STOCK STATUS UPDATE FOR ARROWTOOTH FLOUNDER (*ATHERESTHES STOMIAS*) FOR THE WEST COAST OF BRITISH COLUMBIA IN 2024

Context

Arrowtooth Flounder (*Atheresthes stomias*) stock status on the West Coast of British Columbia was assessed using data from 1996–2021 (Grandin et al. 2024) and examined at a CSAS review meeting on October 19 and 20, 2022. The biomass of this stock has been declining since 2012, and an assessment was requested by the Pacific Groundfish Management Unit (GMU) in 2022. In the 2022 stock assessment, the stock was estimated slightly below the Upper Stock Reference (USR) in the base model and close to the Limit Reference Point (LRP) under one sensitivity model with higher recruitment variation. The model also showed declining estimated spawning stock biomass, declining survey indices, and declining estimated recruitment. Due to all of these issues, a two-year update on the stock was requested by the GMU. Two years was chosen because it it a relatively short amount of time, but long enough that all of the surveys included in the model would have another data point added to their indices.

The 2022 stock assessment estimated a median stock size at the beginning of 2022 (or end of 2021) of 67.95 kilotonnes (kt) with a credible interval of 56.14–83.83 kt. When divided by the estimated unfished biomass (B_0), the median relative biomass for 2022 was estimated to be 0.37 with a credible interval of 0.26–0.51. The estimated median relative biomass for 2011, was estimated to be 0.77 with a credible interval of 0.53–1.09. The estimated biomass declined each year from 2011–2021.

The Science Advisory Report (SAR) for the 2022 stock assessment can be found here: Science Advisory Report 2023/042.

This Science Response results from the Science Response Process of October 2, 2024 on the Stock Assessment Update of Arrowtooth Flounder (*Atheresthes stomias*) in British Columbia in 2024.

Additional publications from this meeting will be posted here at the DFO Science Advisory Schedule website as they become available.

Background

Description of the Fishery and Management

The commercial fishery for Arrowtooth Flounder has been active for decades. Prior to 2006 there were no limits on the amount of Arrowtooth Flounder that could be caught. In 2006 a Total Allowable Catch (TAC) of 15 kt was established and it remained at this level until 2017. In 2017, the TAC was increased to 17.5 kt and remained there for two years until it was reduced to 14 kt in 2019 as a precautionary measure to address concerns raised by the commercial trawl fleet about their oberved reduction in abundance of Arrowtooth Flounder. In 2020 the TAC was decreased to its current level of 5 kt to address industry concerns regarding declining Arrowtooth Flounder abundance on traditional fishing grounds (DFO 2020).

Before the introduction of 100% at-sea observer coverage in the British Columbia groundfish fleets in 1996, reporting of Arrowtooth Flounder discards in fishery logbooks was mandatory, but since Arrowtooth Flounder were not given a TAC until 2005, there was little incentive for skippers to record discards accurately until at-sea observers were present aboard vessels starting in 1996.

Since the 2022 stock assessment, there have been two years of new Arrowtooth Flounder commercial catch (2022 and 2023). These values are presented in Table 1 and Figure 1 along with the rest of the catch data starting in 1996. The catch (landings + discards) for the Freezer Trawler fleet increased by 30.5% from 2021 to 2022, but then decreased by 48.0% from 2022 to 2023. The Shoreside fleet decreased for both years, by 20.1% from 2021 to 2022, and by 14.6% from 2022 to 2023.

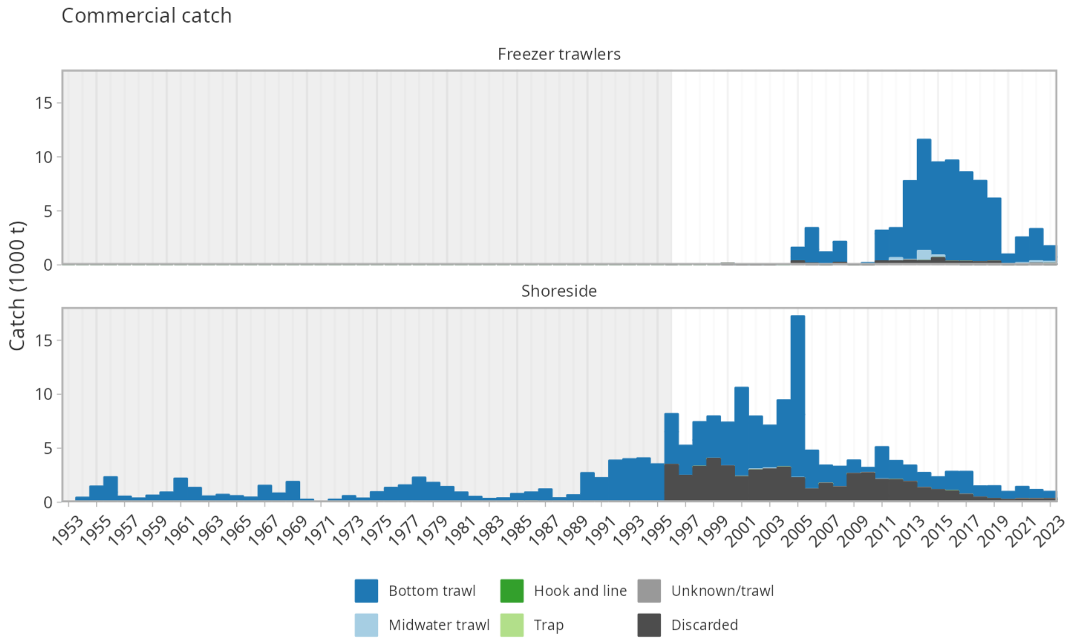

Figure 1. Commercial catch of Arrowtooth Flounder by fleet and gear type. Each year of catch starts on Feb. 21 and ends on Feb. 20. e.g. the year 2005 catch is all catch between Feb. 21, 2005 to Feb. 20, 2006. The shaded grey area from the beginning of the time series to 1996 indicate unreliable data. In the years prior to 1996, many tows of Arrowtooth Flounder were discarded without logs being kept.

Table 1. Recent coastwide commercial fishery landings and discards (tonnes) of Arrowtooth Flounder by fleet. 'Total' columns are the sum of landings and discards by fleet, and 'Total Catch' is the sum of the fleet 'Total' columns.

	Freezer Trawlers			Shoreside			
Year	**Landings**	**Discards**	**Total**	**Landings**	**Discards**	**Total**	**Total Catch**
1996	0.0	0.7	0.7	4,711.5	3,459.0	8,170.4	8,171.1
1997	0.0	0.0	0.0	2,795.8	2,442.5	5,238.3	0.0
1998	0.0	0.0	0.0	4,145.9	3,272.3	7,418.2	0.0
1999	0.0	0.0	0.0	3,927.9	4,019.9	7,947.8	0.0
2000	6.8	106.3	113.1	4,054.9	3,323.1	7,377.9	7,491.1
2001	12.5	18.9	31.4	8,276.9	2,321.5	10,598.4	10,629.8
2002	28.0	22.4	50.4	5,003.5	2,935.2	7,938.7	7,989.0
2003	6.7	9.4	16.1	4,060.7	3,036.5	7,097.2	7,113.4
2004	0.4	0.0	0.4	6,238.9	3,204.2	9,443.1	9,443.5
2005	1,257.8	340.8	1,598.6	14,979.5	2,235.5	17,215.1	18,813.7
2006	3,302.5	113.5	3,416.0	3,598.8	1,186.5	4,785.3	8,201.3
2007	1,123.4	41.8	1,165.3	1,695.7	1,706.1	3,401.8	4,567.0
2008	1,956.0	189.8	2,145.8	1,920.1	1,372.8	3,292.9	5,438.7
2009	0.0	2.1	2.1	1,259.2	2,616.8	3,876.1	3,878.2
2010	140.5	34.5	175.0	505.6	2,680.4	3,186.0	3,361.0
2011	2,841.8	335.3	3,177.1	3,030.8	2,072.1	5,102.8	8,279.9
2012	3,085.2	326.6	3,411.8	1,784.6	2,043.4	3,827.9	7,239.7
2013	7,375.2	392.6	7,767.8	1,537.9	1,865.2	3,403.1	11,170.8
2014	11,231.9	355.9	11,587.8	1,409.4	1,302.9	2,712.3	14,300.1
2015	8,855.3	637.3	9,492.6	1,194.9	1,125.3	2,320.3	11,812.8
2016	9,367.2	305.2	9,672.4	1,817.7	1,007.8	2,825.5	12,497.9
2017	8,286.9	292.9	8,579.8	2,143.3	680.6	2,823.8	11,403.6
2018	7,527.5	257.3	7,784.8	1,048.3	430.5	1,478.9	9,263.6
2019	5,836.1	312.4	6,148.5	1,191.5	302.7	1,494.2	7,642.7
2020	947.3	26.4	973.7	745.5	220.7	966.2	1,939.9
2021	2,504.4	44.8	2,549.1	1,156.5	270.2	1,426.7	3,975.8
2022	3,213.9	113.3	3,327.2	870.1	269.2	1,139.3	4,466.5
2023	1,638.6	92.8	1,731.4	688.7	283.9	972.6	2,704.0

Analysis and Response

Stock assessment model

The model used to assess this stock was the Integrated Statistical Catch-at-Age Model (ISCAM). It was tuned to four fishery-independent trawl survey series covering 1996–2021, a Discard CPUE series as an index of abundance, annual estimates of commercial catch from two fleets (Freezer Trawlers and Shoreside), and age composition data from the two fleets in the commercial fishery and the four surveys. A two-sex, two-fleet base model was selected and implemented in a Bayesian context using Markov Chain Monte Carlo (MCMC) methods. Leading parameters estimated included R_0, initial recruitment, h, steepness of the stock-recruitment relationship, $\bar{R}$, average recruitment, and $q_k, k = 1, 2, 3, 4, 5$, catchability of the four surveys and the Discard CPUE index. Selectivity parameters were also estimated for each sex, fleet, and survey.

