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The 2014 orange roughy stock assessments

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EXECUTIVE SUMMARY

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In 2014, four orange roughy stocks were assessed using very similar models and assumptions. The assessed stocks were Northwest Chatham Rise (NWCR, part of ORH 3B), East and South Chatham Rise (ESCR, part of ORH 3B), ORH 7A, and Mid-East Coast (MEC, ORH 2A south, ORH 2B, and ORH 3A combined). All of the stock assessments were performed using NIWA's Bayesian stock assessment package CASAL.

Age-structured, single-sex, and single-area models were used for all stocks. Within the models, fish numbers were categorised by age and their maturity state (immature or mature). Age frequency data were obtained for all stocks so that recruitment patterns could be estimated within the models. This was essential because it avoided the assumption of deterministic recruitment (all year class strengths equal to 1) which had previously undermined orange roughy modelling efforts.

A high threshold was placed on data quality. This excluded, from the stock assessment models, much data that had previously been used. In particular, CPUE time series were not used in the models. In the past, CPUE indices were used as abundance indices but this is not appropriate for orange roughy fisheries which generally focus on aggregated fish in a small area. It is not possible for a fishery to index a whole stock if it operates only on a small portion of the stock (e.g., fishing on a single hill or hill complex when the stock is spread over a much larger area). Also, although a fishery on spawning aggregations may be sampling most of the stock, the catch rates are unlikely to depend on the level of spawning biomass present but more on how the aggregation is fished (e.g., around the edges or targeting the highest concentrations).

The models focussed on using recent acoustic survey data on orange roughy spawning plumes to provide information on current biomass. The acoustic survey estimates were used as relative biomass indices with an informed prior on the proportionality constant (q). The two components of the q-prior were the target strength of orange roughy (for which estimates have improved markedly in recent years) and the proportion of the spawning biomass being indexed by the survey. The general assumption, for a survey thought to have covered "most" of the spawning biomass, was that 80% of the spawning biomass was being indexed.

The development of the assessments followed the usual Bayesian estimation procedure: experimentation and development of a base model using the mode of the posterior distribution (MPD runs), followed by a subset of runs using the full posterior distribution obtained by Markov chain Monte Carlo simulation (MCMC runs).

Two of the four stocks were assessed as very likely to be above the lower bound of the target biomass range of 30–40% B_0. For the ORH 7A base model, the median and 95% credibility interval (CI) for stock status were 42% B_0 and 35–49% B_0. For the NWCR base model the estimate was 37% B_0 with a 95% CI of 30–46% B_0.

The ESCR is the largest stock and stock status was estimated to be 30% B_0 with a 95% CI of 25–34% B_0. The MEC stock was assessed as very likely to be below the soft limit of 20% B_0 with an estimate of 14% B_0 and a 95% CI of 9–21% B_0.

1. INTRODUCTION

In 2014, four orange roughy stock assessments were conducted: Northwest Chatham Rise (NWCR, part of ORH 3B), East and South Chatham Rise (ESCR, part of ORH 3B), ORH 7A, and Mid-East Coast (MEC, ORH 2A south, ORH 2B, and ORH 3A combined). All assessments used very similar methods and relied on the use of ageing data and recent acoustic surveys of spawning plumes. The assessments were conducted using NIWA's Bayesian stock assessment package CASAL (Bull et al. 2012).

2. METHODS

The methods used in 2014 were different from those used in previous orange roughy assessments in a number of respects. The major differences were in the data quality threshold, model structure, and the use of age data.

2.1 Catch histories

Catch histories were developed in a similar way to previous years with reported catches partitioned across areas and/or model fisheries using estimated catches from tow by tow data (Appendix 1). The estimated over-runs used in the past assessments were also retained (see recent Plenary reports or Appendix 1).

The largest catches were recorded from the ESCR stock with catches (including over-runs) peaking at just under 40 000 t in 1980 (Figure 1). There was a steep decline in catches during the 1990s and in recent years the catches have been about 2000–3000 t. The NWCR catch history also had a peak in the early 1980s but the catches were halved by the mid 1980s (Figure 2). The low catches since and including the 2010–11 fishing year were due to an Industry agreement not to fish the stock.

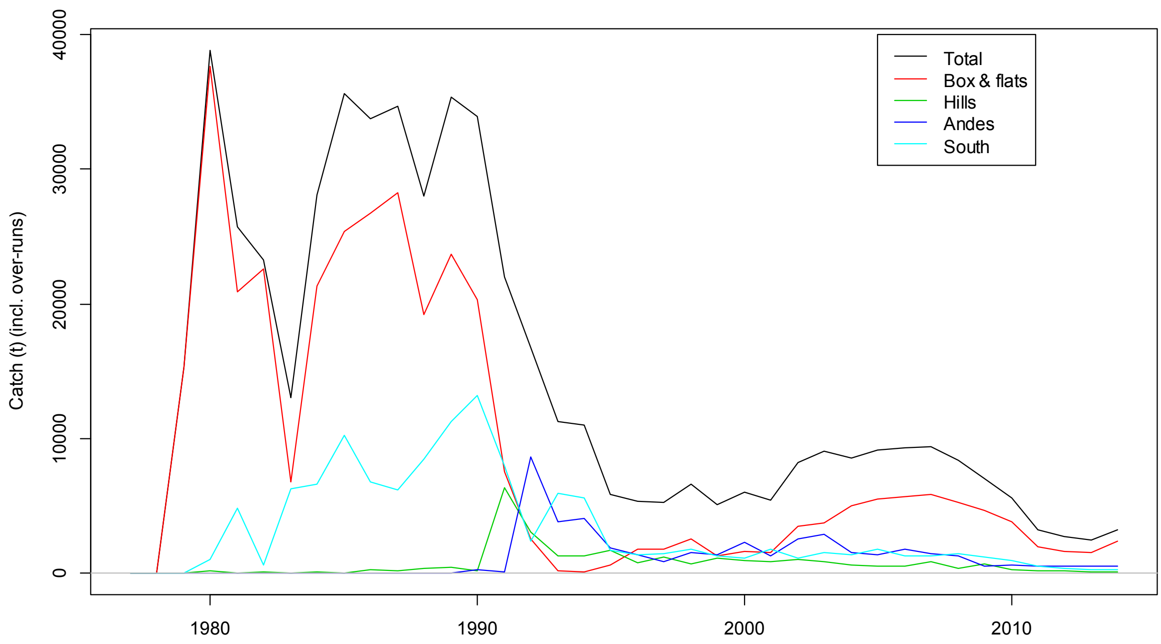

Figure 1: The catch history for the ESCR stock assessment (catches include the assumed over-runs). Four fisheries were modelled in the assessment: spawning box and flats; north-eastern hills; Andes; and the South Chatham Rise.

The ORH7A catch history had two peaks in the 1980s and a steep decline from the late 1980s to the early 1990s (Figure 3). The fishery was closed in 2000–01 due to persistently low catch rates and an associated stock assessment (Field & Francis 2001). The fishery was reopened in 2010–11 after a stock assessment showed that spawning fish had returned to the area in sufficient numbers (Cordue 2010). The MEC catch history shows a sustained peak above 10 000 t from the mid 1980s to the mid

1990s before a steep decline (Figure 4).

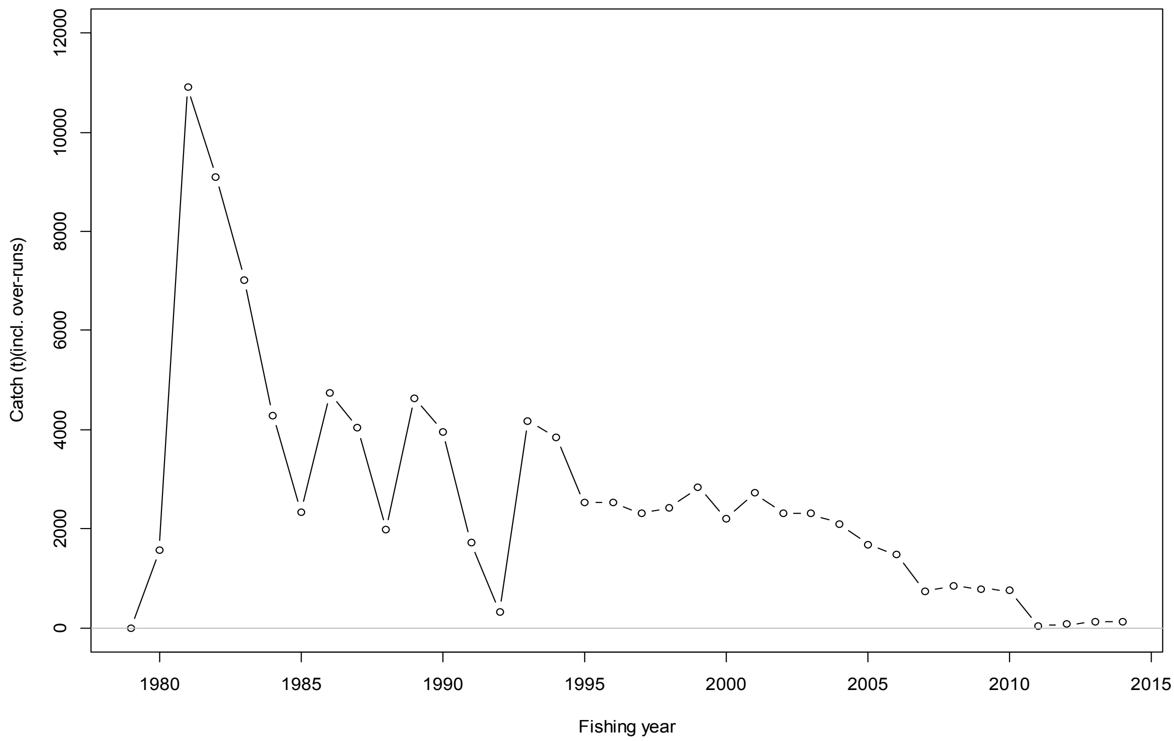

Figure 2: The catch history for the NWCR stock assessment (catches include the assumed over-runs). A single fishery was modelled in the assessment.

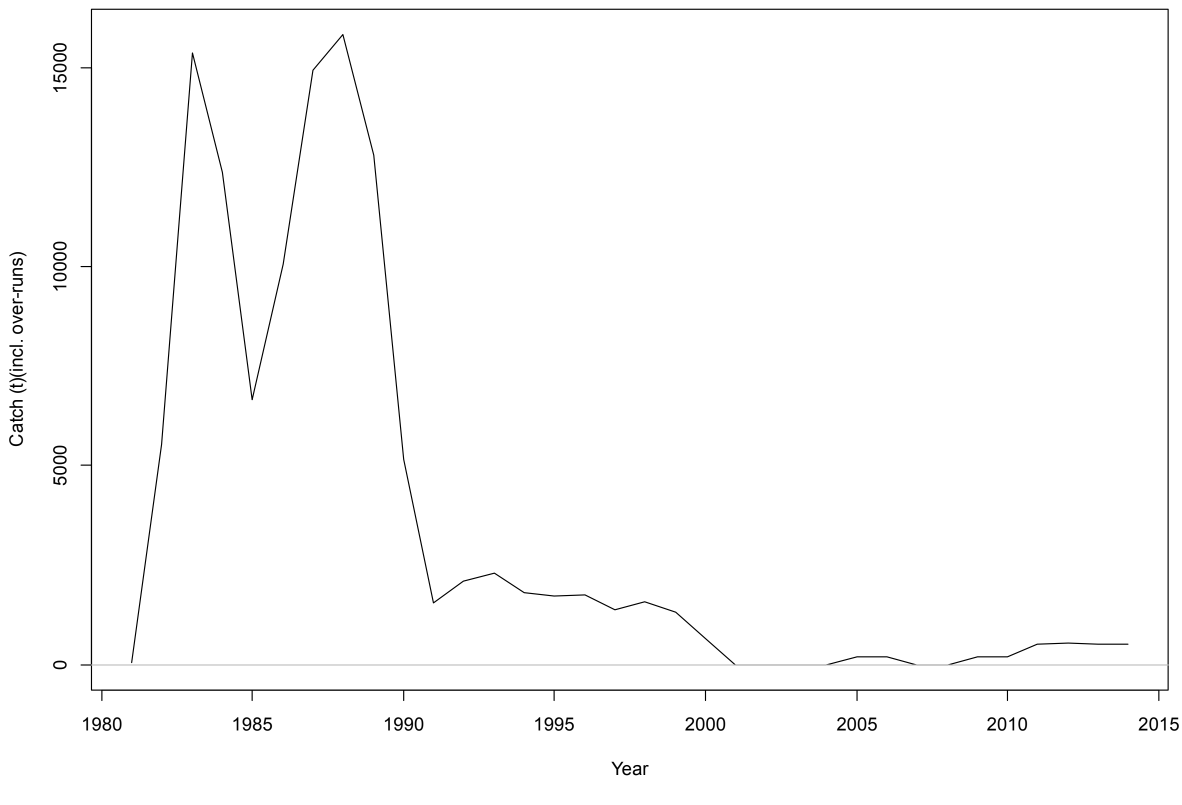

Figure 3: The catch history for the ORH 7A stock assessment (catches include the assumed over-runs). A single fishery was modelled in the assessment.

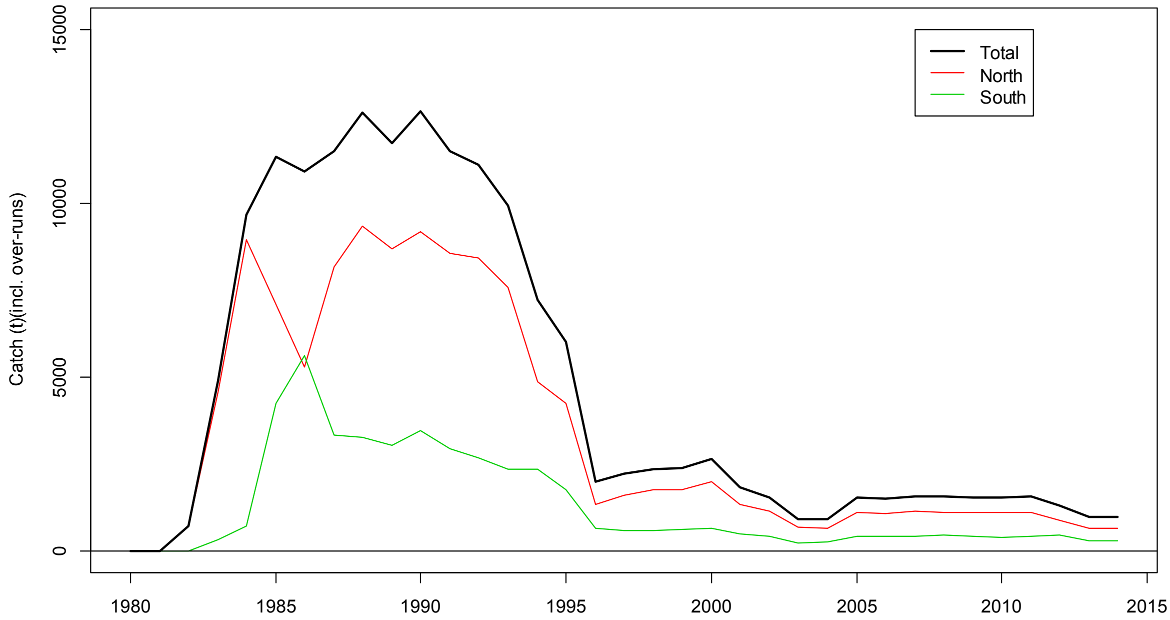

Figure 4: The catch history for the MEC stock assessment (catches include the assumed over-runs). Two fisheries were modelled in the assessment: north (ORH 2A south + ORH 2B) and south (ORH 3A).

2.2 Data quality and input data

A high quality threshold was imposed on data before they were allowed to be used in an assessment. Therefore, a number of biomass indices that may have previously been used were excluded. In particular, CPUE indices were not used in any of the assessments because they are very unlikely to be monitoring stock-wide abundance (e.g., non-spawning season catch rates from a single hill feature or complex within a large area cannot be monitoring stock wide abundance as the fishery is not sampling a large proportion of the stock; at best, such CPUE indices may index localised abundance; during the spawning season catches from a single hill or aggregation may be sampling a large proportion of the stock but the catch rates will depend on how the aggregation is fished rather than how much biomass is present). Also, estimates of biomass from egg surveys were not used as it was found that the available estimates were from very problematic surveys (the assumptions of the survey design were not met and/or there were major difficulties in analysing the survey data – see Francis et al. 1997 and Zeldis et al. 1997). Finally, acoustic-survey estimates of biomass were only used when largely single-species aggregations were surveyed with suitable equipment. Estimates of spawning orange roughy biomass were accepted for plumes on the flat (hull-mounted transducer or towed system) or plumes on underwater features (generally, towed systems only as otherwise the dead zone can be very large).

2.3 Model structure

Model structure was very similar across the four assessed stocks. In each case, the base models were single-sex, single-area models with age and maturity in the partition (i.e., fish numbers were kept track of by age and maturity stage: either mature or immature). Maturation rates at age were estimated within the model; the information coming from age-frequencies of spawning fish and, if available, female proportion spawning at age data from pre-spawning wide-area trawl surveys (available for NWCR and MEC). All mature fish were assumed to spawn each year as this was consistent with the estimates of female proportion spawning at age (see the NWCR and MEC assessment results below). This is a major contrast to earlier assessments where acoustic and egg survey estimates of spawning biomass were scaled up to estimates of transition-zone mature biomass before being used in an assessment. In the 2014 assessments, acoustic estimates of *spawning* biomass were used directly.

2.4 Estimation methods

The stock assessments were done using the general Bayesian estimation package CASAL (Bull et al. 2012). The CASAL input files for each of the base models (and the ESCR "Always" run) are given in Appendix 4. The final assessments were based on the marginal posterior distributions of parameters and derived parameters of interest (e.g., virgin biomass (B_0), current biomass (B_{2014}), and current stock status (B_{2014}/B_0)). The marginal posterior distributions were produced using Markov chain Monte Carlo methods (hence termed "MCMC" runs). Preliminary analysis and many sensitivity runs were performed using just the Mode of the Posterior Distribution (MPD) which can be obtained much more quickly than the full posterior distribution (hence "MPD" runs). The 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.

The philosophy behind Bayesian estimation is to update ones beliefs in a rational manner by the application of data. The initial or prior beliefs are represented by the prior distributions that are specified for each model parameter which is to be estimated. Bayes' Theorem, of conditional probability, provides a "rational" mechanism for updating the prior beliefs based on the observed data. Application of the theorem produces posterior distributions which represent what one should believe given ones prior beliefs and the observed data. The updated beliefs, with regard to parameters or derived parameters of interest, are summarised by statistics from the *marginal* posterior distributions. If a single point estimate is required, then a measure of central tendency for the marginal posterior distribution (either the mode, median, or mean) is calculated. Point estimates and credibility intervals (CIs) are produced from the MCMC samples (e.g., a two-sided 95% CI is constructed by excluding the lowest and highest 2.5% of the MCMC samples; the median is simply the median of all of the MCMC samples).

In New Zealand fisheries stock assessments, the favoured point estimate is the median. The median is probably preferred over the mean because of concerns that the mean may produce overly optimistic estimates of stock status if the marginal posterior distribution is skewed to the right. Of the three choices, the median will generally represent a middle ground between the mode and the mean (they will all be very similar for symmetric marginal posterior distributions and the median will generally be between the mode and the mean for right-tailed distributions).

The MPD point estimates of the parameters of interest may or may not be close to the medians of the marginal posteriors. How the MPD estimates and the MCMC medians relate to each other is of academic interest only. Correct application of Bayesian estimation requires that posterior distributions are calculated. The only advantage of MPD estimation compared to proper Bayesian estimation is its speed. For fisheries stock assessments outside of New Zealand, MPD estimates are often the full extent of a Bayesian estimation procedure. The general claim, in support of this approach, is that the MPD estimates and the MCMC estimates will be very similar. Of course, the veracity of this claim cannot be established unless the MCMC estimates are produced – in which case they should be preferred over the MPD estimates.

The major sources of recent abundance information in the models are acoustic surveys of spawning biomass. For each survey, the spawning biomass estimate is included in the appropriate assessment as an estimate of *relative* spawning biomass rather than *absolute* spawning biomass. The estimates are not used as absolute biomass because there are two major sources of potential bias. The estimates may be biased low or high because the estimate of orange roughy target strength is incorrect. Also, the survey is very unlikely to have covered all of the spawning stock biomass (i.e., the survey availability is unknown). The unknown proportionality constant, or q, for each survey is estimated in the model. To help with this estimation an informed prior is provided for each q. The prior was constructed from two components: orange roughy target strength and survey availability.

Acoustic *q* priors

The target strength prior was derived from the estimates of Macaulay et al. (2013) and Kloser et al. (2013) who both obtained target strength (TS) estimates (at 38 kHz) from visually verified orange roughy as they were herded by a trawl net (the "AOS" system was mounted on the head of the net and acoustic echoes and stereo photos were obtained simultaneously). Macaulay et al. (2013) estimated a TS of –52.0 dB with a 95% CI of –53.3 to –50.9 dB; Kloser et al. (2013) gave a point estimate of –51.1 dB and gave a range, that allowed for the artificial tilt angles of the herded fish, from –52.2 to –50.7 dB (all estimates are for a 33.9 cm fish; adjustments made where necessary using the slope of the length-TS relationship (16.15) estimated by McClatchie et al. 1999). The prior was taken to be normal with a mean of –52.0 dB with 99% of the distribution covered by ± 1.5 dB (which covers both ranges).

For surveys that covered "most" of the spawning stock biomass (e.g., ESCR where in some years surveys covered the "old plume", the "Rekohu plume", and the "Crack") availability was modelled with a Beta(8,2) distribution (this has a mean of 0.8 – i.e., it is assumed *a priori* that 80% of the spawning stock biomass is being indexed). When the availability and TS priors are combined (assuming that they are independent) the result is a prior for the acoustic *q*. This was approximately normal with a mean of 0.8 and a CV of 19%. For surveys that covered less than "most" of the spawning biomass a similar prior was used for the *q* except that a lower mean value was assumed (see individual assessments for how the mean was derived in these cases) and sometimes a higher CV was used. For the NWCR assessment, which was the first one conducted, the *q*-priors were assumed to be normally distributed. Subsequently it was realised that it was more convenient to use a lognormal distribution and this was done for the other three assessments.

The use of values higher than 80%, such as 90–100%, as the base interpretation of "most" is not defensible for two reasons. First, it is known that orange roughy have minor spawning sites in addition to the major sites that are surveyed. For example, for the ESCR stock there are two major spawning aggregations ("old Plume" and "Rekohu plume") with another site nearby ("Mt. Muck" or the "Crack") and multiple other minor sites spread throughout the ESCR (e.g., east hills). It is not feasible to survey all of the spawning sites in any year but experience suggests that 'most" of the biomass is in the sites that are regularly surveyed. The second reason that 90–100% is not defensible as the base assumption is that each annual index is an *average* of biomass snapshots taken during the spawning season. Even in the major spawning sites/aggregations only the plumes can be reliably surveyed and not all of the spawning biomass is pluming at the same time. Snapshot estimates can often vary by a factor of 2 or more during the main spawning season, so that the average across snapshots is not an index of the spawning biomass in the area, but an index of the *average pluming* biomass (e.g., there might be 90% of the stock's spawning biomass in the area but on average only 90% of it is pluming –combining the two factors gives 81% as the average proportion of the spawning stock being indexed).

Values lower than 80%, for use in the base models, could be argued for but the lower the values become the harder they are to defend. A level of 80% was considered reasonable by the DWFAWG for the three stocks where acoustic surveys cover multiple spawning aggregations. For the MEC, only a single aggregation, in a very small area, was surveyed. For this stock the lower value of 60% was used. The sensitivity of the stock assessment results to the assumption for the mean of the acoustic *q*-priors was investigated in multiple MPD runs and also in the MCMC lowM-highq and highM-lowq runs.

The use of a CV of 19% for the *q*-priors may appear low but it is reflective of the excellent knowledge of mean orange roughy target strength that has been achieved in recent years (Macaulay et al. 2013 and Kloser et al. 2013) and the fact that there is not much room between 80% and 100%. A larger CV could perhaps have been used for all *q*-priors where the mean was reduced from 0.8 because some areas were not surveyed. This would reflect a larger level of uncertainty for the *q* caused by possible variation between years in the proportion of spawning biomass found in each area. This was not always done because it was thought unlikely that it would make any difference to the results (a subtle change of the relative weighting of some acoustic indices is not going to matter). The exception to this was for the ESCR where there were a lot of acoustic indices from the old plume time series that were each given a separate *q*. For these "times series" (each with a single year) a CV of 30% was assigned to the *q*-prior to reflect the large uncertainty as to what proportion of the total spawning biomass was being indexed.

Natural mortality

Natural mortality (*M*) was fixed at 0.045 in the base models. In MCMC sensitivities, *M* was estimated with a strongly informed prior, normally distributed with a mean of 0.045 and a CV of 15%. The value of 0.045 has been used in orange roughy assessments since 1994 when it was estimated from data collected on the north Chatham Rise in a 1984 trawl survey (Doonan 1994). The 95% CI was 0.03–0.06. There was a further estimate of *M* obtained from observer sampling in 1996 of the newly developed fishery in the Bay of Plenty (Doonan & Tracey 1997). In this case, *M* was estimated at 0.037 with a 95% CI of 0.02–0.06.

Year class strength estimation

The number of year class strengths (YCS) estimated for each model depended on the age frequency data used in the model. In general a particular YCS was estimated provided that it was observed in at least one age frequency when it was neither "too old" nor "too young". In the case of "too old" the concern is that there is very little information on the cohort because there are very few of them left. In the case of "too young" the concern is that they have a very low selectivity in which case the model is prone to estimate a very large YCS in order to fit what is most likely a "random bump" in the age frequency.

The Haist parameterisation was used for all models (Bull et al. 2012). In the 2013 MEC assessment it was found that the alternative Francis parameterisation unduly restricted YCS estimates as evidenced by a poor fit to the trawl survey biomass indices (Cordue 2014). In contrast the Haist parameterisation, with uniform priors, allowed an excellent fit at the MPD stage and an adequate fit at the MCMC stage. That is not to say that the trawl survey indices were influential in the estimation of the YCS. As was found in the 2014 assessments, YCS estimates are primarily driven by the composition data (age and length frequencies), but if the MEC YCS are unduly penalised, the estimates are restricted to a space which does not allow the trawl biomass indices to be fitted. In the 2014 assessments a "nearly uniform" prior was used with the Haist parameterisation: LN(mode = 1, log-space s.d. = 4).

Data weighting

The general approach taken to data weighting within the stock assessments was to down-weight composition data (length and age frequencies) relative to biomass indices to allow any scale and trend information in the biomass indices to drive the assessment results. This is very much in the spirit 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.

Francis (2011) provided explicit iterative re-weighting methods that could be used to determine effective sizes for composition data provided there were enough years observed in each time series. For the orange roughy assessments his methods could only be explicitly applied to MEC as only short time series of composition data were available for the other three stocks. For time series of composition data (that could not be iteratively re-weighted), effective sample sizes were generally taken to be approximately equal to the number of stations sampled (rather than the number of fish measured/aged). Also, for these short time series of composition data, Pearson residuals were calculated and if any very large residuals were seen (e.g., greater than 3) the effective sample sizes for the whole time series were scaled down sufficiently to reduce the large residuals (e.g., effective sample sizes scaled down by a factor of 2).

Many MPD sensitivity runs were performed to test the effects of changes in data weighting (e.g., see Appendix 2).

Model runs

As far as was appropriate, a consistent set of sensitivity runs were done for each assessment. In addition to a single base model there were runs which estimated natural mortality (*M*); halved and doubled the recent acoustic biomass estimates (to check that the model was sensitive to recent biomass indices); assumed deterministic recruitment (to determine whether the estimation of year class strengths was important or not); increased/decreased the mean of the informed *q*-priors; and two sensitivities that simultaneously increased/decreased *M* and decreased/increased the mean of the informed *q*-priors by 20% (a lower stock status occurs when *M* is decreased and when the mean of the informed *q*-priors is increased; similarly an increased stock status occurs for changes in the other direction). The runs where *M* was estimated ("EstM") and those with the 20% changes in *M* and the mean of informed *q*-priors ("LowM-Highq" and "HighM-Lowq") were taken through to MCMC for every stock.

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 starting at a random jump from the MPD estimate) and 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 the orange roughy assessments, three chains were used and they were run up to a maximum of 15 million samples (see Appendix 3). The three posterior distributions were judged primarily on the basis of their median values as to whether they were sufficiently similar that the chains could be stopped. "Identical" median values were not required (e.g., stock status medians across the three chains of 15, 16, and 17 %B_0 were considered close enough).

Fishing intensity

Fishing intensity was measured in units of 100 – ESD (Equilibrium Stock Depletion, see Cordue 2012 a). That is, the question of "how hard was the stock being fished each year?" was answered by running the model through to deterministic equilibrium at the given level and pattern of fishing each year (using the MPD estimate of parameters or, for MCMCs, doing it at every sample from the posterior). The equilibrium level of spawning biomass is defined to be the ESD for that sample and year (e.g., if the stock is fished at a very high fishing intensity, the equilibrium spawning stock biomass will be close to zero: ESD = 0% B_0; if the stock is being very lightly fished, then ESD = 100% B_0). 100 – ESD ranges from 0–100 with 100 denoting any pattern and level of fishing that would eventually force the stock down to zero spawning biomass. In general, the fishing intensity that forces the stock to deterministic equilibrium at x% B_0 is denoted as U_x.

Reference points

For the calculation of reference points including B_{MSY}, F_{MSY}, MSY, and U_{35} and its associated equilibrium yield, full Bayesian estimation was used. That is, for every sample from the posterior distribution, a deterministic yield curve was calculated and the required reference points determined. Hence, from the MCMC samples of the joint posterior the marginal posterior distributions of the various reference points were obtained. Interpolation with cubic splines was used in the calculations (within the statistical package R using the functions spline and splinefun).

For the stocks with single fisheries (and hence constant selectivity over time for a given posterior sample) interpolation was only necessary in the calculation of the yield curves and the depletion curves (i.e., deterministic yield and depletion were calculated over a range of *U* values and continuous curves were fitted using cubic splines; these curves were applicable to every year of the model). For the ESCR stock, which had four fisheries, there were four periods of years during which the compound selectivity (across the fisheries) was relatively constant. The approach used for constant selectivity was adopted within each of those four time periods (i.e., four sets of yield and depletion curves were calculated). For the MEC stock, which had two fisheries, there were rapid changes in the compound selectivity over time (as the proportion of catch taken by the two fisheries often changed). For this stock, interpolation by cubic splines was used in two dimensions. The yield and depletion curves were constructed over a range of U values and also over a range of p values where p was the proportion of total U from the north fishery (hence, for any given year and posterior sample, the p value could be calculated and the correct yield and depletion curve determined).

Projections

Projections were generally done over a 5-year time period at the level of the current catch and at the 2014–15 yield associated with U_{35}. In each case, the random YCS were brought in immediately after the last estimated YCS and were resampled from the last 10 years of estimates (this is done because YCS are probably correlated rather than being independent from year to year). For long-term projections (e.g., for MEC to estimate T_{min}, the number of years required for the stock to be rebuilt when there is no fishing) the YCS were resampled from all estimated YCS which ensures that the resampled YCS will average to 1 (so that there isn't an implied regime shift). Projections were done for the base model and, as a "worst-case scenario", for the LowM-Highq model.

2.5 Northwest Chatham Rise

An age-structured population model was fitted to acoustic-survey estimates of spawning biomass, a trawl-survey estimate of proportion-at-age and proportion-spawning-at-age, and a few length frequencies from the commercial fishery.

2.5.1 Model structure and fixed parameters

The model was single-sex and age-structured (1–100 years with a plus group) with maturity in the partition (i.e., fish were classified by age and as mature or immature). A single-time step was used and a single fishery was assumed to be year-round on mature fish. Spawning was taken to occur after 75% of the mortality and 100% of mature fish were assumed to spawn each year.

The fixed biological parameters 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

2.5.2 Input data and statistical assumptions

There were three main data sources for observations fitted in the assessment: acoustic-survey spawning biomass estimates from the main spawning hills (Graveyard and Morgue); an age frequency and an estimate of proportion-spawning-at-age from a 1994 wide-area trawl survey; and length frequencies collected from the commercial fishery from 1989–2005.

Acoustic estimates

Three types of acoustic-survey estimates were available for use in the assessment: AOS estimates (from a multi-frequency "Acoustic Optical System" mounted on a trawl net, e.g., see Kloser et al. 2011, Ryan & Kloser 2012); 38 kHz estimates from a towed-body system (Bull et al. 2000, Francis & Bull 2000, Doonan et al. 2003 a); and 38 kHz estimates from a hull-mounted system (e.g., see Soule et al. 2010). The reliability of the data from the different systems in each year was considered and estimates from the AOS and towed-body systems were used in the base model (Table 1). An alternative treatment of the available acoustic data was to include additional survey estimates from 2002 and 2004 (Table 1). All of the data in Table 1 were used in the sensitivity run labelled "Extra acoustics". The acoustic estimates, that were produced using earlier orange roughy length-TS relationships, were converted to the latest mean TS using interpolation from TS sensitivity results in the documents. The latest length-TS relationship is $TS = -76.81 + 16.15 \log_{10}(l)$ where l is the length in cm and TS the mean target strength in dB.

Not all available acoustic survey data were used in the modelling. Wide-area estimates were excluded because they are unreliable due to mixed-species layers and the low target strength of orange roughy relative to other species in the layers (e.g., see the sensitivity analysis in Doonan et al. 2003 a). Also, surveys of hills were excluded if the orange roughy were simply not present at the time (e.g., see Smith et al. 2008 who obtained very low estimates of orange roughy biomass from Graveyard in 2005 using a towed-body system; it appears that the fish were not there at the time they surveyed. On another vessel, using a hull-mounted system to survey Graveyard in the same spawning season, spawning plumes of orange roughy were seen – e.g., see Soule et al. 2010). Estimates from hull-mounted systems on hills are often not reliable because of very large deadzones (e.g., if the fish are on the sides of the hills). The estimates from hull-mounted system estimates from 2004 (Table 1) were included in a sensitivity run because the estimated deadzone was low in that year (i.e., the fish were pluming near the top of the hill or well above the sides of the hill).

Table 1: Acoustic survey estimates of spawning biomass used in the base model (excludes 2002 and 2004) and the sensitivity run "Extra acoustics" (uses all data). "GY" = Graveyard, "M" = Morgue, "O" = other hills. The CVs are those used in the model and do not include any process error.

Year	System	Frequency	Areas	Snapshots	Estimate (t)	CV (%)
1999	Towed-body	38 kHz	GY+M+O	1	8126	22
2002	Towed-body	38 kHz	GY+O	2	9414	20
2004	Hull-mounted	38 kHz	GY	6	2717	16
2012	AOS	38 kHz	GY	3	5550	17
2012	AOS	38 kHz	M	4	9087	11
2013	AOS	120 kHz	GY	1	7379	31

The acoustic estimates in 1999 and 2012 (total = 14 637 t, CV 17%) were assumed to represent "most" of the spawning biomass in each year. This was modelled by treating the acoustic estimates as relative biomass and estimating the proportionality constant (q) with an informed prior. The prior was normally distributed with a mean of 0.8 (i.e., "most" = 80%) and a CV of 19% (see Section 2.4 and Table 1a). The 2013 Graveyard estimate was modelled as relative biomass with an informed prior on the q with a mean of 0.3 (derived from the relative proportions of the Graveyard and Morgue estimates in 2012 with the 80% assumption). In the "Extra acoustics" sensitivity, the 2002 estimate was included with the 1999 and 2012 estimates; and the 2004 estimate was paired with the 2013 estimate (Table 1a).

Table 1a: The *q*-priors used for the acoustic relative biomass time series in the NWCR base model (excludes 2002 and 2004) and the run "Extra acoustics" (uses all data).

Times series years	Distribution	Mean	CV
1999, 2002, 2012	Normal	0.8	0.19
2004, 2013	Normal	0.3	0.19

Trawl survey data

A wide-area trawl survey of the northwest flats was conducted in late May and early June of 1994 (72 stations; Tracey & Fenaughty 1997). An age-frequency for the trawl-selected biomass was estimated using 300 otoliths following the method of Doonan et al. (2013). Also, for the females the proportion spawning-at-age was estimated. These data were fitted in the model: age frequency (multinomial with an effective sample size of 60); proportion-spawning-at-age (binomial with effective sample size at each age equal to the number of female otoliths at age).

A recently developed time series of trawl-survey indices for orange roughy collected in January 2010–2014, at night, during the hoki and middle-depths trawl surveys was not considered for use in the stock assessment. There is a relatively small number of trawl stations in the relevant areas and the time series appears somewhat noisy at this stage. It could be considered for use in future assessments as it develops.

Length frequencies
The length frequencies from the previous assessment in 2006 were used: nine years of length-frequency data from the period 1989–97 were combined into a single length-frequency that was centred on the 1993 fishing year. Eight years of length-frequency data from the period 1998–2005 were combined into a single length-frequency that was centred on the 2002 fishing year. The effective sample size was set at 1/6 of the number of tows for each period: 19 for the "1993" period and 35 for the "2002" period (Hicks 2006). The data were assumed to be multinomial.

2.5.3 Model runs

In the base model the acoustic estimates from 1999, 2012, and 2013 were used and natural mortality (M) was fixed at 0.045. There were five main sensitivity runs: estimate M; add the extra acoustic data and fix M; add the extra acoustic data and estimate M; and the LowM-Highq and HighM-Lowq "standard" runs (see Section 2.4).

In the base model the main parameters estimated were: virgin biomass (B_0), maturity ogive, trawl-survey selectivity, CV of length-at-mean-length-at-age for ages 1 and 100 years (linear relationship assumed for intermediate ages), and year class strengths (YCS) from 1940 to 1979 (with the Haist parameterisation and "nearly uniform" priors on the free parameters).

2.6 East and South Chatham Rise

An age-structured population model was fitted to acoustic-survey estimates of spawning biomass, trawl-survey biomass indices, age frequencies from spawning aggregations, and length frequencies from trawl surveys and commercial fisheries.

2.6.1 Model structure and fixed parameters

The model was single-sex and age-structured (1–100 years with a plus group) with maturity in the partition (i.e., fish were classified by age and as mature or immature). A single-time step was used and four year-round fisheries, with logistic selectivities, were modelled: Box & flats, Eastern hills, Andes, and South Rise. These fisheries were chosen following Dunn (2007) who assessed the Box & flats, Eastern hills, and Andes as separate stocks and hence had already prepared length frequency data for those fisheries. No length frequencies were available from the South Rise fishery and its selectivity was assumed to be the same as the Andes (so effectively there were three fisheries in the model). Spawning was taken to occur after 75% of the mortality, and 100% of mature fish were assumed to spawn each year.

The fixed biological parameters 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

In a sensitivity run, which assumed that the spawning plume first found near Rekohu canyon in 2010 had always existed, a spatially-explicit model structure was used. There were four areas to allow for the three known spawning sites (Rekohu, Old plume, Crack) and an area to hold the remainder of the spawning fish. The areas were only used at (an instantaneous) spawning time to allow the fitting of area-specific data (acoustic estimates and age frequencies). The four year-round fisheries were unchanged.

2.6.2 Input data and statistical assumptions

There were four main data sources for observations fitted in the assessment: acoustic-survey spawning biomass estimates from the old plume (2002–2013), Rekohu (2011–2013) and the Crack (2011, 2013); age frequencies from the spawning areas (2012 and 2013); trawl survey biomass indices and length frequencies; and early length frequencies collected from the commercial fisheries.

Acoustic estimates

The "old plume" was acoustically surveyed as early as 1996, but the survey estimates are only considered to represent a consistent time series from 2002–2012 (see Cordue 2008; Hampton et al. 2008, 2009, 2010; Doonan et al. 2012). Like the Rekohu plume, that was first noted in 2010 and first surveyed in 2011, the old plume occurs on an area of flat bottom and is adequately surveyed using a hull-mounted transducer. In 2011 and 2013, an additional spawning area was surveyed; known as the "Crack" or "Mt. Muck", it is an area of rough terrain which requires a towed-body or trawl-mounted system to be used to reduce the height of the shadow or dead zone (i.e., with the transducer at a depth of about 500–700 m).

The estimates selected by the DWFAWG for use in the stock assessment are shown in Table 2. In 2013 there were a variety of estimates to choose from as surveys were conducted with a hull-mounted system and a multi-frequency AOS system mounted on the trawl net. In order to make the estimates as comparable as possible across years only the 38 kHz estimates were used and those from the hull-mounted system were weather-adjusted in the same way as earlier estimates (see presentations from Kloser and Ryan to the DWFAWG meetings in 2013/14).

Table 2: Acoustic estimates of average pluming spawning biomass in the three main spawning areas as used in the assessment. All estimates were obtained from surveys on *FV San Waitaki* from 38 kHz transducers. Each estimate is the average of a number of snapshots as reflected by the estimated CVs.

	Old plume		Rekohu		Crack	
	Estimate (t)	CV (%)	Estimate (t)	CV (%)	Estimate (t)	CV (%)
2002	63 950	6				
2003	44 316	6				
2004	44 968	8				
2005	43 923	4				
2006	47 450	10				
2007	34 427	5				
2008	31 668	8				
2009	28 199	5				
2010	21 205	7				
2011	16 422	8	28 113	18	6 794	21
2012	19 392	7	27 121	10		
2013	16 312	25	29 890	14	5 471	15

A key question that needs to be answered in order to use the acoustic data appropriately is: how long has the Rekohu plume been in existence? If the Rekohu plume has always existed (and was not discovered until 2010) then it would simply be one of three major spawning sites and could be modelled as such along with the old plume and the Crack. This would imply that the old-plume time series was tracking a consistent part of the spawning biomass (and its decline over time was therefore an important indicator of stock status). If, on the other hand, the Rekohu plume had very recently formed, this would imply that the old-plume time series was a biomass index only up until the year before the creation of the Rekohu plume.

In the base model it is assumed that the old-plume time series cannot be relied on to provide a consistent index for any part of the spawning biomass. In 2011 and 2013, the estimates of average spawning biomass across the three areas were summed together to form a single short time series. The 2012 estimates from Rekohu and the old-plume were summed together to provide a 2012 index with a different proportionality constant or q. The remainder of the old-plume time series from 2002–2010 was used but each point in the time series was given its own q. Informed priors were used for all of the *q*s in the old-plume series and for 2012 and the "2011 & 2013" series.

For 2011 & 2013, it was assumed that "most" of the biomass was being indexed so the "standard" acoustic *q* prior was used: lognormal(mean = 0.8, CV = 19%) (see Section 2.4 and Table 2a). The mean of the *q* prior for 2012 was derived from the observed biomass proportions across the three areas and the assumption that 80% of the spawning biomass was indexed in 2011 and 2013, which gave a mean of 0.7. For 2002 to 2010 the means of the *q* priors were assumed to decrease linearly from 0.7 (2002) down to 0.30 (2010). The linear sequence was derived by assuming 0.7 in 2002 (i.e., assuming that the Rekohu plume did not exist and only the Crack was missing from the survey estimate) and using the observed biomass proportions in 2011 with the 80% assumption (which gave the old-plume being about 25% of the total spawning biomass). To reflect the increased uncertainty in the acoustic *q*s in years other than 2011 and 2013 the priors were given a CV of 30% (Table 2a).

Table 2a: The *q*-priors used for the acoustic relative biomass time series in the ESCR base model . Note, the old-plume time series 2002–2010 was split into nine separate "time series" each with only a single year (i.e., a different *q* in each year).

Times series years	Distribution	Mean	CV
2011, 2013	Log normal	0.80	0.19
2012	Log normal	0.70	0.30
2002	Log normal	0.70	0.30
2003	Log normal	0.65	0.30
2004	Log normal	0.60	0.30
2005	Log normal	0.55	0.30
2006	Log normal	0.50	0.30
2007	Log normal	0.45	0.30
2008	Log normal	0.40	0.30
2009	Log normal	0.35	0.30
2010	Log normal	0.30	0.30

For the sensitivity run where the Rekohu plume was assumed to have always existed the specification of priors was done by splitting the two parts of the standard acoustic *q* prior. The proportion of spawning biomass indexed across all three areas combined was assigned a Beta(8,2) prior (which has a mean of 0.8). This is the availability part of the standard acoustic *q* prior. A single *q* was assumed for the spawning biomass estimates in each area and this was given the target strength part of the standard acoustic *q* prior (which has a mean of 1). (See Appendix 4 for the full details of this run in the CASAL files.)

Trawl survey data

Research trawl surveys of the Spawning Box during July were completed from 1984 to 1994, using three different vessels: *FV Otago Buccaneer*, *FV Cordella*, and *RV Tangaroa* (Figure 5). A consistent area was surveyed using fixed station positions (with some random second phase stations each year).

