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Tini a Tangaroa

The 2025 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1

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TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
1 INTRODUCTION	2
2 DATA AND COVARIATES	3
2.1 Data	3
2.2 Covariates	12
3 STOCK ASSESSMENT	21
3.1 Model	22
3.2 Parameters and priors	23
3.3 Assessment indicators	24
3.4 Bridging analysis	26
3.5 Base case	30
3.6 Model sensitivity	47
4 DISCUSSION	58
5 POTENTIAL RESEARCH	59
6 FULFILMENT OF BROADER OUTCOMES	59
7 ACKNOWLEDGEMENTS	60
8 REFERENCES	60
APPENDIX A. LOGBOOK CPUE DIAGNOSTICS	63
APPENDIX B. CATCH COMPOSITION ANALYSIS ADDITIONAL OUTPUTS	65
APPENDIX C. TAG RECAPTURE DATA	78
APPENDIX D. BASE CASE DIAGNOSTICS	84

PLAIN LANGUAGE SUMMARY

This report documents the 2025 stock assessment of red rock lobsters in CRA 1, including a primary ‘Far North’ assessment excluding areas 903 and 904 and a secondary “all of CRA 1” assessment. The model was fitted to length frequency data, proportion male data, tag-recapture growth increment data, and standardised catch-per-unit-effort indices. The model was fitted using a new lobster stock assessment software *decamod* that was coded in RTMB. This stock assessment estimated the Far North region to have had generally constant or slightly declining harvest rates since the 2000s, with stable population levels over that period. The Far North region lobster population was projected to increase over the next five years with constant current catch given recent recruitment.

EXECUTIVE SUMMARY

Webber, D.N.¹; Rudd, M.B.²; Starr, P.J.³; Roberts, J.⁴; Pons, M.⁵ (2026) The 2025 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1. *New Zealand Fisheries Assessment Report 2026/32*. 97 p.

This document describes the 2025 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1. The stock assessment used the new *decamod* length-structured stock assessment coded in RTMB. Data inputs and technical decisions were discussed and agreed upon by the Rock Lobster Working Group (RLWG), who oversaw this work. Covariates and data included catch estimates for all sectors of the CRA 1 fishery, catch-per-unit-effort (CPUE) indices, standardised length frequency (LF) distributions, standardised proportion male, standardised proportions of mature females that were in berry (egg-bearing), and tag-recapture growth increment data. Stock assessments were done for the 'Far North' only (excluding eastern areas 903 and 904), and also for all of CRA 1.

This document describes the procedure used to find an acceptable base case model. Model inference for this assessment was based on maximum likelihood estimates and Markov chain Monte Carlo simulations. Several sensitivity trials were done to test alternative model assumptions.

This stock assessment assumed a single-region model that combined data across the three CRA 1 Statistical Areas that encompass the Far North (Statistical Areas 901, 902, and 939). Areas 903 and 904 were excluded from the base case stock assessment in response to a commitment from CRAMAC 1 to close these areas to red rock lobster fishing for five years, beginning in April 2025. The reconstruction of the base model began in 1945, as was done in the 2019 assessment. Sensitivity trials to the primary Far North model included a model run for all of CRA 1, and another Far North model starting in 1979.

This stock assessment estimated generally increasing exploitation rates up to the early 1990s, followed by a steep decline to the late 1990s, after which exploitation was either stable or gradually declined. Vulnerable biomass declined steeply up to the mid-1970s, increased to the early 1980s, dropped again to the early 1990s, increased to the late 1990s, and then stabilised or gradually increased. This stock assessment also updated the reference level for CRA 1, with the stock estimated to be above this target level at the beginning of 2026 with a probability of 1.0. Five-year projections predicted a slowly increasing population at current catch levels.

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1 INTRODUCTION

The National Rock Lobster Management Group (NRLMG) directed that stock assessments for red rock lobsters *Jasus edwardsii* in CRA 1 and CRA 2 should be done in 2025. The CRA 1 assessment was completed during May and June 2025. Decisions on data and modelling choices were discussed and approved by the Fisheries New Zealand Rock Lobster Working Group (RLWG). The stock assessment was presented to and approved by the Fisheries New Zealand mid-year Plenary in September 2025 (Fisheries New Zealand 2025).

The CRA 1 Quota Management Area (QMA) extends from Kaipara Harbour on the west coast to the Waipu River, south of Bream Bay and Whangarei on the east coast (Figure 1). This QMA includes the Three Kings Islands, designated as Statistical Area 901. Historically, commercial fishing occurred on both sides of the upper North Island, as well as at the Three Kings. However, in October 2024, CRAMAC 1 fishers voluntarily agreed that no red rock lobsters would be taken from Statistical Areas 903, 904, and also the part of Area 905 that is located inside the CRA 1 domain (Figure 1), for a five-year period starting on 1 April 2025.

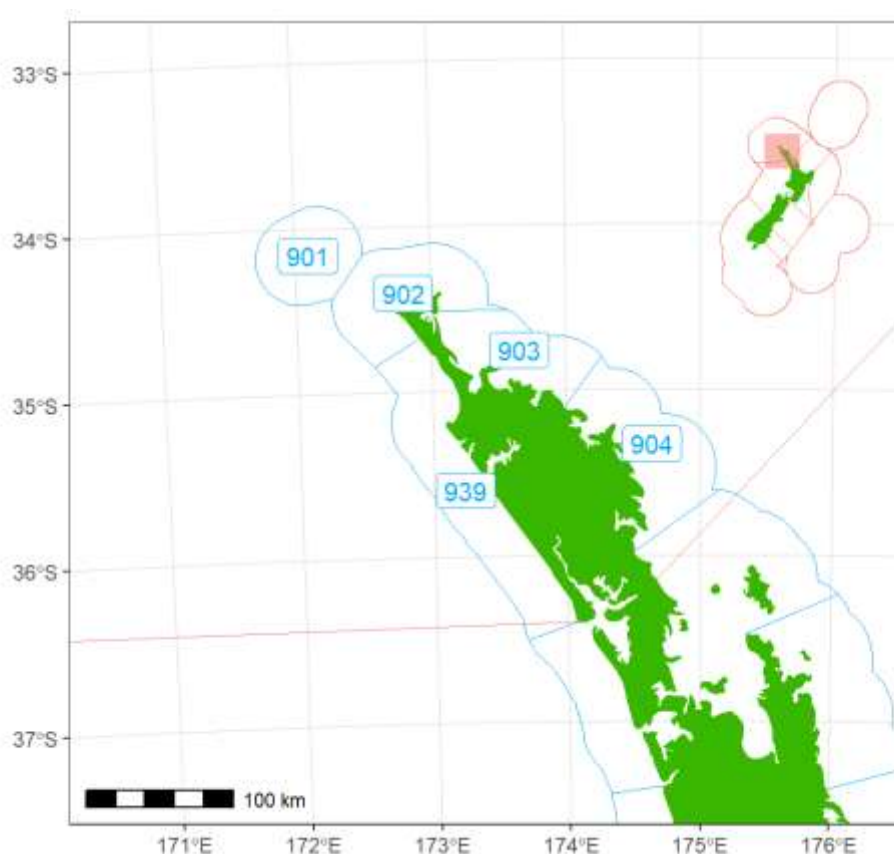


Figure 1: The CRA 1 Quota Management Area (QMA).

The CRA 1 commercial fishery is primarily a trap or pot fishery, fished by small boats on day trips in relatively shallow waters. Multi-day trips with larger vessels are used to fish Statistical Area 901 (Three Kings Islands), a major catching area (Starr 2025). From 2015 to 2018, the CRA 1 Total Allowable Commercial Catch (TACC) was set using a management procedure (MP) based on offset-year (1 October – 30 September) catch-per-unit-effort (CPUE). Because of changes to the collection method of catch and effort data, this form of management was temporarily discontinued. Allowances are added by the Minister for the non-commercial fisheries to produce a Total Allowable Catch (TAC). Other management measures include the protection of ovigerous (berried) females, a minimum legal size (MLS) for each sex, and the use of escape gaps in pots to minimise interactions with sub-legal lobsters.

The first TAC for CRA 1 was set at 273.1 t for the 2015⁶ fishing year following the 2014 stock assessment (Starr et al. 2015), with the CRA 1 TACC remaining unchanged at 131.1 t. The TAC was lowered to 203 t in 2020, 193 t in 2022, and 172 t in 2023 and the TACC lowered to 110 t, 105 t, and 89 t for the respective fishing years. The 2026–27 TAC of 172 t comprised a TACC of 89 t, a recreational allowance of 22 t, a customary allowance of 20 t, and an allowance for all other mortality caused by fishing of 41 t. There is significant iwi involvement in quota share ownership and fishing in CRA 1 and rock lobsters have great cultural significance to local Māori. Each component of the fishery is meant to stay within its allowance, but only the commercial catch is actively constrained to stay within the TACC via the application of the controls implemented through the Quota Management System (QMS).

This document presents a new stock assessment for CRA 1, which includes updates to the CPUE standardisation procedure and other inputs up to the end of the 2024 fishing year. The primary model for this assessment excluded Statistical Areas 903 and 904, representing a ‘Far North’ model run. The CRA 1 stock assessment was accepted by the Plenary in September 2025, including all MCMC sensitivities relative to the Far North model.

The covariates and data used in this stock assessment are summarised below in Section 2.1 and Section 2.2. The stock assessment model settings are described in Section 3.1, model parameters and priors are defined in Section 3.2, and the stock assessment outputs including stock status indicators are defined in Section 3.3. The stock assessment results are presented in Sections 3.4 and 3.5.

2 DATA AND COVARIATES

2.1 Data

The fitted data sets in this stock assessment included commercial fishery CPUE time series, length frequencies (LFs) and proportions male of the commercial catch, and tag-recapture data collected by commercial and recreational fishers.

2.1.1 Catch per unit effort (CPUE)

Six CPUE data sources were considered for use in this stock assessment:

- The catch rate (CR) series is an annual arithmetic average daily catch rate (kg/day) from 1966 to 1973. This series is documented in Bentley et al. (2005).
- The Fisheries Statistics Unit (FSU) series is a seasonal standardised index from the autumn-winter season (AW) of 1979 to AW 1989. The standardisation model was fitted to biomass-based catch rate data aggregated by year, month, Statistical Area, and vessel. Explanatory variables included period (the six-month autumn-winter/spring-summer season with each fishing year), month, Statistical Area, and vessel. The FSU CPUE standardisation included all vessels. Data originated from the FSU database, a static copy of which is held by the rock lobster stock assessment team (Bentley et al. 2005).
- The Catch Effort Landing Return (CELR) series is a seasonal standardised series based on biomass-based catch rate data from the spring-summer season (SS) of 1989 to the autumn-winter season (AW) of 2019. The standardisation model was fitted to catch rate data aggregated by year, month, Statistical Area, and vessel. Explanatory variables included period, month, Statistical Area, and vessel.
- The CELR series was gradually replaced by a new Electronic Reporting System (ERS) over the period April–September 2019. The ERS series is a seasonal standardised series based on biomass-based catch rate data from the SS 2019 to SS 2024. The standardisation model was fitted to catch rate data aggregated by year, month, Statistical Area, and vessel. Explanatory variables included period, month, Statistical Area, and vessel. Furthermore, each stratified

⁶ The 2015–16 fishing year is referred to in this document with the first year (2015) of the pair of years.

observation within this model was weighted by the vessel correction factor (VCF⁷) within the likelihood (i.e., a VCF of 1.0 had full data set weight, but a VCF above/below 1.0 received a lower weight commensurate to its absolute relative distance from 1.0). These electronic report system (ERS) data were considered as potential abundance indicators but were not used in this assessment.

- The logbook (LB) series is a seasonal standardised series based on numerical catch rate information from AW 2015 to SS 2024.

The CR, FSU, and CELR series were not updated for the stock assessment for all of CRA 1, as there were no new data collected since the 2022 assessment for these series. The same methods were used to generate similar CPUE abundance time series for the Far North base case model (Areas 901, 902, and 939 only).

An apparent change in reporting behaviour associated with the change in commercial catch and effort data collection from paper forms to electronic monitoring prevented the extension of the CELR CPUE abundance series beyond AW 2019 (see appendix B in Starr 2025 for the evidence supporting this decision).

For the LB CPUE series, there was no formal model comparison/optimisation process. Instead, a generic model structure was used which had been selected by CPUE model comparisons for all recent assessments (e.g., Roberts et al. 2023; Webber & Starr 2022). This model structure was:

$$N \sim \log(\text{pots}) + \text{period} + \text{area} + (I|\text{month}) + (I|\text{vessel}) + (I|\text{period:area})$$

A negative binomial distribution was assumed. The data were aggregated to the trip level prior to model fitting, to speed up the model run times. Several alternative dependant variables were explored, including:

- the number of legal lobsters (above the MLS and not a berried female),
- the number of lobsters above the MLS,
- the number of lobsters below the MLS,
- the total number of lobsters (above and below the MLS),
- the number of female lobsters above the MLS, and
- the number of male lobsters above the MLS.

All six of the alternative LB series showed similar interannual patterns in CPUE (not shown in this report); therefore, the series that modelled the number of legal lobsters per pot was used within this stock assessment for consistency with equivalent analyses in other CRA QMAs. No issues were detected in the MCMC diagnostics for any of the model runs (i.e., no divergent transitions, good Rhat statistics, and visually acceptable MCMC trace plots, see Figure A.1). The negative binomial assumption was also acceptable (Figure A.2). The standardised series was similar to but less variable than the unstandardised series (Figure 2). This logbook CPUE series was acceptably consistent across the Statistical Areas with the most data (Figure 3).

Although not currently accepted for use in the assessment, a separate exploratory CPUE series was fitted to biomass-based ERS catch rate data. This series resembled the LB series (Figure 4), but was not used in the stock assessment model.

⁷ The vessel correction factor (VCF) is a multiplier used to adjust estimated catches to match landed catch totals. It is calculated as a vessel's total landed catch divided by its estimated catches for an entire fishing year in the QMA.

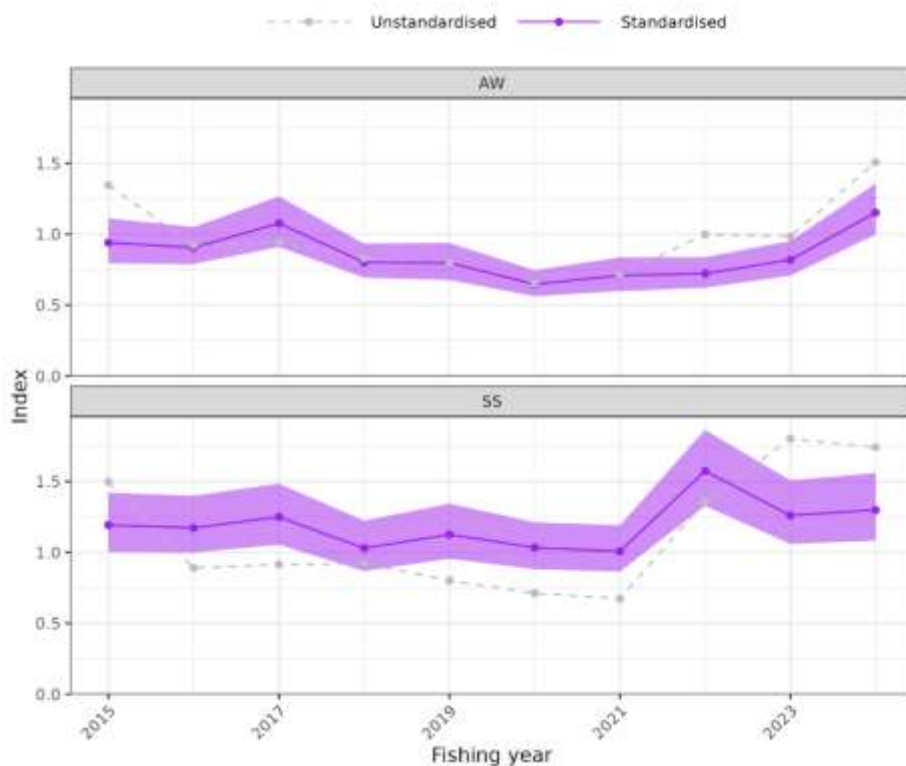


Figure 2: Logbook model standardised and unstandardised relative abundance indices from 2015 to 2024 for the Far North model, faceted by season: autumn/winter (AW, top panel) and spring/summer (SS, bottom panel). The solid purple lines represent the standardized index derived from the Bayesian mixed-effects *brms* model, with the purple shaded regions illustrating the 50% posterior credible intervals (25th to 75th percentiles). Dashed grey lines indicate the raw, unstandardised index trends for comparison.

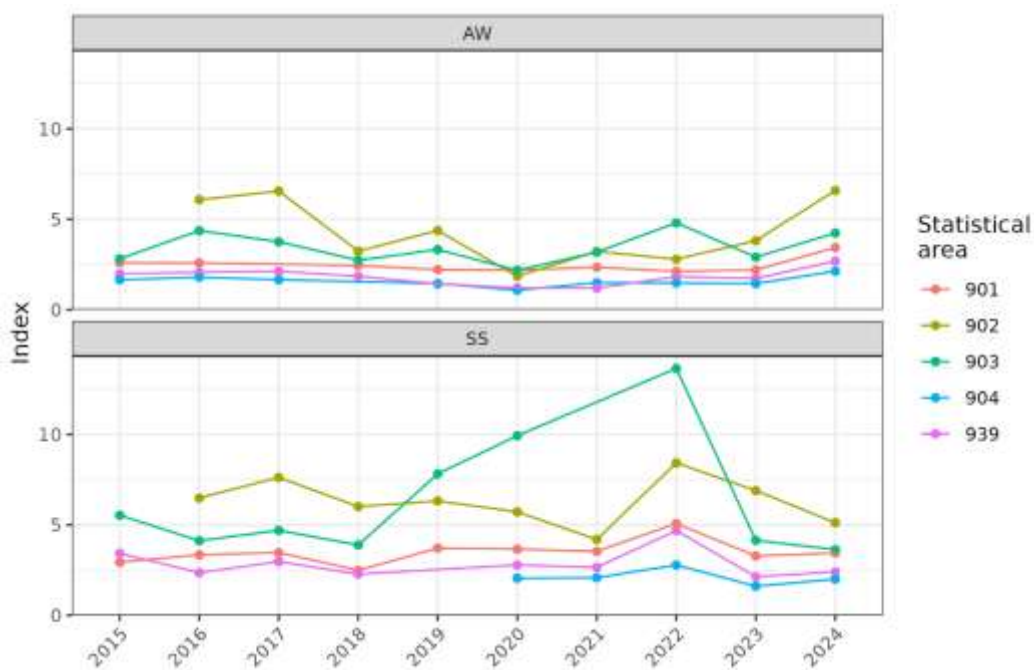


Figure 3: Logbook model standardised CPUE trends from 2015 to 2024 for the five Statistical Areas (901, 902, 903, 904, and 939) for the “all of CRA 1” model, stratified by season: autumn/winter (AW, top panel) and spring/summer (SS, bottom panel).

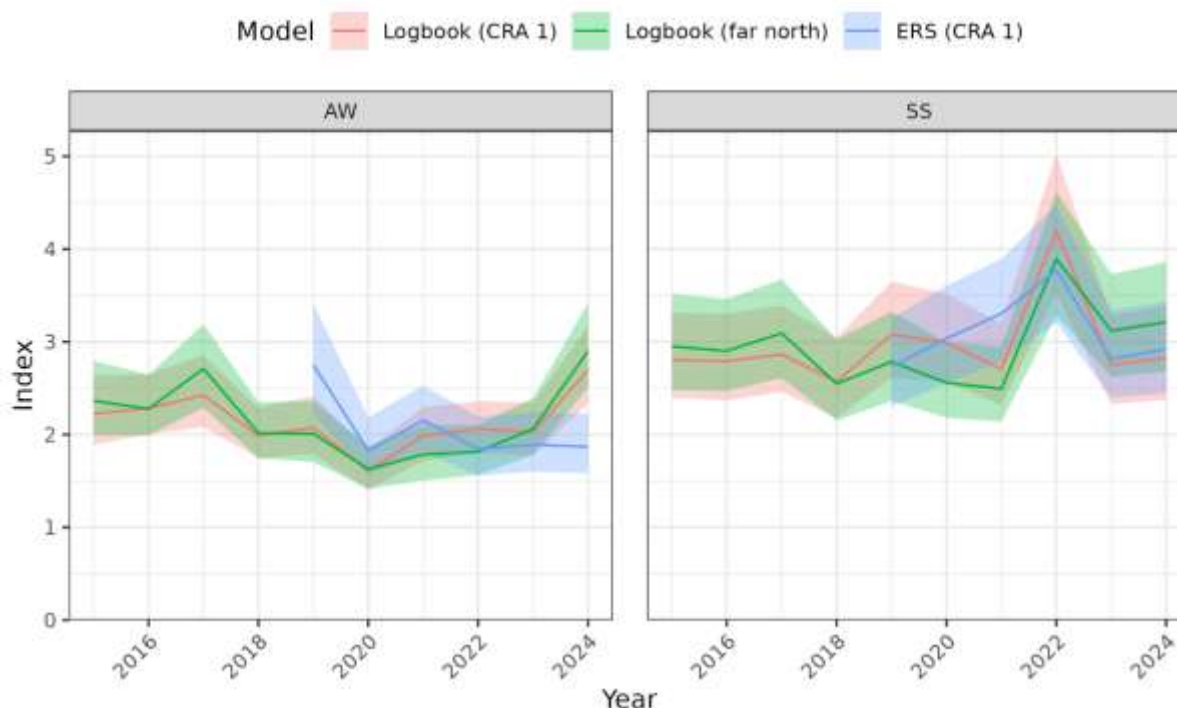


Figure 4: Comparison of relative abundance indices derived from the logbook (legal) series (1993–2024) and the ERS series (2015–2024), faceted by season: autumn/winter (AW, top panel) and spring/summer (SS, bottom panel). Solid lines represent model medians, with shaded ribbons indicating the 50% posterior credible intervals (25th to 75th percentiles). To facilitate direct comparison over the overlapping period, the ERS series has been rescaled to the geometric mean of the logbook series. The ERS series was not ultimately used for the 2025 CRA 1 stock assessment.

2.1.2 Length frequency and proportion male

Participation in the CRA 1 voluntary logbook programme started in 1993, and, although the fishers stopped participating soon after, they have since made a strong commitment to the voluntary logbook programme, from 2015 to the present (Table B.1). Some observer (catch sampling) length composition (LF) data were collected with uncertain design in 1975 and 1976 (not used for the 2025 assessment), and the programme was resumed from 1997 to the present. Both data sets were used in the 2025 stock assessment.

Webber (2022) developed a model-based procedure that unified the two data sources into a single standardised length composition time series, to predict the uncertainty associated with each sampled year/month/statistical area stratum and to correctly weight between the two data sources if both were present in a stratum. Furthermore, the procedure predicted LF distributions for the strata in which catch sampling had not occurred. LFs generated using this procedure were incorporated into the 2025 CRA 1 stock assessment. The same procedure was applied to the sex ratio data derived from the two data sources.

The data from Statistical Areas 903 and 904 were included in the LF and proportion male models, although were removed from the final catch weighted LFs for the base run.

2.1.2.1 Proportion male in the catch

Following the approach of Webber (2022), a model was constructed to predict the proportion male in the catch by fishing year, month, Statistical Area, and fishing vessel. Model explanatory variables included fishing year, month, statistical area, vessel, a fishing year by month interaction term, and a fishing year by Statistical Area interaction term. The fishing year, month, and Statistical Area terms were treated as population-level effects and the vessel and interaction terms were treated as group-level (random) effects.

For a given fishing year, month, Statistical Area, vessel, data source (LB or CS), and trip, counts of the number of lobsters measured by sex category (i.e., male, immature female, or mature female) were generated and arranged as vectors by sex category (i.e., data source and trips were replicates). These counts of lobsters by sex category were fitted using a multinomial distribution and the default *brms* priors were used. MCMC mixing was excellent (Figure B.1). This model was then used to simulate the sex ratios by year, month, and Statistical Area from the posterior distribution. This model-based approach also predicted the proportion male when a catch was taken from a stratum but no logbook or catch-at-sea sampling had occurred, and pooled the available sex ratio data from both data sources if both were present in the respective stratum.

The catch (tonnes) in each fishing year, month, and Statistical Area stratum was calculated from the catch and effort database, using the F0_LFX algorithm (see appendix D in Starr 2025). The simulated sex ratios were rescaled by the monthly catch in each Statistical Area and aggregated by posterior sample, fishing year, season, and sex category (i.e., month and Statistical Area were rolled up).

The model-based standardisation and subsequent catch scaling did little to alter the time series of raw averaged sex ratios by fishing year and season (Figure 5). The proportion male in the catch (see the top row of plots) had no obvious long-term trend over the time series of the data during AW, although was slightly decreased around the turn of the millennium in the SS season and has since gradually increased.

Only the proportion male component of the sex ratio was used in the stock assessment. The mean and associated standard deviation (SD) was calculated for each fishing year and season stratum, and the respective data set weights for each fishing year and season were calculated from the posterior SD values (see Webber 2022).

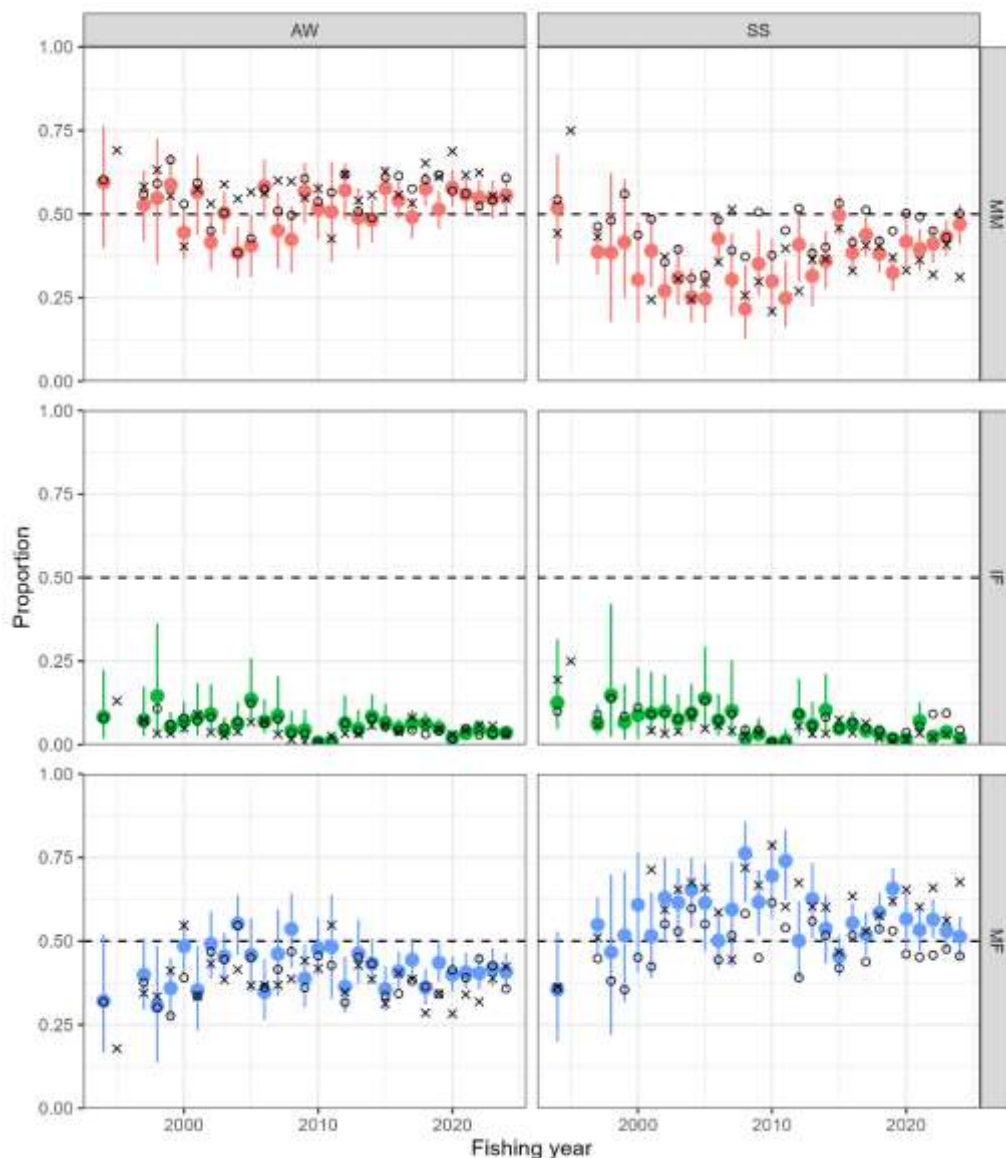


Figure 5: Sex ratio (SR) of males (MM), immature females (IF), and mature females (MF) by fishing year, and season (AW = autumn/winter, SS = spring/summer), showing raw SRs (black crosses), predicted SRs (open black circles), and scaled SRs (closed circles with error bars representing 95% credible intervals).

