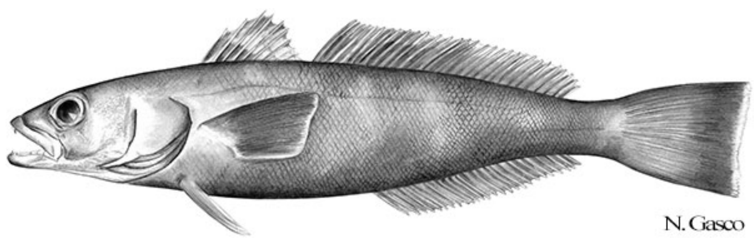
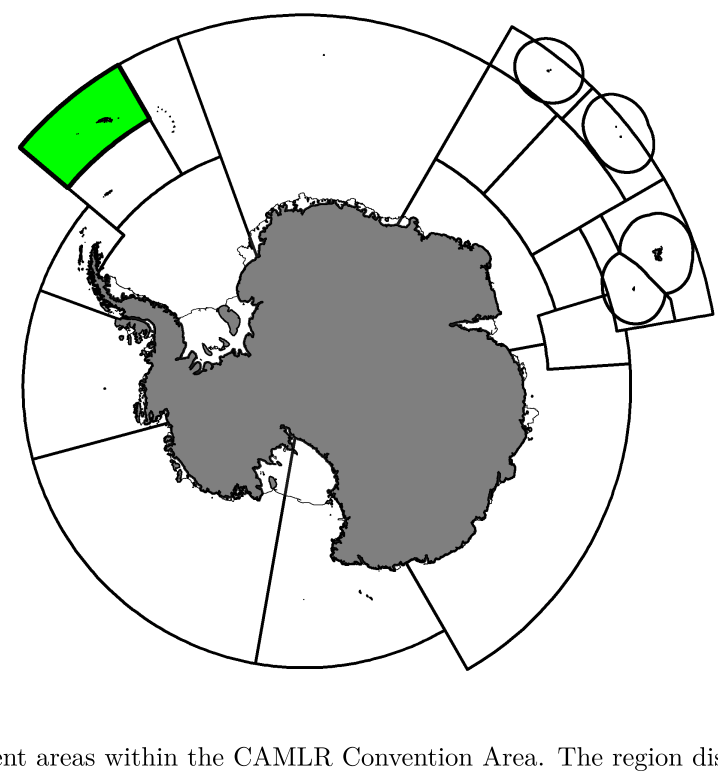
Stock Assessment Report 2024: *Dissostichus eleginoides* in Subarea 48.3

CCAMLR Secretariat

20 December 2024



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. Coastlines and ice shelves: UK Polar Data Centre/BAS and Natural Earth. Projection: EPSG 6932.

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

Tim Earl, Lisa Readdy, Sarah Alewijnse
Cefas, Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk, NR33 0HT

Abstract

The assessment of the Patagonian toothfish (*D. eleginoides*) in Subarea 48.3 was updated with an additional year of data, and updates were made to the methodology for standardising CPUE and fitting to the survey. The updated assessment indicates that the current status of the stock is at 49% of B_0 in 2024.

Alternative recruitment assumptions in projections were investigated, and the use of recruitment trends derived from the most recent 20 years of the survey is proposed. These projections indicate that a constant catch of 2,062 tonnes in the 2025[1] and 2026 seasons would be consistent with the CCAMLR decision rule after accounting for recent mammal depredation rates.

Based on this assessment, we propose two recommendations from Working Group FSA 2024 to the Scientific Committee:

1. Future recruitment assumptions for the implementation of the CCAMLR decision rule should be based on the estimated recent recruitment (20 years) from the age 3 abundance in the survey abundance, and
2. The catch limit for *D. eleginoides* in Subarea 48.3 should be set at 2,062 tonnes for 2025 and 2026 seasons.

1. Introduction

The history of the Subarea 48.3 Patagonian toothfish (*Dissostichus eleginoides*; TOP) fishery is summarised in Marsh and Earl (2023) and the history of the stock assessment is outlined in the stock annex (Earl et al., 2023). In the current assessment, we first revert the method for standardising the CPUE to that used up until 2023 and then add one year of data to provide a basis for investigating further development of the assessment model outlined in Table 1. These developments comprise a revision of the survey compositions from proportions-at-length to proportions-at-age, and inclusion of six rather than four years of tagging post release. Transforming the survey compositions from length to age is intended to slightly speed up model fitting.

The final model run was then used to investigate the effects of alternative recruitment assumptions, test the impact of recent tagging data, and to calculate catch limits based on the CCAMLR decision rules. Further diagnostics to aid understanding of the final model are presented in Earl and Readdy (2024a).

Following the recommendations of WG-FSA-2023, a program of work has been undertaken to investigate the biases that can be introduced into the assessment by changes in the spatial extent of the tag data used in the assessment (Masere et al. 2024a, b). The effect of these spatial changes on the assessment of the stock in Subarea 48.3 is investigated in Earl and Readdy (2024b), which shows that the effect of these changes is to substantially under-estimate current biomass and stock status.

[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.

Table 1: Model runs developing the assessment from that presented to WG-FSA-2023 (Earl and Readdy, 2023).

Software Model run	Objective
2023	Included from Earl and Readdy (2023) for comparison
Revert to GLM	Replace the GAMM method used to estimate standardised CPUE with the GLM estimate used up until 2023
Base	Update the data with one extra year, estimate an additional recruitment multiplier
Final: Survey	Include the survey compositions as proportions at age rather than proportions at length, exclude the abundance from the 2011 data which was exceptionally high and uncertain.

2. Input data

Following the recommendation of WG-FSA-17, in paragraph 3.20 (CCAMLR, 2017) fisheries data from the 2024 season were not included in the assessment. As a result, and following previous practice, fisheries data are included in this assessment up to the end of the 2023 season. The following data sources are used in the updated assessment:

- **Catch tonnage corrected for depredation:** Catch tonnage for the 2024 season was added. The depredation since 2004 was recalculated as part of the CPUE standardisation.
- **Tag scanned length distribution:** Data for the 2023 season were added.
- **Catch per unit effort data:** Data for the 2023 season were added. A GLM was fitted including all data from 2003 onwards used to estimate CPUE from 2004 onwards.
- **Observer data on orca and sperm whale sightings:** Data for the 2023 season were added. Depredation rates were estimated from the CPUE GLM.
- **Tag release data:** Data for the 2022 season were added. As tag recaptures are only included at least one season after release, the 2023 tag releases are not included.
- **Tag recapture data:** Recapture data for the 2023 season were added.
- **Survey biomass and length distributions:** No additional data was available as the survey typically occurs biennially. Length frequencies were converted to age frequencies.
- **Otolith ageing data from a sample of the catch:** Data from the 2023 season were added.

3. Standardised CPUE

In Earl and Readdy (2023), commercial catch per unit effort (kg per hook) was standardised using a GAMM applying the Berg et al. (2014) method implemented in the `surveyIndex` package (Berg, 2020), accounting for location, depth, vessel, sperm and killer whale abundance, day of year and season. In 2024, the addition of a further year of data resulted in the GAMM failing to converge. Minor modifications to the GAMM did not resolve the issue, and so we reverted to the previous method of using a GLM to standardise CPUE, depending on season, month, depth band, vessel nationality, orca and sperm whale presence and area.

The CPUE time series is shown in Figure 1 and the corresponding partial effects are shown in Figure 2. The average catch correction derived from the CPUE GLM (Figure 3) for the last ten years was 3.9%.

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 as the recent catch compositions, but different catchability rates (q) are estimated for the two blocks.

