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Tini a Tangaroa

A 2020 preliminary stock assessment of ORH 7B

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EXECUTIVE SUMMARY

Deepwater Group Ltd. (2024). A 2020 preliminary stock assessment of ORH 7B.

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The orange roughy 7B fishery management area is off the west coast of the South Island and extends straight out to the EEZ boundary from near Westport in the north to south of Jackson Head in the south. A fishery on spawning orange roughy (*Hoplostethus atlanticus*) developed in the winter of 1985 and until 1992 was concentrated on a small area within Cook Canyon. The TACC peaked at 1708 t from 1988–89 to 1994–95, but with a decrease in catch rates and stock status from stock assessments based on CPUE, the TACC was reduced over time, and the fishery was closed from 1 October 2007.

Based on genetic studies, size structure, and parasite composition, orange roughy in this fishery are thought to be a single stock. The most recently accepted stock assessment was in 2004 but, in that assessment, it was assumed that CPUE was directly proportional to biomass and that recruitment followed the assumed recruitment curve. Both assumptions are now considered unacceptable for orange roughy stock assessments. There was an update of the 2004 assessment in 2007, which made the same assumptions, but it was rejected because of the poor fit to the CPUE time series. An assessment was attempted in 2018 using a late-season 2017 acoustic biomass estimate but without any age frequency data it was problematic.

The 2020 assessment uses the late-season acoustic biomass estimate from 2017 together with a 2019 acoustic biomass estimate and an associated age frequency. This assessment is considered preliminary because work was stopped due to the conclusion that the acoustic surveys had probably missed a substantial proportion of the spawning biomass. This was seen in all three models that were considered. In the two models designed as ‘worst case’ scenarios, the over-estimation of the acoustic biomass indices suggested that the observations were ‘too low’. In the model that took a much more standard approach, the absence of spawning biomass was seen directly in a very low estimate of the acoustic q. Essentially, the prior assumption that ‘most’ of the spawning biomass had been surveyed was contradicted.

It is difficult to find support for alternative explanations of the low acoustic biomass indices. One possibility is that a low proportion of mature fish spawn each year (perhaps only 30%). However, this would be unusual for any species and for New Zealand orange roughy there are direct observations of proportion spawning for two stocks (from pre-season random stratified trawl surveys) which strongly suggest that proportion spawning is above 80%.

The only real alternative to an unseen spawning plume is that there has been a dramatic failure in recruitment since the closure of the fishery. The MCMC models give this scenario a close to zero probability as the year class strengths (YCS) are assumed to be independent from year-to-year. In the MPD estimation there are essentially no constraints on the YCS and the model is free to estimate a long run of low YCS. However, the MCMC estimates of YCS are driven by probability mass and not best fit. In terms of probability, conditional on the age frequency, and the assumption of independent YCS, it is extremely unlikely that there has been a long run of low YCS (and the MPD estimate has almost no support). In a model which had a strong positive correlation for YCS there would be more support for a long run of low YCS.

1. INTRODUCTION

The orange roughy 7B (ORH 7B) fishery management area is off the west coast of the South Island and extends straight out to the EEZ boundary from near Westport in the north to south of Jackson Head in the south (Figure 1).

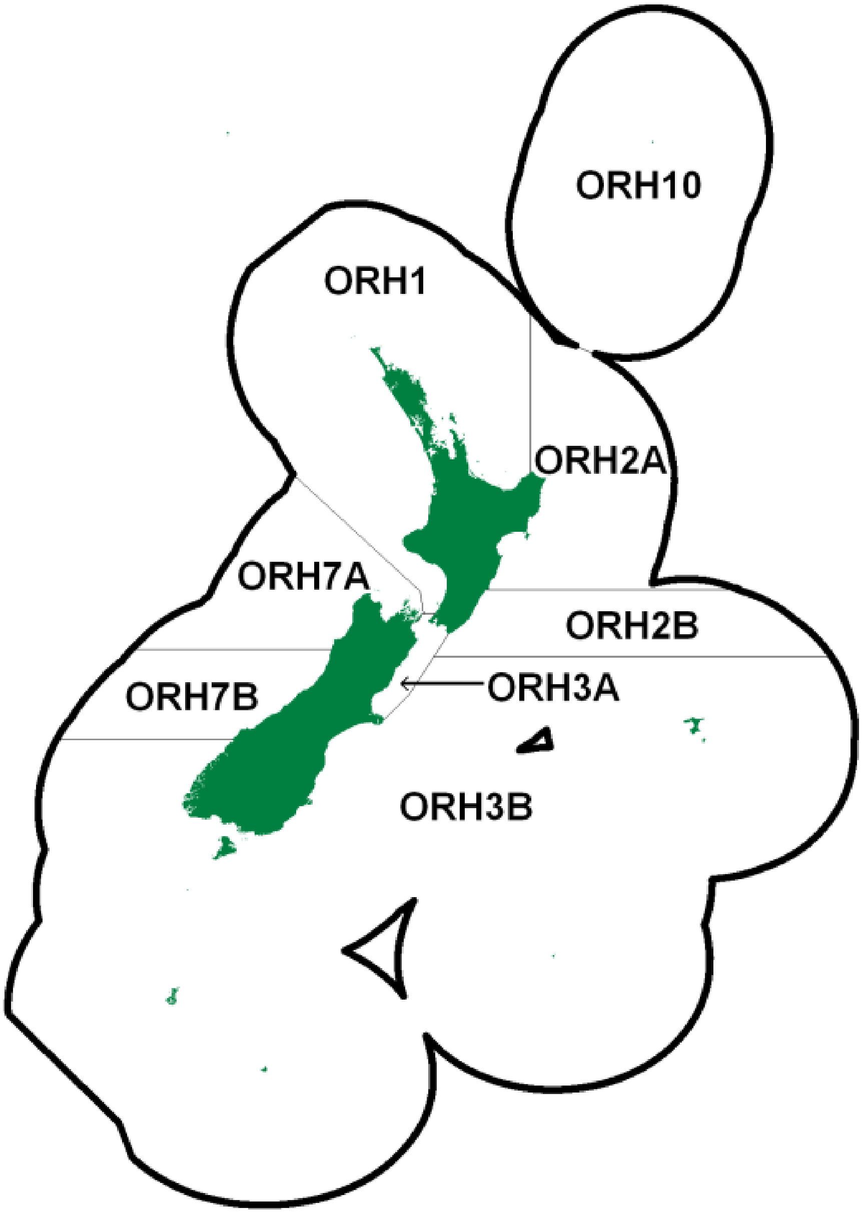

Figure 1: The geographical distribution of fishery management areas (QMAs) for orange roughy (Source: Fisheries New Zealand 2022).

A fishery on spawning orange roughy developed in the winter of 1985 and until 1992 was concentrated on a small area within Cook Canyon (McKenzie 2008). In the mid to late 1990s the fishery also extended to the north and south of Cook Canyon and the focus on the winter months was reduced (McKenzie 2008). The TACC peaked at 1708 t from 1988–89 to 1994–95, but, with a decrease in catch rates and stock assessments based on CPUE, the TACC was reduced over time and from 1 October 2007 the fishery was closed (see Table 1). The area of this fishery is shown in Figure 2; for detailed distributions of catch refer to Dunn et al. (2008).

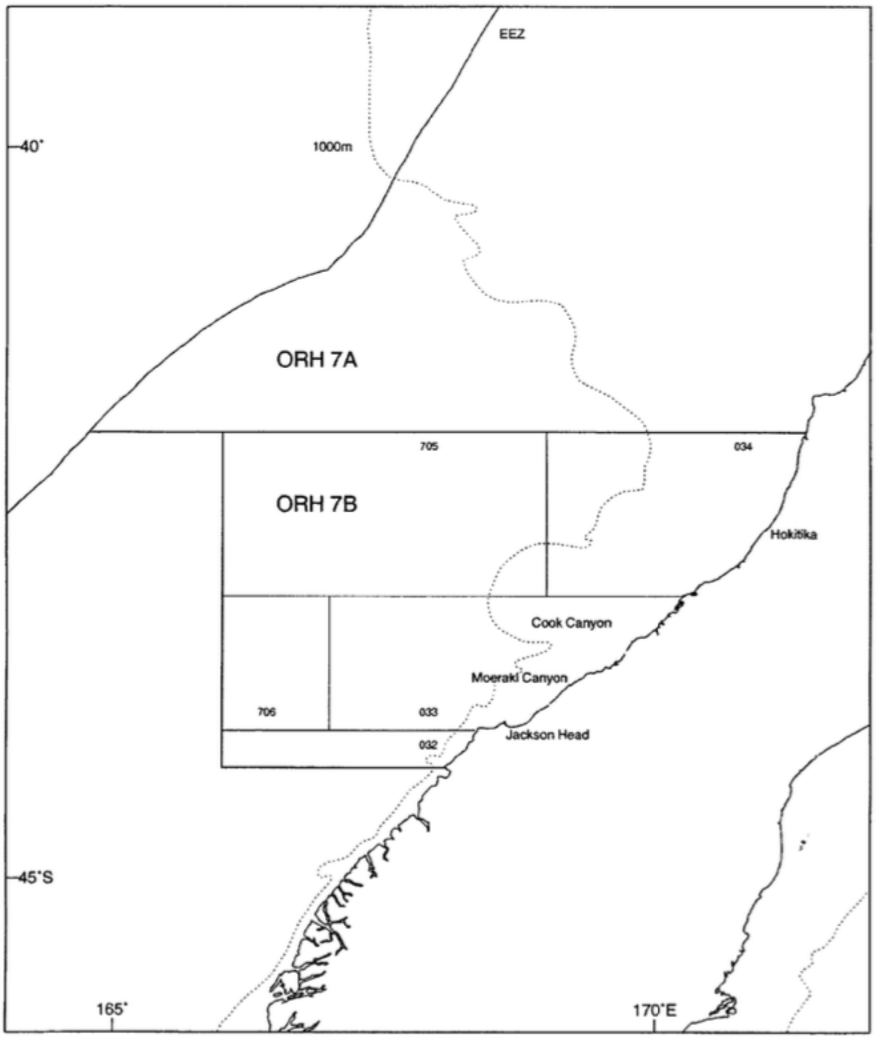

Figure 2: Location of key features of the west coast South Island orange roughy fishery in ORH 7B, also showing approximate statistical reporting areas (source: Dunn et al. 2008).