Parameter estimates and fixed values are given in Table 3. As in the 2022 stock assessment, the natural mortality was fixed at 0.2 for females and 0.35 for males. All estimated parameter estimates were very close to those in Table 6 of the 2022 stock assessment. The median posterior for B_0 decreased from 184.16 in 2022 stock assessment to 178.50 for this model. The median posterior biomass estimates were also slightly less than the estimates in the 2022 stock assessment, so there is almost no scaling effect in the relative biomass and Figure 3 looks almost identical to Figure 9 in the 2022 stock assessment, other than the two new points for 2022 and 2023. In both cases, relative biomass estimates from 2020 and forward were under the USR $0.4B_0$ reference line.

Survey Indices and Catch

In this update, there is one new survey year for each of the three synoptic surveys included in the model (Figure 5). The Hecate Strait Multispecies Assemblage Survey has a terminal year of 2003 and therefore was not updated with any new data. The West Coast Vancouver Island Synoptic Survey took place in 2022; the Queen Charlotte Sound Synoptic Survey and the Hecate Strait Synoptic Survey both took place in 2023. The Discard CPUE Index had a new index point added for each new year, 2022 and 2023 as it is based on the commercial discards in catch. The Discard CPUE Index is created using a Generalized Linear Mixed Model (GLMM), and as such all the indices in the time series are estimated each time new data are added anywhere in the time series. The estimated values for each year in the Discard CPUE Index (the light grey points and bars in Figure 5) were therefore slightly different than those in Figure 14 of the 2022 stock assessment.

The 2022 point for the Discard CPUE Index and the 2023 point for the Queen Charlotte Sound Synoptic Survey were not fit well by the model, however the median posterior estimates are within the range of uncertainty for those years. Overall trends of all index estimates follow those seen in the 2022 stock assessment, with the Queen Charlotte Sound Synoptic Survey and Hecate Strait Synoptic Survey indices being fit slightly better in the 2005–2012 time period than in the 2022 assessment.

The increase in the survey indices for 2023 is driving the increase in estimated biomass for the beginning of 2024 seen in Figures 2 and 3.

Length and Age data

Sex-specific length data have continued to be recorded for the surveys, but have been almost non-existent in the fishery after 2019. Figure 6 shows a summary of the length data; the lack of data since 2019 is evident, except for a small amount in 2019 and moderate amount in 2023 for the Freezer Trawler fleet. Recent survey data show a simliar trend to previous years, with more, and larger, females in the stock. In 2023, the Freezer Trawler fleet saw a larger proportion of smaller males than the large females.

Samples from 2022 and 2023 were not aged for this update, and therefore not included in the update model. Implications of this are discussed in the next section.

Recruitment

The posterior median recruitment was estimated to be below the credible interval for the R_0 estimate for 2020–2023, with a very large credible interval (Figure 4). In the 2022 stock assessment, only the last two years of recruitment estimates had large credible intervals due to uncertainty around age class strength. The last four years of the model presented here have a large credible interval due to lack of new ages being included in the model for 2022 and 2023. Despite the large uncertainties, the recruitment estimates for 2020–2023 appear to be slightly increasing and higher than those estimated for 2015–2019.

It is recommended that in addition to catch data and survey indices, the next assessment or update incorporate age data from 2022 to present in the model to alleviate this limitation.

Growth

Growth parameters were estimated outside the ISCAM model and the only differences when compared to the 2022 stock assessment were in the scalar in length-weight allometry (α) parameter for males which went from 0.0000095 in the 2022 assessment to 0.0000096, the power in length-weight allometry (β) parameter for females which went from 3.0515274 in the 2022 assessment to 3.0511051, and the power in length-weight allometry (β) parameter for males which went from 2.9741834 in the 2022 assessment to 2.9734923. Table 2 shows all the values input into the model for this update, and can be compared directly with Table A.1 in the 2022 stock assessment (Grandin et al. 2024).

Fishing Mortality and Selectivity

The estimated fishing mortality follows the catch data closely, as this model is tuned to catch. The increase in catch in 2022 in the Freezer Trawler fleet is apparent as is the reduction in catch in 2023 (Figure 7).

Posterior estimates of age-at-50%-harvest ($\hat{a}_k$) and the standard deviation in the logistic selectivity ogive ($\hat{\gamma}_k$) are provided in Table 3. The median posterior estimates of those selectivity parameters were similar for males and females for both commercial gears and the surveys. The estimates were all close to the estimates in Table 6 of the 2022 stock assessment. There were no drastic changes in the selectivity estimates caused by the addition of new catch and survey index data. The selectivity plots are shown in Figure 8 which when compared to Figure 27 in the 2022 stock assessment, shows almost no difference.

MCMC Diagnostics

The Markov Chain Monte Carlo (MCMC) chain was run to a length of 10,000,000, with every 5,000th posterior sampled, resulting in 2,000 posteriors saved. Of those, the first 1,000 were removed as burn-in, leaving 1,000 posteriors used for inference. Those 1,000 posteriors were used for all the MCMC diagnostic plots in this update.

Figure 9 shows the traceplots for the leading parameters, all appear stable as they did in the 2022 assessment. Figure 10 shows that there is very little autocorrelation in leading parameters.

The catchability parameters appear to show more correlation with each other in this update model than seen in the 2022 stock assessment. A comparison of the pairs plots from this update (Figure 11) and Figure 41 from the 2022 stock assessment shows that there is a higher correlation between the q_1 and q_3 parameters in particular. These are the catchability parameters for the Queen Charlotte Sound Synoptic Survey and the Hecate Strait Synoptic Survey.

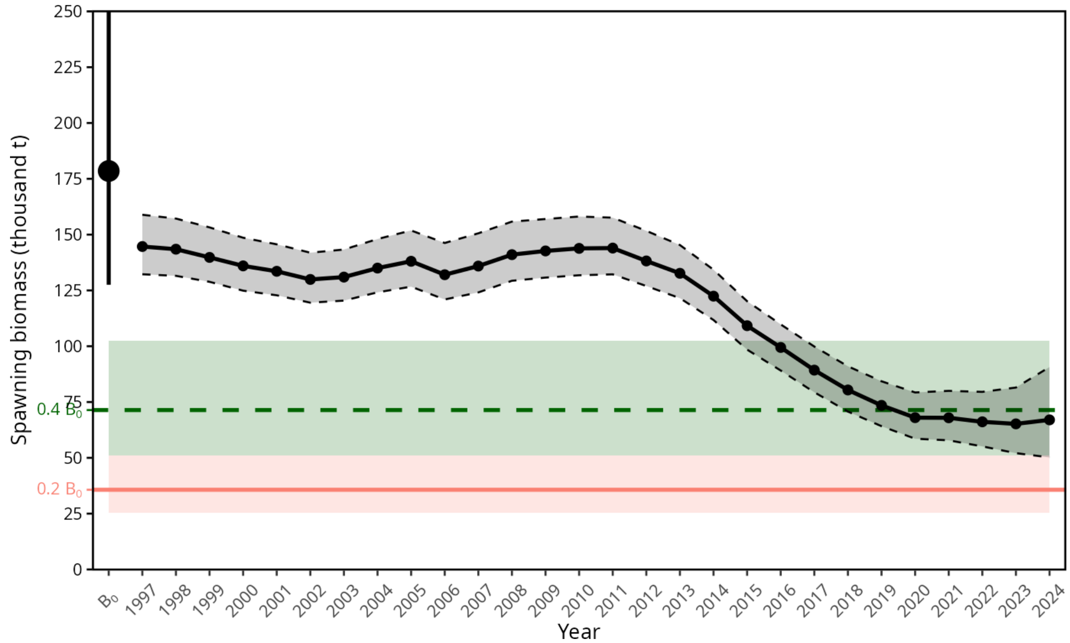

Figure 2. Spawning biomass of Arrowtooth Flounder for the base model with B_0 reference points. The solid black line with points show the medians of the posteriors, the shaded ribbon encapsulated by dashed lines covers the 95% CI for the posteriors, the point at B_0 is the median estimate for the unfished biomass, and the vertical line over that point is the 95% confidence interval.

