch have been increasing since 2009, and have been higher than the long term average since 2016.

Figure 4: Sampled length distributions from catch data (top) and mean length (bottom) stratified by depth.

The number of otoliths read for construction of the age-length key (ALK) is shown in Table 2. The sample size for age determination is typically around 300, although this has been higher in the 2019 and 2020 season at 705 and 601 samples respectively. The length distribution in each year is raised by the empirical age-length key to derive an age distribution. This process is shown in Figure 5 and Figure 6. In addition to the random sampling, since 2017 the catch was sampled in 10 cm bin distributions in order to spread the aged otolith sample range and provide data for the ALK at smaller and larger sizes than those predominantly targeted by the fishery. As a consequence, the distribution of aged fish shows a substantially different length distribution to the catch (Figure 5 lower panels).

Table 2: Sample size for age determination of fish caught in Subarea 48.3.

Year	Sample size for age determination
1998	250
1999	259
2000	298
2001	467
2002	200
2003	200
2004	418
2005	251
2006	250
2007	250
2008	249
2009	512
2010	254
2011	255
2012	250
2013	201
2014	351
2015	235
2016	235
2017	306
2018	380
2019	705
2020	601

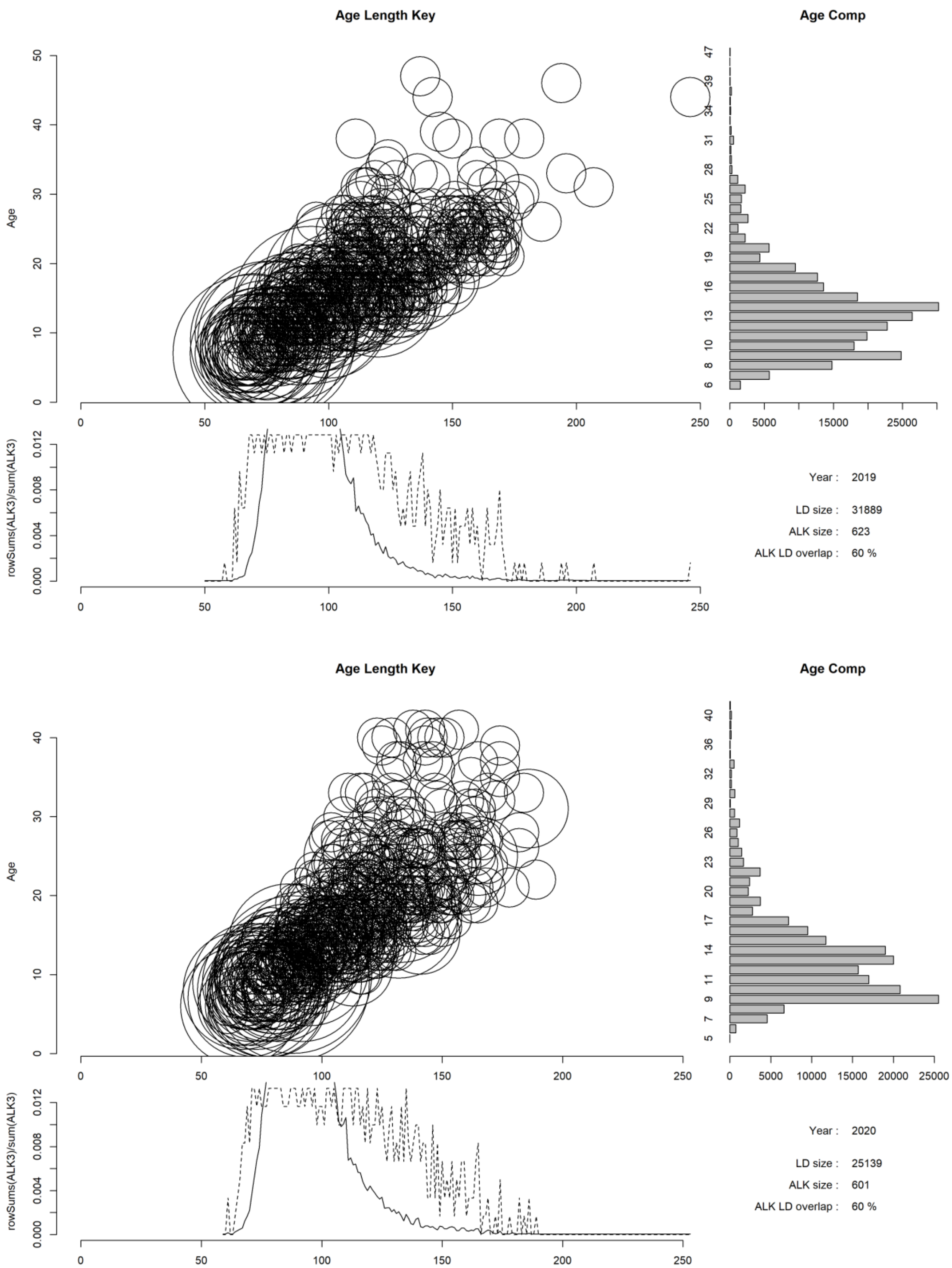

Figure 5: 2019 and 2020 ALKs. Bottom panel shows length distribution of fishery (solid) and aged samples (dotted). The top left panel shows the age and length of aged fish, with size of circles indicating the number of samples. The right panel shows the derived age composition.

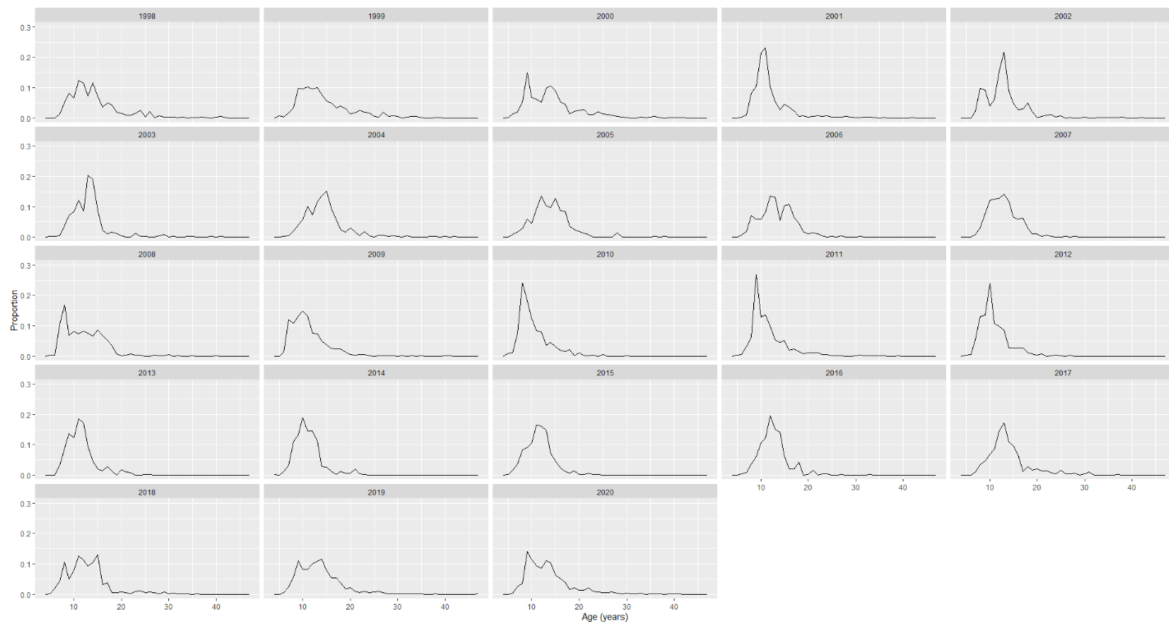

Figure 6: Raised age distribution in the catch over time.

6. Tagging data

Tagging data used within this assessment is shown in Table 3, where releases have been corrected for length-dependent instantaneous tagging mortality and in-year recaptures. In total, the effective release number of tags used in the assessment after accounting for in-year recaptures and instantaneous mortality is 51,000 up to the end of the 2019 season. Of these 6,236 recaptures are used in the assessment (recaptured at least 60 cm, less than 120 cm, and in the four seasons following release).