Based on genetic studies, size structure, and parasite composition, orange roughy in this fishery are thought to be a single stock. Samples of Cook Canyon orange roughy were found to be significantly different genetically to Challenger Plateau and Puysegur Bank samples (Smith et al. 1996). Also, the size structure and parasite composition were different from fish on the Challenger Plateau (Lester et al. 1988). Spawning occurs at a similar time to fish on the Challenger Plateau and the Puysegur Bank.

The most recently accepted stock assessment for the 7B stock of orange roughy was in 2004 but, in that assessment, it was assumed that CPUE was directly proportional to biomass and that recruitment followed the assumed recruitment curve (McKenzie 2005). Both assumptions are now considered unacceptable for orange roughy stock assessments (e.g., Cordue 2014a). There was an update of the 2004 assessment in 2007, which made the same assumptions, but it was rejected because of the poor fit to the CPUE time series (McKenzie 2008). An assessment was attempted in 2018 using a late-season 2017 acoustic biomass estimate but without any age frequency data it was problematic (Cordue 2018).

The 2020 assessment used the late-season acoustic biomass estimate from 2017 together with a 2019 acoustic biomass estimate and an associated age frequency. The assessment is preliminary in that it was neither accepted nor rejected by the Deepwater Working Group (DWWG), exploitation rates were not estimated, and no projections were performed. The assessment was conducted using NIWA’s Bayesian stock assessment package CASAL (Bull et al. 2012).

2. METHODS

Four orange roughy stock assessments were carried out in 2014 which all used similar methods (Cordue 2014a). The same approach has been adopted for orange roughy stock assessments since then: applying a high data quality threshold; fitting to acoustic biomass indices and age frequencies from the spawning population; using informed priors on the acoustic proportionality constants (qs); and estimating year class strengths (YCS) using ‘near uniform’ priors (Cordue 2014a). The partial 2020 assessment of the orange roughy 7B stock followed the same methods. An age-structured population model was fitted to two acoustic estimates of spawning biomass and a single age frequency.

2.1 Catch history

The catch history was taken from earlier Plenary reports with the addition of research survey catches since 2014–15 (Table 1, Figure 3). The runs reported here do not include the small research survey catches in 2014–15 and 2015–16, but their inclusion or otherwise makes no difference to the results. Although there may have been incidental mortality (e.g., burst bags), particularly in the early years of the fishery, no over-run percentages were assumed. No estimates of over-runs have been made for this fishery.

Table 1: Reported landings of orange roughy and TACCs for ORH 7B from 1983–84 to present. QMS data from 1986 to present. Catches taken under special permits during winter research surveys after 2013-14 are also noted. * FSU data.

Fishing year	Reported landings (t)	TACC (t)	Research catch (t)
1983–84*	2	–	
1984–85*	282	–	
1985–86*	1 763	1 558	
1986–87*	1 446	1 558	
1987–88	1 413	1 558	
1988–89	1 750	1 708	
1989–90	1 711	1 708	
1990–91	1 683	1 708	
1991–92	1 604	1 708	
1992–93	1 139	1 708	
1993–94	701	1 708	
1994–95	290	1 708	
1995–96	446	430	
1996–97	425	430	
1997–98	330	430	
1998□99	405	430	
1999–00	284	430	
2000–01	161	430	
2001–02	95	110	
2002–03	90	110	
2003–04	119	110	
2004–05	106	110	
2005–06	77	110	
2006–07	125	110	
2007–08	5.95	1	
2008–09	1.44	1	
2009–10	0.04	1	
2010–11	0.14	1	
2011–12	0.06	1	
2012–13	0.25	1	
2013–14	0.62	1	
2014–15	1.67	1	21.7
2015–16	0.27	1	19.2
2016–17	0.58	1	11.0
2017–18	1.42	1	–
2018–19	1.00	1	57.0

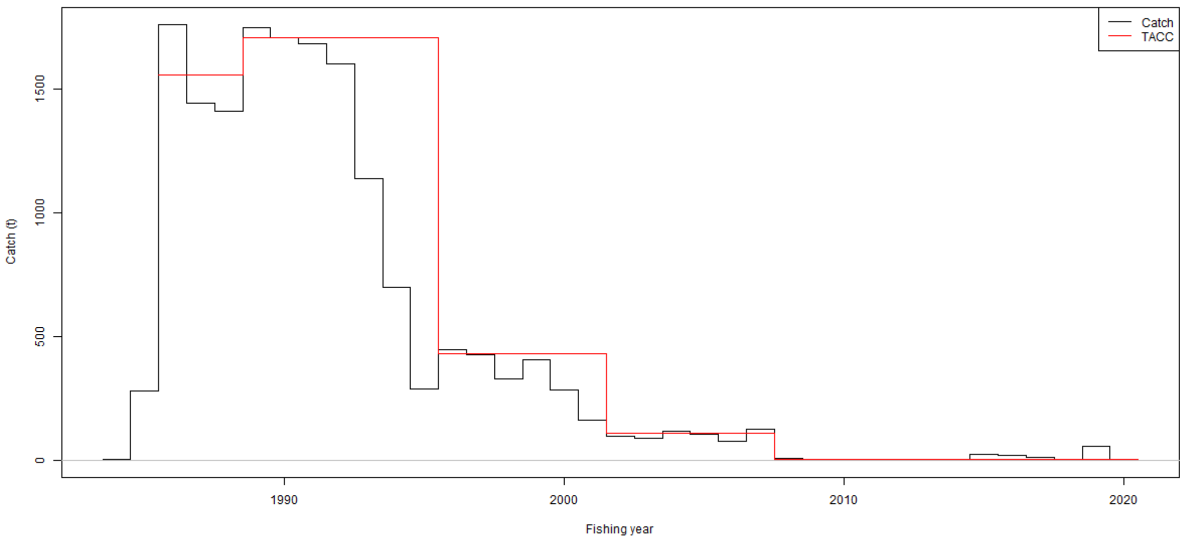

Figure 3: The reported catch history for the ORH 7B fishery and the annual TACCs. Catches since 2013–14 include those taken under special permits during research surveys.

2.2 Data quality, input data, and statistical assumptions

A high quality threshold was imposed on data before they were allowed to be used in the assessment. This followed the approach used in the 2014 orange roughy stock assessments, which excluded much data used in previous assessments and, in particular, dropped all time series of commercial CPUE, which were not considered to be indices of abundance.

There were two data sources for observations fitted in the assessment: spawning biomass estimates from acoustic surveys in 2017 and 2019; and a single age frequency from the acoustic survey in 2019.

2.2.1 Research surveys

There were three random trawl surveys of ORH 7B orange roughy in the early years of the fishery. Two were conducted by the FV *Arrow* (October 1983, and in late July-early August 1986) and another by the RV *Tangaroa* in October 1991 (Armstrong & Tracey 1987, Tracey et al. 1990, Clark 1991). All three used different stratification, but they broadly covered the same total area. Estimates from these trawl surveys are not used in this 2020 assessment.

Between 2014–15 and 2018–19, surveys were regularly conducted in Cook Canyon aimed at locating and acoustically surveying spawning orange roughy plumes. In 2015 an orange roughy plume was seen in Cook Canyon during a search by FV *Amaltal Explorer* but it was transitory and could not be acoustically surveyed (Ryan & Tilney 2016). Another attempt was made from FV *Cook Canyon* from 8 to 11 July 2016 (Doonan et al. 2016). There were two parts to the work in 2016: a search for spawning aggregations (plumes); and a random trawl survey in the area around the Cook Canyon, where most of the historical catch had been taken. A plume was found but it was intermittent and no acoustic estimates were obtained. Most orange roughy catches in the random trawl survey (22 tows) were small (median 19 kg) (Doonan et al. 2016).