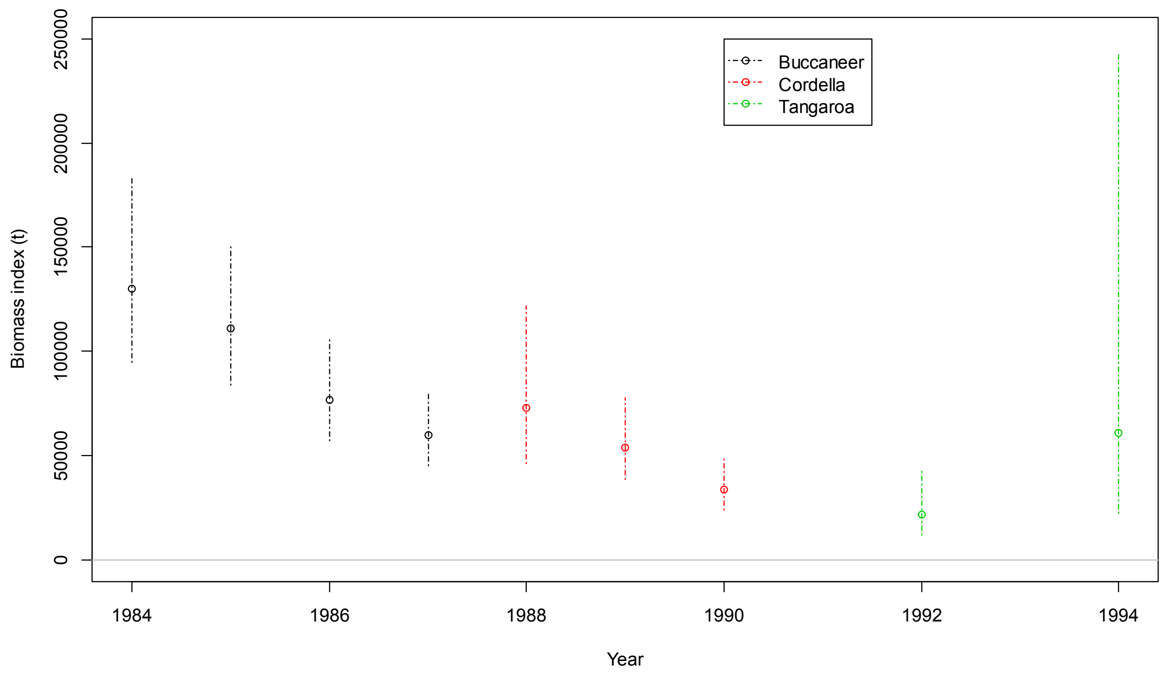

Figure 5: The Spawning Box trawl survey biomass indices (assuming a catchability of 1 for each vessel), with 95% confidence intervals shown as vertical lines.

The biomass indices were fitted as relative indices with a separate time series for each vessel (with uninformed priors on the *q*s). The second point in the *Tangaroa* time series is suspect as the estimate was driven by a single high catch (but it has a large CV so will not affect the assessment results).

Data from two wide-area surveys by *Tangaroa* in 2004 and 2007 were also used. These surveys covered the area which extends from the western edge of the Spawning Box around to the northern edge of the Andes. The area surveyed did not include the spawning plume, the Northeast Hills, or the Andes. The survey used a random design over sixteen strata grouped into five sub-areas. The trawl net used was the full-wing and relatively fine mesh 'ratcatcher' net. The surveys covered the same survey area as the Spawning Box trawl surveys from 1984 to 1994 as well as additional strata to the east. In 2007, the survey ran from 4–27 July and 62 trawl tows were completed. In 2004, the survey ran from 7–29 July and 57 trawl tows were completed.

The surveys had almost identical estimates of total biomass in each year (17 000 t) with low CVs (10% and 13% respectively). They were fitted as relative biomass with an uninformed prior on the *q*.

Length frequencies

The length frequencies from all of the trawl surveys were fitted in the model as multinomial random variables. Effective sample sizes (N) were taken from Dunn (2007) for the spawning box surveys and were assumed equal to the number of tows for the wide-area surveys (across all surveys the effective Ns ranged from about 20–80).

Length frequencies from the commercial fisheries developed by Dunn (2007) were also fitted in the model. These were fitted as multinomial with effective sample sizes ranging from 8–38.

Age frequencies

Age frequencies were developed for the old plume and Rekohu in 2012 and 2013 and also for the Crack in 2013 (Ian Doonan, NIWA, pers. comm.). Approximately 300 otoliths were used from each area in 2012 and 250 from each area in 2013. In 2012, the fish in the old plume were noted as being generally older than those in the Rekohu plume. This pattern was also apparent in 2013 (Figure 6). The fish from the Crack showed a mixture of ages from new spawners (20–30 years) through to much older fish (80–100 years)(Figure 6). In the base model the age frequencies were combined across areas and fitted as multinomial with effective sample sizes of 50 and 60 respectively (reflecting the low number of trawls from which samples were taken).

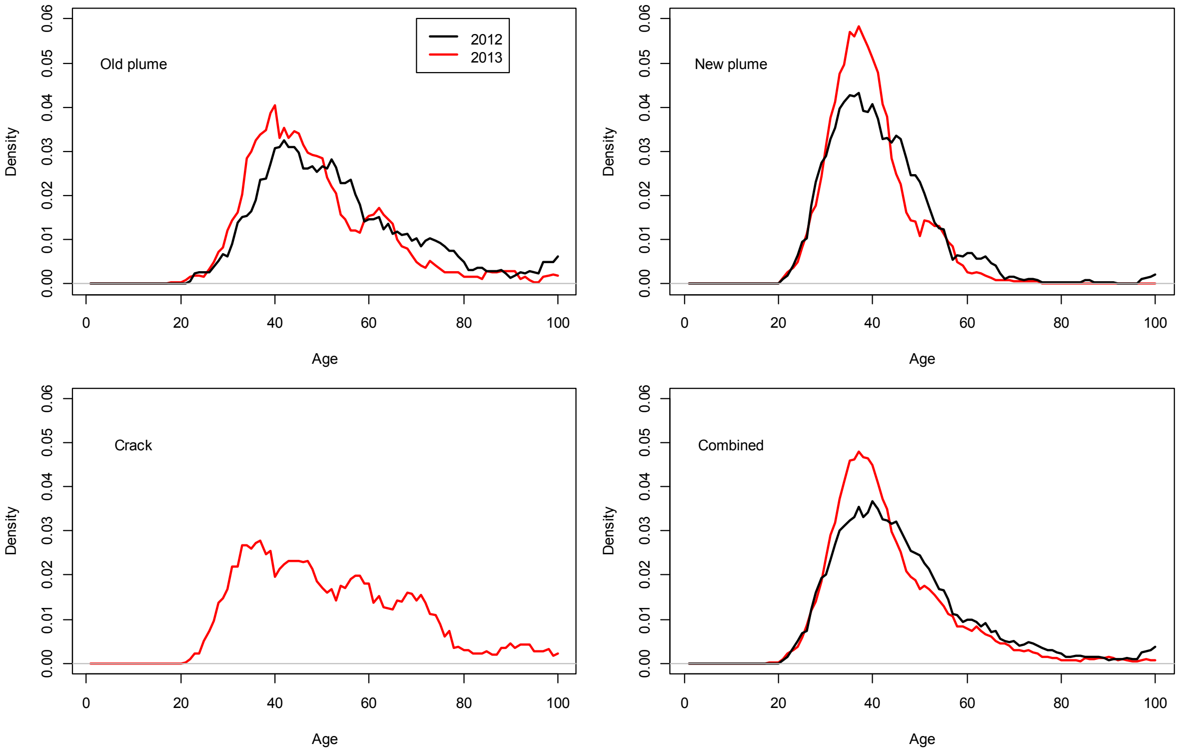

Figure 6: ESCR: *smoothed* spawning season age frequencies for the old plume (2012, 2013), Rekohu (2012, 2013), and the Crack (2013) and for all three areas combined (2012, 2013).

2.6.3 Model runs

In the base model, the old-plume time series was assumed to be unreliable in terms of trend and therefore each point from 2002 to 2010 was given its own q (Table 2a); also, natural mortality (M) was fixed at 0.045. There were several important sensitivity runs: assume that Rekohu had always existed; assume that it was created in 2007; assume it was created in 2010; estimate M; adjust M and the mean of the priors by 20% (the standard LowM-Highq and HighM-Lowq runs, see Section 2.4).

In the base model the main parameters estimated were: virgin biomass (B_0), maturity ogive, trawl-survey selectivities, fisheries selectivities, CV of length-at-mean-length-at-age for ages 1 and 100 years (linear relationship assumed for intermediate ages), and year class strengths (YCS) from 1930 to 1990 (with the Haist parameterisation and "nearly uniform" priors on the free parameters). There were also the numerous acoustic and trawl-survey qs.

2.7 ORH 7A

The assessment was the first model-based assessment since 2005 when a Bayesian model was used to update the 2000 assessment (Annala et al. 2000, Field & Francis 2001). From 2010 to 2013, assessments were conducted using an ad hoc approach which combined the virgin biomass estimate from the 2000 assessment and current biomass estimates from annual combined acoustic and trawl surveys (see Clark et al. 2006, NIWA & FRS 2009, Doonan et al. 2010, Hampton et al. 2013, Hampton et al. 2014, Cordue 2010, 2012 b, 2013).

An age-structured population model was fitted to combined acoustic and trawl-survey estimates of spawning biomass, two trawl-survey time series of spawning biomass, and three trawl-survey age frequencies.

2.7.1 Model structure and fixed parameters

The model was single-sex and age-structured (1–100 years with a plus group) with maturity in the partition (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 fishery on the spawning fish. The fishery selectivity was uniform across ages (for spawning fish) and 100% of mature fish were assumed to spawn each year.

The fixed biological parameters were:

Natural mortality:	0.045
Beverton-Holt steepness:	0.75
Length-weight (a, b):	9.21e–5, 2.71 (cm to kg)
von Bertalanffy (L_∞, k, t_0):	34.2 cm, 0.065, –0.5 years

2.7.2 Input data and statistical assumptions

There were three main data sources for observations fitted in the assessment: spawning biomass estimates from combined acoustic and trawl surveys (2006, 2009–2013); an early trawl-survey time series of relative spawning biomass (1987–1989); and three age frequencies from the trawl surveys (1987, 2006, and 2009).

Research surveys
Trawl surveys of orange roughy on the Challenger Plateau were conducted regularly from 1983 to 1990. However, a variety of vessels and survey strata were used which makes comparisons problematic. Wingtip biomass estimates in 1983–1986 ranged from 100 000–185 000 t but in 1989 and 1990 the estimates were approximately 10 000 t. From these early trawl surveys the "comparable area" series of Clark & Tracey (1994) from 1987–89 was selected for use in the assessment to provide some information on the early rate of spawning biomass decline (Table 3).

In 2005, a new series of combined trawl and acoustic surveys began using the *FV Thomas Harrison* with a survey area comparable to that used from 1987–1990 (Clark et al. 2005). The survey was repeated in 2006 (with an enlarged survey area) and then conducted annually from 2009–2013 (Clark et al. 2006, NIWA & FRS 2009, Doonan et al. 2010, Hampton et al. 2013, Hampton et al. 2014). It was apparent from later surveys that the 2005 survey did not cover an appropriate area as the spawning biomass distribution had shifted. The surveys from 2006 onwards do appear to have covered the bulk of the spawning biomass. The data from these surveys have been analysed to produce three types of indices that were used in the assessment: combined acoustic and trawl survey spawning biomass; acoustic estimates of spawning plumes; trawl survey indices of spawning biomass.

Combined acoustic and trawl survey indices
The method of Cordue (2010, 2012 b) was used to produce combined acoustic and trawl survey indices for 2010 and 2013 (Table 3). The method uses an estimate of orange roughy trawl vulnerability to allow the trawl survey estimates to be combined with the acoustic estimates (trawl estimates are essentially scaled down by a vulnerability distribution with a mean of 1.66). The method accounts for observation error and potential bias in orange roughy target strength by combining priors and "error distributions" centred on the observations (Cordue 2010, 2012 b). Strata 9–11 were excluded from the estimates as they covered hills and/or very rough terrain (i.e., were not included because orange roughy are probably not equally vulnerable to the trawl on the hills and on the flat).

The 2010 and 2013 surveys were used in this way for different reasons. In 2010, the survey specifically excluded spawning plumes from the trawl survey strata and the plumes were surveyed acoustically. In other years, plumes were not explicitly excluded from the trawl survey area and a number of random trawl stations did obtain very high catch rates in the vicinity of plumes. The 2010 design was specifically aimed at combining the acoustic and trawl survey estimates.

The 2013 survey had three trawl stations with very high catch rates in two strata which were near where spawning plumes were surveyed. As a consequence, the trawl survey index had a very high CV of 51%. It seemed better to replace the trawl estimates from the two "plume" strata with the corresponding acoustic estimates and combine them with the remaining trawl estimates (following Cordue 2012 b) which gave a combined index with a lower CV of 35% (Table 3).

The estimates were used as relative biomass with a lognormal informed prior on the *q* (Table 3a). The total survey area was assumed to cover 90% of the spawning biomass and the three excluded strata (9–11) were estimated to account for 15% of the surveyed biomass (from years in which they were surveyed). The mean of the informed prior was therefore 0.9 × 0.85 = 0.77. The CV was chosen so that the CVs for the prior and the observation were equal in 2010. The combined CV from observation error and the prior were equal to 0.3 (2010) and 0.35 (2013) (the CVs of the distribution-estimates of spawning biomass). This gave a prior CV of 0.21.

Acoustic estimate for two plumes in 2009

In 2009, on the 4–5 July, two spawning plumes were acoustically surveyed. The main plume was covered by two snapshots and had a much higher average biomass than was seen in the previous few days (28 June–2 July): 16 800 t compared to 6700 t. A second plume was also surveyed with a single snapshot (6300 t) and the combined estimate was 23 100 t (Table 3). This was an unusual event in that most of the spawning biomass was perhaps present in the two plumes.

The estimate was assumed to represent "most" of the spawning biomass in 2009. This was modelled by treating the acoustic estimate as relative biomass and estimating the proportionality constant (*q*) with an informed prior. The "standard" acoustic *q* prior was used: a mean of 0.8 (i.e., "most" = 80%) and a CV of 19% (Table 3a).

Trawl survey indices

The spawning biomass estimates from the *Thomas Harrison* trawl surveys in 2006, 2009–2012 (Table 3) were used as relative biomass with an informed prior. They excluded strata 9–11 and the mean of the informed prior was: 0.9 × 0.85 × 1.66 = 1.27 (allowing for total-survey availability (0.9), exclusion of strata 9–11 (0.85) and trawl vulnerability – mean of estimated vulnerability distribution = 1.66). Given the problematic nature of these trawl surveys (fish pluming and moving within the area) a process error CV of 20% was added to the estimated CVs (Table 3).

Table 3: Biomass indices used in the stock assessment. The model CV is the observation error used in the base model. A 20% process error CV has been added to the sample CV for the trawl indices. The CV for the combined acoustics and trawl estimates has been split between the informed *q*-prior (CV = 21%) and the observation error in the model.

Series	Year	Biomass index (t)	CV (%)	Model CV (%)
Amaltal Explorer	1987	75 040	26	33
	1988	28 954	27	34
	1989	11 062	11	23
Thomas Harrison	2006	13 987	27	34
	2009	34 864	24	31
	2011	18 425	26	33
	2012	22 451	18	27
	2013	18 993	51	55
Acoustics & trawl	2010	14 766	30	21
	2013	13 637	35	28
Two plumes	2009	23 095	25	25

Table 3a: The *q*-priors used for the relative biomass time series in the ORH 7A base model . "–" means not applicable.

Time series	Distribution	Mean	CV
Amaltal Explorer	Uniform-log	–	–
Thomas Harrison	Log normal	1.27	0.30
Acoustics & trawl	Log normal	0.77	0.21
Two plumes	Log normal	0.80	0.19

Age frequencies
Age frequencies were estimated for three of the trawl surveys for use in the assessment. A previous analysis had already produced age frequencies for the 1987 *Amaltal Explorer* survey and the 2009 *Thomas Harrison* survey (Doonan et al. 2013). However, that study was based on a relatively small number of otoliths (although it was successful in showing that the 2009 age frequency had much younger fish than the 1987 age frequency). For the stock assessment the existing age frequencies were re-estimated with an increased number of otoliths (about 300 for each survey) and a new age frequency (with about 300 otoliths) was produced for the 2006 *Thomas Harrison* survey.

The age frequencies were assumed to be multinomial and were assigned effective sample sizes of 300/5 = 60 (being of a similar magnitude to the number of trawl stations rather than the number of otoliths).

2.7.3 Model runs

In the base model natural mortality (M) was fixed at 0.045. There were numerous MPD sensitivity runs but the three main sensitivities were: estimate M; and the LowM-Highq and HighM-Lowq "standard" runs (see Section 2.4).

In the base model the main parameters estimated were: virgin biomass (B_0), the maturity ogive, and year class strengths (YCS) from 1925 to 1985 (with the Haist parameterisation and "nearly uniform" priors on the free parameters). There were also the proportionality constants (qs) for the two trawl survey time series, the combined acoustic and trawl estimates (2010, 2013) and the two-plumes estimate in 2009.

2.8 Mid-East Coast

The MEC stock assessment was updated in 2014 using the methods common to the four assessments performed in 2014 (see Section 2.4). The previous model-based assessment in 2013 used data which did not meet the quality threshold applied in 2014 (i.e., CPUE indices, wide-area acoustic survey and egg-survey estimates; see Cordue 2014). In 2014, an age-structured population model was fitted to an acoustic-survey estimate of spawning biomass (2013), trawl-survey biomass indices (1992–94, 2010), trawl-survey length and age frequencies and estimates of proportion spawning at age, length frequencies from the commercial fisheries, and age frequencies from the spawning population.

2.8.1 Model structure and fixed parameters

The model was single-sex and age-structured (1–120 years with a plus group) with maturity in the partition (i.e., fish were classified by age and as mature or immature). A single area and a single time step were used with two year-round fisheries defined by different selectivities (a "south" fishery catching young fish (double-normal selectivity) and a "north" fishery catching older fish (logistic selectivity)). The spawning season was assumed to occur after 75% of the mortality, and 100% of mature fish were assumed to spawn each year.

The fixed biological parameters were:

Natural mortality:	0.045
Beverton-Holt steepness:	0.75
Length-weight (a, b):	9.21e–5, 2.71 (cm to kg)
von Bertalanffy (L_∞, k, t_0):	37.63 cm, 0.065, –0.5 years

2.8.2 Input data and statistical assumptions

There were three main data sources for observations fitted in the assessment: a spawning biomass estimate from an acoustic survey (2013); a trawl-survey time series of relative biomass indices (1992–1994, 2010) with associated length frequencies (1992, 1994), and age frequencies and estimates of proportion spawning at age (1993, 2010); and length and age frequencies collected from the commercial fisheries, including four spawning-season age frequencies (1989–1991, 2010).

Research surveys

The MEC area has been surveyed using acoustic and trawl methods and egg surveys have also been conducted. Not all survey data were used in the 2014 assessment. The egg survey estimates appear very problematic; the 1993 survey data were post-stratified and "corrected" for turn-over of fish (Zeldis et al. 1997). The egg-survey estimate was used in the 2013 assessment but was not considered to be reliable enough for the 2014 assessment (which had a higher "quality threshold"). Similarly, the wide-area acoustic survey estimates from 2001 and 2003 (Doonan et al. 2003 b, 2004) were also rejected in 2014 as being unreliable (in particular, because the biomass estimates primarily came from mixed species marks and "orange roughy" marks that were identified subjectively; rather than being from easily identified spawning plumes).

Trawl survey data

A time series of pre-spawning season, random, stratified, trawl surveys were conducted in March-April on *RV Tangaroa* in 1992–94 and 2010 (Grimes et al. 1994, 1996a, 1996b, Doonan & Dunn 2011). The 2010 survey was specifically designed to be comparable with the earlier surveys and to produce an abundance index for the MEC home grounds (Doonan & Dunn 2011). In addition to the relative biomass indices (Table 4), the survey data were analysed to produce length frequencies from all years and age frequencies from 1993 and 2010 (Doonan et al. 2013). Also, estimates of female proportion-spawning-at-age were produced for the 1993 and 2010 surveys (Ian Doonan, pers. comm.).

The biomass indices were fitted as relative biomass with a double-normal selectivity (it is apparent that the trawl survey does not fully select the largest/oldest fish) and an uninformed prior on the proportionality constant (q). The length frequencies from 1992 and 1994 were fitted as multinomial, as were the age frequencies from 1993 and 2010 (the length frequencies from 1993 and 2010 had been used in the production of the age frequencies). The proportion spawning at age was assumed binomial at each age. Effective sample sizes were all taken from the 2013 assessment (Cordue 2014).

Acoustic survey estimate

The only reliable acoustic estimate of spawning biomass for MEC came in 2013 when a multi-frequency "AOS" survey was conducted (acoustic and optical gear mounted on the trawl headline – e.g., see Kloser et al. 2011). Four areas were visited in 2013 but the only substantial spawning plume was seen in the "valley" (a known spawning site near Ritchie Bank). Four snapshots were done and the estimates from 38 kHz were averaged to produce a biomass index (Table 4).

The "standard" assumption in the 2014 stock assessments, for acoustic estimates from spawning plumes, is that they collectively cover "most" of the spawning biomass where "most" is taken to be 80%. However, for MEC, only one spawning plume was found and it was in a very small area. There are many potential sites in the MEC for spawning plumes. For these reasons, "most" was reduced to be 60% in the base model (and sensitivities were done at 40% and 80%). That is, the acoustic estimate was fitted as relative biomass with an informed prior: lognormal(mean = 0.6, CV = 19%)(Table 4a).

Table 4: Biomass indices and CVs used in the MEC stock assessment.

Year	Trawl index (t)	CV (%)	Acoustic index (t)	CV (%)
1992	20 838	29		
1993	15 102	27		
1994	12 780	14		
2010	7 074	19		
2011				
2012				
2013			4 225	20

Table 4a: The *q*-priors used for the relative biomass time series in the MEC base model . "–" means not applicable.

Time series	Distribution	Mean	CV
Trawl	Uniform-log	–	–
Acoustics	Log normal	0.60	0.19

Commercial age and length frequencies

As in the 2011 and 2013 stock assessments, composition data were also used: length frequency samples from the commercial fishery in the north (ORH 2A south and ORH 2B) for 16 years between 1988–89 and 2009–10, and the south (ORH 3A) for nine years between 1989–90 and 2008–09, and age frequency samples from commercial landings of the spawning fishery in ORH 2A south in 1989, 1990, and 1991. The otoliths from the 1989–91 samples were re-aged for the 2013 assessment using the new ageing protocol (Tracey et al. 2007). In addition, age samples taken from a single vessel in the 2010 spawning season were also used. These had been aged with the new protocol but because they were from a single vessel and a fishery 20 years later than in 1990 the age frequency was fitted with its own selectivity. The age frequencies from 1989–91 were assumed to be from spawning fish (i.e., no selectivity fitted). The composition data were all assumed to be multinomial and effective sample sizes from the 2013 assessment were used (except that the south fishery length frequencies were down-weighted following the iterative reweighting procedure of Francis 2011).

2.8.3 Model runs

In the base model natural mortality (M) was fixed at 0.045. There were numerous MPD sensitivity runs but the six main sensitivities were: estimate M; down-weight the trawl indices; separate selectivity for spawning age frequencies; mean acoustics q-prior = 0.4; and the LowM-Highq and HighM-Lowq "standard" runs (see Section 2.4).

In the base model the main parameters estimated were: virgin biomass (B_0), the maturity ogive, the two fishery selectivities, the trawl survey selectivity, the 2010 age-frequency selectivity, and year class strengths (YCS) from 1881 to 1996 (with the Haist parameterisation and "nearly uniform" priors on the free parameters). There were also the CV of length-at-mean-length-at-age parameters and the proportionality constants (qs) for the trawl-survey time series and the 2013 acoustics estimate.

3. RESULTS

3.1 Northwest Chatham Rise

Model diagnostics

The base model provided good MPD fits to the data (Figures 7 and 8). The acoustic indices, free to "move" somewhat as they are relative, were very well fitted with the normalised residuals close to zero except in 2013 (Figure 7, top right). The estimated acoustic qs were not very different from the mean of the informed priors (Figure 7, bottom). The same is not quite true for the MCMCs, although the posteriors for the acoustic qs are not very different from the priors there has clearly been some movement (Figure 9).

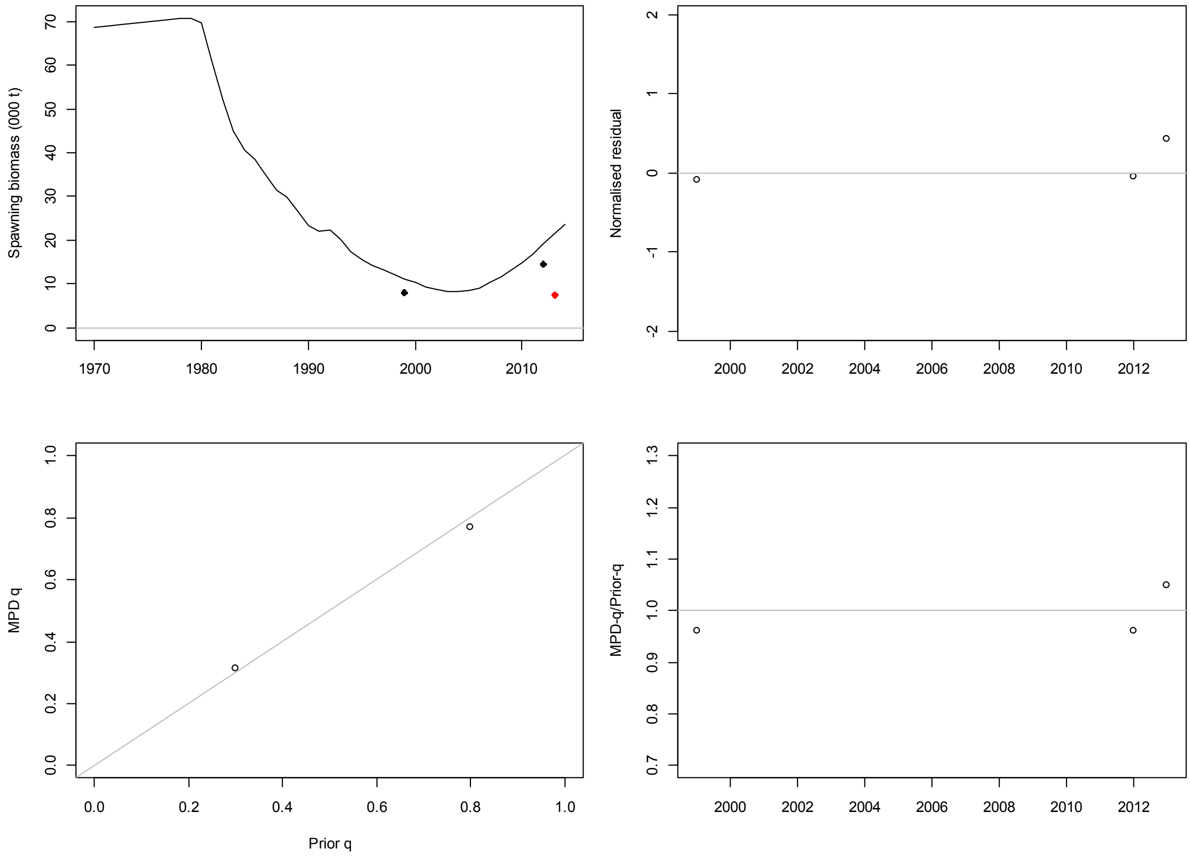

Figure 7: NWCR, base, MPD: fits to the acoustic indices: (top) spawning biomass trajectory and unscaled acoustic indices; normalised residuals; (bottom) estimated *q*s as a function of the mean of the *q* prior; the ratio of the estimated *q* to the mean of the *q* prior.

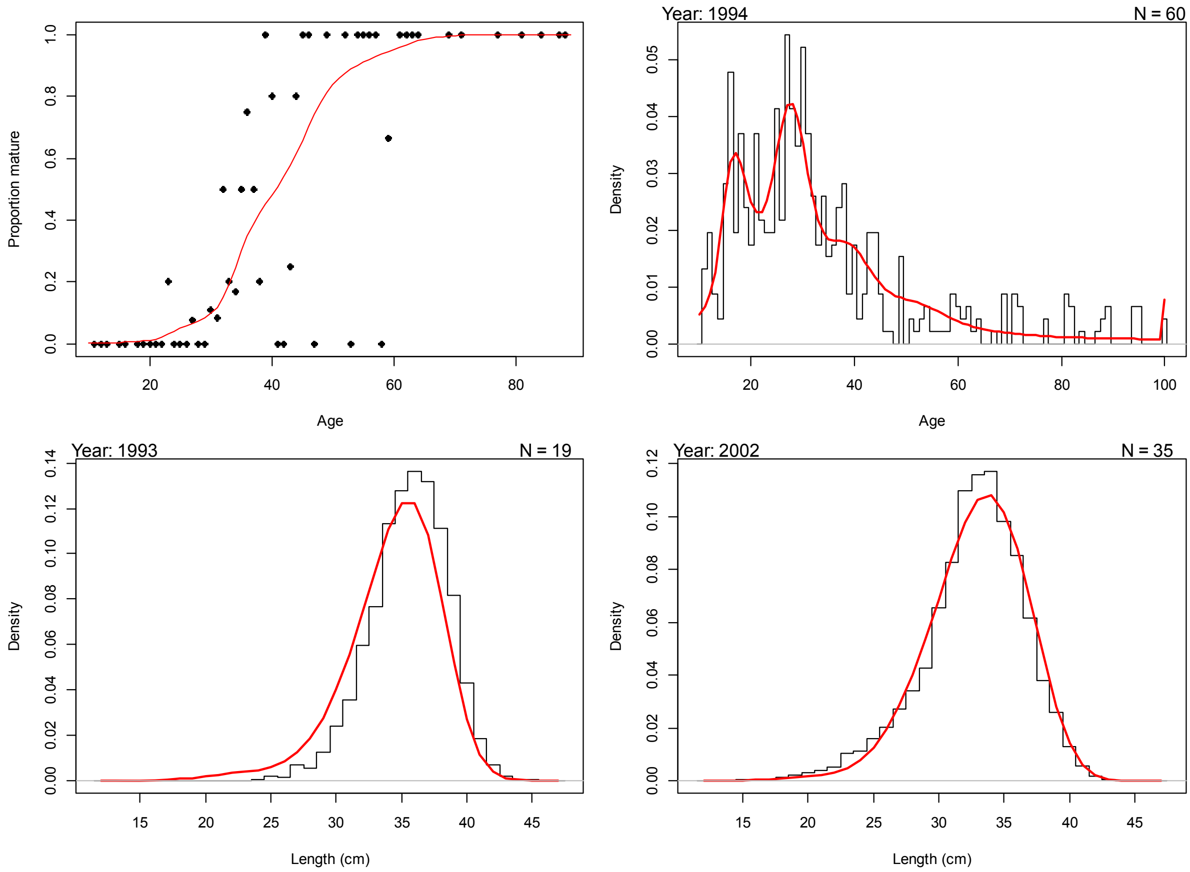

Figure 8: NWCR, base, MPD fits: (observations in black; predictions in red): (top) proportion mature at age; trawl survey age frequency ; (bottom) commercial length frequencies (N is the effective sample size).

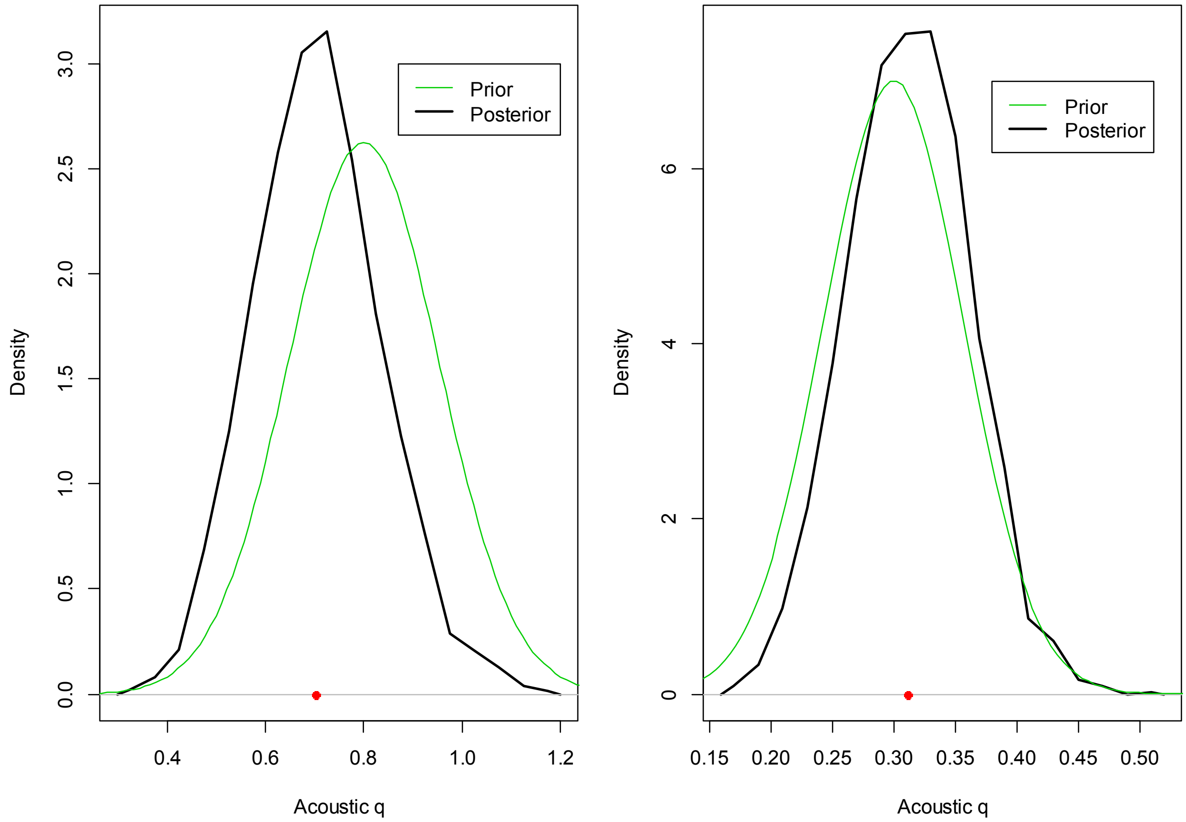

Figure 9: NWCR base, MCMC diagnostics: prior and posterior distributions for the two acoustic *q*s (left, mean *q*-prior = 0.8; right, mean q-prior = 0.3). The red dot shows the median of the posterior.

Numerous MPD sensitivity runs were performed (see Appendix 2). They showed that the main drivers of estimated stock status were natural mortality (*M*) and the means of the acoustic *q* priors (lower *M* and higher mean *q* give lower stock status; higher *M* and lower mean *q* give higher stock status).

MCMC results

For the base model, and the sensitivity runs, MCMC convergence diagnostics were excellent (Appendix 3). Virgin biomass was estimated to be about 65 000 t for all runs (Table 5). Current stock status was similar across the base and the first three sensitivity runs (Table 5). The slightly lower stock status when *M* was estimated reflects the lower estimates of *M* (0.04 rather than 0.045). For the two "bounding" runs, where *M* and the mean of the acoustic *q* priors were shifted by 20%, median current stock status was estimated outside of the biomass target range of 30–40% B_0 for both runs (Table 5).

Table 5: NWCR, MCMC estimates of virgin biomass (B_0) and stock status (B_{2014} as %B_0) for the base model and five sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2014} (%B_0)	95% CI
Base	0.045	66	61–76	37	30–46
Extra acoustics	0.045	64	60–69	34	29–41
Estimate M	0.041	68	61–78	34	26–45
Extra & Est. M	0.040	67	60–74	32	25–40
LowM-Highq	0.036	68	64–76	28	23–36
HighM-Lowq	0.054	66	59–78	46	38–56

The estimated YCS showed little variation across cohorts (Figure 10). The variation in the more recent (true) YCS is due to variation in depletion levels across the MCMC samples (and hence different levels of recruitment taken off the stock-recruitment curve).

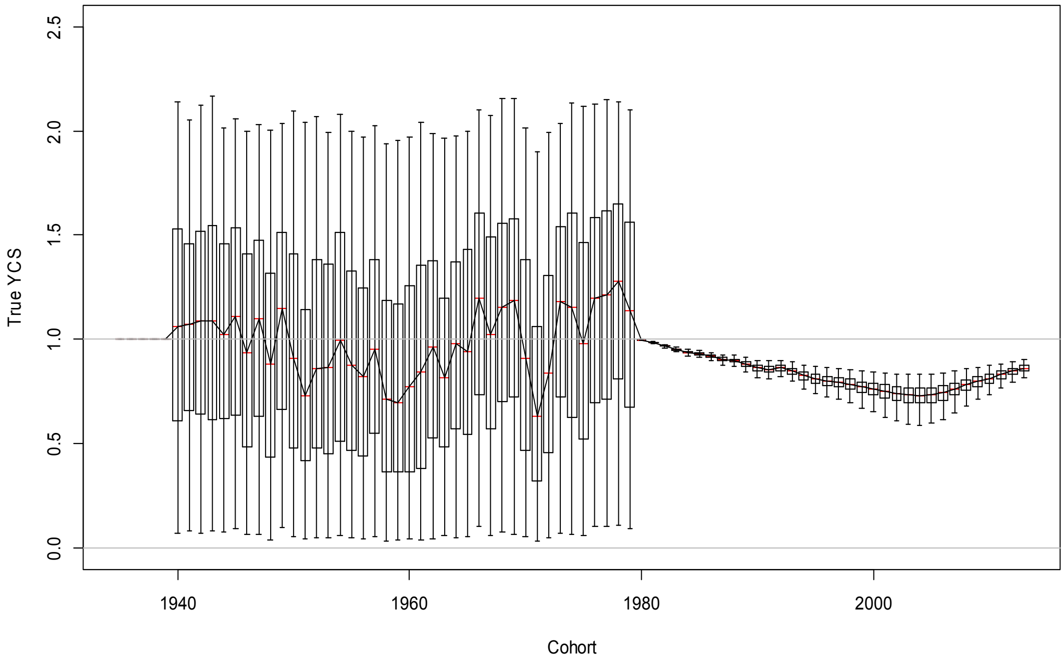

Figure 10: NWCR base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The estimated spawning-stock biomass (SSB) trajectory shows a declining trend from 1980 (when the fishery started) through to 2004 when the biomass was About as Likely as Not (40–60%) to be below the soft limit (Figure 11). Since 2005 the estimated biomass has increased steadily.

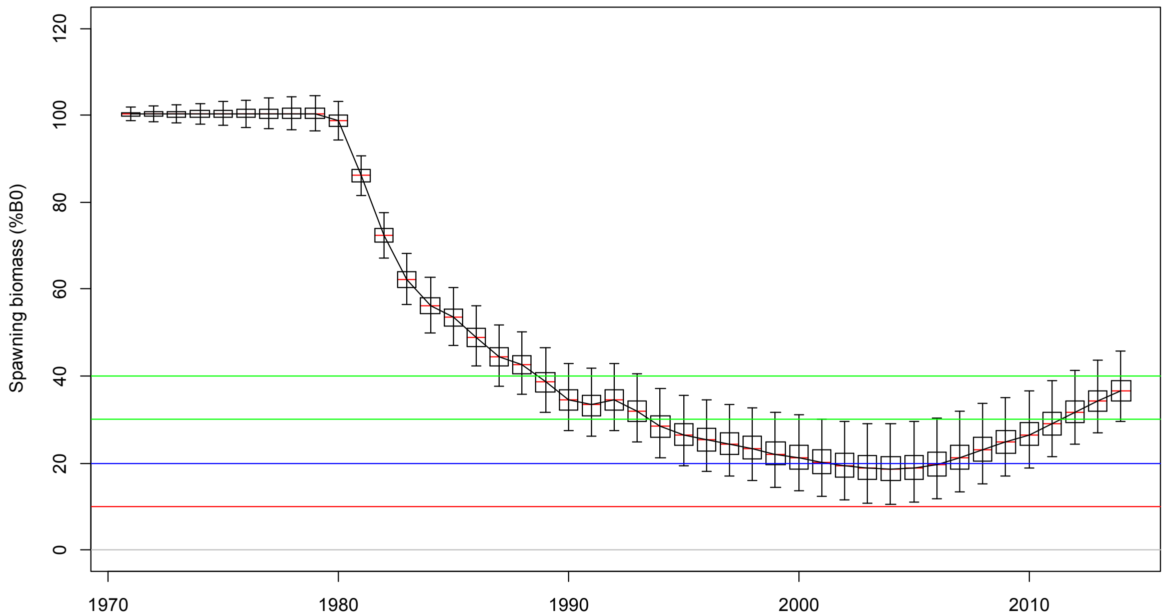

Figure 11: NWCR base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit (red), soft limit (blue), and biomass target range (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity in each year. Fishing intensity is represented in term of Equilibrium

Stock Depletion (ESD), where an intensity of U_x means that fishing (forever) at that intensity will cause the SSB to reach deterministic equilibrium at x% B_0 (e.g., fishing at U_{30} forces the SSB to a deterministic equilibrium of 30% B_0). Fishing intensity in these units is plotted as 100–ESD so that fishing intensity ranges from 0 (U_{100}) up to 100 (U_0).

Estimated fishing intensity was above U_{20} for most of the history of the fishery; it was briefly in the target range (U_{30}–U_{40}) from 2006–2010 before falling substantially when the industry agreed to avoid fishing the NWCR in 2011 (Figure 12). The snail trail is shown in Figure 13.

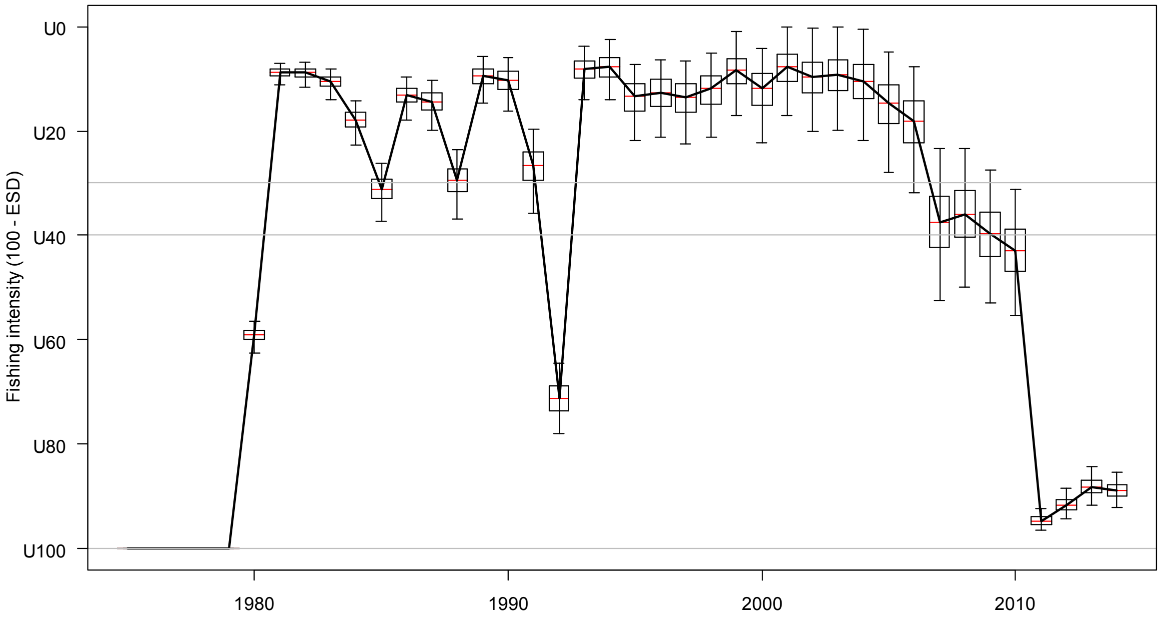

Figure 12: NWCR: MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–40% B_0 is marked by horizontal lines.

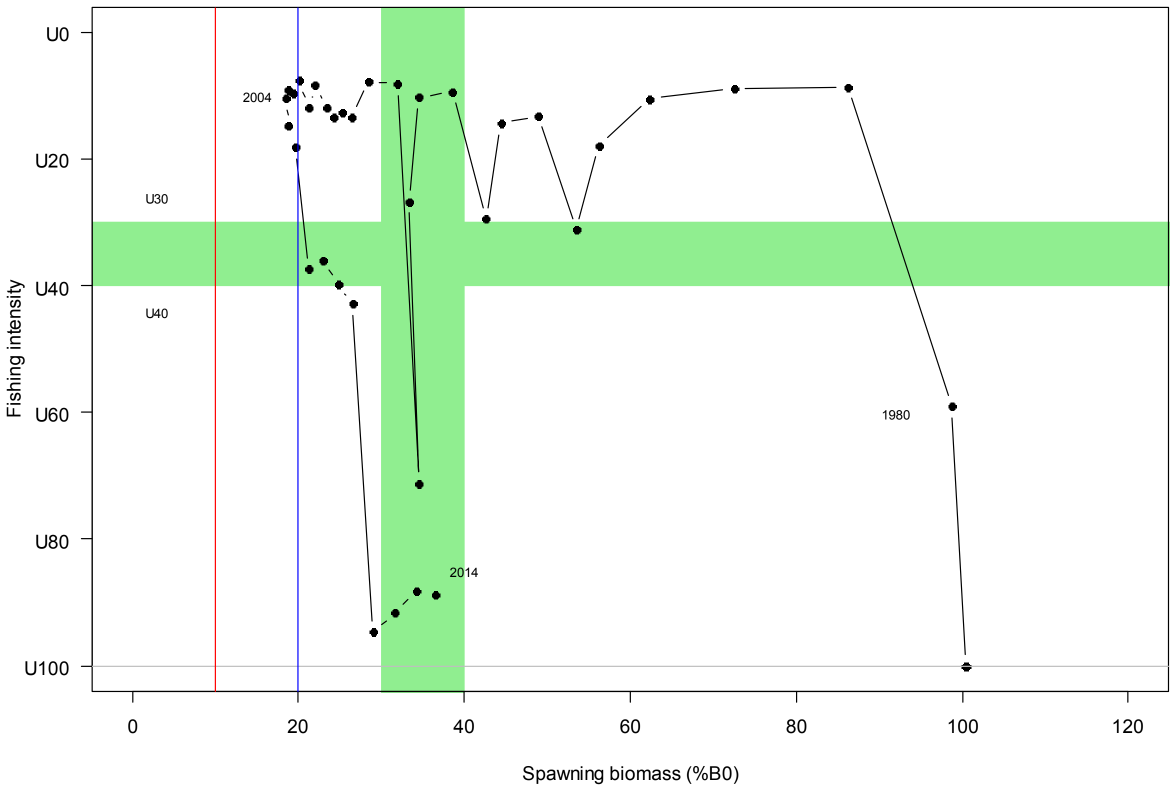

Figure 13: NWCR: historical trajectory of spawning biomass (%B_0) and fishing intensity (%) (base model, medians of the marginal posteriors). The biomass target range of 30–40 % B_0 and the corresponding fishing intensity range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red.