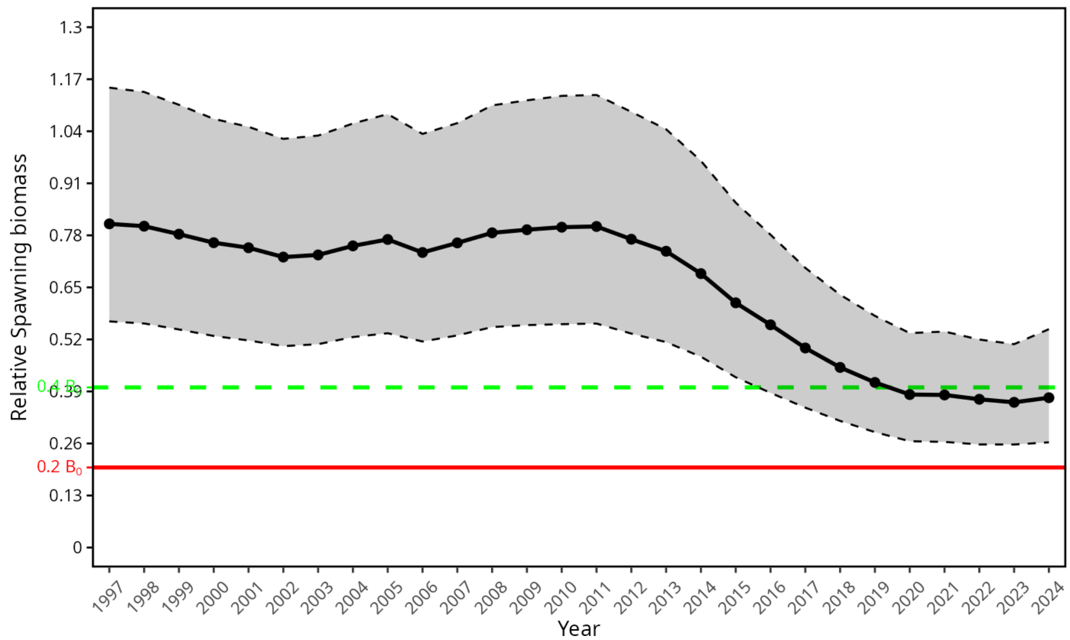

Figure 3. Relative spawning biomass for the base model. The shaded area represents the 95% CI. Horizontal lines indicate the 0.2 B_0 (solid, red) and 0.4 B_0 (dashed, green) reference points. Because the ribbon represents relative spawning biomass (depletion) and the reference points are with respect to B_0, all uncertainty about the ratio of the spawning biomass to the reference points is captured in the ribbon and the reference points are shown as point values.

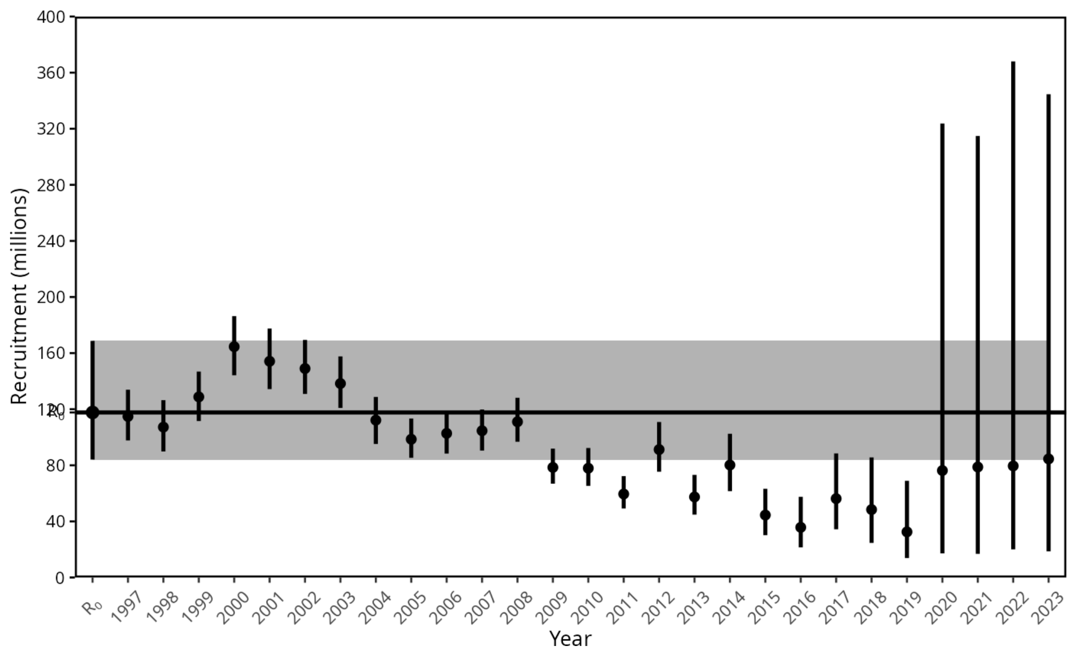

Figure 4. Recruitment of Arrowtooth Flounder for the base model. The black points are the medians of the posteriors, the vertical black lines are the 95% CIs for the posteriors, the point at R_0 is the median estimate for the initial recruitment parameter R_0, and the vertical line over that point and shaded ribbon across the time series is the 95% CI for R_0.

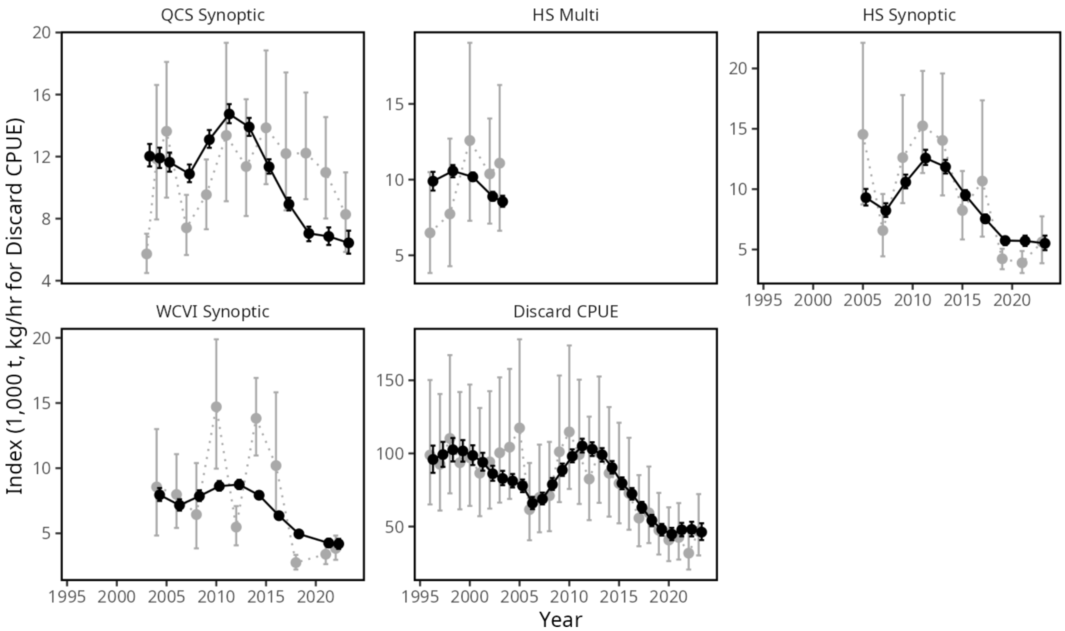

Figure 5. Index fits for the base model. The light grey points and vertical lines show the index values and 95% CIs; the black points show the medians of the posteriors; the black solid vertical lines show the 95% CIs of the posteriors.

Table 2. Growth parameters estimated outside the ISCAM model. All parameters were estimated using samples from the four synoptic surveys, and were filtered to include areas 3CD and 5ABCDE only. For the age-at-50% maturity estimates, the following values were used to further filter the data: maturity_convention_code = 4 (flatfish), maturity_code = 5 (Male - Spawning, testes large, white and sperm evident), (Female - Ripe, ovaries containing entirely translucent, mature ova. eggs loose and will run from oviducts under slight pressure), and usability codes = 0 (Unknown), 1 (Fully usable), 2 (Fail, but all data usable), 6 (Gear torn, all data ok).

Parameter	Female	Male
Asymptotic length (l_{inf})	61.770	47.159
Brody growth coefficient (k)	0.182	0.274
Theoretical age at zero length (t_0)	-0.479	-0.258
Scalar in length-weight allometry (α)	0.0000076	0.0000096
Power parameter in length-weight allometry (β)	3.051	2.973
Age at 50% maturity ($\dot{a}$)	5.566	4.103
SD at 50% maturity ($\dot{\gamma}$)	1.098	0.802

Table 3. Posterior median and 95% credible interval estimates of key parameters for the base model.

Parameter	Gear	Sex	2.5%	50%	97.5%
R_0	–	–	84.07	117.67	168.73
h	–	–	0.70	0.88	0.97
M_1	–	female	0.20	0.20	0.20
M_2	–	male	0.35	0.35	0.35
$\overline{R}$	–	–	72.25	84.54	97.75
$\overline{R}_{\text{init}}$	–	–	56.43	67.20	79.03
B_0	–	–	127.53	178.50	255.95
SB_0	–	–	127.53	178.50	255.95