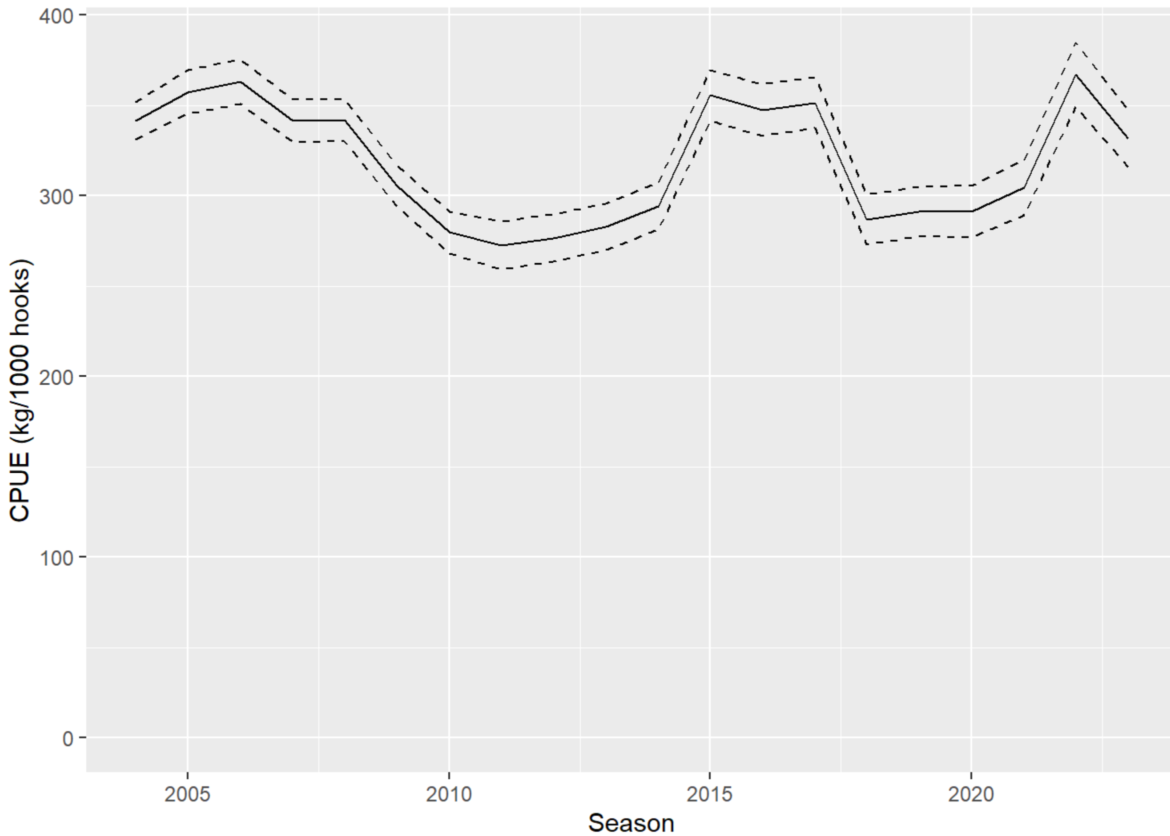


Figure 1: CPUE estimates by year from the CPUE standardisation GLM. Bold black line with dashed intervals shows model fit, with 95% confidence intervals.

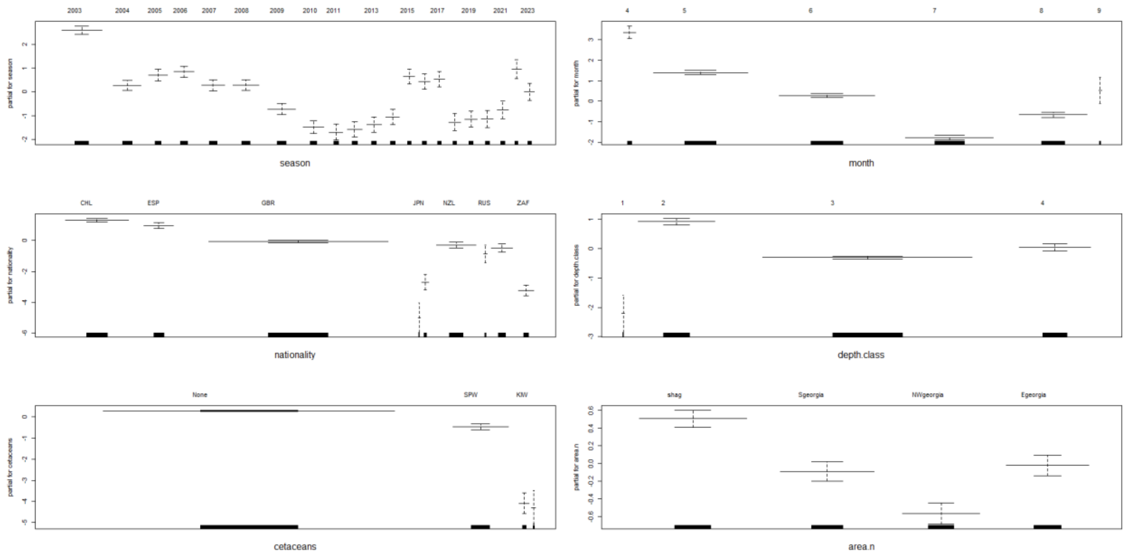


Figure 2: Magnitude of the partial effects on CPUE of the factors included within the GLM described.

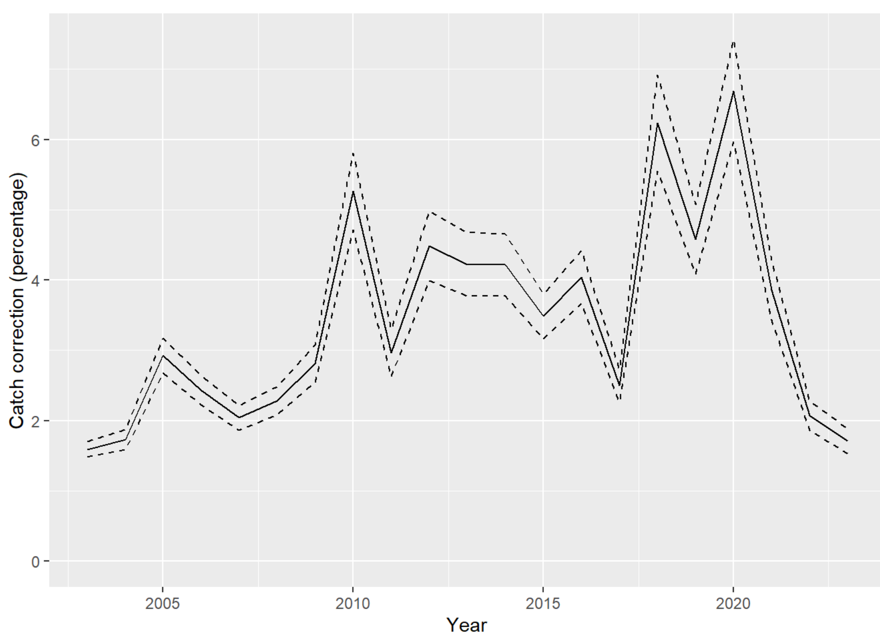


Figure 3: Correction factor applied to the catch to account for depredation, estimated from the frequency of sightings, and the effect of orca presence on CPUE as estimated by the GLM (lines).

4. Catch

Within the Casal2 models, catch from the fishery and estimated depredation is split into two time periods, with each period having a separate selectivity ogive. The period 1988-1997 covers a period where ageing data are not available, and so catch composition is specified as proportions at length. A summary of the catch data is provided in Table 2.

Table 2: Catches and estimated depredation (tonnes) used in the assessment.

Year	Catch	Depredation
1985	517.00	0
1986	732.00	0
1987	1,954.00	0
1988	876.00	0
1989	6,962.00	0
1990	6,828.00	0
1991	3,529.80	24.71
1992	6,861.67	48.03
1993	7,036.61	49.26
1994	5,248.43	31.49
1995	4,970.94	49.71
1996	3,529.00	77.63
1997	3,808.17	79.98
1998	3346.20	63.58
1999	4,292.48	94.43
2000	5,909.79	177.29
2001	4,230.85	126.93
2002	5,715.80	171.47
2003	7,503.12	112.55
2004	4,459.02	77.27
2005	3,029.53	88.67
2006	3,515.20	85.58
2007	3,524.49	71.93
2008	3,806.30	86.90
2009	3,381.55	95.27
2010	2,518.42	132.46
2011	1,732.46	51.38
2012	1,836.07	82.41
2013	2,093.58	88.39
2014	2,179.94	91.89
2015	2,195.10	76.55
2016	2,195.85	88.77
2017	2,194.90	54.84
2018	1,949.97	121.55
2019	2,124.41	97.27
2020	1,883.84	126.05
2021	1,812.79	69.88
2022	1,578.08	32.69
2023	1,615.08	27.61

5. Catch age and length distribution

The length distribution of the catches has been determined annually since 1995 by random sampling of the catch, as well as in four years between 1988 and 1993. This is combined with ageing data to calculate the age structure of the catch from 1998 to present, and is used within the Casal2 models as the numbers at length of fish scanned for tags within 10 cm length bins.

The number of otoliths read for construction of the age-length key (ALK) is shown in Table 3. A total of 466 fish caught in 2023 were used to calculate the age distribution of the 2023 catch (Figure 4). Further information about the age and length data from 2023 is presented in Appendix 1 of Earl and Readdy (2024a).