*Table 3: Tagging release and recapture data used within the assessment. *releases are effective releases after accounting for tag shock and in-year recaptures.*

	Year	Length (cm)							
		40	50	60	70	80	90	100	110
Releases*	2003	1	19	87	178	117	14	2	0
Recaptures	2006			0	7	10	1	0	1
Recaptures	2007			1	1	3	8	0	0
Releases*	2004	0	98	525	1144	912	172	11	3
Recaptures	2006			3	51	47	10	2	1
Recaptures	2007			5	29	41	10	1	0
Recaptures	2008			1	30	51	17	4	0
Releases*	2005	3	167	721	1190	928	229	33	0
Recaptures	2006			10	60	63	16	3	1
Recaptures	2007			6	43	42	14	5	0
Recaptures	2008			4	41	52	19	3	0
Recaptures	2009			5	40	36	16	3	2
Releases*	2006	4	82	772	1675	1165	339	45	4
Recaptures	2007			13	81	52	19	2	0
Recaptures	2008			12	77	63	20	3	0
Recaptures	2009			5	38	54	27	6	0
Recaptures	2010			3	28	49	32	6	1
Releases*	2007	0	132	869	1373	865	308	29	0
Recaptures	2008			34	91	55	25	1	2
Recaptures	2009			8	62	53	11	6	0
Recaptures	2010			6	53	40	19	4	0
Recaptures	2011			0	19	31	11	7	0
Releases*	2008	0	76	807	1813	1179	313	34	0
Recaptures	2009			25	96	73	33	5	0
Recaptures	2010			5	54	58	26	2	0
Recaptures	2011			0	27	50	21	5	0
Recaptures	2012			1	27	35	13	0	0
Releases*	2009	0	16	557	1589	879	189	23	0
Recaptures	2010			11	78	40	8	2	0
Recaptures	2011			0	20	30	12	3	1
Recaptures	2012			2	20	34	4	3	0
Recaptures	2013			0	9	31	17	4	1
Releases*	2010	0	3	344	1500	735	158	28	3
Recaptures	2011			5	26	30	7	2	1
Recaptures	2012			1	27	33	2	1	1
Recaptures	2013			0	15	23	8	2	0
Recaptures	2014			0	12	23	17	2	2
Releases*	2011	0	3	63	988	980	391	141	31
Recaptures	2012			2	36	35	14	9	2
Recaptures	2013			0	24	43	15	5	3
Recaptures	2014			0	10	41	20	7	0
Recaptures	2015			0	3	18	14	4	1
Releases*	2012	0	11	79	994	1091	413	118	30
Recaptures	2013			0	30	63	18	5	1
Recaptures	2014			0	18	39	25	4	4
Recaptures	2015			0	7	31	27	6	3
Recaptures	2016			0	1	37	20	13	1
Releases*	2013	0	4	49	921	1334	480	158	51
Recaptures	2014			0	26	61	25	4	5
Recaptures	2015			0	11	48	18	9	2
Recaptures	2016			0	9	47	27	6	1
Recaptures	2017			0	7	35	32	8	3
Releases*	2014	0	2	31	57	1619	738	174	28
Recaptures	2015			0	15	65	39	4	0
Recaptures	2016			2	10	72	32	12	0
Recaptures	2017			1	4	44	43	10	3
Recaptures	2018			0	9	25	29	9	1
Releases*	2015	0	3	72	605	1599	813	194	30
Recaptures	2016			1	14	71	64	10	6
Recaptures	2017			0	16	62	51	12	2
Recaptures	2018			0	7	32	43	11	3
Recaptures	2019			0	5	31	46	21	7
Releases*	2016	0	2	78	514	1394	867	194	48
Recaptures	2017			2	15	64	84	22	4
Recaptures	2018			0	6	37	53	12	3
Recaptures	2019			1	6	38	38	16	2
Recaptures	2020			0	2	16	20	17	5
Releases*	2017	0	1	26	403	1152	991	342	76
Recaptures	2018			3	7	64	69	18	6
Recaptures	2019			0	6	52	52	19	7
Recaptures	2020			0	4	15	35	12	8
Releases*	2018	0	2	44	455	1250	861	266	73
Recaptures	2019			1	14	52	50	23	8
Recaptures	2020			0	5	23	27	12	3
Releases*	2019	0	1	34	433	1183	902	278	54
Recaptures	2020			0	2	23	33	11	9

7. Survey biomass

Estimates of juvenile toothfish abundance are determined from shallow water (<400m) trawl surveys around Shag Rocks. The index is raised to an estimate of numbers per km^2 using information on the distance towed and the wing spread of the net. Only random tows (i.e. those which do not target concentrations of fish that have been identified prior to fishing) are considered for the index.

This index of juvenile abundance can be highly variable (Figure 7 and Table 4) and may be heavily influenced, in some years, by a small number of stations in the survey. For example, the very high estimate for 2011 is driven by high catches at just two stations that were relatively close together. Subsequent estimates are much lower less than 10% of this high value, and so it seems as if the 2011 index is an anomalously high estimate. The 2021 estimate of biomass is close to the median of the time series.

Table 4: Average density and CV estimates for juvenile toothfish caught in the groundfish survey hauls shallower than 400 m around Shag Rocks.

Year	Average numbers/km^2	CV
1987	301.8	0.302
1988	727.3	0.680
1990	1735.9	0.477
1991	771.5	0.353
1992	1379.8	0.359
1994	1467.5	0.506
2000	502.5	0.452
2002	758.2	0.362
2004	323.3	0.407
2005	410.2	0.351
2006	392.9	0.393
2007	15.4	0.578
2008	79.8	0.433
2009	61.9	0.549
2010	137.1	0.284
2011	2633.3	0.771
2012	103.9	0.367
2013	218.1	0.713
2015	119.2	0.473
2017	21.1	0.582
2019	49.9	0.367
2021	336.4	0.321

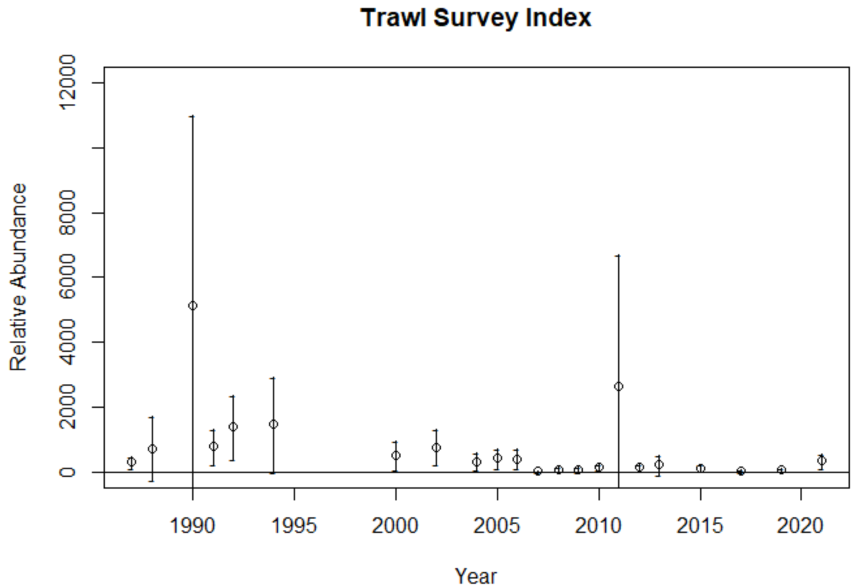

Figure 7: Relative biomass estimates with 95% confidence intervals from the trawl survey biomass index.

8. Survey length distribution

Length distributions are recorded for all toothfish caught in the survey and are shown in Figure 8. There is some evidence that cohorts can be tracked, for example between the surveys in 1990-1992.

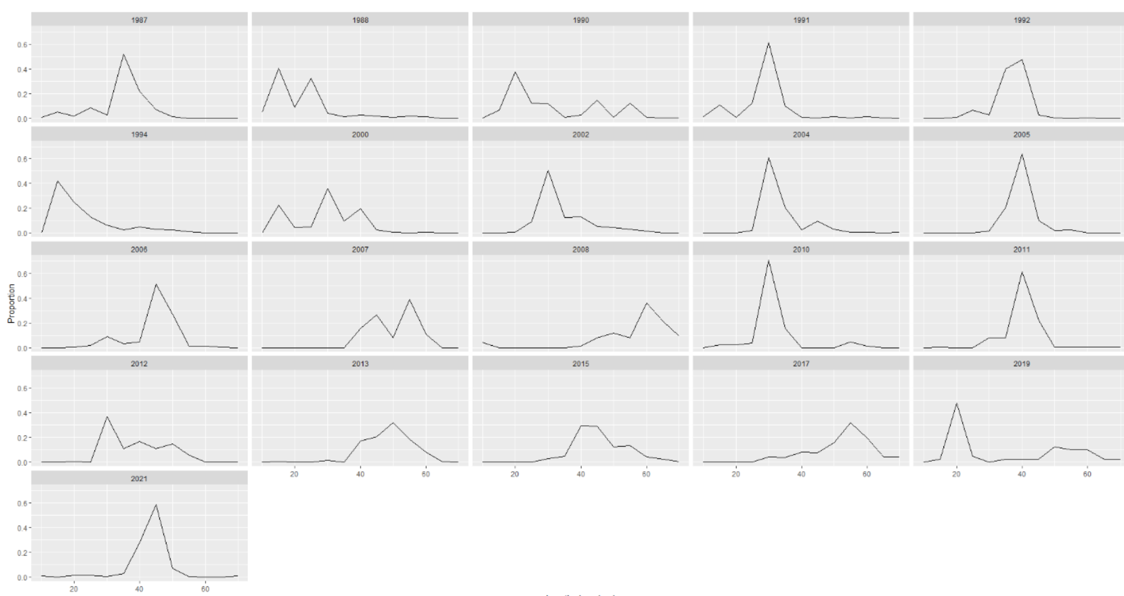

Figure 8: Survey length distribution in cm by 5cm bins, proportions by year.

9. Model structure

As for previous assessments (e.g. Earl, 2019), the CASAL population model was a combined-sex, single-area, three-season model with an annual cycle comprising 3 periods. During the first period (1 December to 31 April) only recruitment and natural mortality occurs; the second period, from the beginning of May to the end of August, includes both natural mortality and fishing and contains the spawning period – half the mortality in that particular period being accounted for before spawning occurs; the final period runs from the beginning of September to the end of November, thus completing the annual cycle, with only natural mortality occurring. A fourth 'virtual' period is added at the end of November, when the fish are assumed to increment their age. It was assumed throughout that the proportions of natural mortality and growth that occur within each period are equal to that period's length as a proportion of a year. The assessment was run for the years 1985 to 2021, with an initial unexploited equilibrium age structure.