Acoustic survey indices

A successful acoustic survey was conducted on FV *Amaltal Explorer* in 2017 using an acoustic-optical towed system (AOS) (Ryan & Tilney 2017). Three snapshots of a single spawning plume in Cook Canyon gave an average estimate of 824 t (Table 2). The timing of the snapshots was not ideal as they appeared to be late relative to the spawning cycle with 40–50% of sampled fish with spent gonads (Ryan & Tilney 2017). In 2019, on FV *Amaltal Mariner*, a plume at the same location as in 2017 was surveyed with a hull mounted system (Ryan & Tilney 2020). The snapshots spanned the main spawning season and there was no trend in the estimates with the increasing percentage of spent fish, which reached 45–65% on 10–11 July (Table 3). The average estimate in 2019 of 877 t was very similar to that in 2017 (Table 3).

Table 2: Biomass estimates from CSIRO's AOS system (38 kHz) during the 2017 acoustic survey. For each snapshot the date, number of transects, the biomass estimate, and the CV of each biomass estimate are given. It is also noted that for each snapshot orange roughy marks were seen on more than two transects (indicating that a genuine spawning plume was surveyed).

Snapshot	Date	Transects	Biomass (t)	CV (%)	Transects with marks
1	4 July 17	5	627	53	> 2
2	5 July 17	7	930	32	> 2
3	6 July 17	7	915	50	> 2
Average			824	26	

Table 3: Biomass estimates from the FV *Amaltal Mariner* 38 kHz hull-mounted system during the 2019 acoustic survey. For each snapshot the date, number of transects, the biomass estimate, and the CV of each biomass estimate are given. The number of transects on which orange roughy marks were seen is also given (1 transect indicates a poor-quality snapshot; 2 transects may be adequate but more than 2 indicates that a genuine spawning plume was surveyed).

Snapshot	Date	Transects	Biomass (t)	CV (%)	Transects with marks
1	26 June 19	6	318	48	2
2	26 June 19	6	1 393	35	2
3	3 July 19	9	927	21	> 2
4	4 July 19	9	746	31	> 2
5	9 July 19	6	511	64	1
6	9 July 19	5	473	38	2
7	10 July 19	10	958	33	> 2
8	16 July 19	4	198	58	1
Average (≥2)			803	14	
Average (>2)			877	17	

Trawl survey indices

No attempt was made to use any of the trawl survey biomass indices in the assessment, as the survey method is considered unlikely to produce any useful biomass estimates. During the spawning season the fish are pluming and catch rates will generally be low outside the plume and very high within the plume. Although the trawl survey biomass indices might be statistically unbiased, they will be highly imprecise.

Age frequencies

Orange roughy otoliths have routinely been collected during research surveys of Cook Canyon but they have only been aged for the 2019 acoustic survey. There are some otoliths from early trawl surveys in 1983 and 1986 but the first survey "took place before the spawning distribution was well known" and the second survey was "carried out after spawning was finished" (O'Driscoll 2001). For the 2015 acoustic survey there are 360 otoliths available for Cook Canyon but there was probably only 1 trawl in the spawning plume (which caught 18 t of orange roughy) (Ryan & Tilney 2016). For 2016, there are 476 otoliths available, but 299 of these were from a single trawl catch of 18 t on the plume (Doonan et al. 2016). The otoliths collected in the 2017 acoustic survey are also likely to be unrepresentative of the spawning population that year as they were collected late in the spawning cycle and are heavily skewed towards females (452 female, 150 male) (Ryan & Tilney 2017).

The 2019 age frequency was constructed using the method of Doonan et al. (2013) from 500 otoliths collected over 6 trawls that targeted the plume. The trawls took place from 26 June to 16 July and caught between 2.5 and 18.0 t of orange roughy (Ryan & Tilney 2020). Males and females were almost equally represented and the age frequency across the 6 stations was similar (Figure 4). The scaled age frequency shows a large plus group at 100 years (Figure 5). The DWWG accepted that the scaled age frequency was likely to be representative of the spawning plume.

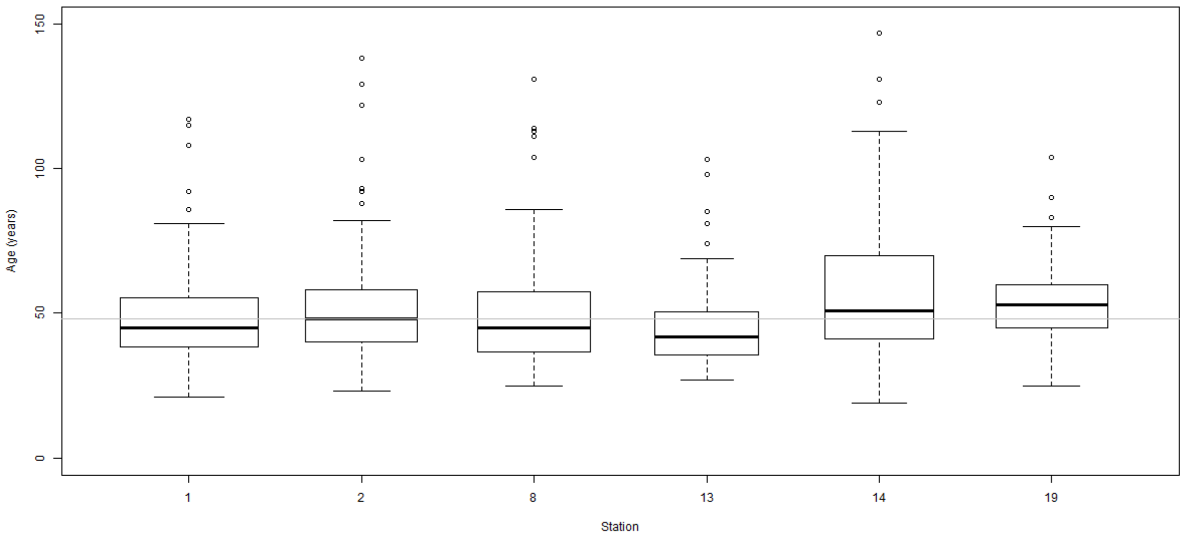

Figure 4: Box and whiskers plots of the ages of orange roughy sampled from each trawl catch from the spawning plume during the 2019 acoustic survey of ORH 7B. The bold lines are at the median age, the box covers the middle 50% of ages, and the whiskers extend to 1.5 times the inter-quartile range. The horizontal grey line is plotted at the median age of all of the fish.

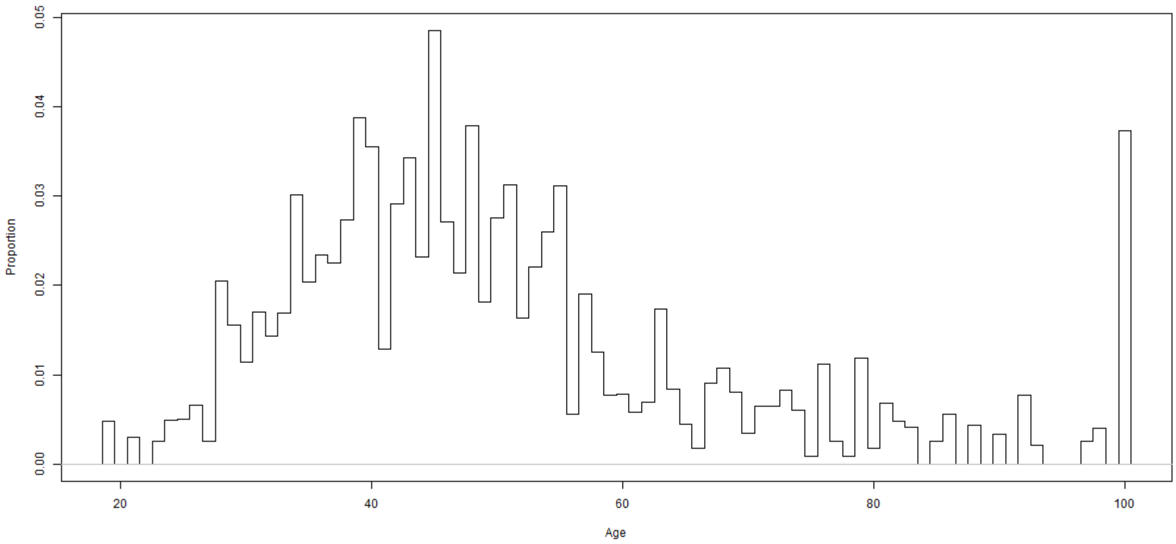

Figure 5: The proportion of orange roughy at-age distribution for the scaled age frequency from trawls targeting the spawning plume in the 2019 acoustic survey. There is a plus-group at 100 years.

2.3 Model structure

The model was single-area, single-sex, and age-structured (1–100 years with a plus group), with maturity also tracked (i.e., fish were classified by age and as mature or immature). Two time steps were used: a full year of natural mortality followed by an instantaneous spawning season and a fishery on the spawning fish (with equal selectivity across age classes).

Natural mortality was fixed and the stock-recruitment relationship was assumed to follow a Beverton-Holt function.