Biological reference points, management targets and yield

MCMC estimates of deterministic B_{MSY} and associated values were produced for the base model. The yield at 35% B_0 (the mid-point of the target range) was also estimated. There is very little variation in the reference points and associated values across the MCMC samples (Table 6).

Table 6: NWCR base, MCMC estimates of deterministic equilibrium SSB and long-term yield (% B_0 and tonnes) for U_{MSY} and U_{35}. The equilibrium SSB at U_{MSY} is deterministic B_{MSY} and the yield is deterministic MSY.

Fishing intensity		**SSB (%B_0)**	**Yield (%B_0)**	**Yield t)**
U_{MSY}	Median	23.7	2.1	1391
	95% CI	23.2–24.7	2.0–2.2	1277–1593
U_{35}	Median	35.0	2.0	1322
	95% CI		1.9–2.1	1214–1512

The estimate of yield associated with U_{35} for the 2014–15 fishing year is 1414 t (95% CI 1069–1984 t)

Projections

Five year projections were conducted (with resampling from the last 10 estimated YCS) for two different constant catch assumptions: 750 t (the current catch limit); and 1400 t (the current estimated yield at U_{35}). In each case a 5% over-run was assumed. Projections were done for the base model and also for the LowM-Highq model (as a "worst case" scenario).

At the current catch limit (750 t), SSB is predicted to increase over the next five years even for the LowM-Highq model (Figure 14). At the catch associated with U_{35} (1400 t) SSB is predicted to rise slightly and then stay steady for both models (Figure 14). For both models and both constant catch scenarios the estimated probability of SSB going below the soft or hard limits is virtually zero (the maximum is 0.01 for the soft limit in the latter years for LowM-Highq at 1400 t).

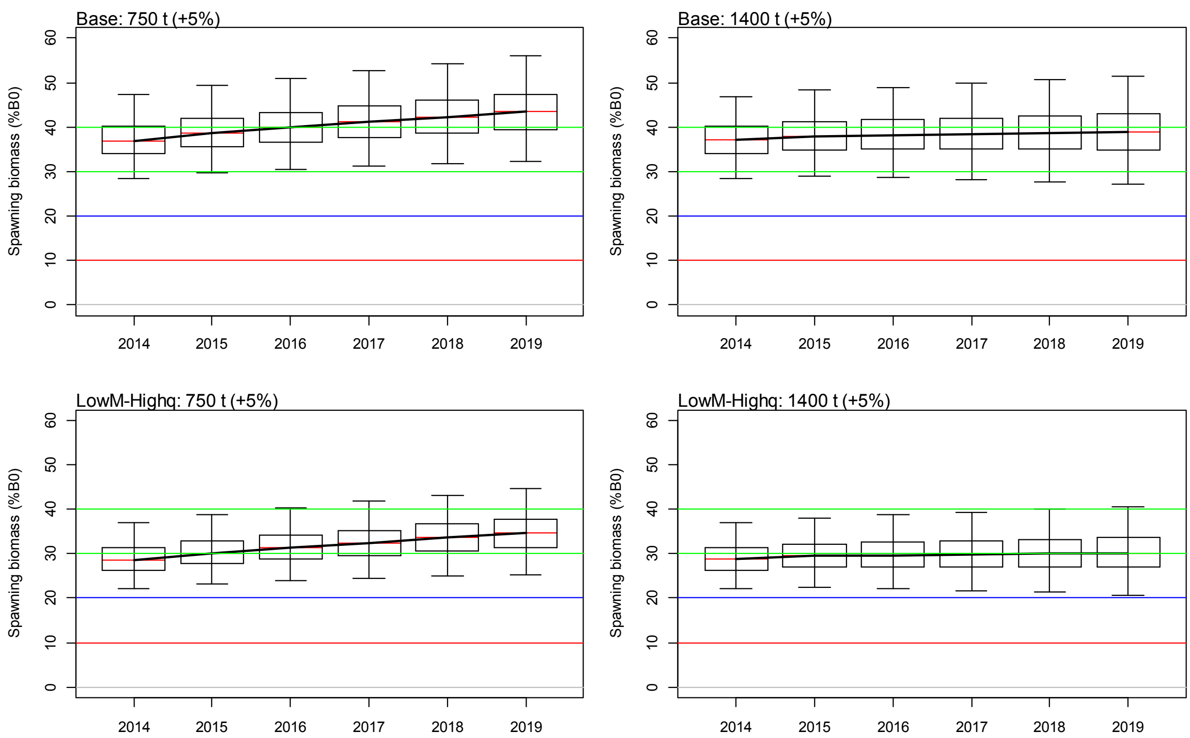

Figure 14: NWCR base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The projections are for the model and annual catch indicated (a 5% over-run was included in each year). The target range is indicated by horizontal green lines.

3.2 East and South Chatham Rise

Model diagnostics

The base model provided good MPD fits to the data. The MPD fits to the acoustic indices were excellent with normalised residuals all very small (Figure 15). Most of the MPD estimated *q*s were lower than the corresponding means of the priors but the lowest ratio was only about 0.7 (Figure 15). The posteriors for the acoustic *q*s were shifted to the left of the priors for 2011 & 2013 and also for 2012 (Figure 16). For the old-plume time series, posteriors were sometimes shifted to the left of the priors but also sometimes to the right (e.g., see Figure 16 for 2002 and 2003) and the ratio of the mean of the posterior to the mean of the prior had a limited range from 0.85 (2003) to 1.2 (2006). The normalised residuals of the acoustic indices for the base MCMC model were excellent (Figure 17).

The MPD fits to the trawl indices were good but the model-predicted biomass had a shallower decline than the indices from the *Buccaneer* and *Cordella* (Figure 18). Also, the model does not fit the very large increase in the *Tangaroa* spawning box survey (Figure 18).

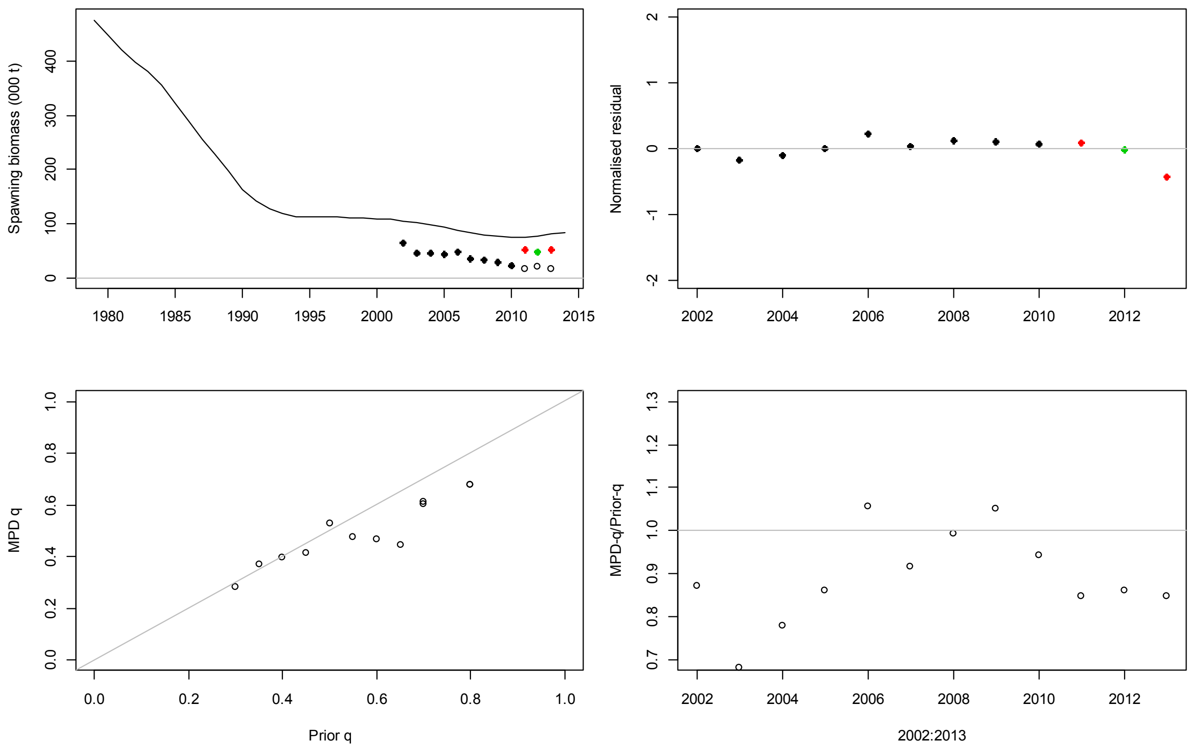

Figure 15: ESCR, MPD, base: fit to the acoustic indices: (top) spawning biomass trajectory and unscaled acoustic indices; normalised residuals; (bottom) estimated *q*s as a function of the mean of the *q* prior; the ratio of the estimated *q* to the mean of the *q* prior.

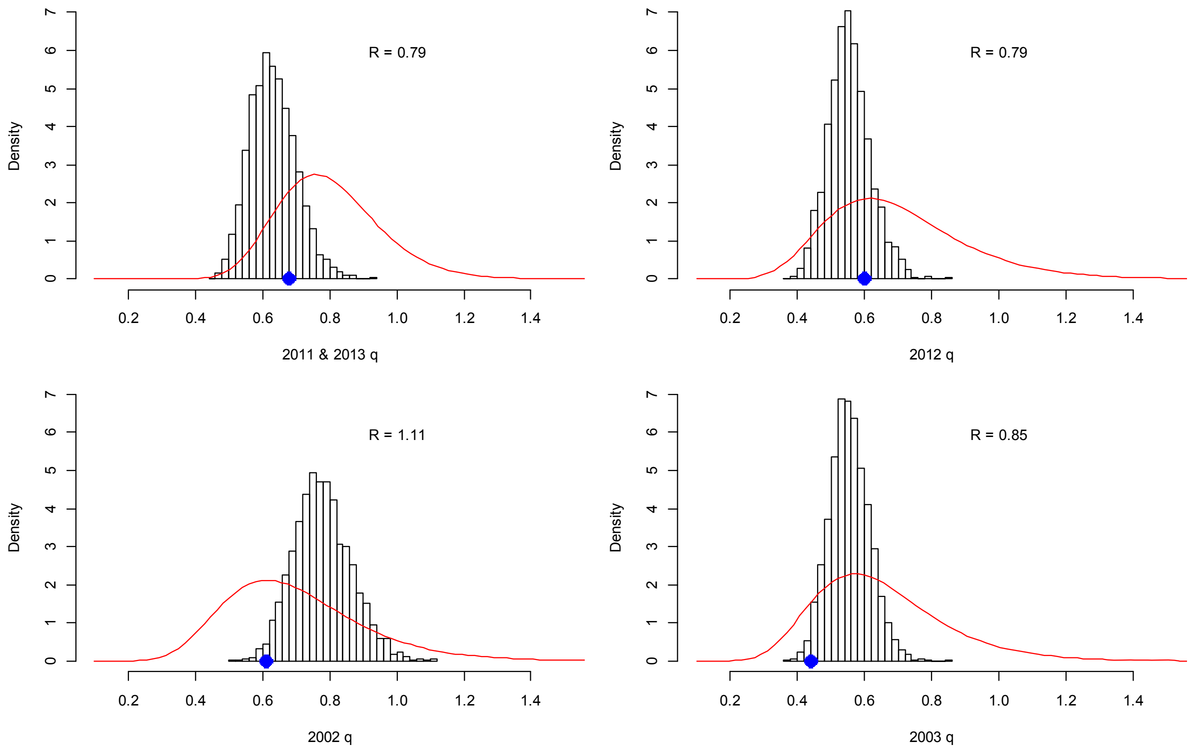

Figure 16: ESCR, MCMC base: prior (in red) and posterior distributions for a selection of acoustic *q*s. The blue dot is the MPD estimate and R is the ratio of the mean of the posterior to the mean of the prior.

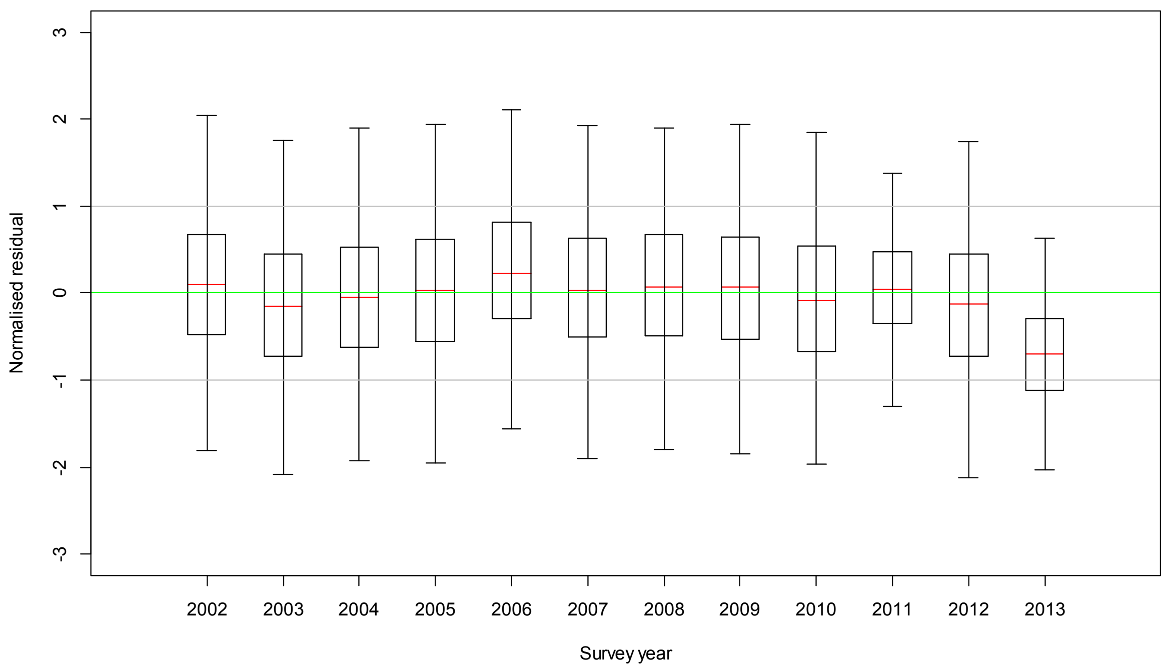

Figure 17: ESCR, MCMC base: normalized residual for the acoustic indices. The box covers 50% of the distribution for each index and the whiskers extend to 95% of the distribution.

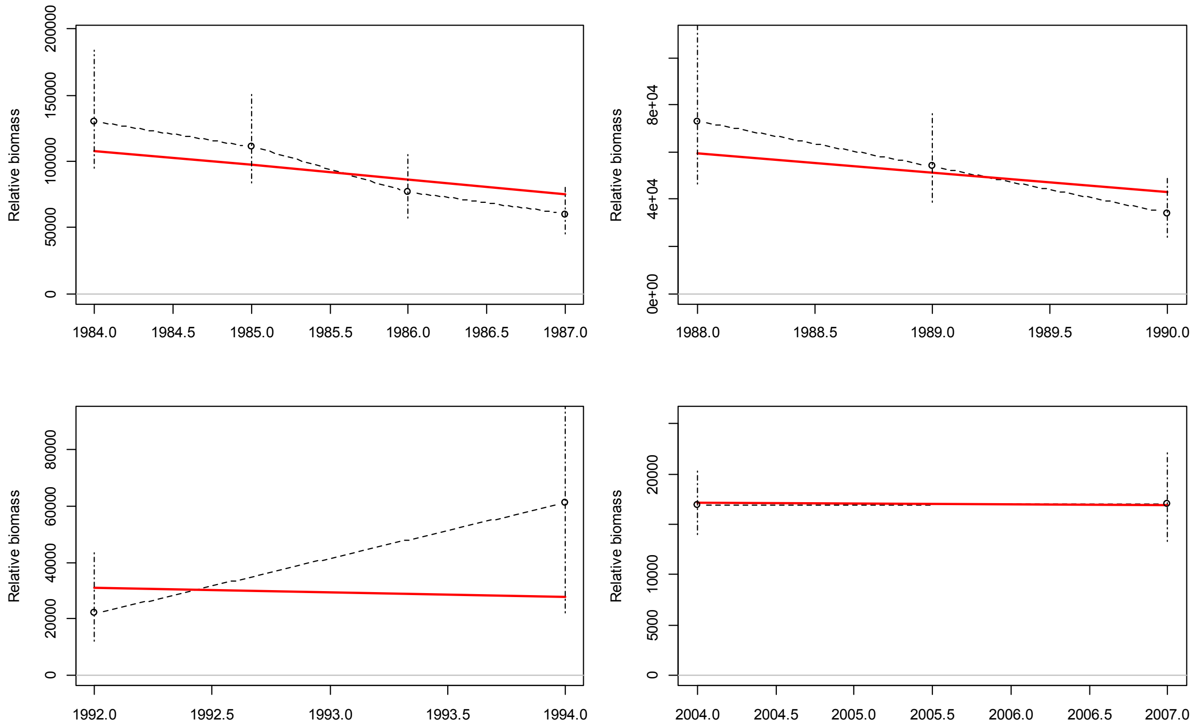

Figure 18: ESCR, MPD base: fits (in red) to the trawl-survey biomass indices (from top to bottom and left to right: *Buccaneer*, *Cordella*, *Tangaroa*, wide-area *Tangaroa*).

The fits to the age frequencies are as good as can be expected given the inconsistent shape of the age frequencies in the two consecutive years (Figure 19). The inconsistency is not caused by having the Crack included in 2013 and not 2012; the problem is too many 30–40 year old fish in 2013 (whereas the Crack had a wide mix of ages).

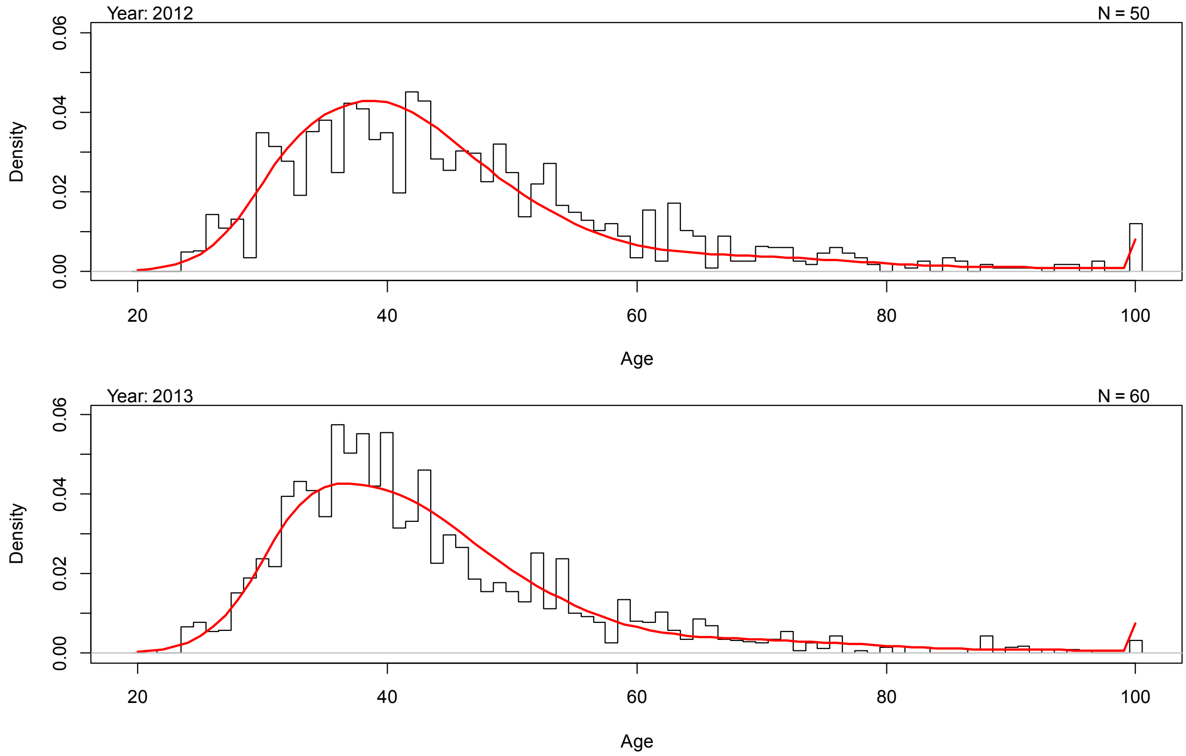

Figure 19: ESCR, MPD base: fits (in red) to the spawning season age frequencies. N is the effective sample size.

The MPD fits to the commercial length frequencies were excellent except for the 1990 Box & flats length frequency (see Figure 20). Likewise, the fits to the trawl survey length frequencies were excellent (e.g., see Figure 21). The long tail to the left which was present in all of the trawl-survey length frequencies from the Spawning Box was easily fitted in the 2014 models because maturity was included in the partition and therefore selectivities could be different for mature and immature fish. The three Spawning Box trawl surveys all had a common immature selectivity which allowed a small proportion of the immature fish to be selected (and hence to fit the left-hand tail). The *Tangaroa* wide-area trawl survey also had separate mature and immature selectivities which allowed a much larger proportion of immature fish to be selected and hence allowed a very good fit to the broad mode of the length frequencies (Figure 21).

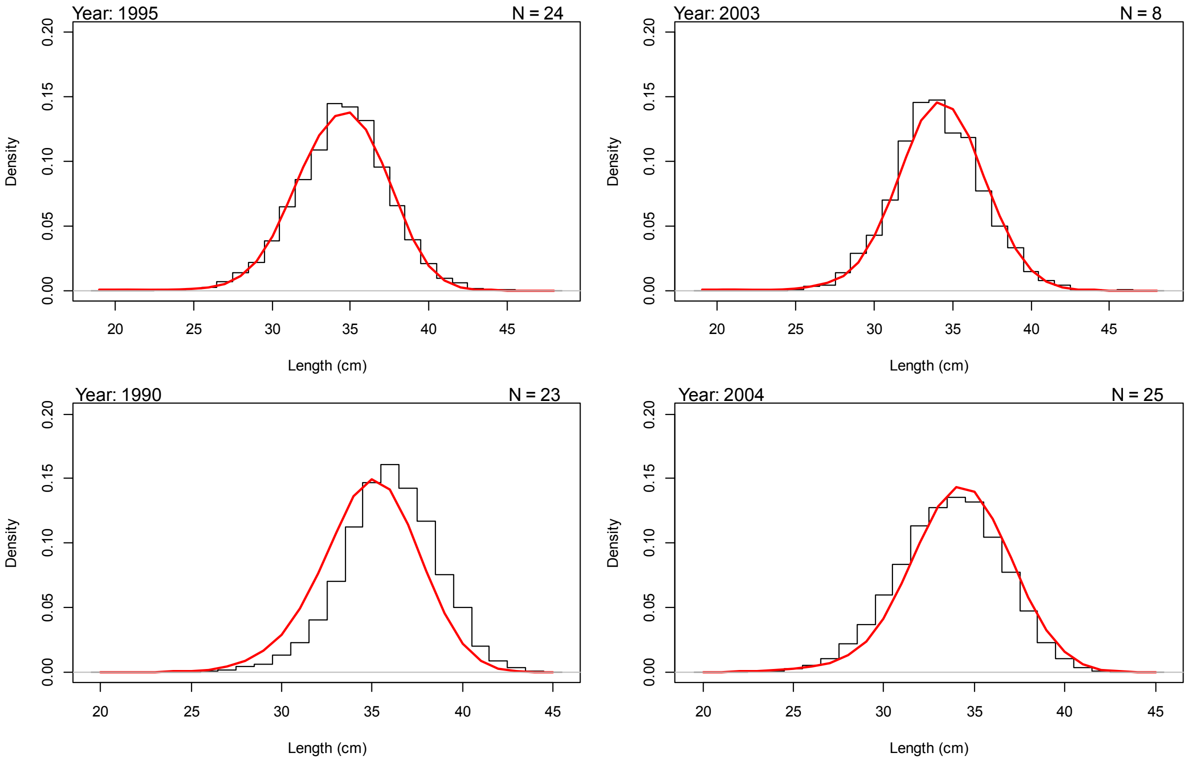

Figure 20: ESCR, MPD base: fits (in red) to the commercial length frequencies for the eastern hills (top) and the Box and flats (bottom). N is the effective sample size.

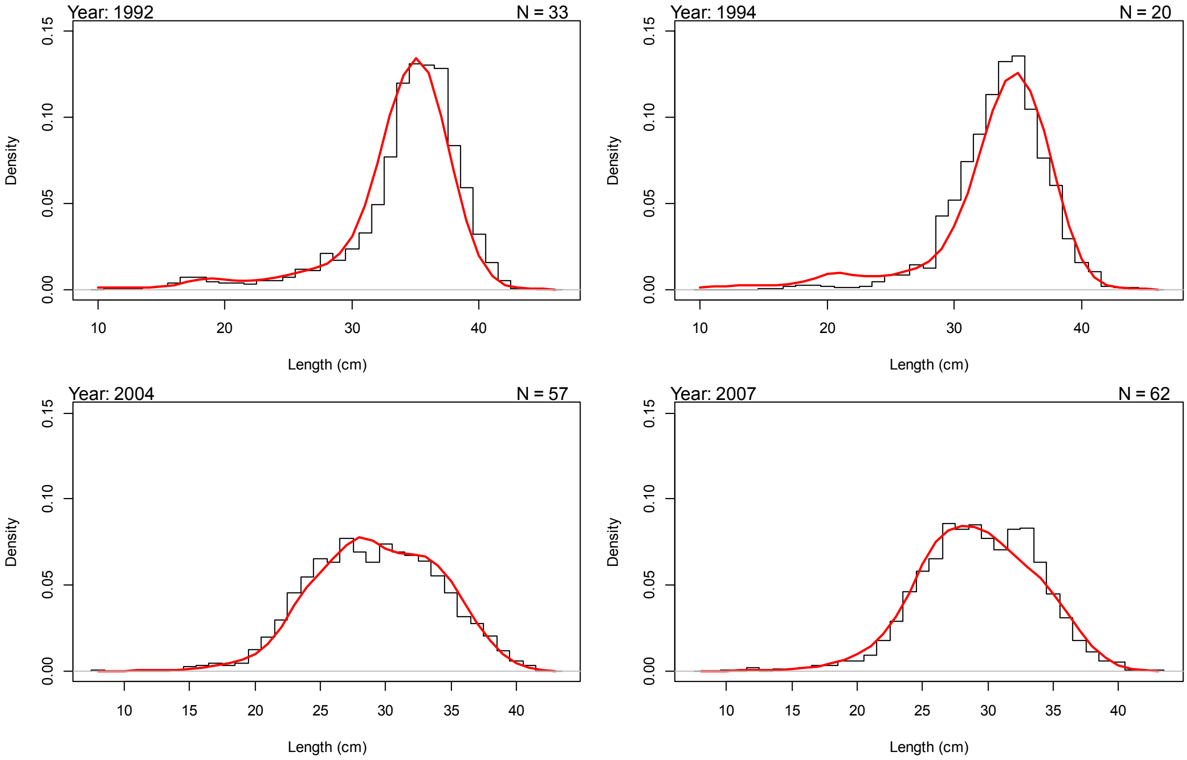

Figure 21: ESCR, MPD base: fits (in red) to the *Tangaroa* length frequencies for the Spawning Box (top) and the wide-area surveys (bottom). N is the effective sample size.

Numerous sensitivity runs were conducted at the MPD stage (see Appendix 2). The estimates were very robust to changes in effective sample sizes for composition data. The model was also robust to changes in M (0.03, 0.06 compared to base of 0.045) or changes in the mean of the acoustic q-priors for 2011 & 2013 (0.6, 0.9 compared to base of 0.8). Major differences in the MPD estimate of current stock status occurred when the acoustic indices were halved or doubled and when deterministic recruitment was assumed (respectively: 14% B_0, 39% B_0, 35% B_0, compared to the base estimate of 24% B_0).

The sensitivities that explored when the Rekohu plume may have come into existence provided another check on the robustness of the base model estimates. The "Always" model (assuming that the Rekohu plume had always existed) provided an adequate fit to the data but the results lacked credibility in three respects. The posterior distribution for the acoustic q was pushed a long way to the right of the prior (Figure 22) as was the posterior for the proportion of spawning biomass being indexed by the three spawning areas combined. In addition, the model estimated that the Rekohu plume had contained over 100 000 t of spawning biomass up until the early 1980s (Figure 23). These three factors combined caused the DWFAWG to conclude that the "Always" run was not a credible alternative to the base model.

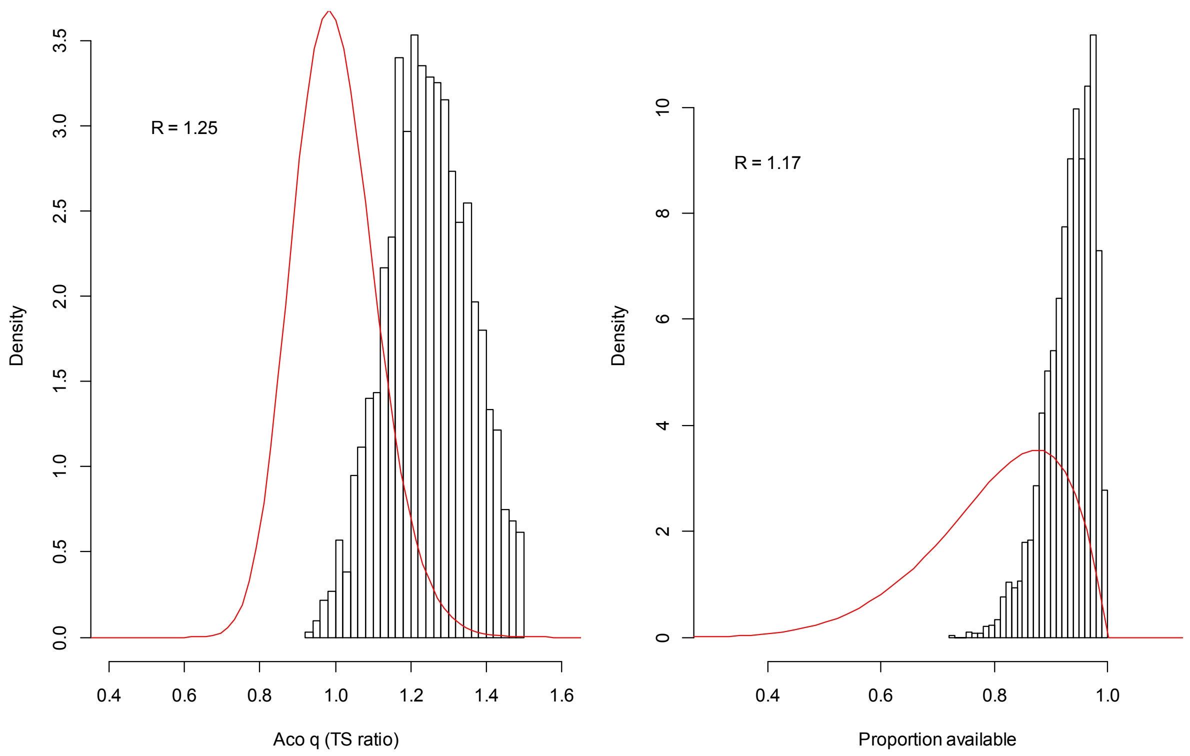

Figure 22: ESCR, MCMC: "Always" sensitivity run: prior (in red) and posterior distributions for the acoustic *q* (left) and the proportion of spawning biomass available to the old-plume, Rekohu, and the Crack combined (right). R is the ratio of the mean of the posterior to the mean of the prior.

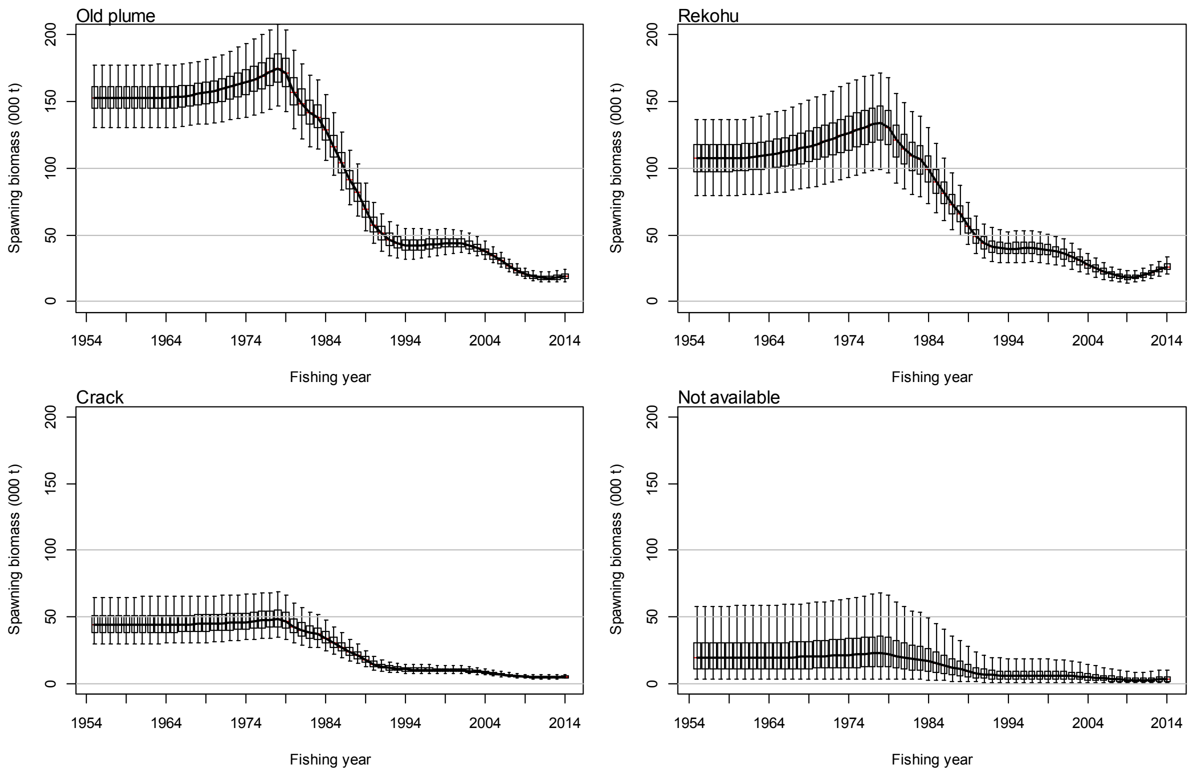

Figure 23: ESCR, MCMC: "Always" sensitivity model: spawning biomass trajectories for each area in the model including the Rekohu plume which is assumed, in this run, to have always existed. The box covers 50% of the distribution in each year and the whiskers extend to 95% of the distribution.

The sensitivities that assumed the creation of the Rekohu plume in 2007 or 2010 were also critically examined to see if they adequately explained the data and were consistent with other ancillary information. It was found that a creation year of 2010 did not allow enough time for the Rekohu plume to build up to the levels of biomass observed in 2011 (unless fish spawning outside the three surveyed areas suddenly began going to Rekohu). A creation year of 2007 did allow enough time for the Rekohu plume to build up to observed levels in 2011 without existing spawning fish changing their spawning sites and it fitted the data adequately. The Rekohu 2007 model was taken through to MCMC but it was not considered as a base model because there is no reason to believe that the Rekohu plume was actually created in 2007.

MCMC results

For the base model, MCMC convergence diagnostics were adequate once the three chains (with random starting values near the MPD estimate) had been run for 15 000 000 iterations. These chains were much longer than those normally required and it appeared that the slow convergence was due to a high correlation between B_0 and the age at 50% maturity. Some technical changes were made to improve chain convergence; they were successful and gave identical results to the base model without the changes. The technical changes were used in the sensitivity runs to avoid running chains out to 15 000 000.

Virgin biomass was estimated to be about 320 000 t for the base model with median estimates ranging from 310 000–360 000 t for the four sensitivity runs presented (Table 7). Current stock status was similar across the base and the first two sensitivity runs (Table 7). The lower stock status when M was estimated reflects the lower estimate of M (0.036 rather than 0.045). For the two “bounding” runs, where M and the mean of the acoustic q-priors were shifted by 20%, current stock status was estimated well below the biomass target range of 30–40% B_0 for the “pessimistic” run and primarily within the target range for the “optimistic” run (Table 7).

Table 7: ESCR, MCMC estimates of virgin biomass (B_0) and stock status (B_{2014} as %B_0) for the base model and four sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2014} (%B_0)	95% CI
Base	0.045	320	280–350	30	25–34
Estimate M	0.036	360	300–410	26	20–32
Rekohu 2007	0.045	310	280–340	26	22–30
LowM-Highq	0.036	340	320–370	22	19–26
HighM-Lowq	0.054	310	280–350	38	32–43

Estimated maturity at age was very similar to the estimated fishing selectivities (Figure 24). The selectivity for the largest fishery (“box and flats”) was almost identical to the proportion of mature fish at age (Figure 24). The three fishery selectivities were close enough to each other that the fisheries could probably be combined into a single fishery without affecting the stock assessment results (Figure 24).

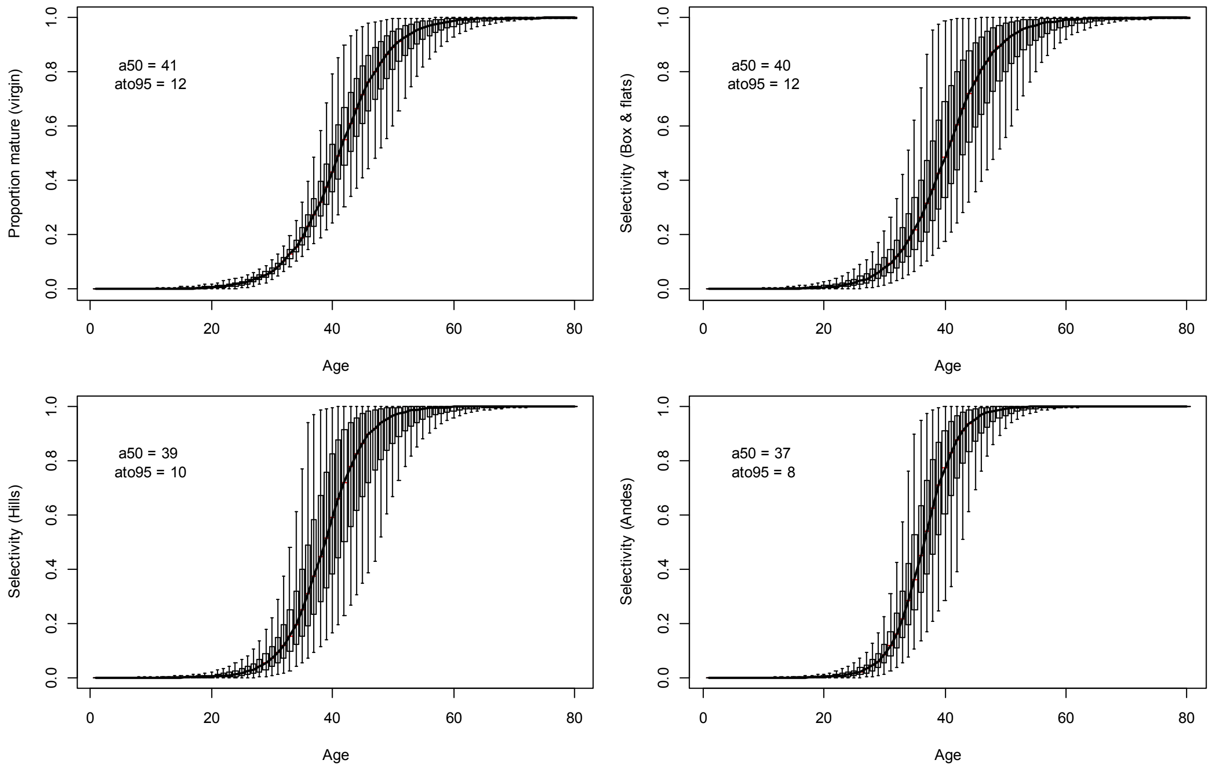

Figure 24: ESCR base, MCMC estimated proportion mature-at-age and fishing selectivities (logistic). The box at each age covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The estimated YCS show little variation across cohorts but do exhibit a long-term trend (Figure 25). The most recent 10 years of estimates (those resampled for short-term projections) are perhaps a little bit above average.

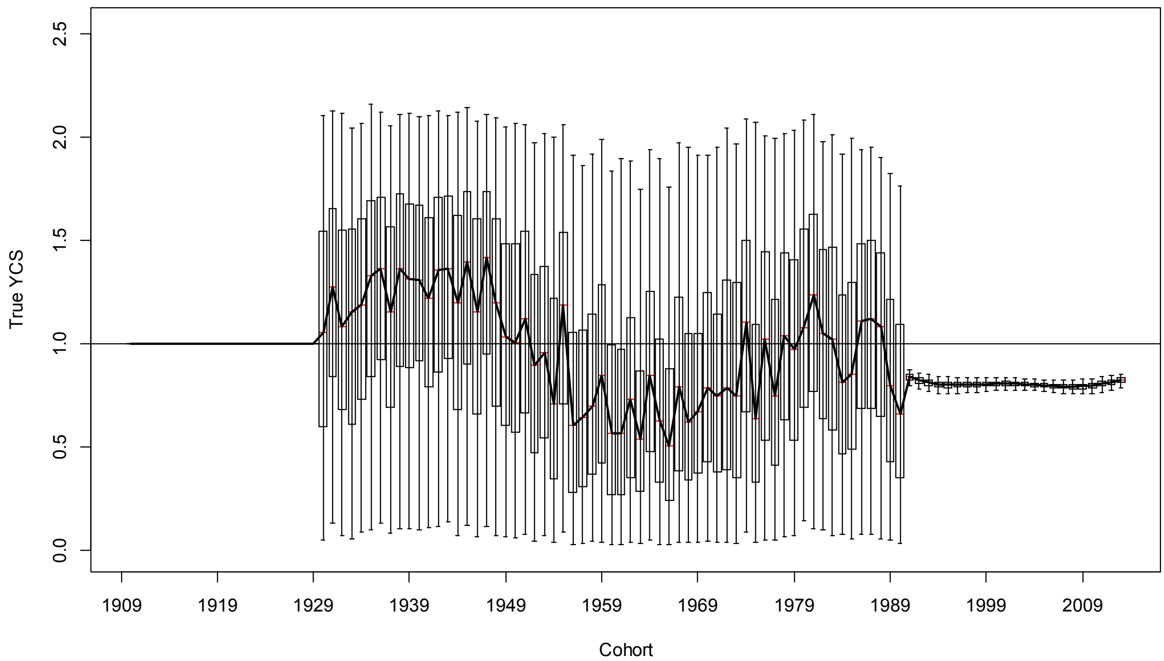

Figure 25: ESCR base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The stock status trajectory shows a steady decline from the start of fishery until the mid 1990s where it remains in the 20–30% range until an upturn in about 2010 (Figure 26).

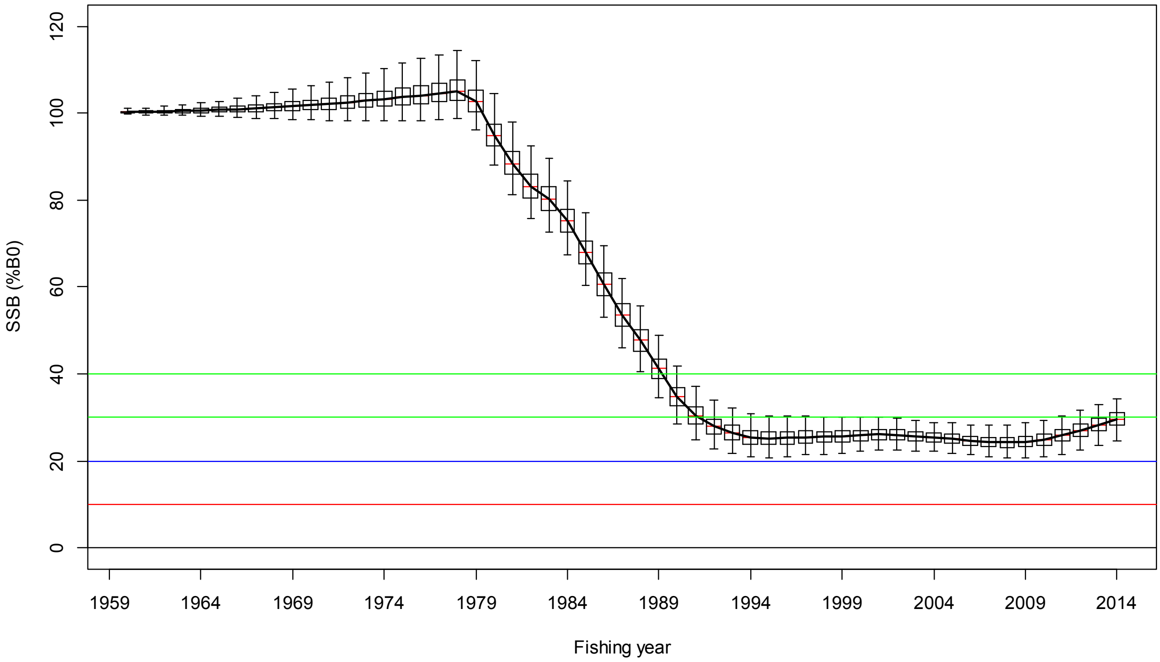

Figure 26: ESCR base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit (red), soft limit (blue), and biomass target range (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity in each year. Estimated fishing intensity was within or above the target range (U_{30}–U_{40}) for most of the history of the fishery; it has been below the target range since 2010 (Figure 27). The snail trail is shown in Figure 28.