The biological parameters used within the model are shown in Table 5.

Table 5: Biological parameter values for Dissostichus eleginoides *in Subarea 48.3.*

Component	Parameter	Value	Component	Parameter	Value
Natural mortality	M	0.13	Tag-related growth retardation		0.75
VBGF	K	0.08	CASAL tag loss rate		0.006377
VBGF	t_0	–0.7	Immediate tagging survivorship		Applied as a vector to length-based tag-release data
VBGF	L_∞	126	Tag probability of detection		1
Length-weight	a	2.54×10^{-9}			
relationship	b	2.8	Stock-recruit relationship steepness	h	0.75
Maturity range: 0 to full maturity		1–23	Lognormal recruitment SD		Estimated

10. Data weighting

An initial run was performed using the following data weighting:

- Tag dispersion constant across all years
- Catch age distribution effective sample size given by number of otoliths aged in each year
- Survey length composition weighted by number of hauls in Shag Rocks.
- Survey index and CPUE have CVs calculated outside the model, and process error constrained to near zero.

Subsequently runs are performed to scale the weightings applied to each data source:

1. Catch age and length compositions and survey length compositions are scaled according to method TA1.8 from Francis (2011) implemented in Francis (2015)
2. Tag dispersion is updated using the `Reweight.tags` function (Francis, 2015)
3. Survey process error is freed to be estimated in the model fit.

11. Model outputs

11.1. Maximum Posterior Density (MPD) fits

The effect on the MPD estimates of stock dynamics of updating the model is shown in Figure 9Figure, and Table 6. The general trajectory of the stock remains consistent, but there is some change in the SSB trajectory. Likelihood components are shown in Figure 10 and Table 7. Figure 11 shows the selectivities estimated in the model, which have changed little from previous models, showing slightly larger fish selected in the catch prior to 1998 than after this. The survey selectivity has been estimated to be highly domed, catching fish of ages 2-6.

Table 6 shows the estimated parameters for the MPD runs in 2017, 2019 and 2021. In 2019 and 2021 the right hand limb of the selectivity in the early part of the catch was estimated to be at the bounds provided as input, indicating an almost flat-topped selectivity. Sensitivity runs in 2019 showed that increasing the bounds made only a very minor difference to the performance of the model.

Figures 12-18 show the fit of the model to the sources of data used in the model. Fits to catch age distribution, CPUE, survey index and survey length distribution appear to be poor, while the fit to the tag recapture numbers and length distribution is much better.

*Table 6: Comparison of MPD estimated parameters (excluding year class strengths) between the 2017 and 2019 model runs. *The parameter is estimated at the bounds of the range provided.*

Parameter Name		**2017**	**2019**	**2021**
B_0		84244	82451	74047
Early CPUE CV process error		0.15	0.14	0.14
Late CPUE CV process error		0.12	0.08	0.08
Survey CPUE CV process error		0.76	0.78	0.78
Early selectivity	Maximum age	13.13	13.45	13.66
	Left hand limb	2.56	2.71	2.77
	Right Hand Limb	241	500*	500*
Late selectivity	Maximum age	9.11	8.27	8.74
	Left hand limb	1.34	0.87	1.10
	Right Hand Limb	196	110	316
Survey selectivity	Maximum age	3.71	3.74	3.99
	Left hand limb	1.62	1.86	1.95
	Right Hand Limb	2.43	2.46	2.27
Derived Quantities				
Final Year SSB		42705	41373	34368
Final Year SSB relative to B_0.		50.1	50.2	46.4

11.2. Profiling on B_0

Profiling of the MPD model was performed on B_0 for a range of values between 60,000 and 140,000 tonnes (the MPD estimate of B_0 using the 2021 model was 74,047) and is shown in Figure 19 and Figure 20. The datasets are more consistent than had been estimated in previous assessments, although the catch composition and tagging data could also be consistent with a larger value of B_0 than the model estimates. Within the tagging data, the individual cohorts of tag releases show that more recent tag cohorts indicate a lower estimate of B_0 than earlier cohorts as the spatial extent and effort of the fishery has contracted.

Figure 9: Stock summary MPD runs; Red: Assessment presented at FSA 2019, Blue: 2021 assessment.

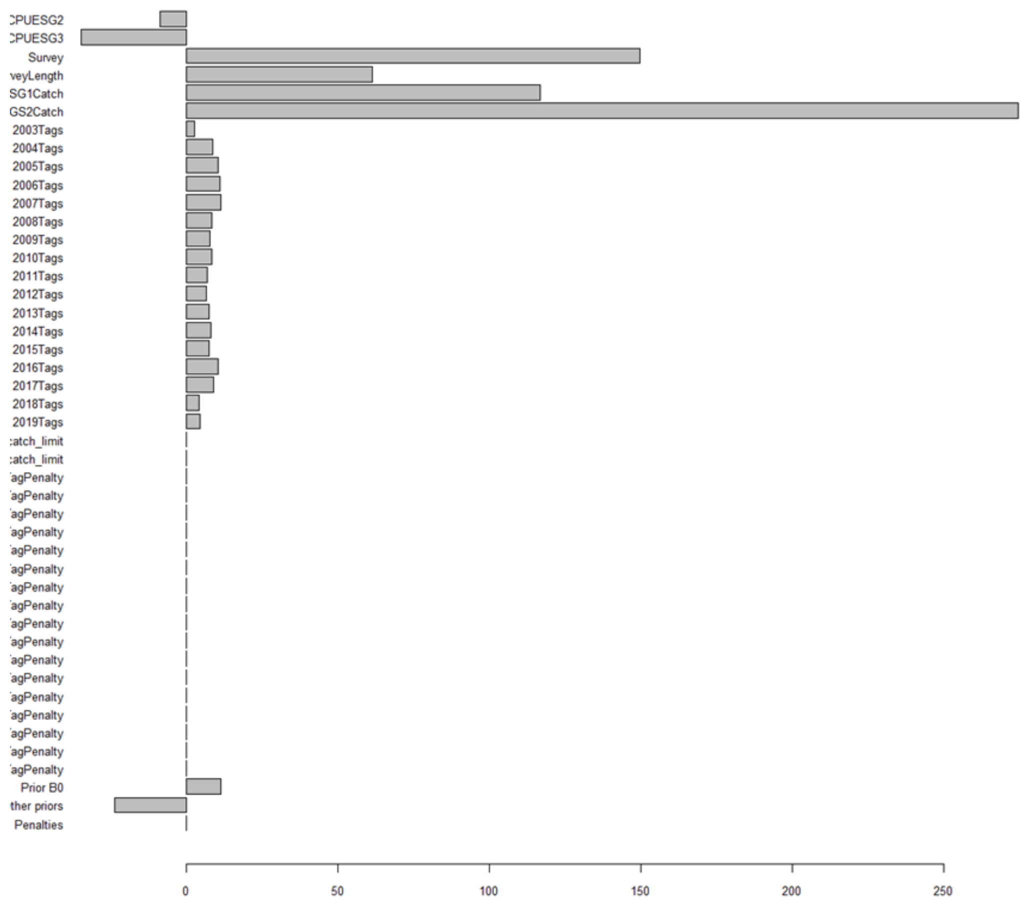

Figure 10: Contributions to the negative log-likelihood from different components of the model fit for the MPD model fit.

Table 7: Likelihood components (negative log likelihood) in the MPD run

Component	Negative log likelihood
CPUESG2	-8.72
CPUESG3	-34.84
Survey	149.8
SurveyLength	61.11
FSG1Catch	116.8
FSGS2Catch	275.8
2003Tags	2.85
2004Tags	9.35
2005Tags	11.38
2006Tags	11.97
2007Tags	12.2
2008Tags	9.1
2009Tags	8.46
2010Tags	8.98
2011Tags	7.5
2012Tags	7.05
2013Tags	8.09
2014Tags	8.81
2015Tags	8.54
2016Tags	11.12
2017Tags	9.95
2018Tags	4.76
2019Tags	2.67
catch_limit	0
catch_limit	0
2003TagPenalty	0
2004TagPenalty	0
2005TagPenalty	0
2006TagPenalty	0
2007TagPenalty	0
2008TagPenalty	0
2009TagPenalty	0
2010TagPenalty	0
2011TagPenalty	0

2012TagPenalty	0
2013TagPenalty	0
2014TagPenalty	0
2015TagPenalty	0
2016TagPenalty	0
2017TagPenalty	0
2018TagPenalty	0
2019TagPenalty	0
Prior B0	11.23
Other priors	-23.84
Penalties	0
Total objective function	690.1

