A brief update of the
ORH3B ESCR and NWCR
stock assessments
to the end of the 2016–17 and 2017–18 fishing years
with application of the Harvest Control Rule
in both years

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Executive summary

In 2014, ISL under contract to DWG used NIWA's stock assessment package CASAL to perform four orange roughy stock assessments that were accepted by MPI as meeting the Research and Science Information Standard for New Zealand Fisheries. This work included assessments for ORH 3B east and south Chatham Rise (ESCR) and ORH 3B northwest Chatham Rise (NWCR). In 2016-17, NIWA, under contract to MPI, updated the two ORH 3B assessments. Prior to the results of the NIWA 2017 assessments being available, DWG contracted ISL to perform separate assessment updates for these two ORH 3B stocks. In August 2017, MPI provided DWG with the CASAL input files that NIWA developed for use for their 2017 ORH 3B assessments. A draft FAR with NIWA's stock assessment updates was provided to ISL in December 2017.

This report presents ISL's stock assessment updates using the supplied CASAL files with minor changes to improve some poor diagnostics. As a result, there are minor differences between the final NIWA and ISL base model results for the ESCR assessments. For the NWCR assessments, the results from ISL's and NIWA's base models are identical.

For the ESCR stock assessment update, new data included a 2016 acoustic survey estimate which was lower than expected. This required that extra variance be acknowledged for the two main acoustic time series that are used in the assessment (recognising that the acoustic proportionality constants (*q*s) are not necessarily constant). Therefore, ISL's base model included an additional 20% process error on the two acoustic time series. The two acoustic time series are closely related and a penalty was also imposed on the ratio of the two acoustic *q*s. The imposition or not of the penalty makes no difference to the main stock assessment results and, in ISL's base model, the stock was estimated to be at 34% B_0 (95% CI: 29–39% B_0) and to be within the target biomass range of 30–50% B_0 with 95% probability. In NIWA's base model (without the 20% process error or the *q* penalty) the stock was estimated to have slightly lower stock status at 33% B_0 (95% CI: 28–37% B_0), lower probability of being above 30% B_0 (86%) and slightly lower B_0 (median 310 000 t compared to 320 000 t).

For the NWCR stock assessment update, new data included a 2016 acoustic survey estimate which was similar to the 2012 estimate, except that all of the spawning biomass was on Morgue and none was found on Graveyard. There was also an age frequency (AF) collected from Morgue during the 2016 survey of spawning aggregations using a standard demersal trawl fished a few meters off the bottom. This age frequency included almost 5% of the fish aged at 100 years or older, which is far more than expected or seen in previous AFs from this stock. When this AF was included in the assessment, the stock was estimated to be at 45% B_0 (95% CI: 35–57% B_0) and when it is excluded the stock was estimated to be at 38% B_0 (95% CI: 30–48% B_0). In both cases, the stock was estimated to almost certainly be above the lower bound of the target biomass range (30% B_0). The base models of NIWA and ISL were identical and excluded the 2016 Morgue age frequency, which followed the advice provided by the DWFAWG.

The orange roughy Harvest Control Rule (HCR) was applied to NIWA's ESCR and NWCR 2017 assessment updates to obtain the HCR catch limits for 2017–18. The HCR was also applied to ISL's

ESCR base model and NIWA's and ISL's base assessments updated to the end of 2017–18 to calculate HCR catch limits for the 2018–19 fishing year (Table 1):

Table 1: HCR catch limits calculated for ORH 3B ESCR & NWCR for different fishing years.

	Catch limit in 2014–15 (t)	Catch limit in 2017–18 (t)		Catch limit in 2018–19 (t)	
		ISL	NIWA	ISL	NIWA
ESCR	3100	6190	5750	6450	5970
NWCR	1043	1160	1160	1210	1210

For ESCR, although the differences between the ISL and NIWA base models are minor and the estimates of stock status are within one percentage point, there are significant differences in the HCR catch limits derived from each of the two models. The differences are due to the lower stock status and a lower vulnerable biomass estimated by NIWA's base model.

The cause of the differences between the 2014–15 catch limits (calculated from the HCR in 2014) and the 2018–19 catch limits was fully investigated. The total change in the catch limits was split into individual components and investigated using the NIWA base case models. For the ESCR, the two dominant effects were the increase in estimated stock status and the increase in vulnerable biomass (both caused by the passage of time). The third most important contributor was the updated assessment (driven by the new data).

For NWCR, the dominant effect was the updated assessment which caused a downward revision in stock status over recent years. This downward revision was more than compensated for by the subsequent growth in stock size and increase in stock status (the next most important effect) and vulnerable biomass (the second next most important effect). The overall effect was a small increase in the calculated catch limit from 2014–15 to 2018–19 of 167 t.

1. Introduction

In 2014, the ORH 3B east and south Chatham Rise (ESCR) and ORH 3B northwest Chatham Rise (NWCR) orange roughy stocks were assessed using NIWA's stock assessment package CASAL (Cordue 2014, Bull et al. 2014). MPI contracted NIWA and DWG separately contracted ISL to update these assessment during 2016–17. MPI supplied ISL with the CASAL files that NIWA used for the base models. A draft FAR with NIWA's stock assessment updates was supplied to ISL in December 2017 and that report contained the results for base models as were presented to the DWFAWG (Dunn and Doonan, draft). The base models were consistent with the CASAL files that had been supplied.

This report presents ISL's stock assessment updates using the supplied CASAL files with minor changes to improve some diagnostics. NIWA's base models were also run to allow comparison with ISL's base models. Finally, the orange roughy Harvest Control Rule (HCR) (Cordue 2014a) was used to calculate proposed catch limits for the 2017–18 and 2018–19 fishing years for each of these two fisheries. To apply the HCR for the 2018–19 fishing year required that the base models (ISL and NIWA) were updated one more year to the end of the 2017–18 fishing year using assumed catches.

This report presents a limited range of model runs to address the issues of comparing the ISL and NIWA models and calculating catch limits using the HCR. Where diagnostic performance was considered poor with regard to the NIWA base models modifications were made.

2. Methods

The CASAL files supplied to DWG were checked for consistency with the agreed advice provided during meetings of the DWFAWG. Essentially, new age frequencies and new and revised biomass indices were to be added to the 2014 assessment files but no other changes were to be made to the population model structure or the estimation approach.

2.1 Data and model structure

A brief summary of the data and model structures is given below. The reader is referred to Cordue (2014) for the full details of the data and model structures and also to the CASAL input files (Appendix 1) and Dunn and Doonan (draft).

For both ESCR and NWCR the most important data are the acoustic biomass time series which are assumed to monitor a constant proportion of spawning biomass. There are two closely related acoustic series for ESCR. Acoustic time series 1 surveyed the Old Plume, Rekohu, and the Crack (Mount Muck). Acoustic time series 2 only surveyed the Old Plume and Rekohu. The CVs for these series are the total CVs after a 20% process error was added to allow for extra variability that was apparent after the 2016 survey index was added to acoustic time series 1 (Table 2).

Table 2: Acoustic biomass estimates (t) and percentage CVs for the two ESCR acoustic time series.

	Acoustic series 1		Acoustic series 2	
	Index (t)	CV (%)	Index (t)	CV (%)
2011	51 329	22		
2012			46 513	21
2013	54 363	22		
2014			63 781	27
2015				
2016	43 560	22		

For the NWCR, the main acoustic time series consists of total estimates from surveys of the two hills Graveyard and Morgue (although some other hills were also surveyed in 1999):

Table 3: Acoustic biomass estimates (t) and percentage CVs for the NWCR acoustic time series.

	Acoustic series	
	Index (t)	**CV (%)**
1999	8 126	22
2012	14 637	17
2016	14 051	13

The 2016 NWCR survey was notable for no biomass estimate from Graveyard (a small number of orange roughy were seen acoustically and caught but no biomass estimate was made). All the spawning roughy acoustically estimated were on the Morgue, which is closed to commercial fishing and where bottom contact has not been permitted during surveys. Also, a spawning season age frequency was obtained in 2016 using a standard demersal trawl fished a few meters off the bottom on Morgue (as part of the acoustic survey). The age frequency is notable for a large plus group at 100 years (Figure 1).

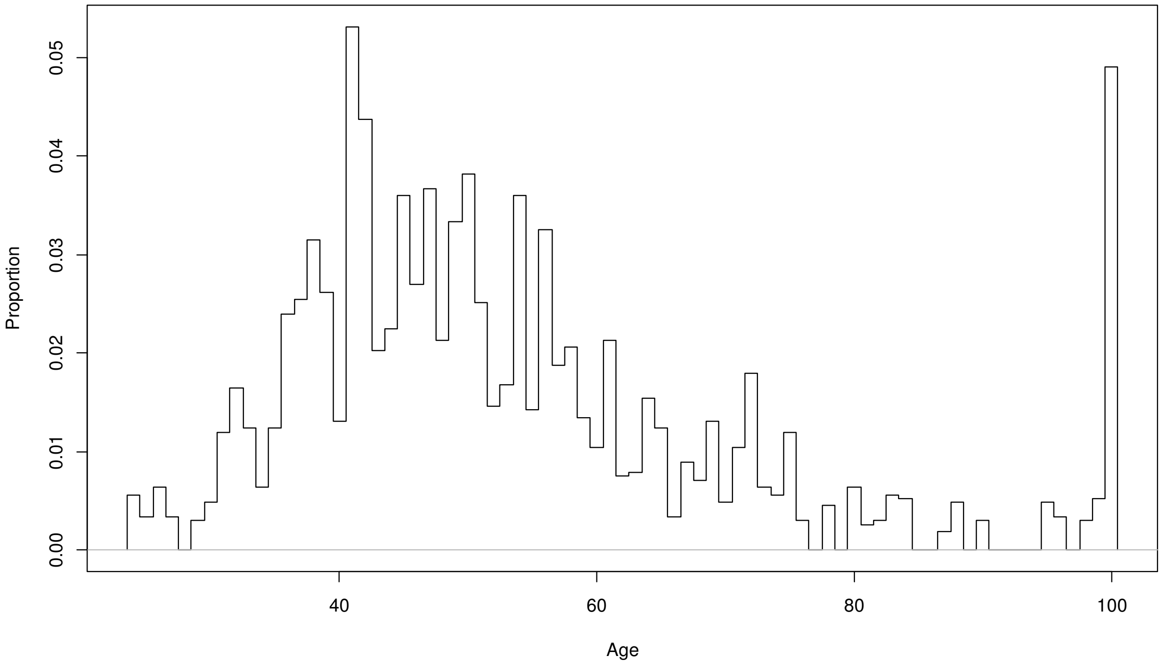


Figure 1: NWCR: age frequency for Morgue obtained during the 2016 spawning season using a standard demersal trawl fished a few meters off the bottom.

The model structure for both ESCR and NWCR is single sex and single area with fish categorised by age and maturity (immature or mature). Natural mortality was assumed equal to 0.045 and a Beverton-Holt stock-recruitment relationship was assumed with steepness equal to 0.75. Virgin biomass, year class strengths, a maturation ogive, and fishing selectivities were estimated in the model (see Cordue 2014, Dunn and Doonan draft).

2.2 Model runs

For the ESCR assessment, the CASAL files used by NIWA were changed to include 20% process error for the acoustic biomass indices in 2012 and 2014 (Old Plume and Rekohu: acoustic series 2) and those in 2011, 2013, and 2016 (Old Plume, Rekohu, and the Crack surveyed: acoustic series 1). Preliminary runs presented to the DWFAWG by NIWA, without the process error, had shown large residuals for some of the acoustic data points. The surveys were conducted by multiple research providers each using somewhat different approaches and equipment. This may have introduced some additional variance or it may just be due to changes in *q* across years. Either way, large residuals should not be accepted in a base model as it is an indication that the data set concerned has been given too much weight and justifies the addition of the extra process error. The addition of 20% process error had been suggested by ISL at a DWFAWG meeting as a solution to this problem (on the basis of preliminary runs done by ISL). Dunn and Doonan (draft) report that the DWFAWG decided not to include the additional 20% process error in the base model.

An additional concern with the ESCR assessment was that the ratio of the *q*s for the two acoustic time series were not constrained in the model run. Clearly, on average, the *q* when all three aggregations/areas are surveyed must be higher than the *q* when the Crack is not surveyed (as all three areas must represent, on average, a greater proportion of the spawning biomass than those from just two areas). An additional ESCR model run was performed where the *q*-ratio was constrained by a highly informed prior (mean = 1.145, CV = 7.5%). The mean was calculated as the ratio of means of the individual *q* priors (0.8/0.7) and the CV was such that ratios of less than 1 were highly penalised. This penalty was not included in NIWA's base model.

For the NWCR assessment, the new 2016 age frequency that was available had come from three trawls on Morgue during the spawning season using a standard demersal trawl fished a few meters above the seabed, conducted as part of the acoustic survey. As noted earlier, this had a very unusual age distribution (Figure 1). The DWFAWG considered both including the AF fitted with its own selectivity and excluding it from the base case model, eventually settling on exclusion. In this report, results are presented for runs done with and without the new age frequency. The run including the new age frequency data had a double normal selectivity fitted with an informed prior (see Appendix 1) to encourage sensible parameter estimates (which did not occur when uniform priors were used).

In order to calculate HCR catch limits for fishing year 2018-19, both the NWCR and ESCR stock assessments were updated one more year to the end of 2017–18. For NWCR, NIWA's and ISLs base models are the same and exclude the new 2016 Morgue age frequency.

The model runs are presented are described in Table 4:

Table 4: Model runs for the NWCR and ESCR stocks.

Model	Changes relative to NIWA base	To the end of 2016–17	To the end of 2017–18
ESCR NIWA base	None	Yes	Yes
ESCR ISL base	q-ratio penalty + 20% process error	Yes	Yes
ESCR ISL sensitivity	+ 20% process error	Yes	No
NWCR NIWA/ISL base		Yes	Yes
NWCR ISL sensitivity	+ Morgue AF	Yes	No

2.3 MCMC methods

For each model run, three chains of length 15 million were produced and one sample in every one thousand was retained. The first 1000 retained samples from each chain were discarded as a "burn-in" and estimates were calculated using the remaining 42,000 samples. The results from the three chains were compared to ensure that convergence was adequate (near identical medians and very similar distributions for the marginal posterior distributions of virgin biomass (B_0) and current biomass (e.g., B_{2017} as $\%B_0$)). For presentational purposes, some graphics use the samples from only the first chain (after burn-in).

2.4 Application of the HCR

The HCR uses the point estimate of current spawning stock status to calculate an exploitation rate to be applied to the next year's beginning-of-year vulnerable biomass to determine the catch limit. For example, the assessments to the end of the 2016–17 fishing year provide an estimate of stock status in the 2017 model year (based on mid-spawning-season spawning-biomass). However, the catch limit for the 2017–18 fishing year is based on the vulnerable biomass at the start of 2017–18 (which in the model is the vulnerable biomass at the beginning of 2018 before any mortality has been applied).

For each assessment model, the vulnerable biomass at the start of the next year was obtained by doing a one year projection. Future catches were set to zero (although the results are independent of catch) and year class strengths (YCS) were sampled empirically from the last 10 estimated years. Random YCS were brought in immediately after the last estimated YCS (although the results are largely independent of the random YCS as few if any are recruited). The exploitation rate was applied to the median estimated vulnerable biomass (an average vulnerable biomass in the case of ESCR as there are four fisheries; the average was a weighted average using the model catches in the current year).

For estimates of stock status within the target biomass range of 30–50% B_0, the exploitation rate is simply stock status multiplied by 0.1125 (see Cordue 2014a, there is a linear relationship between stock status and the exploitation rate and when stock status is estimated at 40% B_0 the exploitation rate is 0.045 which is the M used for orange roughy).

3. Results and discussion

The stock assessment results presented are focussed on the 2016–17 stock assessment updates undertaken by ISL. The objective of this work was essentially to run a comparison with the base model runs done by NIWA. The normal range of sensitivity runs are not presented.

For the ESCR, the results from the base models of ISL and NIWA are compared. For the NWCR the results from the base models are identical.

The HCR is applied to NIWA's and ISL's base models to calculate catch limits for fishing year 2017–18 and 2018–19. The differences between the catch limits calculated for 2014–15 (Cordue 2014a) and those for 2018–19 are fully investigated and explained.

3.1 ESCR update to the end of 2016–17

Both of ISL's models appeared to converge adequately (see Appendix 1). The two runs produced almost identical results (Table 5). The only difference was in the residuals for the two acoustic time series (Figure 2). The imposition of the *q*-ratio penalty was applied to constrain the *q*-ratio to be primarily above 1 as without the penalty half of the posterior distribution had a ratio less than 1 (Table 6). Therefore, the run with the *q*-ratio penalty should be preferred as the base model. Certainly, either run should be preferred to NIWA's base model although the results were very similar (Table 5). NIWA's base model had a slightly lower B_0 and a slightly lower current stock status than ISL's base model (Table 5).