2.1.2.2 Length frequency of the catch

Following the approach of Webber (2022), a *brms* model was constructed that estimated the proportion at length of the catch by sex, fishing year, month, and Statistical Area. Model explanatory variables included: fishing year, month, Statistical Area, data source (i.e., observer catch sampling or voluntary logbook sampling), a source $\times$ vessel interaction term, and a fishing year $\times$ Statistical Area interaction term. All model terms were treated as group-level (random) effects.

For a given sex category (i.e., male or female), fishing year, month, Statistical Area, data source (LB or CS), and vessel, counts of the number of lobsters measured by tail width (TW) bin were generated and arranged as vectors by sex category (i.e., data source and trips were replicates). These counts of lobsters by size category were fitted using a Poisson-decomposed multinomial distribution and the default *brms* priors were used. MCMC mixing was acceptable (Figure B.3, Figure B.4).

The fitted LF models for each sex were used to simulate the predicted LF by sex, fishing year, month, and Statistical Area from the posterior distribution. This model-based approach also predicted the LF if

there was catch in a stratum but no catch sampling from either data source. The available LF data from both data sources were pooled if both were present in the stratum. The catch (tonnes) in each fishing year, month, and Statistical Area stratum was calculated from the commercial catch and effort data, using the F0_LFX algorithm (appendix D in Starr 2025). The simulated LFs were scaled, first by the sex ratio model, then by the monthly catch in each Statistical Area and aggregated by posterior sample, region, fishing year, season, sex category, and length bin, then converted to proportions. The mean and SD by fishing year, season, sex category, and length bin were calculated from the posterior distribution. Finally, the data set weight for each fishing year, season, and sex category was calculated from the posterior SD.

The sample sizes in each fishing year were reasonably high, apart from 1994, which was still deemed a high-quality data year (Table B.1). In general, the standardised LFs (i.e., the scaled, predicted LFs) were similar to the LFs of the raw data (Figure B.2, and Figure B.5 to Figure B.12), but there was still a strong standardisation effect in some years with a good sample size of data but with atypical LF distributions from the raw data (e.g., males and females in 2002 SS) (Figure B.5, Figure B.9). Scaling the LFs by the catch generally did very little to alter the predicted LFs. This was because the CS programme is adjusted in each year so that the samples are distributed approximately proportional to the catch by statistical area in the previous year, while the LB programme design is dynamic, as fishers are asked to mimic their fishing patterns as they deploy the sampled pots. This approach results in a combined data set that is essentially self-weighted with respect to catch.

Based on the standardised LFs, the size distribution of the catch has been consistent over the time series of the data (Figure 6) and this is also apparent based on the raw LF data (Figure 7). The spiky appearance of the standardised LFs resulted from some vessels apparently reporting LB-based length-composition data to a 5 or 10 mm TW resolution, although it was decided to include all vessels in this series and to allow the stock assessment model to ‘smooth’ through the standardised LF predictions.

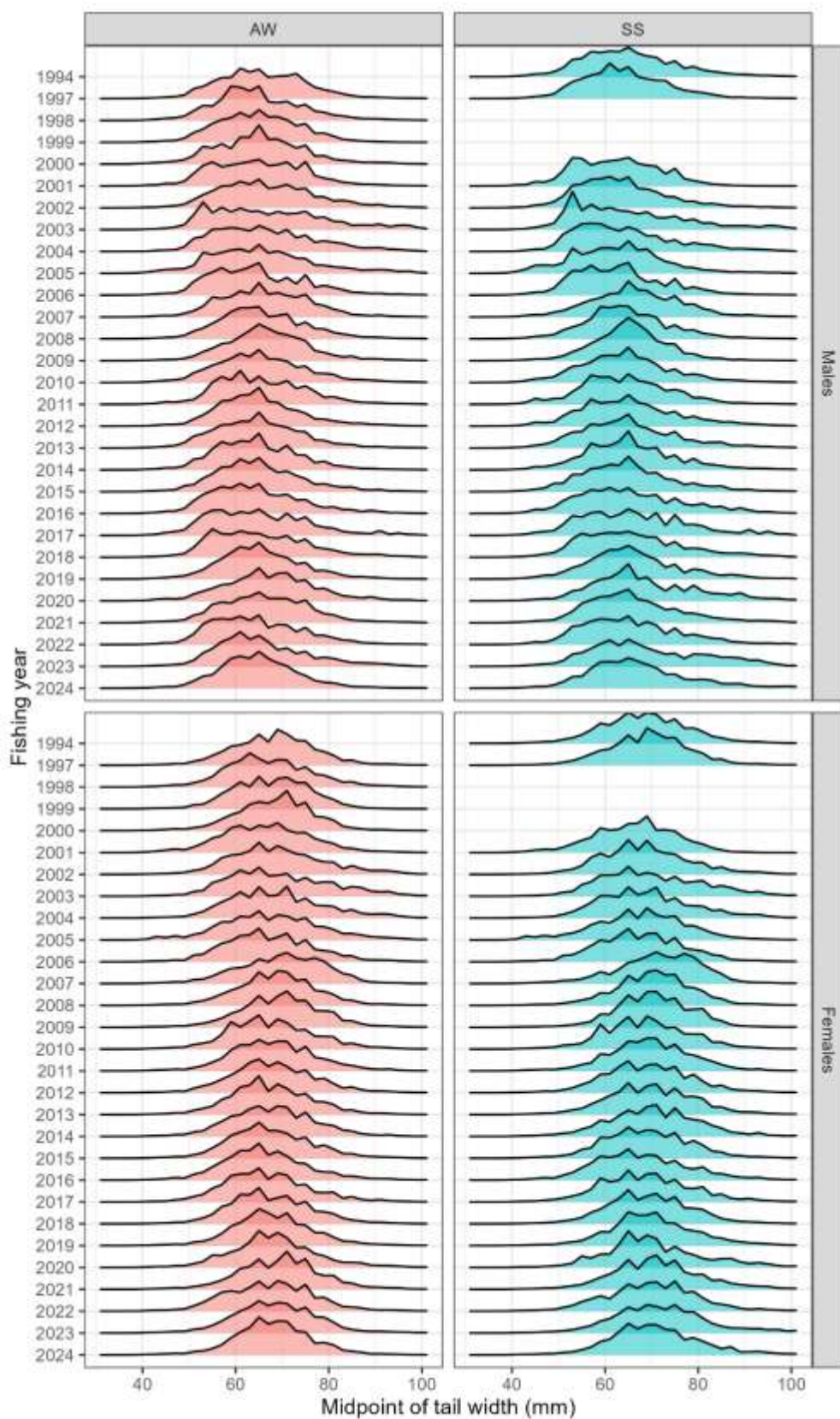


Figure 6: Predicted standardised LFs by fishing year (from 1994 to 2024) for the Far North Statistical Areas (939, 901, and 902), season (AW = autumn/winter, SS = spring/summer), TW bin, and sex.

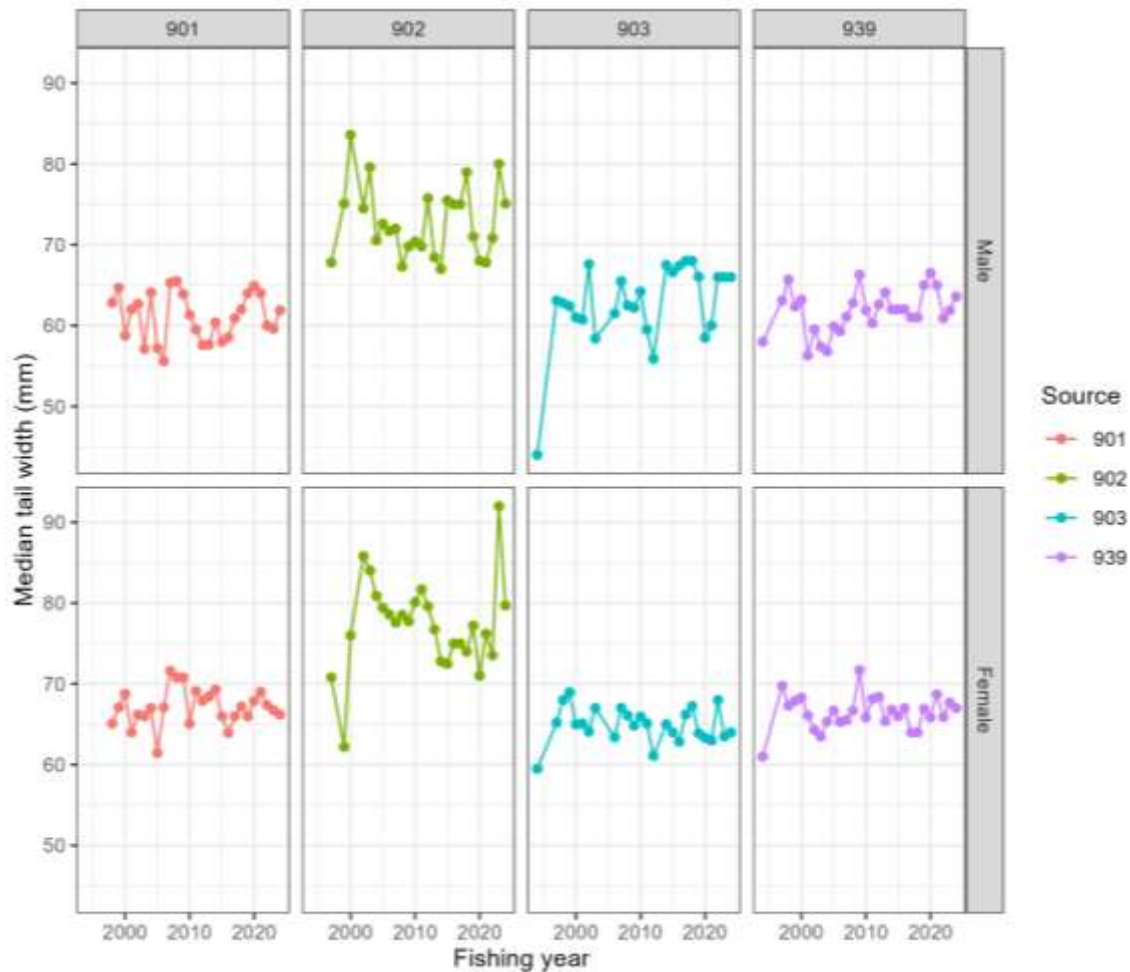


Figure 7: Median tail width (mm) by fishing year, sex (M = males, F = females), and Statistical Area, based on the pooled, unstandardised observer catch sampling and logbook data. Note that Statistical Area 903 is included in this plot although was removed from the final catch weighted LFs by setting the catch in 903 (and 904) to zero.

2.1.3 Tag-recapture data

This section describes tag-recapture data that were used to inform growth in the stock assessment of rock lobster stocks. These data are also useful for informing decisions about stock structure and movement. Tag data for all CRA areas were obtained in May 2025 from Fisheries New Zealand (replog 16686).

2.1.3.1 Data processing

Before the tag data were used to inform growth in stock assessments, they were processed (i.e., obvious errors were corrected and records that cannot be used were removed). This required linking every tag release-recapture event to create a single record while discarding all tags with no recaptures. Processing, linking, and formatting were done using purpose-built software written in the R statistical computing language (see Roberts et al. 2023 for a description of these preparatory steps).

A comparison was done to ensure that the new data extract was not missing records that were available in previous years and to see how many new data records were available. The tag data extract for 2025 was identical to 2024.

2.1.3.2 Tag data summary

Recovery rates (tags returned relative to numbers released) varied by QMA, with the highest rate occurring in CRA 8 (30.42%) and the lowest rate in CRA 9 (2%) (Table C.1). There were 36 204 complete release/recovery record pairs (i.e., not missing a key piece of information such as sex, QMA, initial size, recapture size, or time at liberty) available in the New Zealand rock lobster tagging data set, of which 22 303 were males and the remaining 13 901 were females (Table C.2). The CRA QMA with most recovered tags was CRA 8, and the fewest recaptured tags came from CRA 6 and CRA 9, which had 269 recoveries and 129 recoveries respectively (Table C.2). Tagged lobsters were primarily recaptured in the QMA and statistical area of release, but there was evidence that some individuals moved much greater distances (Table C.3, Table C.4).

The updated CRA 1 assessment used paired individual tag-recapture observations from all tag releases (the previous assessment used only initial tag release-recovery pairs). The 2025 assessment used tag-recaptures from all CRA 1 statistical areas (901, 902, 903, and 939) (none were reported from Area 904), supplemented with tag data from 905 and 906 in the west of CRA 2, as with the 2019 assessment.

CRA 1 tagging effort (and returns) has mostly been in Statistical Areas 939 (in the 1970s and since 2000) and 901 (since 2000) (Table C.5). This was supplemented with tagging data from the two CRA 2 Statistical Areas 905 (since 1996) and 906 (since 1983) because the RLWG agreed that the amount of CRA 1 tag information was insufficient. Across all the data from these Areas, more than 2500 linked release/recovery tag returns were available for each sex (Table C.5).

The monthly distribution of tag releases resulting in recaptures is shown in (Table C.6), indicating acceptable coverage across all months. Times at liberty in the processed tag data varied from 1 day to 3634 days (~10 years) (Table C.7), noting that the data processing procedure dropped recoveries that were at liberty for more than 10 years. The median period at liberty was 254 days for males and 355 days for females (Table C.7). Growth increments (mm) ranged from -37 to +37 mm TW for males and from -30 to +35 mm TW for females (Table C.8).

The RLWG agreed to exclude tagged lobsters that had been at liberty for less than six months (183 days). This exclusion was based on an analysis that showed a decreasing proportion of lobsters in the zero-growth increment bin as the number of months at liberty increased. The zero-growth increment bin was interpreted as lobsters which had failed to moult after tagging, and there was concern that the inclusion of short time at liberty observations in the growth model, in conjunction with seasonal tagging effort, would bias the estimate of growth. While the analysis concluded that nearly all zero-growth lobsters had disappeared by the time they had been at liberty for eight months, the RLWG agreed that a six-month exclusion was a reasonable compromise without excluding too much data. For CRA 1, this resulted in 75% of the tag data being retained after applying this exclusion (Table C.7). This exclusion was necessary because it is not possible to infer whether a lobster has recently moulted through observation of the sampled animal.

2.2 Covariates

The covariates used in this stock assessment included the catch, assumed handling mortality rates associated with the commercial and recreational catch, the MLS, estimates of the proportion of mature females at length, estimates of all females in berry (i.e., egg bearing) at length, size at recruitment (Figure 8) and other fixed quantities (Table 1).

Handling mortality was assumed to be 10% for all lobsters returned to sea before 1990, and 5% from 1990 onwards. This step-reduction in handling mortality was agreed by the RLWG to coincide with the start of the live export market and the introduction of rock lobsters into the QMS, under the assumption that fishers would take more care in the handling of lobsters once they became quota owners in order to maintain a high-quality product for live export. Handling mortality was applied to undersized lobsters of each sex taken in either season by the MLS Size Limited (SL) fishery as well as to mature berried

females returned to the water by both the AW and SS SL fisheries. It was assumed that there were no discards in the non-size-limited (NSL) fishery.

Table 1: Fixed quantities used in the CRA 1 Far North stock assessment model.

Quantity	Value	Quantity	Value
Data set weights		Fixed parameters	
Tags	1	Male length-weight a	4.16e-6
CR CPUE	0.81	Male length-weight b	2.935
FSU CPUE	3.71	Female length-weight a	1.30e-5
CELR CPUE	1.62	Female length-weight b	2.545
LB CPUE	1.53	catchability creep	0.01
Sex Ratio	46		
LF males	7.26	Recruitment	
LF females	5.99	years for <i>ARIMA</i> projections/autocorrelation	1980-2020
		<i>sigmaR</i>	0.4
Catch and handling		recruitment size mean	32 mm
Handling mortality, 1945-1989	0.1	recruitment size SD	2 mm
Handling mortality, 1990-2029	0.05		
Projected SL commercial catch	83.0 t	Growth and maturity	
Projected SL recreational catch	1.3 t	length at <i>Galpha</i>	30
Projected NSL illegal catch	8.3 t	length at <i>Gbeta</i>	80
Projected NSL customary catch	1.0 t	length at <i>Gmin</i>	0.001
		Other	
		Tail compression: male bins	4 to 36
		Tail compression: female bins	4 to 36

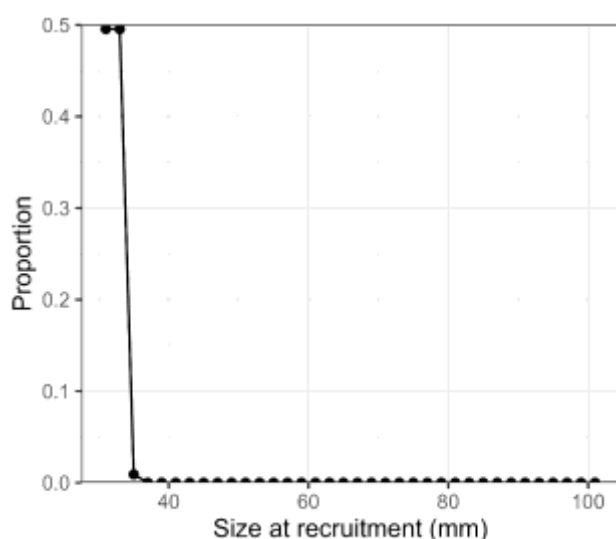


Figure 8: Distribution of recruitment size (mm) assumed in the CRA 1 stock assessment.

2.2.1 Minimum legal size (MLS)

Prior to 1949, there was no MLS for red rock lobster in New Zealand. MLS restrictions were initially implemented for New Zealand red rock lobster as measurements of tail length in inches. This

measurement standard was subject to some abuse because tails could be stretched, but it was used because a significant fraction of the catch came from Fiordland where it was permissible to tail lobsters at sea. The MLS was changed to a width measurement (in mm) across the spines of the second abdominal segment (called the tail width or TW) in 1988 for all New Zealand red rock lobsters, requiring the conversion of the pre-1988 regulations into equivalent TW measurements for use in the stock assessment model (Breen et al. 1988). The current MLS in CRA 1 is 54 mm TW for males and 60 mm for females (Table 2).

Table 2: Minimum legal size (MLS) over time.

Period	Males (mm TW)	Females (mm TW)
< 1950	—	—
1950–1951	47	49
1952–1958	51	53
1959–1988	53	58
1988–1991	54	58
> 1991	54	60

2.2.2 Proportion of females mature or in berry

For the 2025 assessments of CRA 1 and CRA 2, female maturity and the incidence of berried females at length were modelled separately from the stock assessment model; these analyses are described in Appendix D and Appendix E, respectively, in Rudd et al. (2026). Briefly, the proportion of females that were mature in the underlying population was predicted for each length bin using a Generalised Linear Mixed Model (GLMM) fitted to observations from the observer catch sampling and voluntary logbook programmes. The model was fitted using data from the Far North region of CRA 1, and from CRA 2, CRA 3, and CRA 4, with separate ogives predicted for each QMA/assessment region, including the Far North region of CRA 1 (Figure 9).

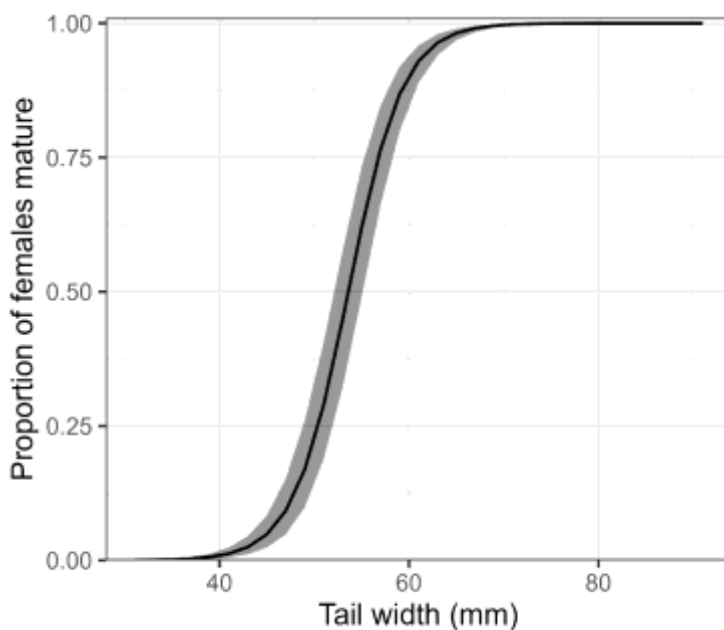


Figure 9: Predicted proportion of females that were mature by tail width bin, as used by the Far North CRA 1 stock assessment.

The proportion of all (i.e., mature and immature) females in berry in the catch was predicted for each length bin and by season using another GLMM fitted to observations from the observer catch sampling and voluntary logbook programmes. This model was also fitted using data from the Far North areas of CRA 1, and from CRA 2, CRA 3, and CRA 4, with a separate ogive predicted for the Far North region of CRA 1. The predicted proportions in berry were weighted by the seasonal distribution of the catch (Figure 10).

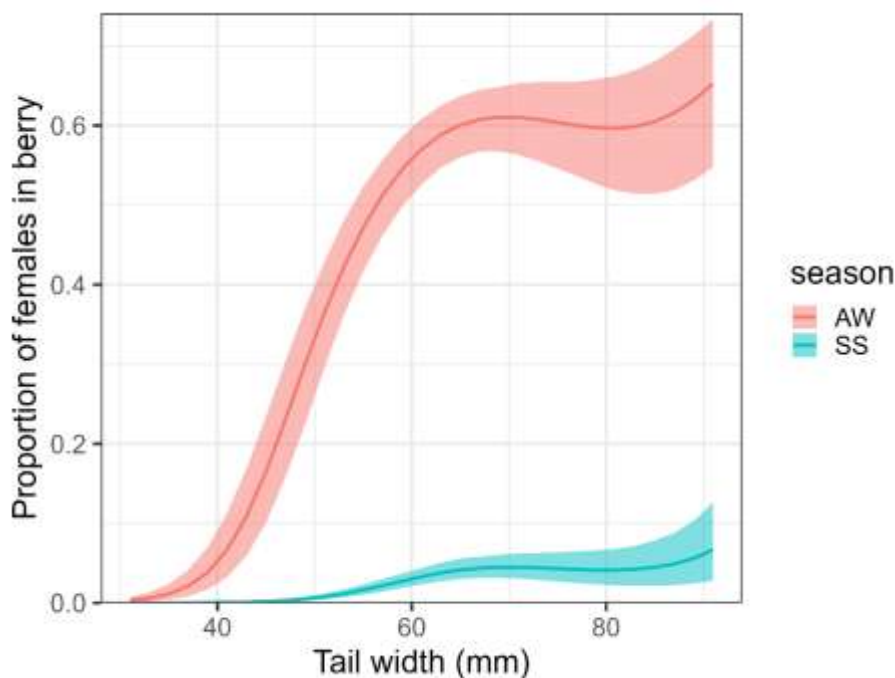


Figure 10: Predicted proportion of females that were in berry by tail width bin and season, as used by the Far North CRA 1 stock assessment.

2.2.3 Catch

2.2.3.1 Commercial catch

Previous CRA 1 stock assessments included annual catch estimates from 1945 to 1978, adding the catches from January–March 1979 to the 1978 annual total. The model then switched to a seasonal catch model which divided the annual catch into two seasons: April–September (Autumn/Winter or AW) and October–March (Spring/Summer or SS). For the 2025 CRA 1 stock assessment, the pre-1979 catch data were split seasonally based on the seasonal information in the Annala & King (1983) data set which covered the period January 1963 to December 1973. Annual catches before 1963 from the Marine Department (Bentley et al. 2005) were split seasonally using the average CRA 1 seasonal split for 1963–1967. The annual CRA 1 1974–1978 (Annala & Esterman 1986) catches were split using the 1969–1973 Annala & King estimates.

From 1 January 1979 to 31 March 1986, catches were taken from monthly data summarised by fishing year from data collected by the Fisheries Statistics Unit (FSU), a version of which is documented and held in the CRACE database (Bentley et al. 2005). There is some uncertainty in the quality of the catch estimates in the years before the FSU system began in 1979, but there is confidence in the quality of the catch estimates from the 1980s when the FSU system was operating. Catch estimates generated from the FSU data that were available to the stock assessment team are consistent with published historical catch estimates from the FSU system.

From 1 April 1986 to 31 March 1988, monthly reported catch totals for all of New Zealand were obtained from Quota Management Returns (QMRs) maintained by the Ministry of Agriculture and

Fisheries. Because QMR returns by individual QMAs were not available for this period, the total New Zealand catches were divided into QMA catches based on the proportional landings reported on FSU forms. From 1 April 1988 to 30 September 2001, catches were summarised from monthly QMRs available for each QMA. The QMRs were replaced by Monthly Harvest Returns (MHRs) on 1 October 2001, but the same information is available from these more recent forms. Catches by season were assigned based on months, where the AW spans from 1 April through 30 September, and the SS spans from 1 October through 31 March annually.

Annual commercial catches in CRA 1 averaged 130 t/year between 1945 and 1978, with a 9-year period in the late 1960s and early 1970s when catches ranged from 190 t to 356 t (Figure 11). CRA 1 commercial catches were also high (174–232 t) in the period leading up to the introduction of rock lobster into the QMS (1980–1989), with catches peaking at 232 t in 1983–84 and averaging 200 t/year during that decade (Figure 11). Commercial catches in CRA 1 were less than the TACC until 1993–94, when the TACC was reduced to 130.5 t. Since then, the TACC had a small increase to 131.1 t in 1999–2000 followed by three successive drops to 110 t, 105 t, and 89 t in 2020–21, 2022–23, and 2023–24 respectively. Landings have matched the TACC since 1993–94 (Figure 11).