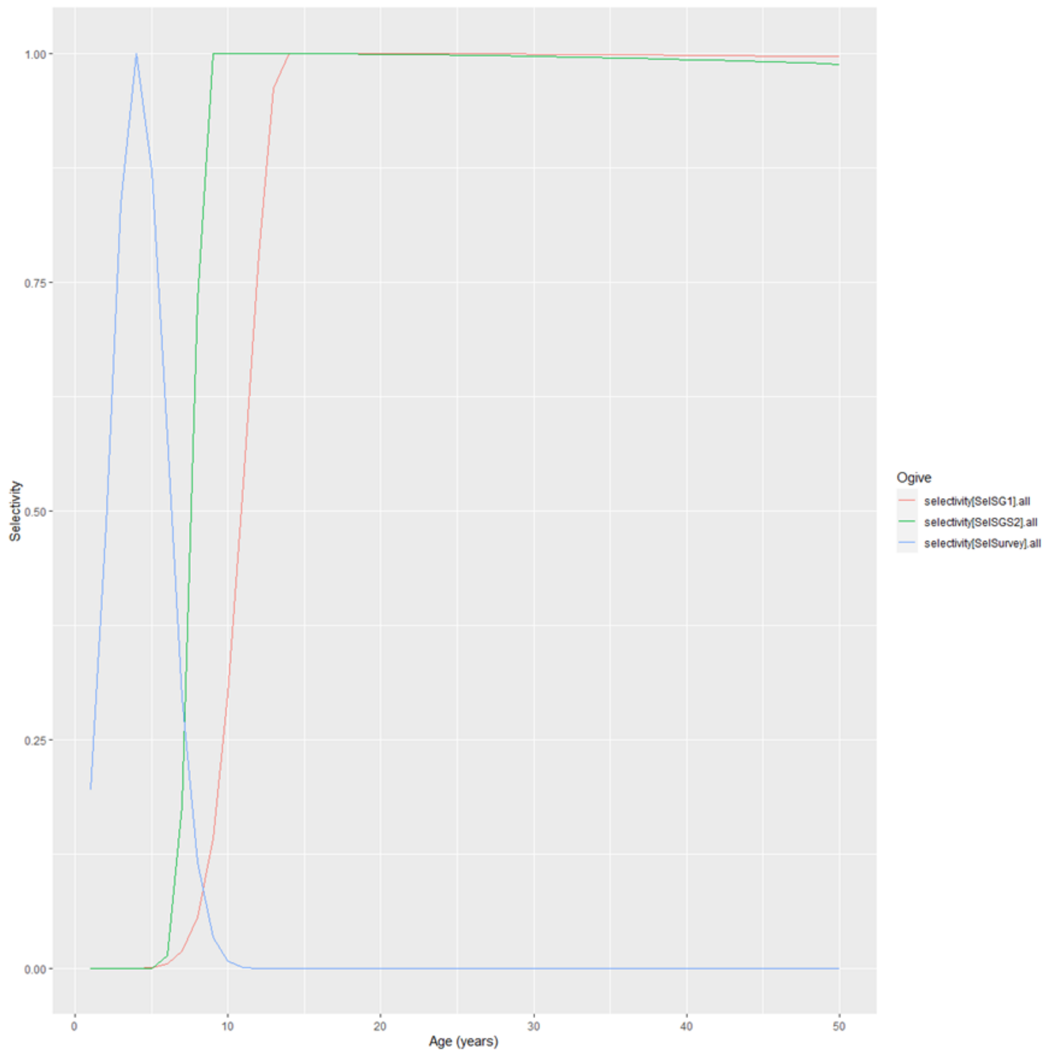

Figure 11: Model estimates of selectivity of the survey (blue) and commercial catch (Red up to 1997, green afterwards).

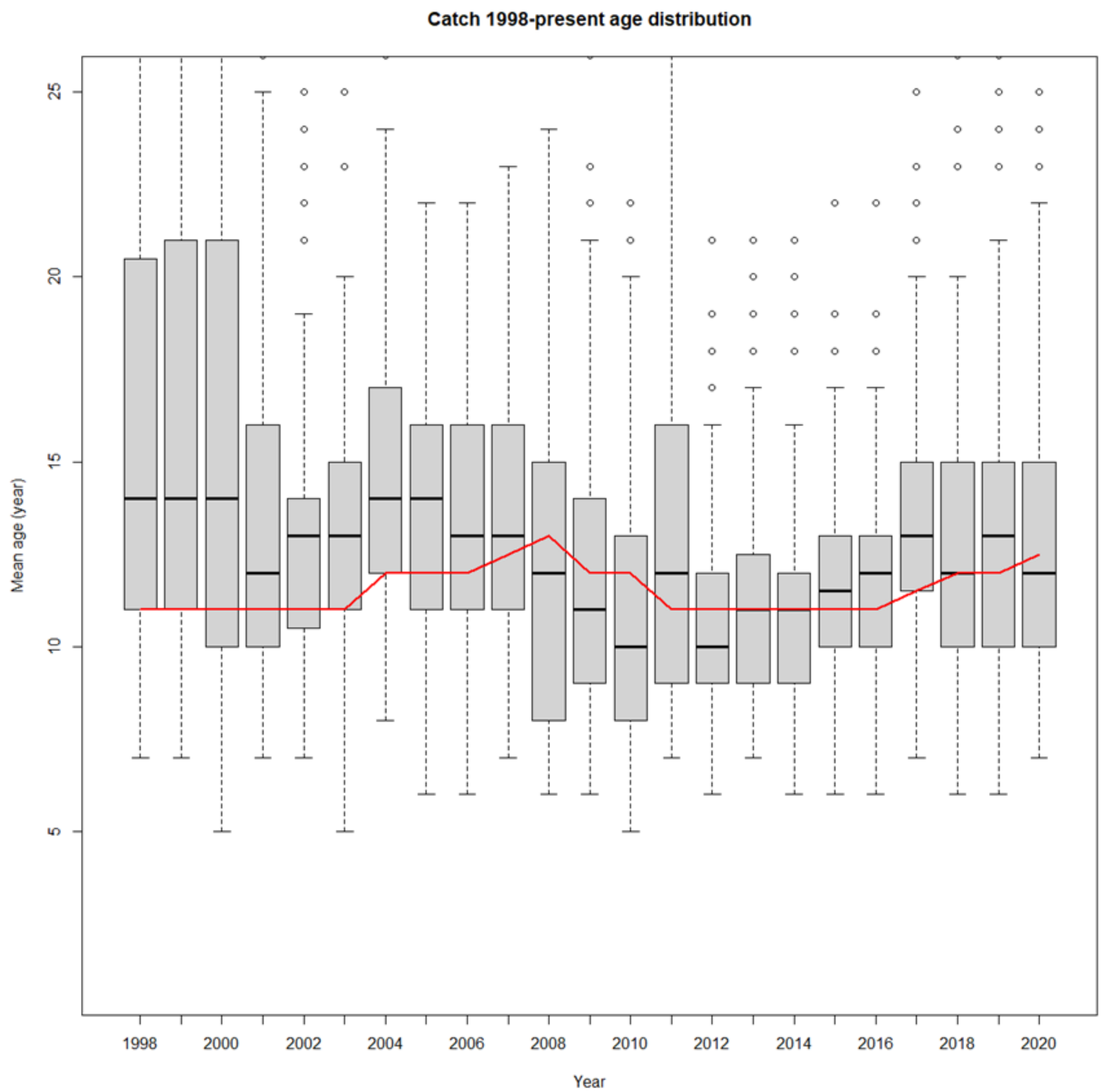

Figure 12: Fit to age data in commercial fishery since 1998. Red line indicates median predicted age.

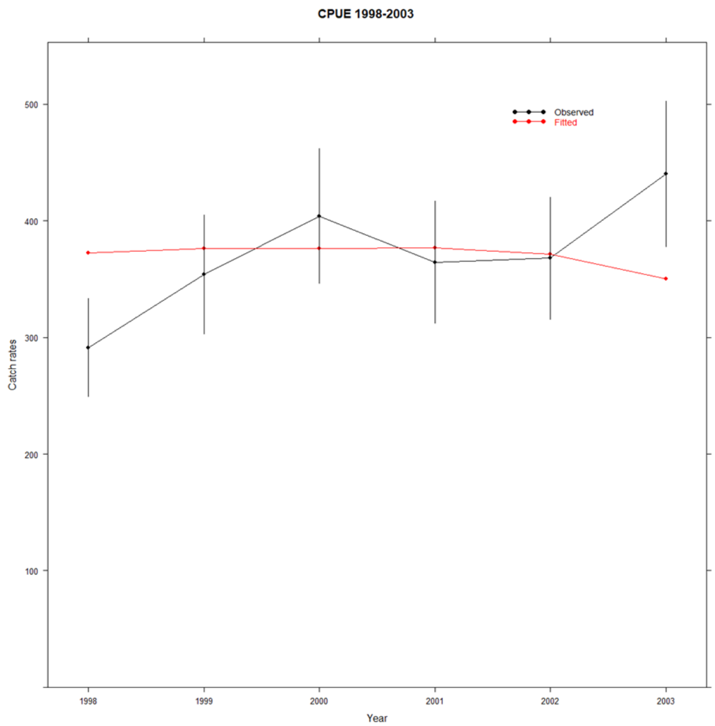

Figure 13: Model to CPUE estimated from catches in 1998-2003.