Table 3: Sample size for age determination of fish caught in Subarea 48.3.

Year	Sample size for age determination
1998	414
1999	479
2000	392
2001	619
2002	408
2003	464
2004	601
2005	406
2006	408
2007	485
2008	560
2009	718
2010	536
2011	447
2012	538
2013	296
2014	498
2015	507
2016	544
2017	600
2018	593
2019	623
2020	601
2021	578
2022	413
2023	466

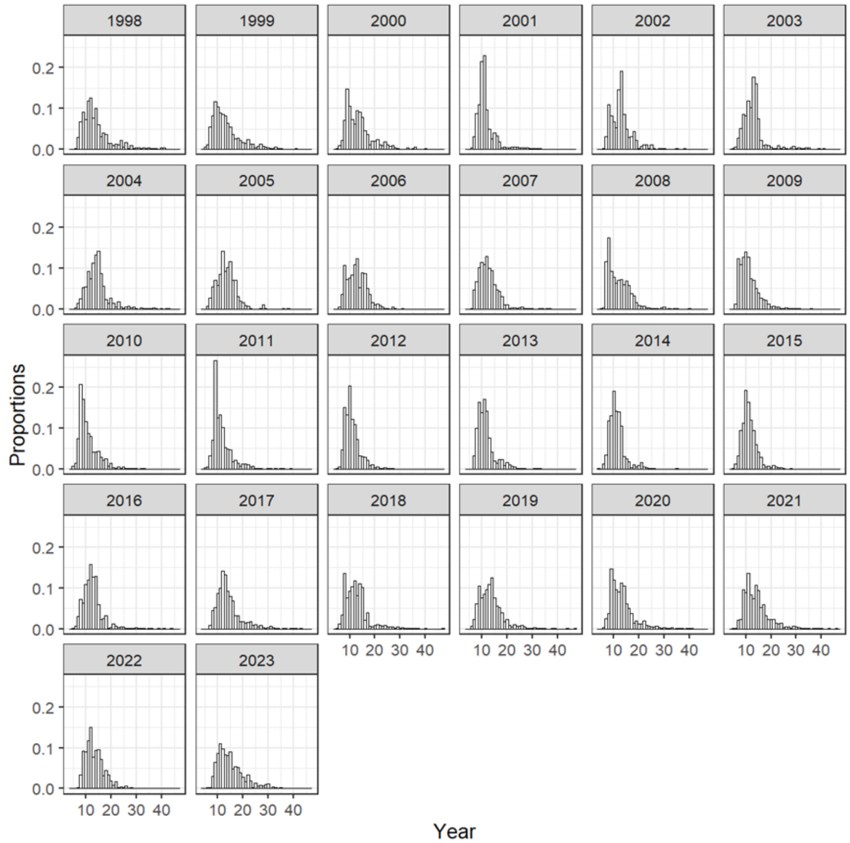


Figure 4: Raised age distribution in the catch over time.

6. Tagging data

Tagging data by length are used within the assessment, where in-year recaptures are removed (i.e. not included in the recaptures used, and deducted from the releases), and release numbers are corrected for length-dependent instantaneous tagging mortality.

In total, the effective release number of tags used in the assessment after removing in-year recaptures and instantaneous mortality is 61,212 up to the end of the 2022 season. Of these releases, 7,903 recaptures are used in the assessment (recaptured length of at least 60 cm and within one to four fishing seasons following release).

7. Survey biomass

Estimates of juvenile toothfish abundance are determined from shallow water (<400m) surveys around Shag Rocks, which constitute part of the biennial UK groundfish survey at South Georgia (Hollyman et al., 2023). The juvenile abundance 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 representative 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 5 and Table 4) and results 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. As a result, the 2011 estimate of abundance was excluded from the assessment. The 2023 value is the third highest value in the time series, suggesting a strong recent recruitment event in 2021.

*Table 4: Average density and coefficient of variation (CV) estimates for juvenile toothfish caught in the groundfish survey hauls shallower than 400 m around Shag Rocks. *2011 survey abundance excluded due to unusually high catch rate.*

Year	Average numbers/km^2	CV
1987	259.5	0.328
1988	722.9	0.790
1990	1,495.1	0.537
1991	832.1	0.313
1992	1,193.2	0.387
1994	1,249.5	0.566
1997	111.8	0.495
2000	435.5	0.469
2002	689.6	0.350
2004	269.9	0.352
2005	334.8	0.327
2006	376.1	0.413
2007	18.9	0.399
2008	77.1	0.374
2009	25.1	0.528
2010	137.8	0.280
2011*	2,605.5	0.758
2012	110.2	0.354
2013	206.7	0.712
2015	115.8	0.484
2017	24.7	0.570
2019	50.5	0.391
2021	329.9	0.307
2023	1,313.0	0.440

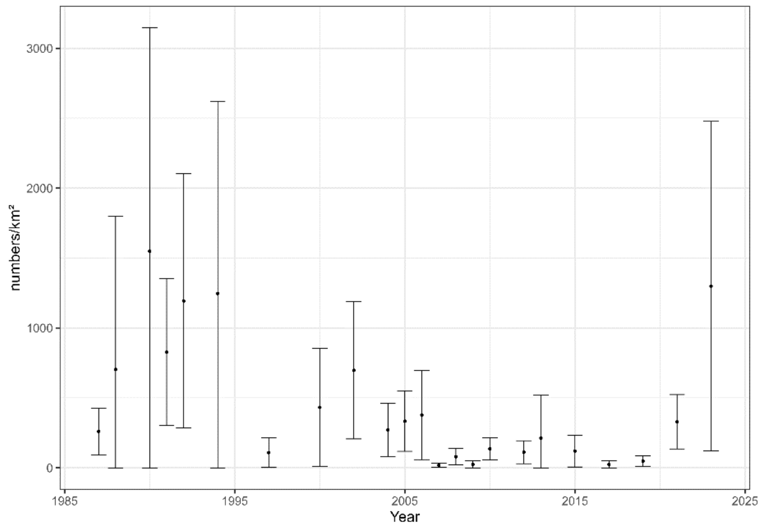


Figure 5: Relative abundance estimates with 95% confidence intervals from the groundfish survey biomass index.

8. Survey length and age distribution

Length distributions are recorded for all toothfish caught in the survey and are shown in Figure 6. There is some evidence that cohorts can be tracked, for example between the surveys in 1990-1992. As part of the development of the assessment in 2024, the compositions were converted to proportions at age (Figure 7). Proportions were calculated for ages 1-7+ using a combined age-length key, as only otoliths from five surveys have been aged.

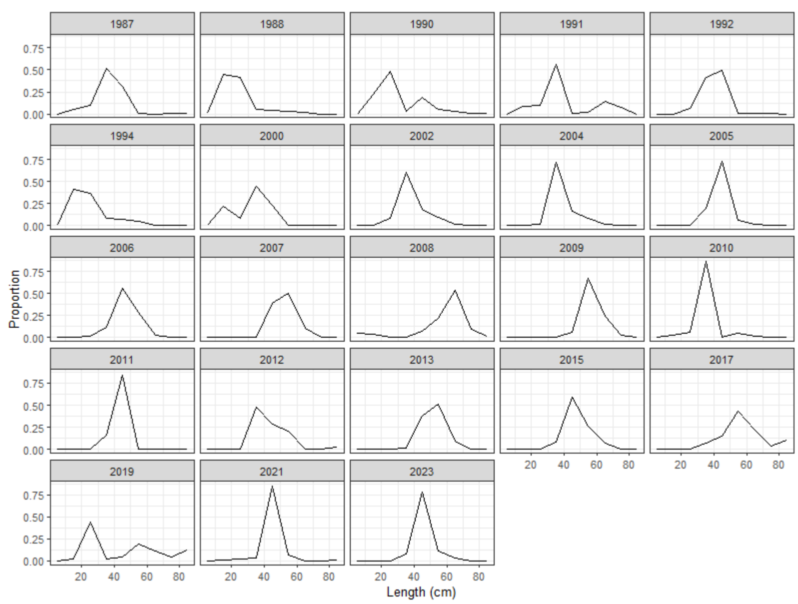


Figure 6: Groundfish survey length distribution in cm by 10 cm bins, proportions by year.