Parameter	Gear	Sex	2.5%	50%	97.5%
so	–	–	6.07	20.14	98.73
β	–	–	0.04	0.17	0.90
ϕ_e	–	–	1.52	1.52	1.52
B_{MSY}	–	–	20.97	33.62	61.14
MSY_1	Freezer trawlers	–	4.47	6.32	9.12
F_{MSY_1}	Freezer trawlers	–	0.44	1.36	2.97
U_{MSY_1}	Freezer trawlers	–	0.35	0.74	0.95
MSY_2	Shoreside	–	6.43	9.11	13.13
F_{MSY_2}	Shoreside	–	0.96	3.54	9.09
U_{MSY_2}	Shoreside	–	0.62	0.97	1.00
q_1	QCS Synoptic	–	0.15	0.17	0.20
q_2	HS Multi	–	0.12	0.14	0.15
q_3	HS Synoptic	–	0.14	0.16	0.18
q_4	WCVI Synoptic	–	0.09	0.11	0.15
q_5	Discard CPUE	–	1.20	1.34	1.49
$\hat{a}_{1,\mathrm{f},1}$	Freezer trawlers	female	7.52	8.08	8.65
$\hat{\gamma}_{1,\mathrm{f},1}$	Freezer trawlers	female	0.91	1.08	1.26
$\hat{a}_{1,\mathrm{m},1}$	Freezer trawlers	male	7.08	7.68	8.40
$\hat{\gamma}_{1,\mathrm{m},1}$	Freezer trawlers	male	0.83	1.00	1.19
$\hat{a}_{2,\mathrm{f},1}$	Shoreside	female	8.42	8.68	8.97
$\hat{\gamma}_{2,\mathrm{f},1}$	Shoreside	female	0.90	0.98	1.08
$\hat{a}_{2,\mathrm{m},1}$	Shoreside	male	7.97	8.38	8.79
$\hat{\gamma}_{2,\mathrm{m},1}$	Shoreside	male	0.95	1.05	1.16
$\hat{a}_{3,\mathrm{f},1}$	QCS Synoptic	female	3.61	5.35	7.92
$\hat{\gamma}_{3,\mathrm{f},1}$	QCS Synoptic	female	1.70	2.52	3.77
$\hat{a}_{3,\mathrm{m},1}$	QCS Synoptic	male	4.49	5.88	8.17
$\hat{\gamma}_{3,\mathrm{m},1}$	QCS Synoptic	male	1.18	1.71	2.45
$\hat{a}_{4,\mathrm{f},1}$	HS Multi	female	9.00	9.00	9.00
$\hat{\gamma}_{4,\mathrm{f},1}$	HS Multi	female	0.50	0.50	0.50
$\hat{a}_{4,\mathrm{m},1}$	HS Multi	male	9.00	9.00	9.00
$\hat{\gamma}_{4,\mathrm{m},1}$	HS Multi	male	0.50	0.50	0.50
$\hat{a}_{5,\mathrm{f},1}$	HS Synoptic	female	8.07	9.25	10.79
$\hat{\gamma}_{5,\mathrm{f},1}$	HS Synoptic	female	2.03	2.39	2.84
$\hat{a}_{5,\mathrm{m},1}$	HS Synoptic	male	8.29	9.59	11.22
$\hat{\gamma}_{5,\mathrm{m},1}$	HS Synoptic	male	1.71	1.98	2.32
$\hat{a}_{6,\mathrm{f},1}$	WCVI Synoptic	female	8.02	8.73	9.53
$\hat{\gamma}_{6,\mathrm{f},1}$	WCVI Synoptic	female	1.38	1.61	1.89
$\hat{a}_{6,\mathrm{m},1}$	WCVI Synoptic	male	6.42	7.04	7.74
$\hat{\gamma}_{6,\mathrm{m},1}$	WCVI Synoptic	male	0.93	1.10	1.32
$\hat{a}_{7,\mathrm{f},1}$	Discard CPUE	female	9.00	9.00	9.00
$\hat{\gamma}_{7,\mathrm{f},1}$	Discard CPUE	female	0.50	0.50	0.50
$\hat{a}_{7,\mathrm{m},1}$	Discard CPUE	male	9.00	9.00	9.00
$\hat{\gamma}_{7,\mathrm{m},1}$	Discard CPUE	male	0.50	0.50	0.50

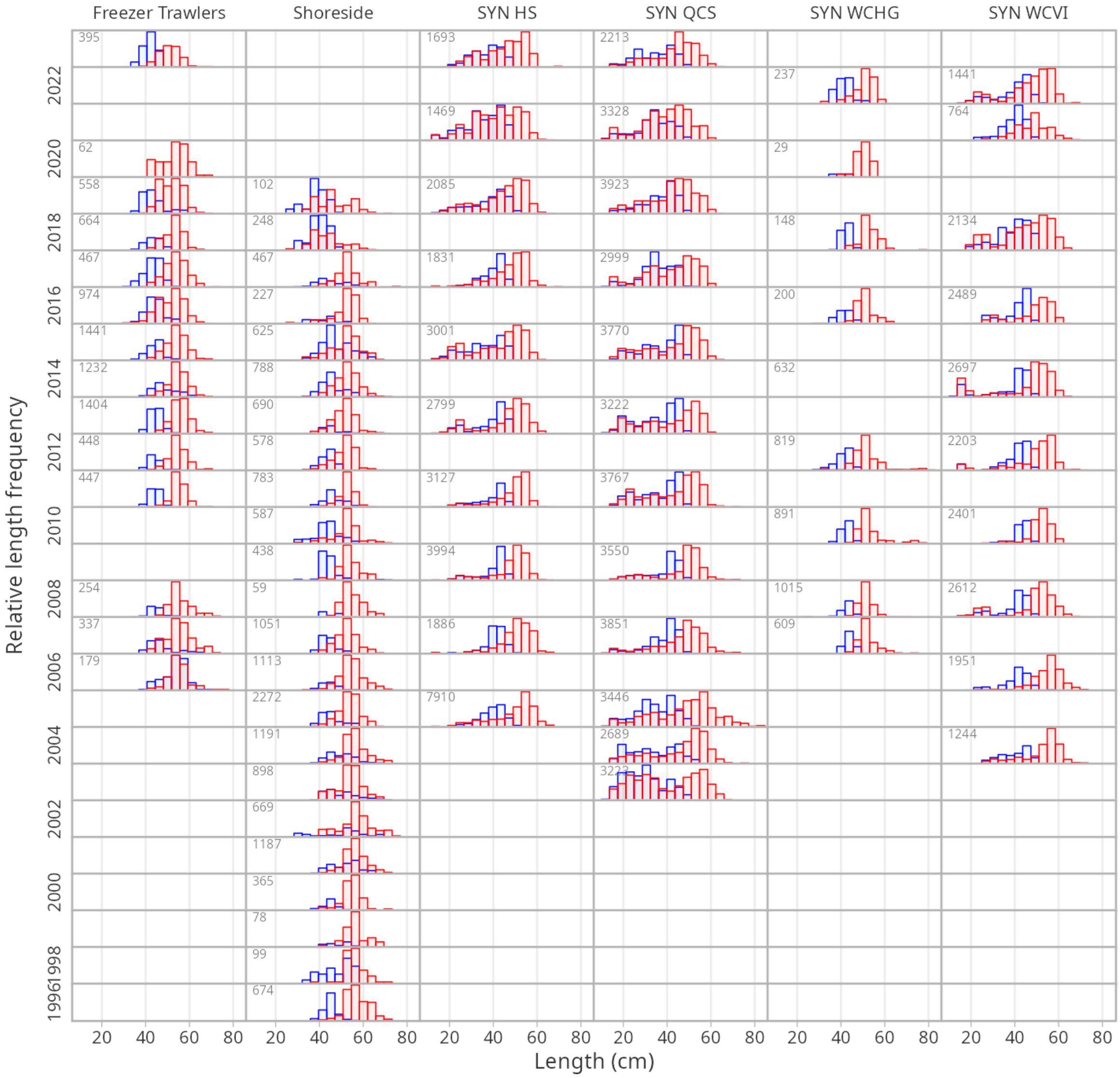

Figure 6. Length-frequency plot where female fish are shown as red bars and male fish are shown behind as blue bars. The total number of fish measured for a given survey or fishery per year are indicated in the top left corner of each panel. Histograms are only shown if there are more than 20 fish measured for a given survey-year combination.

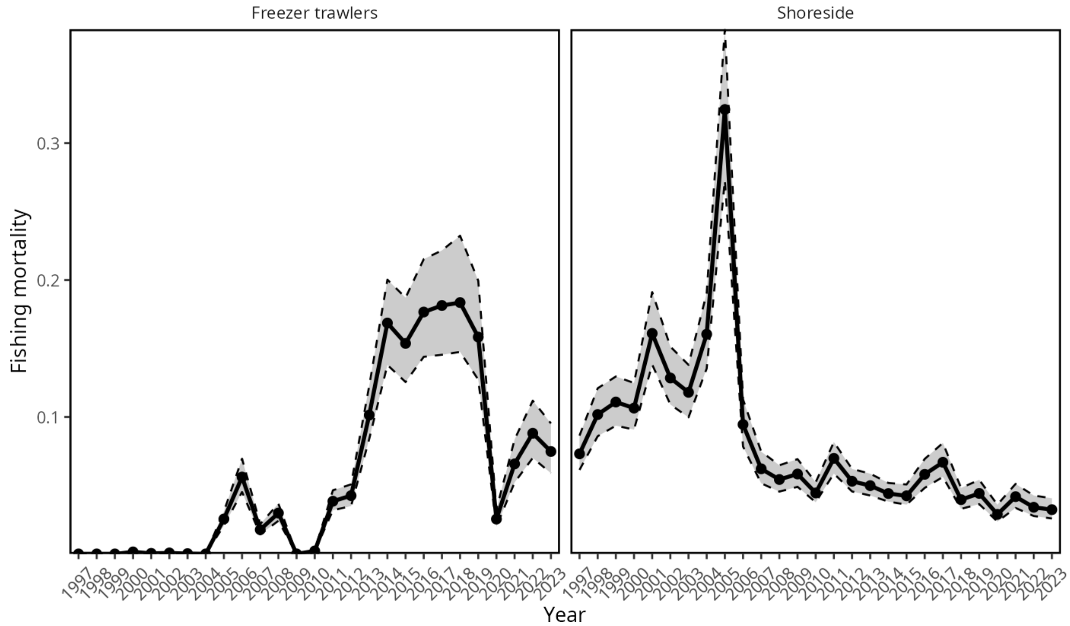

Figure 7. Fishing mortality for the base model for the two trawl fisheries for females only. The plots for the males are not shown, because they are the same. The shaded area represents the 95% CI.