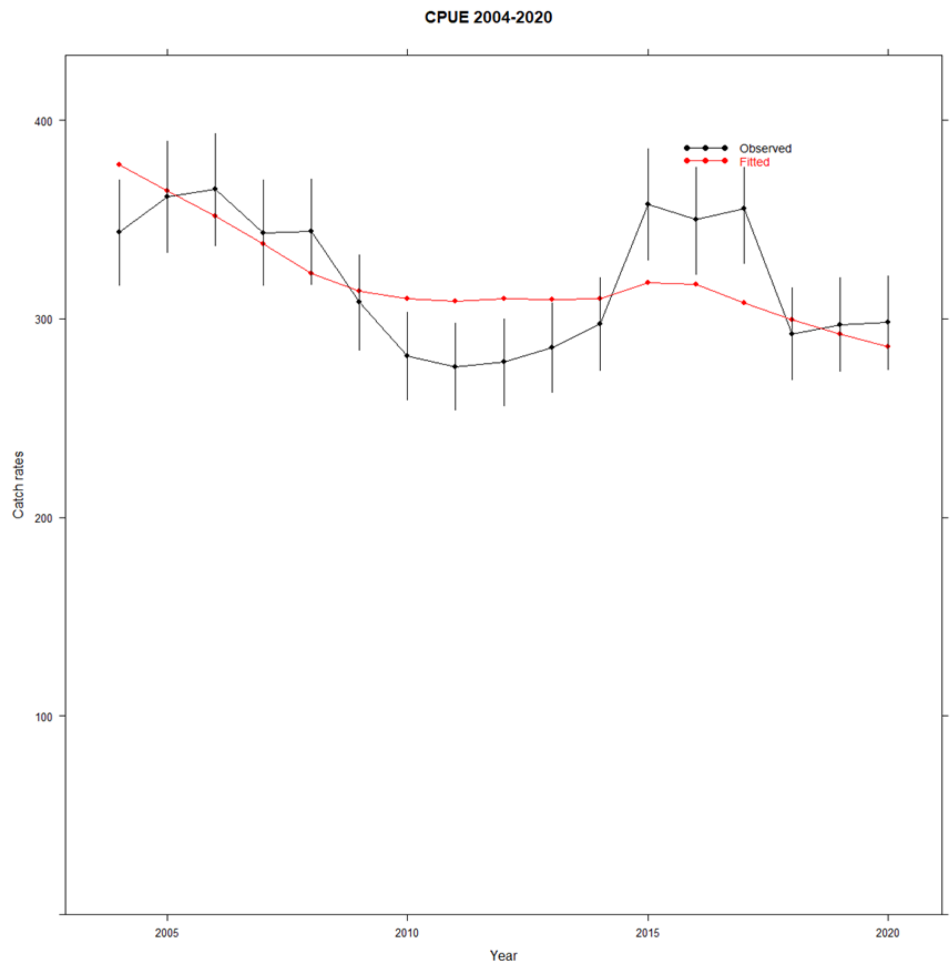

Figure 14: Model fit to CPUE estimated from catches in 2004-2017.

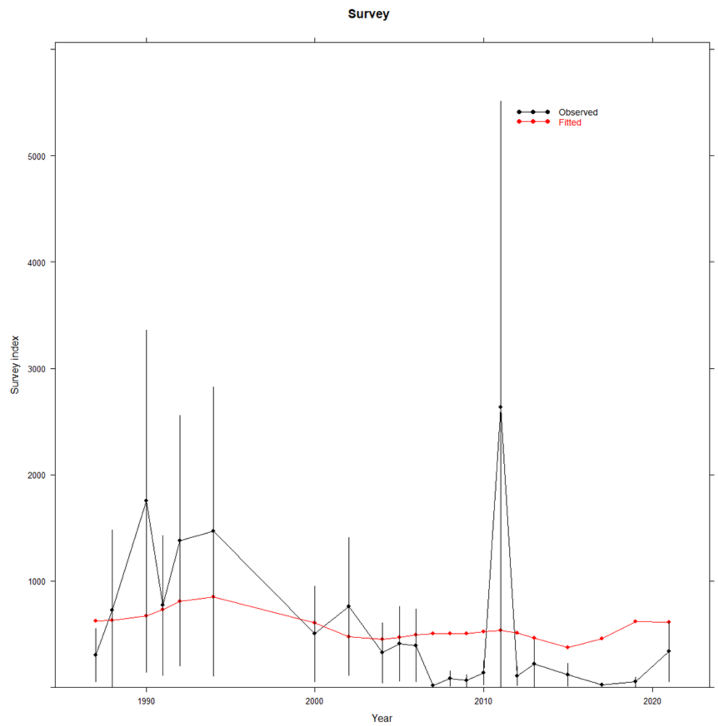

Figure 15: Model fit to survey index.

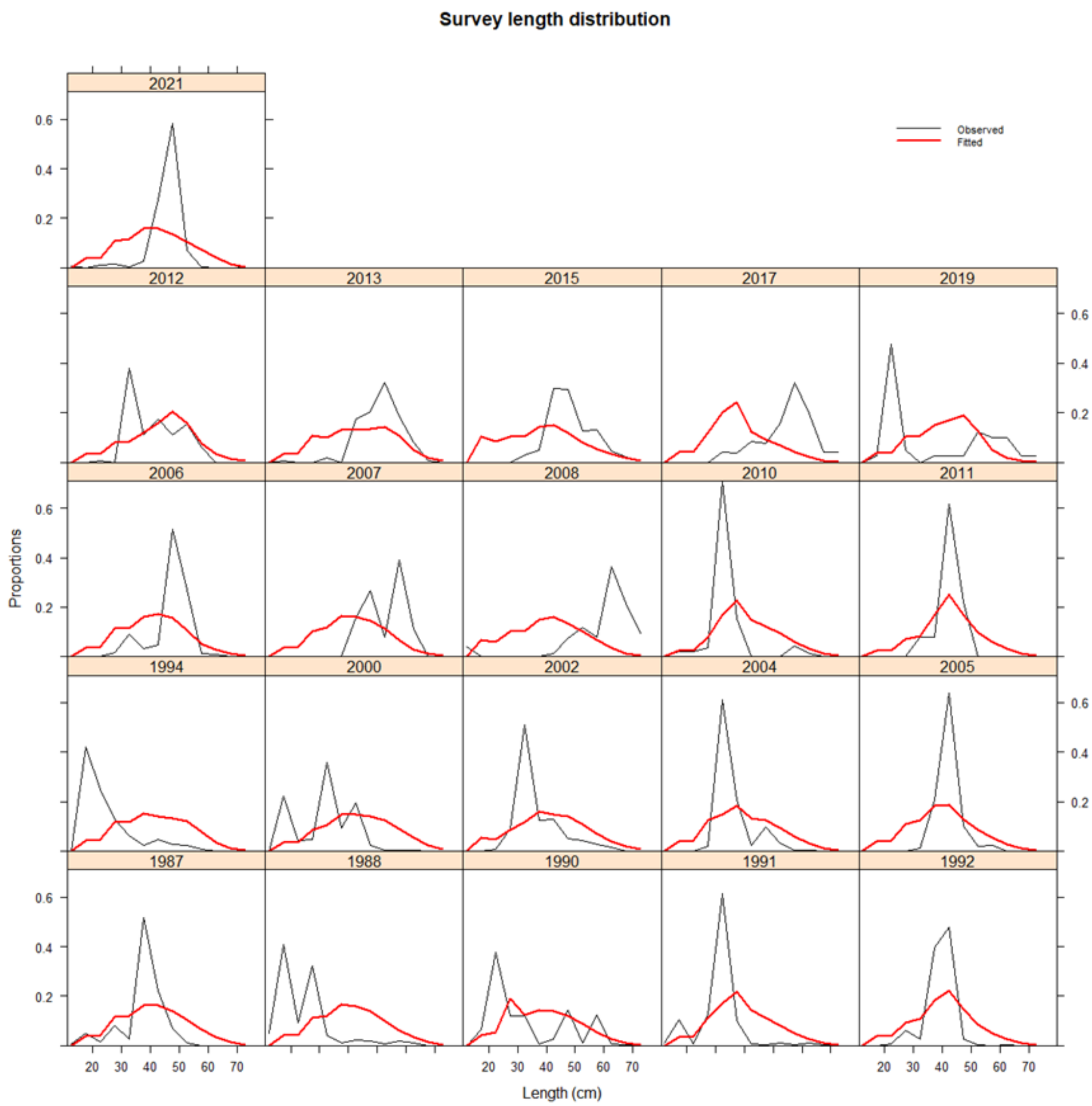

Figure 16: Model fits to survey length distributions.