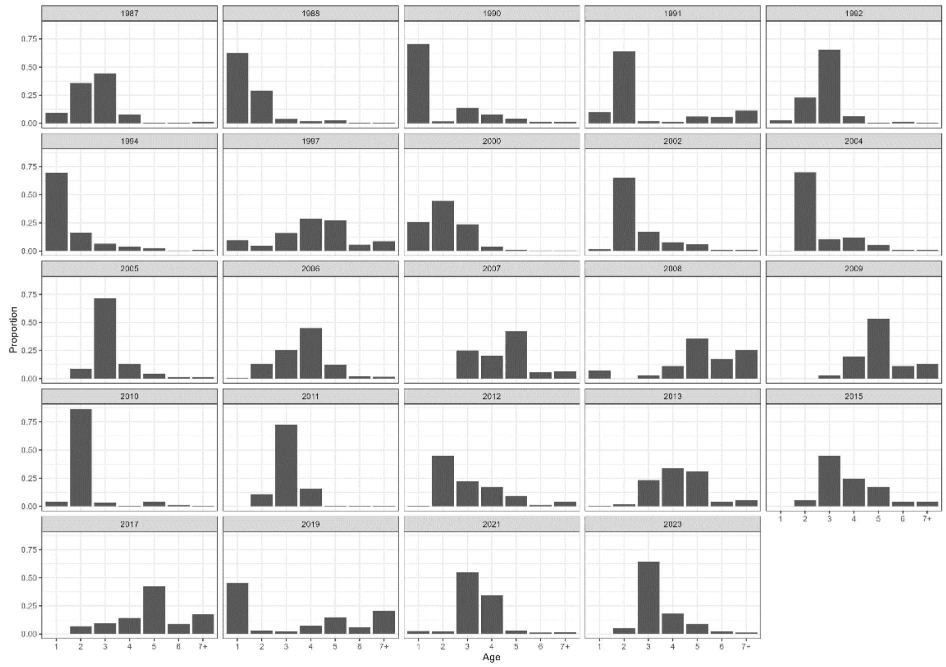


Figure 7: Groundfish survey age distribution, proportions by year.

9. Biological change indicators

Following the recommendation of SC-CAMLR-2023 paragraph 2.149, information is presented in Table 5 summarising the evidence for changes in stock assessment parameters or processes that could be due to the effects of environmental variability including climate change, following the template provided there.

Table 5: Summary of evidence for changes in stock assessment parameters or processes that could be due to the effects of environmental variability including climate change.

Parameter or process			**Evidence for trends and potential drivers**
1a	Recruitment	Mean recruitment	Results from the groundfish surveys indicate a negative relationship between juvenile toothfish density and summer maximum SST prior to spawning (Belchier & Collins, 2008). Survey data (e.g. Hollyman et al. 2023) suggest that a lower period of recruitment observed during the 2006-2019 surveys may now be coming to an end. Proportion of small (< 90 cm TL) individuals has remained relatively constant from 1997 – 2021 (Abreu et al. 2024).
1b		Recruitment variability	No information at present, however, the depletion rule (risk of falling below 20% of B_0) is not a constraint in this assessment. Earl et al. (2024) explored estimating autocorrelation in recruitment estimates.
2	Age at maturity		Evidence of increased age at maturity with time from 2009 - 2021 in females, but not in males (Marsh et al. 2022b). Changes cannot be attributed to climate change or

			environmental variability at present. Size at maturity has remained stable over the last 25 years (Abreu et al. 2024).
3	Stock-recruit relationship		No information at present.
4a	Natural mortality	From direct predation	No information at present.
4b		Not from direct predation	No information at present.
5	Growth rates		Work is ongoing to evaluate changes in growth rate breakpoints with time and bottom temperature. Macleod et al. (2019) and Marsh at al. (2022) showed variability in estimates of growth rate, but no overall trend.
6	Length-weight		No trends in length-weight relationships (Macleod et al. 2019, Marsh at al. 2022).
7	Sex ratio changes		Increase in proportion of females over time likely an artefact of increased fishing depth and not related to climate change (Marsh & Earl 2023, Abreu et al. 2024).
8	Spatial distribution		Preliminary analysis suggests most dissimilarity in spatial distribution of individuals caught is driven by changes in fishery distribution.
9	Stock structure		TOP at Subarea 48.3 are considered an isolated population, with little connectivity to other subareas (Söffker et al. 2022, Earl et al. 2023). There is currently no evidence of changing stock structure due to climate change or environmental variability.
10	Locations of spawning and site fidelity		Biennial groundfish surveys consistently catch the most TOP (largely juveniles) around Shag Rocks (Gregory et al. 2019, Collins et al. 2021 and Hollyman et al. 2023). Spawning hotspot analysis indicates any apparent changes in spawning location are likely driven by changes in fishery distribution rather than being true signals (Bamford et al. 2024).
11	Depredation mortality		Orca and sperm whale presence is recorded and used as a factor in the CPUE standardisation. Estimated orca depredation is included as additional catch in the assessment and projection. Estimated depredation has decreased overall since 2000 (Table 2), though it is unclear if this is related to climate change or environmental variability.

10. Model structure

The Casal2 model structure is described in Earl and Readdy (2023b), with key parameters shown in Table 6, which remain unchanged. Model runs were completed in Casal2 version v24.07 (2024-07-14).

Table 6: Biological parameter values for D. eleginoides in Subarea 48.3.

Component	Parameter	Value	Component	Parameter	Value
Natural mortality	*M*	0.13	Tag-related growth retardation		0.75
VBGF	*K*	0.0653	Casal2 tag loss rate		0.0061 over 4years
VBGF	t_0	-1.4869	Immediate tagging survivorship		Applied as a vector to length-based tag-release data
VBGF	L_∞	154.1977	Tag probability of detection		1
Length-weight	*a*	6.76×10^{-9}			
relationship	*b*	3.085	Stock-recruit relationship steepness	*h*	0.75
Maturity range: 0 to full maturity		1–41	Lognormal recruitment SD		Estimated

11. Data weighting

For each step of the model development, an initial run was performed using the following data weighting:

- Tag dispersion constant across all years
- Catch age composition effective sample size given by number of otoliths aged in each year
- Survey age composition effective sample size given by number of hauls multiplied by average number of otoliths aged from each haul,
- Survey index and CPUE have CVs calculated outside the model, and process error initially fixed to near zero.

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

1. Catch age and length compositions and survey length compositions were 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.

The results of these steps are shown in detail for the final model in Table 7, and summarised for other model runs in Table 8.

Table 7: Data weighting steps in the 2024 assessment.

	Initial weighting	**Weighting step A**	**Weighting step B**	**Estimates from step B****
ESS* per otolith in survey	1	0.021	0.022	-
ESS* per length in catch	1	0.401	0.405	-
ESS* per otolith in catch 1998-present	1	0.031	0.031	-
Tag dispersion	8.68	8.68	16.8	-

Early CPUE process error	0.001	0.001	0.001	0.12
Late CPUE process error	0.001	0.001	0.001	0.17
Survey process error	0.001	0.001	0.001	1.30

*ESS: Effective sample size
**Estimated as parameters in the Casal2 model fit

12. Model outputs

Maximum Posterior Density (MPD) fits

Model development from the 2023 to the 2024 final model was undertaken using a stepwise approach, with key outputs shown in Figure 8 and Table 8. Due to the CPUE GAMM not converging with the addition of 2023 data, the first step was to revert to the GLM approach used until 2023. This shows a re-estimation of the SSB and relative SSB trends, reversing some of the increases in SSB estimated during the 2023 updates ("WG-FSA-2023: Selectivity" run compared with "WG-FSA-2023: Final" showed the effect of changing to the GAMM in 2023). The largest differences occur around 2000, before the start of the tagging program which provides much of the data on abundance. The effect on recruitment is to decrease the slope and increase the variability between years.

Adding an extra year of data and estimating an extra recruitment gives the base model. Relative SSB and recruitment multiplier estimates remain very similar, with a slight downward revision of SSB. The further development to include the survey as age makes little difference to the perception of the stock.

MPD fits of the model estimates to observations are shown in Earl and Readdy (2024a) Figures 6-22. Of particular note is fits to the tag recaptures at length (Figures 18 to 21) which continue to show higher than expected recaptures in recent years, especially in the first year after release. The fit to the CPUE (Figure 17) is slightly improved compared to 2023 but remains poor.