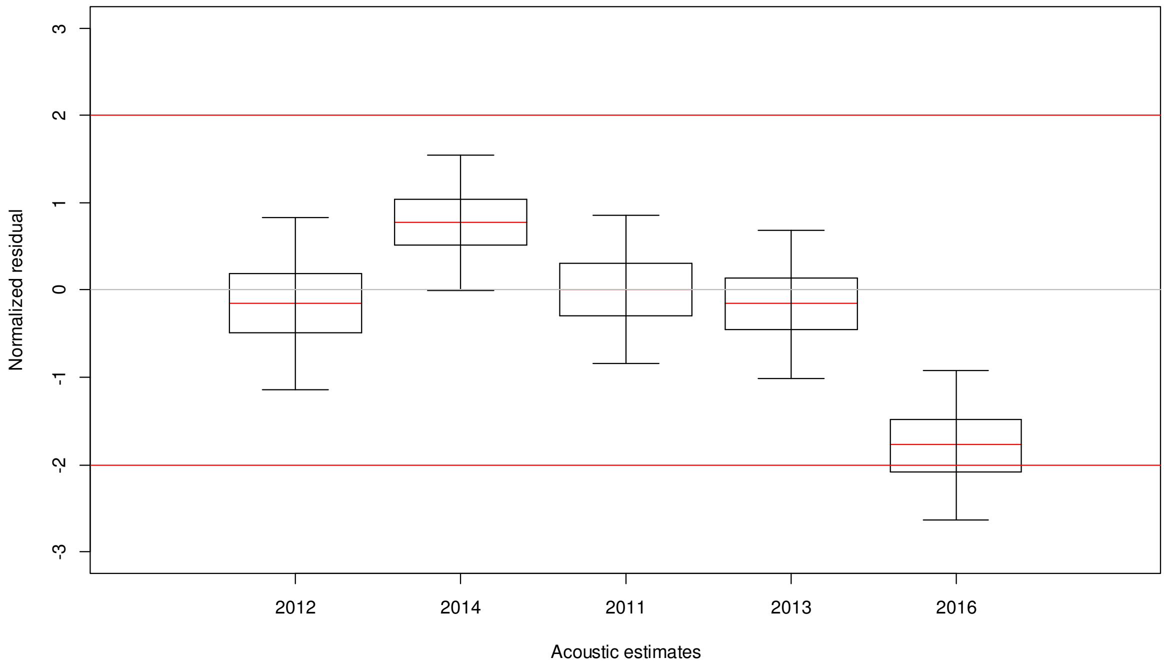
Estimated year class strengths (YCS) were very similar to those estimated in the 2014 stock assessment with above average median YCS for a period followed by below average median YCS and then a return to approximately average median YCS (Figure 3). The ESCR stock is estimated to have rebuilt to be within the 30–50% B_0 target biomass range (Table 5, Figure 4) with an estimated probability of being above 30% B_0 of 95% and with a zero probability of being below 20% B_0 (Table 5).

Table 5: ESCR: MCMC estimates of B_0 and stock status in 2014 (ss_{14}) and 2017 (ss_{17}) for the runs with the *q*-ratio penalty (*q*-ratio, ISL's base model) and without the *q*-ratio penalty (No pen.), NIWA's base model, and the 2014 assessment. Also given are the estimated probabilities of the stock status in 2017 being below 20% B_0 and above 30% B_0.

Run	B_0 (000 t)	95% CI	ss_{14}	95% CI	ss_{17}	95% CI	$P(ss_{17} < 20)$	$P(ss_{17} > 30)$
***q*-ratio**	320	290–360	30	26–34	34	29–39	0	95
No pen.	320	290–350	30	26–34	34	29–38	0	95
NIWA	310	280–350	30	25–34	33	28–37	0	86
2014	320	280–350	30	25–34				

Table 6: ESCR: MCMC estimates of the *q*s for acoustic time series 1 and 2 and the ratio q_1/q_2 for the runs with the *q*-ratio penalty (*q*-ratio) and without the *q*-ratio penalty (No pen.).

Run	q_1	95% CI	q_2	95% CI	q_1/q_2	95% CI
***q*-ratio**	0.62	0.49–0.79	0.56	0.43–0.72	1.12	0.97–1.28
No pen.	0.61	0.45–0.84	0.61	0.45–0.84	1.00	0.70–1.42



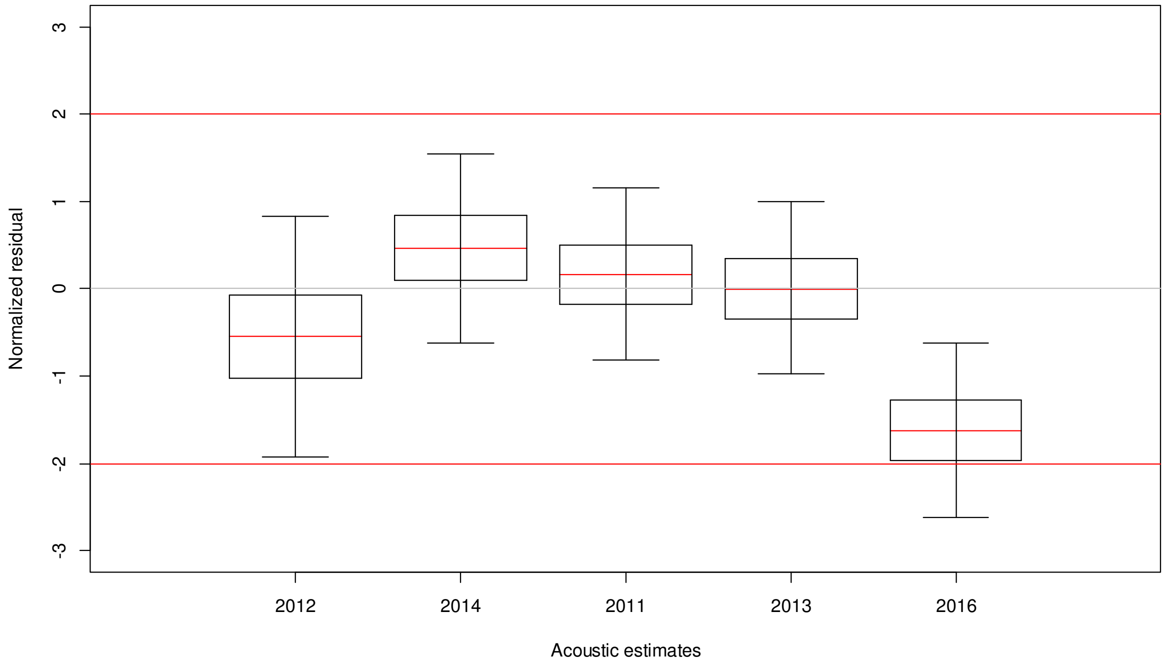


Figure 2: ESCR: MCMC normalized residuals for acoustic time series 1 (2011, 2013, and 2016) and acoustic time series 2 (2012 and 2014) for the run with a *q*-ratio penalty (top) and the run without the penalty (bottom). The boxes include the middle 50% of the distribution and the whiskers extend to 95%. Horizontal lines are plotted at –2 and 2 within which should lie approximately 95% of the residuals.

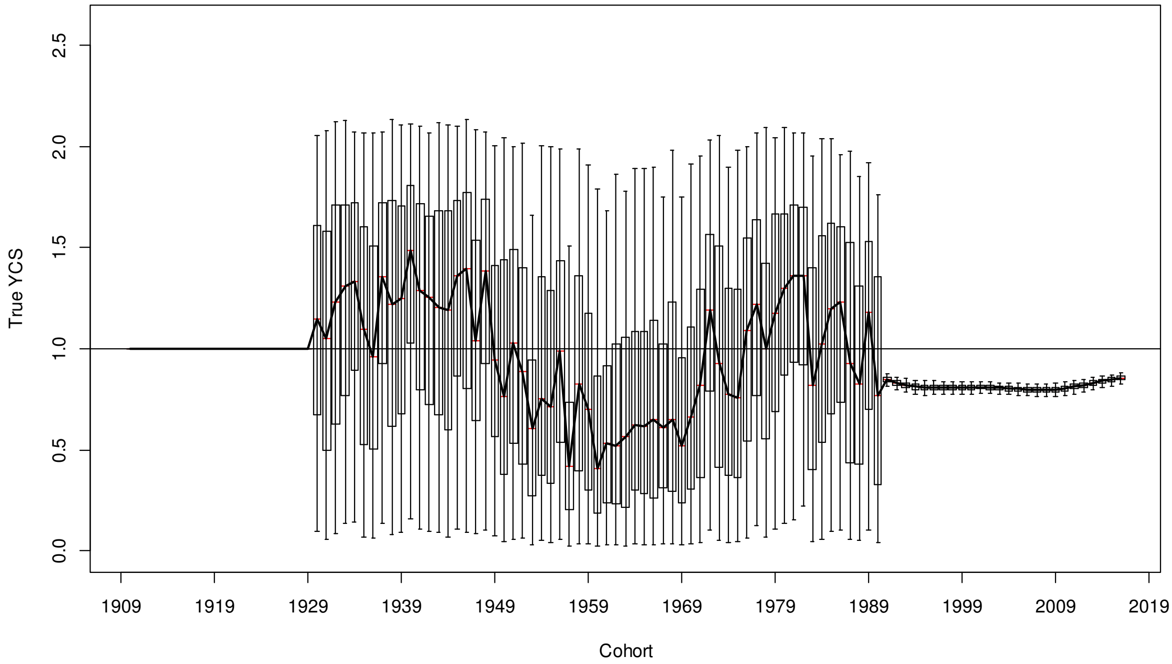


Figure 3: ESCR: MCMC estimates of true YCS for the *q*-ratio model. The boxes include the middle 50% of the distribution and the whiskers extend to 95%.

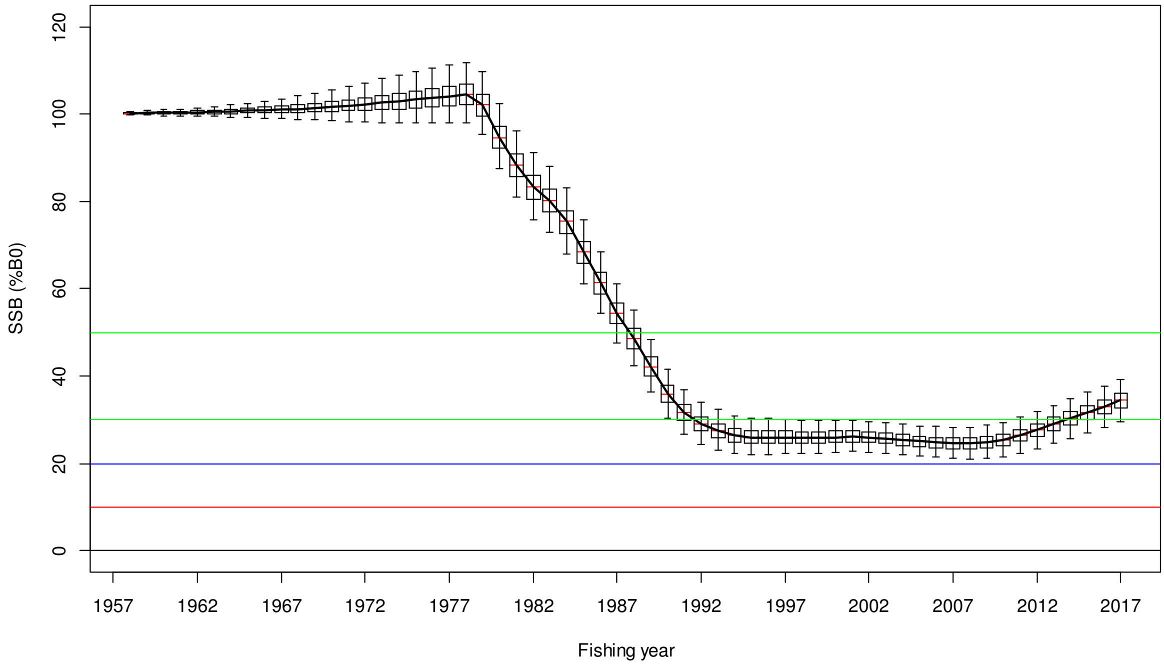


Figure 4: ESCR: MCMC stock status trajectory for the *q*-ratio model. The boxes include the middle 50% of the distribution and the whiskers extend to 95%. Horizontal lines are plotted at management thresholds of 10%, 20%, 30% and 50% of B_0.

3.2 NWCR update to the end of 2016–17

The NWCR stock was estimated to be comfortably within the target biomass range of 30–50% B_0 for both of the model runs (Table 7). When the Morgue age frequency was included, which has about 5% of the fish aged 100 years or older, the current stock status is estimated at 45% B_0 compared to 38% B_0 when the age frequency is excluded (Table 7). Both models are fairly consistent with the 2014 stock assessment in terms of the 95% CIs for B_0 and stock status in 2014, although as noted, the model without the age frequency generated a lower stock status than the model with the age frequency (Table 3).

Table 7: NWCR: MCMC estimates of B_0 and stock status in 2014 (ss_{14}) and 2017 (ss_{17}) for the runs using all of the available data (With AF) and excluding the 2016 AF from Morgue (No AF) and the 2014 assessment. Also given are the estimated probabilities of the stock status in 2017 being below 20% B_0 or above 30% B_0.

Run	B_0 (000 t)	95% CI	ss_{14}	95% CI	ss_{17}	95% CI	P(ss_{17} < 20)	P(ss_{17} > 30)
With AF	73	64–90	41	32–54	45	35–57	0	100
No AF	65	59–75	34	27–44	38	30–48	0	98
2014	66	61–76	37	30–46				

The diagnostics for the model using the age frequency showed two small points of concern. The residuals for the plus group in the age frequency are very large (Figure 5), which reflects the difficulty of fitting an age distribution with so many older fish. According to the dynamics of the model there shouldn't be that many old fish. The age frequency could be down-weighted but the residuals are only large for the plus group.

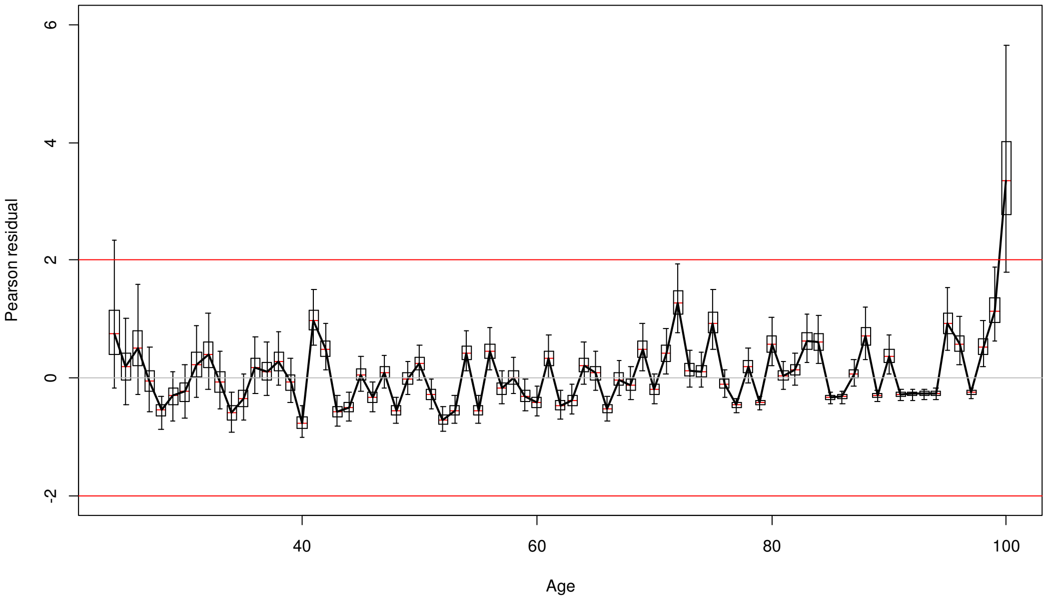


Figure 5: NWCR: MCMC Pearson residuals for the 2016 Morgue age frequency. The boxes include the middle 50% of the distribution and the whiskers extend to 95%. Horizontal lines are plotted at –2 and 2 within which should lie approximately 95% of the residuals.

The marginal posterior distribution of the acoustic *q* was also somewhat too far to the left relative to the prior distribution (Figure 6). It is still within the prior distribution but much more in the tail than that for the run without the Morgue age frequency (Figure 7).