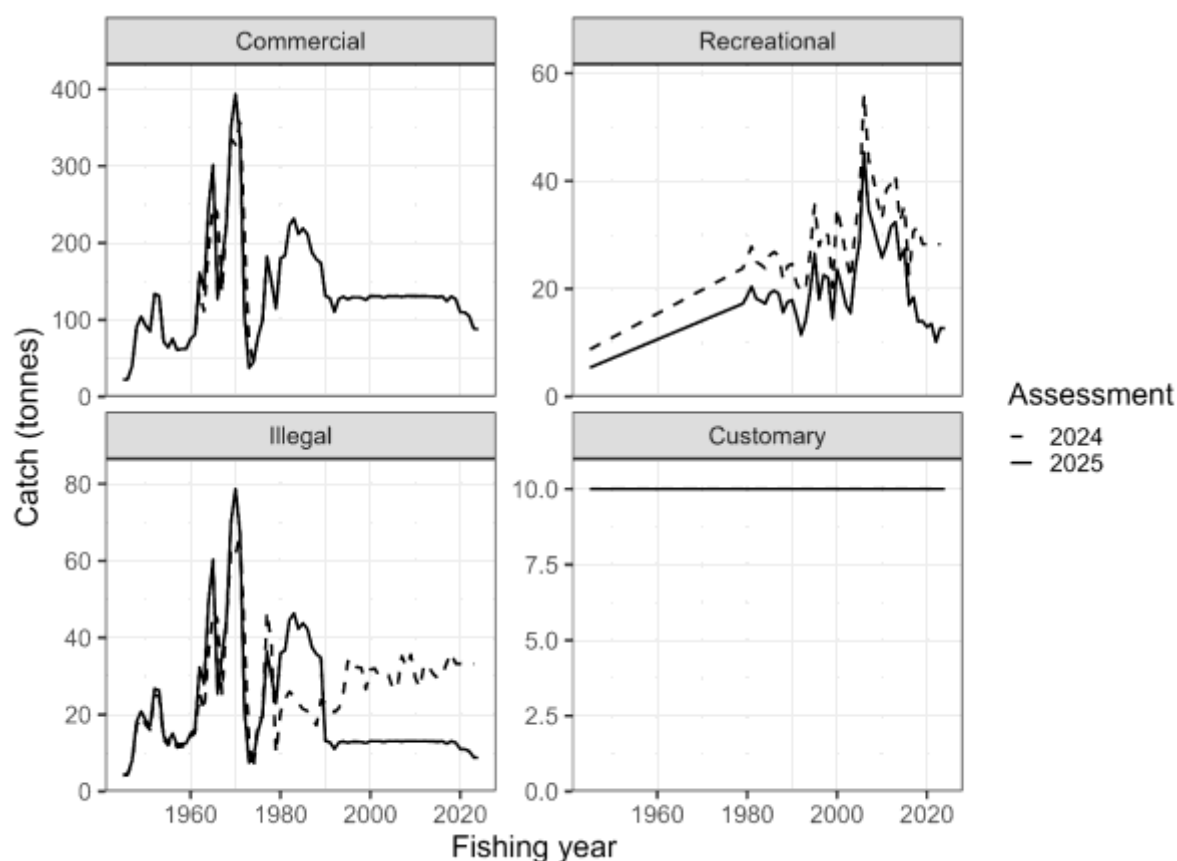


Figure 11: Catches for the 2025 CRA 1 stock assessment by sector (solid black line), compared with catches used for the 2024 rapid update (dashed line).

2.2.3.2 Recreational catch

Eight annual recreational harvest surveys have been undertaken for CRA 1, but only four of these are considered plausible (Table 3). Estimates from the two Kingett Mitchell national telephone diary surveys in 1999–2000 and 2000–01 (Boyd et al. 2004, Boyd & Reilly 2004) were considered implausibly high and not accepted by the RLWG for the 2014 CRA 1 stock assessment (Starr et al. 2015). The earlier regional 1994 and national 1996 telephone diary surveys were considered biased in a review of the available recreational surveys (unpublished minutes: Recreational Technical Working

Group [Auckland NIWA, 10–11 June 2004]) because the interview questions possibly underestimated fisher participation rates by allowing for an easy exit from the interview ('soft refusal' bias). For these reasons, these four early surveys have been dropped for this rock lobster stock assessment.

A large-scale population-based diary/interview survey, known as the National Panel Survey (NPS), was conducted under contract for MPI from 1 October 2011–30 September 2012 (Wynne-Jones et al. 2014). The NPS was repeated from 1 October 2017 to 30 September 2018 (Wynne-Jones et al. 2019) and 1 October 2022 to 30 September 2023 (Heinemann & Gray 2024) using directly comparable methods. The recreational daily limit was reduced during the 2022–23 NPS. These surveys were designed to estimate annual catches by FMA and QMA for all important finfish and non-fish species harvested by recreational fishers, based on a "mesh block" dwelling cluster sampling frame that has been developed for the five-yearly national censuses of the population of New Zealand (Heinemann et al. 2015). Door-to-door surveying of households in randomly selected "mesh block" strata was used to select participants, who were recruited to report their catch for an entire year. A structured and carefully designed Computer Assisted Telephone Interview (CATI) method was used to record harvest in detail from those who had fished. The survey results were thought to be plausible for CRA 1, with 32 (2011), 34 (2017) and 15 (2022) fishers providing catch diaries from 90, 65 and 27 trips where rock lobster were caught for respective survey years (Wynne-Jones et al. 2014, Wynne-Jones et al. 2019, Heinemann & Gray 2024). These estimates have relatively high CVs (0.30 to 0.49, Table 3). All three NPS surveys provided estimates of the distribution of fishing platforms used to take lobsters in CRA 1, with large and small motorboats accounting for about three quarters of the catch and only 15% coming from land (Table 4). The primary capture method used to take rock lobsters in CRA 1 was diving followed by potting, with most fishing taking place from trailer boats (Table 4). NPS survey results from diary participants were in terms of number of fish. Mean recreational catch weight for the most important finfish and non-fish species QMAs was estimated in parallel projects (Hartill & Davey 2015, Davey et al. 2019; 2024).

The 2013–14 catch estimate (Holdsworth 2014, Table 3) was based on data collected by a stratified (summer/winter, weekday/weekend) on-site survey conducted across 75 access points between Rangiputa and Mangawhai Heads in East Northland and 10 949 interviews over the period 1 April 2013 to 31 March 2014 (Holdsworth 2014). A catch estimate for all CRA 1 was generated using scaling factors derived from the 2011–12 NPS survey: the survey area was estimated to have covered 69% of the total CRA 1 recreational fishery. Mean weights were derived from length frequencies collected by the survey during the sampling period.

Table 3: Survey estimates used to model recreational catch for CRA 1.

Survey	Year	Numbers	Mean weight (kg)	Catch weight (t)	CV
NPS: Wynne-Jones et al. 2014	2011	29 739	0.81	23.79	0.30
Holdsworth 2014	2013	50 430	0.78	37.30	0.17
NPS: Wynne-Jones et al. 2019	2017	18 857	0.82	15.50	0.48
NPS: Heinemann & Gray 2024	2022	9 873	0.81	8.00	0.49
Maximum reported s111 landings (t) (in 2006)				5.015	

Table 4: Fishing platform and capture method categories for CRA 1 estimated by the national NPS recreational surveys (Wynne-Jones et al. 2014, 2019, Heinemann and Gray 2024).

Category	2011–12			2017–18			2022–23		
	Catch (t)	CV	% of total	Catch (t)	CV	% of total	Catch (t)	CV	% of total
Capture method									
Hand gather by diving	18.76	0.31	78.8	15.00	0.50	96.7	7.65	0.52	95.6
Pot	4.42	0.90	18.6	0.31	0.69	2.0	0.35	1.01	4.4
Other	0.62	1.03	2.6	0.20	1.00	1.3	-	-	-
Platform									
Trailer boat	18.39	0.37	77.3	12.71	0.59	82.0	6.79	0.57	84.9
Larger motor boat or launch	1.66	0.72	7.0	1.06	0.47	6.8	1.15	0.76	14.4
Off land	3.57	0.63	15.0	1.73	0.41	11.2	0.06	1.01	0.8
Other	0.17	0.80	0.7	-	-	-	-	-	-

A recreational catch time series was initially developed for all of CRA 1 by assuming that recreational catch has been proportional to the CRA 1 SS abundance, as reflected in 1) unstandardised (geometric mean) SS CPUE from Statistical Areas 903 and 904 from 1979 to 2018, and 2) the standardised logbook CPUE rescaled to the geometric mean of the first series from 2019 through to 2024. Statistical Areas 903 and 904 were originally used because the majority of the recreational fishery takes place in these areas, located on the east coast of the North Island (about 70% of the total QMA, Holdsworth 2014). These areas have lower commercial CPUE than the remaining three CRA 1 statistical areas and the CPUE in Area 904 did not show the large increase starting in the late 1990s seen in the other statistical areas. The unstandardised SS CPUE vector was calculated for combined Areas 903 and 904 using data prepared with the F2-LFX algorithm (see Starr 2025). By agreement in the RLWG, the recreational catch vector was based on the three NPS surveys (2011–12, 2017–18 and 2022–23), and the 2013–14 survey. A minimised log likelihood scalar quantity q (Equation 1) is now estimated by obtaining the best fit to these four surveys when minimising a lognormal distribution using the CVs indicated in Table 3.

$$\begin{aligned}
 W_t &= w_t N_t \\
 \hat{W}_y &= \hat{\phi} I_t
 \end{aligned}$$

$$\text{Equation 1} \quad L = \min \left[\sum_{t=1}^T \frac{(\log(W_t) - \log(\hat{W}_t))^2}{2\sigma_t^2} \right]$$

Where t subscripts the four recreational survey estimates in Table 3, w_t is the mean SS weight ($\geq$ MLS) for sampled lobsters in year/survey t for CRA 1, N_t is the mean number of lobsters in year/survey t for CRA 1, I_t is the Statistical Area 903/904 mean SS unstandardised CPUE in year t , W_t is the CRA 1 estimated recreational catch (tonnes) for year t , and ϕ is the estimated scalar parameter relating CPUE with the estimated recreational catch.

The estimated recreational catch trajectory was based on the q estimated in Equation 1, with the following rules:

- apply 20% of the 1979 estimate to 1945 and scale linearly to 1979;
- use the NPS/Holdsworth survey estimates for the respective survey years;
- multiply $q \times$ SS CPUE from 1979–2016 for years without survey estimates;
- apply the mean of the 2017 and 2022 NPS survey estimates to the years after 2017 (except 2022).

This trajectory matched the 2011–12 and 2017–18 NPS surveys, underestimated the 2013–14 observation (Holdsworth 2014) and overestimated the 2022–23 NPS (Figure 12). The q parameter was estimated to be 29 tonnes/CPUE-unit.

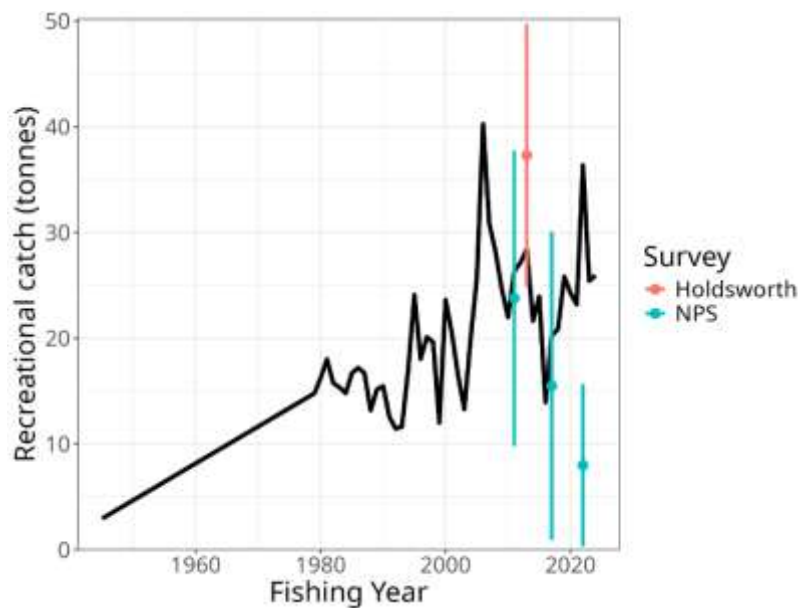


Figure 12: CRA 1 recreational catch trajectory (tonnes) based on the unstandardised (geometric mean) SS seasonal CPUE series for Statistical Areas 903 and 904 (1979–2018) and recent logbook CPUE series (2019–2024) fitted to four recreational catch surveys (Equation 1 and Table 3). Error bars are ± 2 SE, assuming a lognormal distribution.

In addition to the above steps, the RLWG agreed to include the annual recreational landings made by commercial vessels under Section 111 of the Fisheries Act. Greenweight landings with destination code 'F' were extracted from the CRACE database (Bentley et al. 2005) and added to each year. When annual estimates for Section 111 landings were not available, the average Section 111 annual total was added. As well, an estimate of the charter vessel catches was added annually to the total as this catch category was not included in the estimates calculated from the NPS or Holdsworth surveys. The resulting recreational catch vector, when summed from 1945 to 2024, resulted in a total of 1326 tonnes (Figure 13). The seasonal split of recreational catch for CRA 1 was updated from 10% AW and 90% SS used in previous assessments to 30% AW and 70% SS for the 2025 stock assessment based on information from Holdsworth (2014).

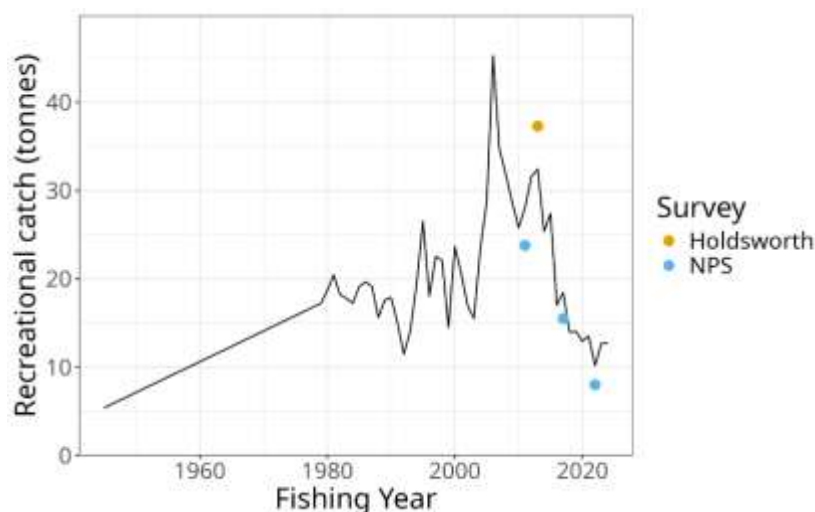


Figure 13: CRA 1 recreational catch series (tonnes) using the average of the 2017–18 and 2022–23 NPS values for years 2018 to 2024, replacing all estimates with the NPS values when available, and adding the annual Section 111 catches and charter catches. Points show the mean estimates for the recreational catch surveys.

2.2.3.3 Customary catch

The 2025 CRA 1 stock assessment used 10 t/year for customary catch, with 70% assumed to have been taken in the SS and the balance in the AW. The total customary catch was the same as used for the 2019 stock assessment, but the seasonal split was updated to match that of the recreational catch for the 2025 assessment.

2.2.3.4 Illegal catch

Recent red rock lobster stock assessments have opted to use a fixed percentage of the total commercial catch before 1990 when rock lobsters were brought into the QMS (usually in the 10% to 20% range), which was then dropped to a lower level in 1990 in recognition of the impact of the introduction to the QMS, as greater control over the sale and receipt of lobsters was introduced once they became a tradeable asset. In line with these decisions and recognising the lack of information that can be used to estimate this catch category, the RLWG chose to set the CRA 1 illegal catch to 20% of the commercial catch in each year prior to 1990 and 10% of the commercial catch in each year from 1990 onwards. This resulted in notably lower assumed illegal catches since the 1990s (Figure 11) compared to those assumed for the 2019 CRA 1 stock assessment, but which the RLWG agreed was more realistic for CRA 1. Illegal catches by year were split between seasons using the same seasonal catch split as reported by the commercial fishery in the same year.

2.2.3.5 Generating a Far North catch data set

Fisheries New Zealand requested a CRA 1 stock assessment that excluded the information from the two statistical area areas on the east coast of CRA 1 (903 and 904). This request was made because CRAMAC 1 fishers voluntarily agreed in October 2024 that no red rock lobster would be taken from areas 903, 904 and the part of area 905 that is in CRA 1, for a five-year period starting on 1 April 2025 (Figure 1). Dropping this information beginning in 1979 was relatively straightforward because catches and associated effort data are reported consistently by statistical area from the FSU, CELR, and ERS catch reporting systems. The RLWG agreed to assume that 90% of the CRA 1 recreational and customary catches originated from Statistical Areas 903 and 904 because it was known that most of the effort from these two fisheries was located in these statistical areas. The RLWG also agreed to apply the 20% and 10% assumed pre- and post-1989 proportions to the Far North commercial catches to split out the illegal catches spatially and seasonally, for the retained Statistical Areas 939, 901, and 902.

The CRA 1 Far North commercial catches were estimated as follows:

- Area 2 as defined by Annala & King (1983) was almost a perfect spatial match with the combined Areas 903 and 904; consequently, the Far North commercial catches from the 1962 SS season to the 1973 AW season could be directly calculated for this period, including the seasonal split;
- the 1963–1967 Annala & King average Far North catch proportions were applied to the 1945–1962 Marine Department annual port of landing estimates; the 1963–1967 Annala & King average Far North seasonal split proportions were then applied to separate the 1945–1962 Marine Department Far North annual catches seasonally;
- the 1969–1973 Annala & King average Far North catch proportions were applied to the 1974–1978 Annala & Easterman (1986) annual catch estimates; the 1972–1973 Annala & King average Far North seasonal split proportions were applied to separate the 1974–1978 Annala & Easterman (1986) Far North catches seasonally;
- the 1986–1987 QMR catches are only available as annual catches for all of NZ; the 1979–1988 FSU proportions with and without Areas 903 and 904 were used to split the CRA 1 catches spatially and seasonally;
- Far North commercial catches beginning in 1988 were estimated by applying the spatial proportion of catch without 903/904 estimated from the relevant FSU, CELR, ERS data set to the seasonally split QMR/MHR data.

Table 5 compares the catches included in each model (total CRA 1 and Far North) for the two-time blocks (1945–1978 and 1979–2024) considered in the assessment models, with the time series of catches by fishery sector plotted in Figure 14.

Table 5: Summary of catch totals with and without Areas 903 and 904 by catch sector and time block.

	All of CRA 1			Far North (exclude Areas 903/904)		
	1945–1978	1979–2024	1945–2024	1945–1978	1979–2024	1945–2024
Commercial	4 427	6 481	10 909	2 396	4 908	7 304
Recreational	379	948	1 326	38	95	133
Illegal	885	860	1 745	479	642	1 121
Customary	340	460	800	34	46	80
Total	6 031	8 749	14 780	2 947	5 691	8 637

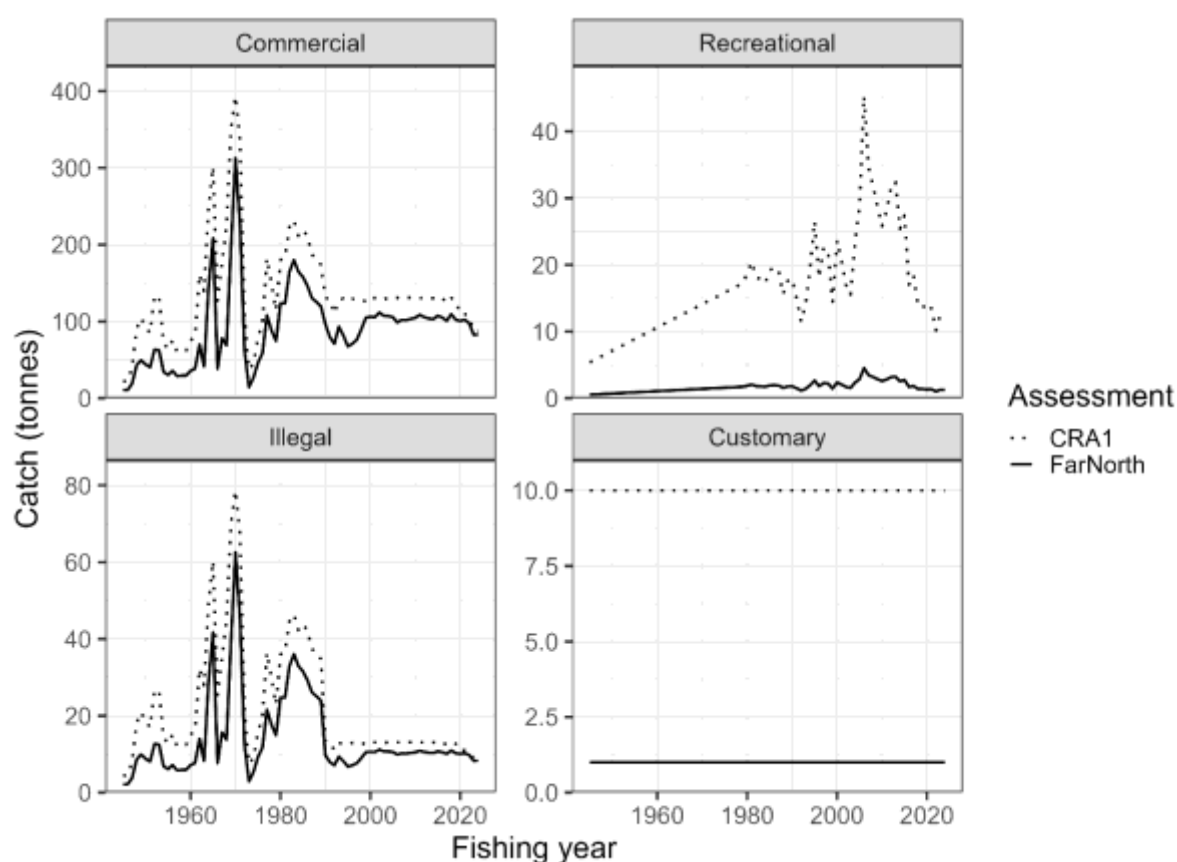


Figure 14: Comparison of commercial, recreational, illegal, and customary catches with (CRA 1) and without (Far North) the presence of the Area 903 and 904 catches.

3 STOCK ASSESSMENT

The previous stock assessment of CRA 1 (2019, Rudd et al. 2021b) used the lobster stock dynamics (LSD) model (Webber et al. 2023). The LSD model was coded in Stan (Stan Development Team 2016, 2017) and had been used as the main assessment software for all recently assessed rock lobster stocks in New Zealand, including CRA 2 (2017, Webber et al. 2018, 2022 Rudd et al. 2023), CRA 6 (2018, Rudd et al. 2019, 2023 Rudd et al. 2024), CRA 3 (2019 Webber et al. 2020, 2024 Roberts et al. 2025), CRA 4 (2020 Rudd et al. 2021a, 2024 Rudd et al. 2025), CRA 5 (2020, Webber et al. 2021), and CRA 7&8 (2021, Webber et al. 2022).

A new model, *decamod*, written in RTMB, was used for this 2025 stock assessment. A key difference between LSD and *decamod* is the switch from three sexes (males, immature females, and mature

females) to two sexes (males and females). Because of this change, the maturation and proportion berried processes needed to be treated differently between the two model structures, which are now estimated outside of the model structure.

This report presents the Far North model run starting in 1945 as the CRA 1 stock assessment, with two models representing all of CRA 1 and another Far North model starting in 1979. Maximum likelihood estimation (MLE) and Markov chain Monte Carlo (MCMC) simulations were used to make inferences about the CRA 1 stock. MLE runs were used to develop a base case model and then a series of MLE runs were used to explore the sensitivity of model outputs to changes in model structure and inputs. Full Bayesian inference using MCMC was then completed for the base case and suite of sensitivity runs. The posterior distribution of the base case model was used to derive the CRA 1 reference level (Rudd et al. 2021c). Finally, the posterior distributions from the base case were used to project the model forward five years to provide management advice.

The 2025 stock assessment model settings are described in Section 3.1 and model parameters and priors are defined in Section 3.2. Bridging analyses between the previous stock assessment model LSD and the new model *decamod* are in Section 3.4. Finally, the stock assessment outputs including stock status indicators are presented in Section 3.5.

3.1 Model

The *decamod* model was new for the 2025 stock assessment. The *decamod* model tracks numbers of individual lobsters in two sex categories (males and females) for each of 36 two-mm TW bins, by year, and season. Size bins ranged from 30 mm TW to the 100 mm TW plus group.

As with the previous 2019 CRA 1 stock assessment model, the first model year was set to 1945, the first year of the commercial fishery, assuming equilibrium population structure with an initial exploitation rate (U_0) fixed to 0.0. The last year in the reconstruction of the stock was 2024, but this was extended to 2030 for the projections. All catches were split into the AW and SS seasons. All model years were fishing years which extended from 1 April to 31 March. The model used two six-month seasons within a model year: AW (April to September) and SS (October to March).

The 2025 stock assessment initially treated CRA 1 as a single homogenous area, as was done in the previous assessment for this stock in 2019 (Rudd et al. 2021b). In 2019, a multi-region stock assessment was explored, but was not completed due to the lack of comprehensive and recent data in Statistical Areas 903 and 904 and given the conclusions drawn by an exploration of evidence for regional separation in CRA 1 (see Appendix C of Starr et al. 2020). This exploration was not repeated in 2025, as instead a primary Far North assessment (which excluded catch histories, CPUE, proportion male, and length composition data from areas 903 and 904) and a secondary all of CRA 1 assessment were undertaken, as in 2019.

New recruits to the model were added equally for each sex and for each season as a normal distribution with a mean size of 32 mm and standard deviation of 2 mm, truncated at the smallest size class (30 mm; Figure 8). Recruitment in a specific year was determined by the mean recruitment parameter (R_0) and the estimated annual deviations from mean recruitment. The vector of recruitment deviations in log space was assumed to be normally distributed with a mean of zero and standard deviation of 0.4. Recruitment deviations were estimated as random effects from 1945–2020. Recruitments in the final four years were constrained using an order 1 autoregressive (AR1) model, where the AR1 parameter was derived using the period 1980–2020. This was an update from previous LSD stock assessment models which fixed the final four years to be the same as the final estimated recruitment deviate, or rewrote the final four recruitments in the projections.

For each sex category, a growth transition matrix specified the probability of an individual remaining in the same size class or transitioning to another size class. Previous rock lobster stock assessments

using LSD modelled immature and mature females separately, and the maturation of females was estimated as a two-parameter logistic curve. The 2025 stock assessment modelled all females combined. Female maturity and the incidence of berried females were modelled separately outside of the stock assessment model and were specified by a function which predicted the maturity and proportion berried by length bin. All tag-recapture events were included, except those where time at liberty was less than six months or where the observed growth increment was less than -10 mm TW. The growth parameter *Galpha* was estimated at 50 mm TW for the 2019 assessment, but was moved to 30 mm TW for the 2025 assessment to better fit to growth increment data, especially for smaller lobsters.

A logistic selectivity ogive was used to define the size composition of the Size Limited (SL) fishery catch (i.e., the commercial and recreational catch), which was assumed to be sex-specific and time-invariant. The *selmax* parameters defined the relative scaling (i.e., the height) of the selectivity curves by sex and season. These parameters by sex and season were estimated relative to males in the AW and were allowed to be estimated to be relatively lower (below 1.0) or higher (above 1.0) than the AW males. The only differences in the structure of estimating selectivity and vulnerability between this assessment and the 2019 stock assessment were 1) that selectivities were estimated for two sexes instead of three sexes, 2) the *selmax* parameters were constrained to be below 1.0 (lower than AW males) in the previous assessment, and 3) the previous assessment assumed a double-normal selectivity function with a fixed right-hand limb to 250 to preclude a descending limb.