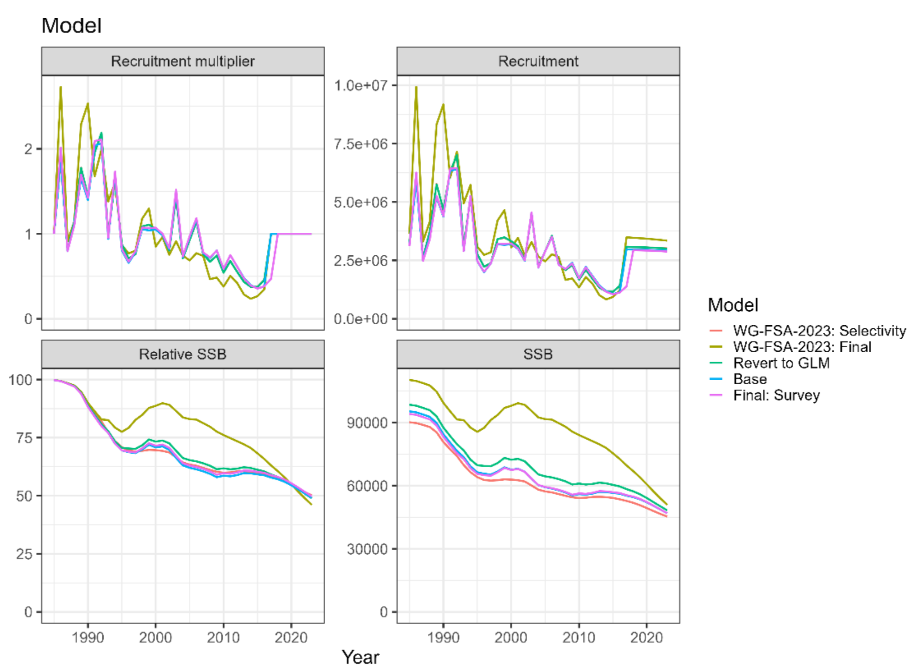


Figure 8: MPD runs showing stepwise development from 2023 final model to 2024 final model. Note that the final year in all of the MPD estimates is 2023, as no data from 2024 are included.

Table 8: Summary of estimated effective sample sizes, parameter estimates and negative log likelihood for each of the model sensitivity runs.

Value	WG-FSA-2023	Revert to GLM	Base	Final: Survey
ESS** per haul	0.178	0.176	0.177	-
ESS** per otolith	-	-	-	0.022
ESS** per length 1988-1997	0.387	0.370	0.357	0.405
ESS** per otolith 1998-2022	0.035	0.032	0.032	0.031
Tag dispersion	7.3	16.1	19.1	16.8
B_0	110386	98619	94264	93850
Early CPUE process error	0.14	0.12	0.12	0.12
Late CPUE process error	0.26	0.14	0.14	0.17
Survey process error	1.39	1.66	1.67	1.30
Early Selectivity (1985-1997)	9.03	9.04	9.06	9.07
	0.05*	0.05*	0.08	0.05*
	9.44	8.98	9.19	8.59
Late selectivity (1998-2021)	7.05	9.55	9.79	9.73
	0.05*	1.72	1.80	1.84
	15.40	15.25	15.64	16.00
Survey selectivity	5.00	3.04	3.19	2.61
	3.44	1.71	1.86	1.29
	0.10	2.30	2.15	2.59

*parameters estimated at or close to bounds
**ESS: Effective sample size

Retrospective analysis

Following the recommendation WG-SAM-2024 (paragraph 5.13), two retrospective analyses were performed using the MPD estimates. The full retrospective (Figure 9) shows the effect of successively removing years of data (and number of estimated recruitments), while keeping the model structure and data weighting consistent. There is reasonable consistency between assessments in the estimates of recruitment multipliers, recruitment and relative SSB. The estimates of SSB in the assessment show a decrease from assessment to assessment as the estimates of B_0 decrease, due to the lower recent estimates of recruitment decreasing the average recruitment assumed for the initial state of the stock.

A retrospective limited to removing successive tag releases and recaptures is shown in Figure 10. This highlights that the SSB estimates from the last six peels are relatively consistent during the period from 2005-2015, but SSB is estimated to decline more steeply following that point with the addition of further tagging data.

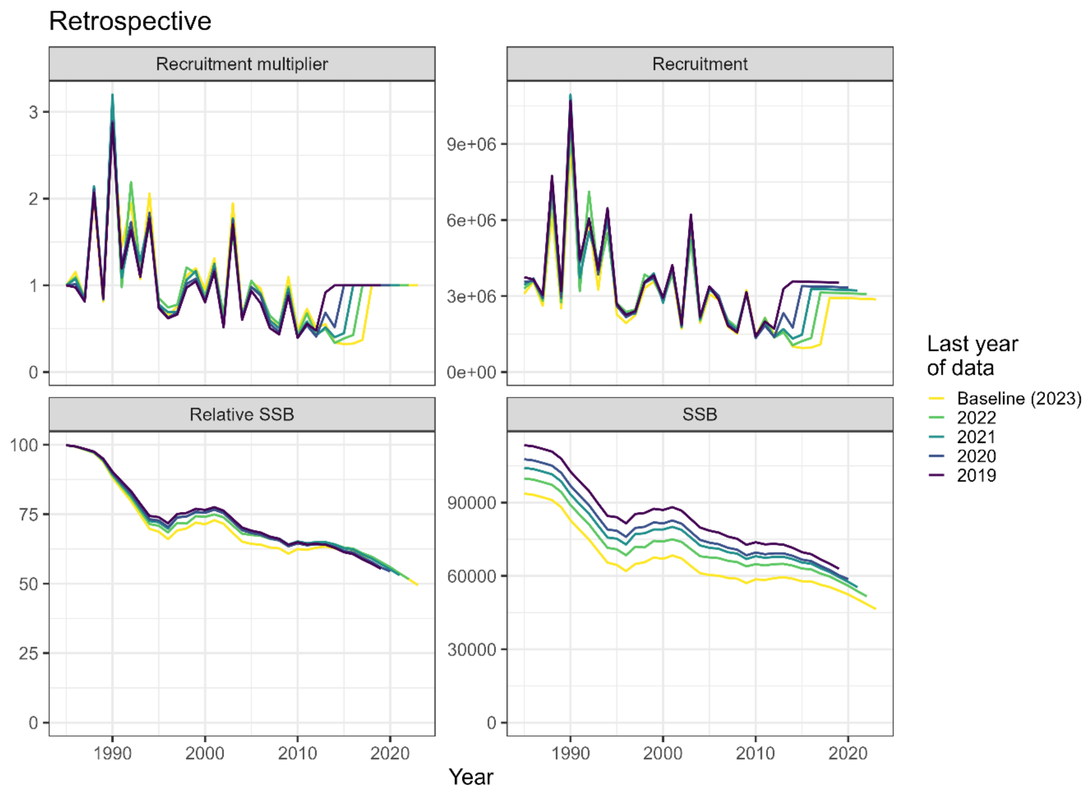


Figure 9: Retrospective analysis showing the effect of successively removing years of data (and estimated recruitment), while keeping the model structure and data weighting consistent.

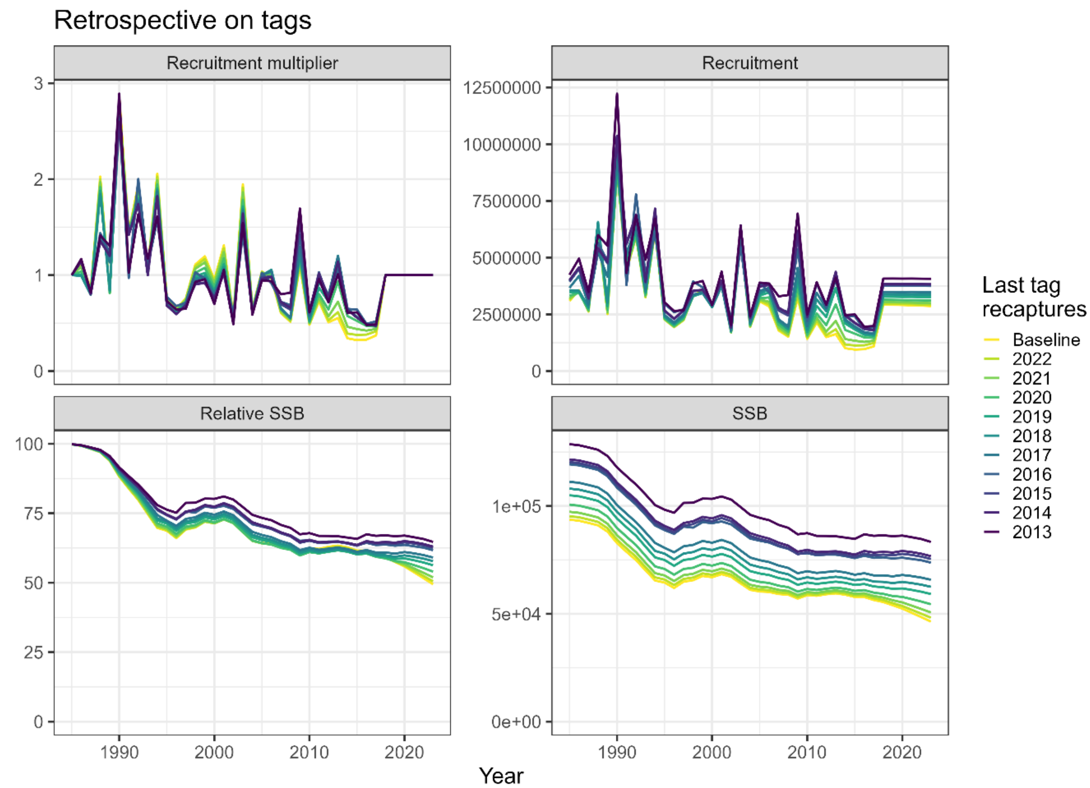


Figure 10: Retrospective analysis showing the effect of successively removing years of tag data, while keeping the model structure and data weighting consistent.