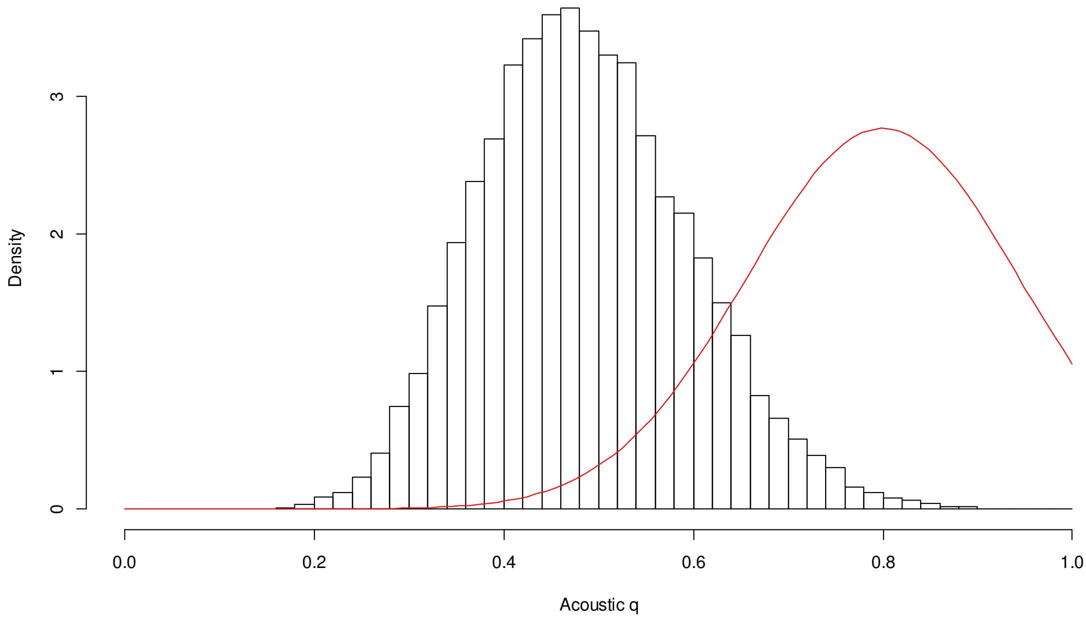


Figure 6: NWCR: Marginal posterior distribution (black bars) and prior (red line)for the acoustic *q* in the run that includes the 2016 Morgue age frequency.

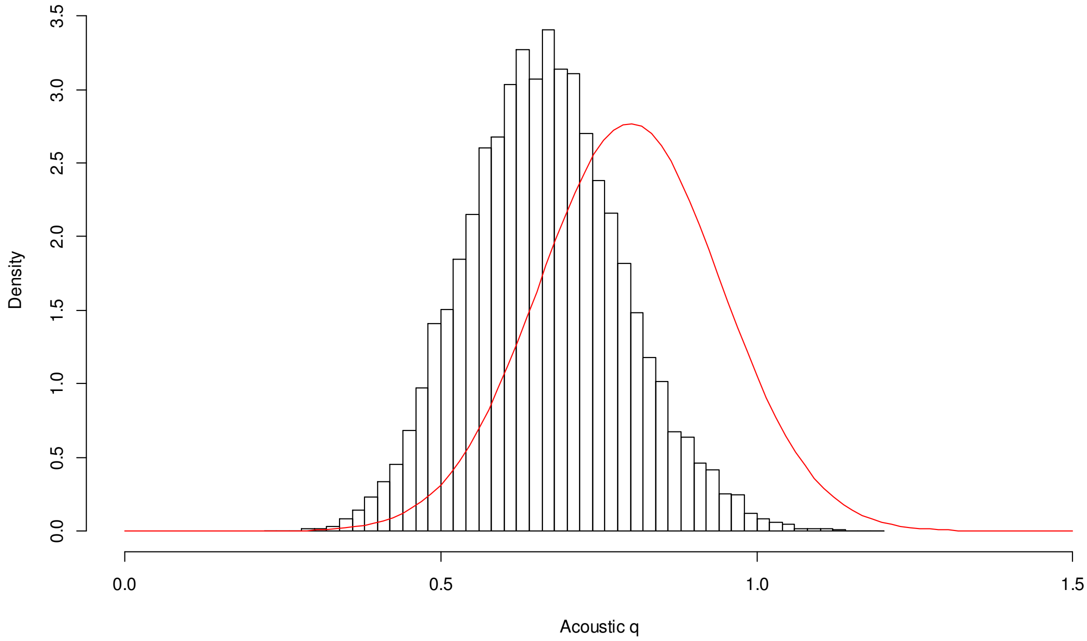


Figure 7: NWCR: Marginal posterior distribution (black bars) and prior (red line) for the acoustic *q* in the run that excludes the 2016 Morgue age frequency.

The estimated selectivity for the Morgue age frequency is also unusual, as the mode is at about 70 years of age (Figure 8). The inclusion of the age frequency made little difference to the estimated YCS which look very similar to those estimated in the 2014 assessment (essentially just noise around average YCS) (Figure 9).

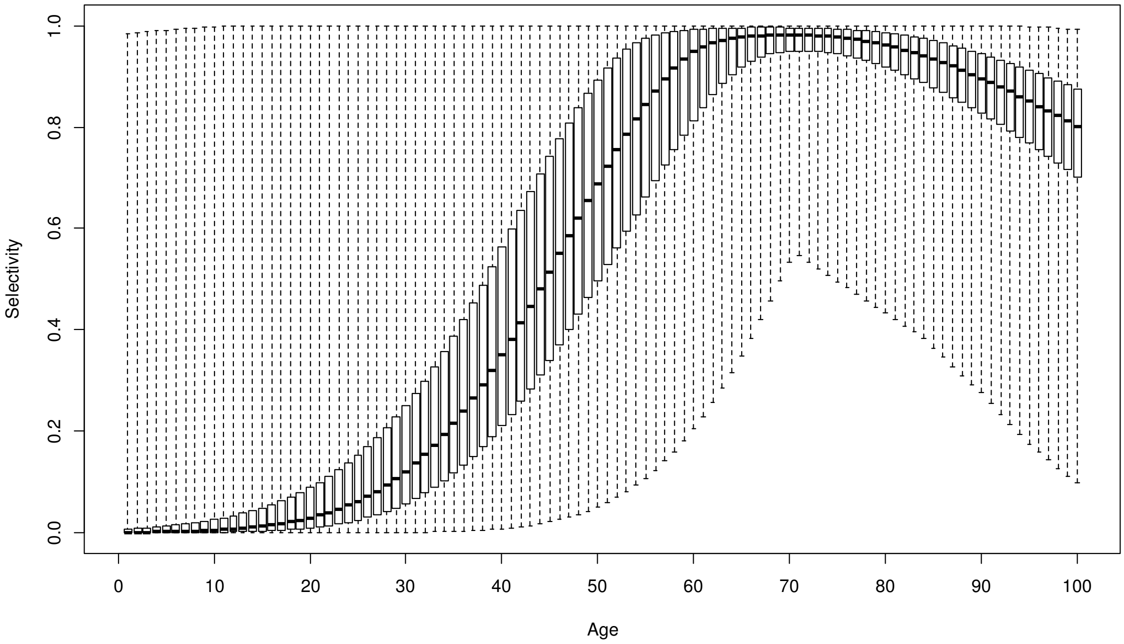


Figure 8: NWCR: Estimated selectivity at age (within mature fish) for the 2016 Morgue age frequency. The boxes include the middle 50% of the distribution and the whiskers extend to 95%.

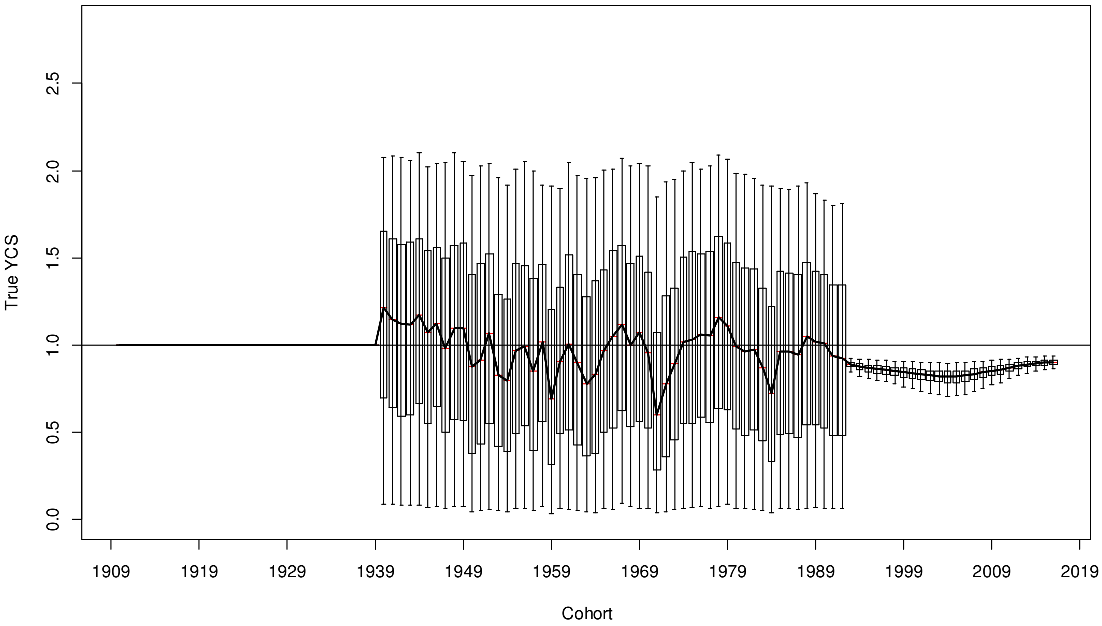


Figure 9: NWCR: MCMC estimates of true YCS for the model using the 2016 Morgue age frequency. The boxes include the middle 50% of the distribution and the whiskers extend to 95%.

The spawning biomass trajectories had the same shape for both models, it is just that when the Morgue age frequency was used the current stock status is higher (Figures 10 and 11). The existence of the large plus group in the age frequency from Morgue in 2016 is intriguing. If representative of the stock as whole, so many old fish does suggest that spawning biomass was never very depleted and so the model using the age frequency might be preferred as the base model. The concerns are that we only have one observation of these old fish and the sampling procedure (using a demersal trawl off the bottom) was non-standard, perhaps the result is just a statistical anomaly. Valid arguments can be made for either model as the base but on balance ISL prefer to exclude the 2016 Morgue age frequency at this stage, as did the DWFAWG, and so ISL's base model and NIWA's base model are identical. In terms of current stock status, both the base model and that including the 2016 Morgue age frequency estimated the stock in the mid to upper part of the target biomass range.

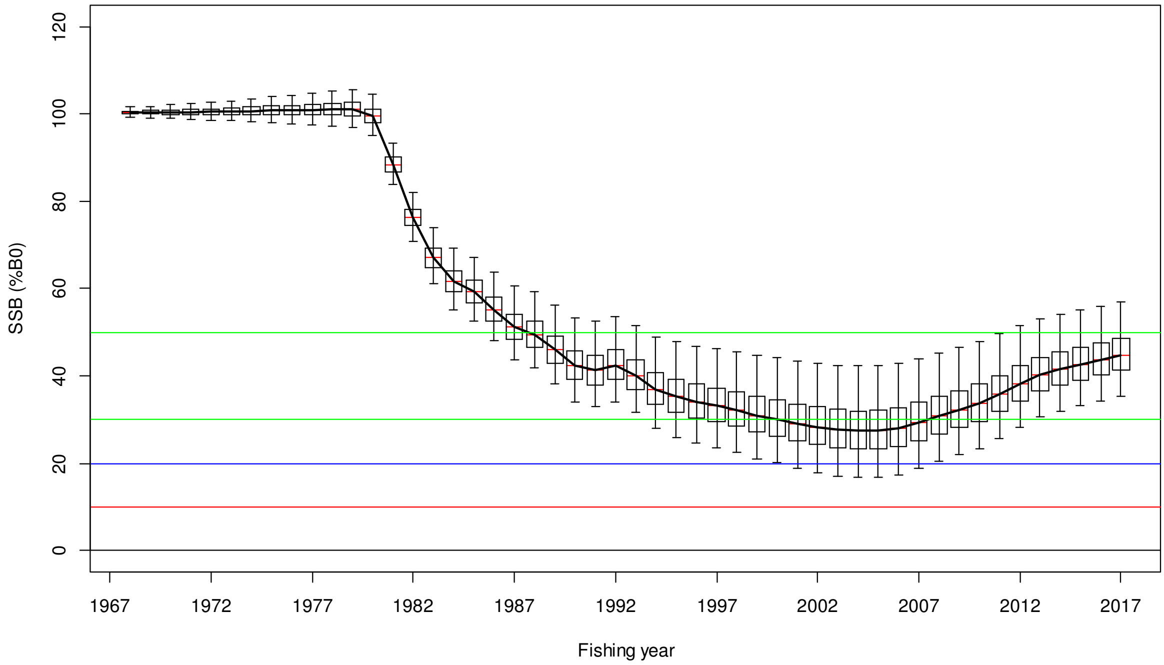


Figure 10: NWCR: MCMC stock status trajectory for the model using the 2016 Morgue age frequency. The boxes include the middle 50% of the distribution and the whiskers extend to 95%. Horizontal lines are plotted at 10%, 20%, 30% and 50% of B_0.

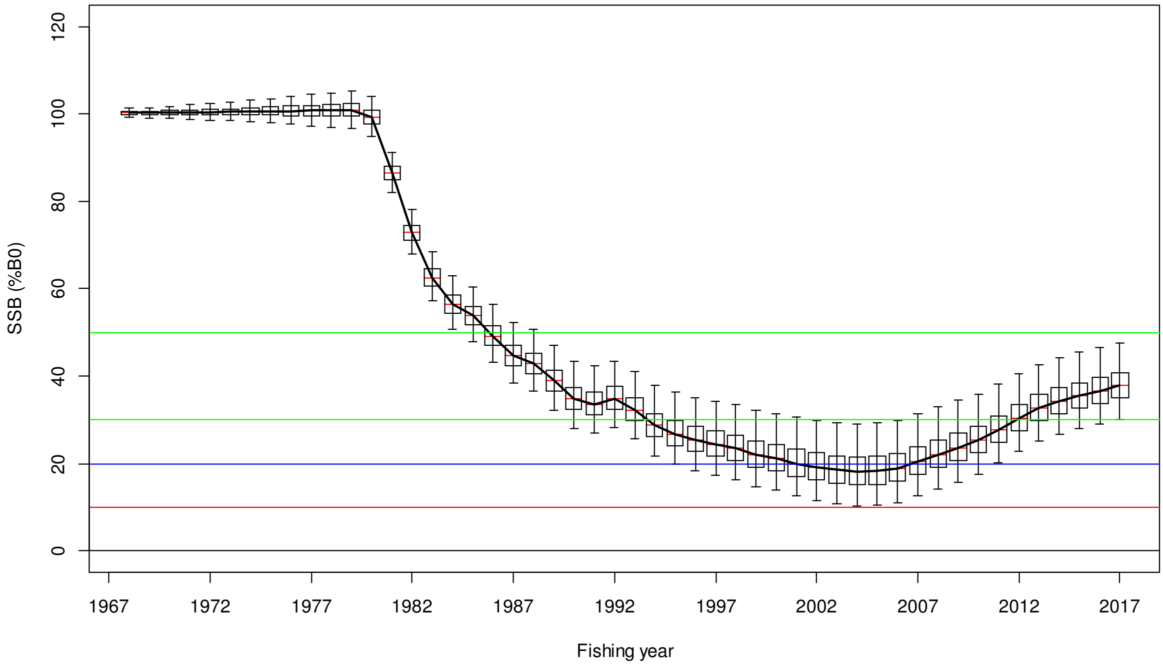


Figure 11: NWCR: MCMC stock status trajectory for the model excluding the 2016 Morgue age frequency. The boxes include the middle 50% of the distribution and the whiskers extend to 95%. Horizontal lines are plotted at 10%, 20%, 30% and 50% of B_0.

3.3 Precision of the MCMC estimates

The precision of the NIWA and ISL base model results for ESCR and NWCR were almost identical to two significant figures (Table 8).

Table 8: The precision of the MCMC estimates for the ESCR and NWCR base models.

	B_0 (000 t)	95% CI	ss_{2017} (%B_0)	95% CI
ESCR ISL	312	281–346	33	28–38
ESCR NIWA	313	281–347	33	28–37
NWCR ISL	65.5	59.2–75.3	38	30–48
NWCR NIWA	65.2	59.9–75.0	38	31–48

The median estimates are probably similar at more than two significant figures, while the limits on credibility intervals are not. The level of precision flows through to the HCR catch limits.

3.4 Application of the HCR

Given a stock assessment to the end of fishing year *x*, the catch limit from the HCR for year *x* + 1 depends on the estimated stock status in year *x* and the beginning-of-year vulnerable biomass in year *x* + 1. A single year projection of the stock assessment for year x is necessary to obtain the vulnerable biomass at the beginning of year x+1.