Retention was defined as the probability of retaining an individual lobster by year, season, sex, and size class. For CRA 1, this included legal status rules (MLS and the proportion of mature females in berry) but did not include any other forms of retention, such as high-grading.

Natural, fishing, and handling mortalities were applied to each sex category in each size class. Natural mortality was assumed to vary by length but was sex and time invariant. Natural mortality assumed a declining function with length with a fixed shape parameter of -1.0. Catch was removed from the population by using discrete exploitation rates, instead of instantaneous fishing mortality rates as was done in the 2019 CRA 1 stock assessments and all rock lobster stock assessments prior to 2022. Exploitation rates were determined from observed catch and model biomass, modified by selectivity, vulnerability, legal status (e.g. MLS, proportion berried females) for the SL fishery, while only selectivity and vulnerability were needed to define exploitation rates for the NSL fishery. The NSL fishery used the estimated SL selectivity function to extract its catch. Annual seasonal proportions of males in the catch were fitted assuming a logit-normal distribution instead of a multinomial distribution. It was determined from the logbook data that discarding of legal lobsters was infrequent in CRA 1, making it unnecessary to model this process.

Model parameters were estimated by the *decamod* model using penalised maximum likelihood. Bayesian inference was used to estimate parameter uncertainty. Samples from the posterior were generated with MCMC simulations using the Hamiltonian Monte Carlo (HMC) algorithm. Estimated parameter descriptions are provided in Table 6 and priors and bounds are provided in Table 7. Fixed parameters and their values are given in Table 1 (also see the maturity and proportion berried ogives shown in Figure 9 and Figure 10).

3.2 Parameters and priors

Estimated model parameters included productivity parameters (i.e., average recruitment, natural mortality, and growth), and fishery parameters (i.e., catchability, selectivity, and vulnerability). All model parameters and their associated priors are listed in Table 6 and Table 7.

Table 6: Parameter definitions for the CRA 1 Far North model.

Type	Number	Description
M_a	1	Natural mortality estimated at 60 mm TW
R_0	1	Unfished equilibrium recruitment (numbers)

<i>galpha</i>	1	Male growth increment estimated at 30 mm TW
	2	Female growth increment estimated at 30 mm TW
<i>gdiff</i>	1	Male growth increment ratio from 80 mm TW to male galpha
	2	Female growth increment ratio from 80 mm TW to female galpha
<i>gshape</i>	1	Shape parameter for the male growth model
	2	Shape parameter for the female growth model
<i>gcv</i>	1	CV of male growth model
	2	CV of female growth model
<i>gobs</i>	1	Observation error for the growth model (shared across sexes)
<i>q</i>	1	Catchability coefficient for the CR series
	2	Catchability coefficient for the FSU series
	3	Catchability coefficient for the CELR series
	4	Catchability coefficient for the logbook series
<i>sel50</i>	1	Length at 50% selectivity (males)
	2	Length at 50% selectivity (females)
<i>sel95</i>	1	Difference in length at 95% selectivity from 50% (males)
	2	Difference in length at 95% selectivity from 50% (females)
<i>selmax</i>	1	Maximum selectivity (vulnerability) for females in AW relative to males in AW
	2	Maximum selectivity (vulnerability) for males in SS relative to males in AW
	3	Maximum selectivity (vulnerability) for females in SS relative to males in AW

Table 7: Specifications for estimated parameters including the upper and lower bounds, prior type, and prior parameters.

Variant	Parameter	Lower bound	Upper bound	Prior type	Prior mean	Prior std/CV
–	$\log_{R_0}$	1.000	25.000	normal	10	1.50
–	$\log_{M_a}$	$\log(0.01)$	$\log(0.35)$	normal	$\log(0.12)$	0.40
Biomass (CR, FSU, CELR)	$\log_q$	-25.000	1.000	normal	-5	2
Numbers (Logbook)	$\log_q$	-25.000	1.000	normal	-10	2
–	$\log_{galpha}$	$\log(0)$	$\log(30)$	normal	1	1
–	$\logit_{gdiff}$	-Inf	Inf	normal	-2	1.50
–	$\log_{gshape}$	$\log(0.1)$	$\log(10)$	normal	$\log(1)$	0.60
Male	$\log_{gcv}$	$\log(0.01)$	$\log(2)$	normal	$\log(0.59)$	0.44
Female	$\log_{gcv}$	$\log(0.01)$	$\log(2)$	normal	$\log(0.82)$	0.34
–	$\log_{gobs}$	$\log(1e-5)$	$\log(5)$	normal	$\log(1.48)$	0.05
–	$\log_{sel50}$	$\log(30)$	$\log(80)$	normal	$\log(50)$	0.50
–	$\log_{sel95}$	$\log(1)$	$\log(50)$	normal	$\log(10)$	1.12
–	$\log_{selmax}$	$\log(0.01)$	$\log(2)$	normal	$\log(1)$	1.00
–	$Rdev_{yr}$	-2.300	2.300	uniform	–	–

3.3 Assessment indicators

This assessment used the same indicators that were used in the 2019 CRA 1 assessment as well as indicators related to Total Biomass and a wider range of probabilities (Table 8, Table 9). The main indicators were related to the relative estimates of AW adjusted vulnerable biomass, SSB, and total biomass. AW adjusted vulnerable biomass was compared with the reference level (B_R), and the current and projected exploitation rate was compared with the fixed exploitation rate that would reach the reference level at equilibrium (U_R). Probabilities were calculated to determine whether each of the biomass indicators would fall below current levels, the reference level (in terms of vulnerable biomass) and the soft and hard limits (in terms of SSB) in the current year and after projecting the current catch forward for five years (Section 3.5.5). Probabilities were calculated over all samples of the posterior distribution.

Table 8: Assessment indicators and reference points.

Type	Description
B_0	Equilibrium AW adjusted vulnerable biomass before fishing
SSB_0	Equilibrium female spawning stock biomass before fishing
T_0	Equilibrium total biomass before fishing
B_{MIN}	The lowest beginning AW adjusted vulnerable biomass in the series
B_{2025}	Beginning of season AW adjusted vulnerable biomass for 2025
B_{2030}	Beginning of season AW adjusted vulnerable biomass for 2030
SSB_{2025}	Beginning of season spawning stock biomass for 2025
SSB_{2030}	Beginning of season spawning stock biomass for 2030
T_{2025}	Beginning of season total biomass for 2025
T_{2030}	Beginning of season total biomass for 2030
U_{2024}	Annual exploitation rate (approximated by the weighted average across seasons) for the final model year 2024
U_{2029}	Annual exploitation rate (approximated by the weighted average across seasons) for the final projection year 2029
H_{2024}	Annual handling mortality for the final model year 2024
H_{2029}	Annual handling mortality for the final projection year 2029
B_R	Average AW vulnerable biomass between projected fixed catch and fixed U rules that maximise catch while meeting risk constraints
U_R	Annual exploitation rate associated with B_R at equilibrium, weighted across seasons by seasonal vulnerable biomass

Table 9: Performance indicators and stock status probabilities.

Type	Description
Performance indicators	
B_{2025}/B_0	Ratio of B_{2025} to B_0
B_{2030}/B_0	Ratio of B_{2030} to B_0
B_{2030}/B_{2025}	Ratio of B_{2030} to B_{2025}
SSB_{2025}/SSB_0	Ratio of SSB_{2025} to SSB_0
SSB_{2030}/SSB_0	Ratio of SSB_{2030} to SSB_0
SSB_{2030}/SSB_{2025}	Ratio of SSB_{2030} to SSB_{2025}
T_{2025}/T_0	Ratio of T_{2025} to T_0
T_{2030}/T_0	Ratio of T_{2030} to T_0
T_{2030}/T_{2025}	Ratio of T_{2030} to T_{2025}
B_{2025}/B_R	Ratio of B_{2025} to B_R
B_{2030}/B_R	Ratio of B_{2030} to B_R
U_{2024}/U_R	Ratio of U_{2024} to U_R
U_{2029}/U_R	Ratio of U_{2029} to U_R
U_{2029}/U_{2024}	Ratio of U_{2029} to U_{2024}
Probabilities	
$P(B_{2025} > B_{MIN})$	Probability B_{2025} is greater than B_{MIN}
$P(SSB_{2025} > 20\% SSB_0)$	Probability SSB_{2025} is greater than 20% SSB_0
$P(SSB_{2025} > 10\% SSB_0)$	Probability SSB_{2025} is greater than 10% SSB_0
$P(SSB_{2030} > 20\% SSB_0)$	Probability SSB_{2030} is greater than 20% SSB_0
$P(SSB_{2030} > 10\% SSB_0)$	Probability SSB_{2030} is greater than 10% SSB_0
$P(B_{2030} > B_{2025})$	Probability B_{2030} is greater than B_{2025}
$P(SSB_{2030} > SSB_{2025})$	Probability SSB_{2030} is greater than SSB_{2025}
$P(T_{2030} > T_{2025})$	Probability T_{2030} is greater than T_{2025}
$P(B_{2025} > B_R)$	Probability B_{2025} is greater than B_R
$P(B_{2030} > B_R)$	Probability B_{2030} is greater than B_R
$P(U_{2024} > U_R)$	Probability U_{2024} is greater than U_R
$P(U_{2029} > U_R)$	Probability U_{2029} is greater than U_R

3.4 Bridging analysis

3.4.1 Model updates: matching new model with previous model

The goal of this section is to compare the new model *decamod* with the previous model LSD in two steps: 1) check that *decamod* can produce nearly identical results to the 2024 rapid update⁸ run with LSD with fixed parameter values, and 2) check how close *decamod* comes to the 2024 rapid update with estimated parameters. Data used in this section are the same as the data used in the 2024 rapid update. The models run in this section have final model year 2023. This section compares the 2024 rapid update with two models:

1. *fixed par*: using the *decamod* model, mimicking model structure of the 2024 rapid update as closely as possible, with all parameters fixed at the 2024 rapid update values,
2. *est 2024*: using the *decamod* model, mimicking model structure of the 2024 rapid update as closely as possible, assuming length-varying proportion in berry, and estimate all model parameters.

The *decamod* model could reproduce the 2024 rapid update very well when parameters were fixed to the same values as the LSD 2024 rapid update estimates (Figure 15, Figure 16). Recruitment deviates matched perfectly, because the values were fixed the same and there was no difference in model structure (Figure 15). The difference in 1945 initial numbers (Figure 16) was directly related to the difference between one season assumed in 1945 using LSD (2024 rapid update) and two-season dynamics used in 1945 in *decamod* (*fixed par*). Equilibrium numbers were calculated outside the model using one or two seasons. The initial 1945 numbers matched perfectly when the seasons matched between models. Therefore, the differences in initial numbers (Figure 16) were due to deriving the equilibrium numbers using one season in LSD and two seasons in *decamod*. Small differences in AW adjusted vulnerable biomass between the 2024 rapid update and fixed parameter *decamod* run are likely to be also due to small structural differences such as one versus two seasons prior to 1979, and switching from a three-sex to two-sex model structure (Figure 17).

Including length-varying proportion in berry estimates improved the ability of *decamod* with two sexes to match the previous model LSD with three sexes when parameters were estimated. This accounted for the fact that in the previous model, immature females which were above the MLS would have been retained. In the two-sex model, the length-varying proportion in berry is needed to account for immature females above the MLS. This was examined in greater detail for the 2025 CRA 2 stock assessment (Rudd et al. 2026) and applied during initial model runs for CRA 1.

The only notable difference in parameter estimates between *decamod* estimates, running with TMB, and the model with fixed parameters is larger *Galpha*, particularly for females (Table 10, Figure 18). This was also observed, to a greater degree, in the 2025 CRA 2 assessment (Rudd et al. 2026). The *Galpha* estimates for CRA 1 were still considered to be credible, so *Galpha* parameters were estimated (as opposed to being fixed in the CRA 2 assessment).

3.4.2 Updated datasets and model settings

This section updated the *decamod* model for CRA 1 with updated data series and model settings for the 2025 assessment. Starting with *decamod est 2024*, using all data series from the 2024 rapid update, model settings and data series were brought in one at a time to work up to a new base model for 2025:

⁸ In 2024 the CRA1 rapid update was run and presented to the RLWG but it was decided not to published it because there was no new information on CPUE data. See Pons, M.; Webber, D.N.; Rudd, M.B.; Roberts, J.; Starr, P.J. (2024). Rapid Updates for CRA1 and CRA5. RLWG 2024-071. 51 p. (Unpublished document held by Fisheries New Zealand, Wellington, NZ).

1. *updated settings*: same data as the 2024 rapid update (final model year 2023), calculated discrete exploitation rates instead of instantaneous fishing mortality rates, removed a bias adjustment on recruitment deviates, and included time-invariant proportion mature appropriate for a two-sex model,
2. *catches*: catch assumptions for the 2025 stock assessment, keeping the final model year 2023,
3. *tags*: exclude proportion at liberty less than six month and growth increments less than -10 mm TW, keeping the final model year 2023,
4. *sex ratio*: include updated sex ratios as a result of standardisation models, keeping the final model year 2023,
5. *LF*: include updated length frequencies as a result of standardisation models, keeping the final model year 2023,
6. *est_2025*: full series for the 2025 assessment, including updated CPUE series and all other data series through to final model year 2024. Selectivity was simplified to account for the change to a two-sex model, combining immature and mature female vulnerabilities.

Results for steps 1–5 were not shown in the following figures and tables, because they did not result in significant changes from the *decamod* model that estimated parameters using data and model settings from the 2024 rapid update (*decamod est 2024*). Recruitment using model settings and data for the 2025 assessment resulted in slightly lower R_0 and smaller recruitment deviates since the 1980s (Figure 15, Table 10). Initial numbers in 1945 using *decamod* with 2025 data and model settings were very similar to initial numbers from the 2024 rapid update (Figure 16). The AW adjusted vulnerable biomass trajectory using *decamod* with 2025 data and model settings was very similar to the 2024 rapid update, except for lower vulnerable biomass in the early years (Figure 17). This could be due to faster growth of small females estimated by *decamod* (Figure 18) as well as updated data series, particularly CPUE.

Table 10: Parameter comparison for 2024 rapid update estimates (*decamod fixed par*) and including length-varying proportion in berry while estimating all parameters (*decamod est par*). Note: *selmax* has five parameters to mimic the vulnerabilities estimated in the three-sex model used in the rapid update.

Parameter	Number	<i>decamod fixed par</i>	<i>decamod est 2024</i>	<i>decamod est 2025</i>
<i>Ma</i>	1	0.107	0.103	0.112
R_0	1	237 000	215 187	20 6389
<i>galpha</i>	1	16.552	17.275	18.480
<i>galpha</i>	2	18.255	22.858	23.383
<i>gcv</i>	1	0.390	0.357	0.378
<i>gcv</i>	2	0.754	0.668	0.667
<i>gdiff</i>	1	0.158	0.148	0.128
<i>gdiff</i>	2	0.068	0.048	0.051
<i>gobs</i>	1	0.670	1.203	1.488
<i>gshape</i>	1	3.180	3.413	4.007
<i>gshape</i>	2	5.263	6.997	7.572
<i>sel50</i>	1	64.998	66.274	52.391
<i>sel50</i>	2	72.595	70.222	49.216
<i>sel95</i>	1	11.125	11.452	10.911
<i>sel95</i>	2	16.386	14.033	10.942
<i>selmax</i>	1	0.868	0.727	0.543
<i>selmax</i>	2	0.514	1.377	0.830
<i>selmax</i>	3	0.514	0.439	0.824
<i>selmax</i>	4	0.736	0.860	
<i>selmax</i>	5	0.608	0.751	

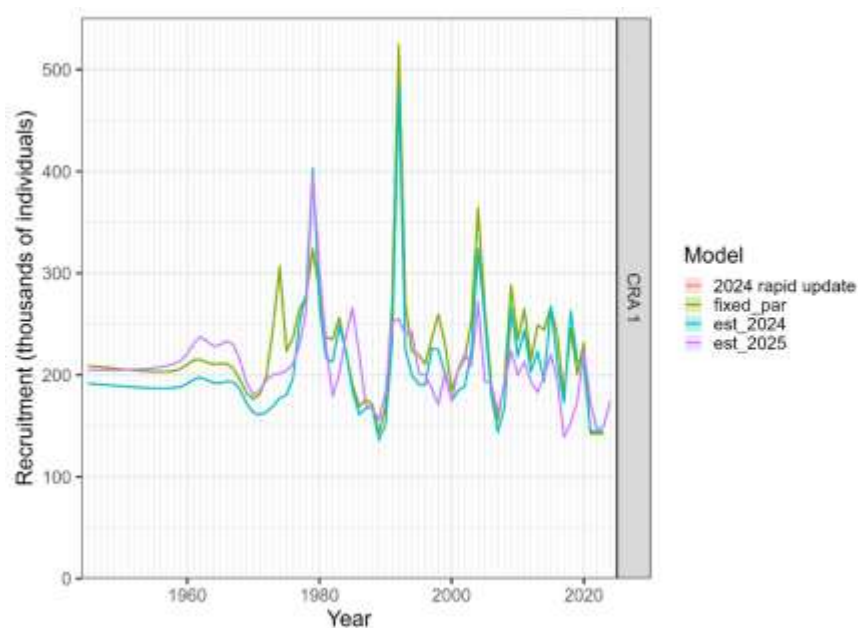


Figure 15: Comparison of annual recruitment deviates: 2024 rapid update vs. decamod with fixed parameters (*fixed_par*), estimated parameters (*est_2024*), and with data through to 2024 (*est_2025*).

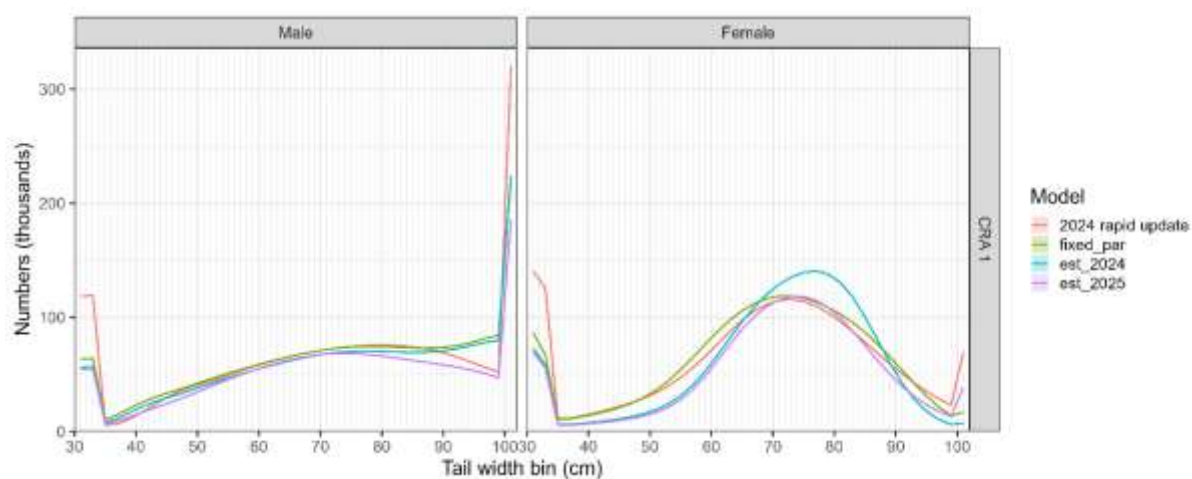


Figure 16: Comparison of initial numbers (1945): 2024 rapid update vs. decamod with fixed parameters (*fixed_par*), estimated parameters (*est_2024*), and with data through 2024 (*est_2025*).

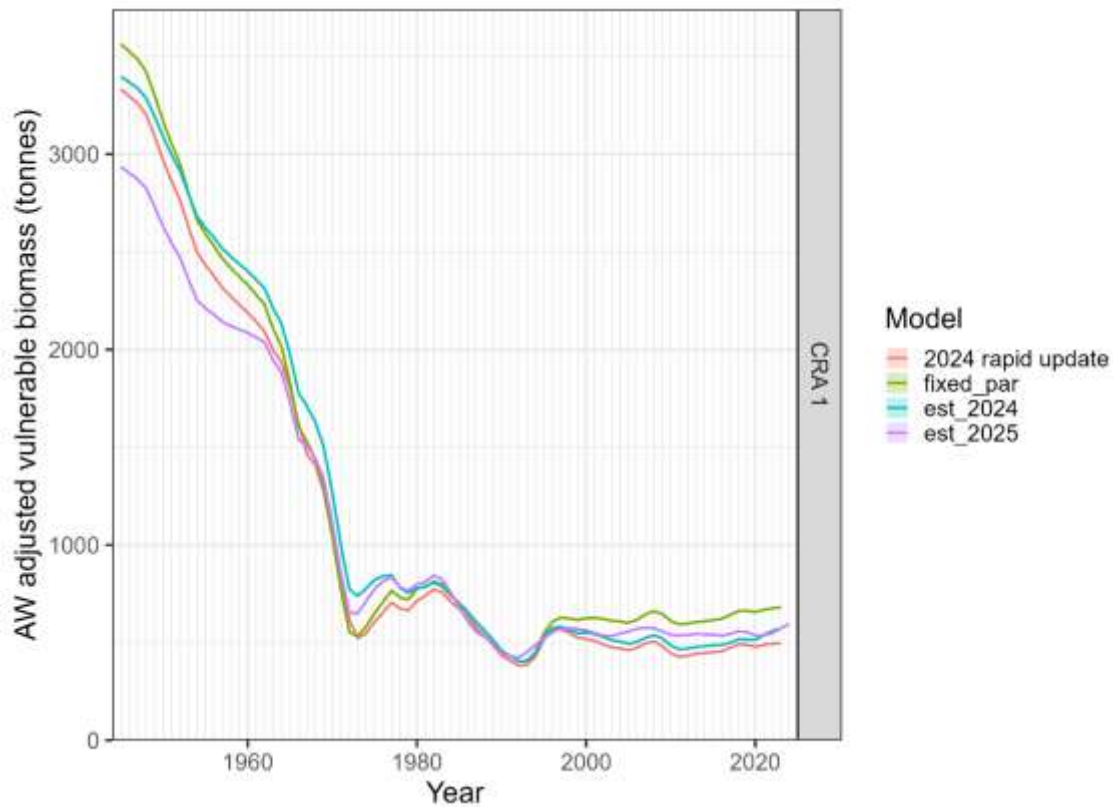


Figure 17: Comparison of AW adjusted vulnerable biomass: 2024 rapid update vs. decamod with fixed parameters (*fixed_par*), estimated parameters (*est_2024*), and with data through to 2024 (*est_2025*).

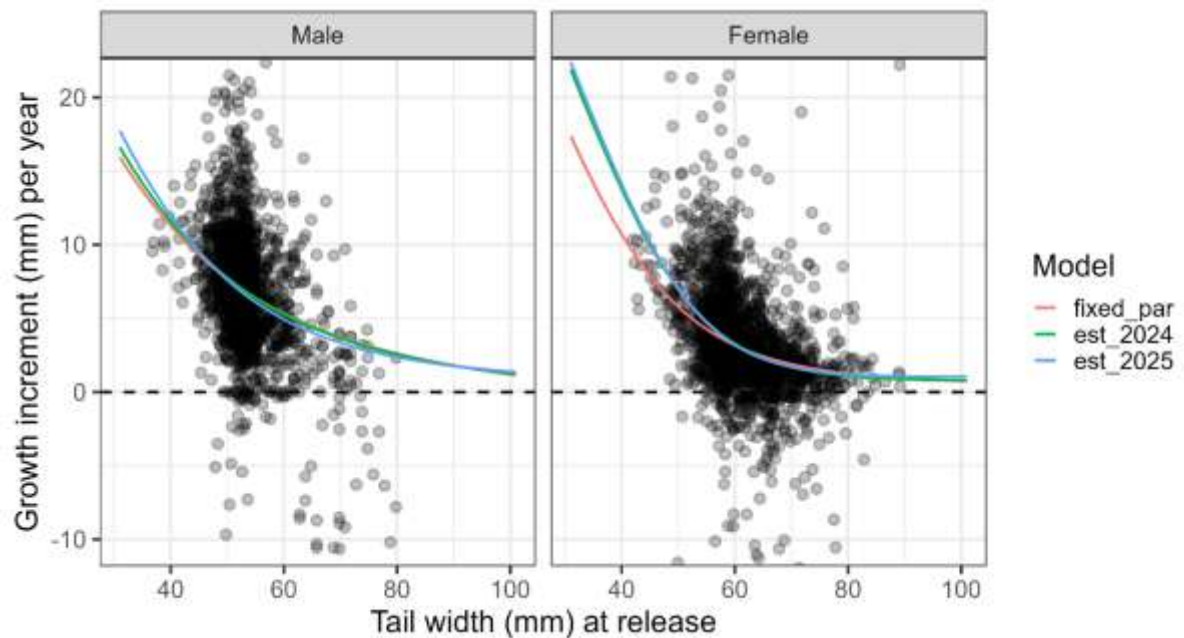


Figure 18: Comparison of estimated annual growth increment (mm) by sex: decamod with fixed parameters, decamod with estimated parameters, and with data through 2024 (*est_2025*).

3.5 Base case

3.5.1 Developing a base case

Bridging analyses and exploratory model runs were done in order to develop a new base case stock assessment model. The following is an abbreviated sequence of steps that led to the CRA 1 base case:

1. Comparison of 2024 rapid update (LSD) and *decamod* with fixed and estimated parameters identified impacts of model structural and estimation differences (Section 3.4.1),
2. Updated data sets for the 2025 assessment, through to fishing year 2024–25. This included updated standardised data and covariates (Section 3.4.2),
3. Recruitment deviates modelled as a random effect, assuming AR1 for the final four model years. This is an update from recent assessments, which estimated recruitment deviates as a random effect until three years prior to the final model year, leaving the final year constant but rewriting them with projected recruitment deviates to determine derived quantities in the current year. Assuming an AR1 process for the final four model years, based on standard deviation and autocorrelation throughout the time series, allows for the estimation of recent recruitment within the stock assessment model with AR1 model constraints,
4. Catchability creep fixed to 1% for all CPUE series, following reviewer comments from the previous stock assessment,
5. Length-based M shared across sexes, following reviewer suggestions from recent assessments and an improved ability to fit to key time series (e.g. sex ratios and length frequency),
6. Exclude tags at liberty less than 6 months and increments less than -10 mm,
7. Calculate discrete exploitation rates (U) instead of instantaneous fishing mortality rates (F),
8. New CELR series (adds one season to previous 2019 stock assessment) and logbook CPUE series (2015–2024),
9. Use standardised LFs, proportion male, and proportion in berry,
10. Proportion male fitted assuming logit-normal distribution (multinomial in the past),
11. Time-invariant selectivity,
12. Exclude Statistical Areas 903 and 904 for a primary Far North model, keeping the full CRA 1 stock as a sensitivity trial.