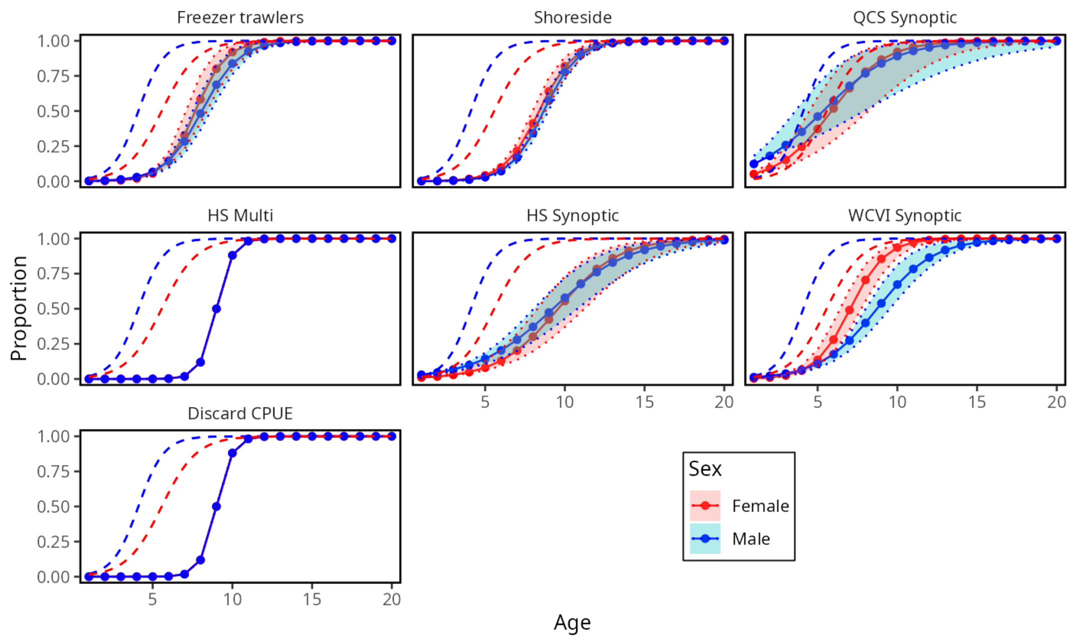

Figure 8. Estimated and fixed selectivities by sex for the base model. The dots show estimated median selectivity-at-age, and the shaded areas show the 95% credible intervals (CI). Single dotted lines with no CI (HS Multi, Discard CPUE) represent fixed selectivities. Dashed lines represent maturity-at-age based on logistic curves fit to the proportion of mature fish at age.

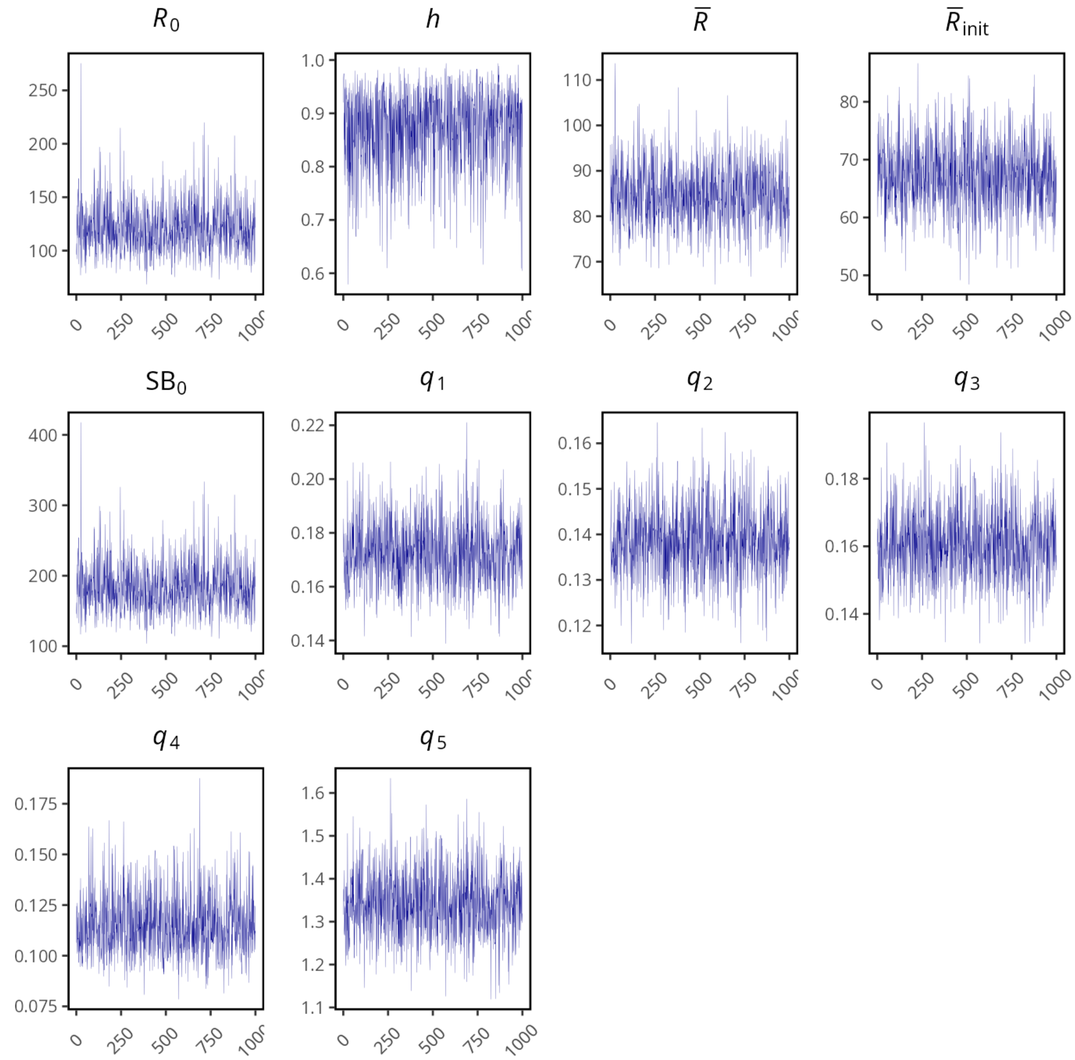

Figure 9. Trace plots for MCMC output of estimated lead parameters in the base model. The MCMC run has chain length 10,000,000 with a sample taken every 5,000th iteration. Of the 2,000 samples taken, the first 1,000 were removed as a burn-in period. Numerical indices on Catchability (q) parameters for the survey indices are defined as: 1 = QCS Synoptic, 2 = HS Multi, 3 = HS Synoptic, 4 = WCVI Synoptic, 5 = Discard CPUE.