The fixed biological parameters in the model were:

Natural mortality:	0.045
Beverton-Holt steepness:	0.75
Length-weight (a, b):	8.0e–5, 2.75 (cm to kg)
von Bertalanffy (L_∞, k, t_0):	37.78 cm, 0.059, –0.491 years

2.4 Estimation methods and model runs

The estimation methods were almost identical to those used in the 2014 orange roughy assessments (Cordue 2014a). The stock assessments were done using the general Bayesian estimation package CASAL (Bull et al. 2012). The CASAL input files for the 'standard model' (model q.8.3) are given in Appendix 2. The final model results used the marginal posterior distributions of parameters and derived values of interest (e.g., virgin biomass (B_0), current biomass (B_{2020}), and current stock status ($ss_{2020} = B_{2020}/B_0$)). The marginal posterior distributions were produced using Markov chain Monte Carlo methods (hence termed 'MCMC' runs). Preliminary analysis was performed using the Mode of the Posterior Distribution (MPD) which can be obtained more quickly than the full posterior distribution (hence 'MPD' runs). An MPD estimate is associated with the 'best fit' that can be obtained – it is useful to check that the 'best fit' is not too bad otherwise there would be concerns about the appropriateness of the model.

Three models were used in this preliminary assessment (Table 4). The q.8.3 model used the 'standard' approach for orange roughy assessment with a high data quality threshold and an informed prior on the acoustic q (Cordue 2014a). There was also an informed prior for the maturation ogive as the model struggled to estimate these parameters with only a single age frequency. The two other models were constructed as 'worst case' scenarios with alternative approaches to forcing low estimated recruitment. In the m.33.13 model, maturation was fixed at a young age to create a 'recruitment hole' in the age frequency and additional YCS were estimated to enable the young age classes to be fitted given the low age of maturity. In the q.6.0 model the acoustic q was fixed at 0.6 to turn the acoustic estimates into low absolute biomass indices (which would require low recruitment estimates to fit the indices).

Table 4: The distinguishing features of the three model runs. N = normal distribution. LN = lognormal distribution.

Model	q prior (mean, CV)	Maturation prior (mean, CV)	YCS estimated
q.8.3	LN(0.8, 0.3)	a_{50}: N(37, 0.1) a_{to95}: N(12, 0.1)	[1915–1995]
m.33.13	LN(0.6, 0.1)	$a_{50} = 33$; $a_{to95} = 13$	[1915–-2000]
q.6.0	$q = 0.6$	a_{50}: N(37, 0.1) a_{to95}: N(12, 0.1)	[1915–-1995]

In the q.8.3 model the parameters estimated were: virgin biomass (B_0), the acoustic q, the maturation ogive, and the year class strengths (YCS) from 1915 to 1995 (with the Haist parameterisation and 'nearly uniform' priors on the free parameters – see Appendix 2). In the m.33.13 model the maturation ogive was fixed, and in the q.6.0 model the acoustic q was fixed (Table 4).

The general approach taken to data weighting within the stock assessment was to down-weight age frequency data relative to biomass indices to allow any scale and trend information in the biomass indices to drive the assessment results. This broadly follows the ideas of Francis (2011) who argued that composition data were generally given far too much weight in stock assessment models and were often allowed to dominate the signals from biomass indices.

MCMC chain diagnostics

Mathematical theory proves that MCMC chains will eventually converge to provide the joint posterior distribution. However, one can never be certain that a chain, or multiple chains, have been run long enough to achieve 'sufficient' convergence. There is never proof that a chain has converged but there may be evidence that a chain has not yet converged. Many diagnostics exist to help determine whether a chain has achieved sufficient convergence.

In New Zealand, a common approach to judge convergence is to use multiple chains (each with a different random number seed) and to compare the marginal posterior distributions for the (derived) parameters of interest. The idea is that the chains are sufficiently converged when all of the chains give the 'same' answer. For this assessment, three chains of 5 million were used. One in every one thousand samples were retained and the first one thousand retained samples were discarded as a 'burn-in' (which allows the chain to move away from the MPD starting value). The three posterior distributions were judged primarily on the basis of their median values as to whether they were sufficiently similar that the chains were long enough. 'Near identical' median values were required (e.g., two out of three chains being the same to two significant figures with the third almost the same; e.g., stock status medians across the three chains of 48, 49, and 49% B_0 were considered close enough). Estimates use all three chains combined after the burn-in (and so are based on 12 000 samples). See Appendix 1 for the MCMC chain diagnostics for model q.8.3.

Fishing intensity
Fishing intensity was not estimated for any of the models.

Projections
No projections were performed.

3. RESULTS

3.1 MPD fits and estimates

The MPD fits to the acoustic biomass indices and the age frequency are very good and very similar for each of the three models (Figure 6). The models all give similar estimates of virgin biomass and current stock status (Table 5).

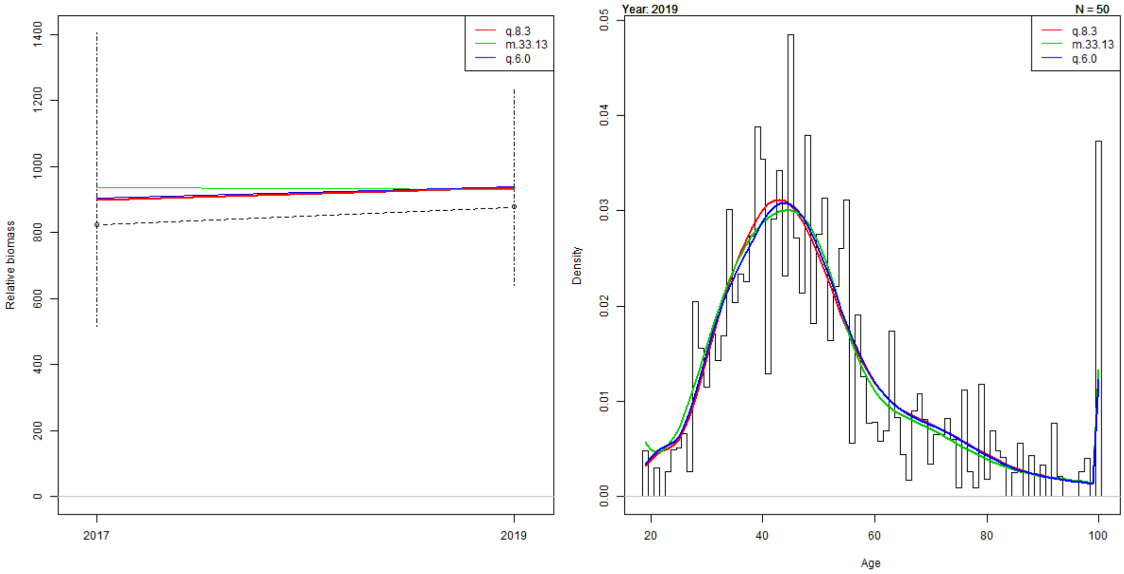

Figure 6: MPD fits of the three models to the acoustic biomass indices (left) and the age frequency density (right). The acoustic biomass indices are plotted as open circles and the vertical dashed lines are 95% confidence intervals. The age frequency density has a plus group at 100 years and the assumed effective sample size was N = 50.

Table 5: The MPD estimates for the three models of the maturity parameters, the acoustic q, virgin biomass (B_0), and current stock status ($ss_{2020} = B_{2020}/B_0$).

Model	a_{50} (years)	a_{to95} (years)	Acoustic q	B_0 (000 t)	ss_{2020} (% B_0)
q.8.3	39	12	0.56	10.2	17
m.33.13	33	13	0.57	10.5	15
q.6.0	38	11	0.60	10.1	16

For model m.33.13 the maturity parameters were fixed and this produces the difference in the MPD estimates of true YCS for the three models (Figure 7). Because of the younger maturity at age, the YCS estimates for m.33.13 are offset to the right of the estimates of the other two models (Figure 7). The three models show very similar trajectories for stock status with an initial increase well above virgin biomass followed by a steep decline with current stock status below 20% B_0 (Figure 7).