3.5.2 Base case description

In summary, the base case model (Far North region only) dimensions and structural choices include:

- **Years:** 1945 to 2024, assuming equilibrium, unfished conditions in the first year,
- **Seasons:** two six-month seasons AW (April to September) and SS (October to March) during each fishing year,
- **Sex categories:** males and females,
- **Tail width bins:** 36 two-mm bins with midpoints from 31 mm to 101 mm tail width (last bin was a “plus group” or accumulator bin),
- **Regions:** a single region including Statistical Areas 901, 902, and 939. Statistical Areas 903 and 904 were excluded for the primary Far North run but included for the secondary model including all of CRA 1,
- **Recruitment:** annual recruitment determined by the mean recruitment parameter (R_0) and the estimated annual deviations from mean recruitment without modification by a stock-recruitment function. The vector of recruitment deviations in log space was assumed to be normally distributed with a mean of zero and standard deviation 0.4. Recruitment deviations were estimated for 1945 to 2020. The 2021 to 2024 recruitment deviations were estimated from an autoregression AR1 function, estimated over the period 1980 to 2020,
- **Growth:** sex-specific using the Schnute-Francis growth model. To address confounding between growth of small individuals and natural mortality, the *Galpha* parameter was set at 30 mm TW and estimated. No density-dependent growth was modelled. Included only CRA 1

tag release/recovery pairs, excluding all recaptures that were at liberty less than 6 months or had observed growth increments less than -10 mm TW,

- **Maturity:** Maturity and the incidence of berried females were modelled separately from the stock assessment model and included in the model as fixed parameters. The maturity ogive was assumed constant over time, and the proportion of berried females varied by season but was constant across years,
- **Natural mortality:** Natural mortality was assumed to be independent of sex but varying with length. The M_a parameter was estimated at 60 mm TW. The shape parameter of the length-varying mortality function was fixed to -1 (Lorenzen 2022),
- **Selectivity:** logistic, sex-specific, and time-invariant. Selectivity height (vulnerability) was assumed to be one for males in the AW season, and estimated relative to this for males in the SS and females in both seasons; these estimated relative vulnerabilities were not capped at one,
- **Handling mortality:** two periods: 1945 to 1989 fixed at 0.1 and 1990 to 2029 fixed at 0.05,
- **Catch:** fixed values from 1979 to 2024 using updated assumptions on commercial, illegal, recreational, and customary catches (Section 2.2.3). Removed using discrete exploitation rates,
- **Abundance indices:** four CPUE series (CR, FSU, CELR, LB), each with a separate catchability coefficient (q). Assumed a fixed q_{creep} at 1% per year for all CPUE series to account for improvement in catchability due to learning,
- **Likelihoods:**
 - CPUE series: Lognormal
 - Tags: Robust-normal
 - LFs: Multinomial
 - Sex ratios: Logit-normal
- **Data weighting:** determined iteratively and simultaneously for all data types. The LFs were weighted following the method of Francis (method TA, Francis 2011) and the other data types were weighted aiming for a standard deviation of the normalised residual (SDNR) of 1.0. No re-weighting of tag data because they are self-weighting through the estimation of an observation error parameter.

3.5.3 Model fits, diagnostics, and parameter estimates

The catch was removed without invoking the catch penalty. There were no divergent transitions after the warmup phase of the MCMC (Figure D.1). All parameters had effective sample size well above 400 with Rhat all below 1.01 (Figure D.2). MCMC trace plots indicated that MCMC chains were well-mixed and all effective sample size statistics were acceptable (Figure D.3, Figure D.4). The traces for key estimated biological parameters, such as M and R_0 , showed an acceptable level of stability, with MCMC chains staying away from parameter bounds (Figure D.3, Figure D.4). The posterior distributions for most model parameters updated the priors (Figure D.5, Figure D.6, Figure D.7, Figure D.8, Figure D.9). The likelihoods, the standard deviations of the normalised residuals (SDNRs), and parameter estimates were inspected, as were the derived parameters and probabilities, including projections, for the Far North model and were found to be acceptable.

Fits to the CPUE index series were very good (Figure 19; Figure D.10). The Far North model fit to the sex ratio data was good, except for a series of negative residuals in the SS season in the 2000s (Figure 20; Figure D.11). Model fits to the LF data were good (Figure D.12). There was some structure in the one step ahead (OSA) LF residuals (Figure D.13), particularly in the AW, but the majority of the residuals were within the -2 to 2 range (Figure D.14, Figure D.15).

Estimates of growth parameters and M were estimated at reasonable values (Table 11, Figure 21), although growth for small females was estimated to be higher than by previous assessments (Section 3.4.2). Natural mortality was assumed to be length-varying, with a median M_a at 60 mm TW of 0.176 (Figure 22).

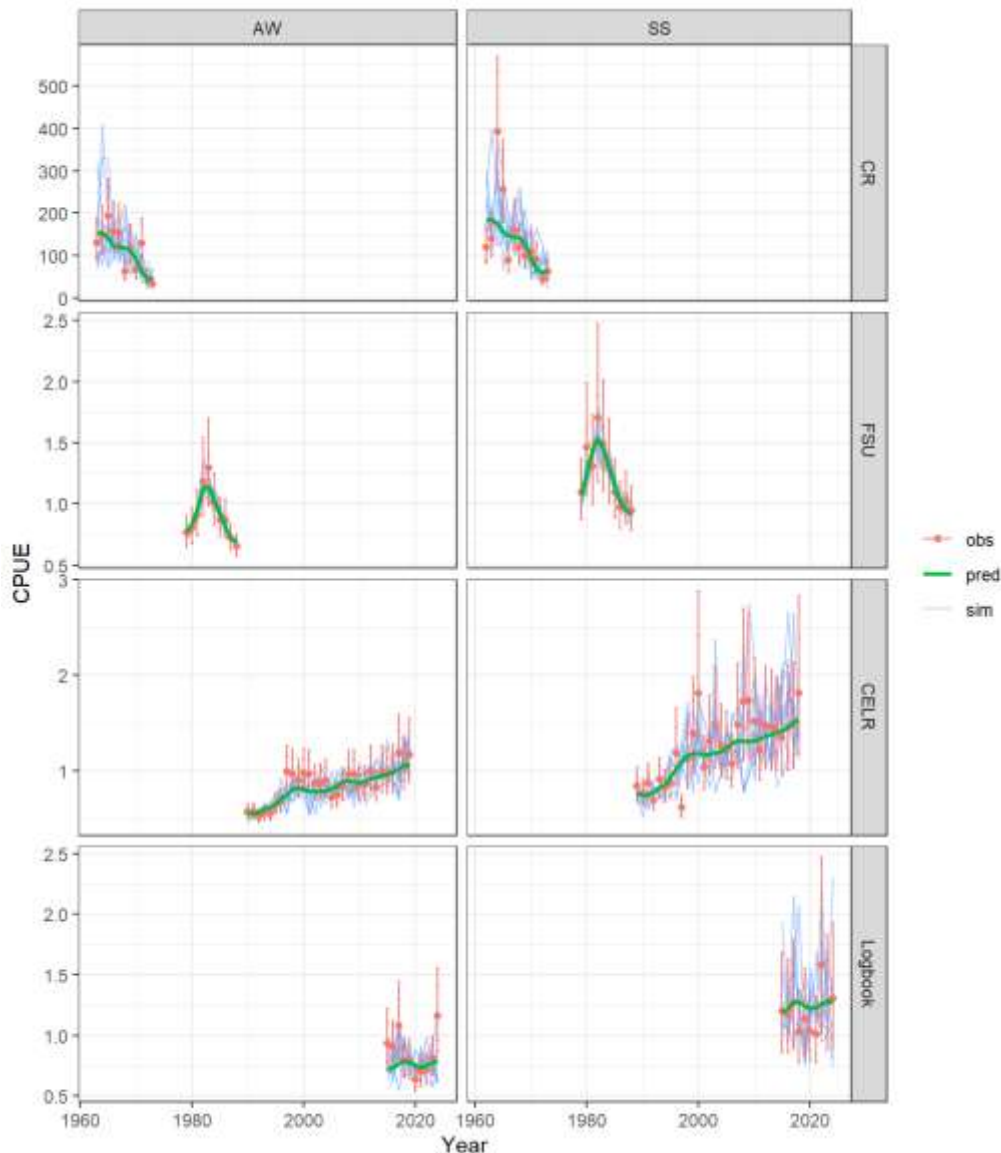


Figure 19: Fits to the FSU, CELR, and logbook CPUE series for the CRA 1 base model (Far North), where points show the observed CPUE with ± 1 SD, blue lines show simulation replicates of CPUE to demonstrate uncertainty in observed CPUE, and the green line shows the MLE for predicted CPUE.

The selectivity functions by sex and season (Figure 23) were assumed to be logistic. Each function reflects the estimated length at 50% selectivity, the length at 95% selectivity, and the relative vulnerability. Vulnerability of males in the SS, and for females in each season were estimated relative to males in AW. Note that the relative vulnerability was allowed to exceed one if the data required it. Uncertainty in selectivity was considerably lower than in the previous assessment, most likely due to the combined female sex category (modelling immature and mature females together, rather than separately) and the fixed maturity relationship estimated outside the model.

Likelihood profiles were done for natural mortality (M ; Figure 24, Figure 25), and average recruitment (R_0 ; Figure 26, Figure 27). The second plot for each parameter compares the MLE likelihood profiles with the posterior distribution of the likelihood components (Figure 25; Figure 27). The M plots indicate that the LF data are consistent with higher estimates for M while the sex-ratio, tagging data and CPUE series are consistent with a lower M estimate. The prior is consistent with similar estimates of M as the

total likelihood. The profile plots on R_0 give a similar evaluation for this parameter, with LF data consistent with higher R_0 estimates for M while the sex-ratio, tagging data, and CPUE series are consistent with a lower R_0 estimate. It is notable that the prior used for R_0 (Table 7) appears to be quite informative.

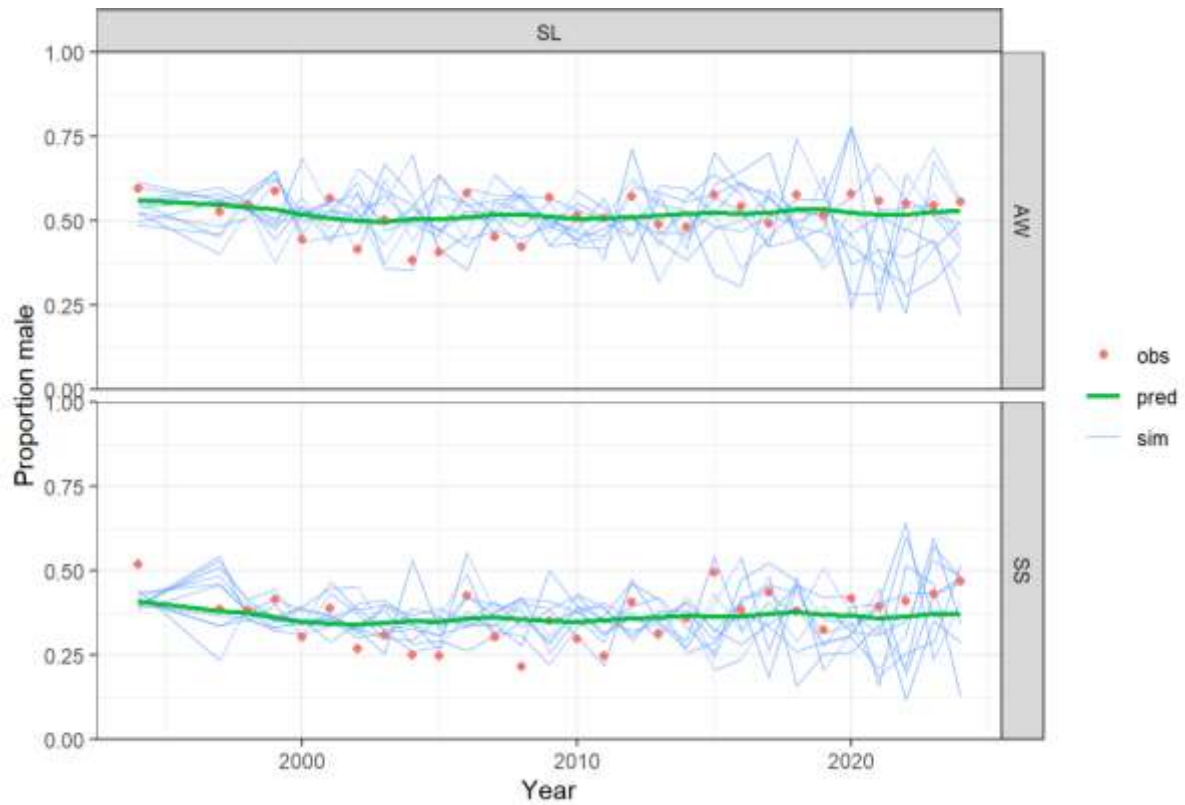


Figure 20: Model fit to sex ratio data (green) and simulations (blue).

Table 11: Summary of the posterior distribution for the model parameter estimates for the base model. The mean, standard deviation (SD) of the mean, median, and 90% credible intervals (i.e. 5% and 95%) are reported. Growth increment values in mm TW, biomass values in tonnes, and R0 in numbers.

Parameter	Number	5%	Median	Mean	95%
<i>Ma</i>	1	0.149	0.176	0.177	0.208
<i>R₀</i>	1	148 914	185 193	188 118	238 255
<i>galpha</i>	1	16.514	17.932	17.918	19.316
<i>galpha</i>	2	22.759	23.501	23.497	24.218
<i>gcv</i>	1	0.367	0.389	0.389	0.411
<i>gcv</i>	2	0.628	0.666	0.666	0.706
<i>gdiff</i>	1	0.116	0.130	0.131	0.148
<i>gdiff</i>	2	0.045	0.049	0.049	0.052
<i>gobs</i>	1	1.372	1.475	1.475	1.580
<i>gshape</i>	1	3.371	3.818	3.825	4.297
<i>gshape</i>	2	7.122	7.493	7.499	7.892
<i>sel50</i>	1	51.924	53.050	53.015	53.956
<i>sel50</i>	2	48.237	49.748	49.748	51.253
<i>sel95</i>	1	10.098	10.810	10.835	11.643
<i>sel95</i>	2	9.035	10.619	10.652	12.377
<i>selmax</i>	1	0.493	0.567	0.569	0.656
<i>selmax</i>	2	0.847	0.885	0.885	0.926
<i>selmax</i>	3	0.796	0.906	0.909	1.034

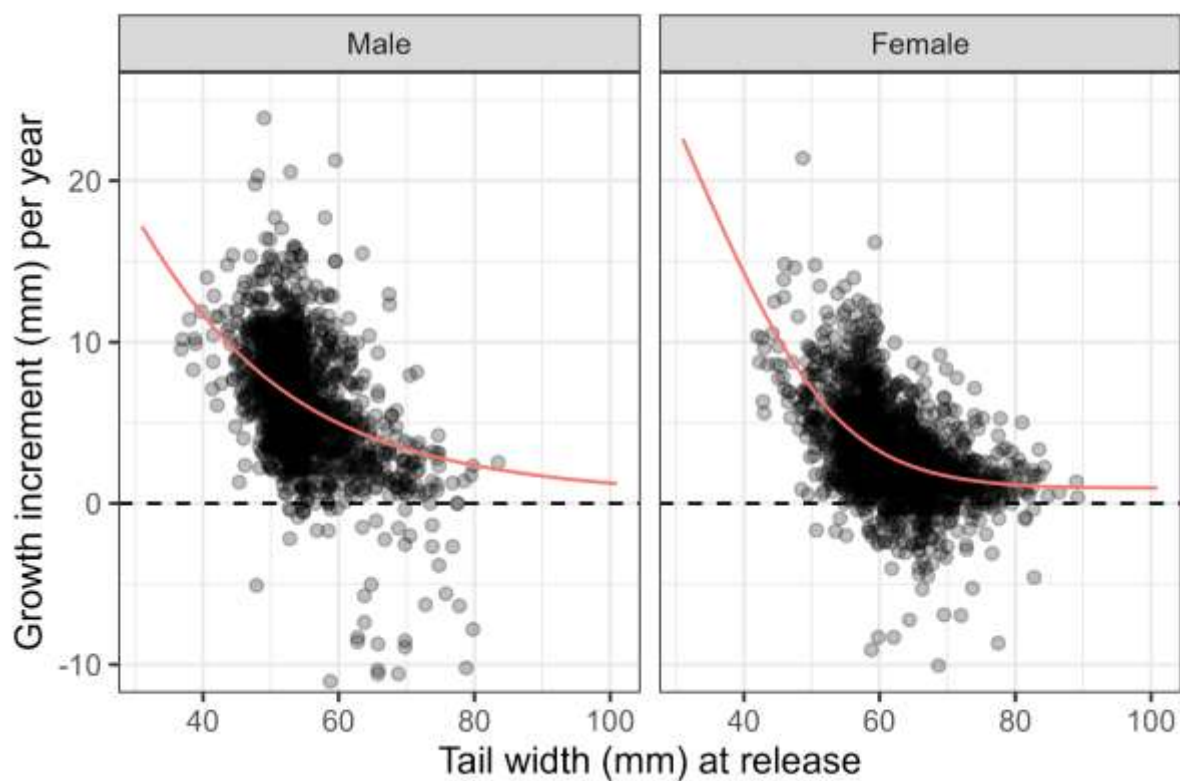


Figure 21: Annual growth increment (mm) by sex.

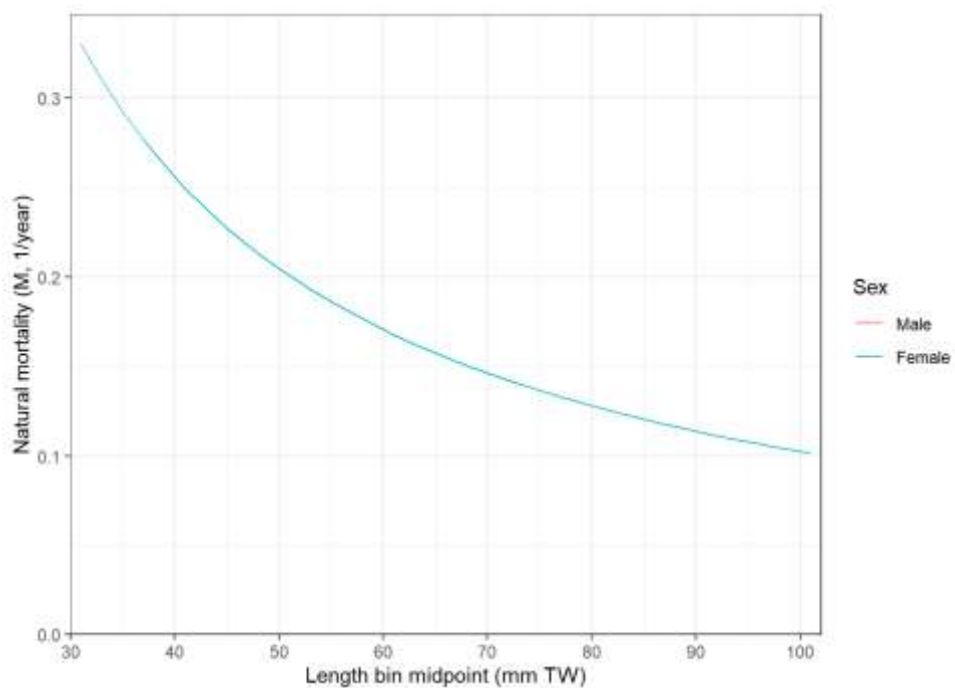


Figure 22: Natural mortality (M) by length.

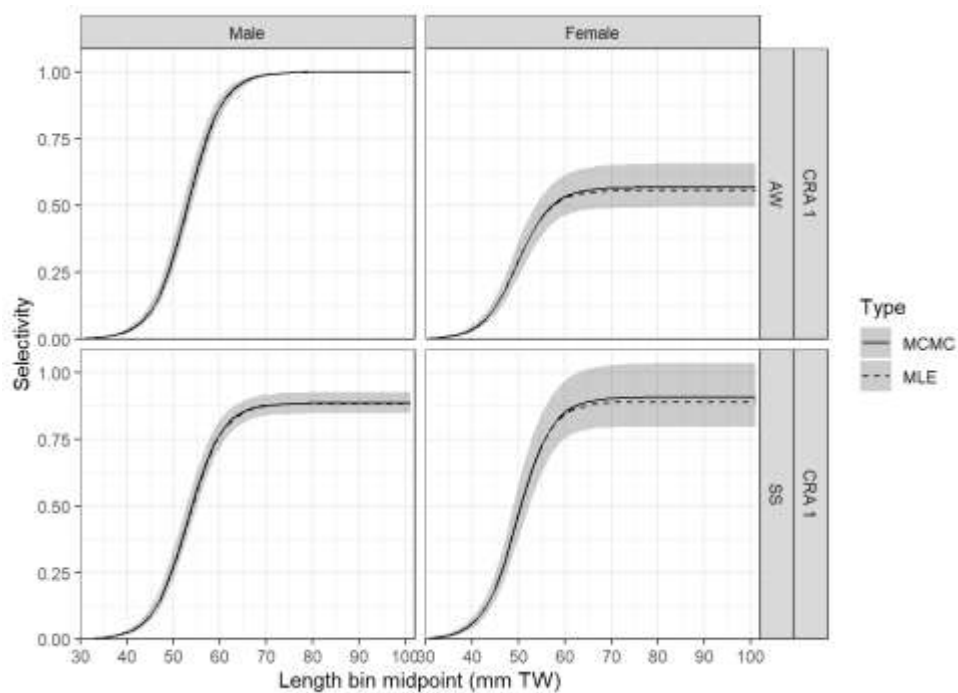


Figure 23: Selectivity by sex and season by length bin for the Far North model.

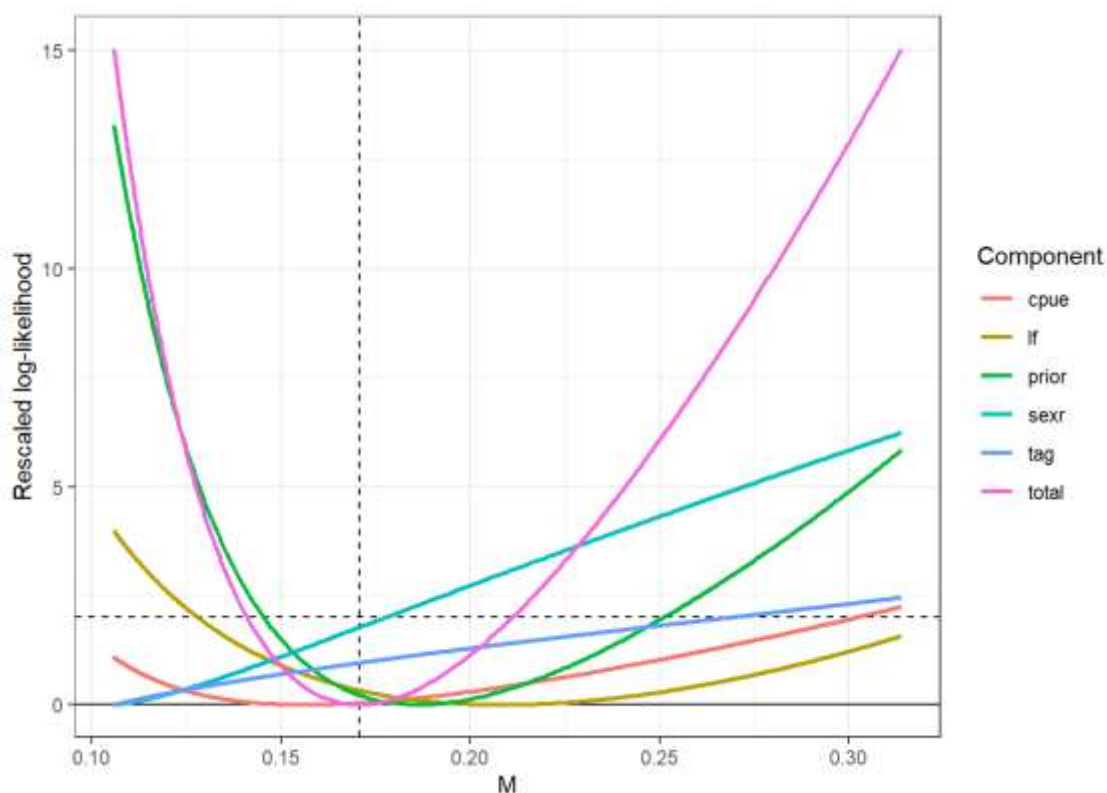


Figure 24: Likelihood profile for natural mortality (M). The dashed vertical line is the MLE and the dashed horizontal line indicates two likelihood units.

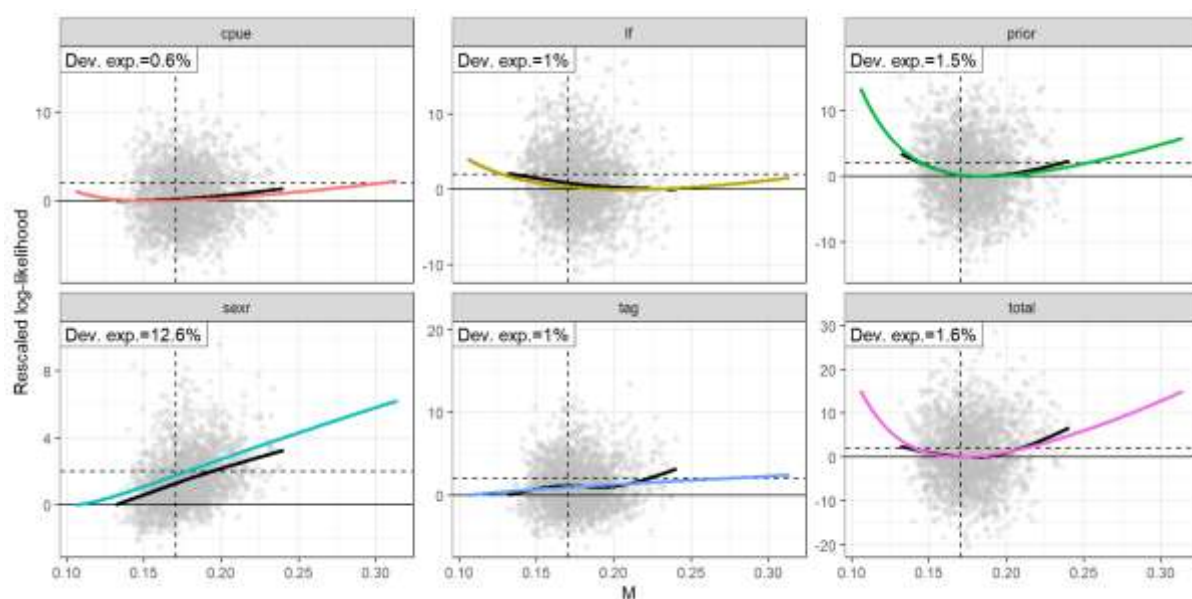


Figure 25: Likelihood profile for natural mortality (M) comparing the MLE profile for each data component (plus the total likelihood) with the distribution of equivalent likelihoods drawn from the posterior MCMC samples. The dashed vertical line is the MLE and the dashed horizontal line indicates two likelihood units. The solid black line in each panel is a smoother fit to the MCMC samples.