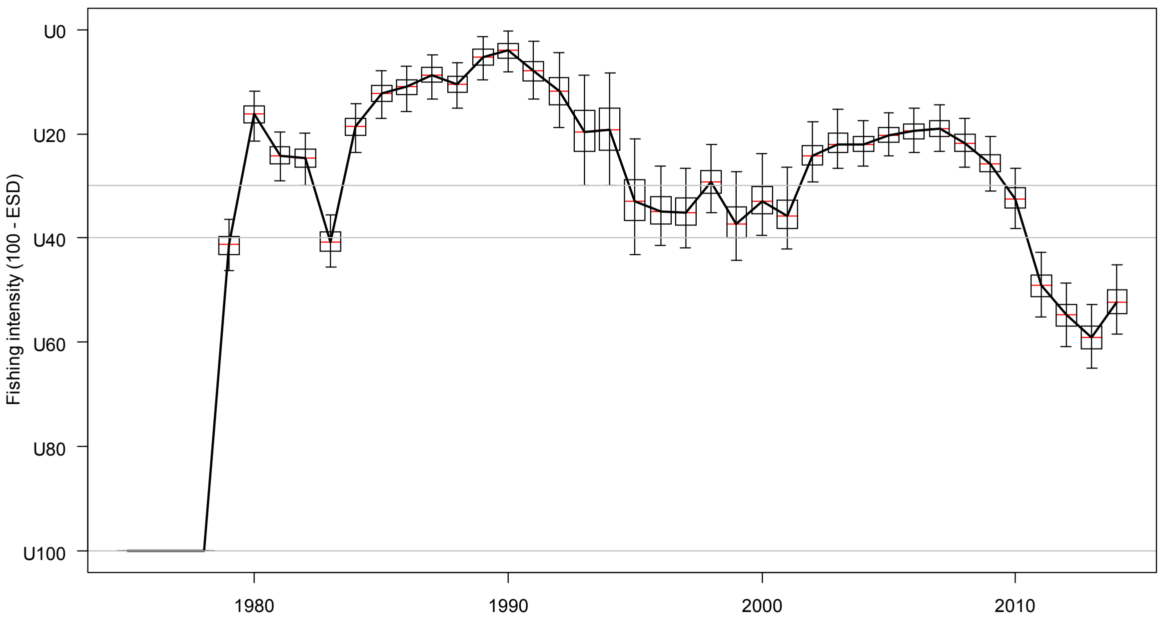

Figure 27: ESCR: MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–40% B_0 is marked by horizontal lines.

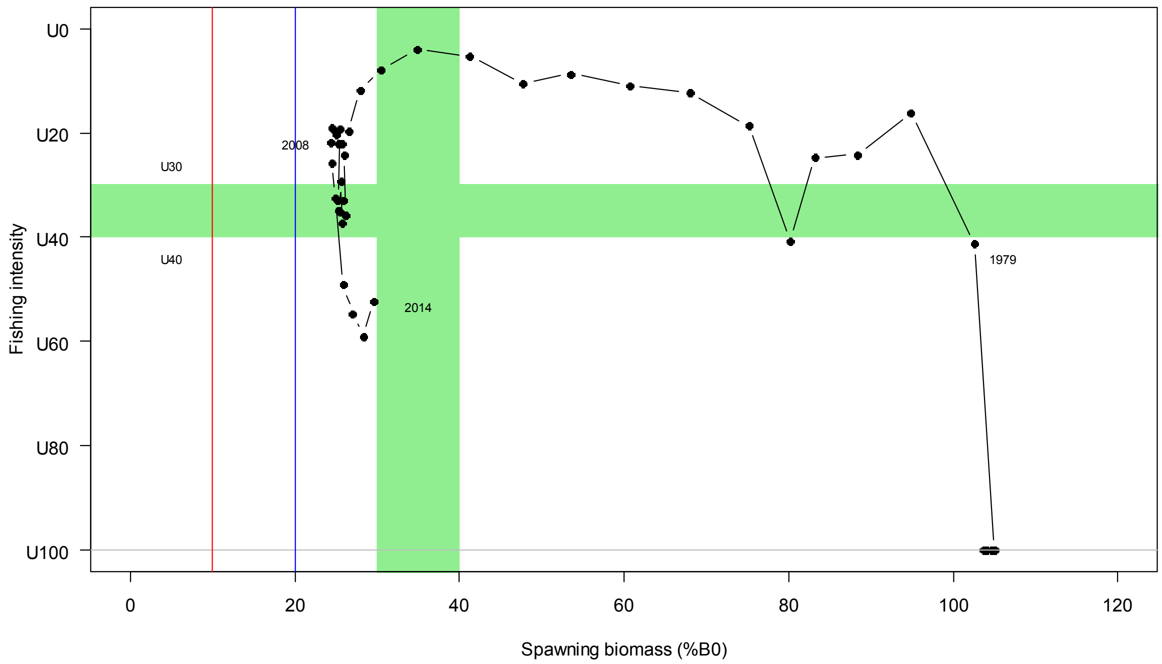

Figure 28: ESCR: historical trajectory of spawning biomass (%B_0) and fishing intensity (%) (base model, medians of the marginal posteriors). The biomass target range of 30–40 % B_0 and the corresponding fishing intensity range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red.

Biological reference points, management targets and yield

MCMC estimates of deterministic B_{MSY} and associated values were produced for the base model. The yield at 35% B_0 (the mid-point of the target range) was also estimated. There is little variation in the reference points and associated values across the MCMC samples (Table 8).

Table 8: ESCR base, MCMC estimates of deterministic equilibrium SSB and long-term yield (% B_0 and tonnes) for U_{MSY} and U_{35}. The equilibrium SSB at U_{MSY} is deterministic B_{MSY} and the yield is deterministic MSY.

Fishing intensity		SSB (%B_0)	Yield (%B_0)	Yield (t)
U_{MSY}	Median	21.8	2.4	7716
	95% CI	20.2–23.4	2.3–2.7	7264–8237
U_{35}	Median	35.0	2.3	7175
	95% CI		2.1–2.5	6740–7666

The estimate of yield associated with U_{35} for the 2014–15 fishing year is 6444 t (95% CI 5255–7747 t)

Projections

Five year projections were conducted (with resampling from the last 10 estimated YCS) for two different constant catch assumptions: 3100 t (the current catch limit); and 6400 t (the current estimated yield at U_{35}). In each case a 5% over-run was assumed. Projections were done for the base model and also for the LowM-Highq model (as a "worst case" scenario).

At the current catch limit (3100 t), SSB is predicted to increase steadily over the next five years for both models (Figure 29). At the catch associated with U_{35} (6400 t) SSB is predicted to rise slightly for both models (Figure 29). For both models and both constant catch scenarios the estimated probability of SSB going below hard limits is zero. There is also zero probability for the base model of going below 20% B_0 under either catch scenario. For the LowM-Highq model there is a non-zero probability that the SSB is already below 20% in 2014 but this decreases over time for both catch scenarios (Figure 29).

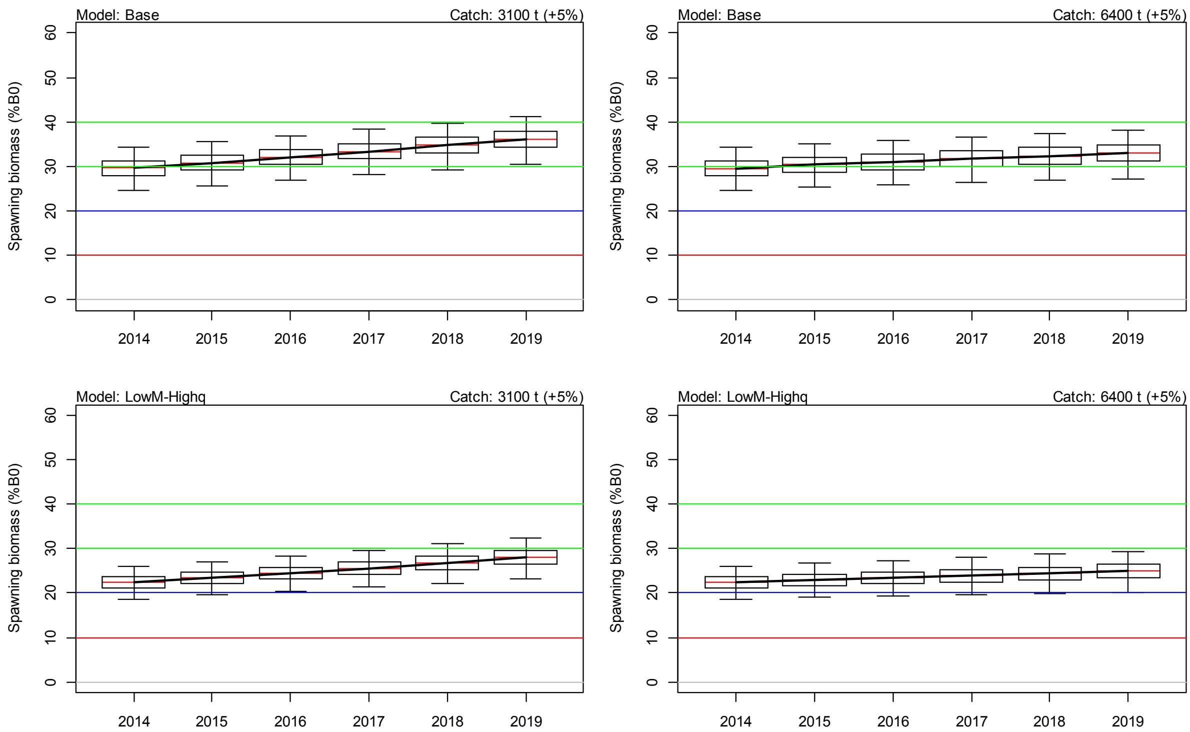

Figure 29: ESCR base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The projections are for the model and annual catch indicated (a 5% over-run was included in each year). The target range is indicated by horizontal green lines.

3.3 ORH 7A

Model diagnostics

The model provided good MPD fits to the biomass indices although the 2009 trawl index had a large positive residual (Figure 30). The large positive residual in 2009 is balanced by negative residuals in the other years. In a sensitivity run, taken through to MCMC, the 2009 index was removed. This had no effect on the stock status estimates for the MPD or MCMC runs but it did provide an improved fit to the other biomass indices (the lesson being that the 2009 index is not influential in terms of important estimates but it does affect the residual pattern). The MCMC normalised residuals for the biomass indices also show a similar pattern to the MPD fit, but the only large residuals are for the *Amaltal Explorer* time series (Figure 31). The magnitude of the *Amaltal Explorer* residuals could be reduced by adding on more process error, but this would not affect any of the important assessment estimates (the same results are obtained if the *Amaltal* time series is removed altogether).

The MPD fit to the age frequencies was very good (Figure 32).

The biomass indices with the informed priors are free to “move” somewhat as they are relative. The MPD estimated *q*s were not very different from the mean of the informed priors (Figure 33, blue dots). The same is not true for the MCMCs, as the *Thomas Harrison q* and the combined acoustics and trawl *q* have both moved to the left appreciably (Figure 33, right-hand plots). Although they have moved, the posteriors are still well within the distribution of the priors and so the estimated *q*s are still credible.

Numerous MPD sensitivity runs were performed (Appendix 2). They showed that the main drivers of estimated stock status were natural mortality (*M*) and the means of the informed *q*-priors (lower *M* and higher mean *q* give lower stock status; higher *M* and lower mean *q* give higher stock status). The base model was very robust to changes in the relative weights of the different data sets. Large changes in estimated stock status only occurred when deterministic recruitment was assumed (49% B_0 compared to 32% B_0 in the base) or when recent biomass indices were halved or doubled (respectively 18% B_0 and 50% B_0).

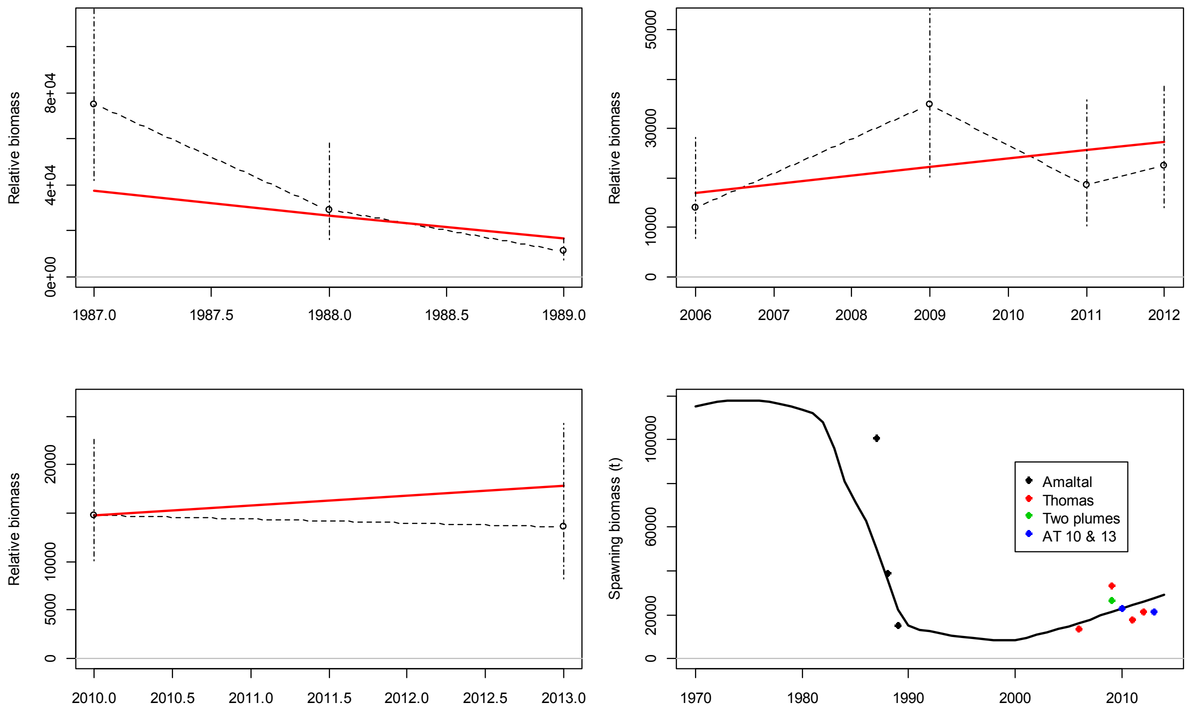

Figure 30: ORH 7A, base, MPD fit to biomass indices: top left: *Amaltal Explorer*; top right: *Thomas Harrison*; bottom left: combined acoustics and trawl; bottom right: indices scaled to spawning biomass (using MPD estimated *qs*). Vertical lines are 95% CIs (model CVs).

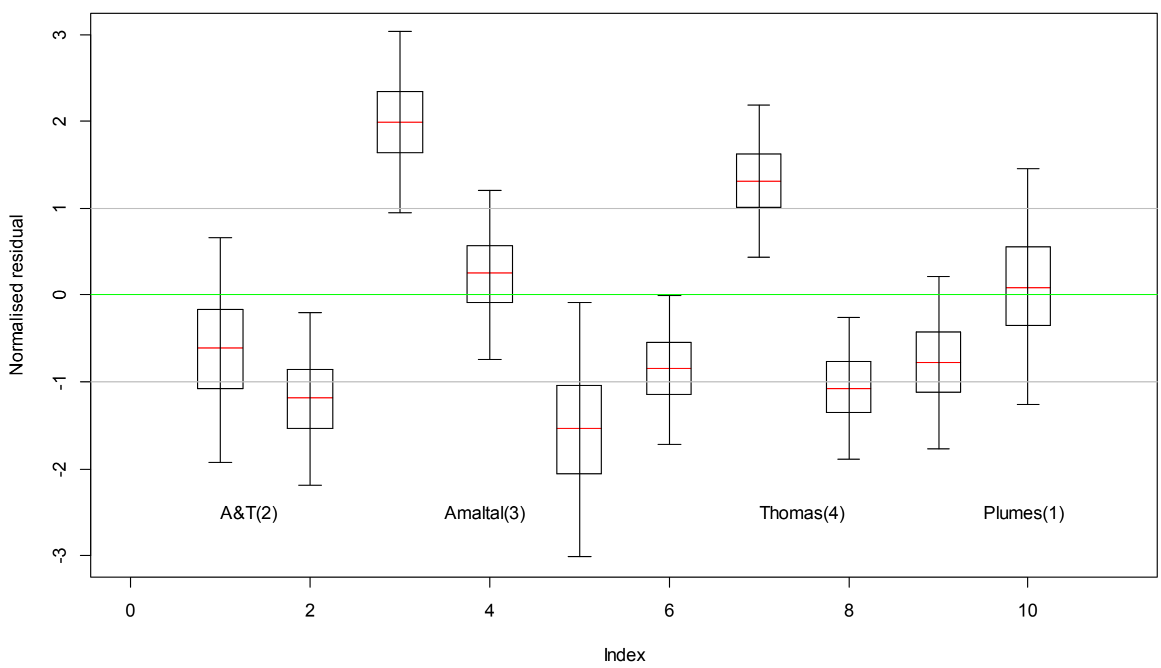

Figure 31: ORH 7A, MCMC base: normalised residuals for the biomass indices. The box covers 50% of the distribution for each index and the whiskers extend to 95% of the distribution. "A&T" denotes combined acoustics and trawl (2010, 2013). "Plumes" denotes the two-plumes estimate (2009).

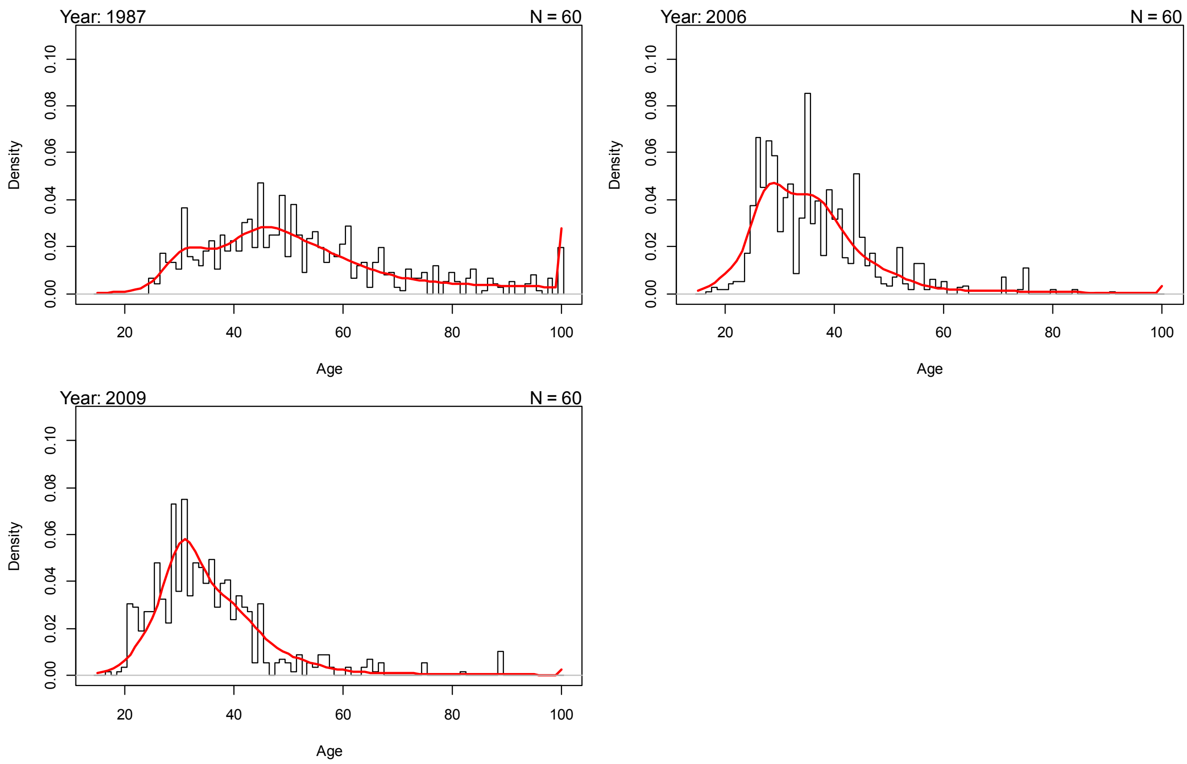

Figure 32: ORH 7A: MPD fit to spawning-season trawl-survey age frequencies (N = 60 is the assumed effective sample size). Observations are square-topped black lines; model predictions are the smooth red lines.

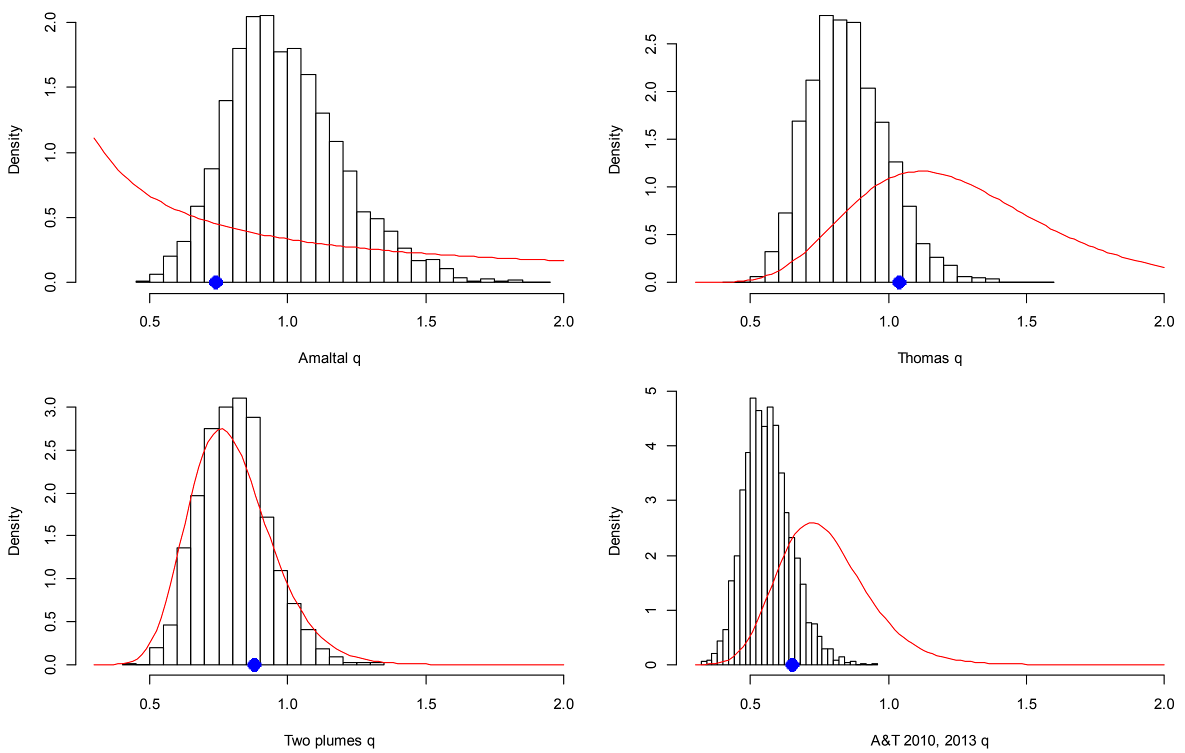

Figure 33: ORH 7A, base MCMC diagnostics: prior and posterior distributions for the biomass time series *q*s (prior in red, posterior black histograms; the blue dot is the MPD estimate; "A&T" denotes combined acoustics and trawl).

MCMC results

For the base model, and the sensitivity runs, MCMC convergence diagnostics were excellent. Virgin biomass was estimated to be about 90 000 t for all runs (Table 9). Current stock status was similar for the base and the estimate-*M* run (Table 9). The slightly lower stock status when *M* was estimated reflects the lower estimate of *M* (0.04 rather than 0.045). For the two "bounding" runs, where *M* and the mean of the informed *q*-priors were shifted by 20%, median current stock status was estimated within the biomass target range of 30–40% B_0 for the "pessimistic" run but well above the range for the "optimistic" run (Table 9).

Table 9: ORH 7A, MCMC estimates of virgin biomass (B_0) and stock status (B_{2014} as %B_0) for the base model and three sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2014} (%B_0)	95% CI
Base	0.045	88	82–96	42	35–49
Estimate M	0.039	92	84–100	38	30–47
LowM-Highq	0.036	90	85–97	33	27–40
HighM-Lowq	0.054	88	81–97	51	44–59

The estimated YCS show little variation across cohorts but do exhibit a long-term trend (Figure 34). The most recent 10 years of estimates (those resampled for short-term projections) are about average.

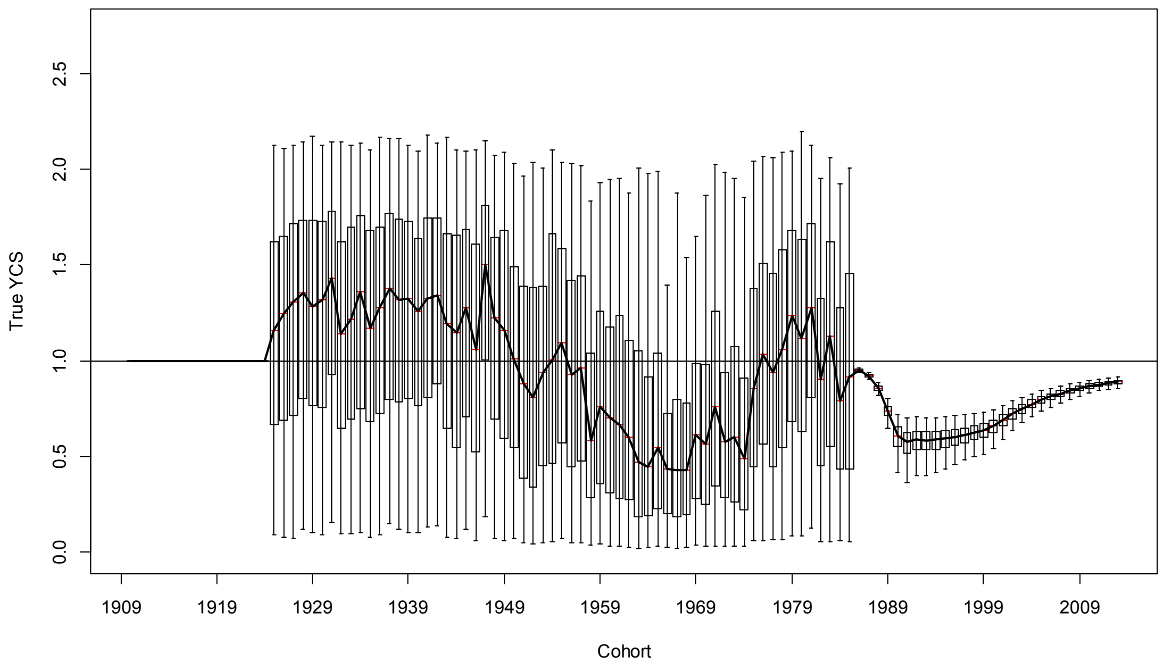

Figure 34: ORH 7A, base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The stock status trajectory shows a steep decline from the start of fishery until 1990 where it reached and remained at about 10% B_0 until a strong upturn in 2000 (Figure 35). It has taken only 14 years to rebuild to the top of the 30–40% biomass range because the fishery was closed in 2001 and reopened in 2011 with relatively limited catches since then.

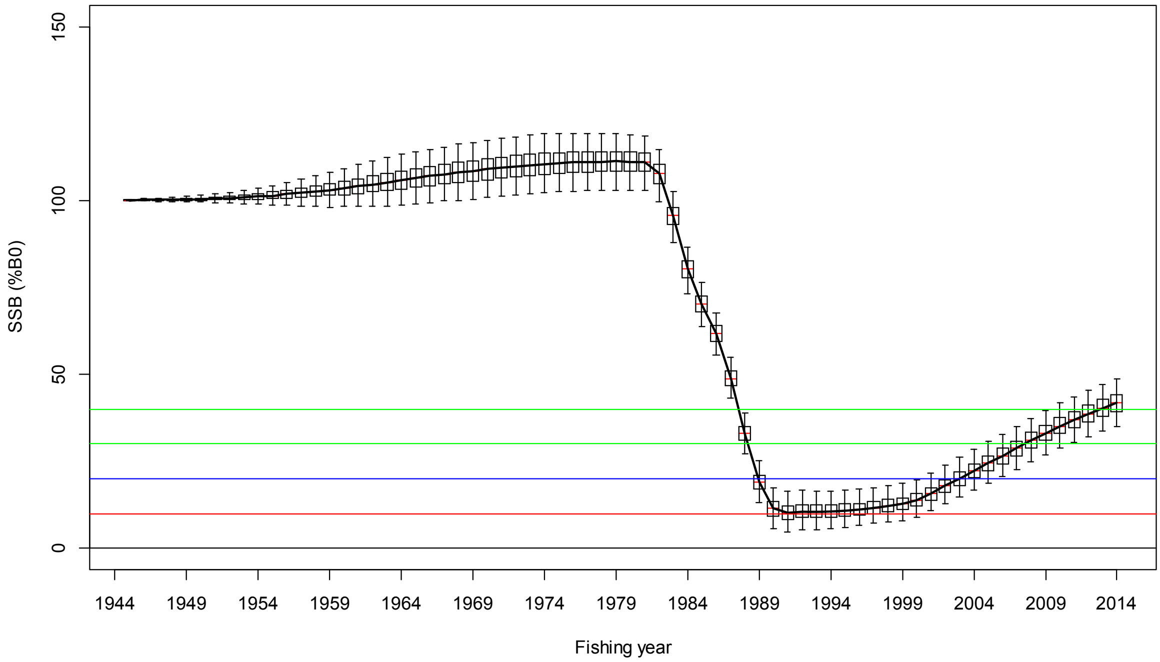

Figure 35: ORH 7A, base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit (red), soft limit (blue), and biomass target range (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity in each year. Estimated fishing intensity was within or above the target range (U_{30}–U_{40}) up until the closure of the fishery in 2001. Since then, it has been well below the target range (Figure 36). The snail trail is shown in Figure 37.

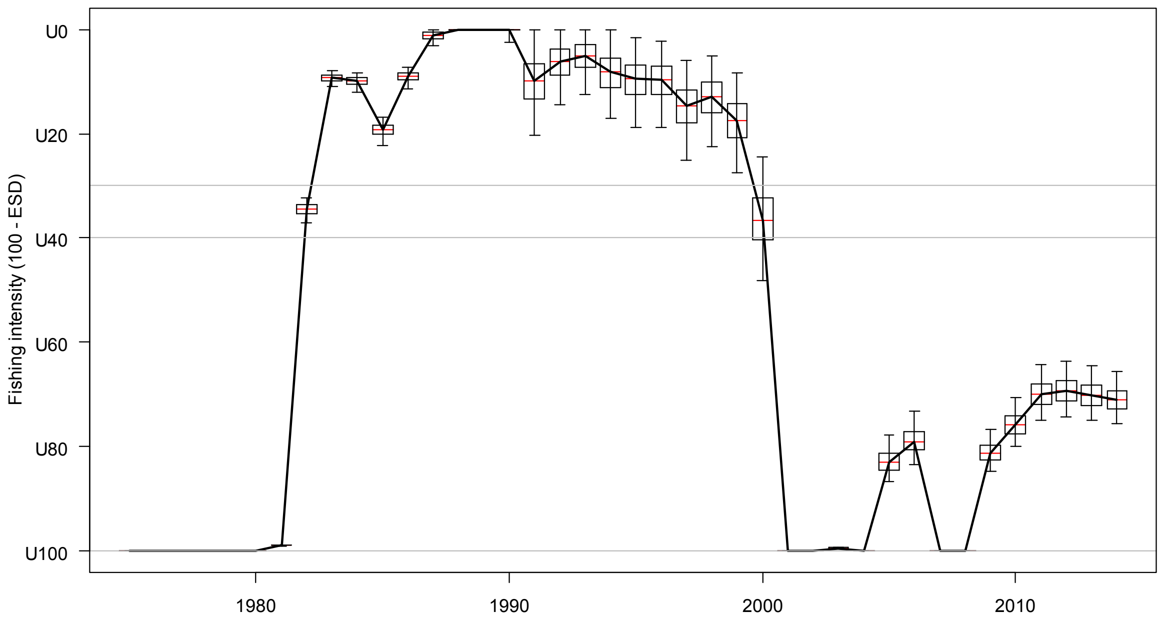

Figure 36: ORH 7A: MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–40% B_0 is marked by horizontal lines.

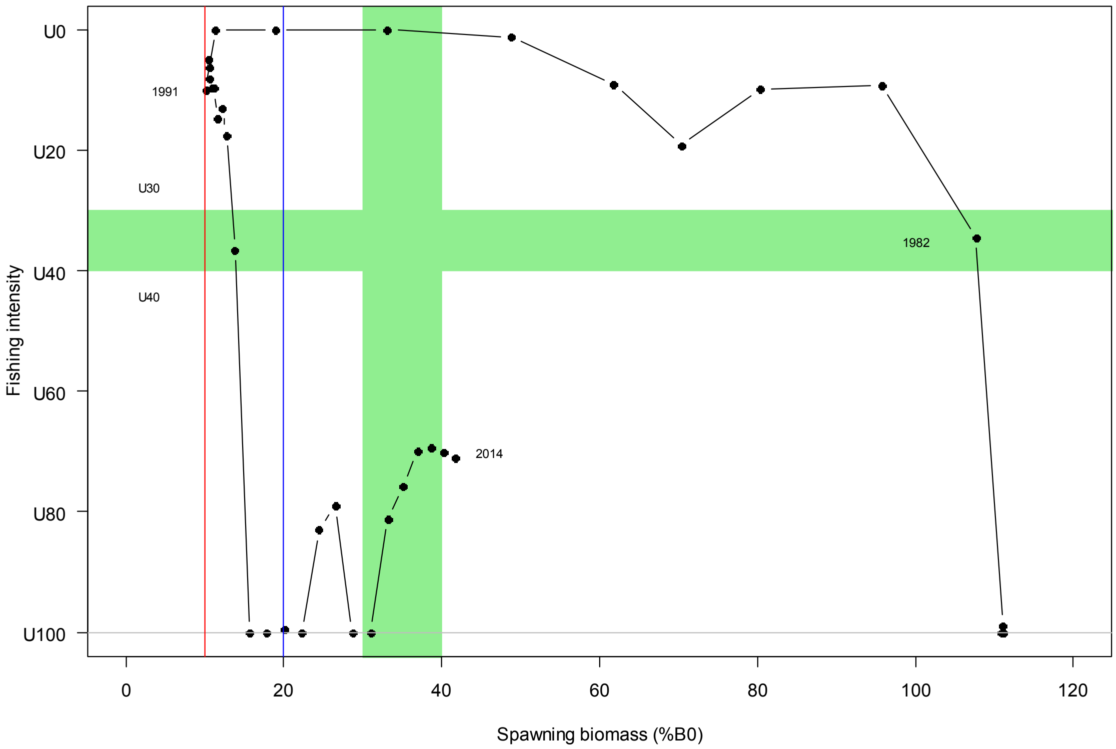

Figure 37: ORH 7A: historical trajectory of spawning biomass (%B_0) and fishing intensity (%) (base model, medians of the marginal posteriors). The biomass target range of 30–40% B_0 and the corresponding fishing intensity range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red.

Biological reference points, management targets and yield

MCMC estimates of deterministic B_{MSY} and associated values were produced for the base model. The yield at 35% B_0 (the mid-point of the target range) was also estimated. There is little variation in the reference points and associated values across the MCMC samples (Table 10).

Table 10: ORH 7A, base, MCMC estimates of deterministic equilibrium SSB and long-term yield (% B_0 and tonnes) for U_{MSY} and U_{35}. The equilibrium SSB at U_{MSY} is deterministic B_{MSY} and the yield is deterministic MSY.

Fishing intensity		SSB (%B_0)	Yield (%B_0)	Yield (t)
U_{MSY}	Median	24.5	2.1	1853
	95% CI	22.9–24.9	2.1–2.1	1728–2009
U_{35}	Median	35.0	2.0	1764
	95% CI		2.0–2.0	1645–1912

The estimate of yield associated with U_{35} for the 2014–15 fishing year is 2128 t (95% CI 1673–2694 t)

Projections

Five year projections were conducted (with resampling from the last 10 estimated YCS) for two different constant catch assumptions: 500 t (the current TAC); and 2100 t (the current estimated yield at U_{35}). In each case a 5% over-run was assumed. Projections were done for the base model and also for the LowM-Highq model (as a “worst case” scenario).

At the current TAC (500 t), SSB is predicted to increase steadily over the next five years for both models (Figure 38). At the catch associated with U_{35} (2100 t) SSB is predicted to decrease slightly for both models (Figure 38). For both models and both constant catch scenarios the estimated probability of SSB going below hard limits is zero. There is also zero probability for the base model of going below 20% B_0 under either catch scenario. For the LowM-Highq model there is a small probability (1.5% and 3% respectively) that the SSB goes below 20% B_0 in 2018 or 2019 under a 2100 t catch (Figure 38).

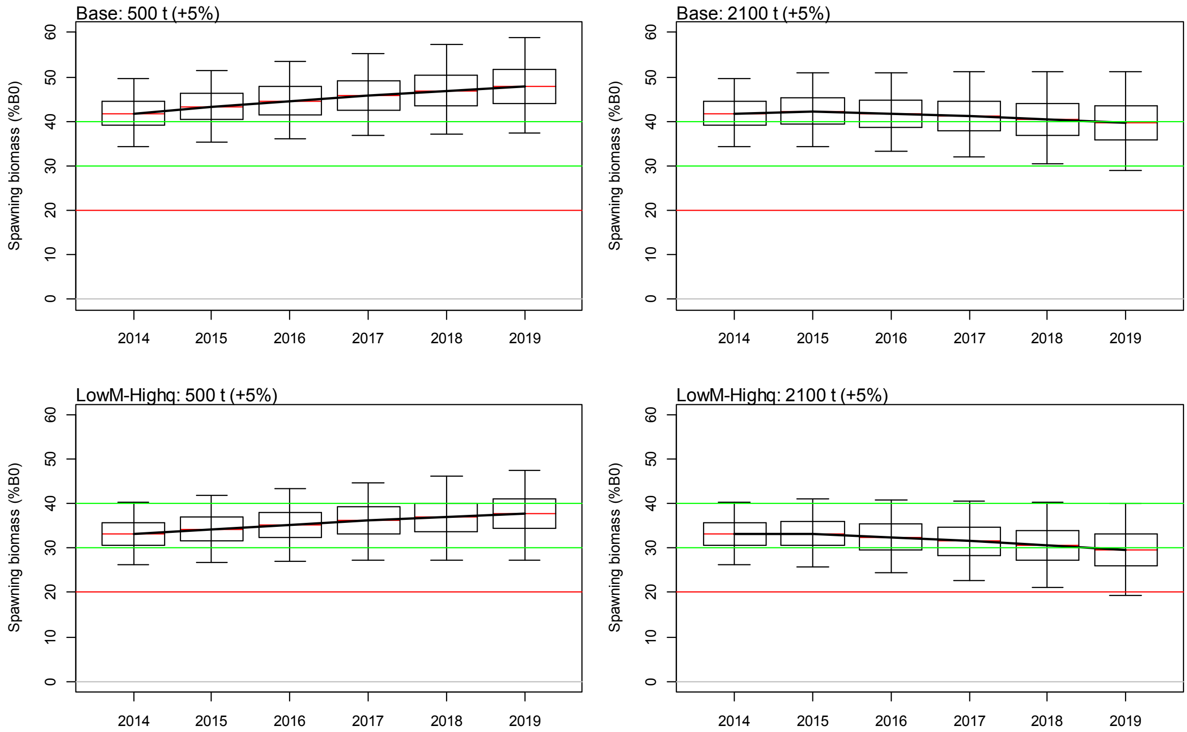

Figure 38: ORH 7A, base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The projections are for the model and annual catch indicated (a 5% over-run was included in each year). The target range is indicated by horizontal green lines.

3.4 Mid-East Coast

Model diagnostics

The model provided excellent MPD fits to the biomass indices (Figure 39) although the MCMC fit was only just adequate for the trawl indices (Figure 40). The much worse MCMC fit to the 2010 trawl index compared to the MPD fit is because the MPD pattern of YCS is unusual compared to the bulk of the posterior distribution (Figure 41). The result highlights the difference between MPD estimates and MCMC estimates: the MPD finds the single vector of parameters which give the best fit to the data, but the MCMC finds the whole parameter space that best explains the data. There is no reason why the MPD has to be in the “middle” of the posterior distribution – here we have an example where it is actually unusual compared to the bulk of the posterior distribution.

The MCMC fit to the acoustics index has also degraded from the MPD fit (see Figures 39 and 40) and, in addition, the acoustics q has also been estimated lower (Figure 42). The cause is the same as for the 2010 trawl index; the MPD spawning biomass trajectory almost exactly matched the 2013 acoustic estimate but when the unusual MPD YCS pattern was removed the spawning biomass trajectory shifted higher (and so the acoustic q shifted lower to try to compensate).

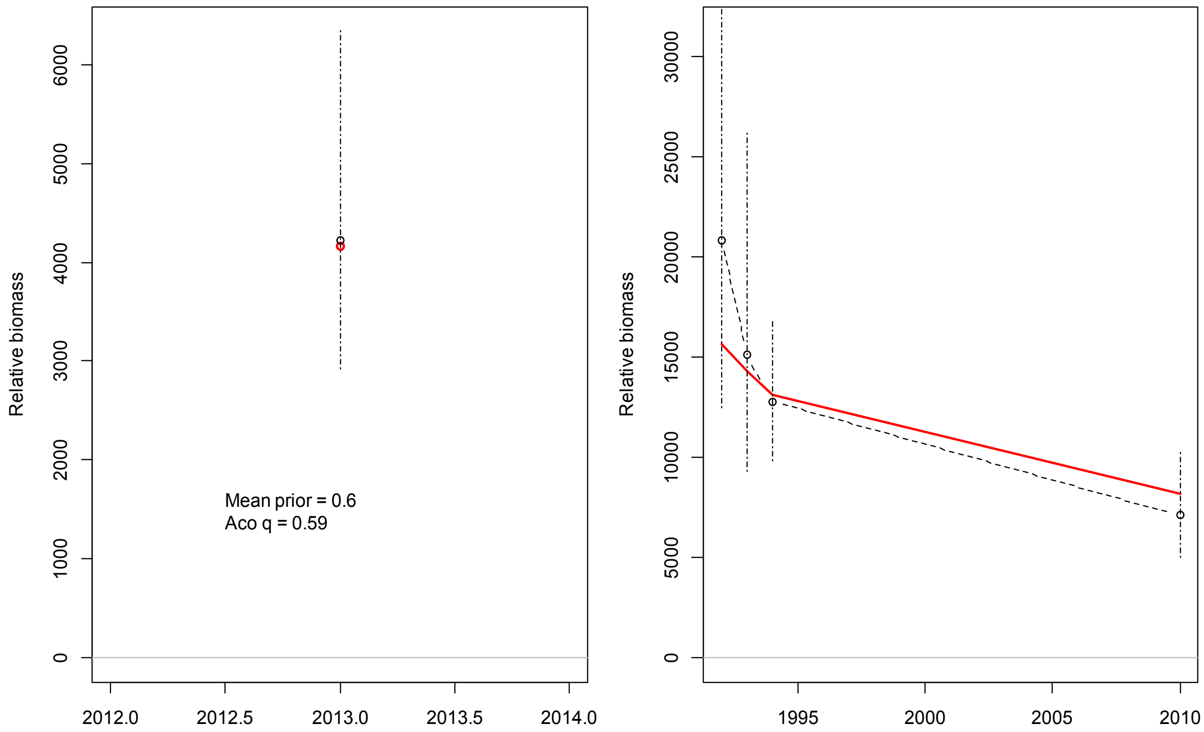

Figure 39: MEC, base, MPD fit to biomass indices: left: acoustic-survey spawning biomass index (fitted with an informed *q* prior, mean = 0.6; MPD estimated *q* = 0.59); right: *Tangaroa* trawl-survey indices. Vertical lines are 95% CIs.

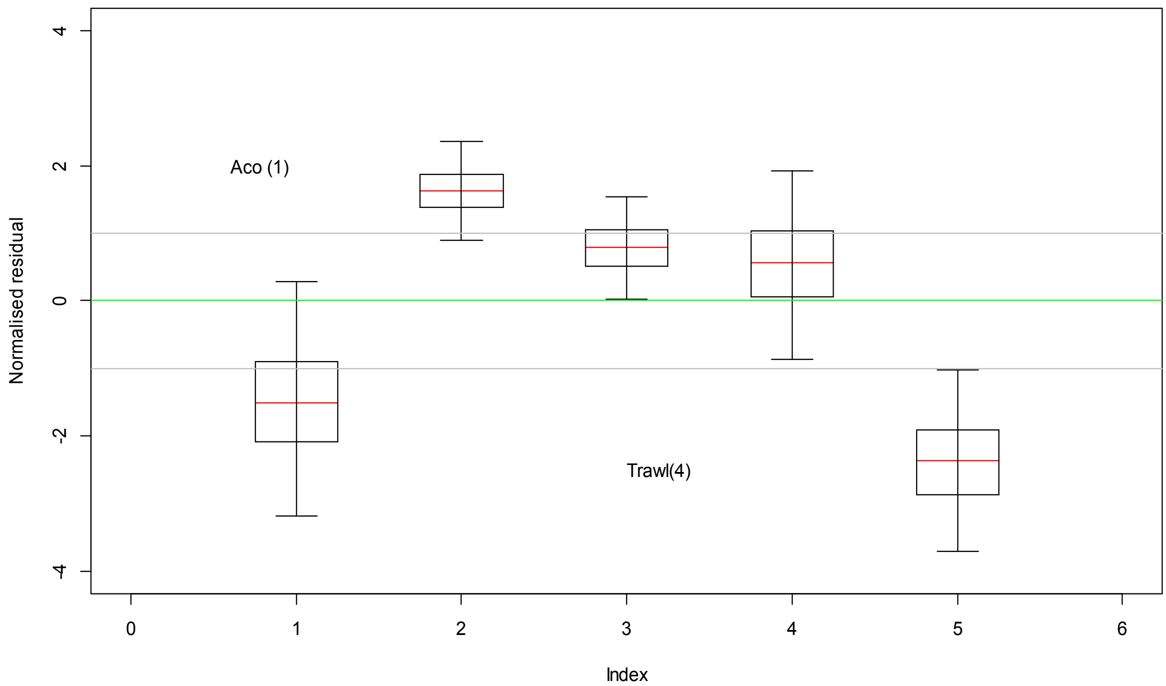

Figure 40: MEC, MCMC base: normalised residuals for the biomass indices. The box covers 50% of the distribution for each index and the whiskers extend to 95% of the distribution. "Aco" denotes the acoustic estimate (2013). "Trawl" denotes the *Tangaroa* trawl-survey time series (1992–94, 2010).