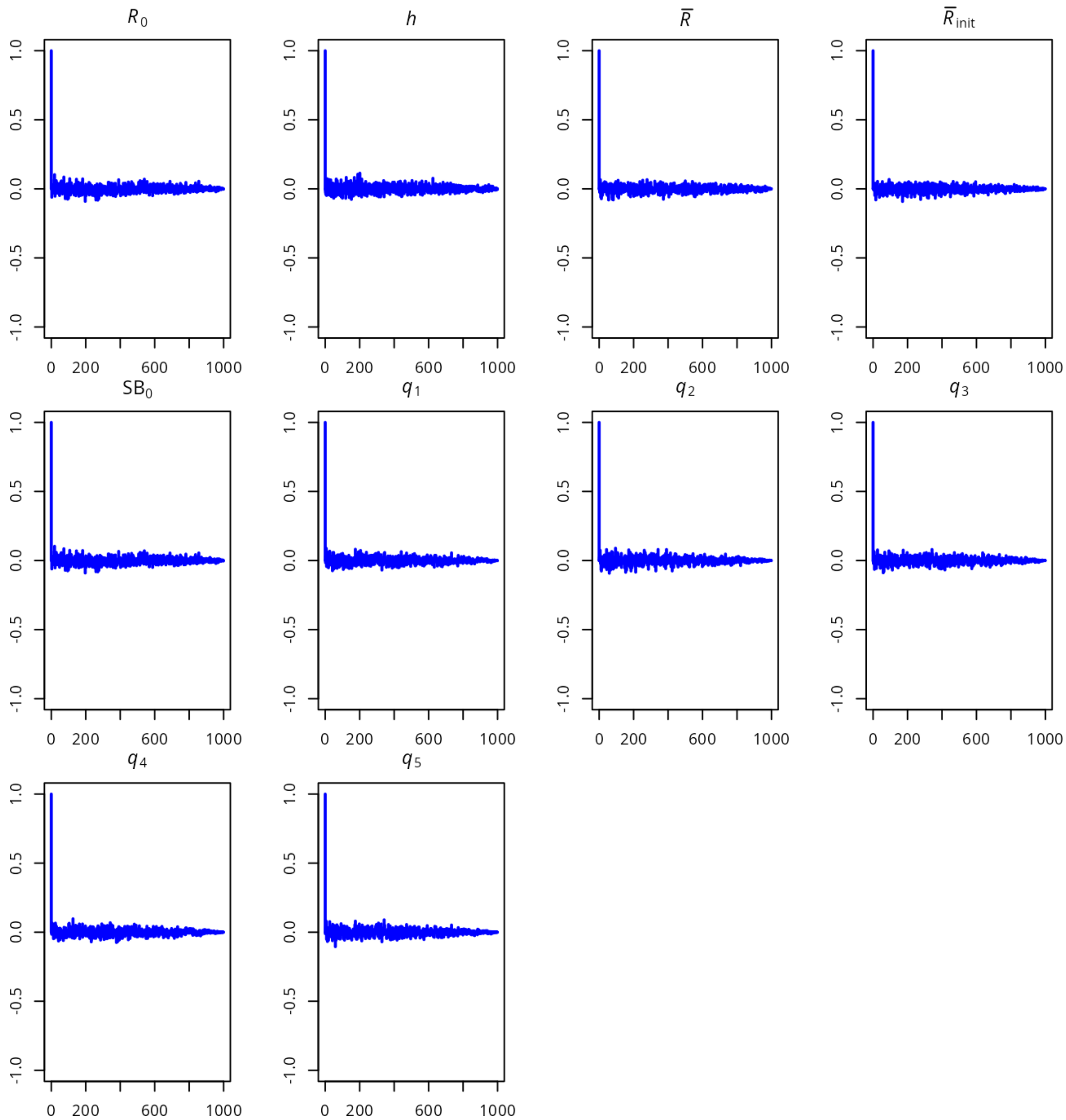

Figure 10. Autocorrelation plots for MCMC output of estimated lead parameters in the base model. The x-axis values are the lag between posteriors. Numerical indices on Catchability (q) parameters for the survey indices are defined as: 1 = QCS Synoptic, 2 = HS Multi, 3 = HS Synoptic, 4 = WCVI Synoptic, 5 = Discard CPUE.

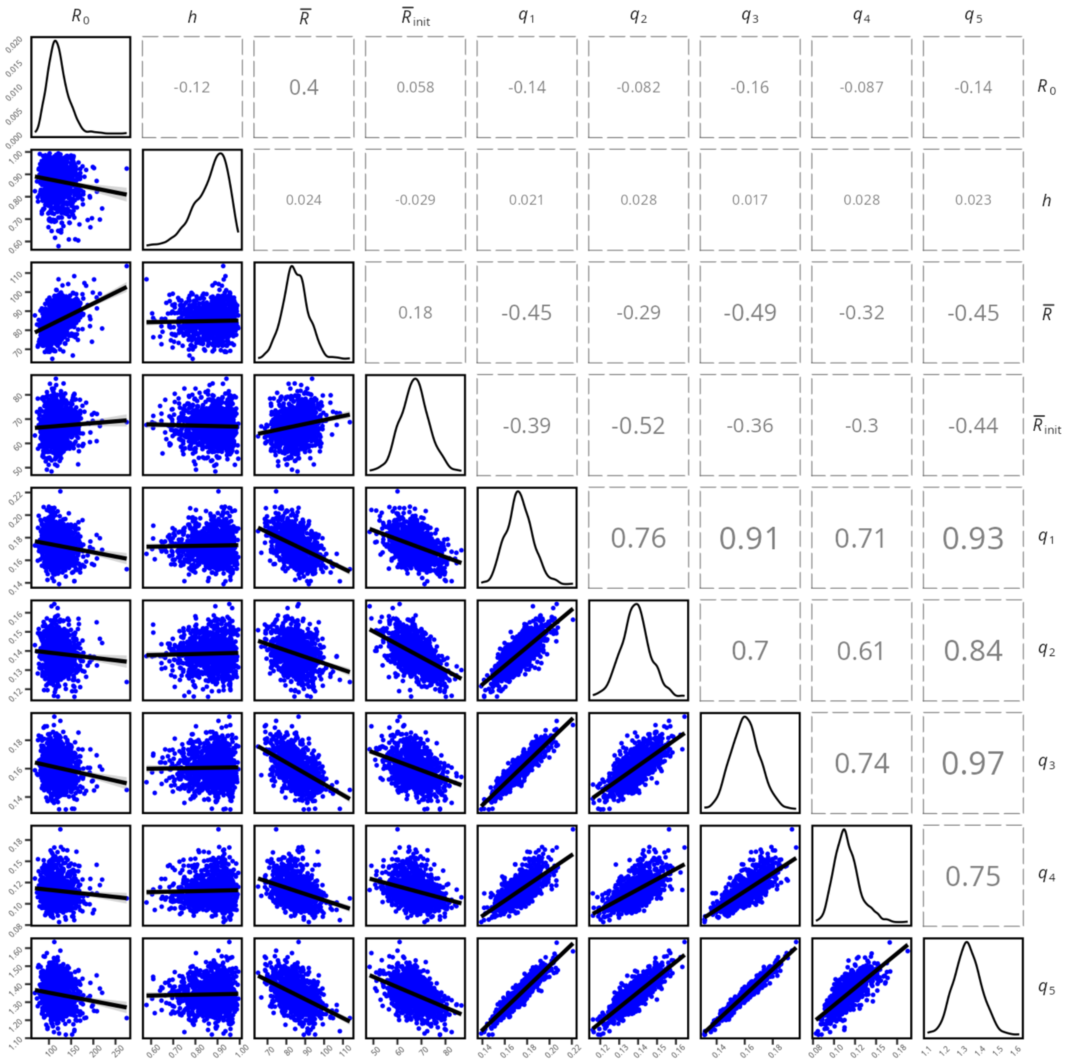

Figure 11. Pairs plots for MCMC estimated parameters in the base model. The lines in the points plots in the lower triangular panels are linear models with shaded 95% confidence intervals. The line plots in the diagonal panels represent density of the parameter values, and the values in the upper triangular panels are the correlations between parameters with text size being directly proportional to the absolute value of those values. Numerical indices on Catchability (q) parameters for the survey indices are defined as: 1 = QCS Synoptic, 2 = HS Multi, 3 = HS Synoptic, 4 = WCVI Synoptic, 5 = Discard CPUE.

Indicators of Stock Status

Typically DFO's reference points of $0.4B_{MSY}$ for the LRP and $0.8B_{MSY}$ for the USR are used as they are defined in the Sustainable Fisheries Framework (SFF, (DFO 2009)). However for Arrowtooth Flounder, reference points based on the Maximum Sustainable Yield (MSY) were strongly impacted by estimates of selectivity in the trawl fisheries. Because the selectivity ogives were estimated to the right of the maturity ogive, the MSY-based reference points were overly optimistic, since the vulnerable biomass appeared to include the entire stock, and not just the mature fish. Reference points based on estimated equilibrium unfished spawning biomass, B_0, were used instead as B_0 is not impacted directly by selectivity estimates. Because the reference points used here are not the standard SFF reference points, the typical stock 'zones' (i.e. healthy, cautious, and critical) are not defined.

Projection of catch levels was performed for this update, but the values were truncated in comparison to the 2022 stock assessment. Advice was given to Science from Fisheries managers that the projected catch levels should be from 1 to 8 kilotonnes (kt) in increments of 1 kt for this update instead of 1 to 15 kt as was applied in the 2022 stock assessment. Figure 12 shows the biomass trajectories resulting in the application of the catch levels as catch to the stock for the years 2025–2027. Figure 13 shows a closer view of the projected trajectories.

Harvest decision tables are provided as advice to managers (Tables 4–7) with constant catch policies ranging from 1 to 8 kilotonnes, from 2025 to 2027. To interpret the decision tables with respect to the LPR ($0.2B_0$) and USR ($0.4B_0$), the probability of being above the USR is $P(B_t > USR)$, the probability of being above the LRP but below the USR is $P(B_t > LRP) - P(B_t > USR)$, and the probability of being below the LRP is $1 - P(B_t > LRP)$, where t is the year, and B_t is the relative biomass at the beginning of year t.

During the review meeting for the 2022 stock assessment, participants deliberated about the validity of the USR being set to $0.4B_0$ and requested an 'alternative USR' of $0.35B_0$. This was included in the 2022 Research Document and is included in this update as well.

Harvest decision tables provided in this document include probabilities at the beginning of the year of being above:

1. the LRP of $02.B_0$ (Table 4),
2. the alternative USR of $0.35B_0$ (Table 5), and
3. the USR of $0.4B_0$ (Table 6),
4. the previous year's biomass (Table 7)

Figures 14–16 show the uncertainty in the relative spawning biomass estimates for projected years given the catch values provided in the harvest decision tables. They are essentially a visual depiction of the decision tables, except that the lower 2.5% and upper 2.5% of the posteriors are not included in the plots, but are included in the probability calculations in the decision tables. The horizontal lines in the figures are the 95% CIs of the relative biomass. The probabilities given in the harvest decision tables are close to being the proportion of those lines to the right of each reference point shown as vertical lines in the plots.