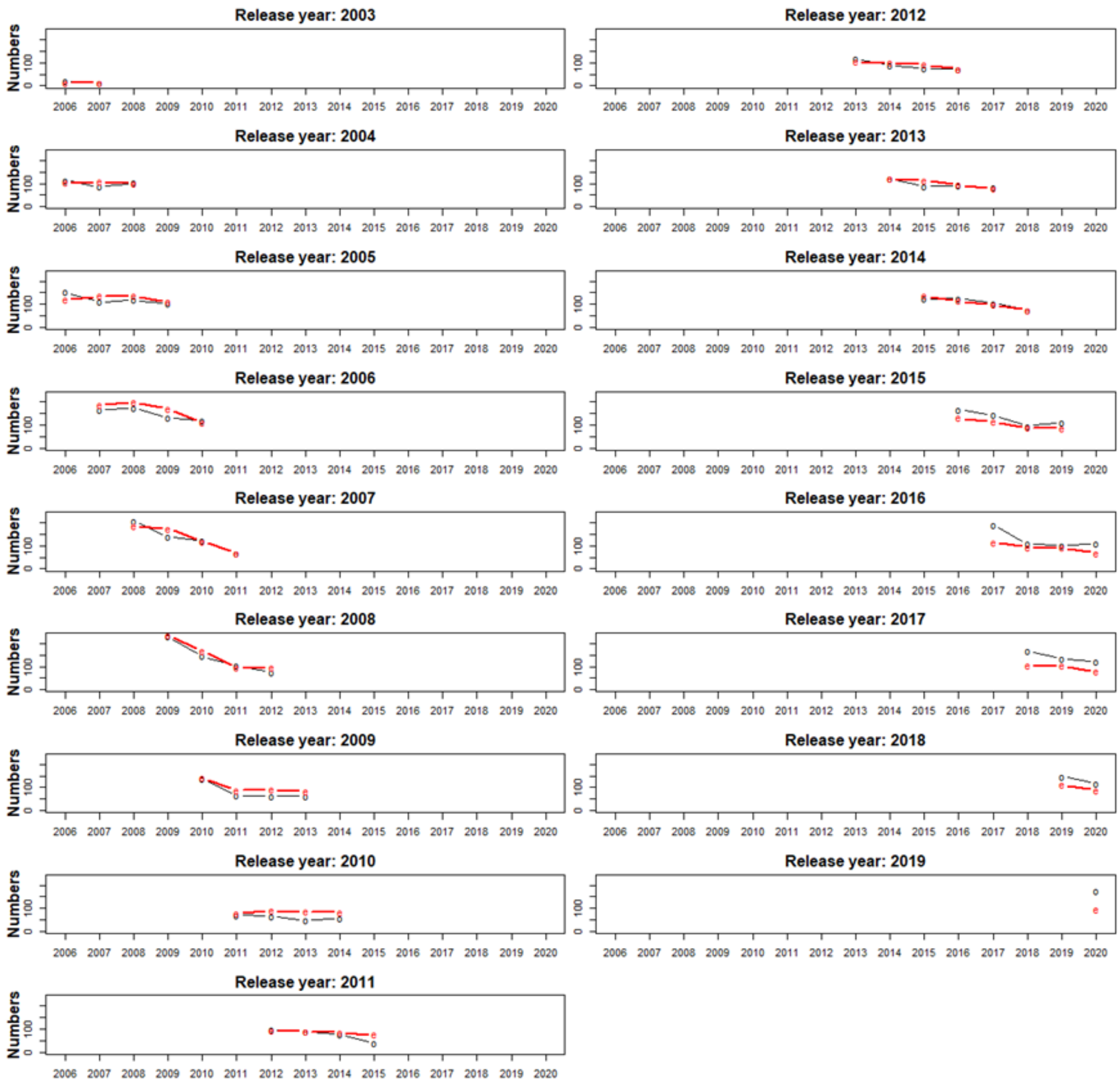

Figure 17: Model fit to tag recapture numbers.

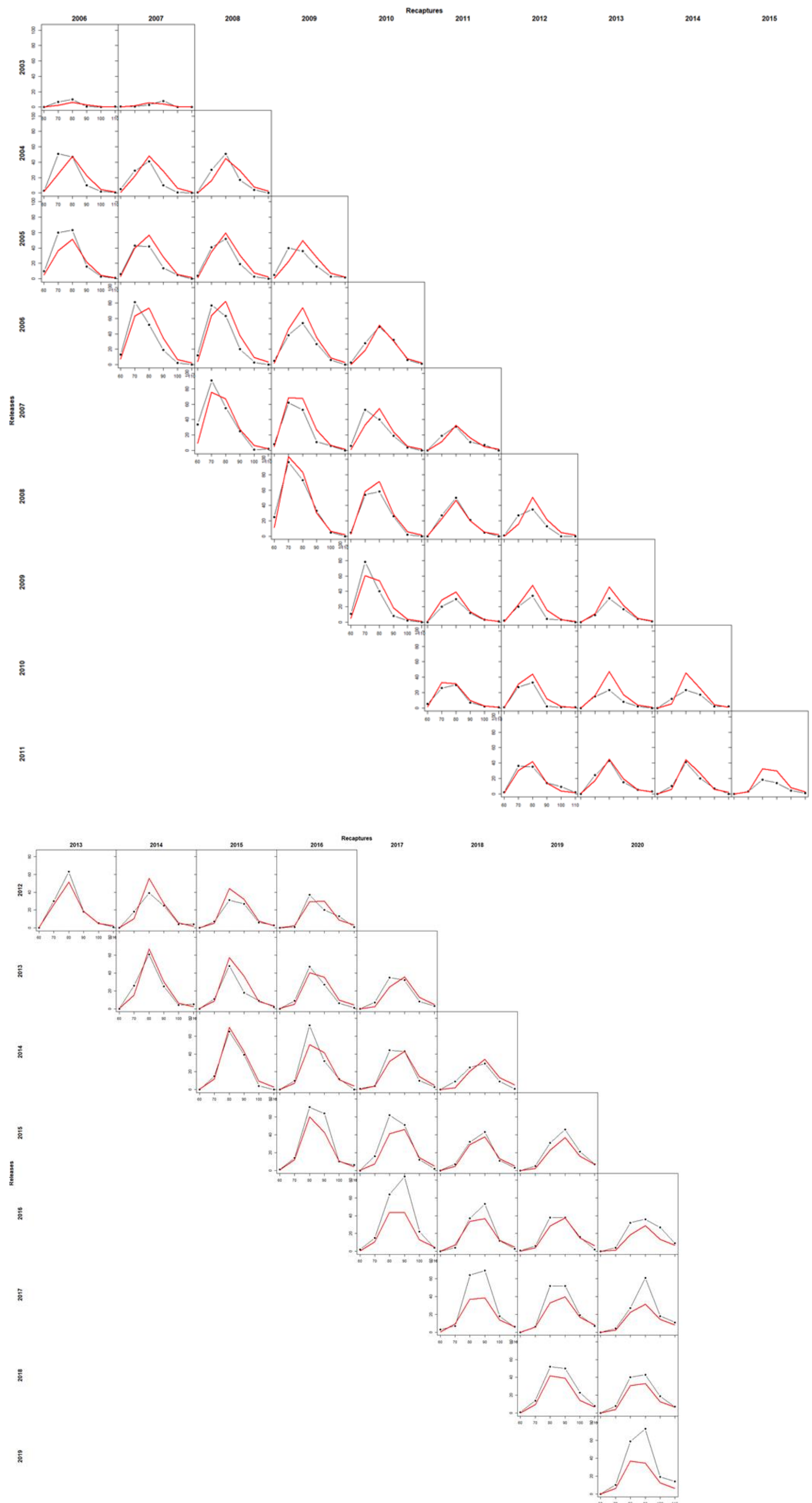

Figure 18: Model fit to tag recapture length distributions.

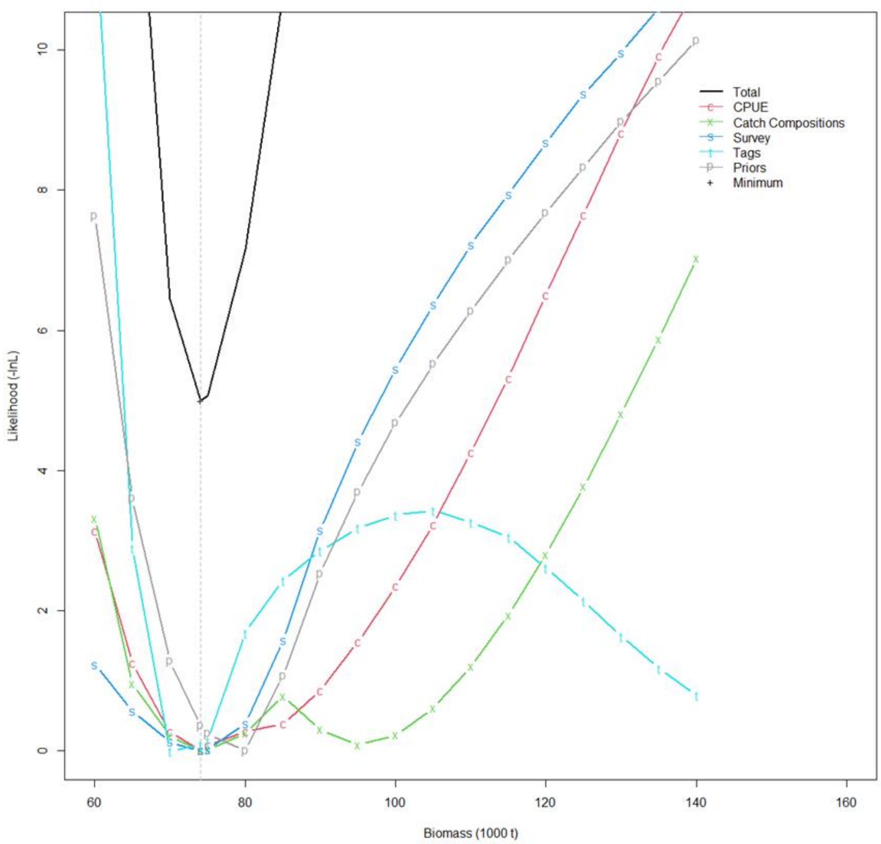

Figure 19: Profile of negative log likelihood around the minimum value estimated by the model (black) and its components. Red 'c': CPUE; Green 'x': Catch compositions; Blue 's': Survey abundance and composition; Turquoise 't': tag recaptures; Grey 'p': Priors and penalties.