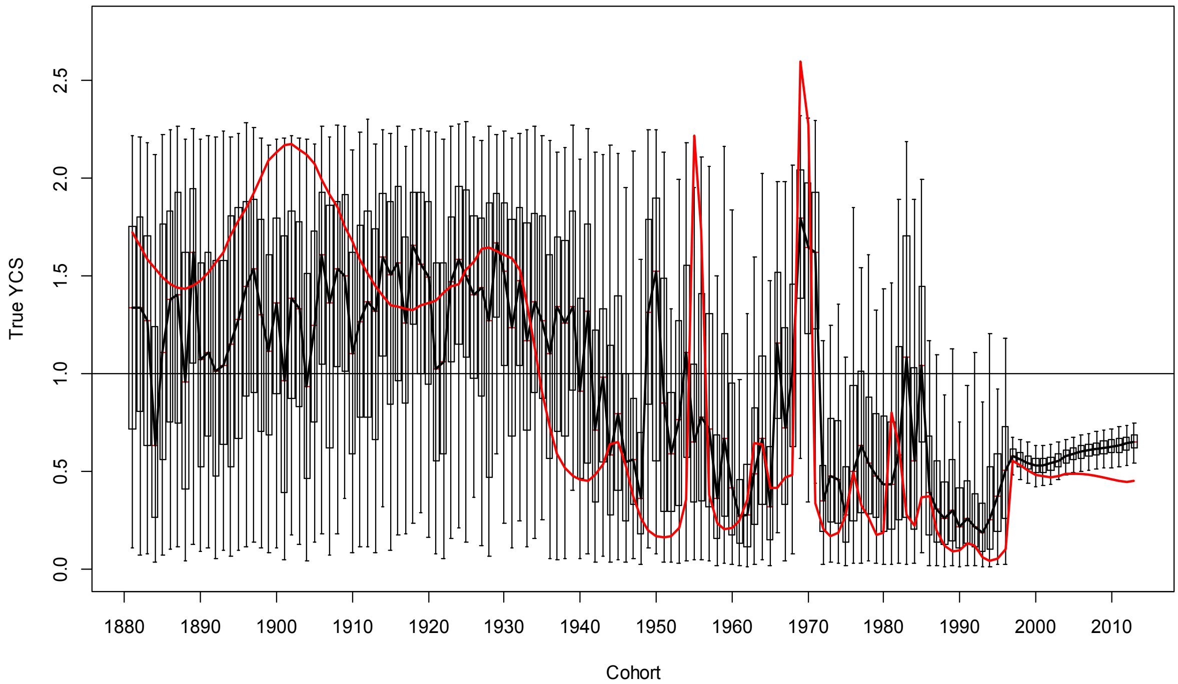

Figure 41: MEC, base model: MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The MPD estimates are shown in red.

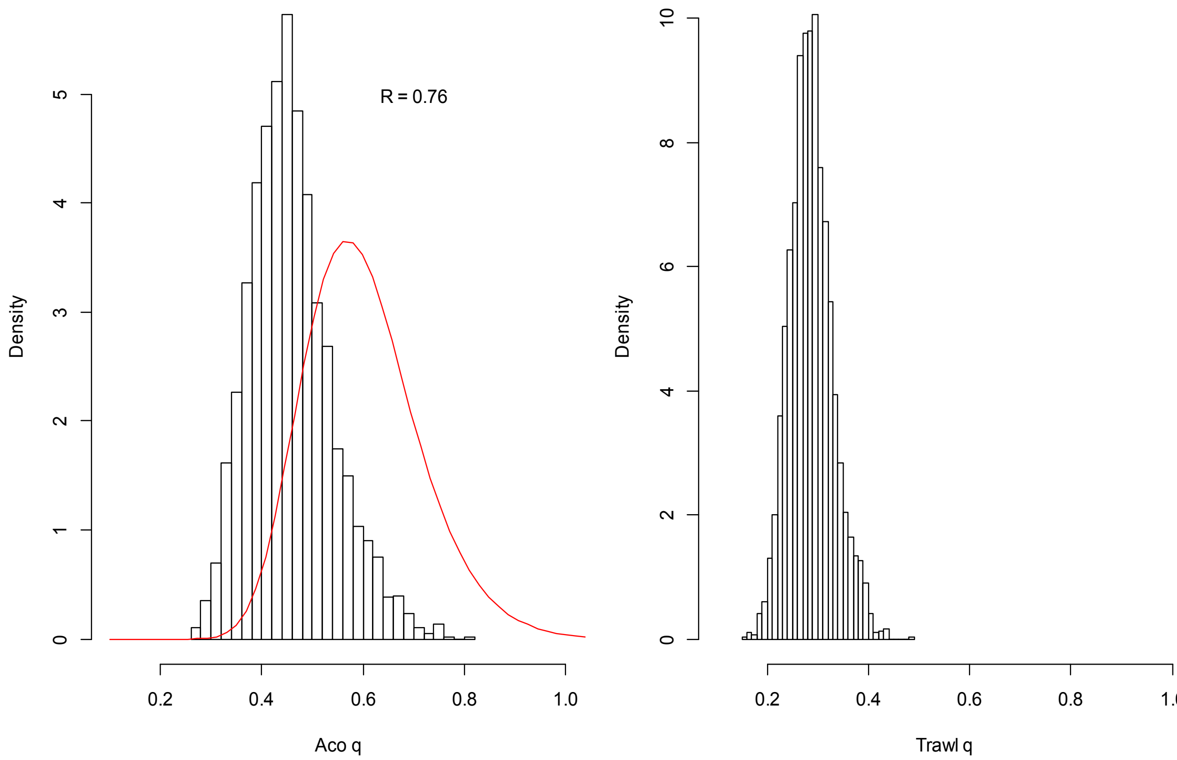

Figure 42: MEC, base model MCMC diagnostics: prior and posterior distributions for the acoustic *q* (prior in red, posterior black histogram); posterior distribution for the trawl-survey *q* (the prior was uninformed). R = 0.76 is the ratio of the mean of the acoustic *q* posterior to the mean of the prior.

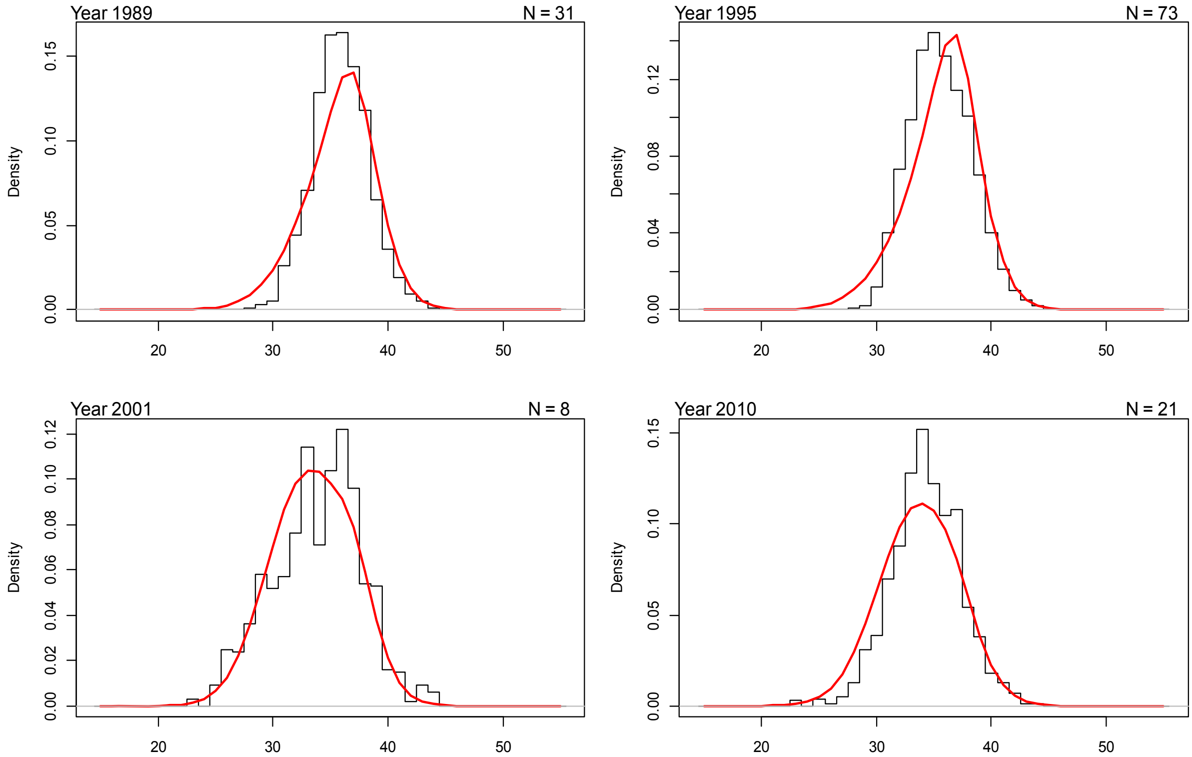

Figure 43: MEC, base: example MPD fits to north fishery length frequencies (N is the assumed effective sample size in the given year; x-axis is fish length (cm)). Observations are square-topped black lines; model predictions are the smooth red lines.

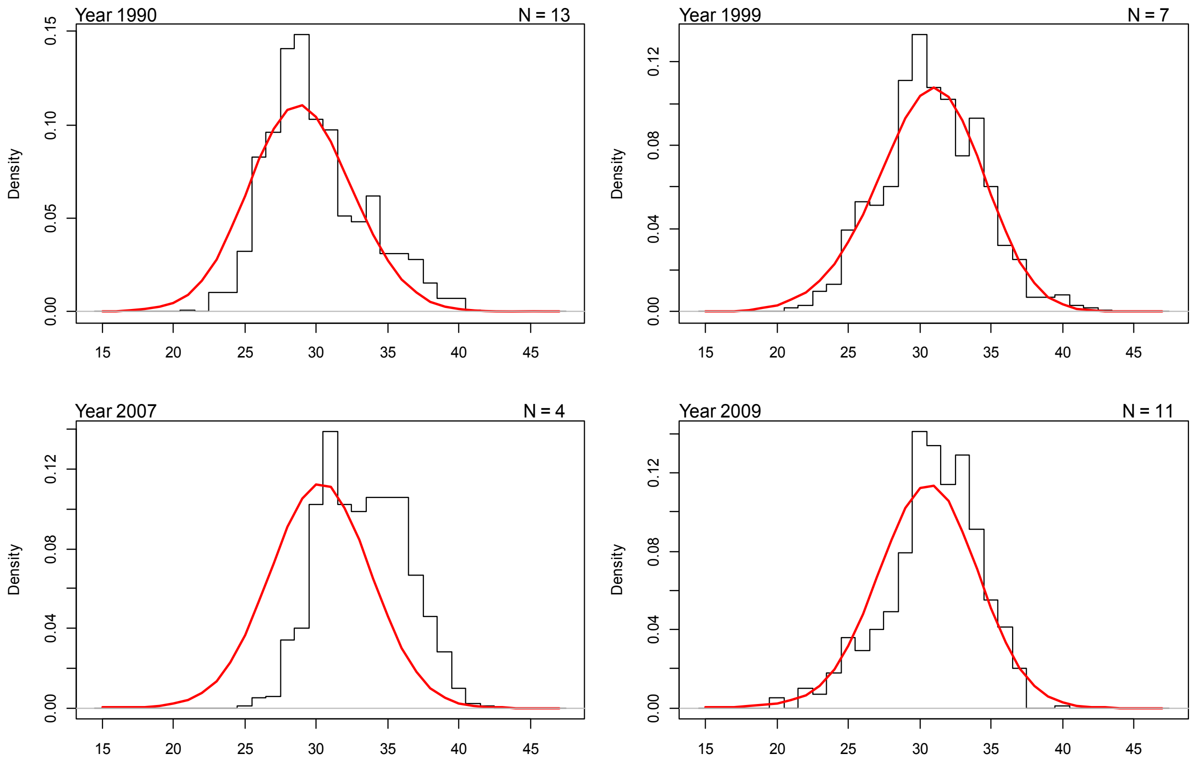

Figure 44: MEC, base: example MPD fits to south fishery length frequencies (N is the assumed effective sample size in the given year; x axis is fish length (cm)). Observations are square-topped black lines; model predictions are the smooth red lines.

The MPD fits to the commercial length frequencies were adequate (Figures 43 and 44). They could never be very good because the length frequencies "jump around" from year to year as evidenced by the annual mean lengths (Figure 45). The model predictions of annual mean length are necessarily fairly smooth from year to year; they track the main trend but not the annual jumps (Figure 45).

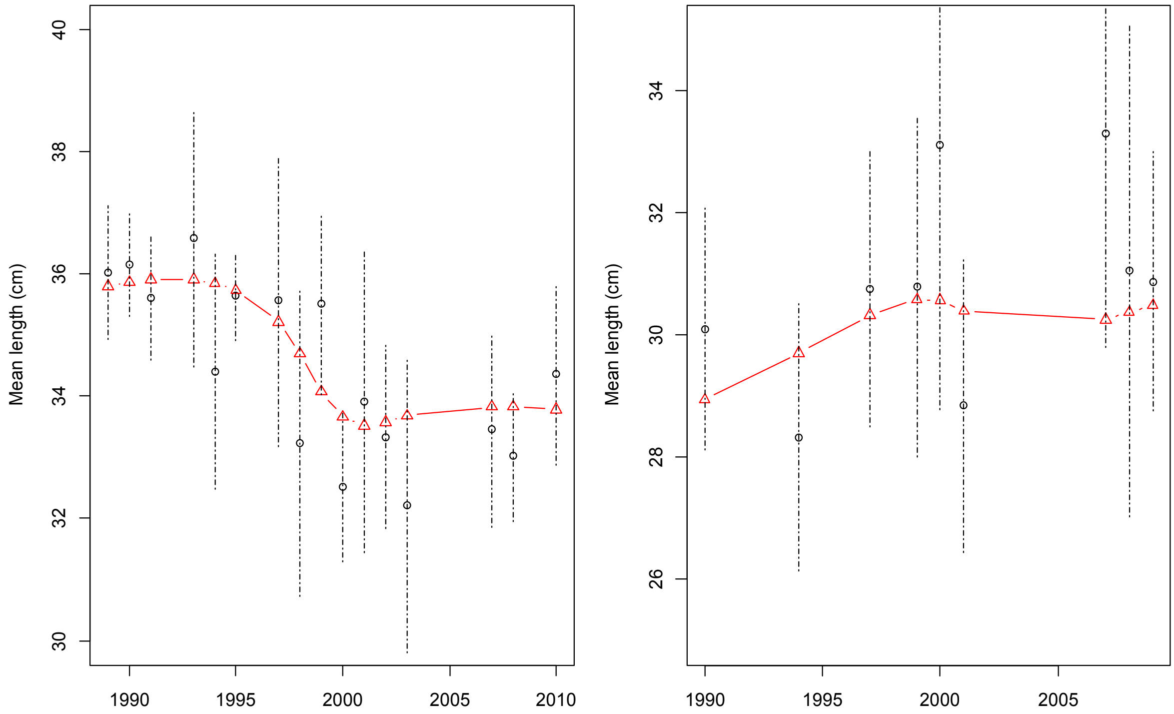

Figure 45: MEC, base, MPD: annual mean lengths for the commercial length frequencies (north on the left, south on the right) with 95% CIs (black, circles, dashed vertical lines) and the model predictions (red, triangles, solid lines).

The MPD fits to the trawl-survey length frequencies and estimates of proportion spawning at age are good (Figure 46). It is notable that the model does fit the different shape of the proportion spawning estimates in 1993 and 2010 (Figure 46). The spawning-season age frequencies are only adequately fitted (Figure 47). There is a misfit for the young ages (except for 2010 which had its own selectivity) as these data compete with the proportion spawning-at-age data to define the maturity ogive (see Figure 46 – young fish are spawning according to the proportion spawning data). In response to the misfit a sensitivity run was done where the 1989–91 spawning age frequencies were allowed to have a logistic selectivity. This improved the fit substantially but did not change the model estimates very much. The base model is still preferred as a matter of consistency across the orange roughy stocks assessed in 2014 where maturity was primarily defined by spawning-season age frequencies in each case.

The fit to the trawl-survey age frequencies is excellent which is perhaps to be expected with the large effective sample size of N = 200 (Figure 48). A number of sensitivity runs were done with alternative data weights including down-weighting the trawl-survey age frequencies. The model was very robust to a wide range of assumptions. For example, the only runs that made a substantial difference to the MPD estimates of stock status were doubling the acoustic index (10.2% B_0 compared to the base estimate of 6.5% B_0) and assuming deterministic recruitment (25.8% B_0); the other 16 runs had MPD estimates in the range 4–9% B_0 (see Appendix 2).

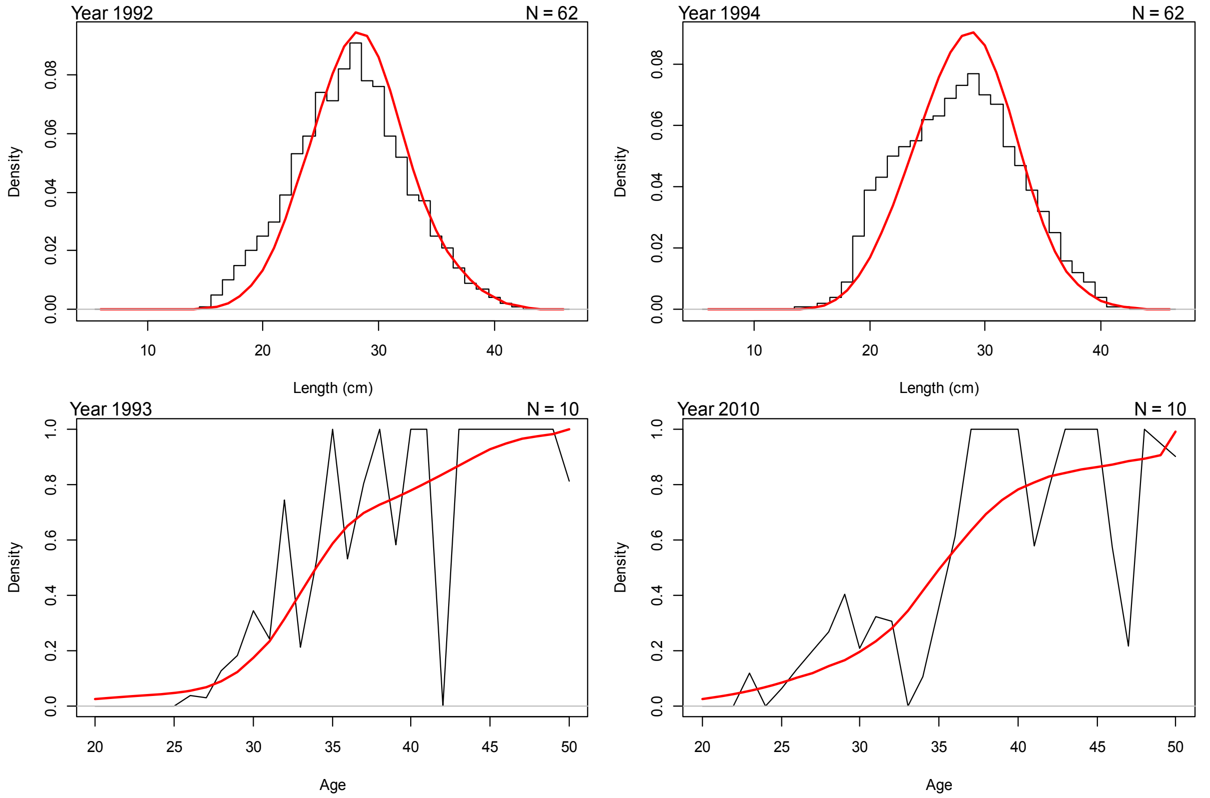

Figure 46: MEC, base, MPD fits to trawl-survey length frequencies (N is the assumed effective sample size in the given year) and proportion spawning-at-age (N =10 is the binomial sample size assumed for each age). Observations are jagged black lines; model predictions are the smooth red lines.

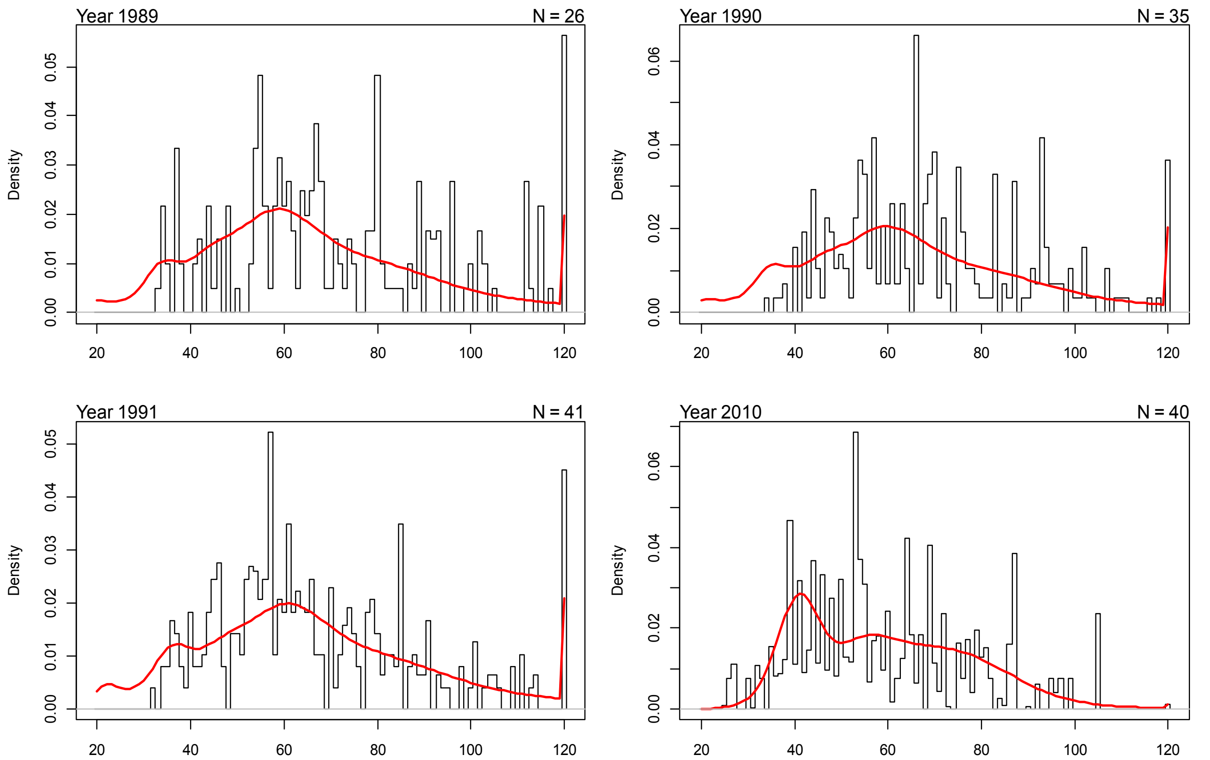

Figure 47: MEC, base, MPD fit to spawning-season age frequencies (N is the assumed effective sample size in the given year). Observations are square-topped black lines; model predictions are the smooth red lines.

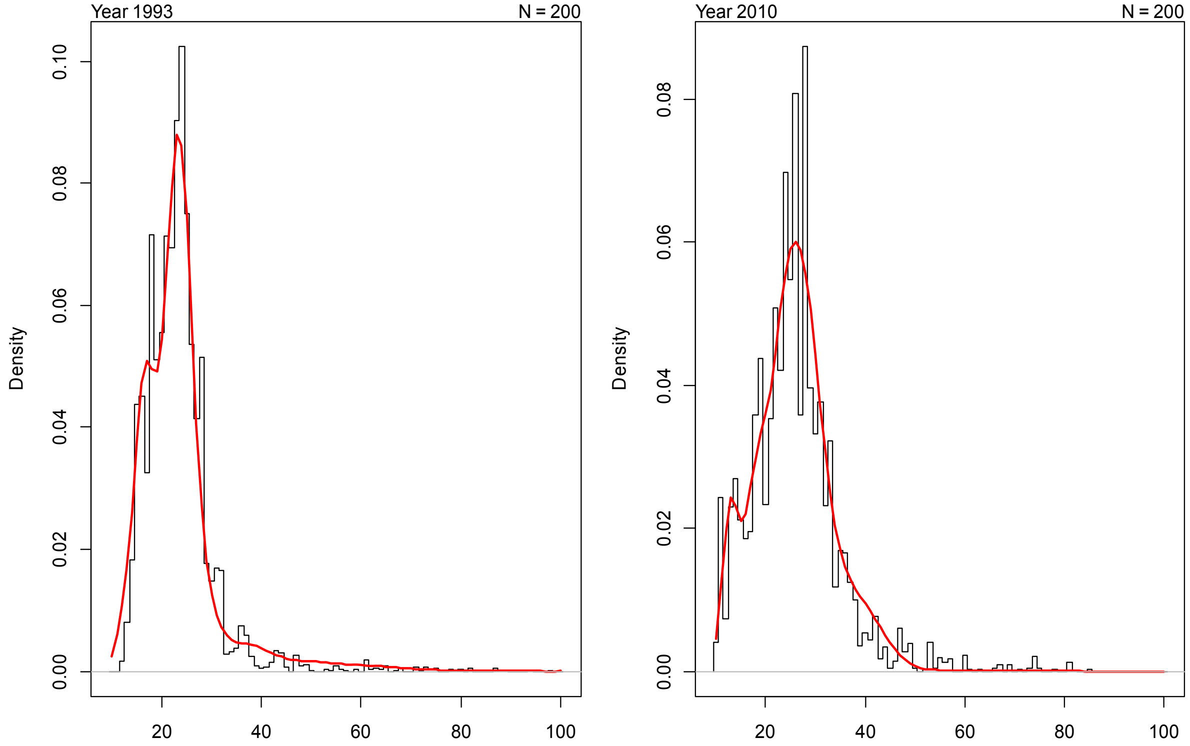

Figure 48: MEC, base, MPD fit to trawl-survey age frequencies (N = 200 is the assumed effective sample size). Observations are square-topped black lines; model predictions are the smooth red lines.

MCMC results

For the base model, and the sensitivity runs, MCMC convergence diagnostics were very good (see Appendix 3). Virgin biomass was estimated to be about 100 000 t for all runs (Table 11). Current stock status was similar for the base and the estimate-*M* run (Table 11). The slightly lower stock status when *M* was estimated reflects the lower estimate of *M* (0.032 rather than 0.045). Down-weighting the trawl indices (by adding process error CV of 20%) reduced the magnitude of the normalised residuals but had little effect on model estimates (Table 11). Giving the 1989–91 spawning age frequencies a selectivity improved the fit and increased estimated stock status only a little (Table 11). The reduction in the mean of the acoustic *q* from 0.6 to 0.4 naturally increased the estimate of stock status but the median estimate was still below the soft limit (Table 11). The two "bounding runs" where *M* and the mean of the acoustic *q* were shifted by 20%, both still had median estimates under the soft limit, with the "pessimistic" run down at the hard limit (Table 11).

Table 11: MCMC estimates of virgin biomass (B_0) and stock status (B_{2014} as $\%B_0$) for the base model and six sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2014} ($\%B_0$)	95% CI
Base	0.045	95	87–104	14	9–21
Estimate M	0.032	104	96–112	11	7–16
Down-weight trawl	0.045	97	88–108	16	11–22
Spawn AF selectivity	0.045	91	83–102	17	12–24
Mean aco. $q = 0.4$	0.045	100	92–112	19	13–26
LowM-Highq	0.036	96	90–103	10	7–15
HighM-Lowq	0.054	99	89–114	19	13–27

The estimated fishery selectivities showed the north fishery taking fish over 30 years with the south fishery primarily taking fish from 20–40 years (Figure 49). The trawl-survey selectivity primarily sampled fish from 10–70 years with peak selection from 20–30 years (Figure 49). The 2010 age frequency appears to have been a select subset of spawning fish aged from about 50–90 years (Figure 49).

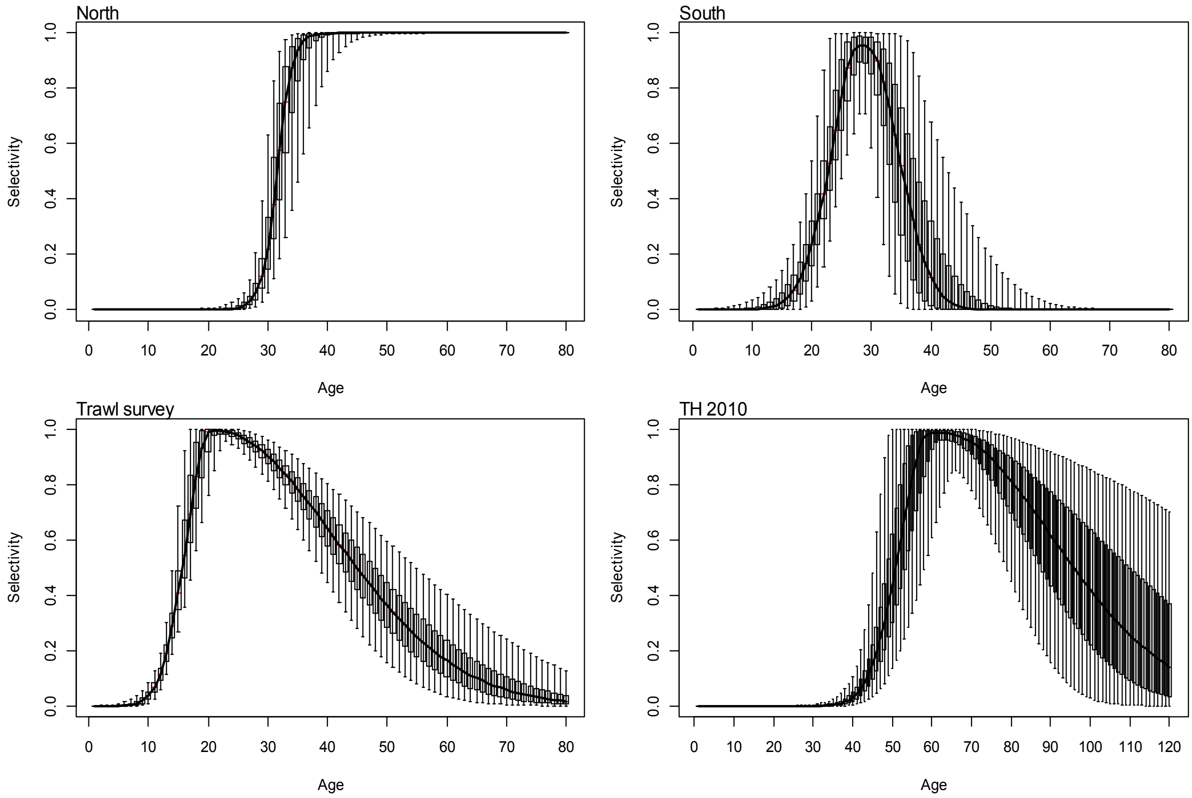

Figure 49: MEC, base, MCMC estimated selectivities (north and south fisheries, the trawl survey, and the 2010 age frequency). The box at each age covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The estimated YCS show strong variation across cohorts and exhibit a long-term trend with recruitment well below average since the mid 1970s (Figure 50). The most recent 10 years of estimates (those resampled for short-term projections) are well below average.

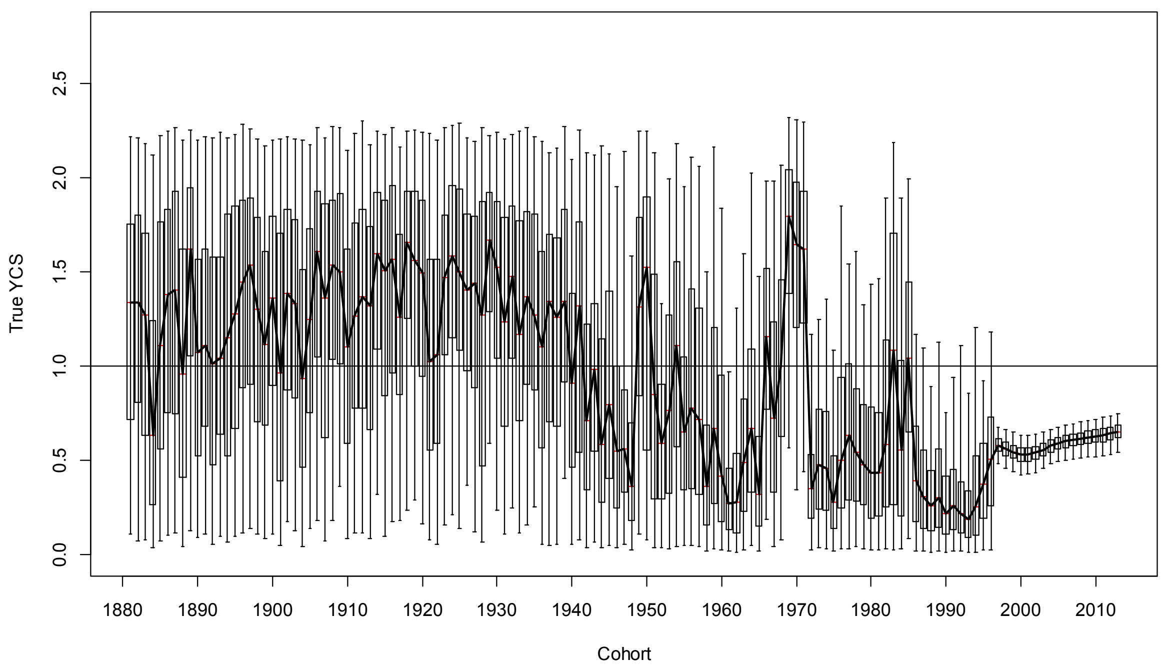

Figure 50: MEC, base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The stock status trajectory shows an increasing trend before the start of fishery as the above average recruitment estimated by the model feeds into the spawning biomass (Figure 51). Then there is a steep decline from the start of fishery until about 2000 when the biomass reaches 10% B_0, after which there is a slow increase (Figure 51).

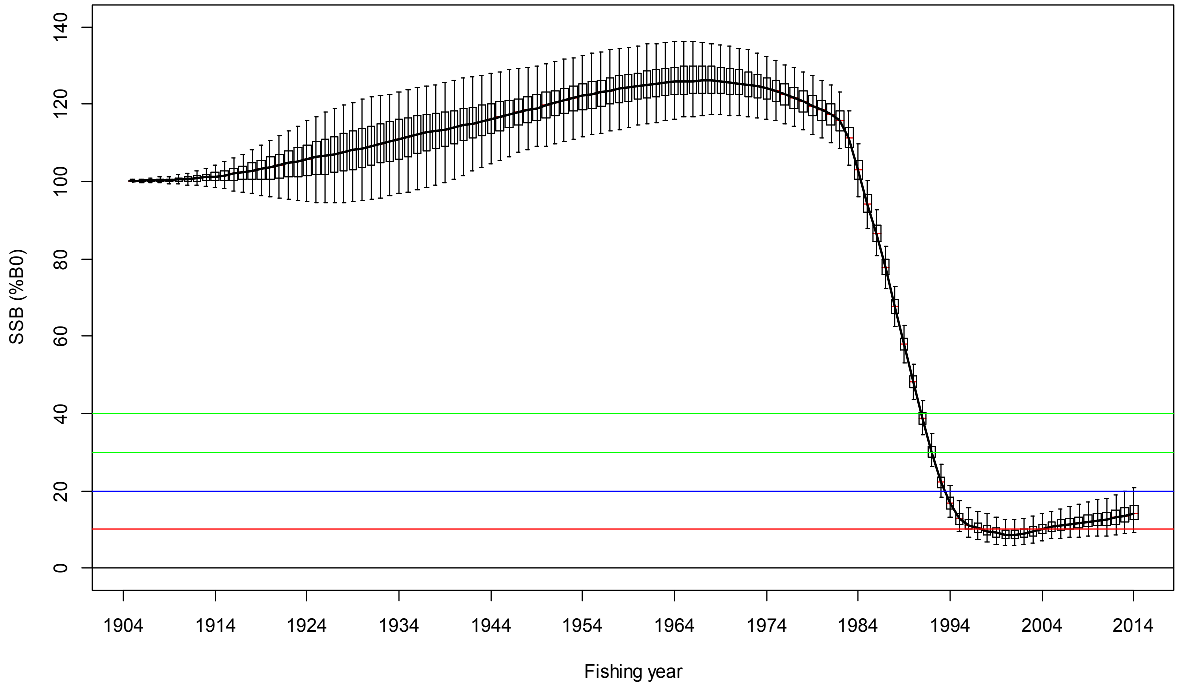

Figure 51: MEC, base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit (red), soft limit (blue), and biomass target range (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity in each year. Estimated fishing intensity was above the target range (U_{30}–U_{40}) from 1984 to 2012 (Figure 52). In the last two years it has decreased to be within the target range. The snail trail is shown in Figure 53.

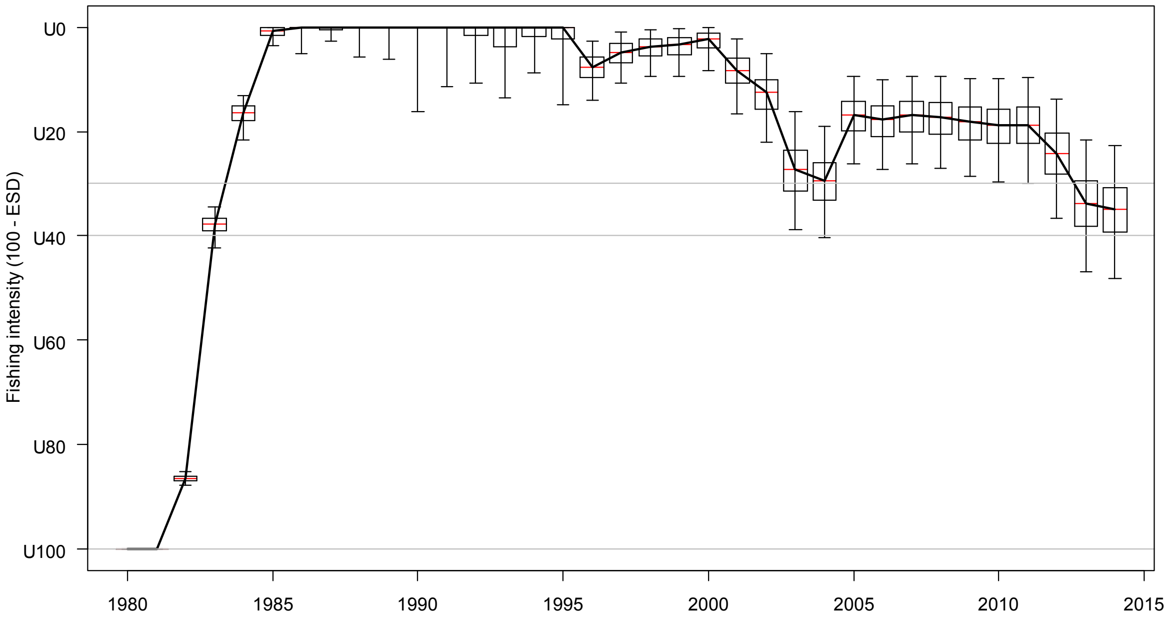

Figure 52: MEC: MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–40% B_0 is marked by horizontal lines.

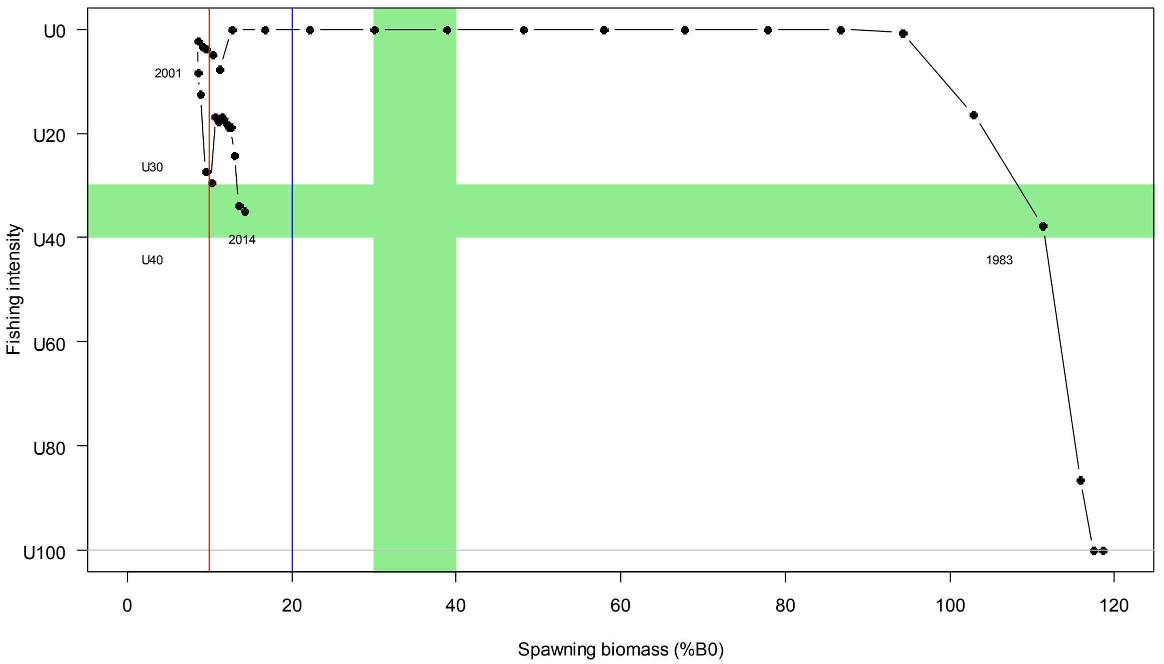

Figure 53: MEC: historical trajectory of spawning biomass (%B_0) and fishing intensity (%) (base model, medians of the marginal posteriors). The biomass target range of 30–40% B_0 and the corresponding exploitation rate (fishing intensity) range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red.

Biological reference points, management targets and yield

MCMC estimates of deterministic B_{MSY} and associated values were produced for the base model. The yield at 35% B_0 (the mid-point of the target range) was also estimated. There is little variation in the reference points and associated values across the MCMC samples (Table 12).

Table 12: Base, MCMC estimates of deterministic equilibrium SSB and long-term yield (% B_0 and tonnes) for U_{MSY} and U_{35}. The equilibrium SSB at U_{MSY} is deterministic B_{MSY} and the yield is deterministic MSY.

Fishing intensity		SSB (%B_0)	Yield (%B_0)	Yield (t)
U_{MSY}	Median	22.5	2.3	2214
	95% CI	21.8–23.0	2.3–2.4	2048–2415
U_{35}	Median	35.0	2.2	2075
	95% CI		2.2–2.2	1916–2264

Projections

Five year projections were conducted (with resampling from the last 10 estimated YCS) for catch at the current catch limit of 930 t (with a 5% over-run assumed). Projections were done just for the base model.

At the current catch limit (930 t), SSB is predicted to increase slowly over the next five years but still be well below the soft limit in 2019 (Figure 54). The estimated minimum time to rebuild (assuming zero catch and requiring a 70% probability of being above the lower bound of the 30–40% B_0 target range) is 21 years (T_{min}).

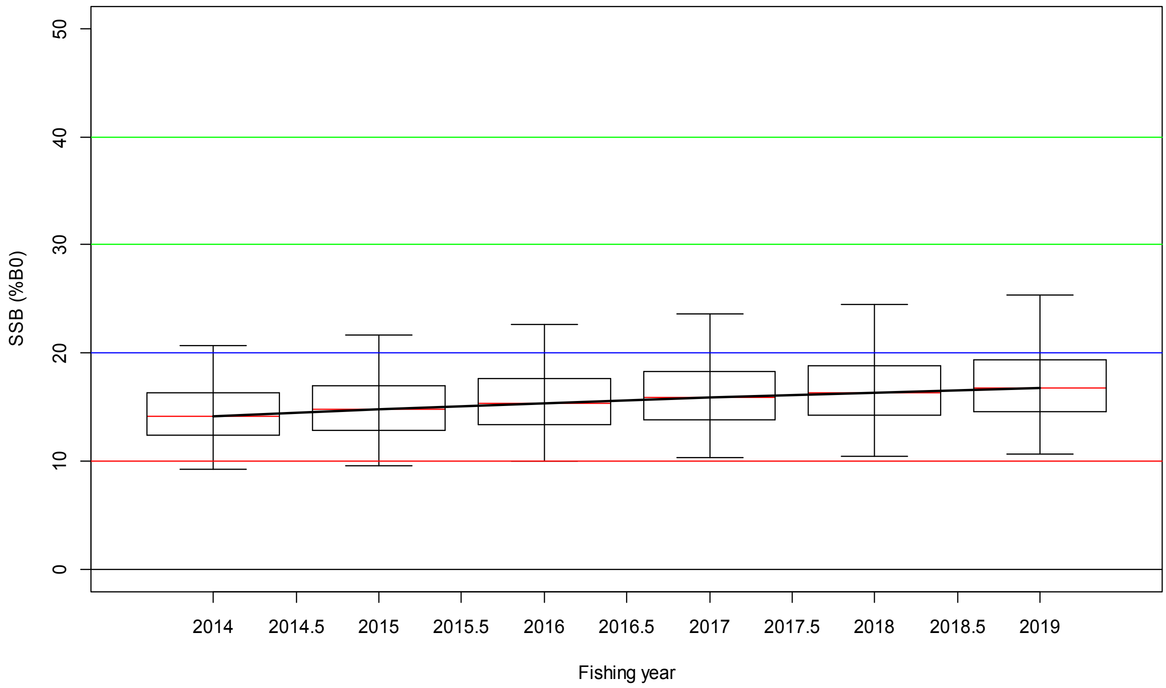

Figure 54: MEC, base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. An annual catch at the current catch limit of 930 t was assumed (with a 5% over-run in each year). The target range is indicated by horizontal green lines, with the soft limit in blue and the hard limit in red.