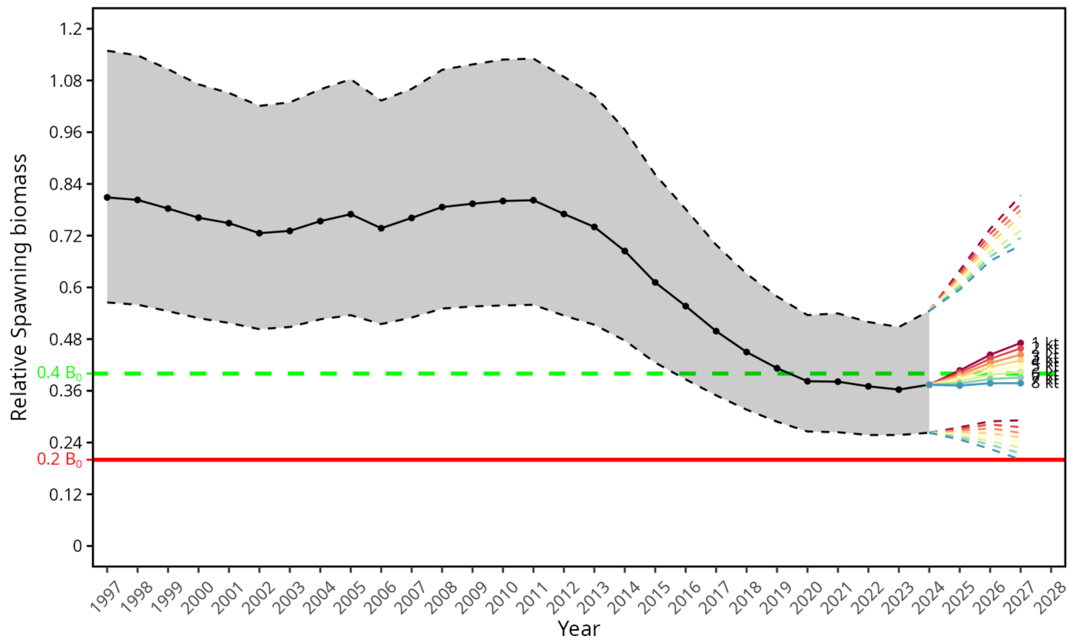

Figure 12. Estimated relative spawning biomass (B_t/B_0) for the base model. The shaded area represents the 95% Credible Interval (CI) and the solid line with points shows the connected medians. Horizontal lines indicate the $0.2B_0$ (solid red) and $0.4B_0$ (dashed green) reference points. The colored dots from 2025–2027 are the posterior medians representing the projected catch levels, with solid lines connecting them; the dashed lines from 2025–2027 represent the 95% CIs for those posteriors. The constant catch values (in kt) are shown as text on the right of the end points of each projected trajectory. See the decision tables (Tables 4–7) for probabilities of being above reference points and of the stock increasing year-to-year in the projection years for each catch level.

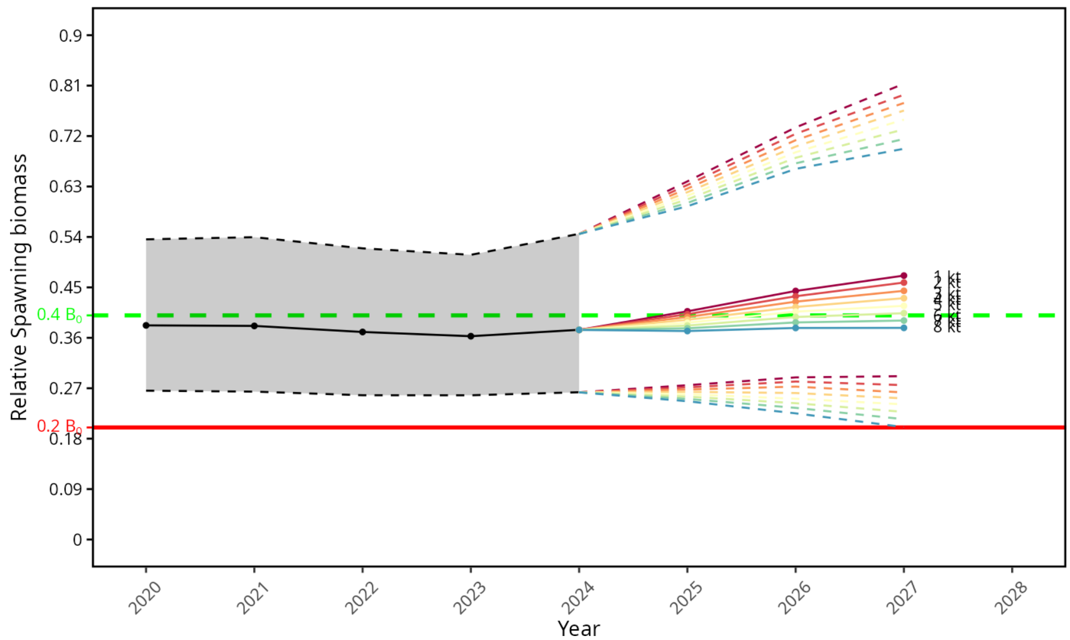

Figure 13. Closeup view of most recent relative spawning biomass (Figure 12) for the Arrowtooth Flounder base model with B_0-based reference points and projections into the future. The constant catch values (in kt) are shown as text on the right of the end points of each projected trajectory. See the decision tables (Tables 4–7) for probabilities of being above reference points and of the stock increasing year-to-year in the projection years for each catch level.

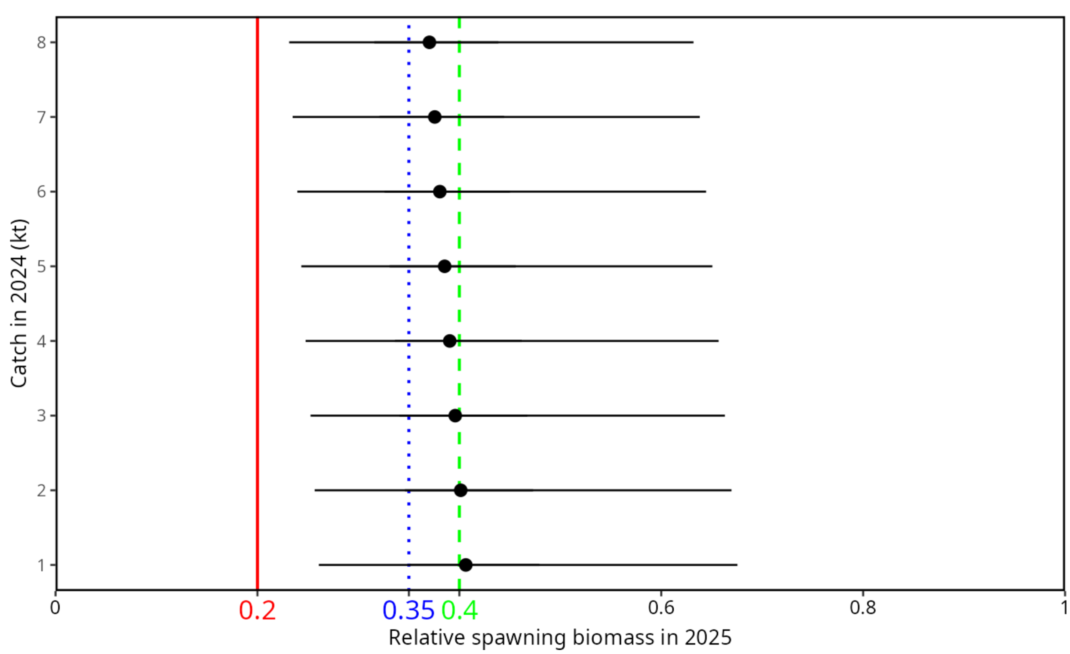

Figure 14. Projected 2025 relative spawning biomass for several possible catch levels in 2024. Black points are medians of the posterior and horizontal black lines are the 95% CI (2.5%–97.5%). The solid red line is the LRP, $0.2B_0$, the dotted blue line is the alternative USR, $0.35B_0$, and the dashed green line is the USR, $0.4B_0$.

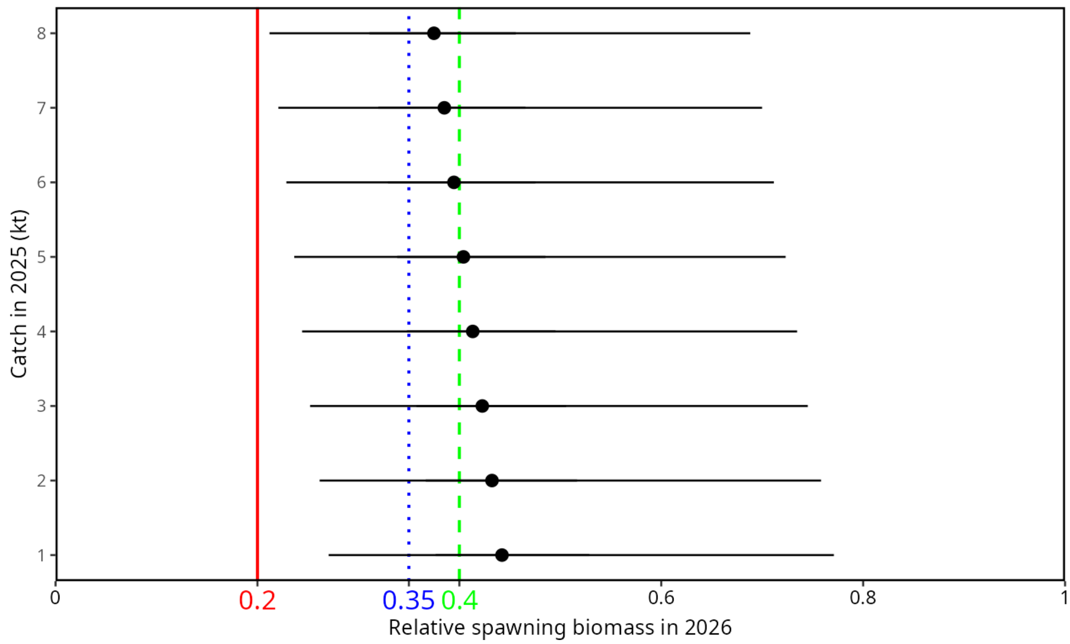

Figure 15. Projected 2026 relative spawning biomass for several possible catch levels in 2025. Black points are medians of the posterior and horizontal black lines are the 95% CI (2.5%–97.5%). The solid red line is the LRP, $0.2B_0$*, the dotted blue line is the alternative USR,* $0.35B_0$*, and the dashed green line is the USR,* $0.4B_0$*.*