This simple fact was overlooked in 2014 when the HCR was applied to the 2014 stock assessments and the beginning-of-year vulnerable biomass in 2014 was used in the calculations instead of the 2015 vulnerable biomass. This error was discovered during the investigation into the differences between the 2014–15 catch limits and the 2017–18 and 2018–19 catch limits (Table 9). Also, in 2014 there was a decision to calculate the catch limit from the vulnerable biomass after half of the natural mortality had been removed (Cordue 2014a). This is the catch equation used in CASAL but in the Management Strategy Evaluation (MSE) it was assumed in the simulations that catch limits were calculated using the beginning-of-year estimated vulnerable biomass before the removals due to mortality (natural or otherwise): a second error in the 2014 catch limit calculations. It is, therefore, more appropriate to use the assumption of the simulations ("No *M*") than to use the catch equation in the estimation model.

The precision in the base model outputs (see Section 3.3) indicates that the HCR derived catch limits should be rounded to two significant figures. However, as there may be some sensitivity to what may appear too coarse a level of rounding, the catch limits are presented here rounded to the nearest 10 t.

Table 9: Catch limits (t) for ESCR and NWCR calculated for the 2017–18 and 2018–19 fishing years for ISL's and NIWA's base models (note, for NWCR the base models are identical). Also shown are the corrected calculations for the 2014–15 fishing year (see the text for an explanation of "Correct year" and "No *M*").

	2014–15			2017–18		2018–19	
	Original	Correct year	No *M*	ISL	NIWA	ISL	NIWA
ESCR	3772	3946	4036	6190	5750	6450	5970
NWCR	1043	1092	1117	1160	1160	1210	1210

The cause of the differences between the 2014–15 catch limits (as calculated in 2014) and the 2018–19 catch limits for NIWA's base models was fully investigated. The total change in the catch limits was split into individual components (Table 11). For ESCR, the two dominant effects were the increase in estimated stock status and the increase in vulnerable biomass (both caused by the passage of time). The third most important contributor was the updated assessment (driven by the new data) (Table 11). The fourth most important contributor was the change in the proportion of catches across the four fisheries (or three fisheries given that Andes and South are assumed to have the same selectivity) (Table 10). This affected the weighted average of the vulnerable biomasses from the individual fisheries.

Table 10: The percentage of total catch within each fishery for the 2013-14 and 2017-18 fishing years. These percentages were used to calculate an average vulnerable biomass for use in the HCR.

	Box and Flats (%)	Hills (%)	Andes + South (%)
2013–14 catches	72.5	1.8	25.7
2017–18 catches	50.4	4.4	45.2

The shift towards a higher proportion of catch from Andes + South increases the average vulnerable biomass as the Andes + South selectivity is to the left of the Box and Flats selectivity (e.g., median a_{50} = 36 years compared to median a_{50} = 39 years in the 2017 NIWA base model).

Table 11: A stepwise increase in catch limits for ESCR from the original 2014–15 catch limits to the 2018–19 catch limits for NIWA's base model. See the text for an explanation of "Correct year" and "No *M*" (errors made in the calculation of the 2014–15 catch limits). "Updated assessment" is NIWA's base model. "Increased vulnerable biomass" is the catch limit calculated with the same stock status as in 2014. "Increased stock status" is the catch limit with the increased estimate of stock status. The change in "catch weighting" is the final calculation using the shift in catch proportions.

	Catch limit year	Catch limit (t)	Difference (t)	Contribution to total difference (%)
Original	2014–15	3772		
Correct year	2014–15	3946	174	8
No *M*	2014–15	4036	90	4
Updated assess	2014–15	4337	301	14
Incr. vul. biomass	2018–19	4980	643	29
Incr. stock status	2018–19	5762	782	36
Catch weighting	2018–19	5974	212	10

For the NWCR, the dominant effect was the updated assessment which caused downward revision in stock status in 2014 (from 37% to 34% B_0) and consequently a decline in the calculated catch limit for 2014–15 (Table 6). This decline was more than compensated for by the subsequent increase in stock status (the next most important effect) and vulnerable biomass (the second next most important effect) (Table 12).

Table 12: A stepwise increase in catch limits for NWCR from the original 2014–15 catch limits to the 2018–19 catch limits for NIWA's base model. See the text for an explanation of "Correct year" and "No *M*" (errors made in the calculation of the 2014–15 catch limits). "Updated assessment" is NIWA's base model. "Increased vulnerable biomass" is the catch limit calculated with the same stock status as in 2014. "Increased stock status" is the catch limit with the increased estimate of stock status.

	Catch limit year	Catch limit (t)	Difference (t)	Contribution to total difference (%)
Original	2014–15	1043		
Correct year	2014–15	1092	49	29
No *M*	2014–15	1117	25	15
Updated assess	2014–15	943	-174	-102
Incr. vul. biomass	2018–19	1058	115	68
Incr. stock status	2018–19	1213	155	91

The calculations of the ESCR catch limits involve a weighted average of the three vulnerable biomasses before application of the exploitation rate (*U*) derived from estimated stock status. The inputs to the calculations of the catch limits for ISL's and NIWA's base models in both years are given in Table 13.

Table 13: ESCR stock status (% B_0), exploitation rate (U), average and fishery specific estimates of vulnerable biomass (kt) and catch limit (t) for the two base models for fishing years 2017-18 and 2017-19.

	Stock status (%B_0)	U	Box & flats (000 t)	Hills (000 t)	Andes & South (000 t)	Average vulnerable (000 t)	Catch limit (t)
ISL 2017–18	34.1	0.03836	142.7	157.6	182.8	161.5	6190
NIWA 2017–18	33.2	0.03735	137.4	149.6	172.7	153.9	5750
ISL 2018–19	35.1	0.03949	148.4	158.3	180.8	163.5	6450
NIWA 2018–19	33.9	0.03814	143.8	146.6	171.9	156.7	5970

Note that the exploitation rates for both models in both years are well below 0.045 which is the value of *M* used in the orange roughy models. The catch limits only appear large because the current catch limit was held down in order to promote faster rebuilding and is thus low in comparison.

For completeness, similar details for NWCR are given in Table 14.

Table 14: NWCR stock status (% B_0), exploitation rate (U), vulnerable biomass (kt) and catch limit (t) for the fishing years 2017-18 and 2017-19.

	Stock status (%B_0)	U	Vulnerable biomass (000 t)	Catch limit (t)
2017–18	38.0	0.04275	27.05	1160
2018–19	39.0	0.04388	27.65	1210

4. Acknowledgments

This work was funded by the DWG.
Thanks to NIWA for the use of their stock assessment package CASAL.

5. References

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6. Appendix 1: MCMC convergence diagnostics and CASAL input files

This appendix contains the main diagnostics that were used for determining if convergence of the posterior distributions were adequate for each of ISL's 2016–17 assessment models. For each model, the marginal posterior distributions of B_0 and current stock status (B_{2017}/B_0) are plotted for each of the three individual chains to check that the medians were almost identical (to 2 significant figures) and that the distributions were very similar. The Appendix also includes the two important CASAL input files for each model (population.csl and estimation.csl).

6.1 ESCR

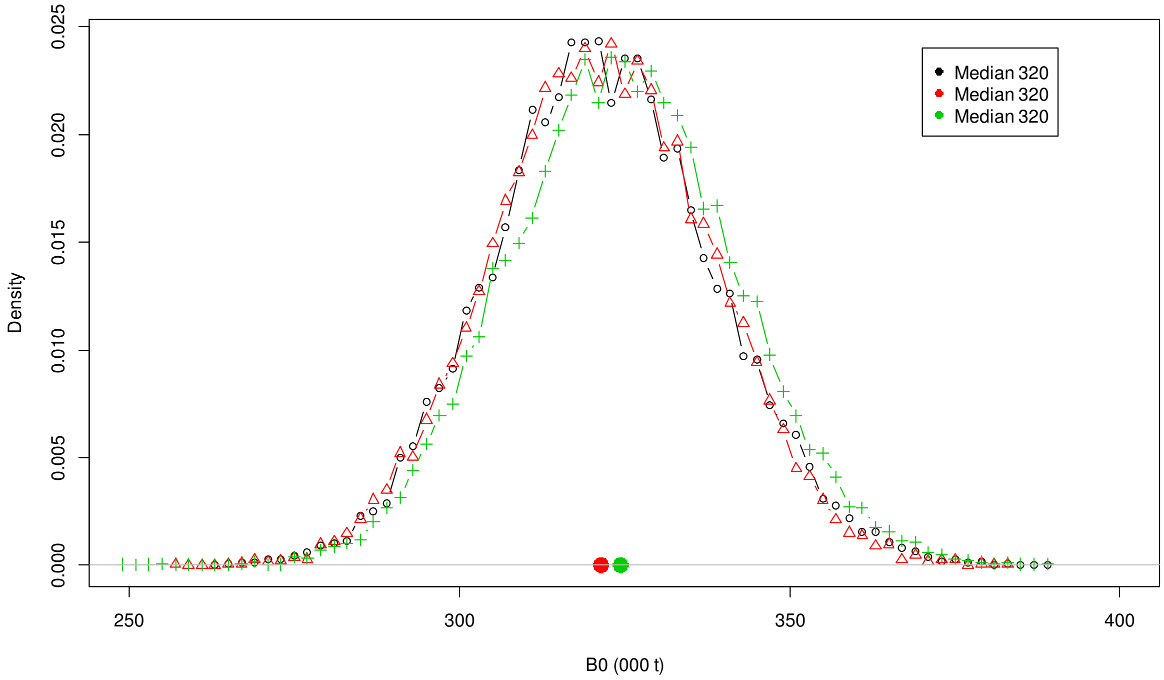

Figure A1: ESCR: Marginal posterior distributions for B_0 from the three separate chains for the model with the *q*-ratio penalty. The medians are marked by the solid dots.

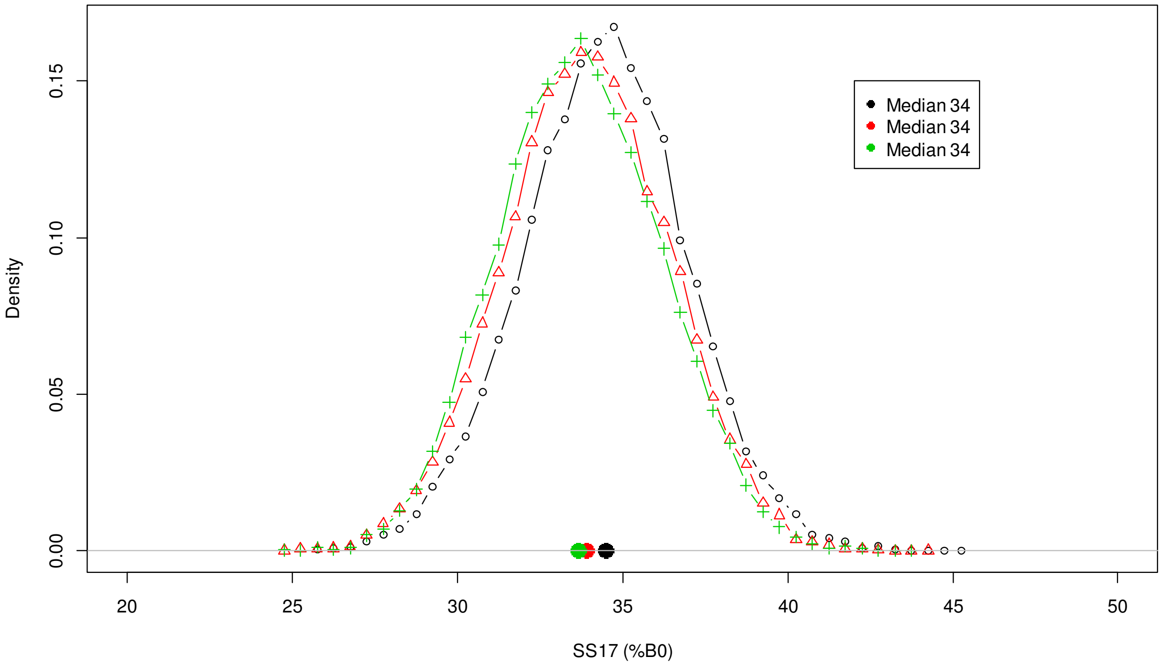

Figure A2: ESCR: Marginal posterior distributions for 2017 stock status (B_{2017}/B_0) from the three separate chains for the model with the *q*-ratio penalty. The medians are marked by the solid dots.

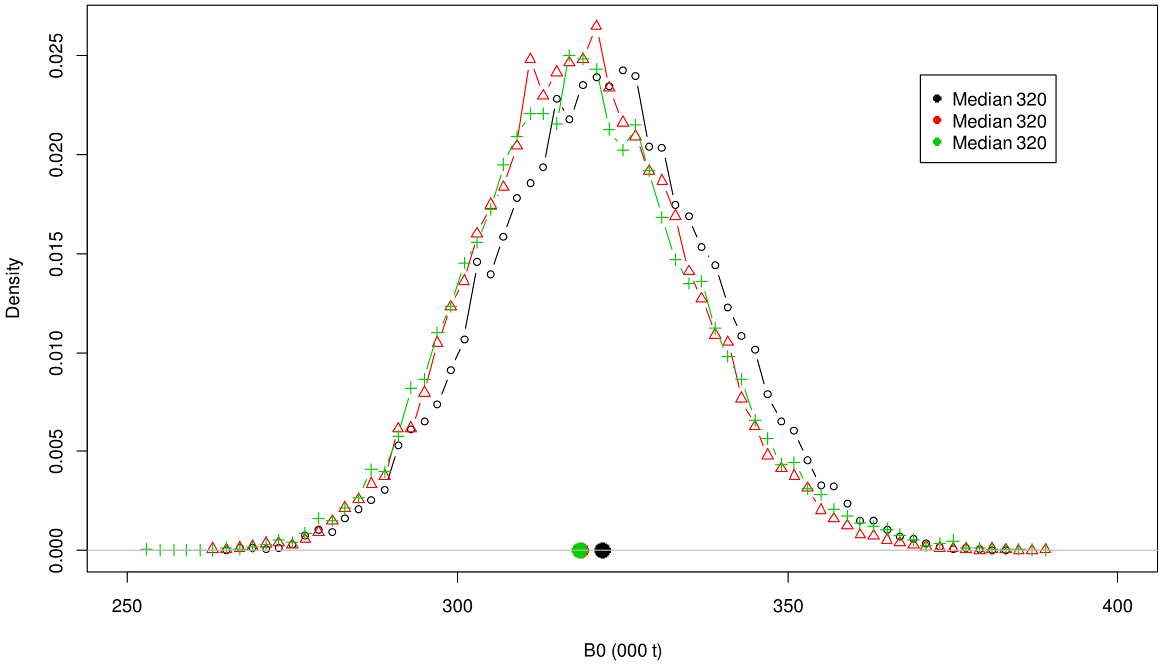

Figure A3: ESCR: Marginal posterior distributions for B_0 from the three separate chains for the model without the *q*-ratio penalty. The medians are marked by the solid dots.

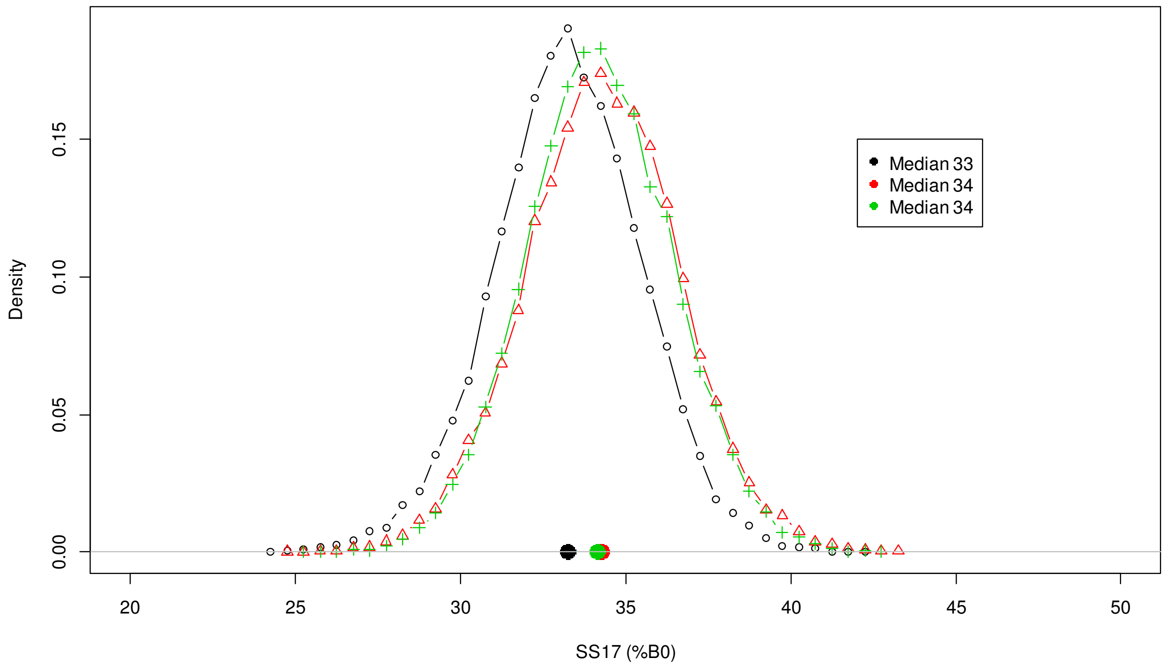

Figure A4: ESCR: Marginal posterior distributions for 2017 stock status (B_{2017}/B_0) from the three separate chains for the model without the q-ratio penalty. The medians are marked by the solid dots.