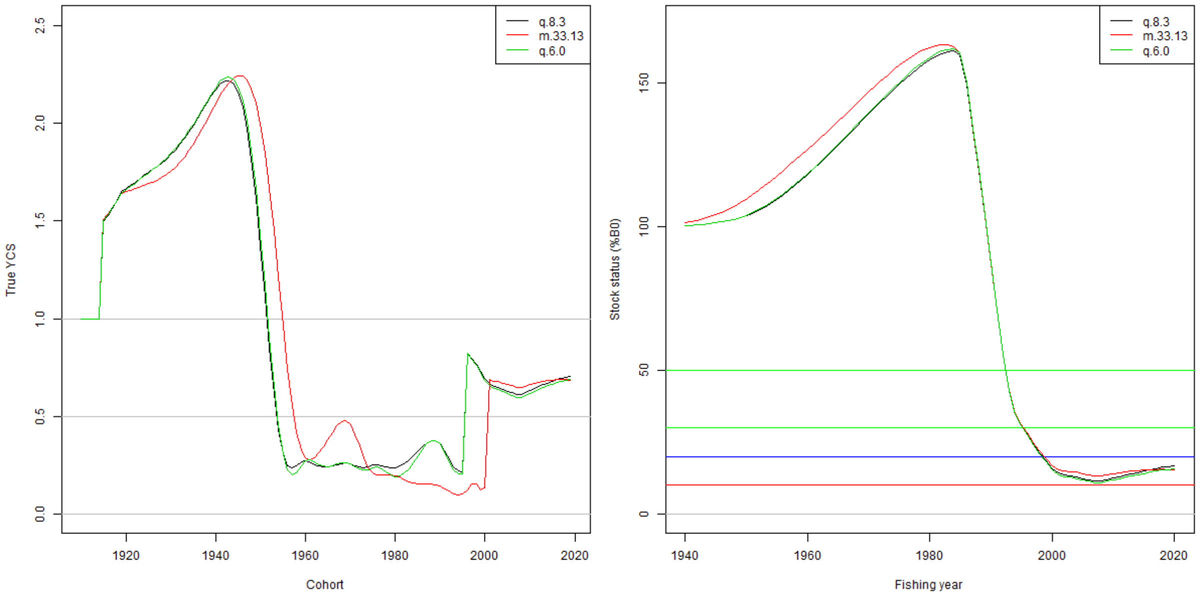

Figure 7: MPD estimates for the three models of the true year class strengths (R_i/R_0) (left) and the stock status trajectory (B_i/B_0) (right). The hard limit 10% B_0 (red), soft limit 20% B_0 (blue), and a potential biomass target range 30–50% B_0 (green) are marked by horizontal lines.

3.2 MCMC fits and estimates

The two models that were designed as 'worst case' scenarios have good MPD fits to the acoustic biomass indices but very poor MCMC fits (Figure 8). There is little overlap between the 95% credibility intervals from the MCMC chains and the 95% confidence intervals of the observations (Figure 8). The median MCMC residuals for the acoustic biomass indices are well outside the 95% confidence intervals, especially so in 2019 (Table 6). In contrast, model q.8.3 shows a fair MCMC fit to the acoustic biomass indices and the normalised residuals, although negative, are typically within two standard deviations of the standardised mean of zero (Figure 9). The MCMC fits to the age frequency are similar across models and similar to the MPD fits (e.g., see Figure 10 for model q.8.3).

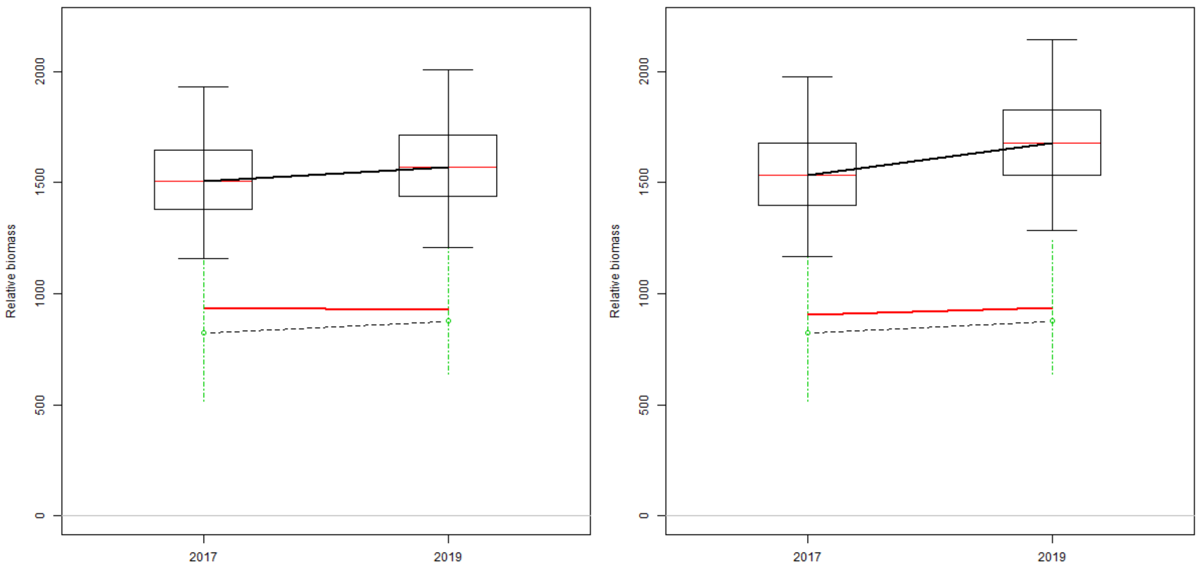

Figure 8: MCMC fits to the acoustic biomass indices (t) for m.33.13 (left) and q.6.0 (right). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The acoustic biomass indices are plotted as the green open circles with the green dashed lines giving 95% confidence intervals. The MPD fit for each model is shown as the red line.

Table 6: For all three models: MCMC estimates of the acoustic *q* and the maturation parameters (a_{50} and a_{to95}) together with the median normalised residuals for the acoustic biomass indices.

	Acoustic q		Median normalised residual		Median maturity (years)	
Model	Median	95% CI	2017	2019	a_{50}	a_{to95}
m.33.13	0.59	0.49-0.71	-2.3	-3.6	33	13
q.6.0	0.60	0.60-0.60	-2.3	-3.7	40	11
q.8.3	0.19	0.13-0.28	-1.2	-1.9	39	12

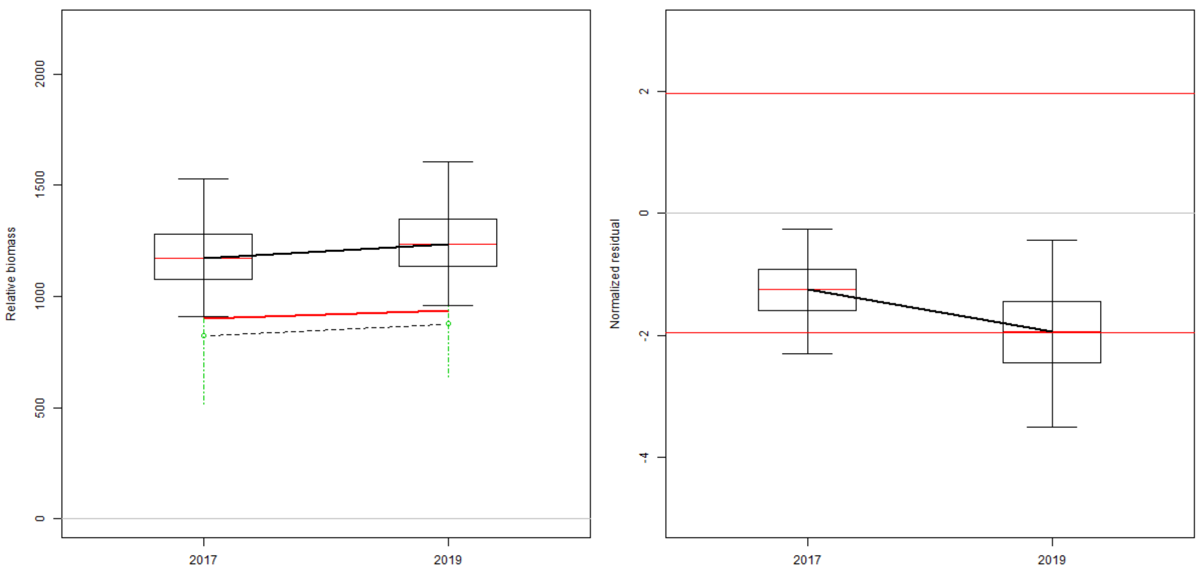

Figure 9: Model q.8.3: MCMC fits to the acoustic biomass indices (t) (left) and the corresponding normalised residuals (right). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The acoustic biomass indices are plotted as the green open circles with the green dashed lines giving 95% confidence intervals. The MPD fit is shown as the red line (left plot).

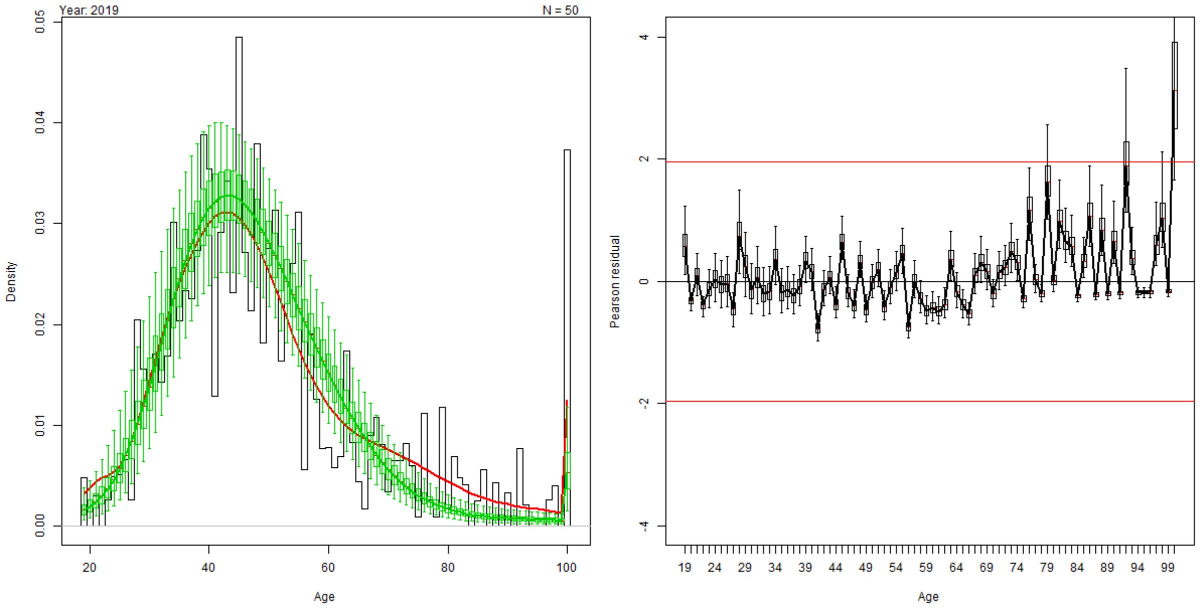

Figure 10: Model q.8.3: MCMC fits to the age frequency density (left) and the corresponding Pearson residuals (right). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The MPD fit is shown in red (left plot). The observations and predictions have a plus group at 100 years.