4. DISCUSSION AND CONCLUSIONS

The use of age data was crucial to the success of the 2014 assessments. For several years, model-based assessment of orange roughy stocks was abandoned because the models were found to be "robust" to the data (in that the same assessment estimates were obtained whether recent abundance indices were included or not). Age data were not used in these models because the old ageing methodology was unreliable and therefore deterministic recruitment was assumed. This resulted in model biomass trajectories showing a strongly increasing trend in recent years which was not supported by abundance indices. The new ageing methodology (Tracey et al. 2007) has allowed age data to be used in the assessments and the models are now responsive to recent abundance indices (e.g., see MPD sensitivity runs in Appendix 2).

The main results of the 2014 stock assessments are summarised below: estimated natural mortality, maturity ogives, year class strength, virgin biomass, and stock status; deterministic B_{MSY} and MSY, with deterministic long-term yields at U_{35} (35% B_0 being the mid-point of the target biomass range).

For each of the four stock assessments the median estimate of natural mortality (*M*) from the "EstM" model was lower than the assumed value in the base model of 0.045 (Table 13). This was despite a fairly tight informed prior on *M* with a mean of 0.045. In each stock assessment there appears to be very little information in the data on the value of *M*; it appears that it can only come from the right-hand limb of age frequencies, where the relative proportion of old fish is related to *M*, but it is also confounded by fishing mortality, selectivity, and year class strength. It seems premature to move to a new value of *M* for the base models. However, as more age data are gathered the estimates of *M* may improve. At the moment there is no reason to believe *M* is higher than 0.045 but there is some evidence to suggest that it could be a bit lower.

Table 13: Estimates of natural mortality for each stock assessed in 2014. These are MCMC estimates from the "EstM" models which are identical to the base models except that *M* is estimated using an informed prior N(mean = 0.045, CV = 0.15)

Stock	*M* (median)	95% CI
NWCR	0.041	0.033–0.051
ESCR	0.037	0.027–0.048
MEC	0.032	0.028–0.037
ORH7A	0.038	0.031–0.047

Estimates of maturity for the four stocks provide a range on age at 50% maturity (a_{50}) of 32–41 years (Table 14). This is considerably older than the estimates of transition-zone maturity which range from 23–33 years (see recent Plenary reports, Francis & Horn 1997). The slopes of the estimated maturity curves are also much shallower than those for transition-zone maturity.

Table 14: Base model, median MCMC estimates of maturity for each stock assessed in 2014. a_{50} is the age, in the virgin population, at which 50% of the fish are mature; a_{to95} is the number of years that need to be added to a_{50} to get the age at which 95% of the fish are mature.

Stock	a_{50} (years)	a_{to95} (years)
NWCR	37	13
ESCR	41	12
MEC	35	10
ORH7A	32	10

There were some similarities in the estimates of year class strength (YCS) across the four stocks (Figure 55). The MEC assessment had the most age data available and therefore it had the largest number of YCS estimated. Early YCS were generally estimated to be above average and recent YCS estimated to be below average. This same pattern was evident for ORH7A and ESCR (though over a shorter duration and of slightly lesser magnitude – see Figure 55). The NWCR was the only assessment where the pattern of recruitment was consistent with average (deterministic) recruitment (Figure 55).

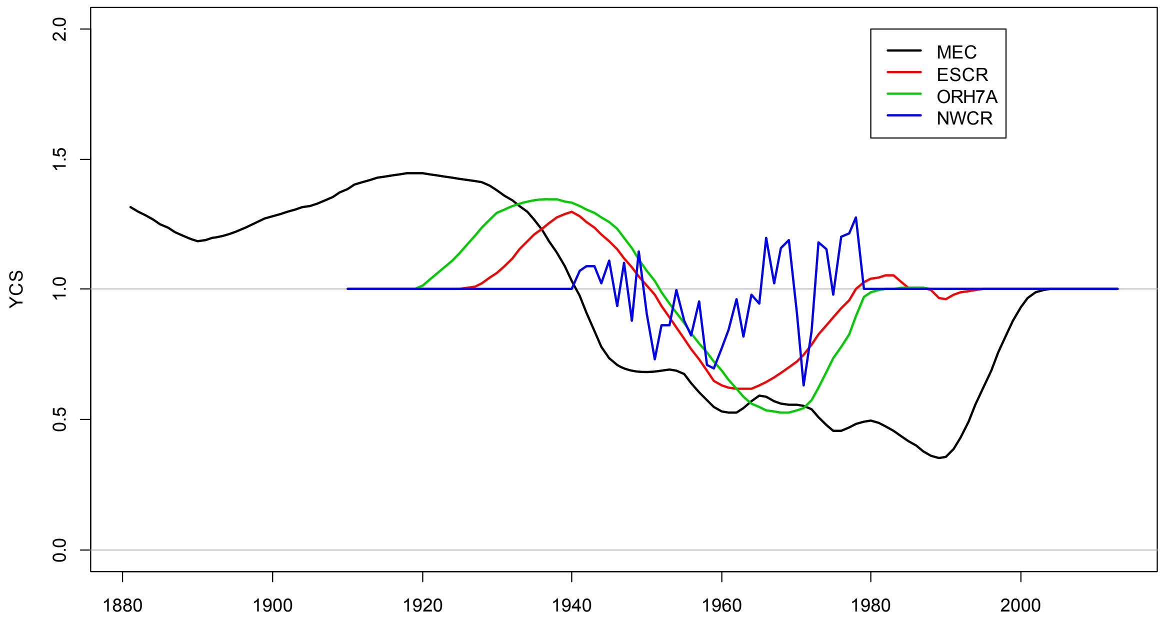

Figure 55: MCMC base models: smoothed median estimates of year class strength (YCS) for the four stocks assessed in 2014. A lowess smoother (f = 0.15) was applied to the MCMC median estimates for each cohort.

The estimated size of the four stocks varies considerably for both virgin and current biomass (Table 15). The ESCR stock is by far the largest with a virgin biomass estimated at over 300 000 t while the other stocks have estimates of less than 100 000 t (Table 15). In terms of current biomass, all of the stocks except for MEC have median current biomass estimates within the 30–40% B_0 target range (Table 15, Figure 56). The MEC stock has a median estimate below the soft limit of 20% B_0 and, according to the assessment, needs to be rebuilt.

Table 15: Base model, median MCMC estimates of virgin biomass (B_0), current biomass (B_{2014}) and current stock status (B_{2014}/B_0).

Stock	B_0 (000 t)	B_{2014} (000 t)	B_{2014} (% B_0)
NWCR	66	24	37
ESCR	320	93	30
MEC	95	14	14
ORH7A	88	37	42

For each of the four stocks, median stock status is trending upwards in recent years (Figure 56). However, the biomass indices for the individual stocks do not generally show an upward trend over those years (or do not contain any trend information because they do not have the same *q*). The driver of the recent increases is the average level of recruitment implied by the virgin size of the stocks *and* the *scale* of the recent biomass indices. Although the recent indices are relative they have quite strongly informed priors and therefore impart important scale information to the stock assessments. This is evidenced by the sensitivity of the MPD stock status estimates to halving and doubling of recent biomass indices (see Appendix 2). The recent biomass indices are an important driver of the stock assessments but they are conditioned, to some extent, by the composition data which provide YCS patterns. The estimated virgin stock size (driven by catch histories), the YCS pattern (driven by composition data), and the scale of the recent biomass indices together with recent catches (or lack of catches), combine to produce the estimates of current biomass and the recent upward trends (Figure 56).

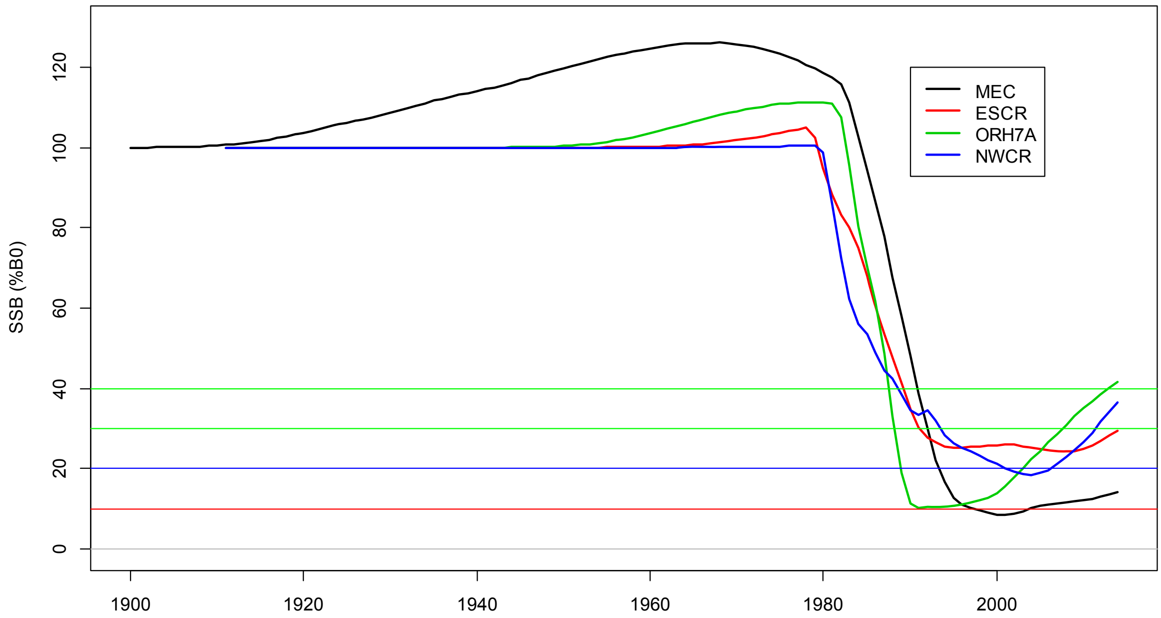

Figure 56: MCMC base models: median estimates of stock status trajectory for the four stocks assessed in 2014. The biomass target range of 30–40% B_0 is shown by green lines, and the soft and hard limits by blue and red lines respectively.

For each assessment, long-term deterministic projections were done for each posterior sample to determine the ESD and yield curves as a function of fishing intensity. This allowed MCMC estimates to be made of deterministic reference points and yields (Table 16). Deterministic B_{MSY} is similar for all four stocks being in the range 21.5–24.5% B_0 (Table 16). In each case, very little yield is lost when moving from deterministic B_{MSY} up to 35% B_0 (the mid-point of the biomass target range). The estimated long-term yields when fishing at U_{35} (the fishing intensity that forces the stock to deterministic equilibrium at 35% B_0) range from 1300–2100 t for the smaller stocks and is about 7200 t for the ESCR stock (Table 16). These yield estimates are unrealistic as they assume deterministic recruitment, known values of h (0.75) and M (0.045) and the exact application of a given level of fishing intensity. More realistic estimates of long-term yield, such as those derived from a management strategy evaluation, would be lower.

Table 16: Base model, median MCMC estimates of deterministic B_{MSY}, MSY, deterministic long-term yield at U_{35}, and the exploitation rate corresponding to U_{35}.

Stock	B_{MSY} (%B_0)	*MSY* (%B_0)	U_{35} yield (%B_0)	U_{35} exploitation rate (%)	U_{35} long-term yield (t)
NWCR	23.7	2.1	2.0	5.3	1320
ESCR	21.8	2.4	2.3	5.3	7180
MEC	22.5	2.3	2.2	5.1	2080
ORH7A	24.5	2.1	2.0	5.4	1740

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APPENDIX 1: The development of the catch histories

Summary
The catch histories for the 2014 orange roughy stock assessments are developed. They are based on existing catch histories from the 2013 Plenary report and supporting documents. The approach of apportioning QMS reported catch into sub-areas using estimated catch from tow-by-tow data is continued. The assumed over-runs given in the 2013 Plenary reported are applied.

Annual totals of MHR data, for the five relevant ORH QMAs, were requested from the Research Data Manager at MPI (RDM) for 2012–13 and some earlier years so that previous catch estimates could be checked. Tow-by-tow data were requested for ORH 3B and ORH 2A so that catches in those QMAs could be estimated for various sub-areas. In general, only minor differences were found between the catch estimates developed here and those given in the 2013 Plenary report and supporting documents.

The largest differences from previous estimates were for the Northwest Chatham Rise (NWCR). This is the smaller of the two stocks assessed for the CR and it is therefore somewhat sensitive to differences in the approach used to groom the tow-by-tow catch data before it is used to apportion Monthly Harvest Return (MHR) catch between areas. In the latest analysis, no grooming was done. In previous analyses, the data were groomed to some extent, possibly to the level needed for CPUE analysis, prior to use in developing the catch histories. I was unable to find full documentation for the grooming process so I am not sure exactly what was done. In any case, even the largest differences in the catch estimates, due to grooming or not grooming, are still relatively minor and of no consequence for stock assessment.

An error in the 2013 Plenary report is noted for the reported catch in 1980 for the ESCR, where the previously reported catch of “1 200 t” for “Rest of east” has morphed into just “200 t”.

Introduction

This appendix describes the methods used to update the orange roughy catch histories for the 2014 assessments of orange roughy (MEC, ORH7A, NWCR, and ESCR) and presents the full catch histories used in the base models.

Catch histories at the QMA level and for some sub-areas, with assumed over-runs, up to the end of 2011–12 were available from the 2013 Plenary report. The general method used to derive those catches was described in the Plenary report and supporting documents, but the details were not given. Much of this appendix is concerned with checking that the methods that I have applied to the 2013 data provide catch estimates that are consistent with the previous results.

Methods
This section is used to describe my methods including the checks that I made on published catch histories. The following “Results” section just has the final catch histories.

The following request was sent to RDM:

“…

My request is for reported catches by QMA and, for some QMAs, the tow-by-tow data required to partition the reported catches by area (i.e., using proportions of estimated catches by area).

Please supply:

Annual reported ORH catches for:

ORH3B: 2003-04 to 2012-13
ORH2A: 2008-09 to 2012-13

ORH2B: 2008-09 to 2012-13
ORH3A: 2008-09 to 2012-13
ORH7A: 2004-05 to 2012-13

AND

Tow-by-tow data (from TCEPR or similar forms) in a spreadsheet or .csv file:

For each tow: QMA, date, start position, estimated ORH catch

For

ORH3B: 2003-04 to 2012-13
ORH2A: 2008-09 to 2012-13

…"

My request was not precise enough with regard to "reported catches" and instead of the MHR data that I was expecting I was sent the annual sums of the estimated catches. On clarification by phone I was sent the landings and MHR data for the years I specified:

Fishstock	Fishing Year	Landings(kgs)	MHR (kgs)
ORH3B	2003-2004 (Oct) Fishing Year	11008397	11254001
ORH3B	2004-2005 (Oct) Fishing Year	12177998	12369623
ORH3B	2005-2006 (Oct) Fishing Year	12538543	12554496
ORH3B	2006-2007 (Oct) Fishing Year	11170897	11271117
ORH3B	2007-2008 (Oct) Fishing Year	10220365	10291230
ORH3B	2008-2009 (Oct) Fishing Year	8745759	8757650
ORH3B	2009-2010 (Oct) Fishing Year	6654674	6661684
ORH3B	2010-2011 (Oct) Fishing Year	3503796	3485617
ORH3B	2011-2012 (Oct) Fishing Year	2765248	2765196
ORH3B	2012-2013 (Oct) Fishing Year	2228448	2515187
ORH2A	2008-2009 (Oct) Fishing Year	1120875	1114307
ORH2A	2009-2010 (Oct) Fishing Year	1117150	1117157
ORH2A	2010-2011 (Oct) Fishing Year	1112107	1112793
ORH2A	2011-2012 (Oct) Fishing Year	876370	876402
ORH2A	2012-2013 (Oct) Fishing Year	726949	726954
ORH2B	2008-2009 (Oct) Fishing Year	173444	173455
ORH2B	2009-2010 (Oct) Fishing Year	213021	213020
ORH2B	2010-2011 (Oct) Fishing Year	157887	157886
ORH2B	2011-2012 (Oct) Fishing Year	140093	140092
ORH2B	2012-2013 (Oct) Fishing Year	101721	101723
ORH3A	2008-2009 (Oct) Fishing Year	413133	414181
ORH3A	2009-2010 (Oct) Fishing Year	361155	389793
ORH3A	2010-2011 (Oct) Fishing Year	421028	419773
ORH3A	2011-2012 (Oct) Fishing Year	406109	428144
ORH3A	2012-2013 (Oct) Fishing Year	329170	295629
ORH7A	2004-2005 (Oct) Fishing Year	65	225
ORH7A	2005-2006 (Oct) Fishing Year	29	179
ORH7A	2006-2007 (Oct) Fishing Year	9	9

ORH7A	2007-2008 (Oct) Fishing Year	59	59
ORH7A	2008-2009 (Oct) Fishing Year	32	196
ORH7A	2009-2010 (Oct) Fishing Year	163	5
ORH7A	2010-2011 (Oct) Fishing Year	475562	475562
ORH7A	2011-2012 (Oct) Fishing Year	380059	511058
ORH7A	2012-2013 (Oct) Fishing Year	512937	512939

The difference between "landings" and "MHR" estimates is not always minor (e.g., ORH 7A, 2011–12), but it is the estimates from the QMS that are normally used (MHR and earlier equivalents).

The methods used to check and derive the catch histories are slightly different for each of the areas so each has its own section below.

Chatham Rise

Two stocks were assessed on the Chatham Rise: NWCR and ESCR. The catch histories were derived from the ORH 3B QMS reports (i.e., total annual removals according to quota reports) and the proportions of estimated catches in each area from catch and effort data (and then application of the overrun percentages).

The first check was to make sure that the MHR extract agreed with the "Reported catch" column of table 1 in the 2013 Plenary report. This was the case with the estimates being identical to the level of precision in the Plenary report table (1 tonne).

The tow-by-tow catch data were used to estimate the total annual catch within each sub-area needed for the stock assessment catch histories:

NWCR:	longitude:	(171, 182)	latitude:	(42, 44)
ESCR:				
spawning box	longitude:	[182, 185)	latitude:	(42, 44)
Andes complex	longitude:	[185, 186.4)	latitude:	[44, 44.35]
eastern hills	within 3 n.mile of a "hill" (see positions used below)			
south CR	longitude:	[170, 185]	latitude:	[44, 46]
east flats	longitude:	[185, 186.4)	latitude:	(42, 46)
(excludes Andes and eastern hills)				

See figure 2 in the 2013 Plenary report for a map of the areas.

The eastern hills (UTFs) used were those mentioned in the last fully quantitative stock assessment of the east rise and Andes, Dunn (2007):

	Longitude	Latitude	
Smith's City:	185.8	43.1	(Dunn, 2007)
	185.58	42.96	(Stewart, 2013)
Camerons:	185.73743.133		(Stewart, 2013)
Erebus:	186.16	43.178	(Stewart, 2013)
Not till Sunday:	43.854	185.7	(Stewart, 2013)

Distance was calculated using the R function, *distMeeus*(), from the package *geosphere* (Hijmans, et al. 2013).

For the NWCR there were some notable differences in the estimates that I produced and those given in table 2 of the 2013 Plenary report:

Fishing year (ending)	NWCR catch estimate (t)	2013 Plenary report (t)
2004	2 116	2 000
2005	1 642	1 600
2006	1 602	1 400
2007	875	700
2008	675	800
2009	754	750
2010	754	720
2011	49	40
2012	73	70
2013	110	–

The differences (2004, 2006, 2007, 2008) must be driven by the estimated catches (in the NWCR and other areas in ORH 3B) because both sets of estimates are using identical QMA totals.

Anderson & Dunn (2012) contains the most recent summary of catch and effort data from ORH QMAs, being to the end of 2008–09. It briefly describes the process used to groom the catch and effort data before the groomed data are used in summary analyses – which presumably includes the production of catch histories. The grooming process, which could include the reassignment of positions (e.g., an east-west error), must be responsible for the differences between my estimates and those in the 2013 Plenary report (which presumably is derived from the process described by Anderson & Dunn, 2012).

For the NWCR, there is a difference in the estimated annual total catches:

Fishing year (ending)	NWCR total of estimated catches (t)	Anderson and Dunn 2012 (t)
2004	1 967	1 952
2005	1 520	1 557
2006	1 475	1 342
2007	797	698
2008	610	711
2009	693	690

This must be a result of reassignment of tows to different areas by the grooming process. Certainly, one would generally prefer the groomed data and the corresponding catch estimates to the estimates from the ungroomed data – but the lack of full documentation and therefore doubt as to why records were included/excluded is a concern. In any case, the catch estimates in recent years (2009–2012) are sufficiently close that I don't have any concerns about using the 2013 estimate even though it is obtained from ungroomed data.

For the spawning box and the south rise, estimates from the current analysis can be checked directly against those in table 2 of the Plenary report:

Fishing year (ending)	Sp. box catch estimate (t)	2013 Plenary report (t)	South CR catch estimate (t)	2013 Plenary report (t)
2004	4 257	4 300	1 342	1 400
2005	4 104	4 100	1 674	1 700
2006	3 840	3 900	1 247	1 300
2007	4 166	4 200	1 213	1 200
2008	3 897	3 800	1 352	1 300
2009	3 447	3 400	1 172	1 170
2010	3 127	3 120	930	940
2011	1 853	1 860	461	460
2012	1 522	1 490	305	300
2013	1 450	–	292	–

Also, estimates from Dunn (2007) can be compared in 2004 and 2005 for the spawning box: 4295 t and 4095 t respectively. All of these estimates are very close so there is no concern using the estimates from the ungroomed data.

For the NE hills, Andes, and the eastern flats, a comparison with the 2013 Plenary report is only possible as a total:

Fishing year (ending)	NE hills (t)	Andes (t)	East flats (t)	Total catch estimate (t)	2013 Plenary report (t)
2004	587	1 455	530	2 572	2 600
2005	517	1 315	1 117	2 949	3 000
2006	518	1 691	1 598	3 808	3 900
2007	796	1 379	1 412	3 587	3 700
2008	364	1 245	1 112	2 722	2 700
2009	653	490	957	2 100	2 150
2010	235	549	480	1 264	1 260
2011	192	531	19	742	740
2012	208	504	57	769	750
2013	56	503	33	592	–

The totals from the 2013 Plenary report and the current analysis are very close and suggest that there is no problem using the estimates from the current analysis unless the selectivities in the three areas are hugely different (which they won't be). The estimates by area from Dunn (2007) (in the caption of table 3) are fairly close: NE hills, 514 t in 2004 and 2005; Andes, 1343 t in 2004 and 2005; and East flats, 524 t in 2004, 1133 t in 2005. However, it seems a bit suspect that the Dunn estimates in 2004 and 2005 are identical for two of the areas. Also, the totals from Dunn (2007) are 2500 t (2004) and 3140 t (2005). The total for 2004 is 100 t less than the 2600 t estimate in the 2013 Plenary report and also 100 t less than the Andes estimate in this report.

Because of the suspect nature of the Dunn (2007) estimates in 2004 and 2005, the catch history is based on Dunn (2007) from 1979–2003 and on the analysis in this report from 2004–2013. Note, the 2013 Plenary report disagrees with Dunn (2007) for the 1980 ESCR total catch: 29 092 t from Dunn (2007); and 28 100 t from the 2013 Plenary report. The 2013 Plenary report is in error in table 2 for 1980 as it gives the catch for "Rest of east" as "200 t" instead of "1 200 t".

ORH7A

The 2013 Plenary report gives estimated catches inside and outside the EEZ from 1980–81 to 1996–97 and then a single total estimate each year up until 2011–12 (see table 1 in the 2013 Plenary report). The document is silent on the definition of the fishing years in the early years but it is of little consequence to the 2014 assessment if some are April-March rather than October-September.

Field & Francis (2001) note that New Zealand vessels have to declare catch outside the EEZ on the Westpac Bank as ORH 7A catch. Also, it appears that Australian vessels have taken little or no catch on the Westpac Bank after 1996–97.

The total orange roughy catches from the trawl-survey reports for 2005, 2006, 2009, and 2010 were noted as these catches were not covered by the MHRs and constitute the vast majority of the removals in those years. The MHR extract is consistent with the 2013 Plenary report except for a minor difference in 2009:

Fishing year (ending)	ORH 7A MHR (t)	Trawl survey (t)	2013 Plenary report (t)
2005	0.225	158	< 1.0
2006	0.179	218	< 1.0
2007	0.009	–	< 0.1
2008	0.059	–	< 0.1
2009	0.196	240	0.12
2010	0.005	344	< 0.1
2011	476	Included in MHR	476
2012	511	Included in MHR	511
2013	513	Included in MHR	–

The 2013 Plenary report notes that the catches for the trawl surveys were approximately 200 t each year which is fairly close (except in 2010).

MEC
This stock is in part of the area covered by QMAs: 2A, 2B, and 3A. The MHR estimates from my extract agreed exactly with table 1 in the 2013 Plenary report. However, QMA2A has to be split into north (East Cape) and south (MEC = 2A south, 2B, and 3A).

A comparison of my 2A south catch estimates and the estimates from table 2 of the 2013 Plenary report show only relatively minor differences:

Fishing year (ending)	Estimated catch 2A north (t)	2013 Plenary report (t)	Estimated catch 2A south (t)	2013 Plenary report (t)
2009	251	230	863	884
2010	270	267	847	850
2011	216	207	896	906
2012	184	245	692	631
2013	190	–	537	–

The biggest differences are in 2012 which is not surprising since the 2A south estimate in the Plenary report is just the sum of the estimated catches (I updated the table that year and I had asked for MHR data but that wasn't what I was given). The differences in the other years are minor so there is no problem going with the Plenary report up until 2011 and then using the ungroomed data from the latest extract for 2012 and 2013.

Results

Chatham Rise
For the NWCR, the rounded values from the 2013 Plenary report were used as the basis for the catch history. These estimates are consistent with those in previous FARs/reports to within about 100 t. The 2013 estimate from the current analysis is used and is assumed for the 2014 year (Table A1.1).

Table A1.1: NWCR: estimated catch (1980–2012 from 2013 Plenary report; 2013 from this report; 2014 assumed equal to 2013), assumed overrun, and total catch used in the 2014 stock assessment.

Fishing year	Estimated catch (t)	Overrun (%)	Total catch (t)
1980	1 200	30	1 560
1981	8 400	30	10 920
1982	7 000	30	9 100
1983	5 400	30	7 020
1984	3 300	30	4 290
1985	1 800	30	2 340
1986	3 700	28	4 736
1987	3 200	26	4 032
1988	1 600	24	1 984
1989	3 800	22	4 636
1990	3 300	20	3 960
1991	1 500	15	1 725
1992	300	10	330
1993	3 800	10	4 180
1994	3 500	10	3 850
1995	2 400	5	2 520
1996	2 400	5	2 520
1997	2 200	5	2 310
1998	2 300	5	2 415
1999	2 700	5	2 835
2000	2 100	5	2 205
2001	2 600	5	2 730
2002	2 200	5	2 310
2003	2 200	5	2 310
2004	2 000	5	2 100
2005	1 600	5	1 680
2006	1 400	5	1 470
2007	700	5	735
2008	800	5	840
2009	750	5	787
2010	720	5	756
2011	40	5	42
2012	70	5	73
2013	110	5	115
2014	110	5	115

For the ESCR, the four fisheries used in Dunn (2007) were continued and the estimates from Dunn were used from 1979–2003. For 2004–2013 the estimates from this analysis are used. For 2014, an increased catch limit for ESCR is accounted for by increasing the catch for the spawning box and east flats fishery (Table A1.2). The increase of 765 t (before application of the 5% overrun) is the difference between the total ESCR catch estimate in 2012 (2335 t before the overrun is applied) and the 2014 catch limit of 3100 t. Thus, the 2014 catch (before overrun) is assumed to equal the 2014 catch limit.

Table A1.2: ESCR: estimated catch, including overruns (see Table A1.1) for each fishery in the 2014 stock assessment model (1979–2003 from Dunn (2007); 2004–2013 from this report; 2014 assumed equal to 2013 except for "Sp. box and flats" which is increased to account for the higher catch limit – see text).

Fishing year	Spawning box and flats (t)	NE hills (t)	Andes (t)	South (t)
1979	15 338	0	0	0
1980	37 660	160	0	1 040
1981	20 910	20	0	4 810
1982	22 560	60	0	650
1983	6 760	0	0	6 240
1984	21 360	90	0	6 630
1985	25 350	0	0	10 270
1986	26 720	290	0	6 784
1987	28 270	200	0	6 174
1988	19 220	370	0	8 432
1989	23 710	400	50	11 224
1990	20 320	200	240	13 200
1991	7 570	6 370	100	7 935
1992	2 590	3 100	8 620	2 420
1993	190	1 280	3 820	5 940
1994	90	1 250	4 060	5 610
1995	570	1 740	1 900	1 680
1996	1 800	810	1 380	1 365
1997	1 800	1 170	820	1 470
1998	2 570	710	1 550	1 785
1999	1 280	1 120	1 390	1 260
2000	1 640	930	2 270	1 155
2001	1 500	880	1 300	1 785
2002	3 460	1 040	2 540	1 155
2003	3 720	870	2 870	1 575
2004	5 026	616	1 528	1 409
2005	5 482	543	1 381	1 757
2006	5 711	544	1 776	1 310
2007	5 857	836	1 448	1 273
2008	5 260	383	1 307	1 419
2009	4 625	686	514	1 231
2010	3 787	247	577	976
2011	1 966	202	558	484
2012	1 659	218	529	320
2013	1 558	59	528	307
2014	2 361	59	528	307

ORH 7A

For ORH 7A, the rounded values from the 2013 Plenary report were used as the basis for the catch history. These estimates are equal to those in the 2001 stock assessment FAR (Field & Francis, 2001). The 2013 estimate from the current analysis is used and is assumed for the 2014 year (Table A1.3). The overrun of 5% from 2005 onwards is assumed to be due to incidental mortality associated with trawling and therefore is applied to trawl-survey catches as well as commercial catches. The trawl-survey catches in 2011–2013 were taken under normal quota and are included in the first column of Table A1.3.

Table A1.3: ORH 7A: estimated catch (1981–2012 from 2013 Plenary report; 2013 from this report; 2014 assumed equal to 2013), catches from trawl surveys not included in estimated catch, assumed overrun, and total catch proposed for use in the 2014 stock assessment.

Fishing year	Estimated catch (t)	Trawl survey catch (t)	Overrun (%)	Total catch (t)
1981	33	0	30	43
1982	4 248	0	30	5 522
1983	11 839	0	30	15 391
1984	9 527	0	30	12 385
1985	5 117	0	30	6 652
1986	7 753	0	30	10 079
1987	11 492	0	30	14 940
1988	12 181	0	30	15 835
1989	10 241	0	25	12 801
1990	4 309	0	20	5 171
1991	1 357	0	15	1 561
1992	1 911	0	10	2 102
1993	2 087	0	10	2 296
1994	1 732	0	5	1 819
1995	1 636	0	5	1 718
1996	1 669	0	5	1 752
1997	1 308	0	5	1 373
1998	1 502	0	5	1 577
1999	1 249	0	5	1 311
2000	629	0	5	660
2001	0	0	5	0
2002	0	0	5	0
2003	4	0	5	4
2004	0	0	5	0
2005	0	158	5	166
2006	0	218	5	229
2007	0	0	5	0
2008	0	0	5	0
2009	0	240	5	252
2010	0	344	5	361
2011	476	0	5	500
2012	511	0	5	537
2013	513	0	5	539
2014	513	0	5	539

MEC

The catch history is based on the estimates in the Plenary report up until 2011 and then uses the estimates of this report for 2012 and 2013 (with 2014 assumed equal to 2013)(Table A1.4). The stock assessment model uses a north fishery (2A south + 2B) and a south fishery (3A) because much smaller fish are caught in the south (off Kaikoura).

Table A1.4: MEC: estimated catch (1982–2011 from 2013 Plenary report; 2012 and 2013 from this report; 2014 assumed equal to 2013), assumed overrun, and total catch proposed for use in the 2014 stock assessment (north fishery = 2A south + 2B, south fishery = 3A).

Fishing year	Estimated catch 2A south (t)	Overrun (%)	Estimated catch 2B (t)	Overrun (%)	Estimated catch 3A (t)	Overrun (%)	North fishery (t)	South fishery (t)
1982	0	50	554	30	0	30	720	0
1983	0	50	3 510	30	253	30	4 563	329
1984	162	50	6 685	30	554	30	8 934	720
1985	1 858	50	3 310	30	3 266	30	7 090	4 246
1986	2 778	50	867	30	4 326	30	5 294	5 624
1987	4 934	40	963	30	2 555	30	8 160	3 322
1988	6 203	30	982	30	2 510	30	9 340	3 263
1989	5 710	25	1 236	25	2 431	25	8 682	3 039
1990	6 239	20	1 400	20	2 878	20	9 167	3 454
1991	6 051	15	1 384	15	2 553	15	8 550	2 936
1992	6 329	10	1 327	10	2 443	10	8 422	2 687
1993	5 807	10	1 080	10	2 135	10	7 576	2 348
1994	3 173	10	1 259	10	2 131	10	4 875	2 344
1995	3 281	5	754	5	1 686	5	4 237	1 770
1996	1 033	5	245	5	612	5	1 342	643
1997	1 270	5	272	5	580	5	1 619	609
1998	1 416	5	254	5	570	5	1 754	598
1999	1 434	5	257	5	582	5	1 776	611
2000	1 666	5	234	5	617	5	1 995	648
2001	1 083	5	190	5	479	5	1 337	503
2002	901	5	180	5	400	5	1 135	420
2003	546	5	105	5	235	5	684	247
2004	533	5	103	5	250	5	668	262
2005	849	5	206	5	416	5	1 108	437
2006	859	5	172	5	415	5	1 083	436
2007	902	5	203	5	401	5	1 160	421
2008	868	5	209	5	432	5	1 131	454
2009	884	5	173	5	414	5	1 110	435
2010	850	5	213	5	390	5	1 116	410
2011	906	5	158	5	420	5	1 117	441
2012	692	5	140	5	428	5	874	449
2013	537	5	102	5	296	5	671	311
2014	537	5	102	5	296	5	671	311

The catches in Table A1.4 for the north and south fisheries are consistent with the values used in the last MEC assessment (they differ by no more than 1 t up until 2011 in the north and 2012 in the south).

References

Anderson, O.F.; Dunn, M.R. (2012). Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, 7A, and 7B to the end of the 2008–09 fishing year. *New Zealand Fisheries Assessment Report 2012/20.* 82 p.

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APPENDIX 2: MPD diagnostics: likelihood profiles and sensitivities

This appendix contains various MPD diagnostics that were examined during the stock assessment process. In particular, there are likelihood profiles for B_0 and *M*. These are checked to see if there is extreme conflict between the data sets or if one data set "dominates" the others. The latter would indicate a possible data-weighting problem (to be explored in sensitivity runs) while the former might suggest that alternative models should be explored with the "contradictory" data sets in separate runs.

The results of various sensitivity runs are also presented. These explore the effect of alternative weights on data sets, assuming deterministic recruitment, halving/doubling biomass indices (to see if the model is "robust to the data" – which is not desirable) and changes in fixed values such as *M* and/or the means of priors for acoustic *q*s.

NWCR

The likelihood profile on B_0 is remarkable by the lack of conflict between the components (Figure A2.1). Most data sets and priors have some aversion to values of B_0 less than 60 000 t but the only apparent constraint on high values of B_0 comes from the acoustic prior (Figure A2.1). The profile on *M* also shows little conflict. The prior on *M* is the strongest component but the age frequency data from the trawl surveys has some influence pushing towards lower values of *M* (Figure A2.2).

The MPD estimate of stock status is sensitive to the value of *M* and to the mean of the acoustic *q* prior (Figure A2.3). It is not sensitive to the assumption of deterministic recruitment (YCS not estimated and all assumed equal to 1). This is unique to NWCR amongst the four assessed stocks.

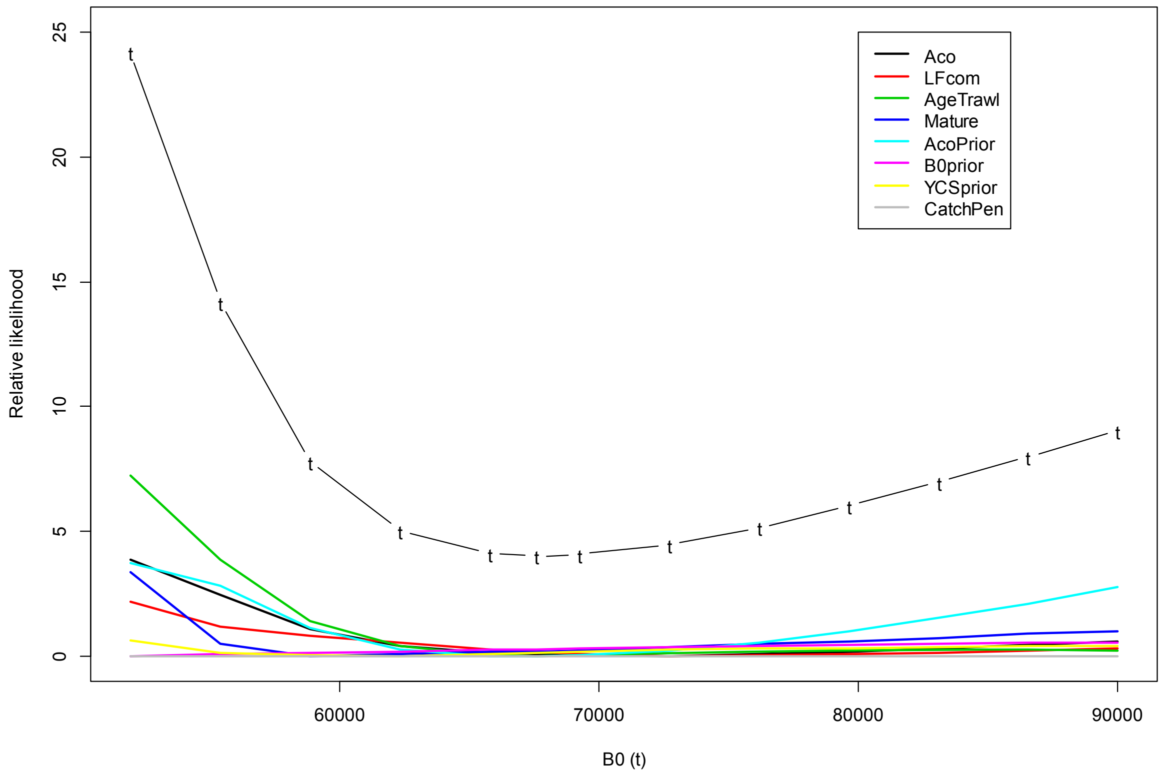


Figure A2.1: NWCR: likelihood profile on B_0. Each component of the objective function has had its minimum subtracted so that the lines sit on the x-axis. The total objective function has been shifted above the x-axis an arbitrary amount (the line with the "t"s).

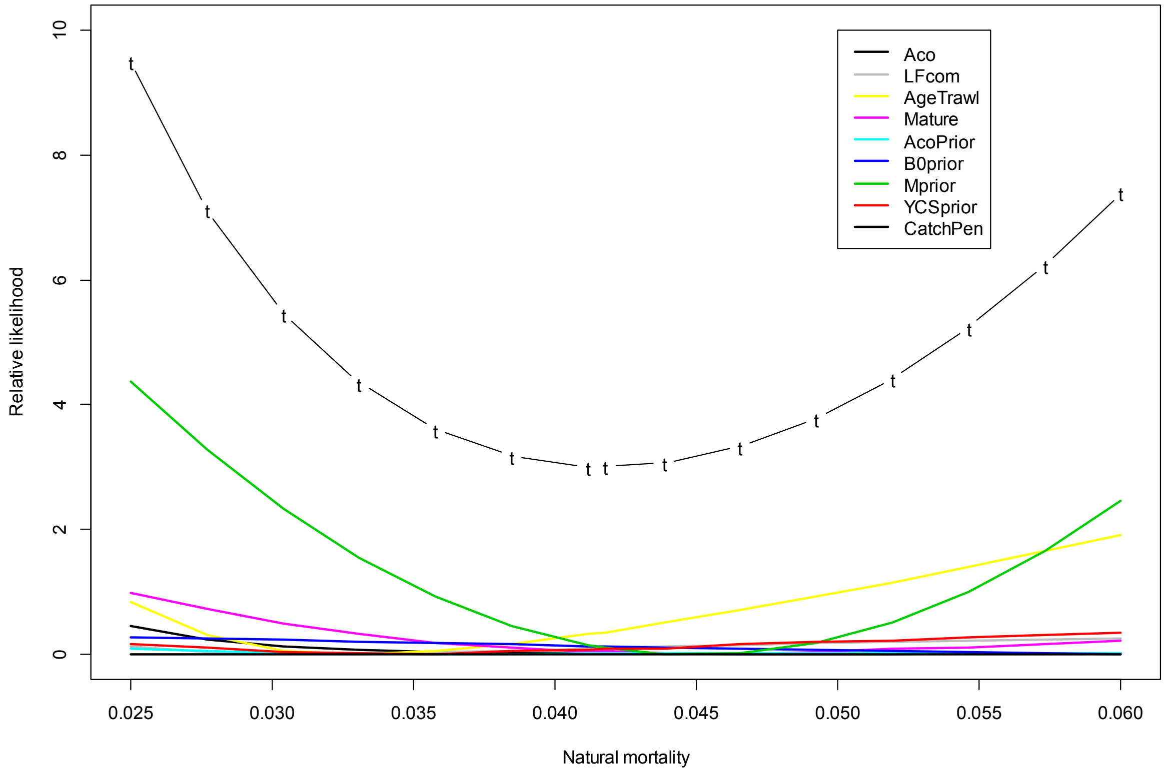


Figure A2.2: NWCR: likelihood profile on *M*. Each component of the objective function has had its minimum subtracted so that the lines sit on the x-axis. The total objective function has been shifted above the x-axis an arbitrary amount (the line with the "t"s).

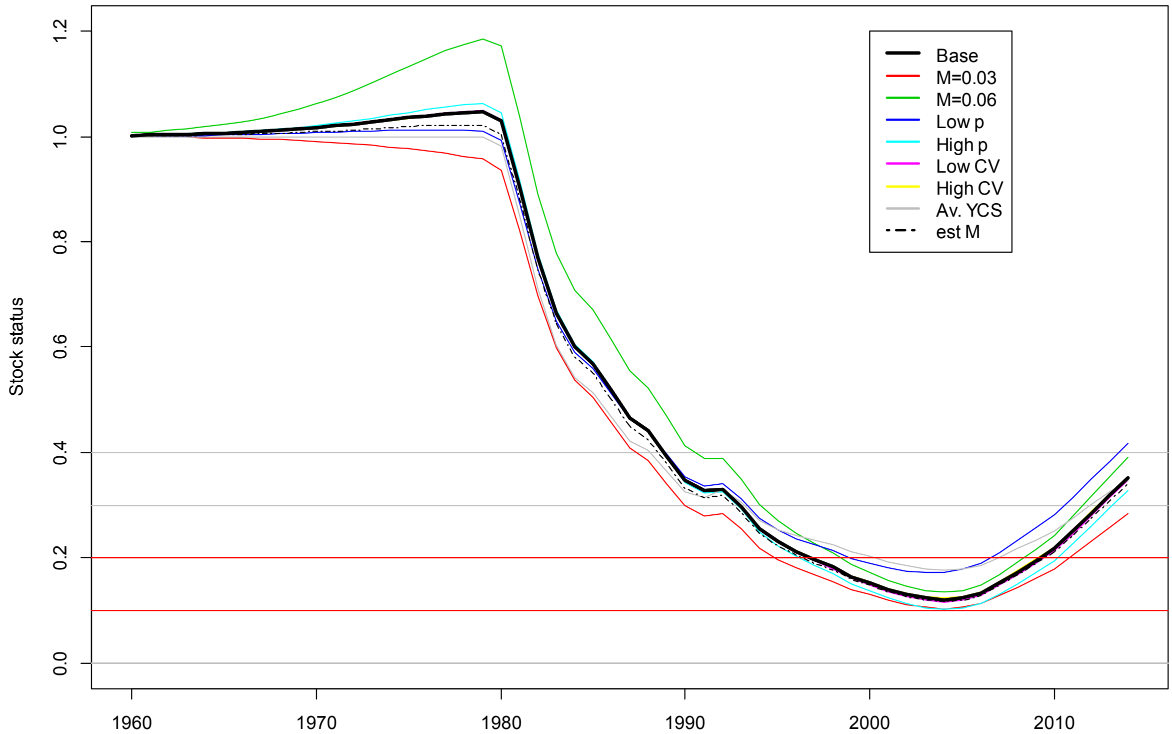


Figure A2.3: NWCR: MPD stock status trajectory for the base model and some sensitivities: low and high values of *M*; low and high values for the mean of acoustic *q* prior ("low p", "high p"); low and high values for the CV of the acoustic *q* prior; all YCS equal to 1 (Av. YCS); and estimating *M* (est M).

ESCR

The profile on B_0 shows little conflict between the components but composition data appear to be providing the most signal (Figure A2.4). Of the composition data, the age frequencies from the 2013 spawning plumes makes the largest contribution (Figure A2.5). The profile for *M* is dominated by the prior (Figure A2.6).