Population.csl (the same for both models)

```
@size_based False
@min_age 1
@max_age 100
@plus_group True
@sex_partition False
@mature_partition True
@n_areas 1

@initial 1911
@current 2017
@final 2017
@annual_cycle
time_steps 1
aging_time 1
recruitment_time 1
fishery_names boxflat hills andes south
fishery_times 1 1 1 1
spawning_time 1
spawning_p 1
spawning_part_mort 0.75
M_props 1
baranov False
n_maturations 1
maturation_times 1

@y_enter 1
```

```
@standardise_YCS True
@recruitment
YCS_years 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925
1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943
1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961
1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997
1998  1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
2016
YCS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
SR BH
steepness 0.75
sigma_r 1.1
first_free 1930
last_free 1990

@randomisation_method lognormal
@first_random_year 2010

@natural_mortality
all 0.045

@fishery boxflat
years 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
2014 2015 2016 2017
catches 15338 37660 20910 22560 6760 21360 25350 26720 28270 19220 23710 20320 7570 2590
190 90 570 1800 1800 2570 1280 1640 1500 3460 3720 5026 5482 5711 5857 5260 4625 3787 1966
1659 1558 1791 2451 1680 1680
selectivity boxflatsel
U_max 0.67

@fishery hills
years 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
2014 2015 2016 2017
catches 0 160 20 60 0 90 0 290 200 370 400 200 6370 3100 1280 1250 1740 810 1170 710 1120 930
880 1040 870 616 543 544 836 383 686 247 202 218 59 150 46 148 148
selectivity hillssel
U_max 0.67

@fishery andes
years 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
2014 2015 2016 2017
catches 0 0 0 0 0 0 0 0 0 0 50 240 100 8620 3820 4060 1900 1380 820 1550 1390 2270 1300 2540
2870 1528 1381 1776 1448 1307 514 577 558 529 528 875 524 1132 1132
selectivity andessel
U_max 0.67

@fishery south
years 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
2014 2015 2016 2017
```

```
catches 0 1040 4810 650 6240 6630 10270 6784 6174 8432 11224 13200 7935 2420 5940 5610 1680
1365 1470 1785 1260 1155 1785 1155 1575 1409 1757 1310 1273 1419 1231 976 484 320 307 528
412 376 376
selectivity andessel # same as andes
U_max 0.67

@selectivity_names boxflatsel hillssel andessel Bucsel Corsel Tansel Tanwidesel matsel
@selectivity boxflatsel
all logistic 37 4.56
@selectivity hillssel
all logistic 37 4.56
@selectivity andessel
all logistic 37 4.56
@selectivity Bucsel
mature constant 1
immature logistic_capped 10 3 0.1
@selectivity Corsel
mature constant 1
immature logistic_capped 10 3 0.1
@selectivity Tansel
mature constant 1
immature logistic_capped 10 3 0.1
@selectivity Tanwidesel
mature constant 1
immature logistic_capped 17 4 0.8

@selectivity matsel
mature constant 1
immature constant 0

@size_at_age_type von_Bert
@size_at_age_dist normal
@size_at_age
k 0.059
t0 -0.491
Linf 37.78
cv1 0.10
cv2 0.06
by_length True
@size_weight
a 8.0e-8
b 2.75

@maturation
rates_all logistic_producing 10 100 37 4.56

@initialization
B0 350000
```

Estimation.csl (for the model with the *q*-ratio penalty)

```
# NIWA's file with 20% process error added to plume+rekohu, plume+rekohu+crack
# And a q-ratio penalty for plume+rekohu+crack vs plume+rekohu

@estimator Bayes
@max_iters 4000
```

```
@max_evals 4000
@grad_tol 0.0001

@MCMC
start 0.2
length 15000000
keep 1000
stepsize 0.015
proposal_t True
df 2
burn_in 1000

@relative_abundance aco
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2011 2013 2016
2011 51329
2013 54363
2016 43560
cv_2011 0.22
cv_2013 0.22
cv_2016 0.22
dist lognormal
q acoq

@estimate
parameter q[acoq].q
prior lognormal
mu 0.8
cv 0.19
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2012
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2012 2014
2012 46513
2014 63781
cv_2012 0.21
cv_2014 0.27
dist lognormal
q acoq2012

@estimate
parameter q[acoq2012].q
prior uniform
lower_bound 0.1
upper_bound 1.5

@ratio_qs_penalty
```

```
label qratpen
q1 acoq
q2 acoq2012
mu 1.143
cv 0.075

@relative_abundance aco2002
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2002
2002 63950
cv 0.06
dist lognormal
q acoq2002

@estimate
parameter q[acoq2002].q
prior lognormal
mu 0.70
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2003
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2003
2003 44316
cv 0.06
dist lognormal
q acoq2003

@estimate
parameter q[acoq2003].q
prior lognormal
mu 0.65
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2004
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2004
2004 44968
cv 0.08
dist lognormal
q acoq2004
```

```
@estimate
parameter q[acoq2004].q
prior lognormal
mu 0.60
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2005
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2005
2005 43923
cv 0.04
dist lognormal
q acoq2005

@estimate
parameter q[acoq2005].q
prior lognormal
mu 0.55
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2006
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2006
2006 47450
cv 0.10
dist lognormal
q acoq2006

@estimate
parameter q[acoq2006].q
prior lognormal
mu 0.50
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2007
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2007
2007 34427
cv 0.05
dist lognormal
```

```
q acoq2007

@estimate
parameter q[acoq2007].q
prior lognormal
mu 0.45
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2008
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2008
2008 31668
cv 0.08
dist lognormal
q acoq2008

@estimate
parameter q[acoq2008].q
prior lognormal
mu 0.40
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2009
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2009
2009 28199
cv 0.05
dist lognormal
q acoq2009

@estimate
parameter q[acoq2009].q
prior lognormal
mu 0.35
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2010
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2010
2010 21205
```

```
cv 0.07
dist lognormal
q acoq2010

@estimate
parameter q[acoq2010].q
prior lognormal
mu 0.30
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance Buc
step 1
proportion_mortality 0.75
biomass True
ogive Bucsel
years 1984 1985 1986 1987
1984 130000
1985 111000
1986 77000
1987 60000
cv_1984 0.17
cv_1985 0.15
cv_1986 0.16
cv_1987 0.15
dist lognormal
q Bucq

@estimate
parameter q[Bucq].q
prior uniform
lower_bound 0.1
upper_bound 2

@relative_abundance Cor
step 1
proportion_mortality 0.75
biomass True
ogive Corsel
years 1988 1989 1990
1988 73000
1989 54000
1990 34000
cv_1988 0.25
cv_1989 0.18
cv_1990 0.19
dist lognormal
q Corq

@estimate
parameter q[Corq].q
prior uniform
lower_bound 0.1
upper_bound 2
```

```
@relative_abundance Tan
step 1
proportion_mortality 0.75
biomass True
ogive Tansel
years 1992 1994
1992 22000
1994 61000
cv_1992 0.34
cv_1994 0.67
dist lognormal
q Tanq

@estimate
parameter q[Tanq].q
prior uniform
lower_bound 0.1
upper_bound 2

@relative_abundance Tanwide
step 1
proportion_mortality 0.75
biomass True
ogive Tanwidesel
years 2004 2007
2004 16878
2007 17000
cv_2004 0.10
cv_2007 0.13
dist lognormal
q Tanwideq

@estimate
parameter q[Tanwideq].q
prior uniform
lower_bound 0.01
upper_bound 1

@proportions_at LFbuc
years 1984 1985 1986 1987
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size True
plus_group False
ogive Bucsel
class_mins 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
39 40 41 42 43 44 45 46 47
1984 0 2e-05 5e-05 0.00014 0.00021 0.00035 0.00061 0.00062 0.00136 0.00137 0.002 0.00378
0.00512 0.00461 0.00601 0.0073 0.00716 0.00795 0.0114 0.01102 0.0223 0.04037 0.06936 0.1073
0.1532 0.15673 0.1364 0.1093 0.0656 0.0375 0.01959 0.00785 0.00312 0.00014 1e-05 0 0
```

```
1985 0 0 4e-05 0 1e-05 7e-05 0.00014 0.00027 0.00039 0.00069 0.00055 0.00119 0.00188 0.00283
0.0049 0.00509 0.00765 0.00945 0.0118 0.0158 0.02144 0.04266 0.06677 0.10311 0.1459 0.1565
0.1334 0.11833 0.06624 0.04492 0.02518 0.00783 0.00375 0.00093 8e-05 0 0
1986 0.000363809 0.000201576 0.000313044 0.000724497 0.000961107 0.000762717 0.001089252
0.001902446 0.002227984 0.003025347 0.003048281 0.006573274 0.007009317 0.008361335
0.009664961 0.01068134 0.01247802 0.01166468 0.01013735 0.01380718 0.01650285 0.0369561
0.05766967 0.1023416 0.1239962 0.1479308 0.1470353 0.1112406 0.07009839 0.04860611
0.02108614 0.007855671 0.002766081 0.000415424 0.000490263 0 0
1987 0.000304629 0.00101668 0.002488507 0.003282107 0.003891475 0.002738269 0.001777553
0.001785247 0.003257106 0.003244254 0.002907047 0.005052689 0.005726629 0.005568948
0.006209599 0.006486545 0.007462302 0.007626307 0.008204232 0.008299334 0.01408508
0.02623393 0.05483458 0.07969361 0.121034 0.1483798 0.1625132 0.126157 0.08036137
0.06211313 0.02218157 0.01085796 0.002392455 0.001485995 0.000269715 0 3.17607e-05
dist multinomial
r 0.00001
N_1984 50
N_1985 50
N_1986 50
N_1987 50

@proportions_at LFcor
years 1988 1989 1990
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size True
plus_group False
ogive Corsel
class_mins 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
39 40 41 42 43 44 45 46 47
1988 5.55404e-05 0.00021537 0.000921929 0.001998269 0.002765154 0.002512129 0.001629095
0.001407058 0.001179429 0.001384099 0.001537445 0.002158094 0.002674344 0.003105022
0.004571368 0.005076823 0.006253296 0.007332135 0.01063835 0.01605556 0.02534579
0.04203481 0.07459223 0.1150154 0.1517476 0.1526584 0.1347846 0.09942918 0.06354944
0.03655482 0.01946503 0.008007625 0.002712382 0.000611234 0 0 0
1989 0 0 9.46743e-05 0.000475164 0.00128098 0.001558001 0.000982196 0.000874103
0.000634979 0.000659882 0.000802537 0.000555626 0.001381085 0.001603655 0.001934873
0.002414614 0.003675653 0.004700243 0.007055017 0.01242235 0.02061924 0.04079466
0.07401608 0.1085542 0.1380276 0.1627439 0.1465626 0.1139847 0.07534233 0.04350086
0.02223969 0.006993559 0.002610414 0.000208229 0.000535547 0.000160699 0
1990 0.000179169 0.000377355 0.000613896 0.000710887 0.002620261 0.004827357 0.004456357
0.003130915 0.002112392 0.003132623 0.00306085 0.004006348 0.004517943 0.00516196
0.007964616 0.007338077 0.009436476 0.008555876 0.01365626 0.01848624 0.0315614 0.0451531
0.07609521 0.1193685 0.1344104 0.1477283 0.1276251 0.08977252 0.06488926 0.03625016
0.01663372 0.004406653 0.001629912 0.000126773 0 0 0
dist multinomial
r 0.00001
N_1988 58
N_1989 63
N_1990 83.5

@proportions_at LFtan
years 1992 1994
step 1
```

```
proportion_mortality 0.75
sexed F
sum_to_one True
at_size True
plus_group False
ogive Tansel
class_mins 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
39 40 41 42 43 44 45 46 47
1992 2.34854e-05 0.000308678 0.000262086 0.000657547 0.000931968 0.001690054 0.003369972
0.006752543 0.006809377 0.00415511 0.003710767 0.003929743 0.003134993 0.005071809
0.004991473 0.006998184 0.01168647 0.01112179 0.02059367 0.01676207 0.02333666 0.03243743
0.04916983 0.07676098 0.119692 0.1312538 0.1303823 0.1284647 0.08351715 0.05890609
0.03192849 0.01540422 0.004831111 0.000670246 0.000208728 1.61971e-05 1.67119e-05
1994 0 1.67578e-05 0 0 3.64622e-05 0.000324472 0.000508716 0.001632322 0.002363805
0.002149121 0.001742358 0.001213862 0.00117852 0.001621137 0.00418043 0.008015245
0.008473403 0.01426134 0.01209774 0.04239483 0.05211802 0.07447671 0.08996584 0.1133403
0.1321768 0.1354024 0.1045433 0.0763996 0.06015297 0.02945513 0.01554921 0.01047846
0.00167165 0.000857003 0.001150507 0 0
dist multinomial
r 0.00001
N_1992 33
N_1994 20

@proportions_at LFtanwide
years 2004 2007
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size True
plus_group False
ogive Tanwidesel
class_mins 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
38 39 40 41 42 43 44
2004 0.000421004 0.000349767 0.000108116 0 0 0 0.00072557 0.002815056 0.003046928
0.004835874 0.003571228 0.004545656 0.01283627 0.0199908 0.02980189 0.04557678 0.05473899
0.06530936 0.0635782 0.07721669 0.06946845 0.06336989 0.07409259 0.06949758 0.0671361
0.06423314 0.05536975 0.04549367 0.03175347 0.02772396 0.02059919 0.01209341 0.006035355
0.003296178 0.000369069 0
2007 0.000131565 0 0.000406217 0.000344372 0.001935977 0.000353429 0.001273066
0.001071211 0.00228752 0.003119033 0.003255851 0.005738309 0.005860219 0.00906548
0.01789553 0.02890255 0.04617305 0.05811292 0.06543589 0.08562423 0.082746 0.08521432
0.07728044 0.07057058 0.08244385 0.08325518 0.06330442 0.04462165 0.03071825 0.01817436
0.01150342 0.005737993 0.005422786 0.000929205 0.000702742 0.000388387
dist multinomial
r 0.00001
N_2004 57
N_2007 62

@proportions_at LFboxflat
years 1990 2004
step 1
proportion_mortality 0.5
sexed F
sum_to_one True
```

```
at_size True
plus_group False
ogive boxflatsel
class_mins 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46
1990 0 0.000158909 9.95e-05 0.000210533 0.000238196 0.000495422 0.001254532 0.002154919
0.004169252 0.006091242 0.01282202 0.0226635 0.04029722 0.07024916 0.1123535 0.1468239
0.1610729 0.1426804 0.1172552 0.07605526 0.04977189 0.02011213 0.008619668 0.003246983
0.000773689 0.000250078
2004 4.39e-05 7.18e-05 0.000205981 0.000496509 0.001227437 0.002327453 0.00524418
0.01091408 0.02208171 0.03721626 0.06004503 0.08323687 0.1132216 0.1275185 0.1350955
0.1320566 0.1049201 0.07721767 0.04762157 0.02328343 0.0107514 0.003991744 0.000962657
0.000194269 1.26e-05 2.76e-06
dist multinomial
r 0.00001
N_1990 23
N_2004 25

@proportions_at LFhills
years 1995 2003
step 1
proportion_mortality 0.5
sexed F
sum_to_one True
at_size True
plus_group False
ogive hillssel
class_mins 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
48 49
1995 0 0 0 0 0.000177128 0.00058855 0.00158803 0.002357302 0.006323779 0.01374448
0.02131003 0.03786901 0.06439271 0.08601061 0.1088883 0.1443275 0.1420557 0.1316293
0.09576356 0.06591011 0.03948215 0.02037994 0.009371813 0.00533847 0.001398399
0.000931798 0.000136528 0 0 2.49e-05
2003 0 0 0 9.86e-06 4.13e-05 9.86e-06 0.00083073 0.003258231 0.004368276 0.01368635
0.02907073 0.04286291 0.07000064 0.1160458 0.1456387 0.1474501 0.1219139 0.1185394
0.0766867 0.04986246 0.03311733 0.01427563 0.00729351 0.004020597 0.000160994 0.000428014
0 0.000428014 0 0
dist multinomial
r 0.00001
N_1995 24
N_2003 8

@proportions_at LFandes
years 1993 1998 2003
step 1
proportion_mortality 0.5
sexed F
sum_to_one True
at_size True
plus_group False
ogive andessel
class_mins 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
1993 0 0 0 5.04e-05 5.58e-05 0.000360539 0.00101749 0.005278528 0.009547897 0.01854913
0.03644313 0.05575062 0.07536409 0.1091069 0.1356637 0.1534083 0.1440175 0.1090498
0.07130127 0.04002192 0.02231478 0.008787828 0.002937921 0.000777596 0.00013616 1.42e-05 0
4.45e-05
```

```
1998 0 0 0 0.000277354 0.001005618 0.001453453 0.004451908 0.008418377 0.01461991
0.0254765 0.04570758 0.06874018 0.1018215 0.1143803 0.1274731 0.1433809 0.1262028
0.1047362 0.0577463  0.03365968 0.009745741 0.008221494 0.001923334 0.000440636
0.000117207 0 0 0
2003 7.56e-05 0 0.00029812 0.000206231 0.000557953 0.001526929 0.003263305 0.008883888
0.0173093 0.02899803 0.04480842 0.06650869 0.1006612 0.1357634 0.1542982 0.1395754
0.1213635 0.08102189 0.05308041 0.02442391 0.01089841 0.004685455 0.001337897 0.000170828
0.000232171 5.09e-05 0 0
dist multinomial
r 0.00001
N_1993 38
N_1998 8
N_2003 29

@proportions_at AFplumes12
years 2012
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size False
plus_group True
ogive matsel
min_class 20
max_class 100
ageing_error True
2012 0 0 0 0 0.004934227 0.005049307 0.01426801 0.01074836 0.01315794 0.003289484
0.03476975 0.03148026 0.02754103 0.01908716 0.03511499 0.0378698 0.02490129 0.04222863
0.04069897 0.03293557 0.0346954 0.01954748 0.04502417 0.04280403 0.02830586 0.02536161
0.03018076 0.02976117 0.0226068 0.03205566 0.02471186 0.01361826 0.02184197 0.02712144
0.01648815 0.01472833 0.01285343 0.01009861 0.01197352 0.008799111 0.003519644 0.015263
0.002524653 0.01702282 0.01009861 0.008799111 0.0008799111 0.008684031 0.002524653
0.002639733 0.006159378 0.006044298 0.006044298 0.002639733 0.001759822 0.004399556
0.006044298 0.004399556 0.003519644 0.001759822 0 0.001759822 0.0008799111 0.002524653 0
0.003519644 0.002639733 0 0.001644742 0.0008799111 0.0008799111 0.0008799111 0.0008799111
0 0.001759822 0.001759822 0 0.002639733 0 0 0.01197352
dist multinomial
r 0.00001
N_2012 50

@proportions_at AFplumes1316
years 2013 2016
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size False
plus_group True
ogive matsel
min_class 20
max_class 100
ageing_error True
2013 0 0.0007814836 0 0 0.006726165 0.007721561 0.005457647 0.005730768 0.01529701
0.01899051 0.02372589 0.02183696 0.03957551 0.0432098 0.04079977 0.03448648 0.05753911
0.05046981 0.05509916 0.04208103 0.05553336 0.03145382 0.03317786 0.04592065 0.02275182
```

```
0.02986571 0.02657233 0.01854391 0.01539028 0.01794228 0.01548356 0.01304583 0.02524875
0.01134949 0.02380642 0.01000043 0.009284529 0.007677311 0.002632531 0.01363473
0.007956802 0.007742889 0.01036683 0.005898211 0.00355376 0.008738286 0.006887238
0.003488182 0.003274269 0.002920611 0.002558364 0.003488182 0.005398438 0.0007814836
0.002780866 0.001209309 0.004335244 0 0.0006417383 0 0.001637135 0 0.001423222 0.001562967
0 0 0 0.0008556511 0.004335244 0 0.001562967 0.001851048 0 0.0008556511 0 0.001069564
0.0007814836 0 0 0 0.003200102
2016 0 0 0.007056693 0.00347577 0.007161846 0.004409342 0.00419527 0.01585127 0.005152948
0.01261368 0.01737885 0.02373639 0.03635007 0.03963963 0.02694114 0.05080678 0.0372633
0.02846495 0.0159477 0.04707249 0.03701262 0.04157157 0.03643111 0.02442305 0.04627195
0.02556316 0.02332362 0.0212665 0.02657282 0.03195233 0.02040149 0.02184425 0.01575396
0.02127524 0.004538602 0.01575773 0.01140533 0.01418194 0.01363991 0.003487382
0.009239299 0.01655828 0.005448069 0.005848342 0.006324699 0.01257331 0.006749079
0.005896555 0.005035301 0.007953665 0.0009576786 0.003463275 0.00621578 0 0.001252799
0.002352231 0.004704462 0.009869023 0.004987088 0.00360503 0.0009576786 0 0.004914768 0
0.003119944 0.001228692 0.004324529 0.00390015 0.004938876 0 0.0006384524 0.001276905
0.002186371 0.001252799 0.001276905 0 0.0009576786 0.001596132 0 0 0.008203457
dist multinomial
r 0.00001
N_2013 60
N_2016 60

@ageing_error
type normal
c 0.1

@q_method free
@q acoq
q 1

@q acoq2012
q 0.5

@q acoq2002
q 0.6

@q acoq2003
q 1

@q acoq2004
q 0.8

@q acoq2005
q 1

@q acoq2006
q 0.6

@q acoq2007
q 0.5

@q acoq2008
q 0.4

@q acoq2009
```

```
q 0.6

@q acoq2010
q 0.6

@q Bucq
q 1

@q Corq
q 0.8

@q Tanq
q 1

@q Tanwideq
q 0.1

@estimate
parameter selectivity[Bucsel].immature
same selectivity[Corsel].immature selectivity[Tansel].immature
lower_bound 1 1 0.001
upper_bound 30 50 0.2
prior uniform

@estimate
parameter selectivity[Tanwidesel].immature
lower_bound 1 1 0.1
upper_bound 30 30 1.0
prior uniform

@estimate
parameter selectivity[boxflatsel].all
lower_bound 10 3
upper_bound 50 50
prior uniform

@estimate
parameter selectivity[hillssel].all
lower_bound 10 3
upper_bound 50 50
prior uniform

@estimate
parameter selectivity[andessel].all
lower_bound 10 3
upper_bound 50 50
prior uniform

@estimate
parameter maturation[1].rates_all
lower_bound 10 2.5
upper_bound 100 100
prior uniform

@estimate
```

```
parameter initialization.B0
lower_bound 1e5
upper_bound 6e5
prior uniform-log

@estimate
parameter size_at_age.cv1
lower_bound 0.03
upper_bound 0.3
prior uniform

@estimate
parameter size_at_age.cv2
lower_bound 0.03
upper_bound 0.3
prior uniform

@estimate
parameter recruitment.YCS
lower_bound     1       1       1       1       1       1       1       1       1       1       1
        1       1       1       1       1       1       1       1       1       0.01    0.01    0.01
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    1       1
        1       1       1       1       1       1       1       1       1       1       1       1
        1       1       1       1       1       1       1       1       1       1       1       1
upper_bound     1       1       1       1       1       1       1       1       1       1       1
        1       1       1       1       1       1       1       1       1       10      10      10
        10      10      10      10      10      10      10      10      10      10      10      10
        10      10      10      10      10      10      10      10      10      10      10      10
        10      10      10      10      10      10      10      10      10      10      10      10
        10      10      10      10      10      10      10      10      10      10      10      10
        10      10      10      10      10      10      10      10      10      10      1       1
        1       1       1       1       1       1       1       1       1       1       1       1
        1       1       1       1       1       1       1       1       1       1       1       1
prior lognormal
mu 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
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26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
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26489122130 26489122130 26489122130
```

```
cv 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
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2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958

@catch_limit_penalty
label boxflatCP
fishery boxflat
multiplier 200
log_scale True

@catch_limit_penalty
label hillsCP
fishery hills
multiplier 200
log_scale True

@catch_limit_penalty
label andesCP
fishery andes
multiplier 200
log_scale True

@catch_limit_penalty
label southCP
fishery south
multiplier 200
log_scale True
```