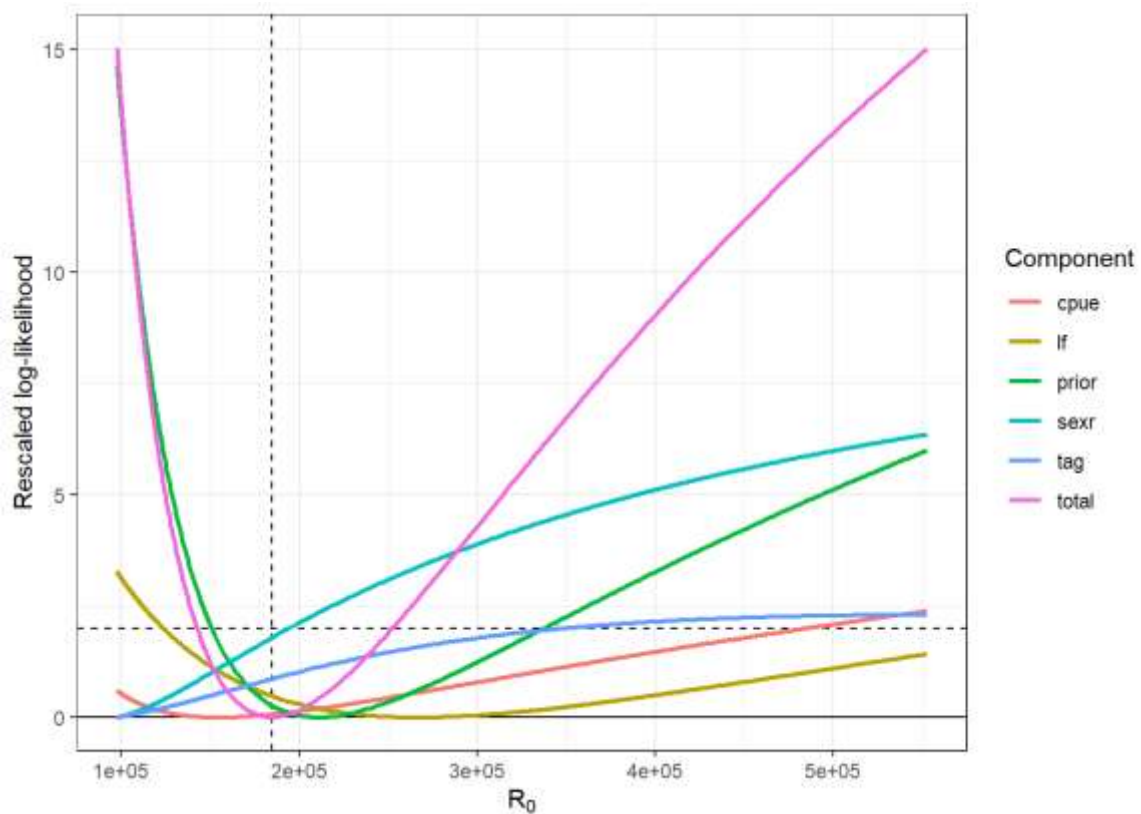


Figure 26: Likelihood profile for average recruitment (R_0). The dashed vertical line is the MLE and the dashed horizontal line indicates two likelihood units.

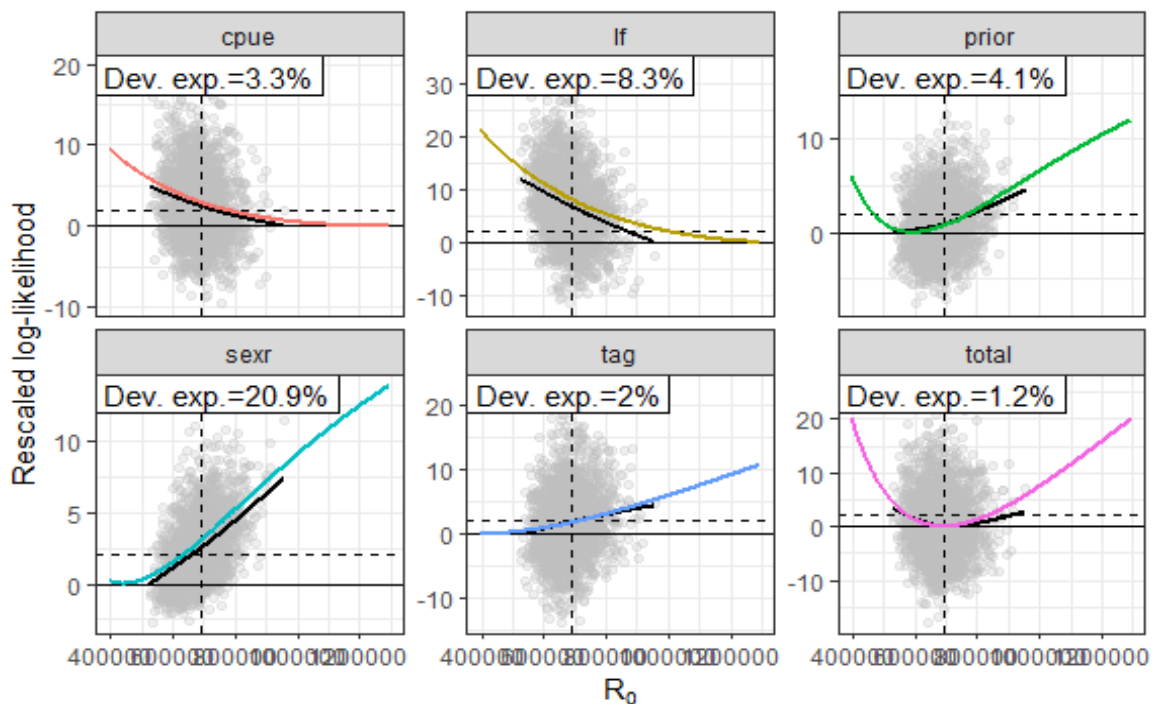


Figure 27: Likelihood profile for average recruitment (R_0) comparing the MLE profile for each data component (plus the total likelihood) with the distribution of equivalent likelihoods drawn from the posterior MCMC samples. The dashed vertical line is the MLE and the dashed horizontal line indicates two likelihood units. The solid black line in each panel is a smoother fit to the MCMC samples.

3.5.4 Reference level

Model-based reference levels for red rock lobster stocks have been calculated for the past few years (see more detailed discussion in Rudd et al. 2021c). This procedure develops interim target reference levels specific for the population that is vulnerable to fishing (B_R) using the stock assessment model to project the vulnerable biomass under a range of harvest rules through simulation. Using the CRA 1 Far North model, projections were made across a range of fixed catch and fixed U levels. These simulations were run for 50 years across the 2000 MCMC posterior samples, with each simulation replicate drawing random recruitment deviates from a normal distribution based on the mean, standard deviation, and autocorrelation of the model-estimated recruitment deviates spanning a period that starts in the first year with a reasonable amount of observed length data and which ends four years before the final model year (the ‘data period’: 1994–2020). This is also the period used for basing the estimate of SSB_0 (SSB_{0_data}).

Only the size-limited catches are modelled in the reference level projections, with the non-size-limited catch (sum of illegal and customary catch) held constant at the 2024 level. Rules that had a probability more than 5% of falling below 20% SSB_{0_data} in the final projection year were rejected. The constant catch rules were further constrained by the requirement that there should be less than a 20% probability of the population crashing under specified fixed catch levels by the final year of the projection period (i.e. exploitation rate exceeding 1.0 for any year or length bin). The vulnerable biomass associated with the fixed catch and fixed U levels that maximised the catch for each harvest strategy while satisfying the risk constraints were then averaged to obtain the interim target reference level for CRA 1 (see Rudd et al. 2021b).

To provide an exploitation rate indicator (U_R), the exploitation rate associated with B_R was calculated, which was defined as the U that resulted in an equilibrium biomass equal to the B_R . U_R was identified by finding the fixed U resulting in a median vulnerable biomass of B_R in the final projection year for the reference level calculation (i.e. projection year 50).

3.5.5 Projections

Five-year projections, for the fishing years 2025 to 2029, were calculated for the Far North model. All catches were assumed to be the same as the final model year (2024), for each season, and were held constant when projecting forward (Table 12, Figure 28, Figure 29). The projected commercial catch in 2025 was 83 tonnes, representing only the Far North region and therefore below the TACC of 89 tonnes.

Table 12: Projected catches held constant for each fishing year from 2025–2029 for the Far North model.

Fishery	AW	SS	Total
Commercial	49.205	33.788	82.993
Recreational	4.921	3.379	8.299
Illegal	0.381	0.890	1.269
Customary	0.300	0.700	1.000

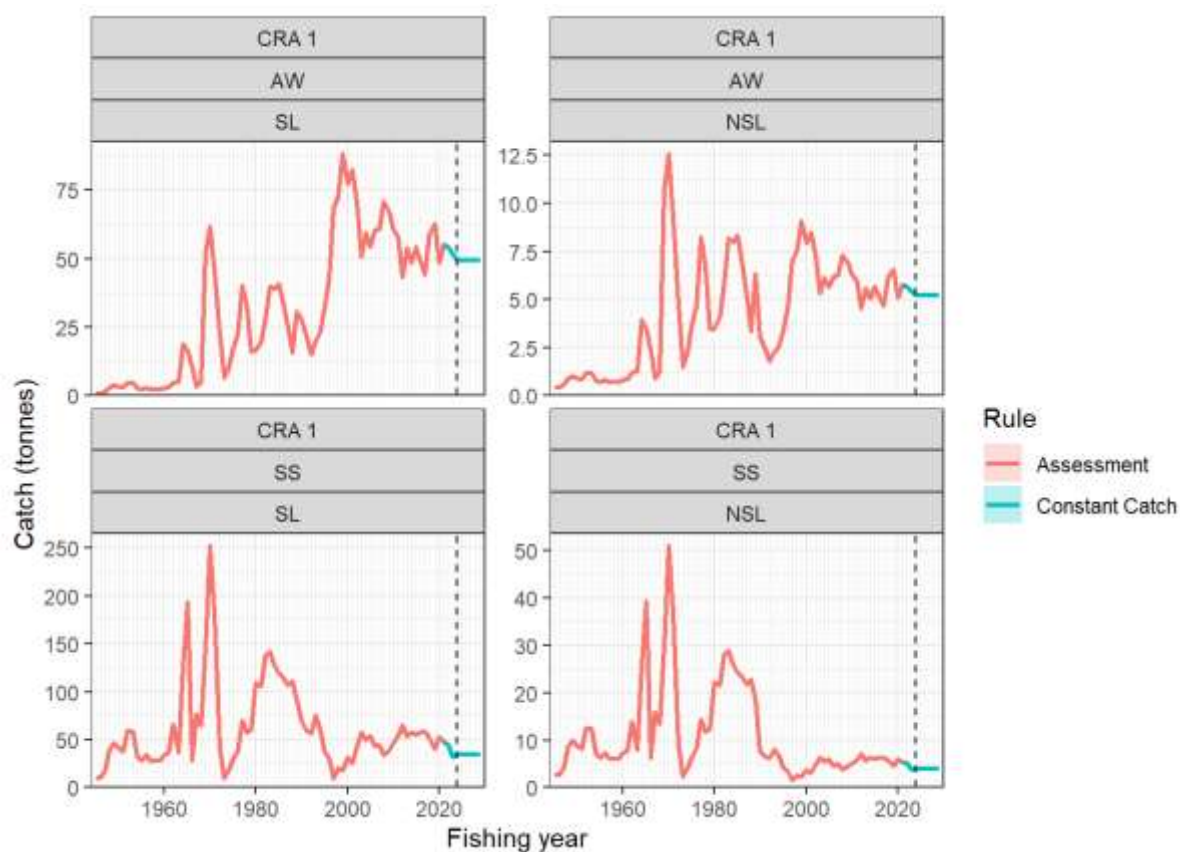


Figure 28: Catch by fishing year, season, and fishery (SL = size-limited, NSL = non-size-limited) for the Far North model. The dashed vertical line indicates the final year of stock reconstruction.

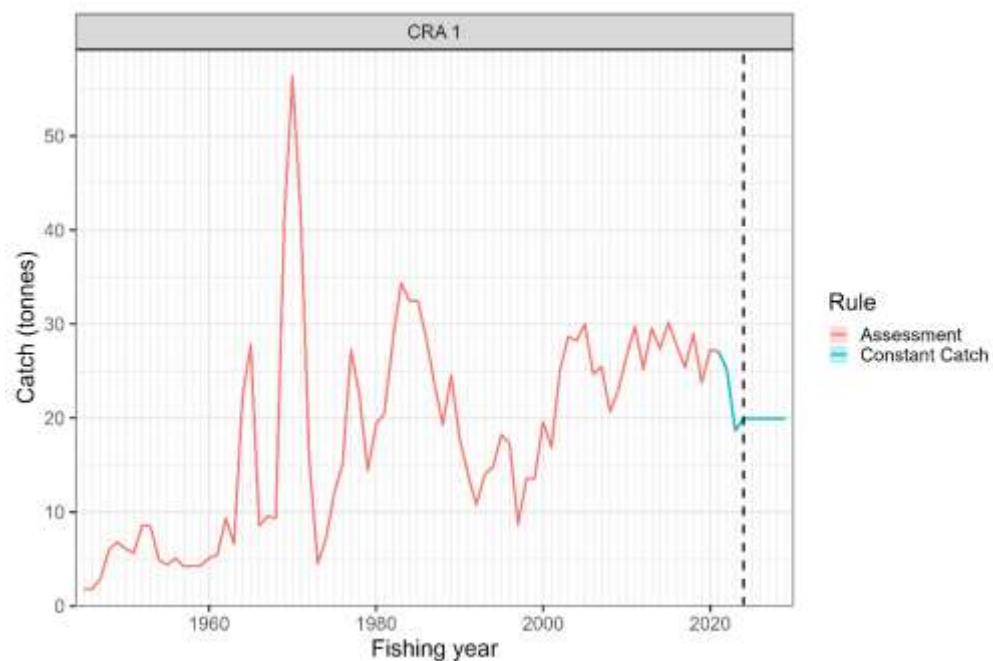


Figure 29: Total catch by fishing year for the Far North model. The dashed vertical line indicates the final year of stock reconstruction.

3.5.6 Stock status

Current stock status estimates used the model-estimated recruitment deviates, based on lognormally distributed recruitment deviates through to 2020 and then recruitment deviates based on AR1 (estimated over the period 1980 through to 2020) for the final four model years. There was one strong recruitment pulse estimated in the late 1970s, followed by lesser recruitment events from the 1980s to present (Figure 30). To calculate five-year projected stock status, the four final model years assuming AR1 recruitment (2021 to 2024) were overwritten by the projected recruitment using ARIMA models (Figure 30) and continued through to 2030. This approach reduced the influence of any patterns in uncertain recent recruitment and instead used longer-term information to inform short-term recruitment.

Median recruitment generally oscillated around R_0 over the stock reconstruction period. This can be seen in the recruitment used for the five-year projections (green) based on ARIMA models, with the median approximately at R_0 (Figure 30).

The NSL exploitation rates were very low compared with the SL exploitation rates, reflecting the small amount of catch in this category (Figure 31). The AW SL exploitation rates increased until about 2000, when they began to decline, and the SS SL exploitation rates increased to a peak of 30% around 1970, decreased and then increased to another peak just above 20% by the mid-1980s, before decreasing again and remaining at intermediate levels less than 10% for the remainder of the time series. The peaks of SS exploitation rates and approximated annual exploitation rates exceeded the exploitation rate associated with the reference level (Figure 32; Figure 33). Exploitation rates (both seasonal and approximated annual) have remained below the exploitation rate associated with the reference level since the mid-1990s (Figure 32; Figure 33).

The AW adjusted vulnerable biomass in CRA 1 declined steeply from the first model year 1945 through the mid-1970s. There was an increase in vulnerable biomass in the early 1980s most likely driven by the main recruitment pulse around 1980 (Figure 30; Figure 34). More consistent, lower catches (Figure 29) and consistent recruitment (Figure 30) most likely contributed to a steady, slightly increasing vulnerable biomass since the early 1990s (Figure 34; Figure 35). Median vulnerable biomass at the beginning of 2025 was 29% B_0 and 170% of B_R (90% credible interval: 137–211%; Table 13, Figure 35). There was a probability of 1.0 that B_{2025} was greater than B_R (Table 14). Vulnerable biomass was projected to continue to increase by 2030 to a median of 34% B_0 and 200% of B_R (Table 13).

The overall SSB abundance trend followed similar patterns to the vulnerable biomass. There was a general decline from the first model year 1945, with an increase in SSB in the late 1970s and early 1980s due to the decline in SS exploitation rate in the 1970s and the main recruitment peak around 1980 (Figure 30, Figure 31, Figure 36). SSB increased in the 1990s due to a reduction in exploitation rate and consistent recruitment and has remained stable with consistent exploitation rate and recruitment since the late 1990s (Figure 36; Figure 37). The pattern in total biomass was similar to that of spawning biomass (Figure 38; Figure 39). Median spawning stock biomass at the beginning of 2025 was 53% SSB_0 (90% credible interval: 43–63%; Table 13, Figure 37) and there was a probability of 1.0 that SSB_{2025} was above the soft limit (Table 14). Spawning stock biomass was projected to continue to increase by 2030 to a median of 60% SSB_0 .

The phase plot shows two years prior to 1980 where the stock's exploitation rate was greater than that associated with the reference level while the biomass was still above the reference level. The exploitation rate decreased in the late 1970s back under the exploitation rate associated with the reference level. For the rest of the time series, the stock status has consistently been in the preferred lower righthand quadrant representing biomass generally between 100% and 200% of the reference level and exploitation rate below the reference level (Figure 40). Stock status in 2025 was estimated to be entirely in the preferred lower righthand quadrant, resulting in an evaluation that the stock is not undergoing overfishing and is not overfished (Figure 40).

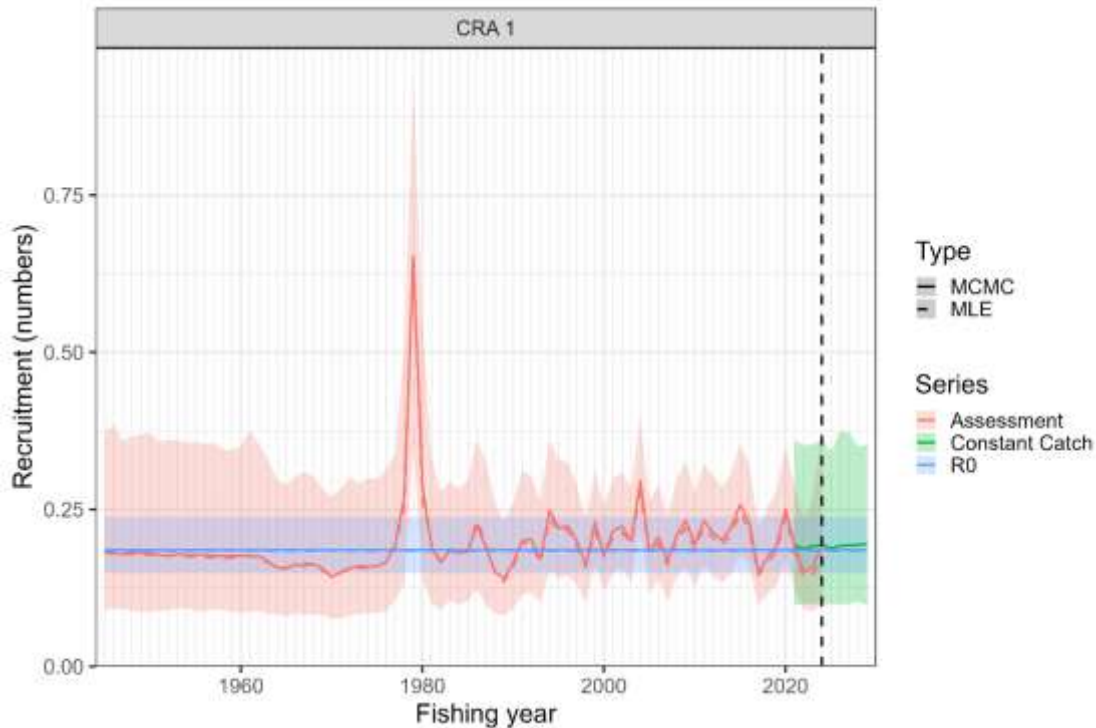


Figure 30: Estimated recruitment for the Far North model (red) compared with R0 (blue) and projected recruitment using ARIMA for the five-year projection (green). The solid line indicates the median of the posterior and shading indicates the 90% credible interval, and the dashed line matching the colour of each series shows the MLE. The black dashed vertical line indicates the final year of stock reconstruction.

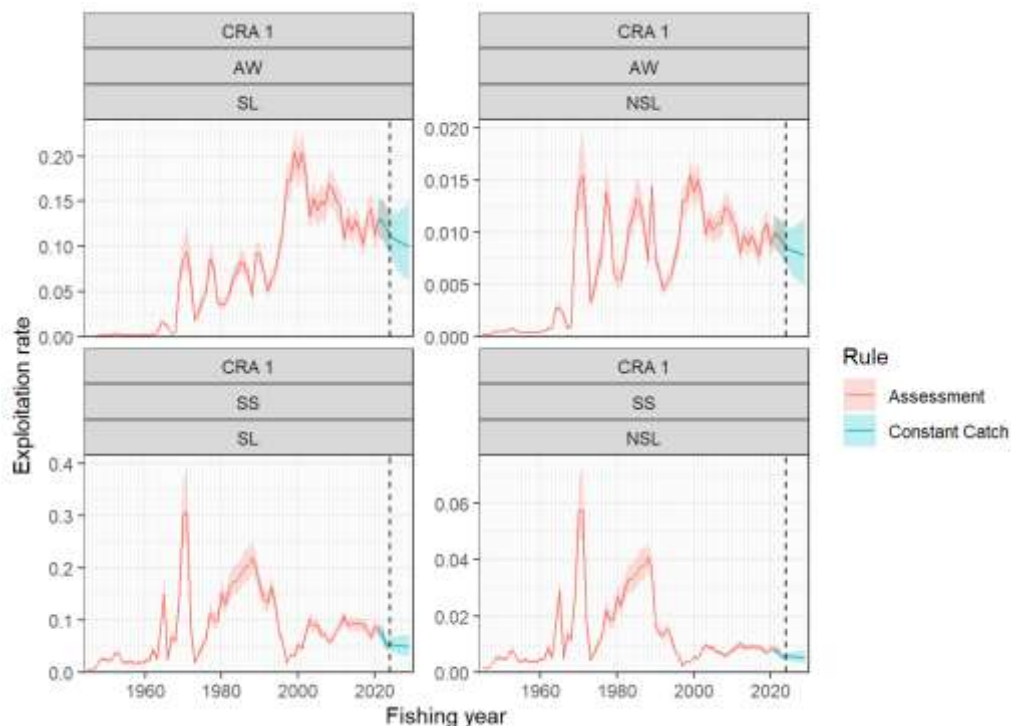


Figure 31: Posterior distribution of exploitation rate (U) by fishing year, season, and fishery (SL = size-limited, NSL = non-size-limited) for the base model run. The solid line indicates the median of the posterior and shading indicates the 90% credible interval. The dashed vertical line indicates the final year of stock reconstruction. Blue shading indicates years influenced by the rewritten last four years of recruitment by the ARIMA models, which only affects the five-year projection.

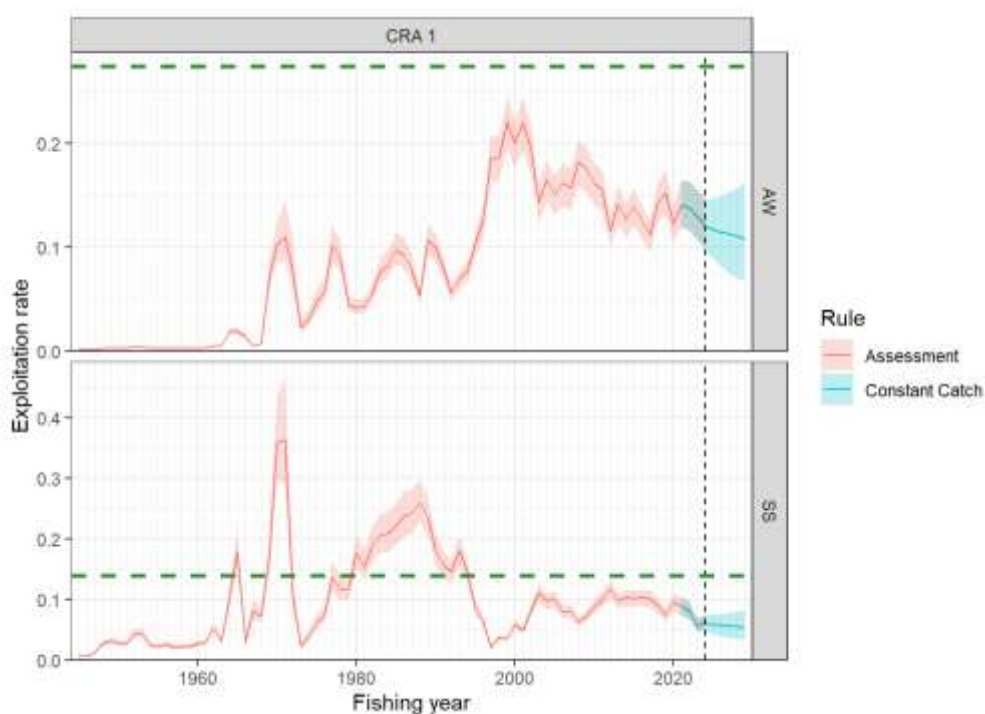


Figure 32: Posterior distribution of exploitation rate (U) by fishing year and season, combined across fisheries (SL + NSL). The solid line indicates the median of the posterior and shading indicates the 90% credible interval. The horizontal dashed green line shows the exploitation rate associated with the reference level by season. The vertical dashed black line indicates the final year of stock reconstruction. Blue shading indicates years influenced by the rewritten last four years of recruitment by the ARIMA models, which only affects the five-year projection.

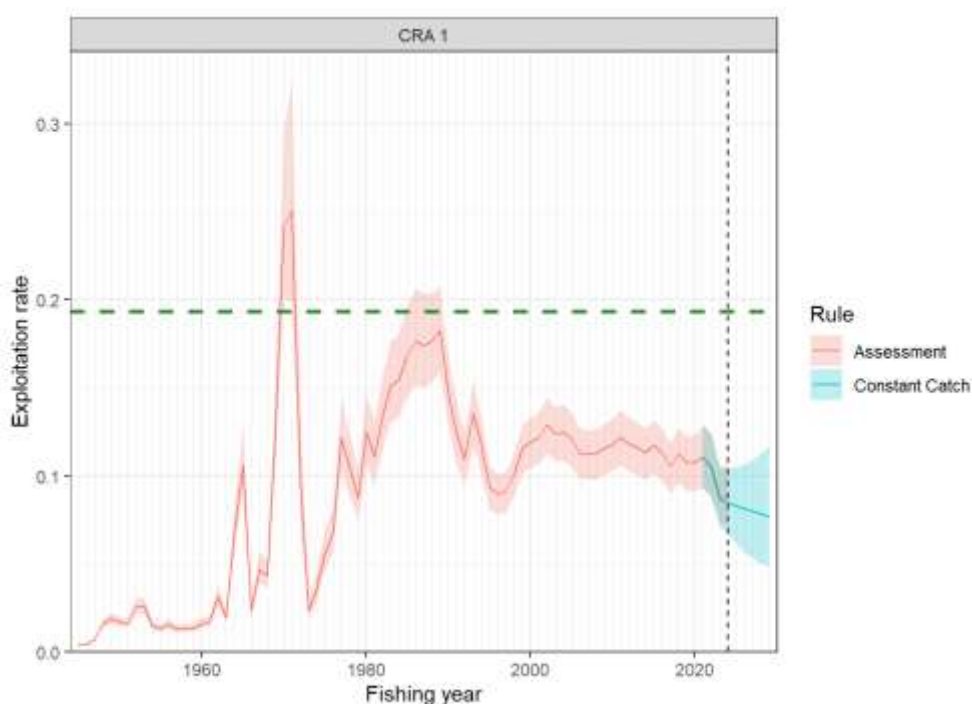


Figure 33: Approximate exploitation rate (U) by fishing year, calculated as a weighted average across seasons by the seasonal vulnerable biomass. The solid line indicates the median of the posterior and shading indicates the 90% credible interval. The horizontal dashed green line shows the approximated annual exploitation rate associated with the reference level based on the weighted average across seasons. The vertical dashed black line indicates the final year of stock reconstruction. Blue shading indicates years influenced by the rewritten last four years of recruitment by the ARIMA models, which only affects the five-year projection.