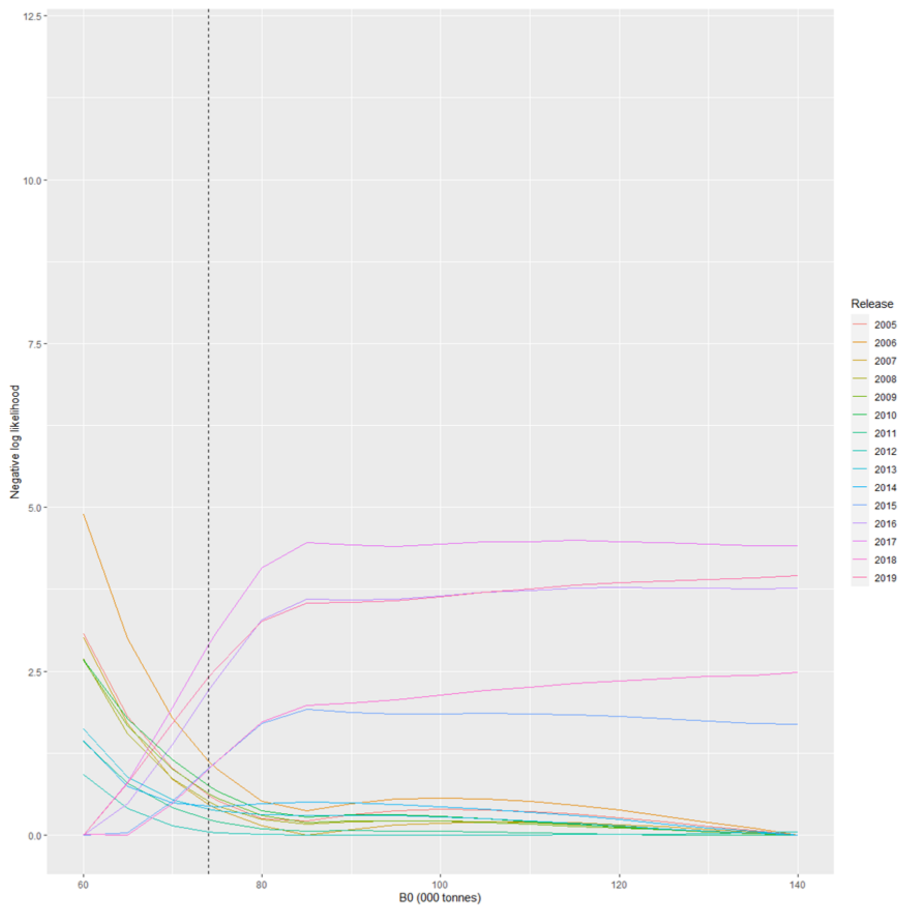

Figure 20: Profile of negative log likelihood from fitting to consecutive tag cohorts around the minimum value estimated by the model

11.3. Markov chain Monte Carlo (MCMC) fit

An MCMC analysis was run for the 2021 assessment to give an indication of the uncertainty in the MPD model fit. The MCMC trace of B_0, shown in Figure 21, indicates no obvious signs of lack of convergence. MCMC diagnostics for other model parameters are presented in the accompanying diagnostics paper. Comparisons with previous assessment models are shown in Table 8.

Table 8: Median spawning biomass and 95% CIs for the initial equilibrium SSB (B_0), the current SSB, (B current) and the ratio of current to initial SSB for the 2007-2021 assessments.

Assessment Year	B_0 (000 tonnes)	B current (000 tonnes)	B current / B_0
2007	112 (98.7-125.0)	67.1 (52.9-79.9)	0.59 (0.54-0.64)

2009	98.5 (93.6-103.8)	60.2 (55.0-65.7)	0.61 (058-0.64)
2011	85.1 (78.9-92.1)	44.9 (38.9-51.9)	0.53 (0.49-0.56)
2013	84.9 (80.5-89.9)	45.6 (41.4-50.8)	0.54 (0.51-0.57)
2015	85.9 (81.6-91.3)	44.7 (41.4-48.7)	0.52 (0.50-0.54)
2017	83.2 (79.0-88.1)	42.2 (38.9-52.6)	0.51 (0.49-0.53)
2019	79.7 (73.9-86.2)	40.1 (35.6-45.4)	0.50 (0.48-0.53)
2021	72.6 (68.2-78.5)	34.3 (30.5-39.7)	0.47 (0.43-0.53)

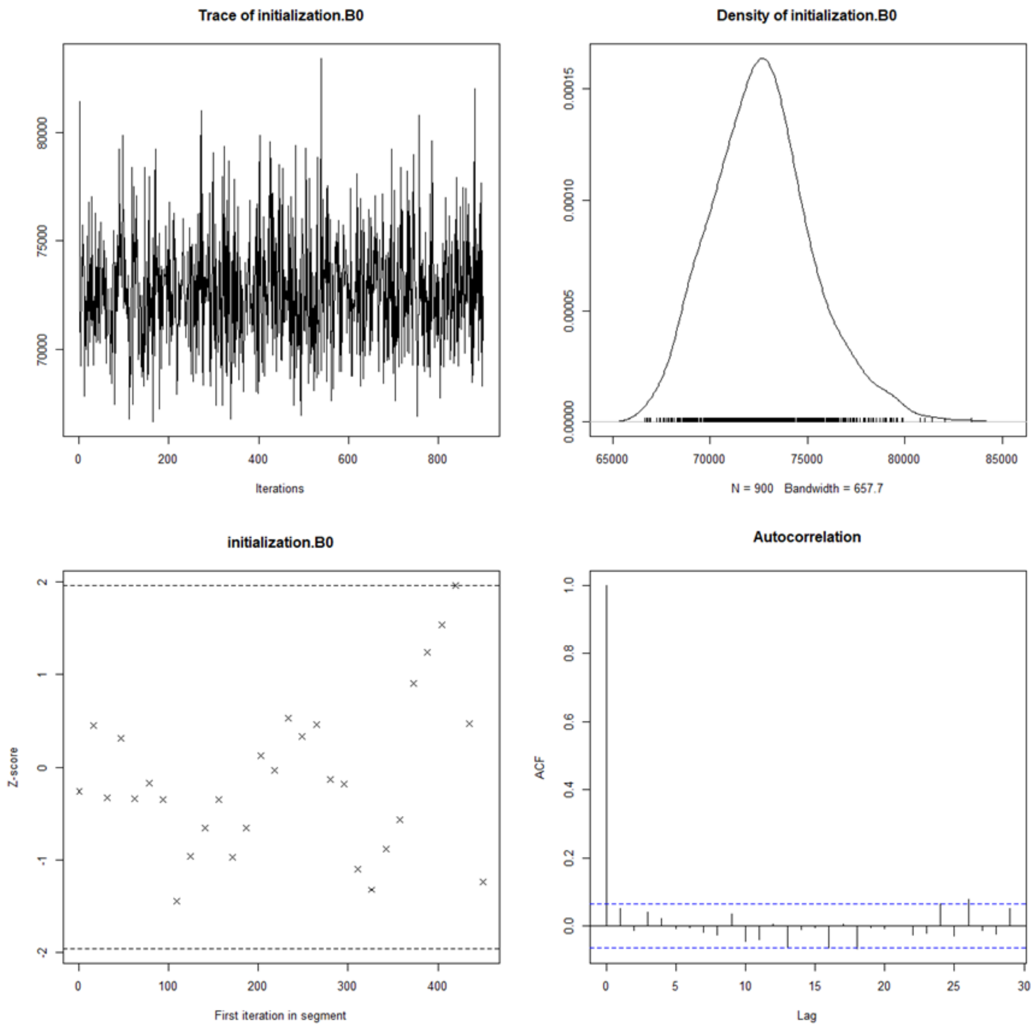

Figure 21: MCMC trace for B_0 (top left), distribution (top right), Geweke diagnostic plots (bottom left) autocorrelation diagnostic (bottom right) after trimming and removal of burn-in period.

11.4. Projections

Projections were carried forward using the 2021 assessments for 35 years using a constant catch, the average recruitment and CV from 1992 to 2015 for the stock projections with a lognormal empirical randomisation method of recruitment, as specified in CCAMLR WG-FSA (2013).

The projection (shown in Figure 23) indicated that total removals of 2,153 tonnes would be expected on average to keep the stock at 50% of B_0 after 35 years, with 0.1% of the simulations falling below 20% of B_0 during the 35-year period. Following the procedure agreed by SC-CCAMLR-38 (paragraph 3.70), this implies that the TAC of 2,072 tonnes would be consistent with the CCAMLR decision rules, after accounting for a recent average estimated depredation rate of 3.9% (2011-2020).