Estimation.csl (for the model without the *q*-ratio penalty)

```
# NIWA's file with 20% process error added to plume+rekohu, plume+rekohu+crack

@estimator Bayes
@max_iters 4000
@max_evals 4000
@grad_tol 0.0001

@MCMC
start 0.2
length 15000000
keep 1000
stepsize 0.015
proposal_t True
df 2
burn_in 1000

@relative_abundance aco
step 1
```

```
proportion_mortality 0.75
biomass True
ogive matsel
years 2011 2013 2016
2011 51329
2013 54363
2016 43560
cv_2011 0.22
cv_2013 0.22
cv_2016 0.22
dist lognormal
q acoq

@estimate
parameter q[acoq].q
prior lognormal
mu 0.8
cv 0.19
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2012
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2012 2014
2012 46513
2014 63781
cv_2012 0.21
cv_2014 0.27
dist lognormal
q acoq2012

@estimate
parameter q[acoq2012].q
prior lognormal
mu 0.70
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2002
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2002
2002 63950
cv 0.06
dist lognormal
q acoq2002

@estimate
parameter q[acoq2002].q
```

```
prior lognormal
mu 0.70
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2003
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2003
2003 44316
cv 0.06
dist lognormal
q acoq2003

@estimate
parameter q[acoq2003].q
prior lognormal
mu 0.65
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2004
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2004
2004 44968
cv 0.08
dist lognormal
q acoq2004

@estimate
parameter q[acoq2004].q
prior lognormal
mu 0.60
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2005
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2005
2005 43923
cv 0.04
dist lognormal
q acoq2005
```

```
@estimate
parameter q[acoq2005].q
prior lognormal
mu 0.55
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2006
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2006
2006 47450
cv 0.10
dist lognormal
q acoq2006

@estimate
parameter q[acoq2006].q
prior lognormal
mu 0.50
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2007
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2007
2007 34427
cv 0.05
dist lognormal
q acoq2007

@estimate
parameter q[acoq2007].q
prior lognormal
mu 0.45
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2008
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2008
2008 31668
cv 0.08
dist lognormal
```

```
q acoq2008

@estimate
parameter q[acoq2008].q
prior lognormal
mu 0.40
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2009
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2009
2009 28199
cv 0.05
dist lognormal
q acoq2009

@estimate
parameter q[acoq2009].q
prior lognormal
mu 0.35
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco2010
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2010
2010 21205
cv 0.07
dist lognormal
q acoq2010

@estimate
parameter q[acoq2010].q
prior lognormal
mu 0.30
cv 0.30
lower_bound 0.1
upper_bound 1.5

@relative_abundance Buc
step 1
proportion_mortality 0.75
biomass True
ogive Bucsel
years 1984 1985 1986 1987
1984 130000
```

```
1985 111000
1986 77000
1987 60000
cv_1984 0.17
cv_1985 0.15
cv_1986 0.16
cv_1987 0.15
dist lognormal
q Bucq

@estimate
parameter q[Bucq].q
prior uniform
lower_bound 0.1
upper_bound 2

@relative_abundance Cor
step 1
proportion_mortality 0.75
biomass True
ogive Corsel
years 1988 1989 1990
1988 73000
1989 54000
1990 34000
cv_1988 0.25
cv_1989 0.18
cv_1990 0.19
dist lognormal
q Corq

@estimate
parameter q[Corq].q
prior uniform
lower_bound 0.1
upper_bound 2

@relative_abundance Tan
step 1
proportion_mortality 0.75
biomass True
ogive Tansel
years 1992 1994
1992 22000
1994 61000
cv_1992 0.34
cv_1994 0.67
dist lognormal
q Tanq

@estimate
parameter q[Tanq].q
prior uniform
lower_bound 0.1
upper_bound 2
```

```
@relative_abundance Tanwide
step 1
proportion_mortality 0.75
biomass True
ogive Tanwidesel
years 2004 2007
2004 16878
2007 17000
cv_2004 0.10
cv_2007 0.13
dist lognormal
q Tanwideq

@estimate
parameter q[Tanwideq].q
prior uniform
lower_bound 0.01
upper_bound 1

@proportions_at LFbuc
years 1984 1985 1986 1987
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size True
plus_group False
ogive Bucsel
class_mins 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
39 40 41 42 43 44 45 46 47
1984 0 2e-05 5e-05 0.00014 0.00021 0.00035 0.00061 0.00062 0.00136 0.00137 0.002 0.00378
0.00512 0.00461 0.00601 0.0073 0.00716 0.00795 0.0114 0.01102 0.0223 0.04037 0.06936 0.1073
0.1532 0.15673 0.1364 0.1093 0.0656 0.0375 0.01959 0.00785 0.00312 0.00014 1e-05 0 0
1985 0 0 4e-05 0 1e-05 7e-05 0.00014 0.00027 0.00039 0.00069 0.00055 0.00119 0.00188 0.00283
0.0049 0.00509 0.00765 0.00945 0.0118 0.0158 0.02144 0.04266 0.06677 0.10311 0.1459 0.1565
0.1334 0.11833 0.06624 0.04492 0.02518 0.00783 0.00375 0.00093 8e-05 0 0
1986 0.000363809 0.000201576 0.000313044 0.000724497 0.000961107 0.000762717 0.001089252
0.001902446 0.002227984 0.003025347 0.003048281 0.006573274 0.007009317 0.008361335
0.009664961 0.01068134 0.01247802 0.01166468 0.01013735 0.01380718 0.01650285 0.0369561
0.05766967 0.1023416 0.1239962 0.1479308 0.1470353 0.1112406 0.07009839 0.04860611
0.02108614 0.007855671 0.002766081 0.000415424 0.000490263 0 0
1987 0.000304629 0.00101668 0.002488507 0.003282107 0.003891475 0.002738269 0.001777553
0.001785247 0.003257106 0.003244254 0.002907047 0.005052689 0.005726629 0.005568948
0.006209599 0.006486545 0.007462302 0.007626307 0.008204232 0.008299334 0.01408508
0.02623393 0.05483458 0.07969361 0.121034 0.1483798 0.1625132 0.126157 0.08036137
0.06211313 0.02218157 0.01085796 0.002392455 0.001485995 0.000269715 0 3.17607e-05
dist multinomial
r 0.00001
N_1984 50
N_1985 50
N_1986 50
N_1987 50

@proportions_at LFcor
```

```
years 1988 1989 1990
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size True
plus_group False
ogive Corsel
class_mins 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
39 40 41 42 43 44 45 46 47
1988 5.55404e-05 0.00021537 0.000921929 0.001998269 0.002765154 0.002512129 0.001629095
0.001407058 0.001179429 0.001384099 0.001537445 0.002158094 0.002674344 0.003105022
0.004571368 0.005076823 0.006253296 0.007332135 0.01063835 0.01605556 0.02534579
0.04203481 0.07459223 0.1150154 0.1517476 0.1526584 0.1347846 0.09942918 0.06354944
0.03655482 0.01946503 0.008007625 0.002712382 0.000611234 0 0 0
1989 0 0 9.46743e-05 0.000475164 0.00128098 0.001558001 0.000982196 0.000874103
0.000634979 0.000659882 0.000802537 0.000555626 0.001381085 0.001603655 0.001934873
0.002414614 0.003675653 0.004700243 0.007055017 0.01242235 0.02061924 0.04079466
0.07401608 0.1085542 0.1380276 0.1627439 0.1465626 0.1139847 0.07534233 0.04350086
0.02223969 0.006993559 0.002610414 0.000208229 0.000535547 0.000160699 0
1990 0.000179169 0.000377355 0.000613896 0.000710887 0.002620261 0.004827357 0.004456357
0.003130915 0.002112392 0.003132623 0.00306085 0.004006348 0.004517943 0.00516196
0.007964616 0.007338077 0.009436476 0.008555876 0.01365626 0.01848624 0.0315614 0.0451531
0.07609521 0.1193685 0.1344104 0.1477283 0.1276251 0.08977252 0.06488926 0.03625016
0.01663372 0.004406653 0.001629912 0.000126773 0 0 0
dist multinomial
r 0.00001
N_1988 58
N_1989 63
N_1990 83.5

@proportions_at LFtan
years 1992 1994
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size True
plus_group False
ogive Tansel
class_mins 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
39 40 41 42 43 44 45 46 47
1992 2.34854e-05 0.000308678 0.000262086 0.000657547 0.000931968 0.001690054 0.003369972
0.006752543 0.006809377 0.00415511 0.003710767 0.003929743 0.003134993 0.005071809
0.004991473 0.006998184 0.01168647 0.01112179 0.02059367 0.01676207 0.02333666 0.03243743
0.04916983 0.07676098 0.119692 0.1312538 0.1303823 0.1284647 0.08351715 0.05890609
0.03192849 0.01540422 0.004831111 0.000670246 0.000208728 1.61971e-05 1.67119e-05
1994 0 1.67578e-05 0 0 3.64622e-05 0.000324472 0.000508716 0.001632322 0.002363805
0.002149121 0.001742358 0.001213862 0.00117852 0.001621137 0.00418043 0.008015245
0.008473403 0.01426134 0.01209774 0.04239483 0.05211802 0.07447671 0.08996584 0.1133403
0.1321768 0.1354024 0.1045433 0.0763996 0.06015297 0.02945513 0.01554921 0.01047846
0.00167165 0.000857003 0.001150507 0 0
dist multinomial
r 0.00001
N_1992 33
```

```
N_1994 20

@proportions_at LFtanwide
years 2004 2007
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size True
plus_group False
ogive Tanwidesel
class_mins 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
38 39 40 41 42 43 44
2004 0.000421004 0.000349767 0.000108116 0 0 0 0.00072557 0.002815056 0.003046928
0.004835874 0.003571228 0.004545656 0.01283627 0.0199908 0.02980189 0.04557678 0.05473899
0.06530936 0.0635782 0.07721669 0.06946845 0.06336989 0.07409259 0.06949758 0.0671361
0.06423314 0.05536975 0.04549367 0.03175347 0.02772396 0.02059919 0.01209341 0.006035355
0.003296178 0.000369069 0
2007 0.000131565 0 0.000406217 0.000344372 0.001935977 0.000353429 0.001273066
0.001071211 0.00228752 0.003119033 0.003255851 0.005738309 0.005860219 0.00906548
0.01789553 0.02890255 0.04617305 0.05811292 0.06543589 0.08562423 0.082746 0.08521432
0.07728044 0.07057058 0.08244385 0.08325518 0.06330442 0.04462165 0.03071825 0.01817436
0.01150342 0.005737993 0.005422786 0.000929205 0.000702742 0.000388387
dist multinomial
r 0.00001
N_2004 57
N_2007 62

@proportions_at LFboxflat
years 1990 2004
step 1
proportion_mortality 0.5
sexed F
sum_to_one True
at_size True
plus_group False
ogive boxflatsel
class_mins 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46
1990 0 0.000158909 9.95e-05 0.000210533 0.000238196 0.000495422 0.001254532 0.002154919
0.004169252 0.006091242 0.01282202 0.0226635 0.04029722 0.07024916 0.1123535 0.1468239
0.1610729 0.1426804 0.1172552 0.07605526 0.04977189 0.02011213 0.008619668 0.003246983
0.000773689 0.000250078
2004 4.39e-05 7.18e-05 0.000205981 0.000496509 0.001227437 0.002327453 0.00524418
0.01091408 0.02208171 0.03721626 0.06004503 0.08323687 0.1132216 0.1275185 0.1350955
0.1320566 0.1049201 0.07721767 0.04762157 0.02328343 0.0107514 0.003991744 0.000962657
0.000194269 1.26e-05 2.76e-06
dist multinomial
r 0.00001
N_1990 23
N_2004 25

@proportions_at LFhills
years 1995 2003
step 1
proportion_mortality 0.5
```

```
sexed F
sum_to_one True
at_size True
plus_group False
ogive hillssel
class_mins 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
48 49
1995 0 0 0 0 0.000177128 0.00058855 0.00158803 0.002357302 0.006323779 0.01374448
0.02131003 0.03786901 0.06439271 0.08601061 0.1088883 0.1443275 0.1420557 0.1316293
0.09576356 0.06591011 0.03948215 0.02037994 0.009371813 0.00533847 0.001398399
0.000931798 0.000136528 0 0 2.49e-05
2003 0 0 0 9.86e-06 4.13e-05 9.86e-06 0.00083073 0.003258231 0.004368276 0.01368635
0.02907073 0.04286291 0.07000064 0.1160458 0.1456387 0.1474501 0.1219139 0.1185394
0.0766867 0.04986246 0.03311733 0.01427563 0.00729351 0.004020597 0.000160994 0.000428014
0 0.000428014 0 0
dist multinomial
r 0.00001
N_1995 24
N_2003 8

@proportions_at LFandes
years 1993 1998 2003
step 1
proportion_mortality 0.5
sexed F
sum_to_one True
at_size True
plus_group False
ogive andessel
class_mins 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
1993 0 0 0 5.04e-05 5.58e-05 0.000360539 0.00101749 0.005278528 0.009547897 0.01854913
0.03644313 0.05575062 0.07536409 0.1091069 0.1356637 0.1534083 0.1440175 0.1090498
0.07130127 0.04002192 0.02231478 0.008787828 0.002937921 0.000777596 0.00013616 1.42e-05 0
4.45e-05
1998 0 0 0 0.000277354 0.001005618 0.001453453 0.004451908 0.008418377 0.01461991
0.0254765 0.04570758 0.06874018 0.1018215 0.1143803 0.1274731 0.1433809 0.1262028
0.1047362 0.0577463  0.03365968 0.009745741 0.008221494 0.001923334 0.000440636
0.000117207 0 0 0
2003 7.56e-05 0 0.00029812 0.000206231 0.000557953 0.001526929 0.003263305 0.008883888
0.0173093 0.02899803 0.04480842 0.06650869 0.1006612 0.1357634 0.1542982 0.1395754
0.1213635 0.08102189 0.05308041 0.02442391 0.01089841 0.004685455 0.001337897 0.000170828
0.000232171 5.09e-05 0 0
dist multinomial
r 0.00001
N_1993 38
N_1998 8
N_2003 29

@proportions_at AFplumes12
years 2012
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size False
```

```
plus_group True
ogive matsel
min_class 20
max_class 100
ageing_error True
2012 0 0 0 0 0.004934227 0.005049307 0.01426801 0.01074836 0.01315794 0.003289484
0.03476975 0.03148026 0.02754103 0.01908716 0.03511499 0.0378698 0.02490129 0.04222863
0.04069897 0.03293557 0.0346954 0.01954748 0.04502417 0.04280403 0.02830586 0.02536161
0.03018076 0.02976117 0.0226068 0.03205566 0.02471186 0.01361826 0.02184197 0.02712144
0.01648815 0.01472833 0.01285343 0.01009861 0.01197352 0.008799111 0.003519644 0.015263
0.002524653 0.01702282 0.01009861 0.008799111 0.0008799111 0.008684031 0.002524653
0.002639733 0.006159378 0.006044298 0.006044298 0.002639733 0.001759822 0.004399556
0.006044298 0.004399556 0.003519644 0.001759822 0 0.001759822 0.0008799111 0.002524653 0
0.003519644 0.002639733 0 0.001644742 0.0008799111 0.0008799111 0.0008799111 0.0008799111
0 0.001759822 0.001759822 0 0.002639733 0 0 0.01197352
dist multinomial
r 0.00001
N_2012 50

@proportions_at AFplumes1316
years 2013 2016
step 1
proportion_mortality 0.75
sexed F
sum_to_one True
at_size False
plus_group True
ogive matsel
min_class 20
max_class 100
ageing_error True
2013 0 0.0007814836 0 0 0.006726165 0.007721561 0.005457647 0.005730768 0.01529701
0.01899051 0.02372589 0.02183696 0.03957551 0.0432098 0.04079977 0.03448648 0.05753911
0.05046981 0.05509916 0.04208103 0.05553336 0.03145382 0.03317786 0.04592065 0.02275182
0.02986571 0.02657233 0.01854391 0.01539028 0.01794228 0.01548356 0.01304583 0.02524875
0.01134949 0.02380642 0.01000043 0.009284529 0.007677311 0.002632531 0.01363473
0.007956802 0.007742889 0.01036683 0.005898211 0.00355376 0.008738286 0.006887238
0.003488182 0.003274269 0.002920611 0.002558364 0.003488182 0.005398438 0.0007814836
0.002780866 0.001209309 0.004335244 0 0.0006417383 0 0.001637135 0 0.001423222 0.001562967
0 0 0 0.0008556511 0.004335244 0 0.001562967 0.001851048 0 0.0008556511 0 0.001069564
0.0007814836 0 0 0 0.003200102
2016 0 0 0.007056693 0.00347577 0.007161846 0.004409342 0.00419527 0.01585127 0.005152948
0.01261368 0.01737885 0.02373639 0.03635007 0.03963963 0.02694114 0.05080678 0.0372633
0.02846495 0.0159477 0.04707249 0.03701262 0.04157157 0.03643111 0.02442305 0.04627195
0.02556316 0.02332362 0.0212665 0.02657282 0.03195233 0.02040149 0.02184425 0.01575396
0.02127524 0.004538602 0.01575773 0.01140533 0.01418194 0.01363991 0.003487382
0.009239299 0.01655828 0.005448069 0.005848342 0.006324699 0.01257331 0.006749079
0.005896555 0.005035301 0.007953665 0.0009576786 0.003463275 0.00621578 0 0.001252799
0.002352231 0.004704462 0.009869023 0.004987088 0.00360503 0.0009576786 0 0.004914768 0
0.003119944 0.001228692 0.004324529 0.00390015 0.004938876 0 0.0006384524 0.001276905
0.002186371 0.001252799 0.001276905 0 0.0009576786 0.001596132 0 0 0.008203457
dist multinomial
r 0.00001
N_2013 60
N_2016 60
```

```
@ageing_error
type normal
c 0.1

@q_method free
@q acoq
q 1

@q acoq2012
q 0.5

@q acoq2002
q 0.6

@q acoq2003
q 1

@q acoq2004
q 0.8

@q acoq2005
q 1

@q acoq2006
q 0.6

@q acoq2007
q 0.5

@q acoq2008
q 0.4

@q acoq2009
q 0.6

@q acoq2010
q 0.6

@q Bucq
q 1

@q Corq
q 0.8

@q Tanq
q 1

@q Tanwideq
q 0.1

@estimate
parameter selectivity[Bucsel].immature
same selectivity[Corsel].immature selectivity[Tansel].immature
lower_bound 1 1 0.001
```

```
upper_bound 30 50 0.2
prior uniform

@estimate
parameter selectivity[Tanwidesel].immature
lower_bound 1 1 0.1
upper_bound 30 30 1.0
prior uniform

@estimate
parameter selectivity[boxflatsel].all
lower_bound 10 3
upper_bound 50 50
prior uniform

@estimate
parameter selectivity[hillssel].all
lower_bound 10 3
upper_bound 50 50
prior uniform

@estimate
parameter selectivity[andessel].all
lower_bound 10 3
upper_bound 50 50
prior uniform

@estimate
parameter maturation[1].rates_all
lower_bound 10 2.5
upper_bound 100 100
prior uniform

@estimate
parameter initialization.B0
lower_bound 1e5
upper_bound 6e5
prior uniform-log

@estimate
parameter size_at_age.cv1
lower_bound 0.03
upper_bound 0.3
prior uniform

@estimate
parameter size_at_age.cv2
lower_bound 0.03
upper_bound 0.3
prior uniform

@estimate
parameter recruitment.YCS
lower_bound   1      1      1      1      1      1      1      1      1      1      1
       1      1      1      1      1      1      1      1      1      0.01   0.01   0.01
```

```
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
        0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    1       1
        1       1       1       1       1       1       1       1       1       1       1       1
        1       1       1       1       1       1       1       1       1       1       1       1
upper_bound     1       1       1       1       1       1       1       1       1       1       1
        1       1       1       1       1       1       1       1       1       10      10      10
        10      10      10      10      10      10      10      10      10      10      10      10
        10      10      10      10      10      10      10      10      10      10      10      10
        10      10      10      10      10      10      10      10      10      10      10      10
        10      10      10      10      10      10      10      10      10      10      10      10
        10      10      10      10      10      10      10      10      10      10      1       1
        1       1       1       1       1       1       1       1       1       1       1       1
        1       1       1       1       1       1       1       1       1       1       1       1
prior lognormal
mu 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
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26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130
cv 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958

@catch_limit_penalty
label boxflatCP
fishery boxflat
multiplier 200
log_scale True

@catch_limit_penalty
label hillsCP
fishery hills
multiplier 200
```

```
log_scale True

@catch_limit_penalty
label andesCP
fishery andes
multiplier 200
log_scale True

@catch_limit_penalty
label southCP
fishery south
multiplier 200
log_scale True
```