The MCMC estimates of the acoustic *q* were very different between model m.33.13 (which had a CV of 10% on the prior) and model q.8.3 (which had a CV of 30%) (Table 6). Models m.33.13 and q.6.0 have an acoustic *q* at or near to 0.6 which means that they cannot adequately fit the acoustic biomass indices (Table 6). In contrast, model q.8.3 allowed the acoustic *q* to move to much lower values which enabled the acoustic biomass indices to be fitted more precisely (Table 6).

Maturity was fixed at a low age for model m.33.13 but when it was estimated in the other two models (albeit with some constraints) similar estimates were obtained (Table 6, Figure 11).

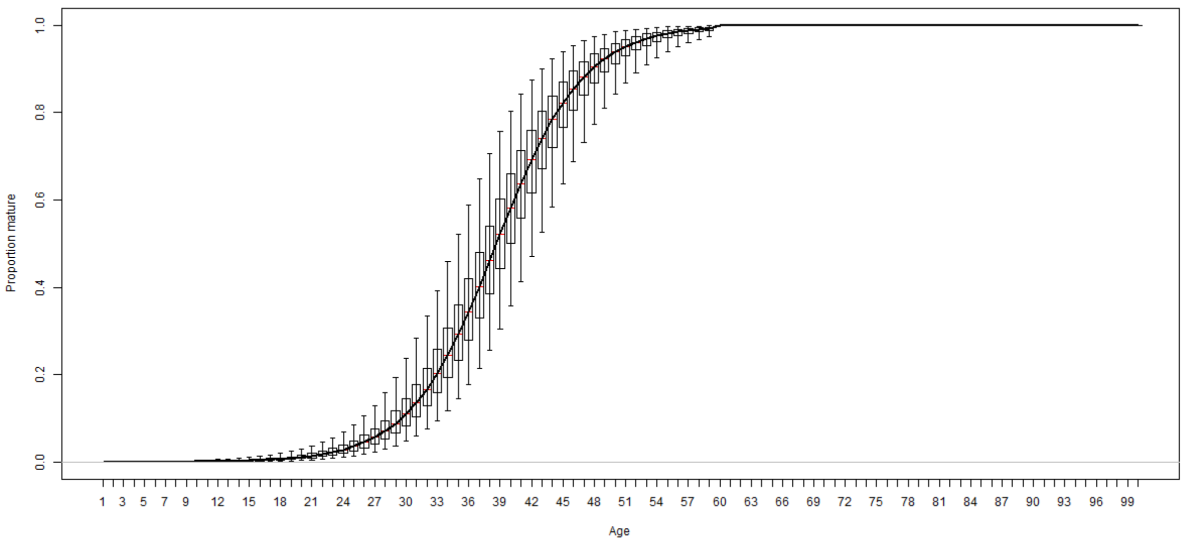

Figure 11: Model q.8.3: MCMC estimated proportion mature at age in the virgin population. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The two models designed as 'worst case' scenarios do deliver much lower stock status estimates than the 'standard' model q.8.3 (Table 7). They also estimate lower virgin and current biomass than model q.8.3 (Table 7). The MCMC estimates of YCS are less extreme than the MPD estimates but they show the same pattern of above average strength up until about the mid-1950s and below average strength since then (e.g., see Figure 12 for model q.8.3).

Table 7: For all three models: MCMC estimates of virgin biomass (B_0), current biomass (B_{2020}), and current stock status (B_{2020} as $\%B_0$).

	B_0 (000 t)		B_{2020} (000 t)		SS_{2020}	
Model	Median	95% CI	Median	95% CI	Median	95% CI
m33.13	11.5	10.7–12.4	2.8	2.1–3.8	25	19–31
q.6.0	10.5	9.7–11.4	2.9	2.2–3.7	27	22–34
q.8.3	13.3	11.6–15.8	6.7	4.8–9.4	50	40–61

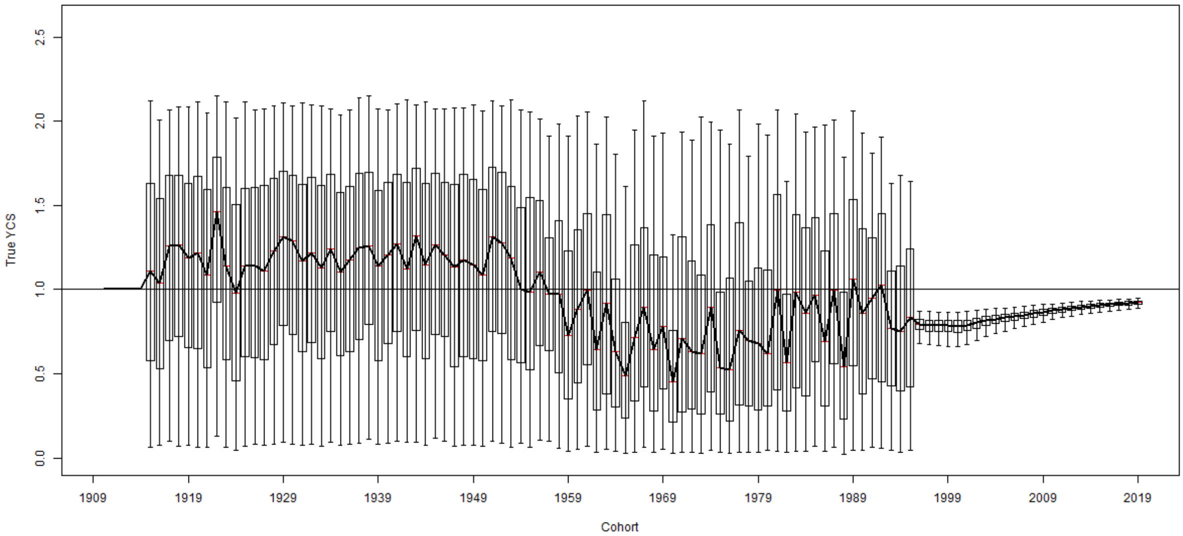

Figure 12: Model q.8.3: MCMC estimated YCS. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

Driven by the catch history and the estimated YCS, the MCMC stock status trajectories are similar across models, with a steep decline during the period of the fishery, followed by an increase of some extent (e.g., see Figure 13 for model q.8.3).

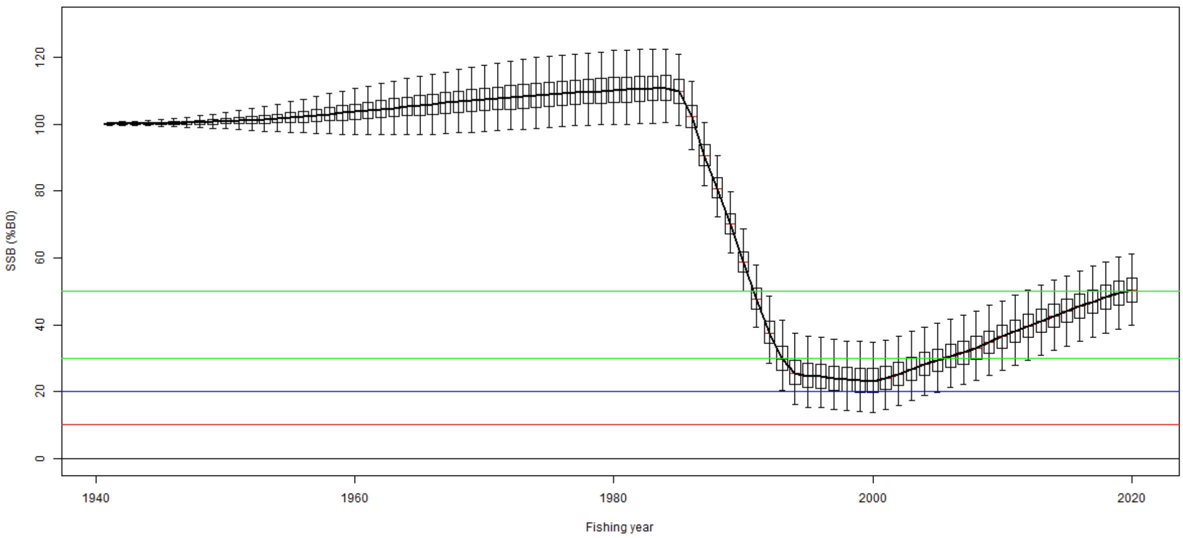

Figure 13: Model q.8.3: MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit 10% B_0 (red), soft limit 20% B_0 (blue), and a potential biomass target range 30–50% B_0 (green) are marked by horizontal lines.