Profiling on B_0

Profiling of the MPD model was performed on B_0 for a range of values between 70,000 and 140,000 tonnes (the MPD estimate of B_0 using the 2024 final model was 93,850). Likelihood components are shown in Earl and Readdy (2024a) Figures 23–26. As with previous assessments, the tag release and recapture cohorts have a substantial trend in the B_0 at which they achieve a minimum. In contrast, the time at liberty shows no overall trend in B_0 and each subset of the recaptures is consistent with a higher estimate of B_0 than the MPD estimate.

Markov chain Monte Carlo (MCMC) fit

An MCMC analysis was run for the 2024 assessment to give an indication of the uncertainty in the MPD model fit and provide a basis for the stochastic projection. The MCMC trace of B_0, shown in Earl and Readdy (2024a) Figure 27, indicates no obvious signs of lack of convergence. MCMC diagnostics for other model parameters are presented in Figures 28–67 and Table 5 of that document. R hat statistics (Figure 68 of Earl and Readdy, 2024a) comparing three chains show that chains are well mixed for all estimated parameters, with the exception of the left-hand selectivity (σ_L) of the survey. Performance is generally good, although parameters associated with the selectivities show some autocorrelation within the chains, and in the case of the left-hand limb of the survey selectivity, an inability to estimate the parameter. This is likely to be related to the narrow range of ages caught in the survey, and further work to investigate alternative selectivity models could help to resolve this. Comparisons with previous assessment models are shown in Table 8. The estimated B_0 is higher than recent assessments, with the exception of the 2023 assessment, and the current SSB is estimated at

49% of B_0, a slight increase compared to previous years. The recent decline in stock size can be attributed to some lower recruitments in 2015-2017 as well as the contraction of the spatial coverage of data collection methods (Masere et al. 2024a, b, Earl et al. 2024).

Table 9: 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 2007-2024 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)
2022	76.6 (71.3-82.7)	35.9 (31.5-41.3)	0.47 (0.44-0.51)
2023	109.1 (100.8-119.6)	51.6 (46.0-59.0)	0.47 (0.44-0.52)
2024	94.1 (87.0-102.8)	46.9 (40.1-57.0)	0.49 (0.44-0.59)

Projections

WG-FSA and WG-SAM (e.g. Earl et al. 2024) have previously highlighted the importance of recruitment assumptions when calculating catch limits using the CCAMLR decision rules. In other integrated toothfish assessments in the CAMLR Convention area, projections have assumed average recruitment from the assessment will continue, whereas a multiplier of 85% was applied to the future recruitments in Subarea 48.3 originating from uncertainty about the early recruitments. WG-FSA-2023 requested further work investigating recruitment assumptions used for the projections and catch limit estimation.

We consider the following possibilities:

1) Using the assumption that average recruitment persists
2) Using information from the groundfish survey to provide information on trends in recruitment
3) Excluding an exceptionally high recruitment before calculating the average yearclass strength.

Option 1

Projections using option 1 assume that future year class strengths have the same mean as the estimates from the assessment period. This approach is consistent with what has been previously assumed in other toothfish assessments in the CCAMLR convention area (e.g. Masere and Ziegler, 2023, Massiot-Granier et al. 2023 and Mormede et al., 2023). These recruitment assumptions result in a catch limit of 2,733 tonnes.

Option 2

The most direct source of recruitment information used in the stock assessment is the groundfish survey, typically carried out biennially, and catching predominantly age 3-5 toothfish. Using these data we propose using the abundance of age 3 fish as an indicator of recent recruitment. We propose that using a 20-year average relative to the long-term mean would give an indicator of the trends in recruitment, while recognising that toothfish recruitment may follow multi-decadal cycles. Such an index taken directly from the survey data is largely independent of any mis-estimation of recruitment in the stock assessment. Using this index of recruitment we project with future recruitments that are 88% of the long-term average, leading to a catch limit of 2,062 tonnes.

Option 3

The estimated recruitment (Figure 12) shows that the 1990 estimate of recruitment was exceptionally high, compared to any recruitment estimated before or after. Such a large single estimate of recruitment has a relatively large influence on the average future recruitment, without it the average recruitment would be 94% of the average including it. By applying this multiplier to the future recruitment, the catch consistent with the CCAMLR decision rule would be 2,381 tonnes

U-based catch limits

WG-SAM-2024 investigated the effect of using U-based harvest control rules for setting catch limits. This has the advantage of increasing the extent to which the catch limit decreases if stock size decreases, while allowing more catch to be taken when the stock is around or above the target reference point (Ziegler et al. 2024a, b). Exploratory runs of the rules considered by WG-SAM-2024, using the 2024 Subarea 48.3 final assessment provide catch limits of 2,966-3,598 tonnes depending on the choice of rule. Showing these rules on the Kobe plot (Figure 11) shows that the current exploitation rate (U) is appropriate for the estimated stock status.

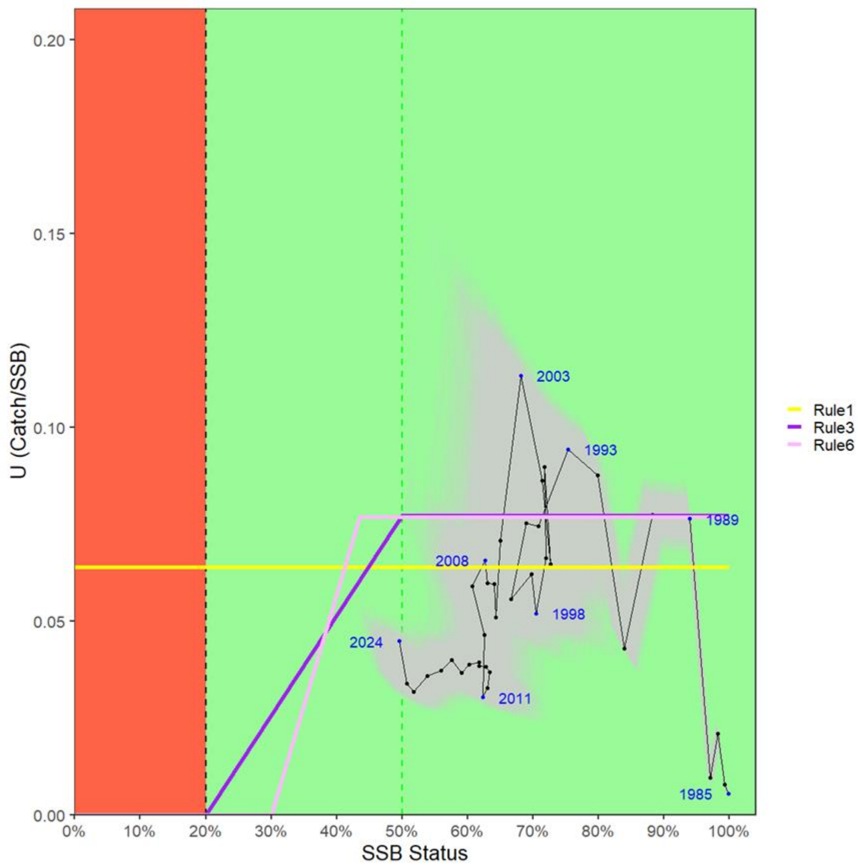


Figure 11: Kobe plot (phase plot) of MCMC SSB projections relative to B_0 compared to harvest rate U; median (black line) with MCMC uncertainty range (grey). Coloured lines show the U-based rules proposed by WG-SAM-2024.

Choice of projection approach

We propose using option 2 for setting the catch limit in this and future years, scaling future recruitment according to the recent abundance of age 3 fish in the survey. Such a result recognises the value of the groundfish survey as a model-independent index of recruitment.