6.2 NWCR

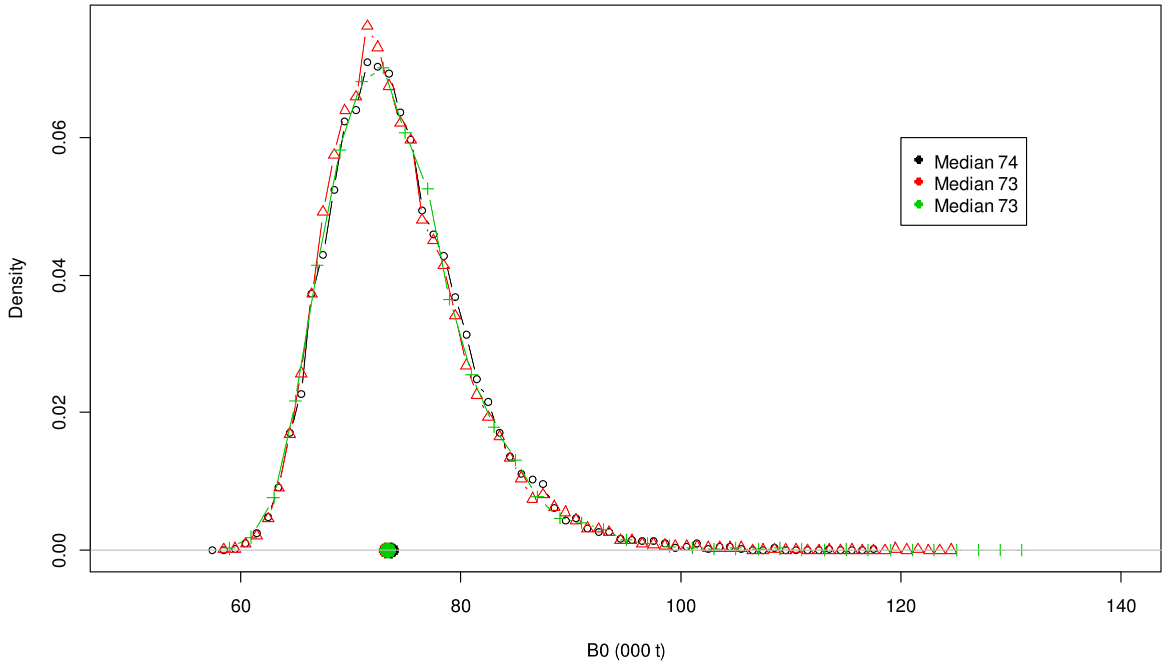

Figure A5: NWCR: Marginal posterior distributions for *B_0* from the three separate chains for the model using the Morgue age frequency. The medians are marked by the solid dots.

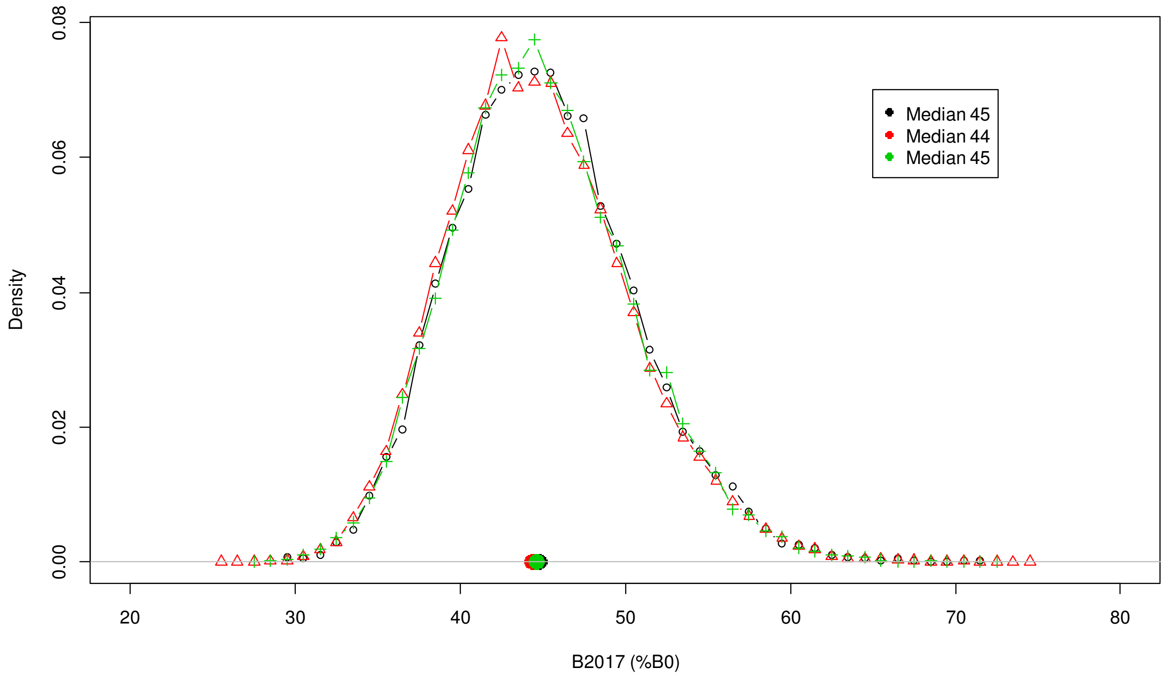

Figure A6: NWCR: Marginal posterior distributions for 2017 stock status (B_{2017}/B_0) from the three separate chains for the model using the Morgue age frequency. The medians are marked by the solid dots.