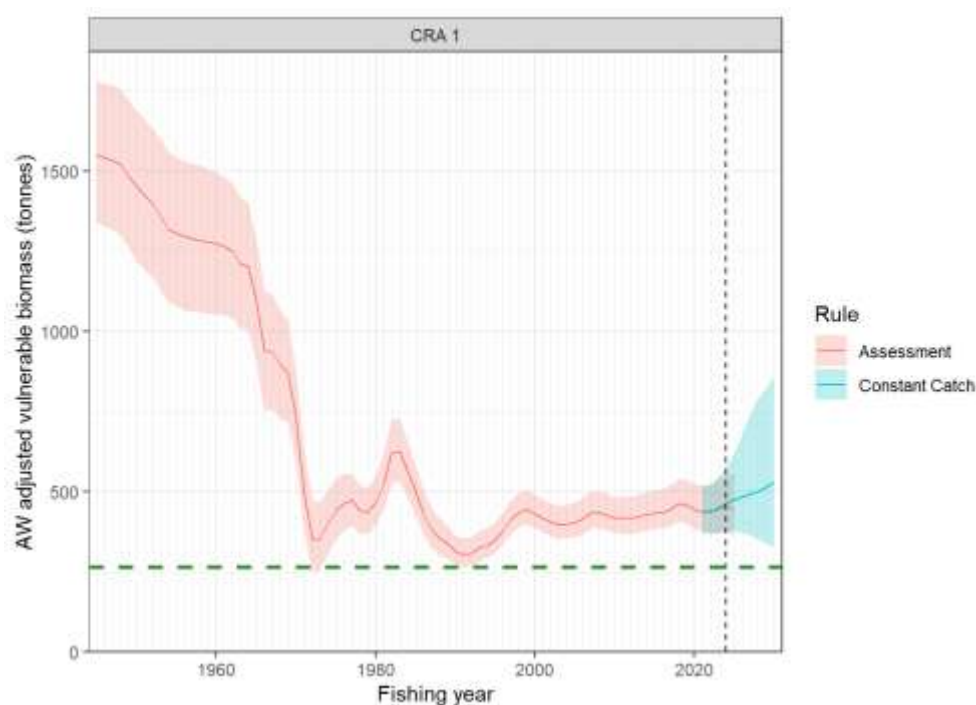


Figure 34: Projected vulnerable biomass. The green dashed horizontal line is the reference level. The dashed vertical line shows the final year of stock reconstruction. The final year from the assessment is the current stock status, calculated as the end of the final fishing year (start of the first projection year). The “Constant catch” series indicates projections which use recruitment that overwrites the last four years of the assessment.

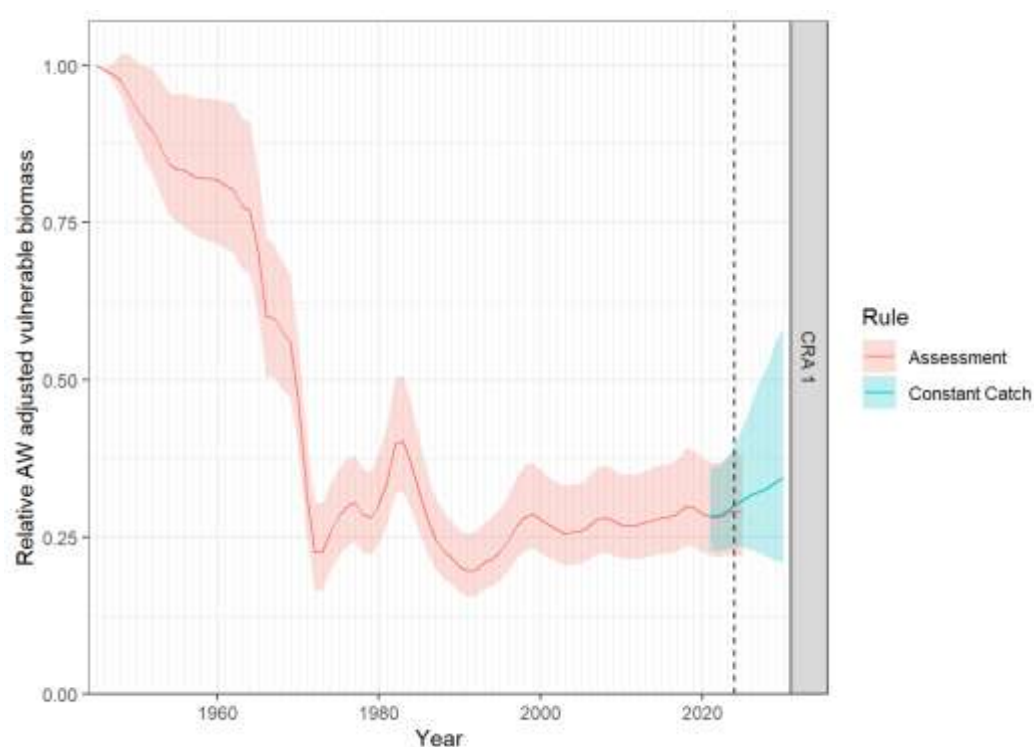


Figure 35: Projected relative vulnerable biomass (B/B_0) by fishing year. The dashed vertical line shows the final year of stock reconstruction. The final year from the assessment is the current stock status, calculated at the end of the final fishing year (start of the first projection year). The “Constant catch” series indicates projections which use recruitment that overwrites the last four years of the assessment.

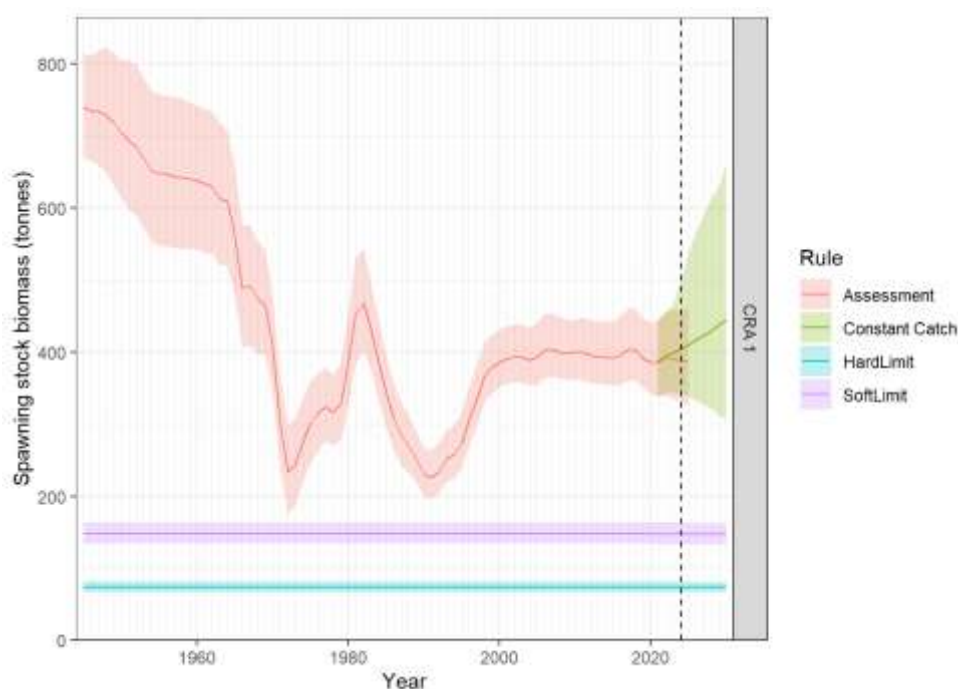


Figure 36: Projected spawning stock biomass (SSB) by fishing year. The dashed vertical line shows the final year of stock reconstruction. The final year from the assessment is the current stock status, calculated at the end of the final fishing year (start of the first projection year). Also plotted are the soft limit ($0.2 SSB_0$) and the hard limit ($0.1 SSB_0$). The “Constant catch” series indicates projections which use recruitment that overwrites the last four years of the assessment.

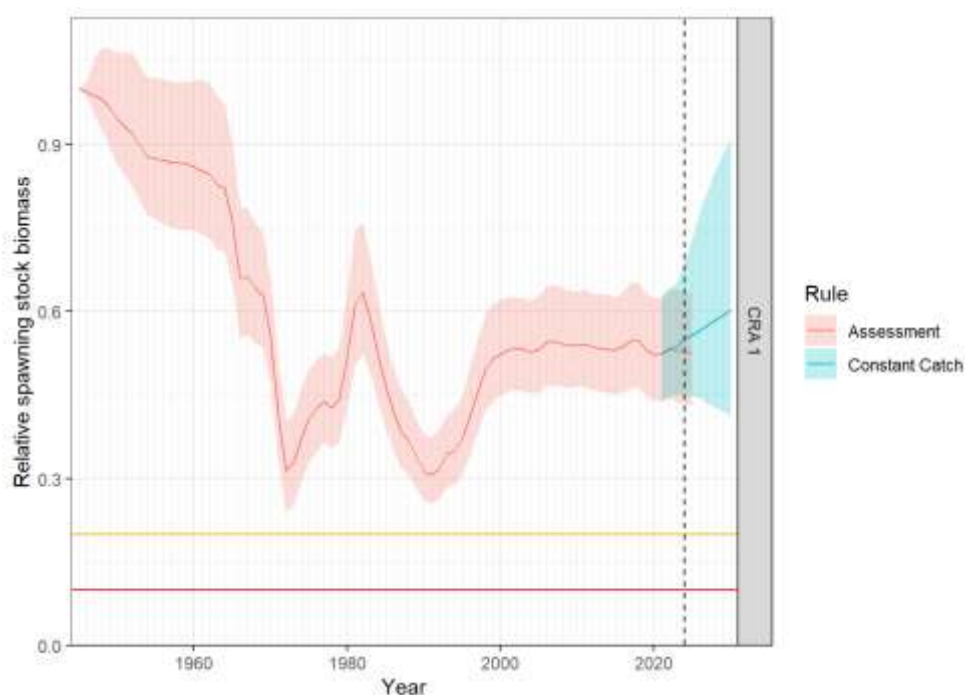


Figure 37: Projected relative (to SSB_0) spawning stock biomass (SSB) by fishing year showing the 90% credible interval. The dashed vertical line shows the final year of stock reconstruction. The final year from the assessment is the current stock status, calculated at the end of the final fishing year (start of the first projection year). Also plotted are the soft limit ($0.2 SSB_0$) and the hard limit ($0.1 SSB_0$). The “Constant catch” series indicates projections which use recruitment that overwrites the last four years of the assessment.

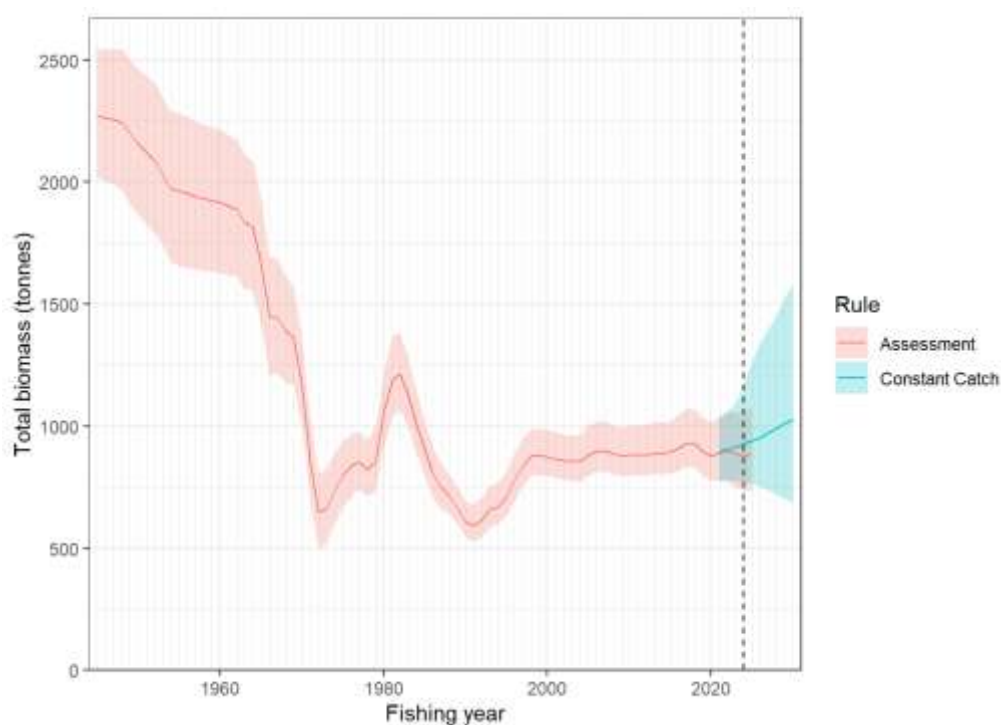


Figure 38: Projected total biomass. The dashed vertical line shows the beginning of the final year of stock reconstruction. The final year from the assessment is the current stock status, calculated at the end of the final reconstruction year (start of the first projection year). The “Constant catch” series indicates projections which use recruitment that overwrites the last four years of the assessment.

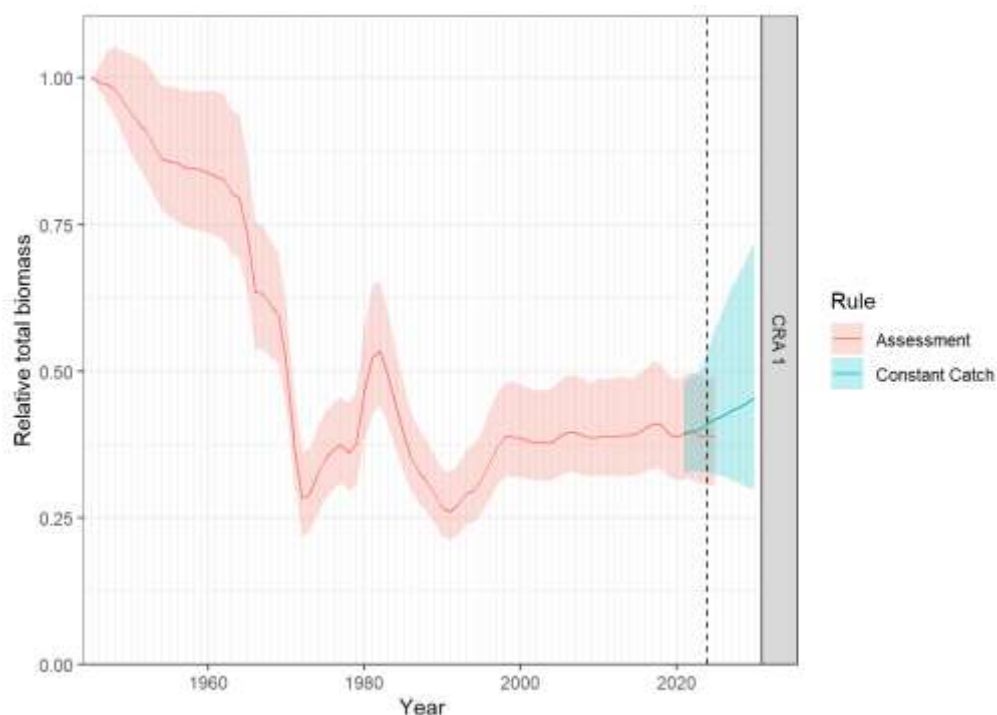


Figure 39: Projected relative (to T_0) total biomass (T) by fishing year. The dashed vertical line shows the beginning of the final reconstruction year. The final year from the assessment is the current stock status, calculated as the end of the final reconstruction year (start of the first projection year). The “Constant catch” series indicates projections which use recruitment that overwrites the last four years of the assessment.

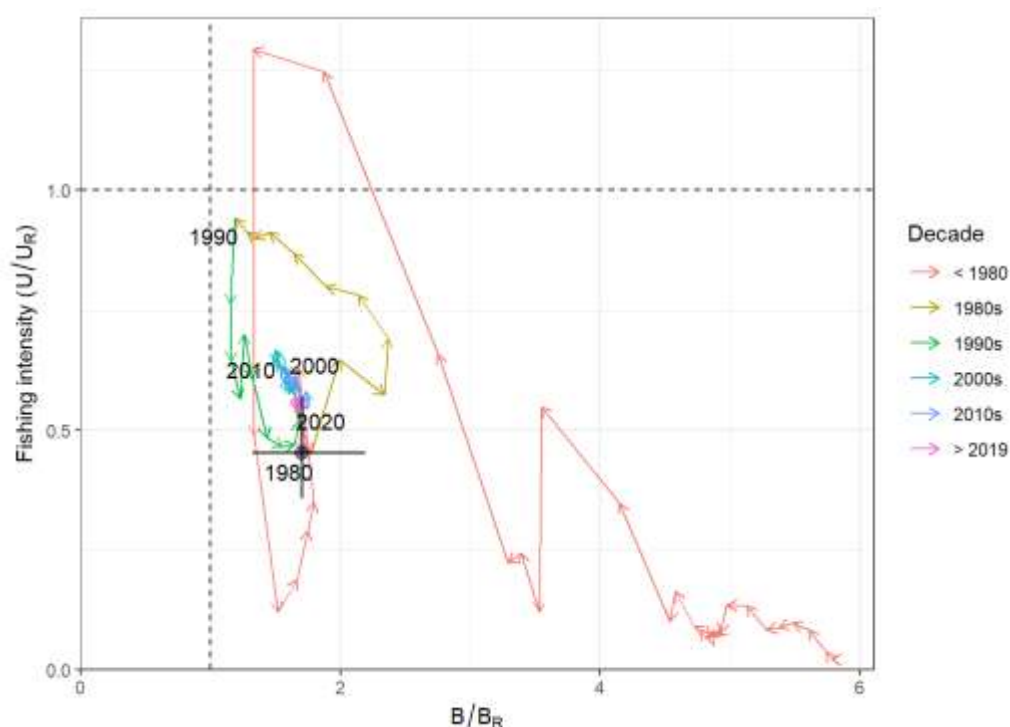


Figure 40: Phase plot showing stock status B relative to B_R (in terms of AW adjusted vulnerable biomass) and U relative to U_R (in terms of the weighted exploitation rate across seasons). Years for U were lagged to match the U from the previous year that led to the resulting start-of-year AW vulnerable biomass (B) (e.g. the final year shows B_{2025} on the x-axis and U_{2024} on the y-axis).

Table 13: Summary of the posterior distribution for the derived quantities for the FarNorth model. The mean, median, and 90% credible interval (i.e. 5% and 95%) are reported. Biomass values and handling mortality (H) are reported in tonnes.

Variable	Year	5%	Median	Mean	95%
B_0	—	1337.491	1549.299	1555.505	1781.786
B_R	—	264.809	264.809	264.809	264.809
B_R / B_0	—	0.149	0.171	0.172	0.198
B_{MIN}	—	244.437	293.956	292.695	342.302
SSB_0	—	670.444	739.207	739.897	814.079
T_0	—	2023.202	2270.147	2279.368	2545.131
U_R	—	0.194	0.194	0.194	0.194
B	2025	363.953	449.912	453.986	557.456
B	2030	327.149	530.29	553.553	862.117
B / B_0	2025	0.219	0.29	0.295	0.385
B / B_0	2030	0.209	0.344	0.361	0.584
B / B_{MIN}	2025	1.256	1.532	1.562	1.954
B / B_{MIN}	2030	1.079	1.821	1.912	3.075
B / B_R	2025	1.374	1.699	1.714	2.105
B / B_R	2030	1.235	2.003	2.09	3.256
SSB	2025	326.699	388.131	390.477	463.275
SSB	2030	306.996	444.668	457.954	662.038
SSB / SSB_0	2025	0.431	0.526	0.529	0.633
SSB / SSB_0	2030	0.413	0.603	0.623	0.91
T	2025	732.725	886.742	892.619	1077.699

Variable	Year	5%	Median	Mean	95%
T	2030	685.212	1028.997	1064.727	1581.22
T / T_0	2025	0.304	0.391	0.394	0.495
T / T_0	2030	0.299	0.454	0.472	0.723
U	2024	0.072	0.088	0.089	0.106
U	2029	0.048	0.077	0.079	0.117
U / U_R	2024	0.371	0.454	0.457	0.55
U / U_R	2029	0.25	0.396	0.407	0.605
H	2024	0.97	1.051	1.053	1.145
H	2029	0.873	1.052	1.059	1.259

Table 14: Probabilities based on the posterior distributions of derived quantities for the base model.

Variable	Probability
$P(SSB_{2025} < 20\% SSB_0)$	0.000
$P(SSB_{2025} < 10\% SSB_0)$	0.000
$P(SSB_{2030} < 20\% SSB_0)$	0.000
$P(SSB_{2030} < 10\% SSB_0)$	0.000
$P(SSB_{2030} > SSB_{2025})$	0.716
$P(B_{2030} > B_{2025})$	0.702
$P(B_{2025} > B_R)$	1.000
$P(B_{2030} > B_R)$	0.991
$P(B_{2025} > B_{MIN})$	1.000
$P(B_{2030} > B_{MIN})$	0.983
$P(U_{2029} > U_{2024})$	0.312
$P(U_{2024} > U_R)$	0.000
$P(U_{2029} > U_R)$	0.000
$P(T_{2030} > T_{2025})$	0.711

3.6 Model sensitivity

The MCMC sensitivity runs in addition to the Far North run are reported here. Other sensitivity trials were also made for the CRA 1 stock assessment that are not reported here, because they did not materially alter the interpretation of assessment results.

1. *farnorth_1979*: same as Far North run except the model is started in 1979 by estimating U_0 ,
2. *totalCRA1*: all of CRA 1 including data from areas 903 and 904 (catch, all four CPUE series, logbook and observer sampling data: length composition, sex ratio, proportion in berry), starting the model in 1945,
3. *totalCRA1_1979*: same as *totalCRA1* model but start the model in 1979 by estimating U_0 .

Results from the base case and sensitivity trials are compared in Table 15 through to Table 18, as well as Figure 41 through to Figure 51.

farnorth_1979: this model run did not fit as well as the Far North run starting in 1945 and produced very different derived biomass estimates. This was particularly true for the equilibrium stock size estimates, with both of the initial biomass estimates being much larger for the *farnorth_1979* run (the

Far North B_0 was 1549 t compared with the farnorth_1979 run estimate of 2291 t; Far North SSB_0 was 739 t compared with the farnorth_1979 estimate of 985 t). However, the current (2025) stock size estimates were similar for the two runs (median Far North B_{2025} was 450 t compared to farnorth_1979 estimate of 429 t; current median Far North SSB_{2025} was 388 t compared with the farnorth_1979 run estimate of 374 t). The reason for this disparity in equilibrium stock size is not well understood, but it is known that estimates of initial exploitation rate (U_0) are often unreliable, being sensitive to the data that are adjacent to the model start year. In the case of the two Far North models, the relative impact of excluding the Area 903/904 catches was greatest during the 1945–1978 period, accounting for about 91 t/year compared to 66 t/year in the 1979–2024 period; this compares to the Far North Areas (901, 902, 939) contribution of 87 t/year in the first period and 124 t/year in the second period (see Table 5). These disparities in the relative removals by region and time block may have resulted in a bias towards a larger relative stock size for the Far North component of CRA 1, by the model beginning in 1979 compared with the model beginning in 1945. The stock status estimates from the farnorth_1979 run were less optimistic than for the Far North run, with the farnorth_1979 model returning lower levels of stock status ratios (median Far North B_{2025}/B_0 was 0.290 compared with the farnorth_1979 run estimate of 0.185; current median Far North SSB_{2025}/SSB_0 was 0.526 compared with the farnorth_1979 estimate of 0.377, Table 16). This model was the only one of the four that fell below the soft limit at any point in the time series (Figure 51) but it had a very low probability of being below the soft limit in the current year (Table 17). A reference level was calculated for this model in addition to the primary Far North model. The B_R for the farnorth_1979 model was 380 tonnes, compared with 265 tonnes for the primary Far North model. The current farnorth_1979 vulnerable biomass was above the farnorth_1979 B_R with a probability of 0.792, and very unlikely to be undergoing overfishing (probability 0.001 of current U greater than U_R , Table 18).

totalCRA1: as expected, the stock size estimates for this model are greater than for the Far North run due to the higher catch totals used in the reconstruction of this run (Table 5). Derived initial biomass estimates are greater (Far North median B_0 was 2791 t compared with the Far North estimate of 1549 t; totalCRA1 median SSB_0 was 1271 t compared with the Far North estimate of 739 t), as are the 2025 stock sizes (median totalCRA1 B_{2025} was 679 t compared with the Far North estimate of 450 t; current median totalCRA1 SSB_{2025} was 558 t compared with the Far North estimate of 388 t). However, the stock status estimates from the Far North model are generally more optimistic than for the totalCRA1 run, with the Far North model returning higher stock status ratio levels (median Far North B_{2025}/B_0 was 0.290 compared with the totalCRA1 estimate of 0.243; current median Far North SSB_{2025}/SSB_0 was 0.526 compared with the totalCRA1 estimate of 0.439, Table 16). This result indicates that exploitation on the east side of the North Cape Peninsula was likely to have been disproportionately higher than for the more remote Far North areas, at least in the earlier years.

totalCRA1_1979: all derived biomass estimates for this sensitivity run were nearly the same as for the totalCRA1 case run (totalCRA1 median B_0 was 2791 t compared with the totalCRA1_1979 run estimate of 2703 t; totalCRA1 SSB_0 was 1271 t compared with the totalCRA1_1979 estimate of 1251 t; median totalCRA1 B_{2025} was 679 t compared with the totalCRA1_1979 estimate of 674 t; current median totalCRA1 SSB_{2025} was 558 t compared with the totalCRA1_1979 estimate of 562 t). The resulting stock status estimates from the totalCRA1_1979 model are about the same as for the totalCRA1 run (median totalCRA1 B_{2025}/B_0 was 0.243 compared with the totalCRA1_1979 run estimate of 0.247; current median totalCRA1 SSB_{2025}/SSB_0 was 0.439 compared with the totalCRA1_1979 estimate of 0.446, Table 16).

Table 15: Base case and sensitivity runs reporting the median and 90% credible intervals of the posterior distribution for each parameter (excluding catchability coefficients).