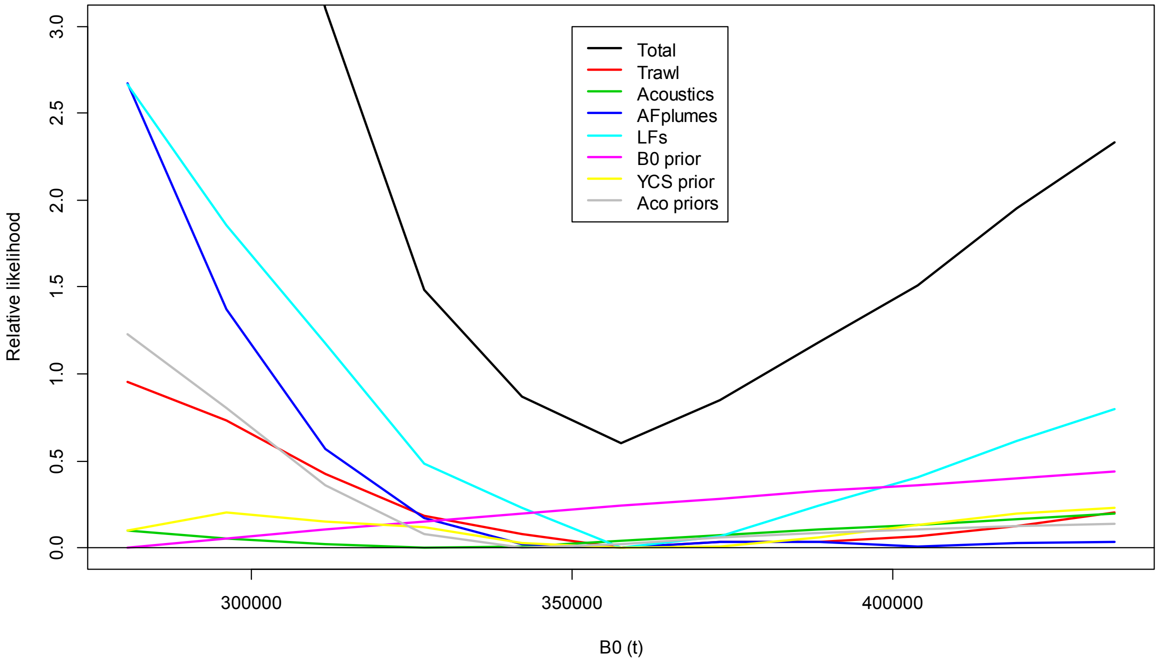


Figure A2.4: ESCR: likelihood profile on B_0. Each component of the objective function has had its minimum subtracted so that the lines sit on the x-axis except for the total which is shifted above the x-axis arbitrarily.

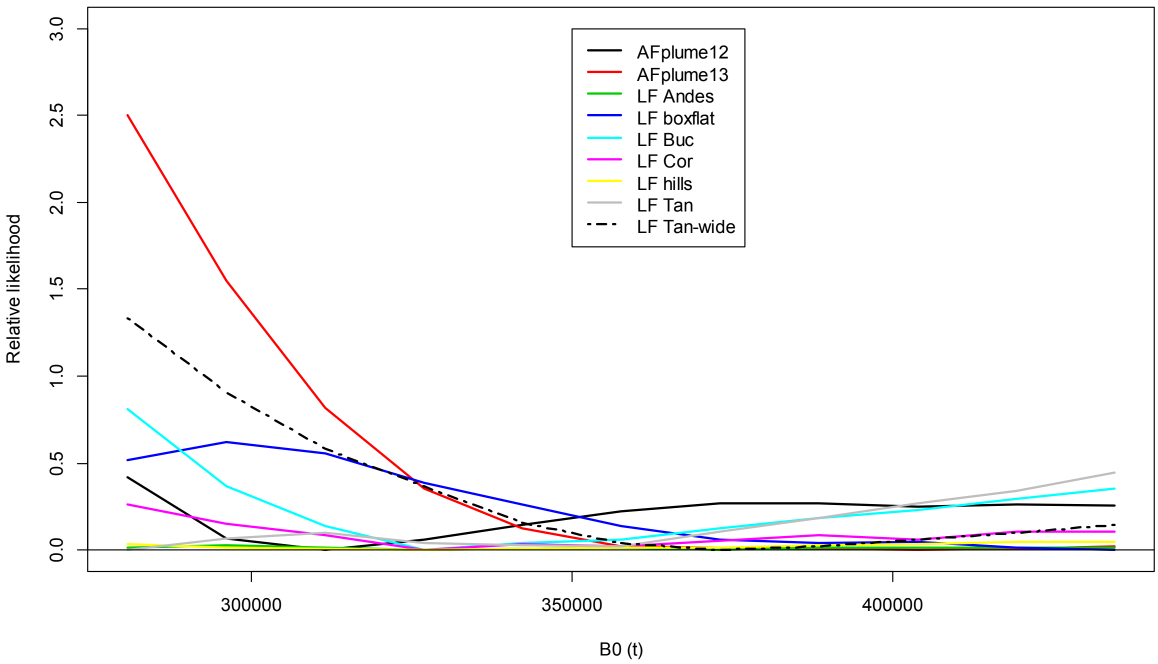


Figure A2.5: ESCR: likelihood profile on B_0 for the composition data sets. Each component of the objective function has had its minimum subtracted so that the lines sit on the x-axis.

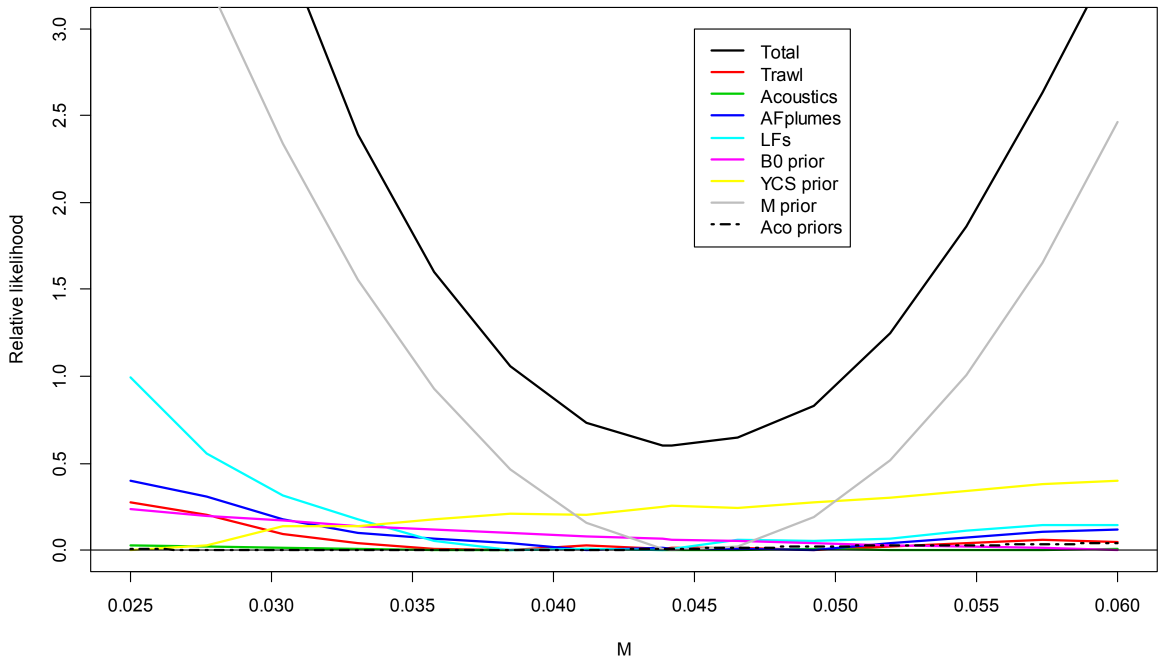


Figure A2.6: ESCR: likelihood profile on *M*. Each component of the objective function has had its minimum subtracted so that the lines sit on the x-axis except for the total which is shifted above the x-axis arbitrarily.

The results of numerous MPD sensitivities are presented in Tables A2.1 and A2.2. The main points of interest from these runs are: estimated stock status is very robust (in Table A2.1 it varies from 21–26% B_0); the model is sensitive to the scale of the acoustic indices (halving gives 14% B_0; doubling gives 39% B_0; Table A2.2); the assumption of deterministic recruitment gives much higher stock status (35% B_0 compared to 24% B_0; Table A2.2).

Table A2.1: Estimates of virgin biomass (B_0), current biomass (B_{2014}), and stock status (B_{2014}/B_0) for MPD sensitivity runs: using alternative acoustic estimates (AOS 120 kHz); including early age data (Early age); alternative values for the mean of the acoustic *q* prior (Most 0.6, 0.9); estimating *M* (Estimate *M*); fixed values of *M*; and alternative weights on the length frequency (LF) or age frequency (AF) data.

	B_0 (000 t)	B_{2014} (000 t)	B_{2014} (% B_0)
Base	356	84	24
AOS 120 kHz	363	90	25
Early age	367	88	24
Most 0.6 (2011 & 2013)	363	94	26
Most 0.9 (2011 & 2013)	354	80	23
Estimate *M* (0.044)	358	84	23
Low *M* (0.03)	400	84	21
High *M* (0.06)	335	84	25
Halve LF N	354	83	23
Double LF N	360	86	24
Halve AF N	357	84	23
Double AF N	356	85	24

Table A2.2: Estimates of virgin biomass (B_0), current biomass (B_{2014}), and stock status (B_{2014}/B_0) for MPD sensitivity runs: no trawl biomass indices; no acoustic indices; lower CVs on the acoustic indices; halving or doubling the acoustic indices; having all YCS equal to 1 (deterministic recruitment); decreasing *M* by 20% while also increasing the mean of the acoustic *q* priors by 20% (LowM-Highq); and increasing *M* by 20% while also decreasing the mean of the acoustic *q* priors by 20% (HighM-Lowq).

	B_0 (000 t)	B_{2014} (000 t)	B_{2014} (% B_0)
Base	356	84	24
Minus all trawl bio	355	86	24
Minus all acoustics	384	110	29
Tight CVs on all acoustics	357	82	23
Tight CVs on 2011 & 2013	350	72	21
Halve acoustics indices	295	42	14
Double acoustics indices	443	174	39
Deterministic recruitment	309	108	35
LowM-Highq (20%)	362	69	19
HighM-Lowq(20%)	368	105	28

ORH 7A

The likelihood profile on B_0 shows only minor conflict between age frequency data and the *Amaltal Explorer* trawl survey indices (Figure A2.7). The age frequency data has strong aversion for B_0 values less than about 90 000 t (Figure A2.7). The same data set has an aversion to low values of *M* and is the only data that competes with the prior on *M* in the likelihood profile for *M* (Figure A2.8).

The MPD estimates of stock status are sensitive to the assumption of deterministic recruitment (Figure A2.9), the scale of the biomass indices, and to the moderate (20%) simultaneous shift of *M* and the mean of the *q* priors (Figure A2.10).

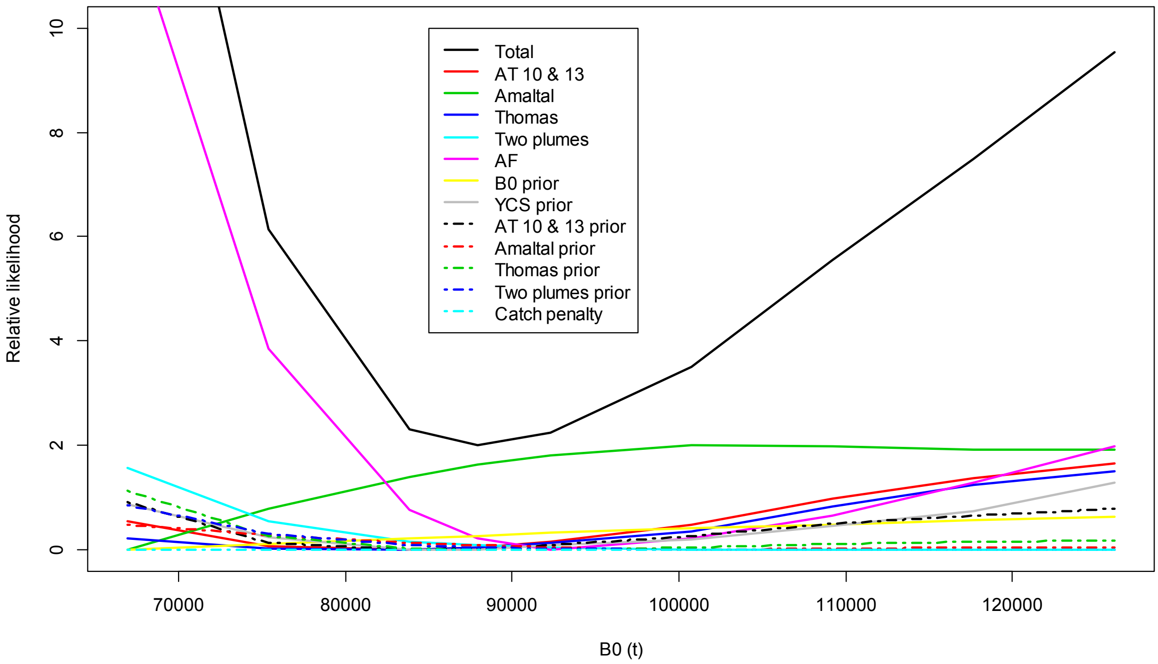


Figure A2.7: ORH7A: likelihood profile on B_0. Each component of the objective function has had its minimum subtracted so that the lines sit on the x-axis except for the total which is shifted above the x-axis arbitrarily.

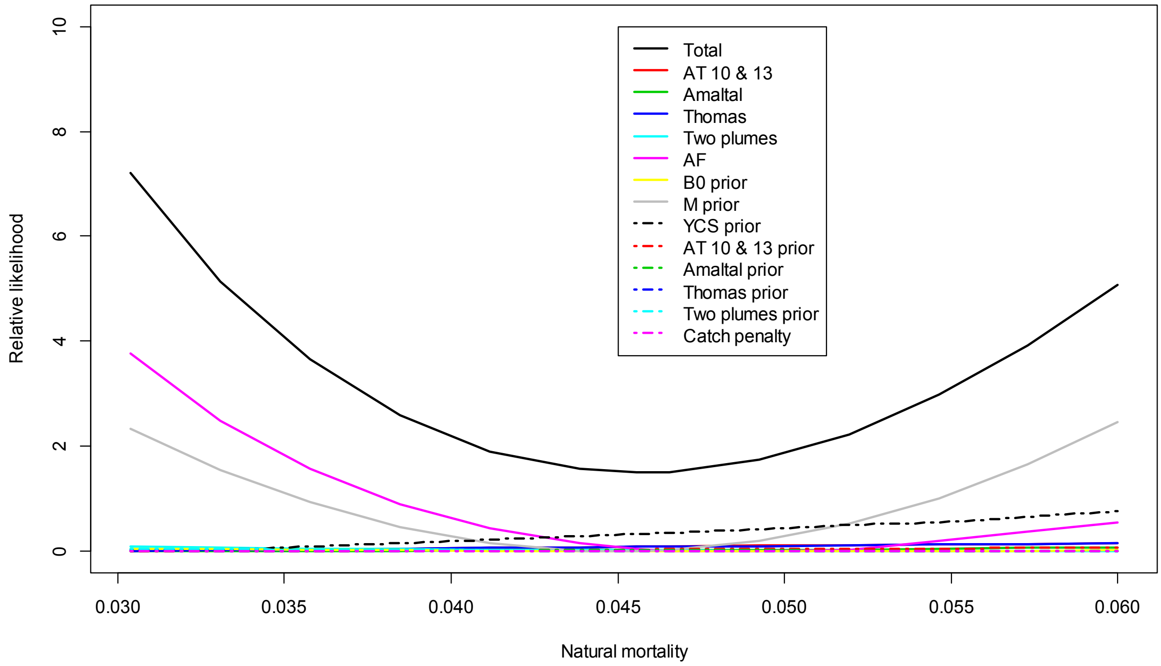


Figure A2.8: ORH7A: likelihood profile on *M*. Each component of the objective function has had its minimum subtracted so that the lines sit on the x-axis except for the total which is shifted above the x-axis arbitrarily.

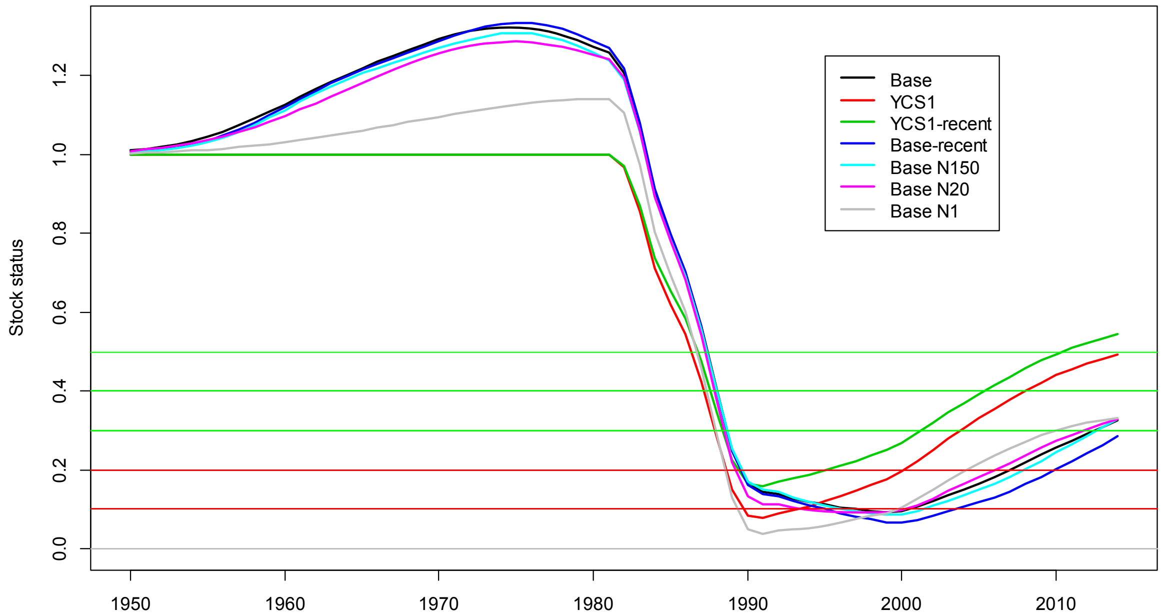


Figure A2.9: ORH7A: MPD stock status trajectory for the base model and some sensitivities: deterministic recruitment with or without recent biomass indices (YCS1, YCS1-recent); the base model without recent biomass indices; alternative effective sample sizes for the age frequency data (N = 150, 20, 1).

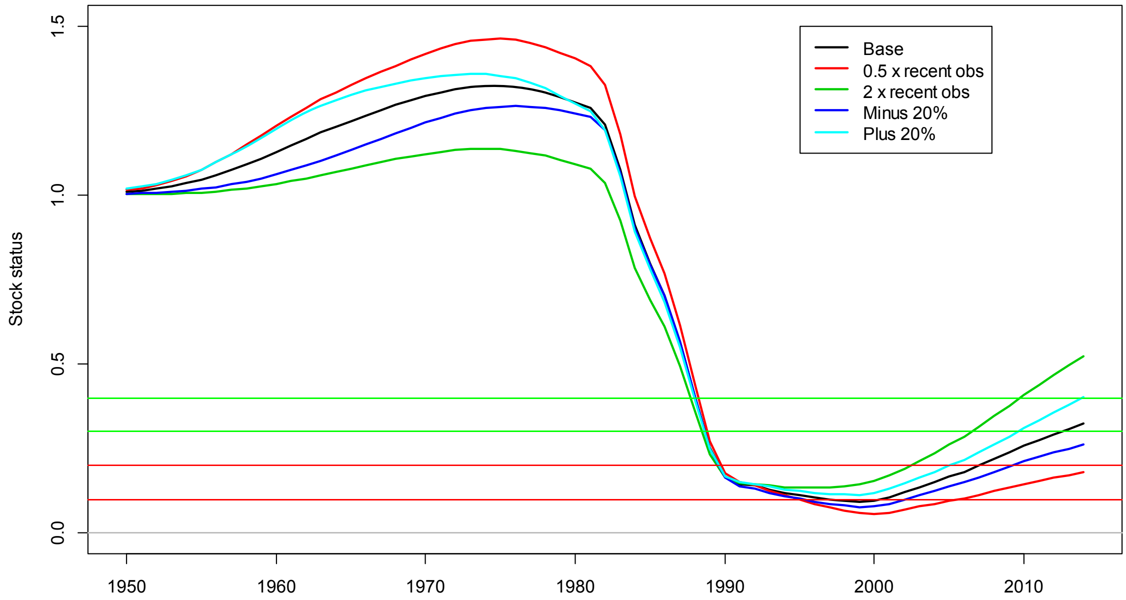
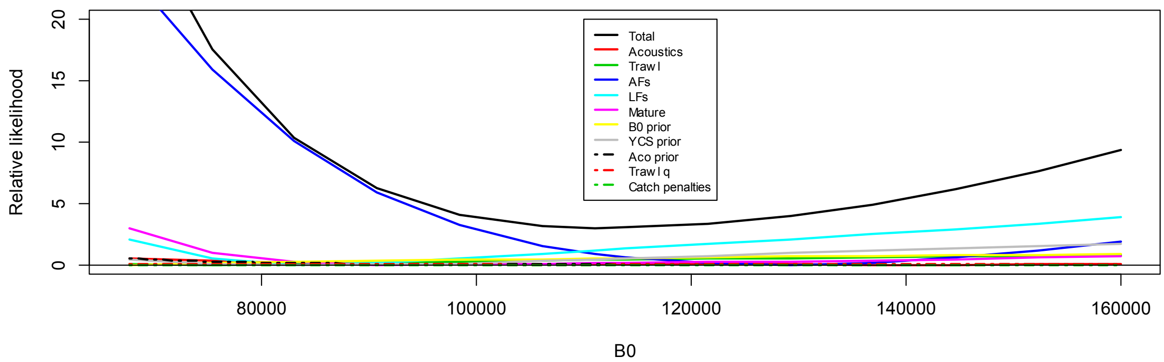


Figure A2.10: ORH7A: MPD stock status trajectory for the base model and some sensitivities: recent biomass indices halved or doubled; decreasing *M* by 20% while also increasing the mean of the *q* priors by 20% (Minus 20%); and increasing *M* by 20% while also decreasing the mean of the *q* priors by 20% (Plus 20%) .

MEC

The likelihood profile on B_0 is dominated, for low values, by the age frequencies (Figure A2.11, top). When the age frequency components are separated it is found that it is the samples from the spawning fishery in 1989–91 that have a strong aversion to values of B_0 less than about 100 000 t (Figure A2.11, bottom).



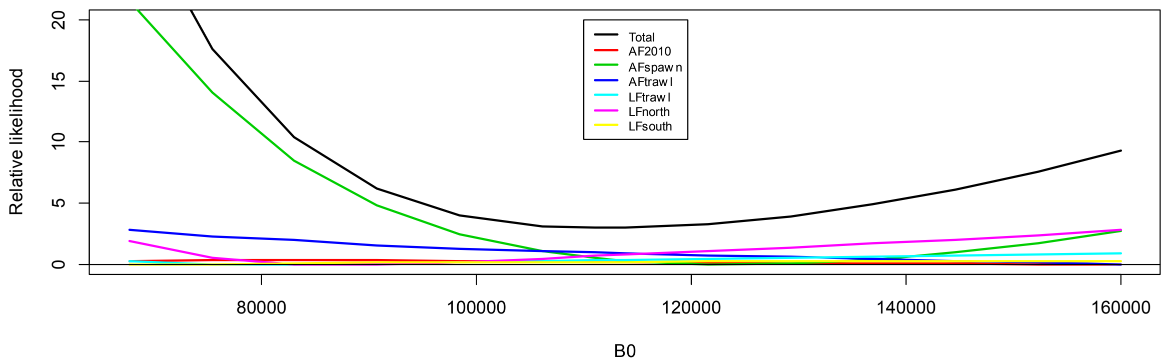


Figure A2.11: MEC: likelihood profiles on B_0 for all components (top) and composition data only (bottom). Each component of the objective function has had its minimum subtracted so that the lines sit on the x-axis except for the total which is shifted above the x-axis arbitrarily.

The likelihood profile on *M* also looks less than ideal with the YCS prior strangely showing up for higher values of *M* (Figure A2.12, top). With a nearly uniform prior on each YCS this is an unlikely result but the cause of it is apparent when the YCS-free-parameter estimates are plotted for each fixed value of *M* (Figure A2.12, bottom). The higher *M* gets the larger the early recruitment is (e.g., see 1880 YCS) with the YCS-free-parameters hitting the upper bound of 10 for the three highest values of *M* (Figure A2.12, bottom). It is apparent that the proportions of fish in the older age classes in the age frequencies are inconsistent with the high values of *M* unless very strong recruitment is put into the model in the 1880s. This is a problem with high values of *M* rather than a problem with the model.

MPD estimated stock status is very robust and stays below 10% B_0 unless the acoustic index is doubled (Table A2.3) or deterministic recruitment is assumed (Table A2.4). The estimate is very stable even under some extreme changes in data weighting (e.g., effective Ns for age frequencies and spawning-at-age data multiplied by 0.25 or 5; Table A2.4).

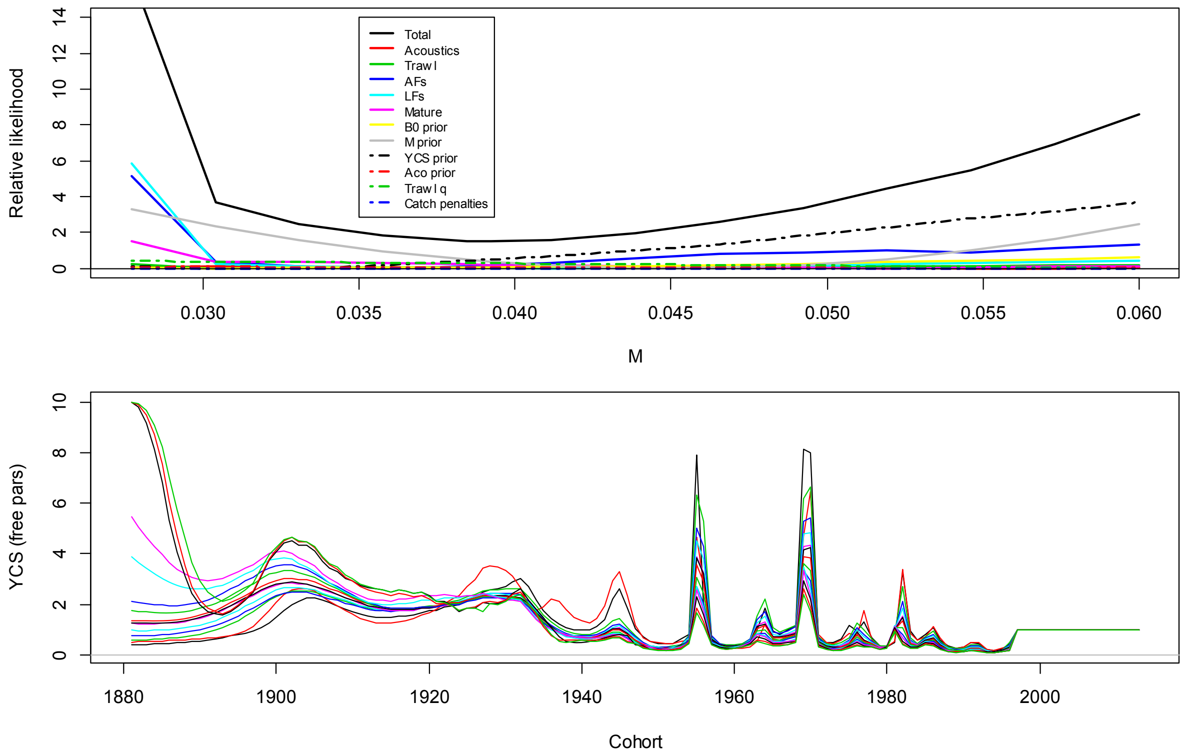


Figure A2.12: MEC: likelihood profile on *M* (top) and YCS estimates (the free parameters which are not yet scaled so that they average 1) for the different values of *M* in the profile (bottom). For the likelihood profile, each component of the objective function has had its minimum subtracted so that the lines sit on the x-axis except for the total which is shifted above the x-axis arbitrarily.

Table A2.3: Estimates of virgin biomass (B_0), current biomass (B_{2014}), and stock status (B_{2014}/B_0) for MPD sensitivity runs: alternative values for the mean of the acoustic *q* prior; estimating *M* (Estimate *M*); alternative fixed values of *M*; halving and doubling the acoustics estimate; and alternative weights on the length frequency (LF), age frequency (AF), or spawning-at-age data ("mat N").

	B_0 (000 t)	B_{2014} (000 t)	B_{2014} (%B_0)
Base	111	7.2	6.5
Mean aco q 0.4	113	9.5	8.4
Mean aco q 0.8	110	5.9	5.4
Estimate M (0.039)	101	6.9	6.9
Low M (0.03)	96	6.5	6.8
High M (0.06)	173	7.9	4.6
Halve 2013 aco obs	109	4.4	4.0
Double 2013 aco obs	115	11.7	10.2
Halve LF N	115	7.2	6.2
Double LF N	109	7.8	7.2
Halve trawl AF N	110	7.3	6.6
Halve trawl mat N	111	7.2	6.4
Halve trawl AF&mat N	110	7.2	6.6

Table A2.4: Estimates of virgin biomass (B_0), current biomass (B_{2014}), and stock status (B_{2014}/B_0) for MPD sensitivity runs: very low or very high weights on the age frequency (AF) and spawning-at-age data ("mat N"); excluding trawl biomass indices; excluding the acoustic index; fixing all YCS equal to 1 (deterministic recruitment); "adding" 20% to the trawl biomass indices CV.

	B_0 (000 t)	B_{2014} (000 t)	B_{2014} (%B_0)
Base	111	7.2	6.5
All AF & mat N × 0.25	98	7.7	7.9
All AF & mat N × 5	126	6.9	5.4
No trawl biomass	113	8.1	7.2
No 2013 aco obs	110	6.3	5.7
Deterministic recruitment	93	24.1	25.8
Trawl biomass CV + 20%	112	7.5	6.8

APPENDIX 3: The MCMC chain diagnostics for the base models

For MCMC estimation, three independent chains, starting at a random jump from the MPD estimate, were used for each of the model runs. The primary diagnostic used to decide whether there was adequate chain convergence was a comparison of the marginal posterior distributions of B_0 (t) and B_{2014} (%B_0) across the three chains.

The MCMC diagnostics were excellent for NWCR, ORH7A, and MEC. They were initially problematic for ESCR so the three chains were allowed to run out to 15 million samples. The diagnostic for the ESCR was still less than perfect, but the same results were obtained for MCMC runs for two minor variations on the base model: an informed prior on maturation; and a maximum correlation rate in the proposal distribution of 0.5 rather than the CASAL default of 0.8. Chain lengths for NWCR, ORH7A, and MEC were much shorter than the 15 million being respectively 6.5, 5.3, and 3.8 million.

Plots of the marginal posterior distributions of virgin and current biomass follow for each of the stocks (Figures A3.1–A3.4).

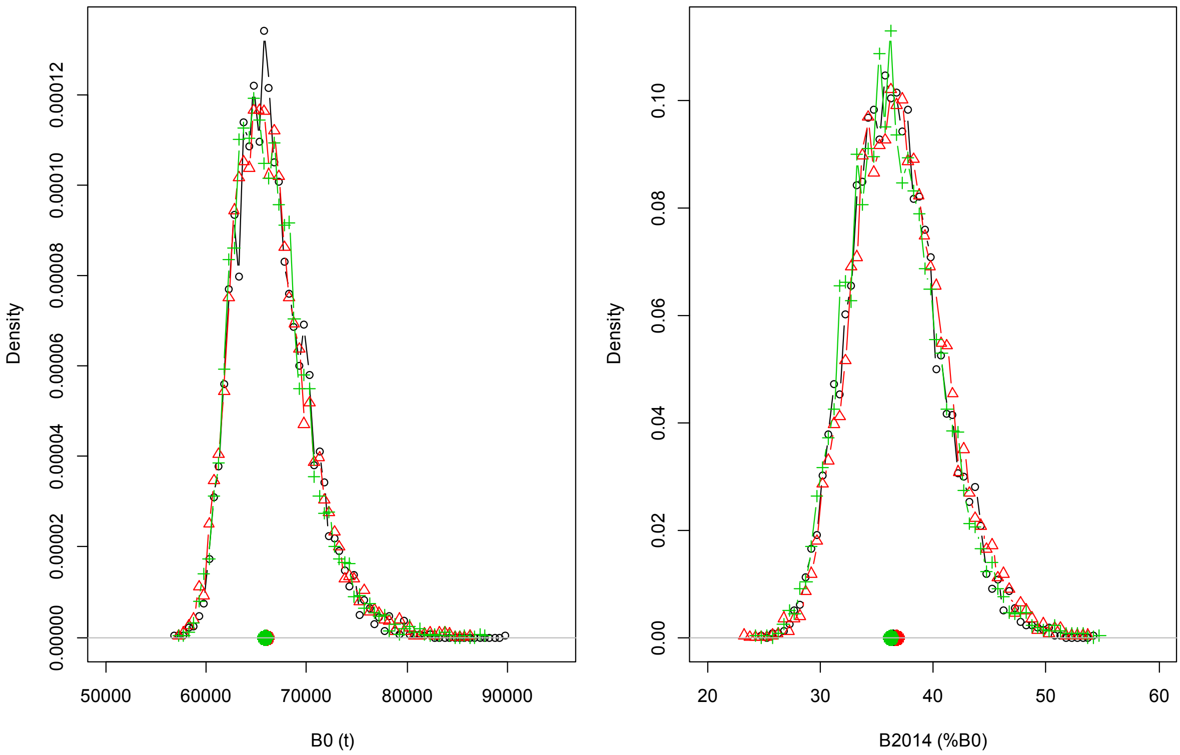


Figure A3.1: Marginal posterior distributions for virgin (B_0) and current biomass (B_{2014}) for each of the three chains for the NWCR base model. Each chain has its own colour and the filled circles mark the median of the distribution for each chain.

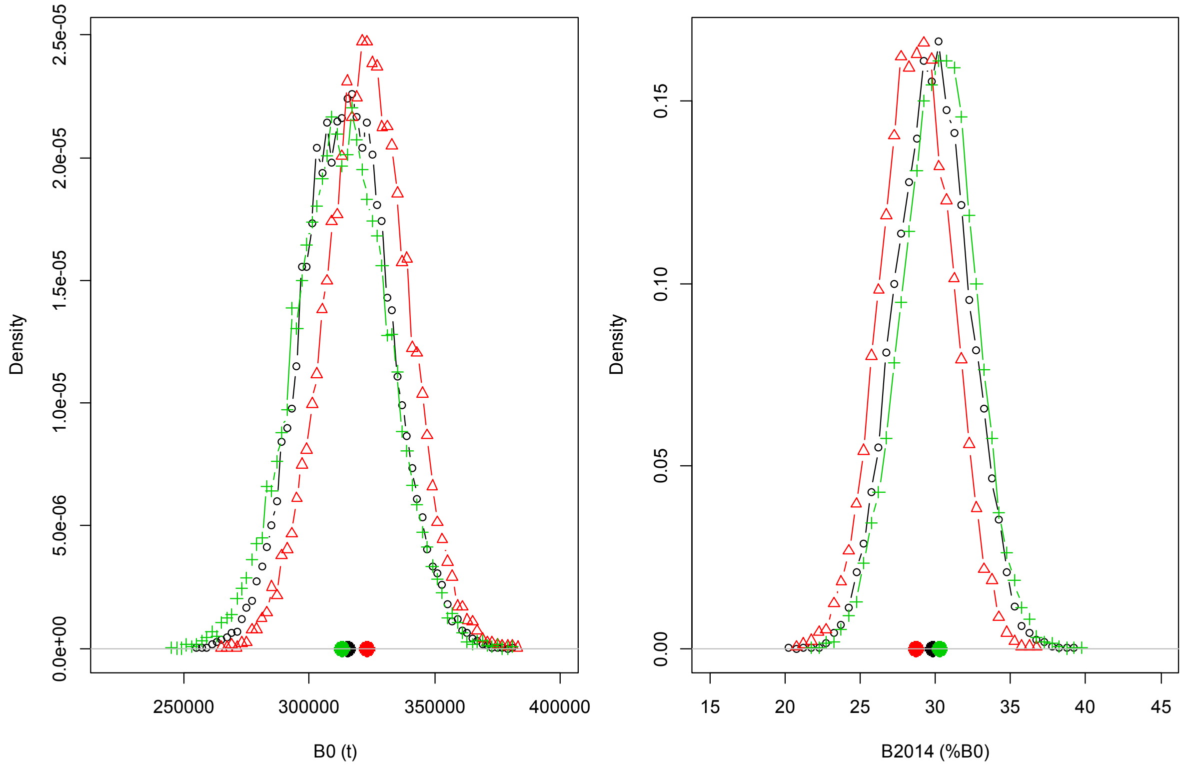


Figure A3.2: Marginal posterior distributions for virgin (B_0) and current biomass (B_{2014}) for each of the three chains for the ESCR base model. Each chain has its own colour and the filled circles mark the median of the distribution for each chain.

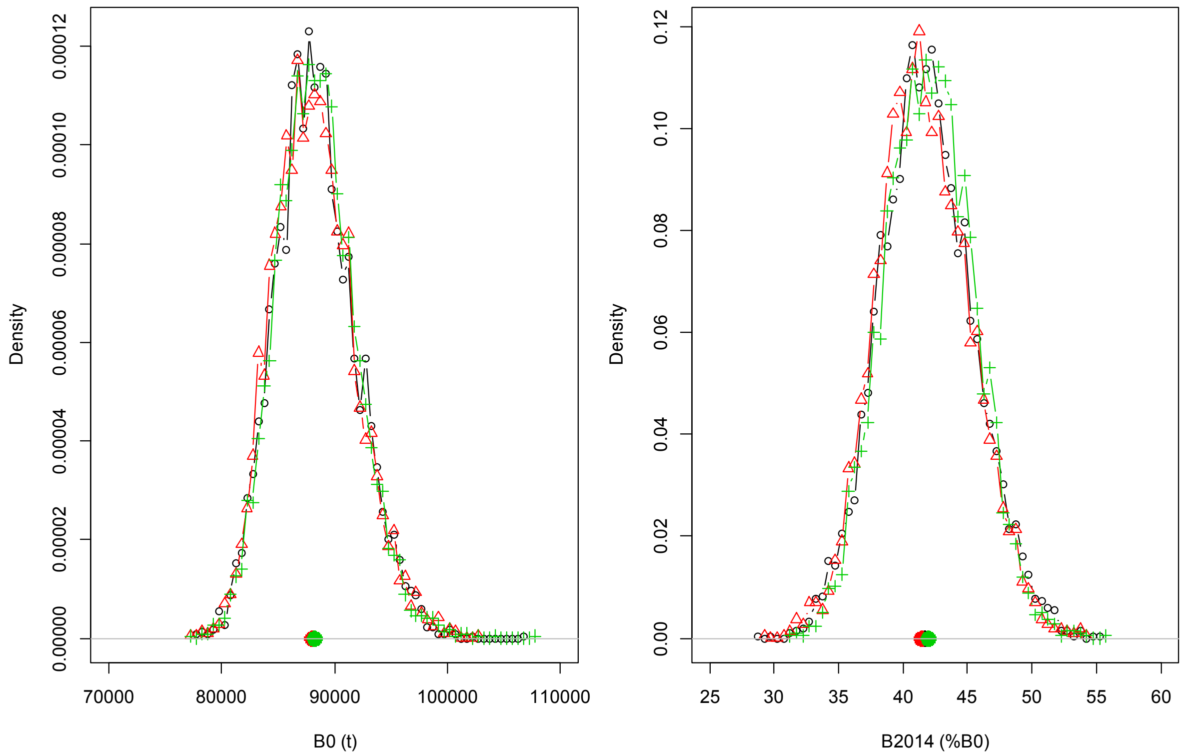


Figure A3.3: Marginal posterior distributions for virgin (B_0) and current biomass (B_{2014}) for each of the three chains for the ORH7A base model. Each chain has its own colour and the filled circles mark the median of the distribution for each chain.

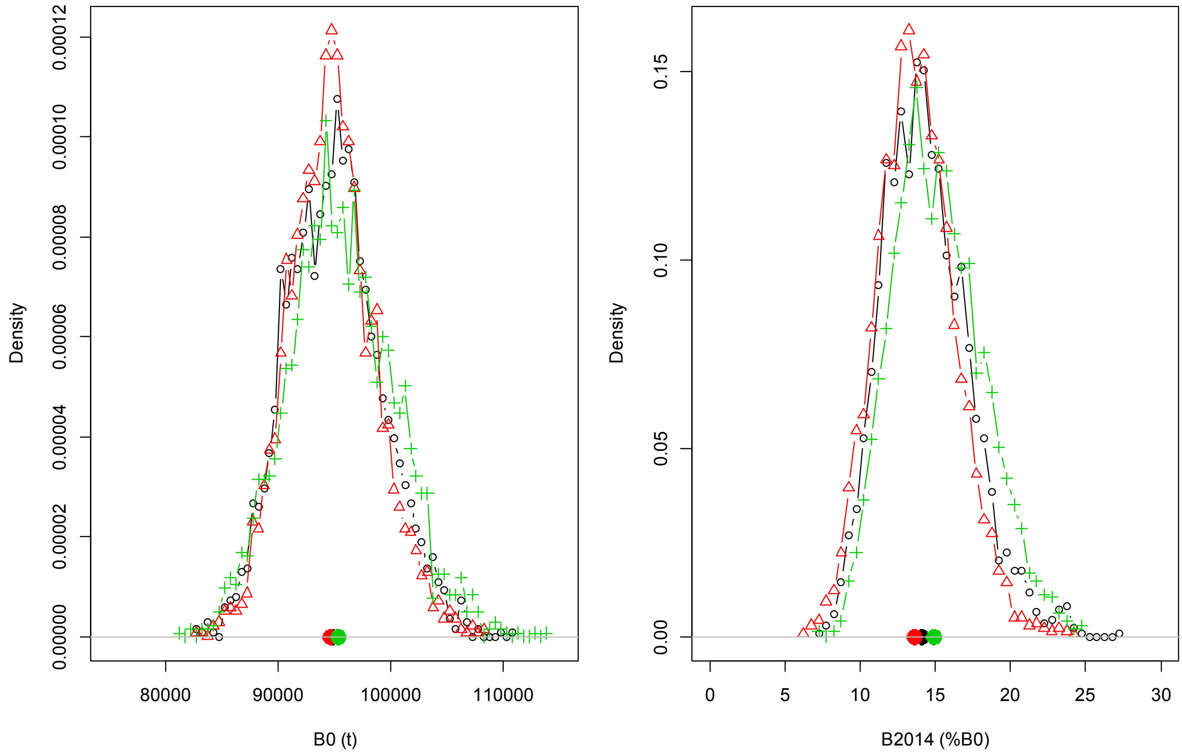


Figure A3.4: Marginal posterior distributions for virgin (B_0) and current biomass (B_{2014}) for each of the three chains for the MEC base model. Each chain has its own colour and the filled circles mark the median of the distribution for each chain.

APPENDIX 4: CASAL input files for the base models

The population and estimation files used in the MCMC base models (and the ESCR "Always" run) are given below for each stock.