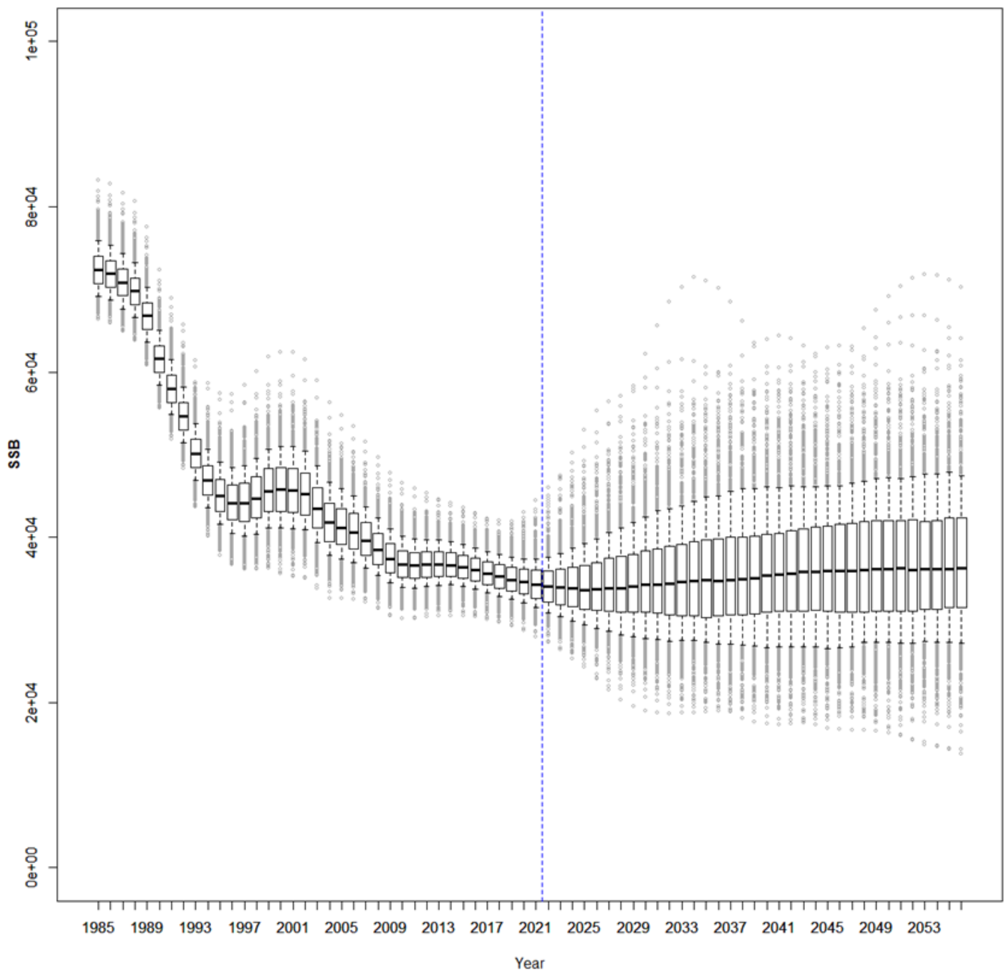

Figure 22: SSB projections with uncertainty based on removals of 2,153t from the MCMC model run. Boxes indicate inter-quartile range, and whiskers extent from 10-90%, with values outside this range being represented by circles.

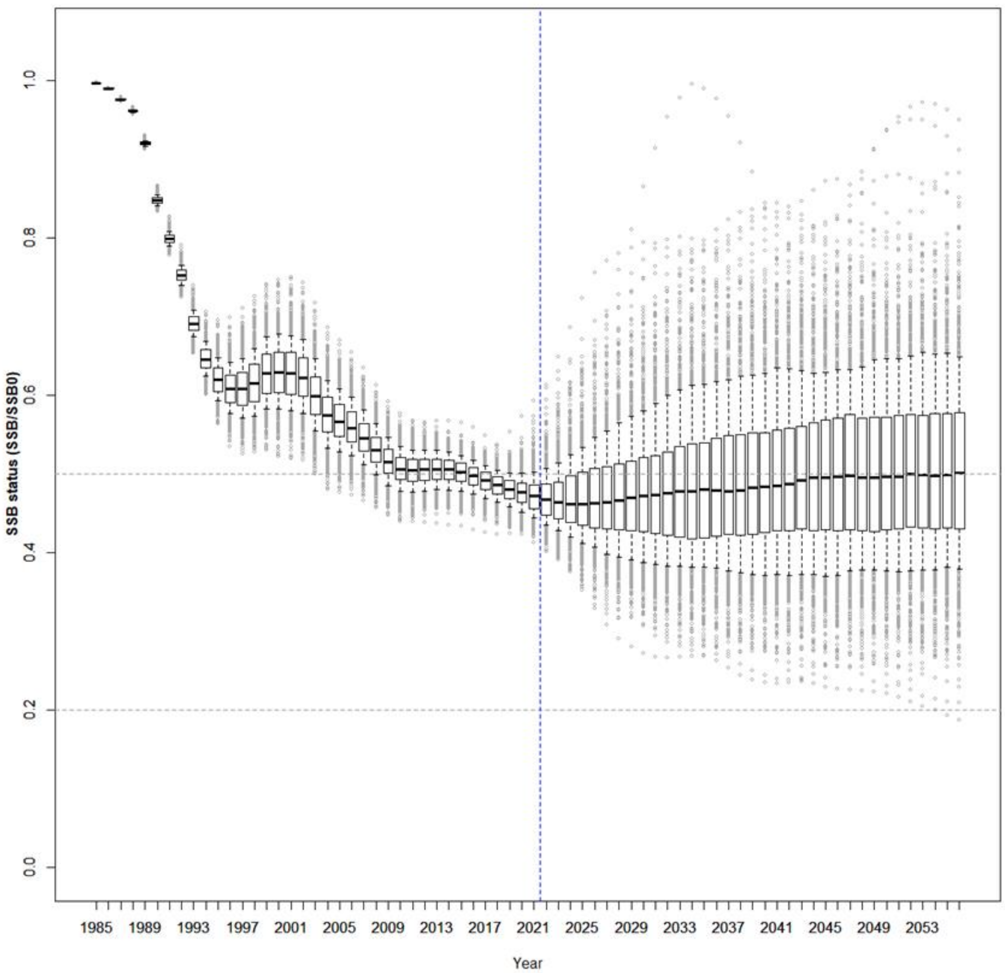

Figure 23: Stock status projections with uncertainty based on removals of 2,153t from the MCMC model run. Boxes indicate inter-quartile range, and whiskers extent from 10-90%, with values outside this range being represented by circles.

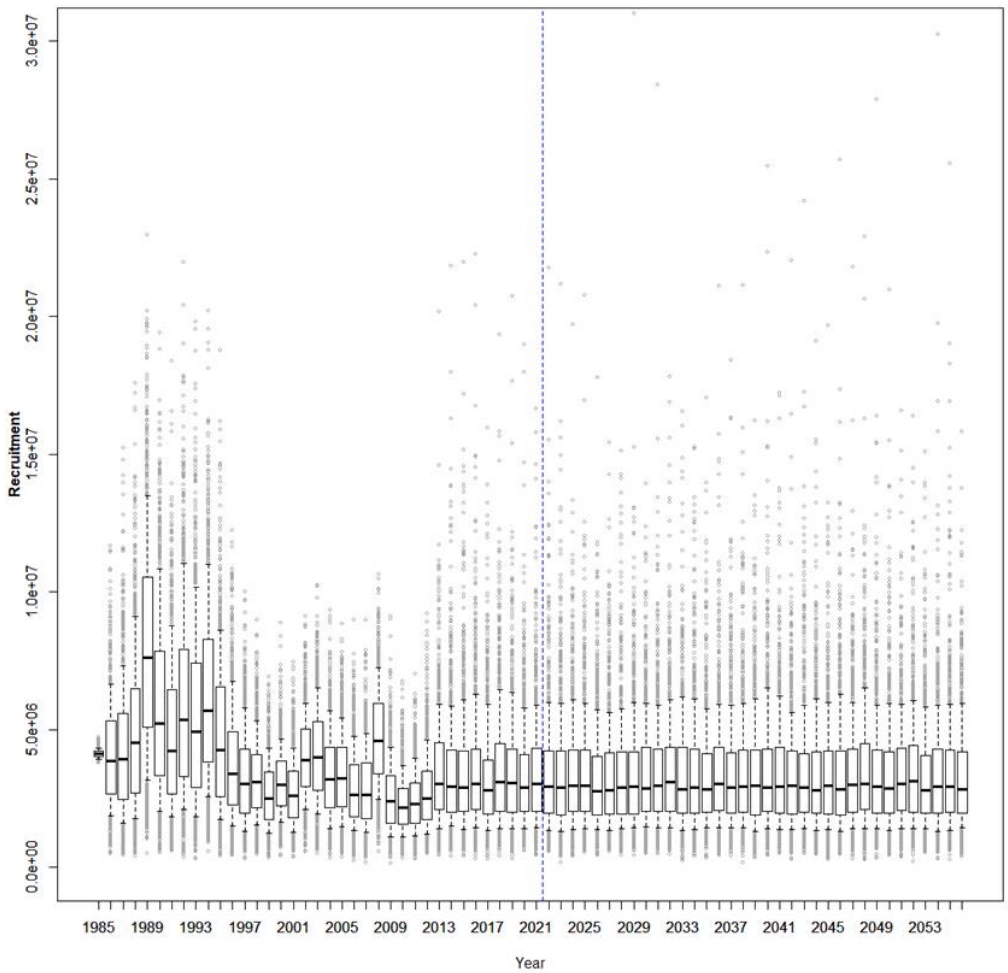

Figure 24: Recruitment projections with uncertainty based on removals of 2,153t from the MCMC model run. Boxes indicate inter-quartile range, and whiskers extent from 10-90%, with values outside this range being represented by circles.

11.5. Equilibrium harvest

Running long term simulations from an equilibrium age structure suggest that an F of 0.039 would be consistent with the CCAMLR decision rules in equilibrium. This would be expected to lead to average yields of 2,044 tonnes.

12. Summary

Assessment of the Patagonian toothfish (*D. eleginoides*) in Subarea 48.3 indicates that the current status of the stock is at 47% of B_0. Spawning biomass has been close to 50% of virgin biomass in recent years. The 2008 year class is estimated to be well above average, since then recruitment has been at or below average. Projections indicate that removals of 2,153 tonnes (catch of 2,072 tonnes) would be consistent with the CCAMLR decision rules.

13. References

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Additional Resources

- Fishery Summary: pdf, html
- Fishery Report: pdf, html
- Species Description: pdf, html
- Fisheries Documents Browser