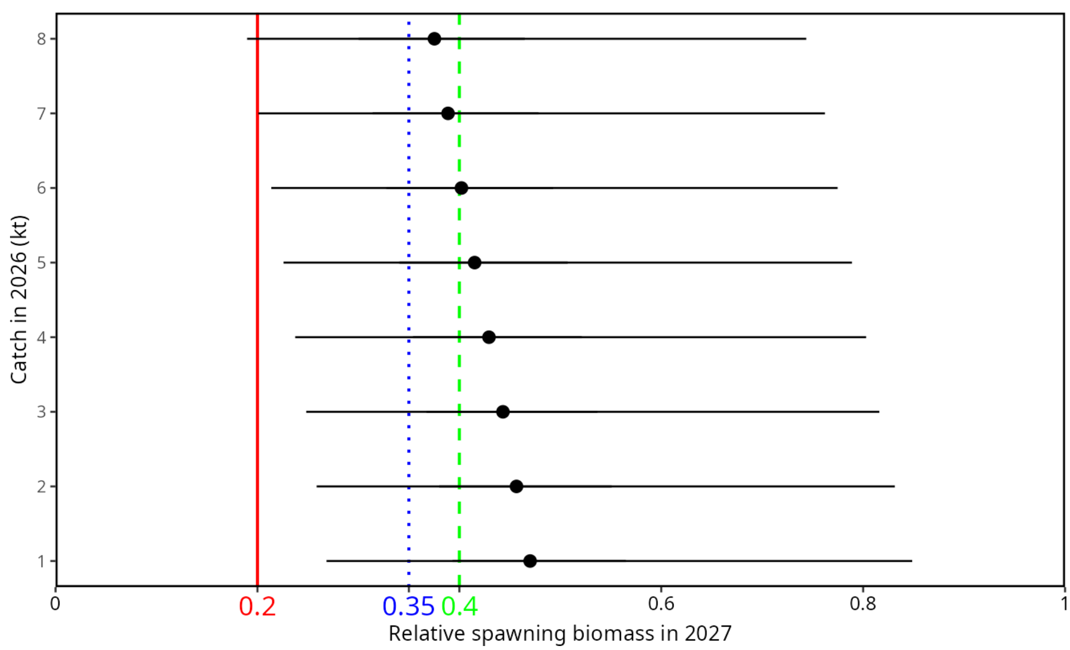

Figure 16. Projected 2027 relative spawning biomass for several possible catch levels in 2026. Black points are medians of the posterior and horizontal black lines are the 95% CI (2.5%–97.5%). The solid red line is the LRP, $0.2B_0$*, the dotted blue line is the alternative USR,* $0.35B_0$*, and the dashed green line is the USR,* $0.4B_0$*.*

Table 4. Probabilities that projected biomass will be above the $0.2B_0$ LRP for catch levels of 1 to 8 kt.

Catch (kt)	P(B_{2025} > $0.2B_0$)	P(B_{2026} > $0.2B_0$)	P(B_{2027} > $0.2B_0$)
1	0.998	0.998	0.998
2	0.997	0.998	0.998
3	0.997	0.997	0.998
4	0.997	0.997	0.996
5	0.997	0.997	0.994
6	0.995	0.992	0.990
7	0.994	0.991	0.985
8	0.993	0.988	0.975

Table 5. Probabilities that projected biomass will be above the $0.35B_0$ alternative USR for catch levels of 1 to 8 kt.

Catch (kt)	P(B_{2025} > $0.35B_0$)	P(B_{2026} > $0.35B_0$)	P(B_{2027} > $0.35B_0$)
1	0.776	0.864	0.899
2	0.756	0.838	0.871
3	0.731	0.804	0.836
4	0.703	0.771	0.791
5	0.680	0.740	0.746
6	0.655	0.705	0.702
7	0.636	0.658	0.647
8	0.606	0.615	0.603

Table 6. Probabilities that projected biomass will be above the $0.4B_0$ USR for catch levels of 1 to 8 kt.

Catch (kt)	P(B_{2025} > $0.4B_0$)	P(B_{2026} > $0.4B_0$)	P(B_{2027} > $0.4B_0$)
1	0.543	0.694	0.761
2	0.512	0.654	0.717
3	0.490	0.609	0.664
4	0.468	0.564	0.623
5	0.438	0.527	0.569
6	0.406	0.484	0.517
7	0.386	0.434	0.469
8	0.369	0.403	0.420

Table 7. Probabilities that projected biomass will increase for catch levels of 1 to 8 kt.

Catch (kt)	P(B_{2025} > B_{2024})	P(B_{2026} > B_{2025})	P(B_{2027} > B_{2026})
1	0.964	0.952	0.898
2	0.925	0.929	0.852
3	0.867	0.885	0.795
4	0.781	0.812	0.715
5	0.681	0.748	0.655

Catch (kt)	P(B_{2025} > B_{2024})	P(B_{2026} > B_{2025})	P(B_{2027} > B_{2026})
6	0.591	0.668	0.586
7	0.516	0.607	0.521
8	0.455	0.540	0.469

Conclusions

The ISCAM model used in this update was of the same structure, and having the same assumptions as the model used in the 2022 stock assessment. New data added were commercial catch for 2022 and 2023, new survey index points, and new Discard CPUE index points. The growth parameters, estimated outside the ISCAM framework, changed by a very small amount, which did not affect the model esitmates.

With the addition of the new data, the relative spawning biomass only had negligible differences from 1996–2021, as reported in the 2022 stock assessment, although the inital biomass, B_0, and the spawning biomass values were estimated to be slightly lower in this update than in the 2022 stock assessment.

Index fits appeared slightly better in this update, and there were no large changes in fits to any index points in the four survey indices and the Discard CPUE Index. Three of the synoptic survey indices had one new index point added each (the Hecate Strait Multispecies Assemblage Survey has a terminal year of 2003 and was not updated), and the Discard CPUE Index had two new index points added (2022 and 2023) since it is based on commercial catch.

Typically DFO's reference points of $0.4B_{MSY}$ for the LRP and $0.8B_{MSY}$ for the USR are used as they are defined in the Sustainable Fisheries Framework (SFF, DFO (2009)). However for Arrowtooth Flounder, reference points based on the Maximum Sustainable Yield (MSY) were strongly impacted by estimates of selectivity in the trawl fisheries. For this reason, B_0-based reference points were used for this stock in the 2022 stock assessment, and in this update as well. The projeced catch streams show medians and credible intervals for catches of 1 to 15 kt, in 1 kt increments (Figures 12 and 13). The figure shows that for catch values of 1-6 kt the biomass will increase to 2027. For values of 7-8 kt the biomass will remain flat, and remain below the USR of $0.4B_0$.

Recruitment estimates have a large CI for the last 4 years of the model (Figure 4), which is two more years than the 2022 stock assessment has. This is due to the lack of new ages being included in the model for 2022 and 2023. This will be rectified in the next assessment or update by having ageing completed for those years, and any new years to be added.

There are several harvest decision tables provided in this document (Tables 4–7) which, for 8 different catch levels from 1 kt to 8 kt, give the probabilites of the projected relative biomass being above:

1. the LRP of $02.B_0$ (Table 4),
2. the alternative USR of $0.35B_0$ (Table 5),
3. the USR of $0.4B_0$ (Table 6), and
4. the previous year's biomass (Table 7).

Some observations from the decision tables:

1. The probability of being above the LRP of $0.2B_0$ at the beginning of 2025 is 0.993 if the highest catch level of 8 kt is caught in 2024 (Table 4),
2. The probability of being above the LRP of $0.2B_0$ at the beginning of 2027 is 0.975 if the highest catch level of 8 kt is caught each year from 2024 to 2026 (Table 4),
3. The probability of being above the alternative USR of $0.35B_0$ at the beginning of 2025 is 0.606 if the highest catch level of 8 kt is caught in 2024 (Table 5),
4. The probability of being above the alternative USR of $0.35B_0$ at the beginning of 2027 is 0.603 if the highest catch level of 8 kt is caught each year from 2024 to 2026 (Table 5),
5. The probability of being above the USR of $0.4B_0$ at the beginning of 2025 is 0.369 if the highest catch level of 8 kt is caught in 2024 (Table 6),
6. The probability of being above the USR of $0.4B_0$ at the beginning of 2027 is 0.420 if the highest catch level of 8 kt is caught each year from 2024 to 2026 (Table 6),
7. A probability of 0.5 of being above the USR of $0.4B_0$ at the beginning of 2025 occurs between 2 and 4 kt of catch in 2024. A higher catch will result in the probability being less than 0.5 (Table 6),
8. A probability of 0.5 of being above the USR of $0.4B_0$ at the beginning of 2027 occurs between 4 and 5 kt of constant catch for each year from 2024 to 2026. A higher constant catch will result in the probability being less than 0.5 (Table 7), and
9. A probability of 0.5 of biomass increasing year-to-year for each year from 2024 to 2026 occurs between 7 and 8 kt of constant catch in each year (Table 7).

Contributors

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Approval

Approval text will be added when approval is finalized

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