Northwest Chatham Rise

population.csl

```
# NWCR 2014 stock assessment

# 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 2014

@annual_cycle
time_steps 1
aging_time 1
recruitment_time 1
fishery_times 1
fishery_names NWCR
spawning_time 1
spawning_p 1
spawning_part_mort 0.75
M_props 1
baranov False

# Maturation
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
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

SR  BH
steepness 0.75
sigma_r  1.1
first_free 1940
last_free 1979

@natural_mortality
all   0.045
```

```
@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
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 73.5 115.5 115.5
selectivity NWsel
U_max 0.67

@selectivity_names NWsel Trawlsel
@selectivity NWsel
mature  constant 1
immature constant 0
@selectivity Trawlsel
all  logistic    25  4


## 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 0.06
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 4.56

@initialization
B0 60000
```

estimation.csl

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

@MCMC
start 0.2
length 15000000
keep 1000
stepsize 0.006
proposal_t True
df 2
burn_in 1000

#-------------------------------------------------
#
# Acoustic estimates for NW hills
#
#-------------------------------------------------

@relative_abundance aco
step 1
proportion_mortality 0.75
```

```
biomass True
ogive NWsel
years 1999 2012
1999 8126
2012 14637
cv_1999 0.22
cv_2012 0.09
dist lognormal
q acoq

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

@relative_abundance aco13
step 1
proportion_mortality 0.75
biomass True
ogive NWsel
years 2013
2013 7379
cv_2013 0.31
dist lognormal
q aco13q

@estimate
parameter q[aco13q].q
prior normal
mu 0.3
cv 0.19
lower_bound 0.03
upper_bound 0.6

@q_method free

@q acoq
q  0.8

@q aco13q
q  0.3


#-----------------------------------------------------------------
#
# 1994 trawl survey data
#
#-----------------------------------------------------------------


@proportions_at Trawl1994
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

# Proportion mature

@proportions_mature Mature1994
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


#------------------------------------------------------------------
#
# LF data
#
#------------------------------------------------------------------

@proportions_at LFcom   # From Hicks, 1989-1997, 1998-2005
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

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

@estimate
parameter selectivity[Trawlsel].all
lower_bound 5     3
upper_bound 50    20
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 5e3
upper_bound 3e5
prior uniform-log

@profile
parameter initialization.B0
n 14
l 45e3
u 90e3

# cv1 on length at age
@estimate
parameter size_at_age.cv1
lower_bound     0.03
upper_bound    1
prior uniform

# cv1 on length at age
@estimate
parameter size_at_age.cv2
lower_bound     0.03
upper_bound    1
prior uniform
```

```
# YCS
@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 1 1 1 1 1 1 1 1 1 1 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 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 1 1 1 1 1 1
1 1 1 1 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: nearly uniform LN(mode=1, rsd=4)
prior lognormal
mu 26489122130 26489122130 26489122130 26489122130 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
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2980.958 2980.958 2980.958 2980.958 2980.958 2980.958

#------------------------------------------------------------
#
# Catch penalty and ageing error
#
#-------------------------------------------------------------
@catch_limit_penalty
label catchPenalty
fishery NWCR
multiplier 200
log_scale True

@ageing_error
type normal
c 0.1
```

East and South Chatham Rise

population.csl

```
# ESCR 2014 stock assessment

# 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 2014

@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

# Maturation
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
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

SR  BH
steepness 0.75
sigma_r  1.1
first_free 1930
last_free 1990

@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
```

```
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 2361
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
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 59
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
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
529 528 528
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
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 976 484 320 307 307
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  logistic    37  4.56
immature  logistic_capped 10 3  0.1
@selectivity Corsel
mature  logistic    37  4.56
immature  logistic_capped 10 3  0.1
@selectivity Tansel
mature  logistic    37  4.56
immature  logistic_capped 10 3  0.1
@selectivity Tanwidesel
mature  logistic    35  5
immature  logistic_capped 17 4  0.8

@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 4.56

@initialization
B0 350000
```

estimation.csl

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

@MCMC
start 0.2
length 15000000
keep 1000
stepsize 0.006
proposal_t True
df 2
burn_in 1000

#-----------------------------------------------
#
# 2011, 2013 total spawning biomass estimate
#
#-----------------------------------------------

@relative_abundance aco
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2011 2013
2011 51329
2013 51673
cv_2011 0.11
cv_2013 0.11
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
```

```
#-------------------------------------------------
#
# 2012 new + old plume spawning biomass estimate
#
#-------------------------------------------------

@relative_abundance aco2012
step 1
proportion_mortality 0.75
biomass True
ogive matsel
years 2012
2012 46513
cv 0.07
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

#-------------------------------------------------
#
# 2002-2010 old plume spawning biomass estimates
#
#-------------------------------------------------

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

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

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

@relative_abundance aco2005
step 1
```

```
proportion_mortality 0.75
biomass True
ogive matsel
years 2005
2005 43923
cv 0.04
dist lognormal
q acoq2005

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

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

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

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

@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[acoq2002].q
```

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

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

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

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

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

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

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

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

@estimate
parameter q[acoq2010].q
prior lognormal
mu 0.30
```

```
cv 0.30
lower_bound 0.1
upper_bound 1.5



#-------------------------------------------------
#
# Trawl surveys
#
#-------------------------------------------------


# Otago Buccaneer trawl

@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
#mu 1
#cv 0.6
lower_bound 0.1
upper_bound 2

# Cordella trawl

@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
#mu 1
#cv 0.6
lower_bound 0.1
upper_bound 2
```

```
# Tangaroa trawl

@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
#mu 1
#cv 0.6
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
#mu 1
#cv 0.6
lower_bound 0.01
upper_bound 1

### Trawl survey LFs

@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


### Commercial LFS - put in as proportions-at because they are
### lumped across years rather than being real catch
### sampling in a given year(i.e., catch-at)

@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

####
#### 2012 spawning plumes age freq (only old + new)
####

@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

####
#### 2013 spawning plumes age freq (old + new + crack)
####

@proportions_at AFplumes13
years 2013
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
dist multinomial
r 0.00001
N_2013 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
```

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

@estimate
parameter selectivity[Bucsel].mature
lower_bound 10     3
upper_bound 50    50
prior uniform

@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[Corsel].mature
lower_bound 10     3
upper_bound 50    50
prior uniform
{
@estimate
parameter selectivity[Corsel].immature
lower_bound 1   1  0.001
upper_bound 30  50 0.2
prior uniform
}
@estimate
parameter selectivity[Tansel].mature
lower_bound 10     3
upper_bound 50    50
prior uniform
{
@estimate
parameter selectivity[Tansel].immature
lower_bound 1   1  0.001
upper_bound 30  50 0.2
prior uniform
}

@estimate
parameter selectivity[Tanwidesel].mature
lower_bound 10     3
upper_bound 50    50
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

@profile
parameter initialization.B0
n 14
l 280e3
u 450e3

# cv1 on length at age
@estimate
parameter size_at_age.cv1
lower_bound     0.03
upper_bound    0.3
prior uniform

# cv1 on length at age
@estimate
parameter size_at_age.cv2
lower_bound     0.03
upper_bound    0.3
prior uniform

# YCS
@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
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
prior lognormal
mu 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 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
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2980.958 2980.958 2980.958 2980.958 2980.958 2980.958

#------------------------------------------------------------
#
# Penalties
#
#-------------------------------------------------------------

@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
```

ESCR: Always

population.csl

```
# ESCR Always model: spatially explicit

# PARTITION
@size_based False
@min_age 1
@max_age 100
@plus_group True
@sex_partition False
@mature_partition True
@n_areas 4
@area_names home crack rekohu oldplume

# TIME SEQUENCE
@initial 1911
@current 2014
@final 2019

@annual_cycle
time_steps 3
aging_time 1
recruitment_time 1
recruitment_areas home
fishery_names boxflat hills andes south
fishery_times 1 1 1 1
fishery_areas home home home home
spawning_time 1
spawning_areas home
spawning_p 1
spawning_part_mort 0.75
M_props 1 0 0
baranov False

# Migrations
n_migrations 6
migration_names HtoR RtoC RtoO CtoH RtoH OtoH
migration_times 2 2 2 3 3 3
migrate_from home rekohu rekohu crack rekohu oldplume
migrate_to rekohu crack oldplume home home home

# Maturation
n_maturations 1
maturation_times 1

@migration HtoR
migrators mature
prop 0.8

@migration RtoC
migrators mature
rates_all logistic_capped 35 5 0.5

@migration RtoO
migrators mature
rates_all logistic_capped 35 5 0.5

@migration CtoH
migrators mature
prop 1

@migration RtoH
migrators mature
prop 1
```

```
@migration OtoH
migrators mature
prop 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
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

SR  BH
steepness 0.75
sigma_r  1.1
first_free 1930
last_free 1990

@randomisation_method lognormal

@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
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 2361
future_years      2015 2016  2017     2018  2019
future_catches      0     0     0     0     0
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
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 59
future_years      2015 2016  2017     2018  2019
future_catches      0     0     0     0     0
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
```

```
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
529 528 528
future_years      2015 2016  2017     2018  2019
future_catches      0     0     0     0     0
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
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 976 484 320 307 307
future_years      2015 2016  2017     2018  2019
future_catches      0     0     0     0     0
selectivity andessel # same as andes for now
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  logistic    37  4.56
immature  logistic_capped 10 3  0.1
@selectivity Corsel
mature  logistic    37  4.56
immature  logistic_capped 10 3  0.1
@selectivity Tansel
mature  logistic    37  4.56
immature  logistic_capped 10 3  0.1
@selectivity Tanwidesel
mature  logistic    35  5
immature  logistic_capped 17 4  0.8


@selectivity matsel
mature constant 1
immature constant 0

## SIZE AT AGE  From Hicks (p. 3, floor + 0.5).
@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 4.56
```

```
@initialization
B0 350000
```

estimation.csl

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

@MCMC
start 0.2
length 15000000
keep 1000
stepsize 0.006
proposal_t True
df 2
burn_in 1000
max_cor 0.5


#------------------------------------------------
#
# 2002-2013 old plume spawning biomass estimates
# + 5% process error on CVs
#
#------------------------------------------------

@relative_abundance acoold
step 2
area oldplume
biomass True
ogive matsel
years 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
2002 63950
2003 44316
2004 44968
2005 43923
2006 47450
2007 34427
2008 31668
2009 28199
2010 21205
2011 16422
2012 19392
2013 16312
cv_2002 0.08
cv_2003 0.08
cv_2004 0.09
cv_2005 0.06
cv_2006 0.11
cv_2007 0.07
cv_2008 0.09
cv_2009 0.07
cv_2010 0.09
cv_2011 0.09
cv_2012 0.09
cv_2013 0.25
dist lognormal
q acoq

#------------------------------------------------
#
# 2011-2013 new plume spawning biomass estimates
#
#------------------------------------------------
```

```
@relative_abundance aconew
step 2
area rekohu
biomass True
ogive matsel
years 2011 2012 2013
2011 28113
2012 27121
2013 29890
cv_2011 0.18
cv_2012 0.10
cv_2013 0.14
dist lognormal
q acoq

#------------------------------------------------
#
# 2011 & 2013 crack spawning biomass estimates
#
#------------------------------------------------

@relative_abundance acocrack
step 2
area crack
biomass True
ogive matsel
years 2011 2013
2011 6794
2013 5471
cv_2011 0.21
cv_2013 0.15
dist lognormal
q acoq

# They all get the same q because it's a spatial model

@estimate
parameter q[acoq].q
prior lognormal
mu 1.00
cv 0.11
lower_bound 0.1
upper_bound 1.5



#------------------------------------------------
#
# Trawl surveys
#
#------------------------------------------------


# Otago Buccaneer trawl

@relative_abundance Buc
step 1
area home
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
#mu 1
#cv 0.6
lower_bound 0.1
upper_bound 2

# Cordella trawl

@relative_abundance Cor
step 1
area home
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
#mu 1
#cv 0.6
lower_bound 0.1
upper_bound 2

# Tangaroa trawl

@relative_abundance Tan
step 1
area home
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
#mu 1
#cv 0.6
lower_bound 0.1
```

```
upper_bound 2

@relative_abundance Tanwide
step 1
area home
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
#mu 1
#cv 0.6
lower_bound 0.01
upper_bound 1

### Trawl survey LFs

@proportions_at LFbuc
years 1984 1985 1986 1987
step 1
area home
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
area home
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
area home
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
area home
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


### Commercial LFS - put in as proportions-at because they are
### lumped across years rather than being real catch
### sampling in a given year(i.e., catch-at)

@proportions_at LFboxflat
years 1990 2004
step 1
area home
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
area home
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
area home
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

####
#### 2012 and 2013 spawning plumes age freqs by area
####

@proportions_at AFold
years 2012 2013
step 2
area oldplume
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 0.004514673 0.01128668 0.002257336 0 0 0.009029345
0.009029345 0.01580135 0.006772009 0.02257336 0.03386005 0.009029345
0.01128668 0.01580135 0.03386005 0.03837472 0.0248307 0.05643341
0.03386005 0.01354402 0.02708804 0.02257336 0.03837472 0.01580135
0.03160271 0.03386005 0.01805869 0.01805869 0.03160271 0.03386005
0.02934537 0.02031603 0.009029345 0.01805869 0.02257336 0.009029345
0.01805869 0.002257336 0.02257336 0.009029345 0.02257336 0.002257336
0.01805869 0.002257336 0.006772009 0.01580135 0.01128668 0.01128668
0.006772009 0.004514673 0.01128668 0.01128668 0.01128668 0.009029345
0.004514673 0 0.004514673 0.002257336 0.002257336 0 0.009029345
0.006772009 0 0 0.002257336 0.002257336 0.002257336 0.002257336 0
0.004514673 0.004514673 0 0.006772009 0 0 0.01805869
2013 0 0.002624672 0 0 0.002624672 0.005249344 0.002624672 0 0
0.01312336 0.01049869 0.0183727 0.01312336 0.02887139 0.01574803
0.01312336 0.04199475 0.06824147 0.02887139 0.03149606 0.03674541
0.02362205 0.03937008 0.05511811 0.01574803 0.04461942 0.01574803
0.04724409 0.02099738 0.02099738 0.04199475 0.01312336 0.04199475
0.01312336 0.01574803 0.007874016 0.01049869 0.007874016 0.005249344
0.02362205 0.01312336 0.01312336 0.02624672 0.0183727 0.01049869
0.01574803 0.01312336 0.005249344 0.005249344 0.002624672
0.007874016 0.005249344 0.005249344 0.002624672 0 0.002624672
0.01312336 0 0 0 0.002624672 0 0.002624672 0.005249344 0 0 0 0
0.01312336 0 0.005249344 0.002624672 0 0 0 0 0.002624672 0 0 0
0.007874016
dist multinomial
r 0.00001
N_2012 30
N_2013 25

@proportions_at AFnew
years 2012 2013
step 2
area rekohu
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 0.008086253 0.005390836 0.01617251 0.01617251
0.02156334 0.005390836 0.05121294 0.0458221 0.03504043 0.02695418
0.04312668 0.04043127 0.03504043 0.06199461 0.05660377 0.03234501
0.03234501 0.01617251 0.03773585 0.04851752 0.03773585 0.02425876
0.03504043 0.02425876 0.02695418 0.03234501 0.01886792 0.01078167
0.02425876 0.02425876 0.005390836 0.005390836 0.008086253 0.01078167
0.008086253 0 0 0.01347709 0.002695418 0.01347709 0.01078167 0 0
```

```
0.002695418 0.002695418 0 0 0.002695418 0.002695418 0 0 0
0.002695418 0 0 0 0 0 0 0.002695418 0 0 0 0 0.002695418 0 0 0 0 0 0
0 0 0 0 0 0.008086253
2013 0 0 0 0 0.009493671 0.009493671 0.006329114 0.009493671
0.0221519 0.0221519 0.03164557 0.0221519 0.05696203 0.05379747
0.05379747 0.04746835 0.0664557 0.04746835 0.07278481 0.05063291
0.06962025 0.03797468 0.03164557 0.04746835 0.02531646 0.0221519
0.03164557 0.003164557 0.01265823 0.01582278 0.003164557 0.01265823
0.01898734 0.009493671 0.02848101 0.009493671 0.009493671
0.003164557 0 0.006329114 0.003164557 0.003164557 0.003164557 0 0
0.003164557 0.003164557 0 0 0 0 0 0.003164557 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
dist multinomial
r 0.00001
N_2012 30
N_2013 25

@proportions_at AFcrack
years 2013
step 2
area crack
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 0 0 0.002169197 0.004338395 0.00867679 0 0.01952278
0.01735358 0.01518438 0.03036876 0.01301518 0.02169197 0.03687636
0.01952278 0.04989154 0.01518438 0.02603037 0.02169197 0.02603037
0.01518438 0.02386117 0.00867679 0.02819957 0.03253796 0.02819957
0.02603037 0.01518438 0.02169197 0.01084599 0.01518438 0.01301518
0.01735358 0.01952278 0.01952278 0.004338395 0.03470716 0.01084599
0.02819957 0.02169197 0.01952278 0.006507592 0.004338395 0.004338395
0.02169197 0.01084599 0.01952278 0.01735358 0.02169197 0.002169197
0.01952278 0.01952278 0 0.02819957 0.004338395 0.004338395 0
0.006507592 0 0.00867679 0 0.006507592 0 0 0 0 0.00867679
0.004338395 0 0 0.01084599 0 0.00867679 0 0.01084599 0 0 0 0
0.00867679
dist multinomial
r 0.00001
N_2013 25


@ageing_error
type normal
c 0.1

@q_method free

@q acoq
q  1

@q Bucq
q  1
@q Corq
q  0.8
@q Tanq
q  1
@q Tanwideq
q  0.1
```

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

@estimate
parameter selectivity[Bucsel].mature
lower_bound 10     3
upper_bound 50    50
prior uniform

@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[Corsel].mature
lower_bound 10     3
upper_bound 50    50
prior uniform
{
@estimate
parameter selectivity[Corsel].immature
lower_bound 1   1  0.001
upper_bound 30  50 0.2
prior uniform
}
@estimate
parameter selectivity[Tansel].mature
lower_bound 10     3
upper_bound 50    50
prior uniform
{
@estimate
parameter selectivity[Tansel].immature
lower_bound 1   1  0.001
upper_bound 30  50 0.2
prior uniform
}

@estimate
parameter selectivity[Tanwidesel].mature
lower_bound 10     3
upper_bound 50    50
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 normal
mu 36.9 13.5
cv 0.15 0.30

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

@profile
parameter initialization.B0
n 14
l 250e3
u 450e3

# cv1 on length at age
@estimate
parameter size_at_age.cv1
lower_bound     0.03
upper_bound    0.3
prior uniform

# cv1 on length at age
@estimate
parameter size_at_age.cv2
lower_bound     0.03
upper_bound    0.3
prior uniform

# migration parameters

@estimate
parameter migration[HtoR].prop
lower_bound 0
upper_bound 1
prior beta
mu 0.8
stdev 0.12

@estimate
parameter migration[RtoC].rates_all
lower_bound      10    2.5   0.01
upper_bound      100   30    0.9
prior uniform

@estimate
parameter migration[RtoO].rates_all
lower_bound      10    2.5   0.01
upper_bound      100   30    0.9
prior uniform
```

```
# YCS
@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
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
#prior uniform
prior lognormal
mu 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130
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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
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2980.958 2980.958 2980.958 2980.958 2980.958 2980.958

#-----------------------------------------------------------
#
# Penalties
#
#------------------------------------------------------------

@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
```

ORH7A

population.csl

```
# ORH7A 2014 stock assessment

# 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 2014
@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 SpawnFish
fishery_times         2


# RECRUITMENT
@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
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 2 1 2 1 2 1 2 1 1 1 .4 1 .3 1 2 1 .6 1 .8 1 2 .2 1 .5
1 2 1 2 1 .5 1 .5 1 .5 1 1 1 1 1 1 1 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 1925
last_free 1985


@fishery SpawnFish
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
catches  43  5522 15391 12385  6652 10079 14940 15835 12801  5171
1561  2102  2296  1819  1718  1752  1373 1577  1311   660     0
0     4     0   166   229     0     0   252   361   500   537   539
  539
selectivity SELspawn
U_max 0.8

# MATURITY
@maturation
rates_all logistic_producing 15 50 30 3

# SELECTIVITIES
@selectivity_names SELspawn
@selectivity SELspawn
mature constant 1
immature constant 0

# NATURAL MORTALITY
@natural_mortality
all    0.045

# SIZE AT AGE
@size_at_age_type von_Bert
@size_at_age_dist normal
@size_at_age
k 0.065
t0 -0.5
Linf 34.2
cv1 0.10
cv2 0.05
by_length True
@size_weight
a 9.21e-8
b 2.71

# INITIALISATION
@initialization
B0 130000
```

estimation.csl

```
@estimator Bayes
@max_iters 1000
@max_evals 3000
@grad_tol 0.0001

@MCMC
start 0.2
length 15000000
keep 1000
stepsize 0.006
proposal_t True
df 2
burn_in 1000


####
#### 1987 Amaltal Explorer and
#### 2006, 2009 Thomas Harrison age freqs
####

@proportions_at AFreq
years 1987 2006 2009
step 2
proportion_mortality 0.5
sexed F
sum_to_one True
at_size False
plus_group True
ogive SELspawn
min_class 15
max_class 100
ageing_error True
1987 0 0 0 0 0 0 0 0 0 0 0.00656168 0.003937008 0.01706037
0.01312336 0.01312336 0.01049869 0.03674541 0.01574803 0.0144357
0.01181102 0.0183727 0.02230971 0.01049869 0.02493438 0.0183727
0.02230971 0.0183727 0.03018373 0.03149606 0.01968504 0.04724409
0.01968504 0.02493438 0.02493438 0.04199475 0.01574803 0.03805774
0.02493438 0.009186352 0.02362205 0.02624672 0.01968504 0.01312336
0.01706037 0.01574803 0.02099738 0.02887139 0.00656168 0.01181102
0.01312336 0.002624672 0.01312336 0.01968504 0.007874016 0.009186352
0.002624672 0.001312336 0.01049869 0.00656168 0.00656168 0.009186352
0 0.01181102 0 0.005249344 0.009186352 0.005249344 0 0.00656168
0.01049869 0 0.001312336 0.00656168 0.003937008 0.002624672 0
0.005249344 0 0 0.003937008 0.007874016 0.001312336 0 0.00656168 0
0.01968504
2006 0 0 0.0008532423 0.002559727 0.001706485 0.001706485
0.004266212 0.005119454 0.005119454 0.01706485 0.03754266 0.0665529
0.04522184 0.06484642 0.05887372 0.02645051 0.04095563 0.04692833
0.008532423 0.03242321 0.08532423 0.02986348 0.03924915 0.0162116
0.0443686 0.03156997 0.03583618 0.01535836 0.01279863 0.05119454
0.02389078 0.01194539 0.01706485 0.006825939 0.004266212 0.003412969
0.006825939 0.01962457 0.004266212 0.001706485 0.01279863 0.01279863
0.001706485 0.005972696 0.002559727 0.005119454 0 0 0.002559727
0.003412969 0 0 0 0 0 0 0.006825939 0 0 0.001706485 0.01109215 0 0 0
0 0.001706485 0 0 0 0.001706485 0 0 0 0 0 0 0.0008532423 0 0 0 0 0 0
0 0 0
2009 0 0 0.001703578 0 0.001703578 0.003407155 0.0306644 0.02896082
0.01873935 0.02725724 0.02725724 0.04770017 0.03236797 0.02214651
0.07325383 0.03577513 0.07495741 0.03407155 0.04770017 0.04599659
0.03918228 0.04940375 0.02896082 0.03918228 0.04088586 0.02385009
0.03407155 0.02896082 0.02725724 0.005110733 0.0306644 0.005110733 0
0.005110733 0.00681431 0.005110733 0.001703578 0.008517888 0
0.005110733 0.003407155 0.008517888 0.008517888 0.003407155 0 0
0.003407155 0 0 0.003407155 0.00681431 0.001703578 0.005110733 0 0 0
```

```
0 0 0 0 0.005110733 0 0 0 0 0 0 0.001703578 0 0 0 0 0 0 0.01022147 0
0 0 0 0 0 0 0 0 0 0
dist multinomial
r 0.00001
N_1987 60
N_2006 60
N_2009 60


@ageing_error
type normal
c 0.1

####
#### 2010, 2013 combined acoustic and trawl estimates
#### excluding str 9-11
####

@relative_abundance AT1013
step 2
biomass True
ogive SELspawn
proportion_mortality 0.5
dist lognormal
q AT1013q
years 2010 2013
2010 14766
2013 13637
cv_2010 0.21
cv_2013 0.28

@estimate
parameter q[AT1013q].q
lower_bound 0.1
upper_bound 1.5
prior lognormal
mu 0.77
cv 0.21


#
# Amaltal Explorer trawl indices
# Clark's reduced area comparable indices
#

@relative_abundance Amaltal
step 2
biomass True
ogive SELspawn
proportion_mortality 0.5
dist lognormal
q Amaltalq
years 1987 1988 1989
1987  75040
1988  28954
1989  11062
cv_1987 0.33
cv_1988 0.34
cv_1989 0.23

@estimate
parameter q[Amaltalq].q
lower_bound 0.10
upper_bound 2.00
prior uniform-log
```

```
#
# Thomas Harrison trawl indices
# Using short-tow adjusted, excl. strata 9-11
#

@relative_abundance Thomas
step 2
biomass True
ogive SELspawn
proportion_mortality 0.5
dist lognormal
q Thomasq
years 2006 2009 2011 2012 #2013
2006 13987
2009 34864
2011 18425
2012 22451
# 2013 18993
cv_2006 0.34
cv_2009 0.31
cv_2011 0.33
cv_2012 0.27
# cv_2013 0.55

@estimate
parameter q[Thomasq].q
lower_bound 0.1
upper_bound 2.5
prior lognormal
mu 1.27
cv 0.30

#
# Thomas Harrison 2009 acoustic estimate
# from the two plumes
#

@relative_abundance aco2009
step 2
biomass True
ogive SELspawn
proportion_mortality 0.5
dist lognormal
q aco2009q
years 2009
2009 23095
cv_2009 0.25

@estimate
parameter q[aco2009q].q
lower_bound 0.1
upper_bound 1.5
prior lognormal
mu 0.8
cv 0.19

@q_method free

@q Amaltalq
q .5
@q Thomasq
q .7
@q aco2009q
q 1.1
@q AT1013q
q 1.0
```

```
# ESTIMATION BLOCKS

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

# B0
@estimate
parameter initialization.B0
lower_bound 30000
upper_bound 200000
prior uniform-log

@profile
parameter initialization.B0
n 14
l 50e3
u 160e3

# YCS
@estimate
parameter recruitment.YCS
lower_bound 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 1 1
upper_bound 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 1 1
prior lognormal
mu 26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130
26489122130 26489122130 26489122130 26489122130 26489122130
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# CATCH PENALTIES

@catch_limit_penalty
label CatchPenaltySpawn
fishery SpawnFish
multiplier 200
log_scale True
```

Mid-East Coast

```
# MEC 2014 assessment

# PARTITION
@size_based False
@min_age 1
@max_age 120
@plus_group True
@sex_partition False
@mature_partition True
@n_areas 1

# TIME SEQUENCE
@initial 1882
@current 2014
@annual_cycle
time_steps 1
aging_time 1
recruitment_time 1
spawning_time 1
spawning_p 1
spawning_part_mort 0.75
M_props 1
fishery_names North South
fishery_times 1     1

# maturation
n_maturations 1
maturation_times 1


# RECRUITMENT
@y_enter 1
@standardise_YCS True
@recruitment
YCS_years  1881 1882 1883 1884 1885 1886 1887 1888 1889 1890 1891
1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904
1905 1906 1907 1908 1909 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
```

```
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 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 1881
last_free 1996

# MATURITY
@maturation
rates_all logistic_producing 15 80 44 9

# NATURAL MORTALITY
@natural_mortality
all    0.045

# FISHING
@fishery North
years      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
catches    0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     720 4563 8934
7090 5294 8160 9341 8683 9167 8551 8422 7576 4875 4237 1342 1620
1754 1776 1995 1337 1135 683 668 1107 1082 1160 1130 1110 1117
     1117  874   671 671
selectivity SELnorth
U_max 0.67

@fishery South
years      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
catches    0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0 329 720
4246 5624 3322 3263 3039 3454 2936 2687 2349 2344 1770 643 609 599
611 648 503 420 247 263 437 436 421 454 435 410  441   449   311 311
selectivity SELsouth
U_max 0.67


# SELECTIVITIES
@selectivity_names SELnorth SELsouth SELspawn SELtrawl SEL2010
@selectivity SELnorth
all logistic 43.5709 9.2542
@selectivity SELsouth
all double_normal 30.3334 6.74983 7.36724
@selectivity SELtrawl
all double_normal 20 5 5
@selectivity SELspawn
mature constant 1
immature constant 0
@selectivity SEL2010
all double_normal 30 5 5
```

```
# SIZE AT AGE
@size_at_age_type von_Bert
@size_at_age_dist normal
@size_at_age
k 0.065
t0 -0.5
Linf 37.63
cv1 0.1
cv2 0.05
by_length True

# SIZE WEIGHT
@size_weight
a 9.21e-8
b 2.71

# INITIALISATION
@initialization
B0 140000
```

estimation.csl

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

@MCMC
start 0.2
length 15000000
keep 1000
stepsize 0.006
proposal_t True
df 2
burn_in 1000
subsample_size 3000
systematic False

#-------------------------------------------------
#
# 2013 spawning biomass estimate
# (AOS 38 kHz, mean of 4 snapshots)
#
#-------------------------------------------------

@relative_abundance aco
step 1
proportion_mortality 0.75
biomass True
ogive SELspawn
years 2013
2013 4225
cv_2013 0.20
dist lognormal
q acoq

@estimate
parameter q[acoq].q
prior lognormal
mu 0.6
cv 0.19
lower_bound 0.1
upper_bound 1.5

# Age freqs from spawning fishery
# Use as proportions-at-age for mature/spawning fish
```

```
@proportions_at AFspawn
years 1989 1990 1991
step 1
proportion_mortality 0.75
sexed F
sum_to_one TRUE
at_size    FALSE
plus_group TRUE
ageing_error True
ogive SELspawn
min_class 20
max_class 120
1989 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.004950495 0.02161716 0.00990099 0
0.03333333 0.00990099 0 0 0.00990099 0.01485149 0 0.02161716
0.004950495 0.01485149 0 0.02161716 0 0.004950495 0 0 0.00990099
0.03333333 0.04818482 0.02161716 0.004950495 0.02161716 0.03151815
0.02161716 0.02656766 0.01666667 0.004950495 0.02475248 0.01980198
0.02475248 0.03828383 0.02656766 0.004950495 0.004950495 0.01485149
0.00990099 0.004950495 0.01485149 0.00990099 0 0 0.01666667
0.01666667 0.04818482 0.00990099 0.004950495 0.004950495 0.004950495
0.004950495 0 0.00990099 0.004950495 0.02656766 0 0.01666667
0.01485149 0.01666667 0 0 0.02656766 0 0 0.004950495 0.00990099 0
0.01666667 0.00990099 0 0.004950495 0 0 0 0 0 0 0.02656766
0.004950495 0 0.02161716 0 0.004950495 0 0 0.05627063
1990 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.003448276 0 0.003448276
0.003448276 0.006896552 0 0.015625 0 0.01907328 0.003448276
0.0294181 0.01034483 0.003448276 0.02252155 0.01907328 0.01034483
0.0137931 0.01034483 0.003448276 0.02252155 0.03631466 0.03286638
0.01034483 0.04159483 0.006896552 0.02068966 0.006896552 0.02596983
0.006896552 0.02596983 0.01034483 0 0.06594828 0.006896552
0.02596983 0.03286638 0.03814655 0.003448276 0.02252155 0.006896552
0 0.03469828 0.01907328 0.01034483 0.01034483 0.006896552
0.003448276 0.003448276 0.003448276 0.03286638 0 0.006896552
0.003448276 0.03125 0 0.003448276 0.003448276 0.01034483 0.006896552
0.04159483 0.015625 0.006896552 0.006896552 0.006896552 0 0.01034483
0.003448276 0.003448276 0.015625 0.003448276 0.003448276 0 0
0.01034483 0 0.003448276 0.003448276 0.003448276 0 0 0 0 0.003448276
0 0.003448276 0 0.03631466
1991 0 0 0 0 0 0 0 0 0 0 0 0 0.003937008 0 0.007874016 0.007874016
0.01659524 0.01420313 0.007874016 0.003937008 0.01814014 0.007874016
0.007874016 0.01026612 0.01814014 0.02446925 0.02755906 0.007874016
0 0.01420313 0.01420313 0.01026612 0.02446925 0.02686136 0.02601415
0.02053224 0.02446925 0.05217781 0.01026612 0.02053224 0.01814014
0.03473537 0.01814014 0.02207715 0.01898734 0.01814014 0.02446925
0.01026612 0.01026612 0 0.02292435 0.003937008 0.01026612 0.01574803
0.01898734 0.01420313 0.007874016 0 0.01814014 0.02053224 0.01420313
0.006329114 0.01026612 0.01026612 0.007874016 0.03473537 0
0.007874016 0.01026612 0.006329114 0.006329114 0.01659524 0
0.006329114 0.003937008 0.003937008 0 0 0.007874016 0 0.003937008
0.01265823 0 0.003937008 0.006329114 0.006329114 0.003937008 0 0
0.007874016 0 0.01026612 0 0.003937008 0.006329114 0 0 0 0 0
0.0450015
dist multinomial
r 0.00001
N_1989     26
N_1990     35
N_1991     41

@proportions_at AF2010
years 2010
step 1
proportion_mortality 0.75
sexed F
sum_to_one TRUE
at_size    FALSE
```

```
plus_group TRUE
ageing_error True
ogive SEL2010
min_class 20
max_class 120
2010 0 0 0 0 0 0.0008569541 0.00738454 0.01105906 0 0 0.00738454
0.0002884425 0.01083565 0.00738454 0 0.0154158 0.008031263
0.008587893 0.01207627 0.04663494 0.01099546 0.03192034 0.009134918
0.01463622 0.03680318 0.01145306 0.03312438 0.009478425 0.02739578
0.008031263 0.03211817 0.01282013 0.01156077 0.06861253 0.03704274
0.03099879 0.006540953 0.01701115 0.01807374 0.009473022 0.02430277
0.001780238 0.00738454 0.01250276 0.0424366 0.01836219 0.006329673
0.01829331 0 0.0406665 0.01135584 0.004280971 0.02370649
0.0004038196 0 0.01638619 0.007672983 0.0172267 0.003971296
0.01940522 0.01267348 0.01505752 0.00738454 0 0.002600658
0.0006922621 0.01596809 0.03862918 0 0 0.0004038196 0 0.006050017 0
0 0.00738454 0.003971296 0.00738454 0 0.00738454 0 0 0 0 0
0.02367885 0 0 0 0 0 0 0 0 0 0 0 0 0 0.001103655
dist multinomial
r 0.00001
N_2010     40


@proportions_at AFtrawl
years 1993 2010
step 1
proportion_mortality 0.5
ogive SELtrawl
sexed F
sum_to_one True
at_size False
min_class 10
max_class 100
plus_group True
ageing_error True
1993 0 0 0.00163 0.00804 0.01833 0.04376 0.04505 0.03249 0.07162
0.05118 0.05558 0.07139 0.06942 0.09030 0.10252 0.07508 0.05355
0.04137 0.05142 0.01761 0.01476 0.01697 0.01660 0.00288 0.00316
0.00372 0.00754 0.00597 0.00234 0.00087 0.00047 0.00061 0.00148
0.00341 0.00302 0.00063 0.00000 0.00253 0.00088 0.00100 0.00008
0.00000 0.00000 0.00026 0.00008 0.00095 0.00027 0.00016 0.00000
0.00024 0.00000 0.00187 0.00021 0.00041 0.00036 0.00092 0.00000
0.00005 0.00047 0.00000 0.00000 0.00067 0.00008 0.00059 0.00026
0.00054 0.00000 0.00000 0.00029 0.00010 0.00021 0.00000 0.00047
0.00000 0.00000 0.00000 0.00000 0.00047 0.00008 0.00005 0.00000
0.00000 0.00000 0.00000 0.00005 0.00000 0.00000 0.00000 0.00017
0.00000 0.00000
2010 0.00412 0.02428 0.00740 0.02305 0.02692 0.02117 0.01857 0.01954
0.03591 0.04367 0.02330 0.03533 0.05091 0.04214 0.06975 0.05477
0.08077 0.03580 0.08743 0.03967 0.03327 0.03762 0.02308 0.03218
0.01185 0.01690 0.01660 0.01245 0.00998 0.00360 0.00540 0.00430
0.00772 0.00170 0.00338 0.00048 0.00135 0.00600 0.00277 0.00392
0.00049 0.00000 0.00024 0.00404 0.00036 0.00192 0.00123 0.00170
0.00000 0.00000 0.00226 0.00030 0.00000 0.00030 0.00000 0.00000
0.00049 0.00086 0.00000 0.00085 0.00000 0.00030 0.00000 0.00042
0.00205 0.00044 0.00000 0.00000 0.00030 0.00000 0.00000 0.00121
0.00011 0.00000 0.00000 0.00024 0.00000 0.00000 0.00000 0.00000
0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00000 0.00000 0.00000

dist multinomial
r 0.00001
N 200

@ageing_error
type normal
```

```
c 0.1

# Proportion mature from trawl surveys

@proportions_mature Mature_age
years 1993 2010
step 1
proportion_mortality 0.5
sexed F
at_size False
min_class 20
max_class 50
plus_group True
ageing_error True
1993 0 0 0 0 0 0 0.03905646 0.02680013 0.1253618 0.1829738 0.3443686
0.2408688 0.7437104 0.2102544 0.5283447 1 0.5322298 0.8021025 1
0.5828449 1 1 0 1 1 1 1 1 1 0.8115202
2010 0 0 0 0.1183311 0 0.06118033 0.129729 0.1972661 0.2672396
0.4031943 0.2060199 0.3236865 0.3069467 0 0.1054707 0.3578779
0.6137749 1 1 1 1 0.5774974 0.79 1 1 1 0.5746427 0.2171537 1 0.95
0.9003207

dist binomial
r 0.00001
N 10


### Commercial LFs
@catch_at  LFnorth

fishery North
years 1989 1990 1991 1993 1994 1995 1997 1998 1999 2000 2001 2002
2003 2007 2008 2010
sexed F
sum_to_one TRUE
at_size    TRUE
plus_group FALSE
class_mins 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    48    49
      50    51    52    53    54    55    56
1989        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.000 0.000 0.000 0.001 0.003 0.005 0.026 0.044 0.071 0.129 0.163
      0.164 0.144 0.118 0.065 0.036 0.019 0.009 0.005 0.001 0.000 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
1990        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.001 0.000 0.000 0.000 0.002 0.008 0.027 0.036 0.069 0.116 0.145
      0.163 0.126 0.116 0.091 0.065 0.023 0.009 0.003 0.000 0.000 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
1991        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.000 0.000 0.000 0.001 0.006 0.014 0.038 0.067 0.095 0.117 0.135
      0.154 0.137 0.101 0.060 0.047 0.019 0.008 0.001 0.000 0.000 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
1993        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 0.050 0.021 0.071 0.051 0.149
      0.121 0.129 0.169 0.119 0.070 0.030 0.010 0.010 0.000 0.000 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
1994        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.000 0.000 0.001 0.007 0.019 0.039 0.080 0.092 0.129 0.155 0.148
      0.081 0.098 0.068 0.047 0.022 0.003 0.001 0.000 0.000 0.000 0.007
      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
1995        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.000 0.000 0.000 0.001 0.002 0.012 0.040 0.073 0.099 0.135 0.144
      0.132 0.114 0.101 0.070 0.040 0.021 0.010 0.005 0.002 0.000 0.000
      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
```

```
1997          0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
        0.000 0.000 0.000 0.000 0.005 0.009 0.035 0.084 0.070 0.126 0.140
        0.153 0.171 0.093 0.055 0.029 0.016 0.011 0.002 0.000 0.000 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
1998          0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.001 0.000
        0.005 0.015 0.016 0.024 0.039 0.056 0.109 0.099 0.119 0.172 0.157
        0.076 0.069 0.021 0.008 0.014 0.000 0.000 0.000 0.000 0.000 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
1999          0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.001 0.002
        0.001 0.004 0.003 0.005 0.008 0.022 0.035 0.051 0.101 0.129 0.155
        0.116 0.127 0.079 0.059 0.042 0.023 0.019 0.013 0.004 0.000 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
2000          0.000 0.000 0.000 0.000 0.000 0.001 0.003 0.004 0.003 0.005
        0.011 0.018 0.031 0.041 0.050 0.089 0.112 0.137 0.106 0.114 0.086
        0.076 0.046 0.027 0.014 0.019 0.004 0.001 0.001 0.000 0.001 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
2001          0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.003 0.000
        0.009 0.025 0.024 0.036 0.058 0.052 0.057 0.076 0.114 0.071 0.104
        0.122 0.096 0.054 0.053 0.016 0.015 0.002 0.009 0.006 0.000 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
2002          0.000 0.000 0.001 0.000 0.001 0.000 0.003 0.000 0.001 0.004
        0.005 0.010 0.018 0.018 0.036 0.051 0.072 0.126 0.150 0.154 0.124
        0.080 0.071 0.037 0.022 0.009 0.005 0.000 0.001 0.000 0.000 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
2003          0.000 0.000 0.002 0.009 0.008 0.004 0.005 0.016 0.008 0.024
        0.028 0.034 0.035 0.026 0.032 0.054 0.072 0.110 0.089 0.110 0.092
        0.095 0.065 0.014 0.035 0.008 0.020 0.006 0.000 0.000 0.000 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
2007          0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.003
        0.005 0.016 0.003 0.012 0.093 0.054 0.114 0.094 0.137 0.114 0.089
        0.101 0.052 0.033 0.035 0.026 0.010 0.005 0.005 0.000 0.000 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
2008          0.000 0.000 0.000 0.000 0.000 0.001 0.001 0.001 0.003 0.006
        0.005 0.009 0.027 0.037 0.054 0.092 0.106 0.120 0.128 0.112 0.078
        0.087 0.052 0.026 0.022 0.018 0.012 0.005 0.001 0.001 0.000 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
2010          0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.003 0.000
        0.004 0.001 0.005 0.013 0.031 0.039 0.070 0.088 0.128 0.152 0.122
        0.105 0.108 0.054 0.038 0.018 0.013 0.007 0.001 0.001 0.000 0.000
        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
dist multinomial
r 0.00001
N_1989     31
N_1990     50
N_1991     34
N_1993     8
N_1994     10
N_1995     73
N_1997     8
N_1998     8
N_1999     24
N_2000     34
N_2001     8
N_2002     21
N_2003     8
N_2007     18
N_2008     39
N_2010     21

@catch_at  LFsouth
fishery South
years 1990 1994 1997 1999 2000 2001 2007 2008 2009
sexed F
sum_to_one TRUE
at_size    TRUE
plus_group FALSE
```

```
class_mins 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    48
1990        0.000 0.000 0.000 0.000 0.000 0.000 0.001 0.000 0.010 0.010
      0.032 0.083 0.096 0.141 0.148 0.103 0.097 0.051 0.048 0.062 0.031
      0.031 0.028 0.015 0.007 0.007 0.001 0.000 0.000 0.000 0.000 0.000
      0.000
1994        0.001 0.000 0.000 0.002 0.008 0.024 0.037 0.049 0.053 0.058
      0.078 0.075 0.076 0.080 0.080 0.079 0.061 0.046 0.037 0.028 0.031
      0.036 0.021 0.017 0.011 0.008 0.005 0.000 0.000 0.000 0.000 0.000
      0.000
1997        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.002 0.003 0.012
      0.021 0.055 0.061 0.104 0.112 0.129 0.127 0.110 0.090 0.043 0.039
      0.031 0.017 0.010 0.006 0.008 0.009 0.008 0.002 0.000 0.000 0.000
      0.000
1999        0.000 0.000 0.000 0.000 0.000 0.000 0.002 0.003 0.010 0.013
      0.039 0.053 0.051 0.060 0.111 0.133 0.108 0.102 0.075 0.093 0.060
      0.032 0.025 0.007 0.007 0.008 0.003 0.002 0.001 0.000 0.000 0.000
      0.000
2000        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.005 0.002
      0.014 0.016 0.045 0.064 0.049 0.121 0.072 0.050 0.090 0.050 0.074
      0.115 0.079 0.078 0.026 0.026 0.018 0.005 0.000 0.000 0.000 0.000
      0.000
2001        0.001 0.000 0.000 0.000 0.000 0.003 0.002 0.014 0.028 0.058
      0.061 0.101 0.099 0.132 0.092 0.095 0.100 0.084 0.041 0.029 0.015
      0.007 0.018 0.007 0.008 0.005 0.000 0.000 0.000 0.000 0.000 0.000
      0.000
2007        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
      0.001 0.005 0.006 0.034 0.040 0.102 0.139 0.102 0.099 0.106 0.106
      0.106 0.067 0.046 0.028 0.010 0.002 0.001 0.000 0.000 0.000 0.000
      0.000
2008        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.006 0.011 0.020
      0.041 0.030 0.064 0.077 0.107 0.101 0.120 0.072 0.130 0.054 0.067
      0.013 0.041 0.002 0.018 0.015 0.003 0.003 0.003 0.000 0.000 0.000
      0.003
2009        0.000 0.000 0.000 0.000 0.000 0.005 0.000 0.010 0.007 0.018
      0.036 0.029 0.040 0.049 0.079 0.141 0.134 0.114 0.129 0.091 0.055
      0.041 0.020 0.000 0.000 0.001 0.000 0.000 0.000 0.000 0.000 0.000
      0.000
dist multinomial
r 0.00001
N_1990     13
N_1994     10
N_1997     10
N_1999     7
N_2000     3
N_2001     10
N_2007     4
N_2008     3
N_2009     11


# OBSERVATIONS - TRAWL SURVEYS

@relative_abundance trawl
step 1
q trawlq
proportion_mortality 0.5
biomass True
ogive SELtrawl
years 1992 1993 1994 2010
1992 20838
1993 15102
1994 12780
2010 7074
cv_1992 0.29
```

```
cv_1993 0.27
cv_1994 0.14
cv_2010 0.19
dist lognormal


# OBSERVATIONS - TRAWL LENGTH FREQUENCY
@proportions_at LFtrawl9294
years 1992 1994
step 1
proportion_mortality 0.5
sexed F
sum_to_one True
at_size True
plus_group False
ogive SELtrawl
class_mins 6     7     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    45    46    47
1992        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.001
      0.005 0.010 0.015 0.020 0.025 0.030 0.039 0.053 0.059 0.074 0.071
      0.082 0.091 0.078 0.076 0.059 0.052 0.039 0.037 0.025 0.021 0.014
      0.009 0.007 0.004 0.002 0.001 0.000 0.000 0.000 0.000
1994        0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.001 0.001
      0.002 0.004 0.009 0.024 0.039 0.043 0.050 0.053 0.055 0.062 0.063
      0.069 0.073 0.077 0.070 0.067 0.053 0.047 0.039 0.032 0.025 0.016
      0.012 0.009 0.004 0.001 0.001 0.000 0.000 0.000 0.000
dist multinomial
r 0.00001
N     62


# ESTIMATION BLOCKS

@estimate
parameter size_at_age.cv1
lower_bound      0.01
upper_bound      1
prior uniform

@estimate
parameter size_at_age.cv2
lower_bound      0.01
upper_bound      1
prior uniform

@estimate
parameter q[trawlq].q
lower_bound 1e-2
upper_bound 10
prior uniform-log

@q_method free

@q acoq
q  0.8

@q trawlq
q  0.5

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

```
phase 1

### selectivities

@estimate
parameter selectivity[SELnorth].all
lower_bound      5     2.5
upper_bound      55    100
prior uniform
phase 1

@estimate
parameter selectivity[SELsouth].all
lower_bound      5     2.5   2.5
upper_bound      55    100   100
prior uniform
phase 1

@estimate
parameter selectivity[SELtrawl].all
lower_bound      5     2.5   2.5
upper_bound      55    100   100
prior uniform
phase 1

@estimate
parameter selectivity[SEL2010].all
lower_bound      5     2.5   2.5
upper_bound      100   100   100
prior uniform
phase 1

#B0
@estimate
parameter initialization.B0
lower_bound 10000
upper_bound 500000
prior uniform-log
phase 1

@profile
parameter initialization.B0
n 14
l 60e3
u 160e3

## YCS
@estimate
parameter recruitment.YCS
lower_bound 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
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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
upper_bound 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 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
prior lognormal
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# CATCH PENALTIES
@catch_limit_penalty
label CPenMECnorth
fishery North
multiplier 100
log_scale True

@catch_limit_penalty
label CPenMECsouth
fishery South
multiplier 100
log_scale True
```