The projection (shown in Figures 12 and 13, and in more detail in Earl and Readdy 2024, Table 6 and Figures 69–72) indicated that a catch of 2,062 tonnes with an additional 81 tonnes of depredation assumed (based on a 3.9% average 2014–2023) would be expected on average to keep the stock above 50% of B_0 after 35 years, with 0.1% of the simulations falling below 20% of B_0 during the 35-year period. The projection (shown in Figures 12 and 13, and in more detail in Earl and Readdy 2024, Table 6 and Figures 69–72) indicated that a catch of 2,062 tonnes with an additional 81 tonnes of depredation assumed (based on a 3.9% average 2014–2023) would be expected on average to keep the stock above 50% of B_0 after 35 years, with 0.1% of the simulations falling below 20% of B_0 during the 35-year period. The associated statistics are shown in Table 10. Following the procedure agreed by SC-CCAMLR-38 (paragraph 3.70), this implies that the catch limit of 2,062 tonnes would be consistent with the CCAMLR decision rules.

Table 10: Forecast summary values

Quantity	Value
Proposed yield (t)	2062
Expected depredation (t)	81.2
MPD B0 (t)	93850
MCMC median B0 (t)	94064
Total objective function value	771.7
Risk 1	0.500
Risk 2	0.001

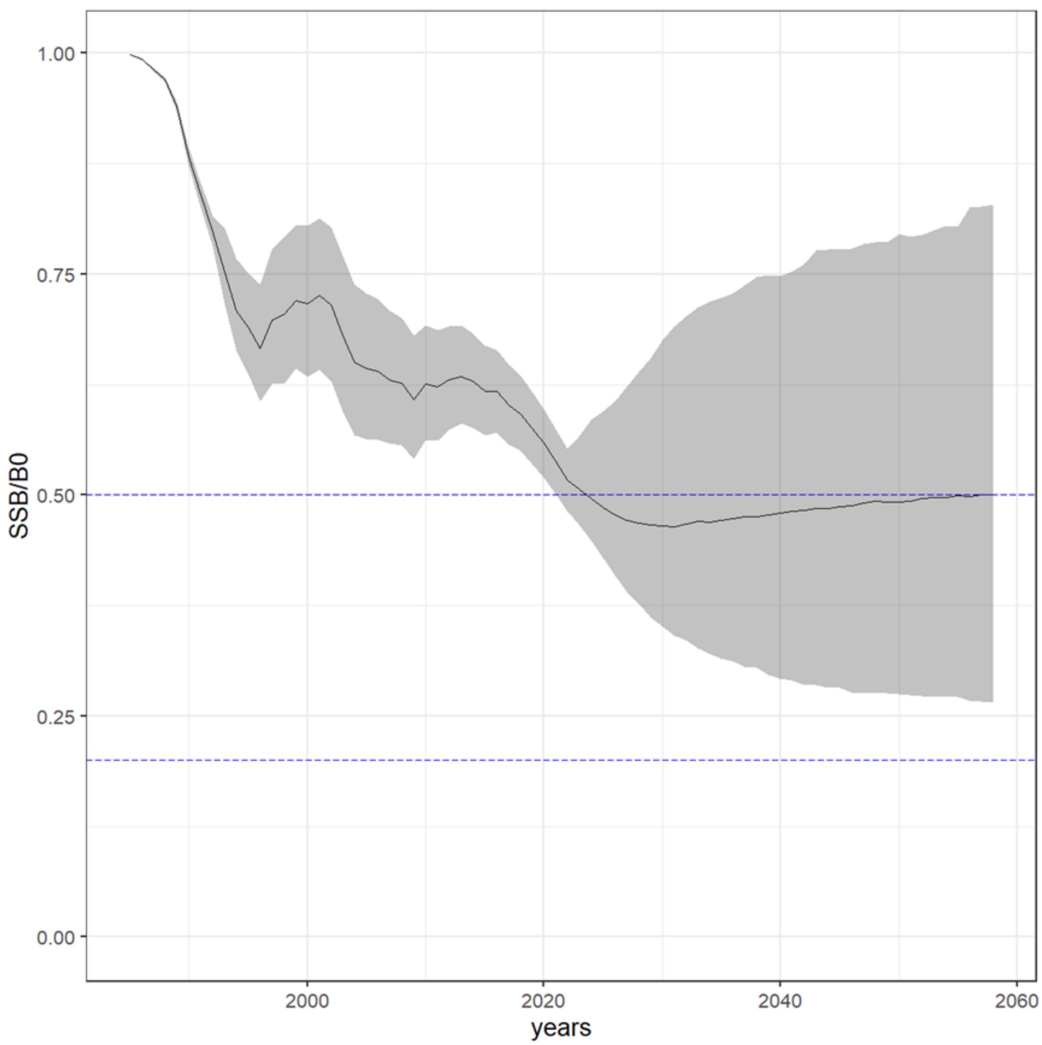


Figure 12: MCMC SSB projections relative to B_0; median (line) with 95% confidence intervals (shaded). The blue horizontal lines show the 50% and 20% reference points used in the CCAMLR decision rule.

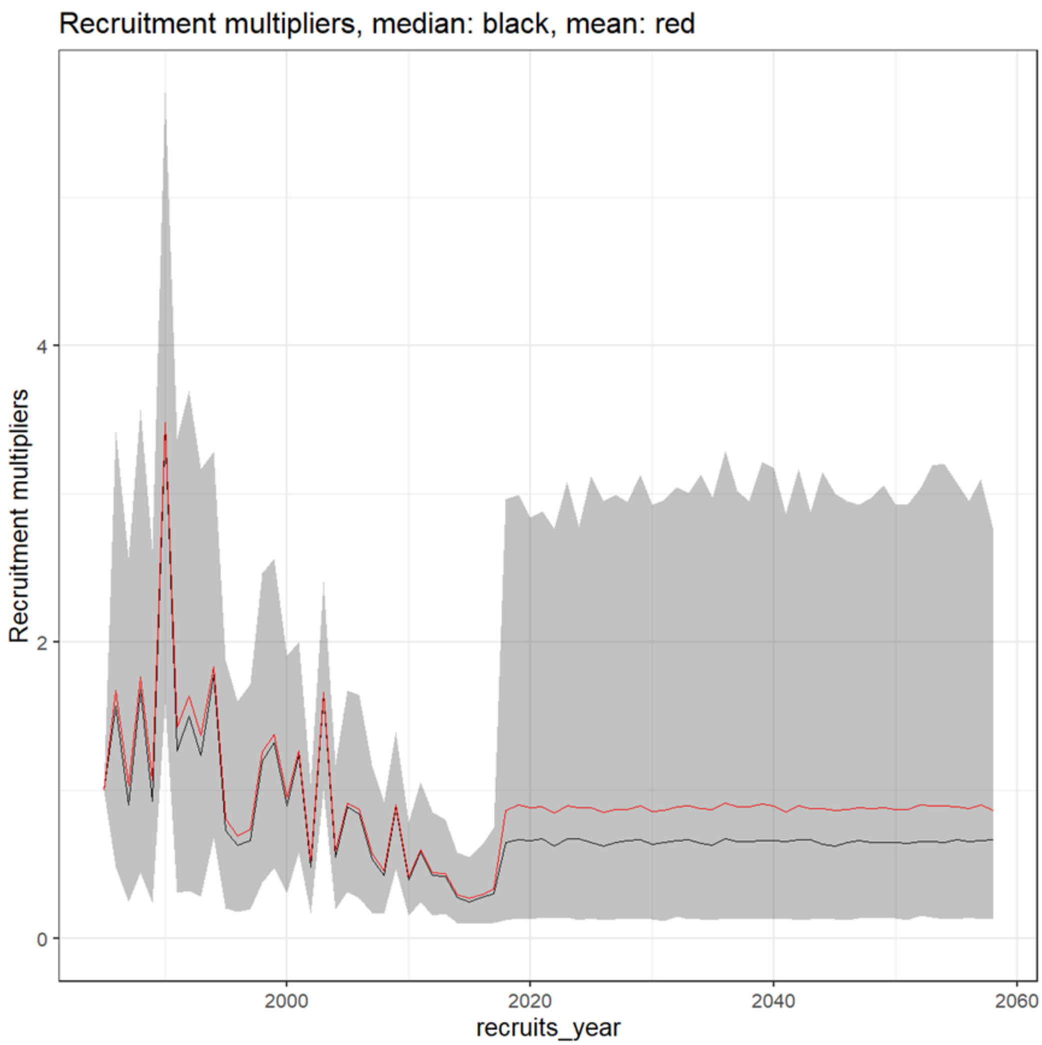


Figure 13: MCMC recruitment projections; median (black line) and mean (red line) with 95% confidence intervals (shaded).