4. DISCUSSION AND CONCLUSIONS

This assessment was a preliminary and partial assessment because work was stopped due to concerns that the acoustic surveys had probably missed a substantial proportion of the spawning biomass. This was seen in all three of the models. In the two models designed as ‘worst case’ scenarios, the over-estimation of the acoustic biomass indices suggested that the observations were ‘too low’. In the model that took a more standard approach (q.8.3), the absence of spawning biomass was seen directly in a very low estimate of the acoustic *q*. Essentially, the prior assumption that ‘most’ of the spawning biomass had been surveyed was contradicted. Unless it is accepted that there is more spawning biomass yet to be found, then all of the models failed due to poor diagnostics.

It is difficult to find support for alternative explanations of the low acoustic biomass indices. One idea is that a low proportion of mature fish spawn each year (perhaps only 30%). However, this would be unusual for any species and for New Zealand orange roughy we have direct observations of proportion spawning for two stocks (from pre-season random stratified trawl surveys) which strongly suggest that proportion spawning is at or above 80% (Cordue 2014a). Another idea is that the estimates of virgin biomass are too high (and hence productivity is too high) because the catch history has been exaggerated (e.g., due to misreporting of the Fishery Management Area for orange roughy catch). This scenario was investigated by arbitrarily and substantially reducing the early catch history, but the resulting estimates of stock status were similar to that of model q.8.3. As catch history is reduced, virgin biomass comes down, but the acoustic biomass estimates are then a higher proportion of the lower spawning biomass and stock status is still estimated to have recovered.

The only real alternative to an unseen spawning plume is that there has been a dramatic failure in recruitment since the closure of the fishery. The MCMC models give this scenario a close to zero probability as the YCS are assumed to be independent from year to year. In the MPD estimation there are essentially no constraints on the YCS as a ‘near uniform’ prior is used (Cordue 2014a) and the model is free to estimate a long run of low YCS. However, the MCMC estimates of YCS are driven by probability mass and not best fit. In terms of probability, conditional on the age frequency, and the assumption of independent YCS, it is extremely unlikely that there has been a very long run of low YCS (and the MPD estimate has almost no support). In a model which had a strong positive correlation for YCS there would be much more support for a long run of low YCS.

5. ACKNOWLEDGEMENTS

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APPENDIX 1: MCMC chain diagnostics for model q.8.3

Examples of the MCMC chain diagnostics are given below. Model q.8.3 is used but the diagnostics for the other models were of a similar quality. The chains for the free parameters are mixing adequately. Although there is some ‘medium frequency’ structure, the estimates are not staying at high or low values for an extended period of time (Figures A1 & A2).

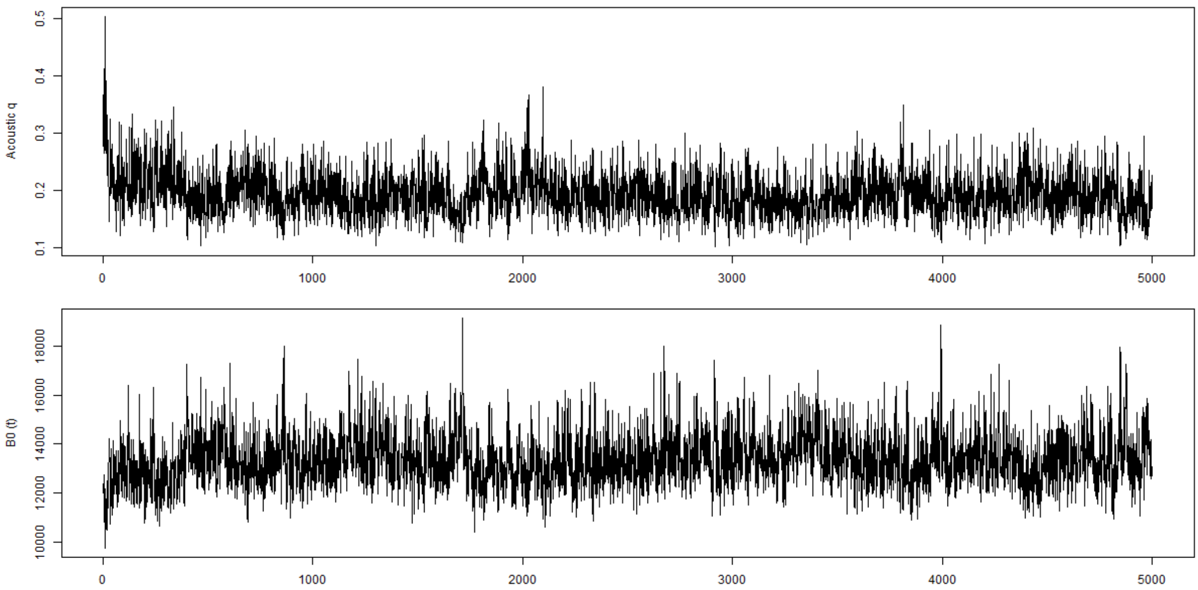

Figure A1: MCMC model q.8.3: estimates of the acoustic *q* (top) and B_0 (bottom) for the retained samples in the first chain including the burn-in (the first 1000 retained samples).

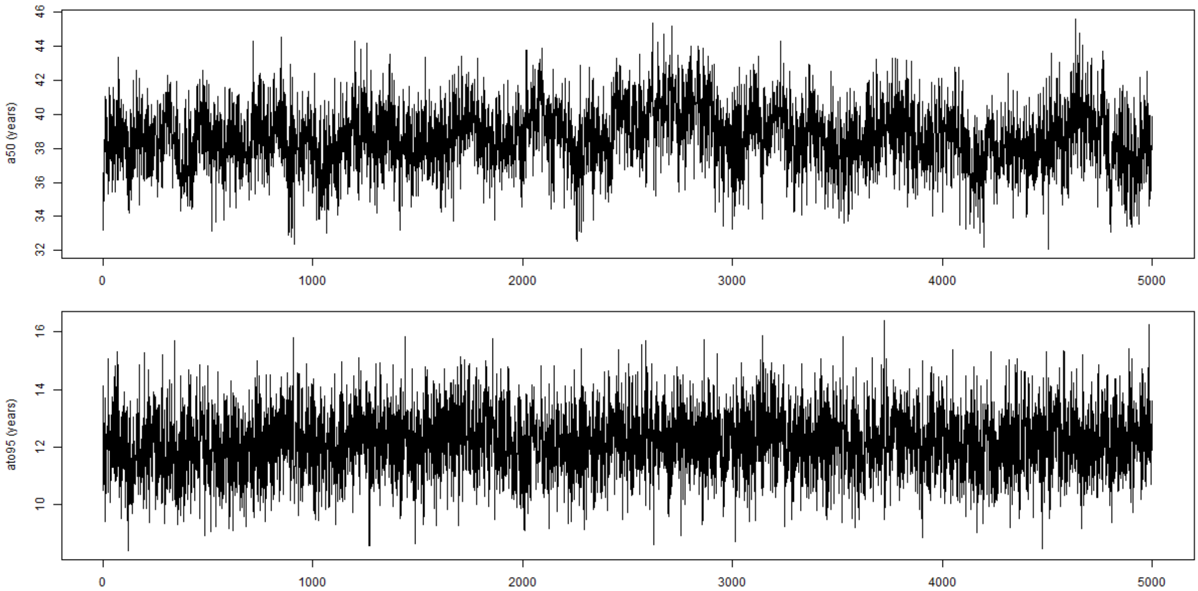

Figure A2: MCMC model q.8.3: estimates of the maturation parameters a_{50} (top) and a_{to95} (bottom) for the retained samples in the first chain including the burn-in (the first 1000 retained samples).

Each of the three chains deliver very similar marginal posterior distributions for the free parameters as evidenced by overlaying histograms of the estimates for each of the chains (Figures A3 & A4). The marginal posterior distribution for the acoustic *q* is in the extreme left-hand tail of the prior distribution (Figure A3). The marginal posterior distributions for the maturation parameters are well within the prior distributions (Figure A4).