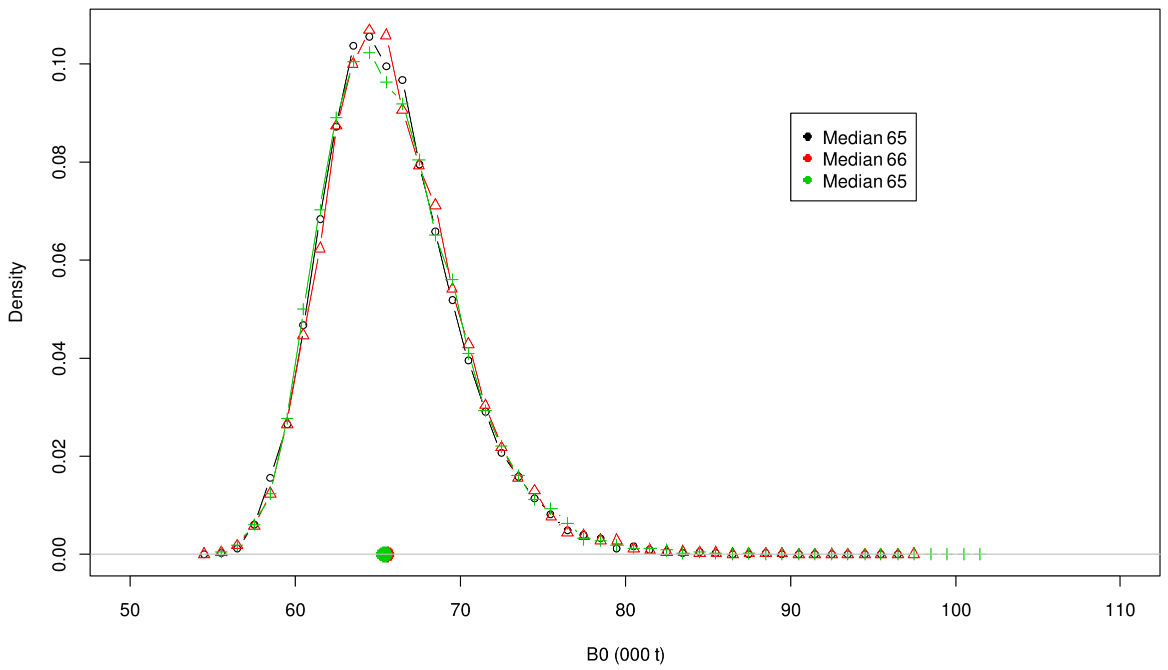

Figure A7: NWCR: Marginal posterior distributions for B_0 from the three separate chains for the model excluding the Morgue age frequency. The medians are marked by the solid dots.

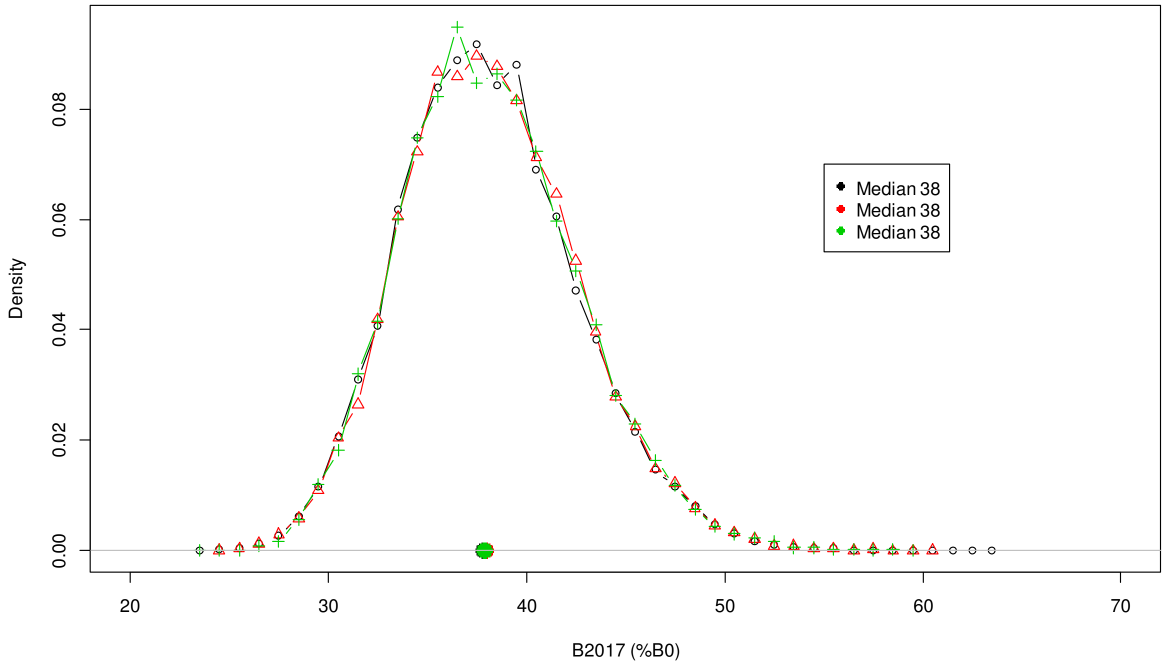

Figure A8: NWCR: Marginal posterior distributions for 2017 stock status (*B_{2017}/B_0*) from the three separate chains for the model excluding the Morgue age frequency. The medians are marked by the solid dots.

The files below are for the model using the Morgue age frequency. The files for the model without the Morgue age frequency are easily derived by deleting the selectivity for the Morgue age frequency from the population file and deleting the data and the selectivity from the estimation file.

Population.csl (for the model with the Morgue age frequency)

```
@initialization
B0 60000

@size_based False
@sex_partition False
@mature_partition True
@min_age 1
@max_age 100
@plus_group True
@n_areas 1
@initial 1911
@current 2017
@final 2017
@annual_cycle
baranov False
time_steps 1
aging_time 1
M_props 1
spawning_time 1
```

```
spawning_p 1
spawning_part_mort 0.75
n_maturations 1
maturation_times 1
recruitment_time 1
fishery_times 1
fishery_names NWCR

@y_enter 1
@standardise_YCS True
@recruitment
YCS_years 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925
1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943
1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961
1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
2016
YCS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
SR BH
steepness 0.75
sigma_r 1.1
first_free 1940
last_free 1992
@randomisation_method lognormal
@first_random_year 2010

@fishery NWCR
years 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
2015 2016 2017# revised 2014; including 5% overruns
catches 1560 10920 9100 7020 4290 2340 4736 4032 1984 4636 3960 1725 330 4180 3850 2520
2520 2310 2415 2835 2205 2730 2310 2310 2100 1680 1470 735 840 787.5 756 42 73.5 115.5 829.5
840  761  761
selectivity NWsel
U_max 0.67

@selectivity_names NWsel Trawlsel MGsel
@selectivity NWsel
  mature constant 1
  immature constant 0
@selectivity Trawlsel
  all logistic 25 4
@selectivity MGsel
  mature double_normal 50 10 10
  immature constant 0

@natural_mortality
all 0.045

@maturation
rates_all logistic_producing 10 60 37 4.56

@size_at_age_type von_Bert
```

```
@size_at_age_dist normal
@size_at_age
  k 0.059
  t0 -0.491
  Linf 37.78
  cv1 0.06
  cv2 0.06
  by_length True
@size_weight
  a 8.0e-8
  b 2.75
```

Estimation.csl (for the model with the Morgue age frequency)

```
@estimator Bayes
@max_iters 4000
@max_evals 4000
@grad_tol 0.0001
@MCMC
start 0.2
length 15000000
keep 1000
stepsize 0.03
proposal_t True
df 2
burn_in 1000

@relative_abundance aco_99_12
step 1
proportion_mortality 0.75
biomass True
ogive NWsel
years 1999 2012 2016
  1999 8126
# 2002 9414
  2012 14637
  2016 14051
  cv_1999 0.22
# cv_2002 0.20
  cv_2012 0.17
  cv_2016 0.13
dist lognormal
q acoq_99_12

@estimate
parameter q[acoq_99_12].q
prior normal
mu 0.8
cv 0.19
lower_bound 0.1
upper_bound 1.5

@relative_abundance aco_13
step 1
proportion_mortality 0.75
biomass True
```

```
ogive NWsel
years 2013
#2004 2717
2013 6656
#cv_2004 0.16
cv_2013 0.31
dist lognormal
q acoq_13

@estimate
parameter q[acoq_13].q
prior normal
mu 0.3
cv 0.19
lower_bound 0.03
upper_bound 0.6

@q_method free

@q acoq_99_12
q 0.8

@q acoq_13
q 0.3

@proportions_at Trawl_1994
years 1994
step 1
proportion_mortality 0.5
sexed False
sum_to_one True
at_size False
min_class 10
max_class 100
ageing_error True
plus_group True
ogive Trawlsel
1994 0 0.0131 0.0196 0.0087 0.0044 0.0283 0.0479 0.0196 0.037 0.024 0.0174 0.037 0.0218 0.0196
0.0196 0.0414 0.0218 0.0545 0.0414 0.0349 0.0523 0.037 0.0261 0.0174 0.0261 0.0153 0.0174 0.024
0.0283 0.0087 0.0174 0.0044 0.0087 0.0196 0.0196 0.0087 0.0022 0.0022 0 0.0153 0 0.0044 0.0022
0.0044 0.0065 0.0022 0.0022 0.0022 0.0022 0.0087 0.0065 0.0044 0.0065 0.0022 0.0044 0 0 0.0022 0
0.0087 0 0.0087 0.0065 0 0 0 0 0.0044 0 0 0 0.0087 0.0065 0 0.0022 0 0 0.0022 0.0044 0.0065 0 0 0 0
0.0065 0.0065 0 0 0 0 0.0044
dist multinomial
r 0.00001
N 60

@proportions_mature Mature_1994
years 1994
step 1
proportion_mortality 0.5
sexed F
at_size False
min_class 10
max_class 89
```

```
plus_group False
ageing_error True
1994 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
0.28571430 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.20000000 0.00000000
0.00000000 0.00000000 0.07692308 0.00000000 0.00000000 0.11111110 0.08333333 0.50000000
0.20000000 0.16666670 0.50000000 0.75000000 0.50000000 0.20000000 1.00000000 0.80000000
0.00000000 0.00000000 0.25000000 0.80000000 1.00000000 1.00000000 0.00000000 0.00000000
1.00000000 0.00000000 0.00000000 1.00000000 0.00000000 1.00000000 1.00000000 1.00000000
1.00000000 0.00000000 0.66666670 0.00000000 1.00000000 1.00000000 1.00000000 1.00000000
0.00000000 0.00000000 0.00000000 0.00000000 1.00000000 0.00000000 1.00000000 0.00000000
0.00000000 0.00000000 0.00000000 0.00000000 1.00000000 0.00000000 0.00000000 0.00000000
1.00000000 0.66666670 0.00000000 1.00000000 0.00000000 0.00000000 1.00000000 1.00000000
0.50000000
dist binomial
r 0.00001
Ns_1994 0 5 3 4 0 4 8 0 9 1 5 8 7 5 7 5 2 13 8 4 9 12 4 5 6 2 4 6 5 3 5 2 2 4 5 3 1 1 0 1 0 0 1 1 3 1 1 1
1 3 0 2 1 1 2 0 0 0 0 4 0 2 0 0 0 0 0 1 0 0 0 3 0 0 1 0 0 1 1 0


@proportions_at MorgueAF2016
years 2016
step 1
proportion_mortality 0.5
ogive MGsel
at_size 0
sum_to_one 1
plus_group 1
sexed False
min_class 24
max_class 100
2016    0.005611672   0.003367003   0.006359895   0.003367003   0         0.002992892
        0.004863449   0.01197157    0.01646091    0.01234568    0.006359895   0.01234568
        0.02394314    0.02543958    0.03142536    0.0261878     0.0130939     0.05312383
        0.04377104    0.02020202    0.02244669    0.0359147     0.02693603    0.03666293
        0.02132435    0.03329592    0.03815937    0.02506547    0.01459035    0.01683502
        0.0359147     0.01421624    0.0325477     0.01870557    0.02057613    0.01346801
        0.01047512    0.02132435    0.00748223    0.007856341   0.01533857    0.01234568
        0.003367003   0.008978676   0.007108118   0.0130939     0.004863449   0.01047512
        0.01795735    0.006359895   0.005611672   0.01197157    0.002992892   0
        0.004489338   0         0.006359895   0.00261878    0.002992892   0.005611672
        0.005237561   0         0         0.001870557   0.004863449   0         0.002992892   0
        0         0         0         0.004863449   0.003367003   0         0.002992892
        0.005237561   0.049008602
N_2016 60
ageing_error True
dist multinomial
r 0.000001


@proportions_at LFcom
years 1993 2002
step 1
proportion_mortality 0.5
sexed False
sum_to_one True
```

```
at_size True
class_mins 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
41 42 43 44 45 46 47
plus_group True
ogive NWsel
1993 0 0 0 0 0 0 0 0 9.20E-05 9.20E-05 0 0.000109156 0.000543102 0.00193728 0.001826512
0.006905244 0.005842306 0.012439678 0.024062154 0.03569912 0.059544832 0.076954497
0.113241442 0.127653548 0.136083093 0.131562826 0.111258205 0.081511835 0.043014651
0.018749065 0.007108662 0.002293693 0.000655585 0.000655585 0.000163896 0
2002 0 2.97E-05 0.000211007 0.000399846 0.000576484 0.000612998 0.001346714 0.002134871
0.003066961 0.003858695 0.005353435 0.010377816 0.011370252 0.016180037 0.020347562
0.026998427 0.033944844 0.042524468 0.065460658 0.082785711 0.109540123 0.115663169
0.116892718 0.098344233 0.085405525 0.061781647 0.037837223 0.025856601 0.012955292
0.005545166 0.00179434 0.000463022 0.000221013 6.26E-05 0 5.68E-05
dist multinomial
r 0.00001
N_1993 19
N_2002 35

@estimate
parameter recruitment.YCS
lower_bound 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0.01 0.01 0.01 0.01 0.01 0.01
0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
0.01 0.01 0.01 0.01 0.01 0.01 0.01 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1# free to 1992
upper_bound 1  1    1    1    1    1    1    1    1    1    1    1
        1    1    1    1    1    1    1    1    1    1    1    1
        1    1    1    1    1    1    10   10   10   10   10   10
        10   10   10   10   10   10   10   10   10   10   10   10
        10   10   10   10   10   10   10   10   10   10   10   10
        10   10   10   10   10   10   10   10   10   10   10   10
        10   10   10   10   10   10   10   10   10   10   10   1
        1    1    1    1    1    1    1    1    1    1    1    1
        1    1    1    1    1    1    1    1    1    1    1
prior lognormal
mu 26489122130 26489122130 26489122130 26489122130 26489122130 26489122130
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cv 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958 2980.958
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@estimate
parameter initialization.B0
lower_bound 5e3
upper_bound 3e5
prior uniform-log

@estimate
parameter selectivity[Trawlsel].all
lower_bound 5 3
upper_bound 50 20
prior uniform

@estimate
parameter selectivity[MGsel].mature
lower_bound 10 3 3
upper_bound 90 100 100
prior normal
mu 40 20 20
cv 0.3 2 2

@estimate
parameter maturation[1].rates_all
lower_bound 10 2.5
upper_bound 100 100
prior uniform

@estimate
parameter size_at_age.cv1
lower_bound 0.03
upper_bound 1
prior uniform

@estimate
parameter size_at_age.cv2
lower_bound 0.03
upper_bound 1
prior uniform

@catch_limit_penalty
label catchPenalty
fishery NWCR
multiplier 200
log_scale True

@ageing_error
type normal
c 0.1
```