13. Summary

The assessment of the *D. eleginoides* in Subarea 48.3 indicates that the current status of the stock is at 49% of B_0, and undergoing a period of slight decline due to the low recruitments observed in the 2017 and 2019 surveys. Projections indicate that catches of 2,062 tonnes would be consistent with the CCAMLR decision rules.

14. References

Abreu, J., Hollyman, P.R., Xavier, J.C., Bamford, C.C.G., Phillips, R.A., Collins, M.A., 2024. Trends in population structure of Patagonian toothfish over 25 years of fishery exploitation at South Georgia. Fisheries Research 279, 107122. https://doi.org/10.1016/j.fishres.2024.107122

Bamford, C.C.G., Hollyman, P.R., Abreu, J., Darby, C., Collins, M.A., 2024. Spatial, temporal, and demographic variability in patagonian toothfish (*Dissostichus eleginoides*) spawning from twentyfive years of fishery data at South Georgia. Deep Sea Research Part I: Oceanographic Research Papers 203, 104199. https://doi.org/10.1016/j.dsr.2023.104199

Belchier, M., Collins, M.A., 2008. Recruitment and body size in relation to temperature in juvenile Patagonian toothfish (Dissostichus eleginoides) at South Georgia. Mar Biol 155, 493–503. https://doi.org/10.1007/s00227-008-1047-3

Berg, C. W., Nielsen, A., and Kristensen, K. 2014. Evaluation of alternative age-based methods for estimating relative abundance from survey data in relation to assessment models. Fisheries Research 151, 91–99.

Berg, C. W. 2020. surveyIndex: Calculate survey indices of abundance from DATRAS exchange data. R package version 1.07.

CCAMLR. 2024. Report of the Working Group on Statistics, Assessment and Modelling (WG-SAM-2024) preliminary report. Leeuwarden, The Netherlands.

Collins et al. 2021. Report of the UK Groundfish Survey at South Georgia (CCAMLR Subarea 48.3) in May 2021. CCAMLR working document submitted to WG-FSA-2021, CCAMLR, Hobart, Australia.

Earl, T. and Readdy, L. 2023. Assessment of Patagonian Toothfish (*Dissostichus eleginoides*) in Subarea 48.3. CCAMLR working document WG-FSA-2023 WG-FSA-2023/15 Rev. 1, CCAMLR, Hobart, Australia.

Earl, T., Readdy, L. and Marsh, J. 2023 Stock Annex for the 2023 assessment of Subarea 48.3 (South Georgia) Patagonian toothfish (*Dissostichus eleginoides*). CCAMLR working document WG-FSA-2023/60, CCAMLR, Hobart, Australia.

Earl, T., Readdy, L., Alewijnse, S., Devine, J., Dunn, A., Le Clech, R., Maschette, D., Masere, C., Massiot-Granier, F., Ouzoulias, F., Péron, C., Walker N. and Ziegler P. 2024 Approaches to projecting recruitment in toothfish assessment models. CCAMLR working document WG-SAM-2024/23, CCAMLR, Hobart, Australia.

Earl, T., and Readdy, L. 2024 Assessment of Patagonian Toothfish (*Dissostichus eleginoides*) in Subarea 48.3: Assessment Diagnostics. CCAMLR working document submitted to WG-FSA-2024, CCAMLR, Hobart, Australia.

Earl, T., Readdy, L., and Alewijnse, S. 2024. Accounting for spatial trends in fishing within the assessment of Patagonian Toothfish (*Dissostichus eleginoides*) in Subarea 48.3. CCAMLR working document submitted to WG-FSA-2024, CCAMLR, Hobart, Australia.

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.

Francis R. I. C. C. 2015. Data Weighting: Data Weighting package. R package version 1.0. http://www.niwa.co.nz.

Gregory et al. 2019. Report of the UK Groundfish Survey at South Georgia (CCAMLR Subarea 48.3) in January/February 2019. CCAMLR working document WG-FSA-2019/20, CCAMLR, Hobart, Australia.

Hollyman et al. 2023. Report of the UK Groundfish Survey at South Georgia (CCAMLR Subarea 48.3) in February 2023. CCAMLR working document WG-FSA-2023/45, CCAMLR, Hobart, Australia.

Macleod, E. Bradley, K., Earl, T., Söffker, M and Darby, C. 2019. An exploration of the biological data used in the CCAMLR Subarea 48.3 Patagonian toothfish stock assessments. CCAMLR working document WG-SAM-2019/32, CCAMLR, Hobart, Australia.

Marsh, J., Earl, T. and Darby, C. 2022a. Estimates of tag loss rates for Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3 tagged between 2004 to 2020. CCAMLR working document WG-SAM-2022/17, CCAMLR, Hobart, Australia.

Marsh, J., Earl, T., Hollyman, P. and Darby, C. 2022b. Maturity and growth estimates of Patagonian toothfish in Subarea 48.3 between 2009 to 2021. CCAMLR working document WG-FSA-2022/59, CCAMLR, Hobart, Australia.

Marsh, J. and Earl, T. 2023. Fishery characterisation for Patagonian toothfish (*Dissostichus eleginoides*) around South Georgia (Subarea 48.3): 2023 update. CCAMLR working document submitted to WG-FSA-2023, CCAMLR, Hobart, Australia.

Masere, C. and Ziegler, P. 2023. Draft integrated stock assessment for the Heard Island and McDonald Islands Patagonian toothfish (*Dissostichus eleginoides*) fishery in Division 58.5.2. CCAMLR working document WG-FSA-2023/26, CCAMLR, Hobart, Australia.

Masere, C., Le Clech, R., Alewijnse, S., Devine, J., Dunn, A., Earl, T., Maschette, D., Massiot-Granier, F., Ouzoulias, F., Péron, C., Readdy, L., Walker N. and Ziegler P. 2024a. Consideration of the impact of tagging and recapture effort on mark-recapture abundance estimators within integrated Casal2 stock assessments CCAMLR working document WG-SAM-2024/22, CCAMLR, Hobart, Australia.

Masere, C., Le Clech, R., Alewijnse, S., Devine, J., Dunn, A., Earl, T., Maschette, D., Massiot-Granier, F., Ouzoulias, F., Péron, C., Readdy, L., Walker N. and Ziegler P. 2024b. Consideration of the impact of tagging and recapture effort on mark-recapture abundance estimators within integrated Casal2 stock assessments – supplementary material. CCAMLR working document WG-SAM-2024/24, CCAMLR, Hobart, Australia.

Mormede, S., Grüss, A., Dunn, A. and Devine, J. 2023. Assessment model for Antarctic toothfish (Dissostichus mawsoni) in the Ross Sea region to 2022/23. CCAMLR working document WG-FSA-2023/13, CCAMLR, Hobart, Australia.

Massit-Granier, F., Ouzoulias, F. and Péron, C. 2023. Updated Stock Assessment Model for the Kerguelen Island EEZ Patagonian Toothfish (*Dissostichus eleginoides*) Fishery in Division 58.5.1 for 2023. CCAMLR working document WG-FSA-2023/67, CCAMLR, Hobart, Australia.

Söffker, M., Hollyman, P. R., Colling, M. A., Hogg, O. T., Riley, A., Laptikhovsky, V... & Darby, C. 2022. Contrasting life-history traits of two toothfish (*Dissostichus spp.*) species at their range edge around the South Sandwich Islands. *Deep-Sea Research Part II*, 201, 105098.

Welsford, D. 2023. Summary and Recommendations from independent review of CCAMLR toothfish assessments, 2023. CCAMLR working document SC-CAMLR/42/02 Rev. 2., CCAMLR, Hobart, Australia.

Ziegler, P., Dunn, A., Alewijnse, S., Devine, J., Earl, T., Le Clech, R., Maschette, D., Masere, C., Massiot-Granier. F., Ouzoulias, F., Péron, C., Readdy, L. and Walker, N. 2024a. Development of U-based harvest control rules for assessed toothfish fisheries – 1 Background. CCAMLR working document WG-SAM-2024/16, CCAMLR, Hobart, Australia.

Ziegler, P., Dunn, A., Alewijnse, S., Devine, J., Earl, T., Le Clech, R., Maschette, D., Masere, C., Massiot-Granier. F., Ouzoulias, F., Péron, C., Readdy, L. and Walker, N. 2024b. Development of U-based harvest control rules for assessed toothfish fisheries – 2 Exploration of U-based HCRs. CCAMLR working document WG-SAM-2024/17, CCAMLR, Hobart, Australia.

Additional Resources

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