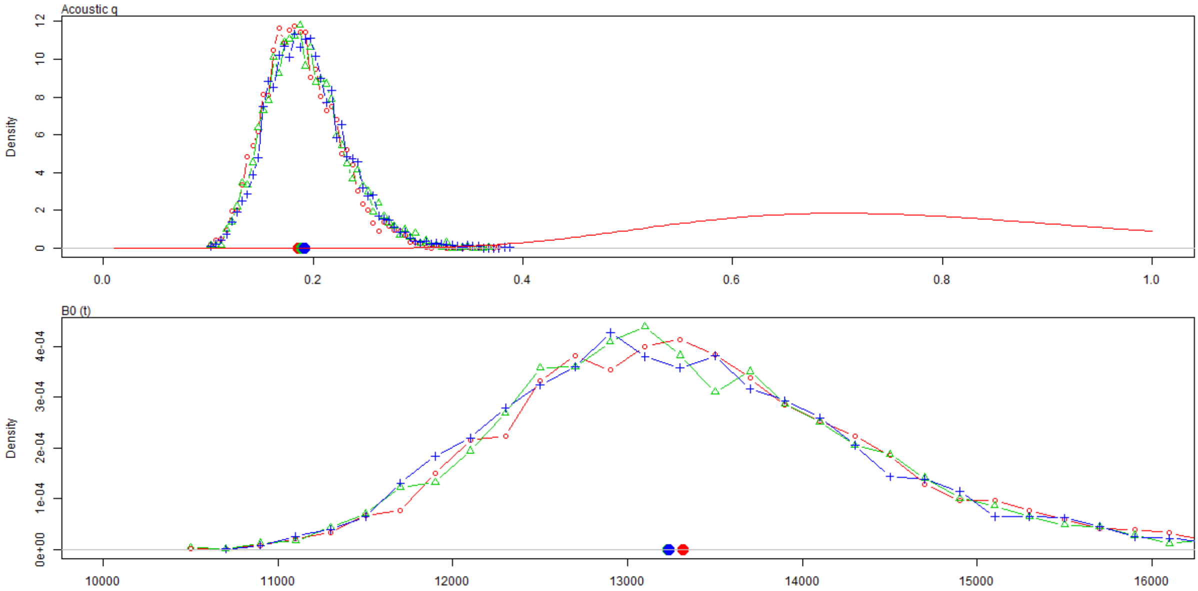

Figure A3: MCMC model q.8.3: histograms of the acoustic *q* (top) and B_0 (bottom) estimates for the retained samples for each of the three chains excluding the burn-in (the first 1000 retained samples). The medians of the estimates for the three chains are plotted as different coloured solid circles on the x-axis. For the acoustic *q* the prior distribution is shown as a smooth red line.

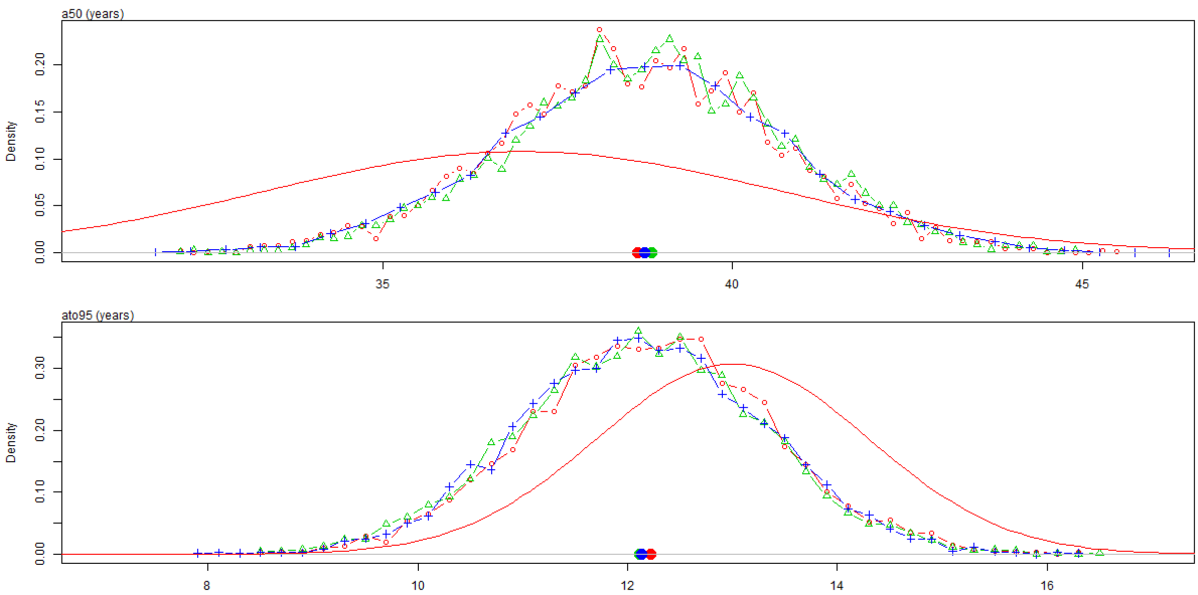

Figure A4: MCMC model q.8.3: estimates of the maturation parameters a_{50} (top) and a_{to95} (bottom) for the retained samples for each of the three chains excluding the burn-in (the first 1000 retained samples). The medians of the estimates for the three chains are plotted as different coloured solid circles on the x-axis . The prior distributions are shown as smooth red lines.

APPENDIX 2: CASAL input files for model q.8.3

The population and estimation files used for the model q.8.3 are given below.

population.csl

```
# ORH7B simple model

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

# TIME SEQUENCE
@initial 1911
@current 2020
@final 2028

@annual_cycle
time_steps 2

# recruitment
recruitment_time 1

# spawning
spawning_time 2
spawning_part_mort 0.5
spawning_p 1

# growth and mortality
aging_time 1
M_props 1 0
baranov False

# maturation
n_maturations 1
maturation_times 1

# fishery
fishery_names Spawn
fishery_times     2


@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 2017 2018 2019
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 1 1 1

SR  BH
```

steepness 0.75
sigma_r 0.9
first_free 1915
last_free 1995

@randomisation_method lognormal

@natural_mortality
all 0.045

@fishery Spawn
years 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 2018 2019 2020
catches 0 0 0 2 282 1763 1446 1413 1750 1711 1683 1604 1139 701 290 446 425 330 405 284 161 95 90 119 106 77 125 6 1.4 0 0 0 0 0 0 0 11 0 57 0
future_constant_catches 0
selectivity matsel
U_max 0.67

@selectivity_names matsel

@selectivity matsel
mature constant 1
immature constant 0

SIZE AT AGE
@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
@size_weight
a 8.0e-8
b 2.75

@maturation
rates_all logistic_producing 10 60 37 12

@initialization
B0 10000

estimation.csl

ESTIMATION
@estimator Bayes
@max_iters 4000
@max_evals 4000
@grad_tol 0.001

MCMC

```
@MCMC
start 0.2
length 5000000
keep 1000
stepsize 0.07
proposal_t True
df 2
burn_in 1000

@relative_abundance aco
step 2
proportion_mortality 0.5
biomass True
ogive matsel
years 2017 2019
2017 824
2019 877
cv_2017 0.26
cv_2019 0.17
dist lognormal
q acoq

@q_method free

@q acoq
q  0.8

@estimate
parameter q[acoq].q
prior lognormal
mu 0.80
cv 0.30
lower_bound 0.1
upper_bound 1.5

@proportions_at AFplumes19
years 2019
step 2
proportion_mortality 0.5
sexed F
sum_to_one True
at_size False
plus_group True
ogive matsel
min_class 19
max_class 100
ageing_error True
2019 0.00479904 0 0.003006873 0 0.00257732 0.004895413 0.005058267 0.006565439 0.00257732
0.02045905 0.01556364 0.01146085 0.01705587 0.01428993 0.01689301 0.03011279 0.02041087 0.02336955
0.02251792 0.02730949 0.03878528 0.03547847 0.01290489 0.0291166 0.03423052 0.02315104 0.04853127
0.02714663 0.02137382 0.03788546 0.01814843 0.02754294 0.03129426 0.01638951 0.02204765 0.02601
0.03115717 0.005584192 0.01903331 0.01253847 0.007717013 0.007813386 0.005795233 0.006872852
0.01733004 0.008324366 0.004417673 0.001718213 0.009020619 0.01073883 0.00809838 0.003436426
0.006443299 0.006524726 0.008235466 0.006013746 0.000859107 0.01119415 0.00257732 0.000859107
0.01180898 0.00179964 0.00686538 0.004806513 0.00407702 0 0.002529133 0.005584192 0 0.004295533 0
0.00329934 0 0.007731959 0.002058867 0 0 0 0.00257732 0.00398812 0 0.03731548
dist multinomial
r 0.00001
N_2019 50
```

```
@ageing_error
type normal
c 0.1

#----------------------------------------------------------------------
#
# Estimated parameters
#
#----------------------------------------------------------------------

@estimate
parameter maturation[1].rates_all
lower_bound      10         2.5
upper_bound      100        25
prior normal
mu 37 12
cv 0.1 0.1

@estimate
parameter initialization.B0
lower_bound 1e3
upper_bound 50e3
prior uniform-log

# YCS (near uniform prior)
@estimate
parameter recruitment.YCS
lower_bound 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
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upper_bound 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
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prior lognormal
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#----------------------------------------------------------
#
# Penalties
#
#-----------------------------------------------------------

@catch_limit_penalty
label CPen
fishery Spawn
multiplier 100
log_scale True
```