Parameter	Number	Model	5%	Median	Mean	95%
<i>Ma</i>	1	<i>farnorth</i>	0.149	0.176	0.177	0.208
<i>Ma</i>	1	<i>farnorth_1979</i>	0.098	0.133	0.133	0.170
<i>Ma</i>	1	<i>totalCRAI</i>	0.134	0.162	0.163	0.196
<i>Ma</i>	1	<i>totalCRAI_1979</i>	0.130	0.166	0.168	0.211
<i>R0</i>	1	<i>farnorth</i>	148914	185193	188118	238256
<i>R0</i>	1	<i>farnorth_1979</i>	123929	155090	157832	202459
<i>R0</i>	1	<i>totalCRAI</i>	222658	279556	283009	357640
<i>R0</i>	1	<i>totalCRAI_1979</i>	225527	286555	294349	387856
<i>U0</i>	1	<i>farnorth_1979</i>	0.111	0.142	0.143	0.179
<i>U0</i>	1	<i>totalCRAI_1979</i>	0.059	0.088	0.088	0.116
<i>galpha</i>	1	<i>farnorth</i>	16.514	17.932	17.918	19.316
<i>galpha</i>	1	<i>farnorth_1979</i>	16.803	18.173	18.166	19.527
<i>galpha</i>	1	<i>totalCRAI</i>	17.124	18.521	18.505	19.866
<i>galpha</i>	1	<i>totalCRAI_1979</i>	17.043	18.415	18.410	19.718
<i>galpha</i>	2	<i>farnorth</i>	22.759	23.501	23.497	24.218
<i>galpha</i>	2	<i>farnorth_1979</i>	22.397	23.204	23.196	23.963
<i>galpha</i>	2	<i>totalCRAI</i>	22.373	23.197	23.182	23.971
<i>galpha</i>	2	<i>totalCRAI_1979</i>	22.423	23.231	23.225	24.006
<i>gcv</i>	1	<i>farnorth</i>	0.367	0.389	0.389	0.411
<i>gcv</i>	1	<i>farnorth_1979</i>	0.364	0.387	0.387	0.409
<i>gcv</i>	1	<i>totalCRAI</i>	0.365	0.388	0.388	0.410
<i>gcv</i>	1	<i>totalCRAI_1979</i>	0.366	0.388	0.388	0.410
<i>gcv</i>	2	<i>farnorth</i>	0.628	0.666	0.666	0.706
<i>gcv</i>	2	<i>farnorth_1979</i>	0.631	0.667	0.667	0.704
<i>gcv</i>	2	<i>totalCRAI</i>	0.631	0.669	0.669	0.707
<i>gcv</i>	2	<i>totalCRAI_1979</i>	0.632	0.668	0.669	0.708
<i>gdifff</i>	1	<i>farnorth</i>	0.116	0.130	0.131	0.148
<i>gdifff</i>	1	<i>farnorth_1979</i>	0.115	0.129	0.130	0.145
<i>gdifff</i>	1	<i>totalCRAI</i>	0.112	0.125	0.125	0.141
<i>gdifff</i>	1	<i>totalCRAI_1979</i>	0.113	0.126	0.127	0.142
<i>gdifff</i>	2	<i>farnorth</i>	0.045	0.049	0.049	0.052
<i>gdifff</i>	2	<i>farnorth_1979</i>	0.047	0.050	0.050	0.054
<i>gdifff</i>	2	<i>totalCRAI</i>	0.047	0.050	0.050	0.054
<i>gdifff</i>	2	<i>totalCRAI_1979</i>	0.046	0.050	0.050	0.054
<i>gobs</i>	1	<i>farnorth</i>	1.372	1.475	1.475	1.580
<i>gobs</i>	1	<i>farnorth_1979</i>	1.378	1.478	1.478	1.576
<i>gobs</i>	1	<i>totalCRAI</i>	1.378	1.475	1.476	1.577
<i>gobs</i>	1	<i>totalCRAI_1979</i>	1.373	1.474	1.476	1.580
<i>gshape</i>	1	<i>farnorth</i>	3.371	3.818	3.825	4.297
<i>gshape</i>	1	<i>farnorth_1979</i>	3.458	3.907	3.907	4.381
<i>gshape</i>	1	<i>totalCRAI</i>	3.557	4.026	4.026	4.505
<i>gshape</i>	1	<i>totalCRAI_1979</i>	3.521	3.985	3.990	4.459

Parameter	Number	Model	5%	Median	Mean	95%
<i>gshape</i>	2	<i>farnorth</i>	7.122	7.493	7.499	7.892
<i>gshape</i>	2	<i>farnorth_1979</i>	7.028	7.412	7.409	7.803
<i>gshape</i>	2	<i>totalCRA1</i>	7.006	7.398	7.404	7.819
<i>gshape</i>	2	<i>totalCRA1_1979</i>	7.021	7.411	7.415	7.822
<i>sel50</i>	1	<i>farnorth</i>	51.924	53.050	53.015	53.956
<i>sel50</i>	1	<i>farnorth_1979</i>	51.638	52.688	52.666	53.623
<i>sel50</i>	1	<i>totalCRA1</i>	51.652	52.831	52.796	53.830
<i>sel50</i>	1	<i>totalCRA1_1979</i>	51.800	52.950	52.936	53.949
<i>sel50</i>	2	<i>farnorth</i>	48.237	49.748	49.748	51.253
<i>sel50</i>	2	<i>farnorth_1979</i>	47.819	49.397	49.414	51.069
<i>sel50</i>	2	<i>totalCRA1</i>	48.717	50.156	50.171	51.692
<i>sel50</i>	2	<i>totalCRA1_1979</i>	48.634	50.151	50.137	51.552
<i>sel95</i>	1	<i>farnorth</i>	10.098	10.810	10.835	11.643
<i>sel95</i>	1	<i>farnorth_1979</i>	10.097	10.865	10.877	11.705
<i>sel95</i>	1	<i>totalCRA1</i>	10.095	10.916	10.932	11.834
<i>sel95</i>	1	<i>totalCRA1_1979</i>	10.138	10.948	10.958	11.781
<i>sel95</i>	2	<i>farnorth</i>	9.035	10.619	10.652	12.377
<i>sel95</i>	2	<i>farnorth_1979</i>	8.947	10.538	10.613	12.573
<i>sel95</i>	2	<i>totalCRA1</i>	9.744	11.329	11.374	13.079
<i>sel95</i>	2	<i>totalCRA1_1979</i>	9.759	11.308	11.316	12.989
<i>selmax</i>	1	<i>farnorth</i>	0.493	0.567	0.569	0.656
<i>selmax</i>	1	<i>farnorth_1979</i>	0.493	0.563	0.566	0.644
<i>selmax</i>	1	<i>totalCRA1</i>	0.466	0.538	0.540	0.619
<i>selmax</i>	1	<i>totalCRA1_1979</i>	0.458	0.529	0.531	0.614
<i>selmax</i>	2	<i>farnorth</i>	0.847	0.885	0.885	0.926
<i>selmax</i>	2	<i>farnorth_1979</i>	0.840	0.878	0.878	0.918
<i>selmax</i>	2	<i>totalCRA1</i>	0.794	0.825	0.825	0.857
<i>selmax</i>	2	<i>totalCRA1_1979</i>	0.783	0.815	0.816	0.848
<i>selmax</i>	3	<i>farnorth</i>	0.796	0.906	0.909	1.034
<i>selmax</i>	3	<i>farnorth_1979</i>	0.789	0.885	0.889	1.003
<i>selmax</i>	3	<i>totalCRA1</i>	0.722	0.819	0.821	0.930
<i>selmax</i>	3	<i>totalCRA1_1979</i>	0.706	0.801	0.802	0.906

Table 16: Base case and sensitivity run MCMC derived quantities, reporting the median and 90% credible intervals of the posterior distribution. Biomass values in tonnes, H (handling mortality) in tonnes, U is an exploitation rate bounded between 0 and 1.

Variable	Model	5%	Median	95%
B	<i>farnorth</i>	363.953	449.912	557.456
B	<i>farnorth_1979</i>	344.980	429.210	527.498
B	<i>totalCRA1</i>	558.224	679.049	818.715
B	<i>totalCRA1_1979</i>	561.483	674.330	820.795
B / B_0	<i>farnorth</i>	0.219	0.290	0.385
B / B_0	<i>farnorth_1979</i>	0.120	0.185	0.279
B / B_0	<i>totalCRA1</i>	0.183	0.243	0.325

Variable	Model	5%	Median	95%
B / B_0	<i>totalCRA1_1979</i>	0.169	0.247	0.360
B / B_{MIN}	<i>farnorth</i>	1.256	1.532	1.954
B / B_{MIN}	<i>farnorth_1979</i>	1.336	1.632	2.002
B / B_{MIN}	<i>totalCRA1</i>	1.270	1.480	1.722
B / B_{MIN}	<i>totalCRA1_1979</i>	1.261	1.472	1.695
B_0	<i>farnorth</i>	1337.491	1549.299	1781.786
B_0	<i>farnorth_1979</i>	1732.089	2290.764	3257.308
B_0	<i>totalCRA1</i>	2340.607	2790.566	3306.144
B_0	<i>totalCRA1_1979</i>	2113.881	2702.754	3595.728
SSB	<i>farnorth</i>	326.699	388.131	463.275
SSB	<i>farnorth_1979</i>	313.930	373.990	440.382
SSB	<i>totalCRA1</i>	473.747	558.418	654.270
SSB	<i>totalCRA1_1979</i>	478.686	562.747	670.747
SSB / SSB_0	<i>farnorth</i>	0.431	0.526	0.633
SSB / SSB_0	<i>farnorth_1979</i>	0.264	0.377	0.510
SSB / SSB_0	<i>totalCRA1</i>	0.353	0.439	0.542
SSB / SSB_0	<i>totalCRA1_1979</i>	0.336	0.446	0.581
SSB_0	<i>farnorth</i>	670.444	739.207	814.079
SSB_0	<i>farnorth_1979</i>	802.806	984.860	1323.431
SSB_0	<i>totalCRA1</i>	1132.613	1271.230	1438.731
SSB_0	<i>totalCRA1_1979</i>	1065.201	1250.816	1530.739
T	<i>farnorth</i>	732.725	886.742	1077.699
T	<i>farnorth_1979</i>	689.967	837.074	1009.171
T	<i>totalCRA1</i>	1091.379	1308.817	1553.570
T	<i>totalCRA1_1979</i>	1103.012	1312.807	1598.278
T / T_0	<i>farnorth</i>	0.304	0.391	0.495
T / T_0	<i>farnorth_1979</i>	0.174	0.260	0.375
T / T_0	<i>totalCRA1</i>	0.250	0.327	0.423
T / T_0	<i>totalCRA1_1979</i>	0.237	0.332	0.464
T_0	<i>farnorth</i>	2023.202	2270.147	2545.131
T_0	<i>farnorth_1979</i>	2509.023	3208.184	4436.499
T_0	<i>totalCRA1</i>	3485.789	4010.493	4643.541
T_0	<i>totalCRA1_1979</i>	3208.218	3912.578	5014.894
U	<i>farnorth</i>	0.072	0.088	0.106
U	<i>farnorth_1979</i>	0.077	0.093	0.113
U	<i>totalCRA1</i>	0.066	0.079	0.095
U	<i>totalCRA1_1979</i>	0.066	0.080	0.095
H	<i>farnorth</i>	0.970	1.051	1.145
H	<i>farnorth_1979</i>	0.982	1.062	1.149
H	<i>totalCRA1</i>	0.992	1.077	1.175
H	<i>totalCRA1_1979</i>	0.990	1.074	1.175

Table 17: Probabilities calculated from the MCMC posteriors for the indicated derived quantities.

Variable	Far North	farnorth_1979	totalCRA1	totalCRA1_1979
$P(SSB_{2025} < 20\% SSB_0)$	0.000	0.002	0.000	0.000
$P(SSB_{2025} < 10\% SSB_0)$	0.000	0.000	0.000	0.000
$P(B_{2025} > B_{MIN})$	1.000	1.000	1.000	1.000

Table 18: Reference level summary for Far North and farnorth_1979 sensitivity.

Variable	Far North	farnorth_1979
B_R	265	0.171
B_R / B_0	0.171	0.166
B_{2024} / B_R	1.708	1.108
$P(B_{2024} > B_R)$	1.000	0.792
U_R	0.194	0.130
U_{2024} / U_R	0.454	0.717
$P(U_{2024} > U_R)$	0.000	0.001

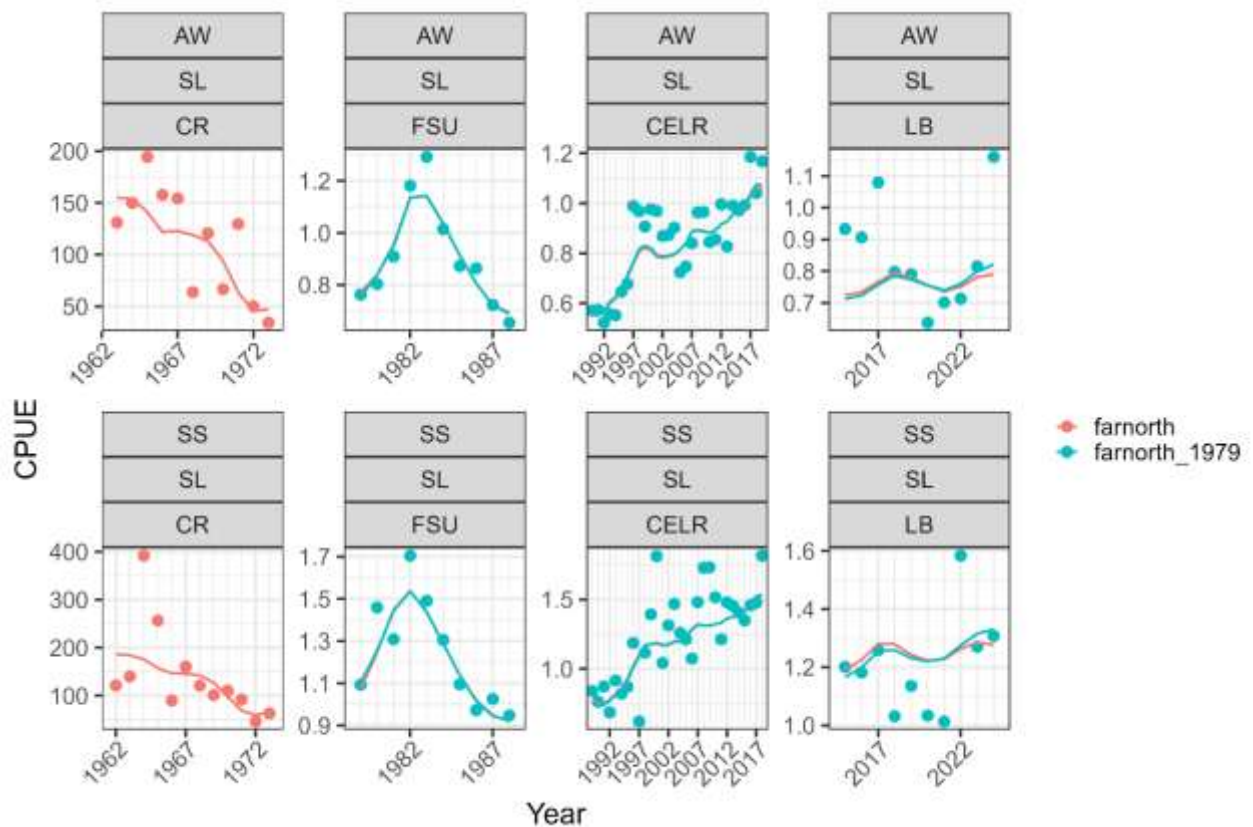


Figure 41: Comparison of CPUE fits for Far North models.

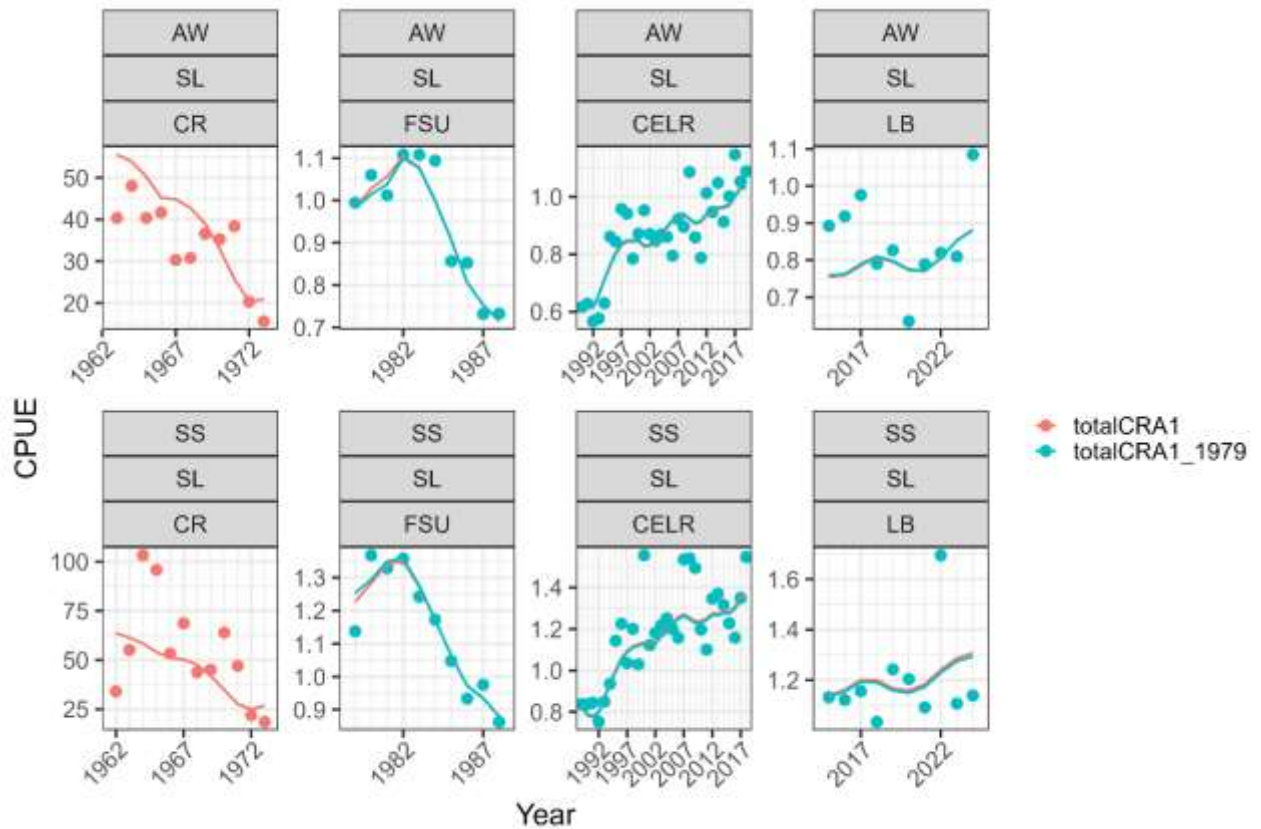


Figure 42: Comparison of CPUE fits for totalCRA1 models.

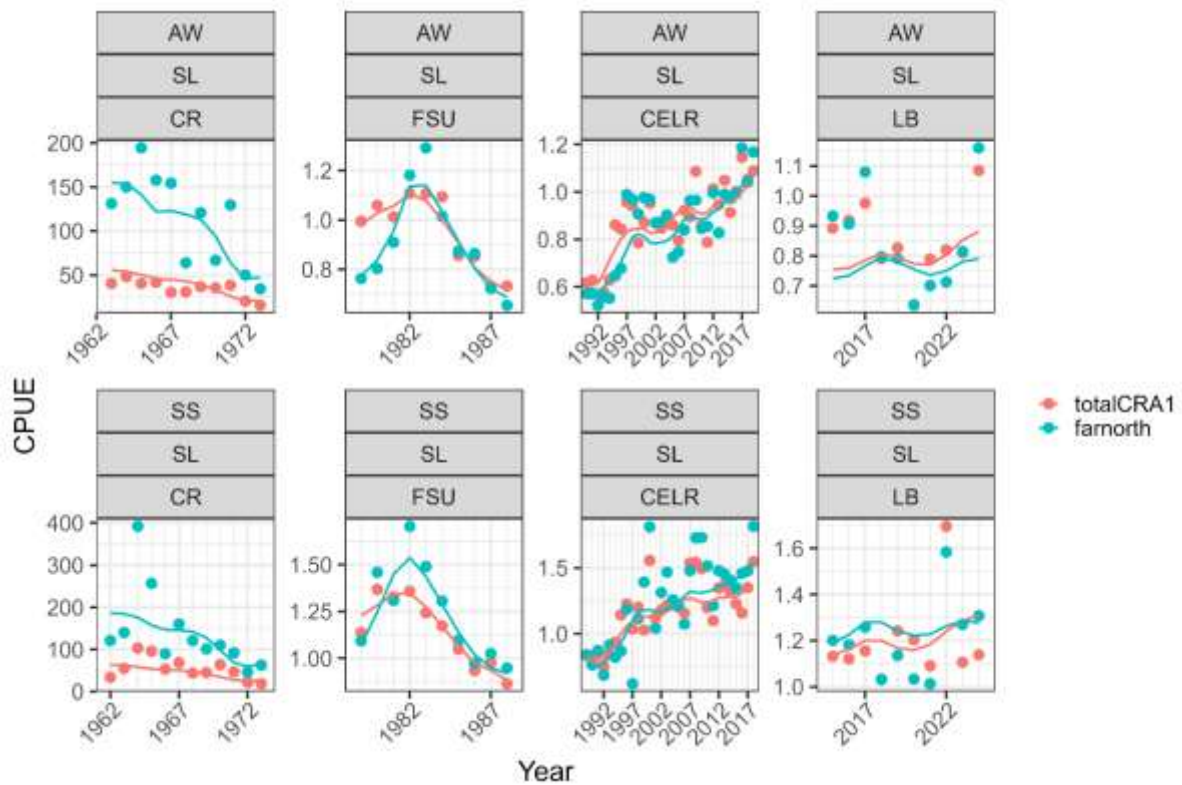


Figure 43: Comparison of CPUE fits for models starting in 1945.

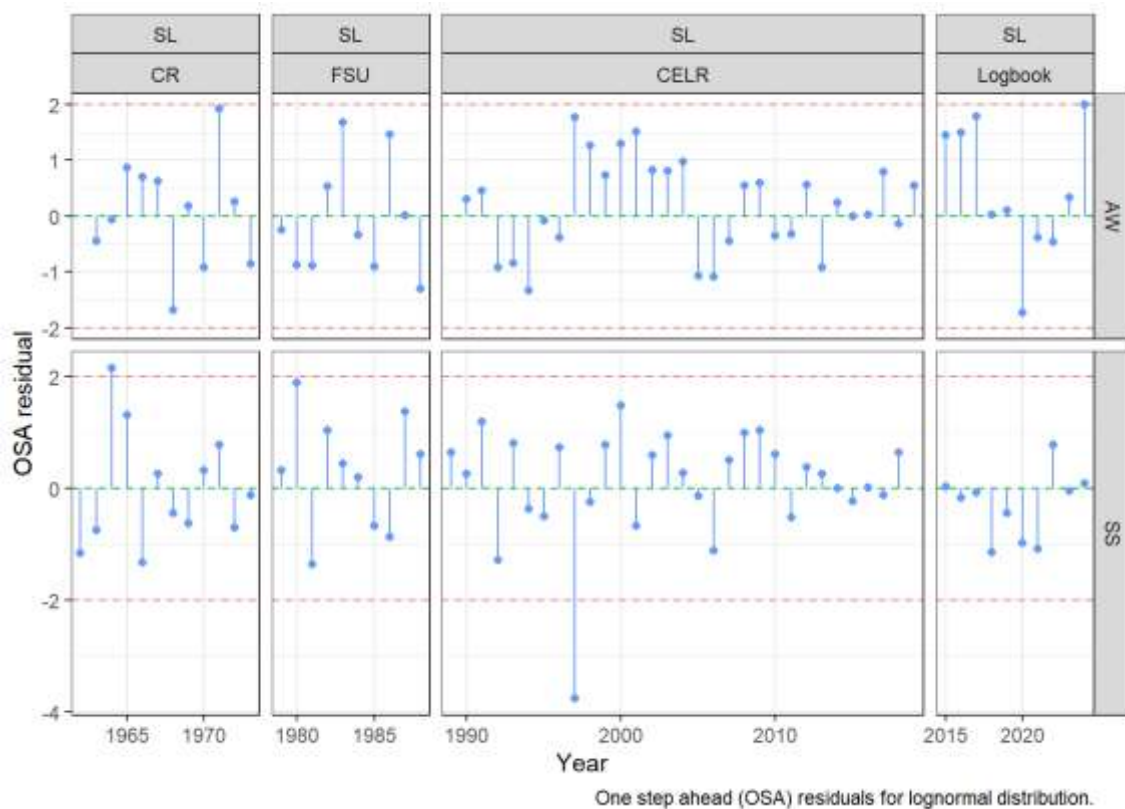


Figure 44: CPUE OSA residuals for the Far North model.

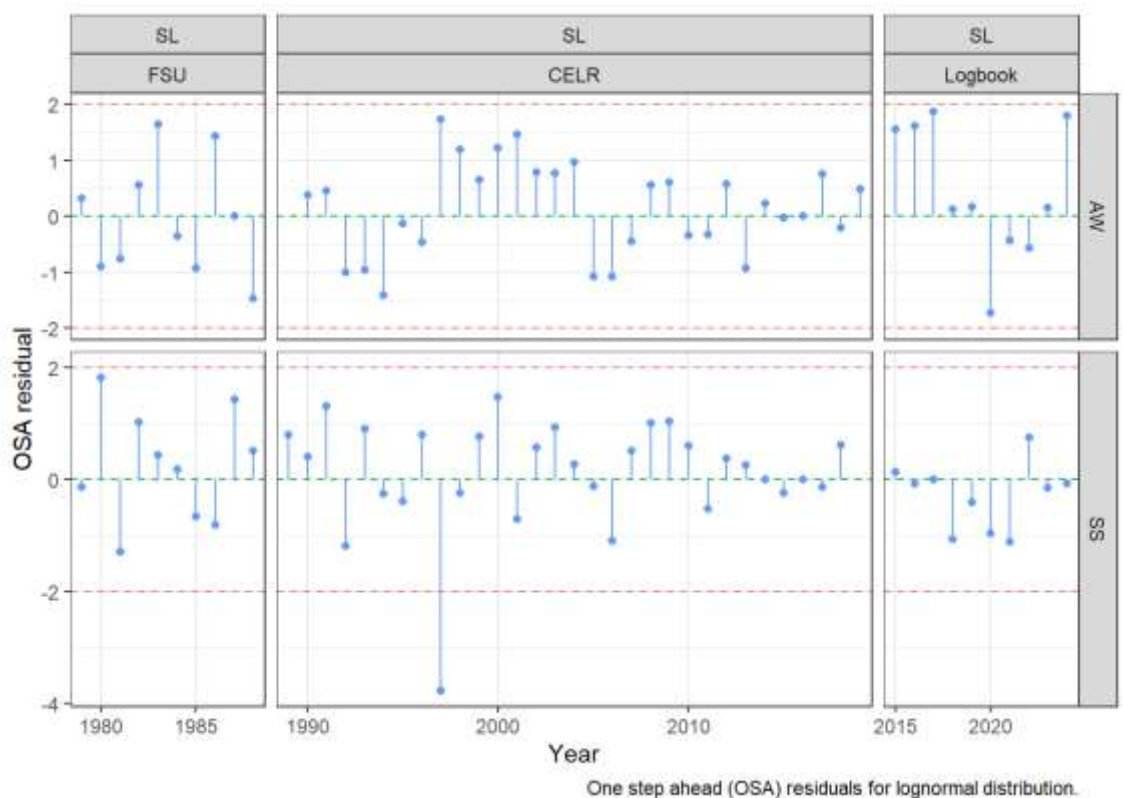


Figure 45: CPUE OSA residuals for the farnorth_1979 model.

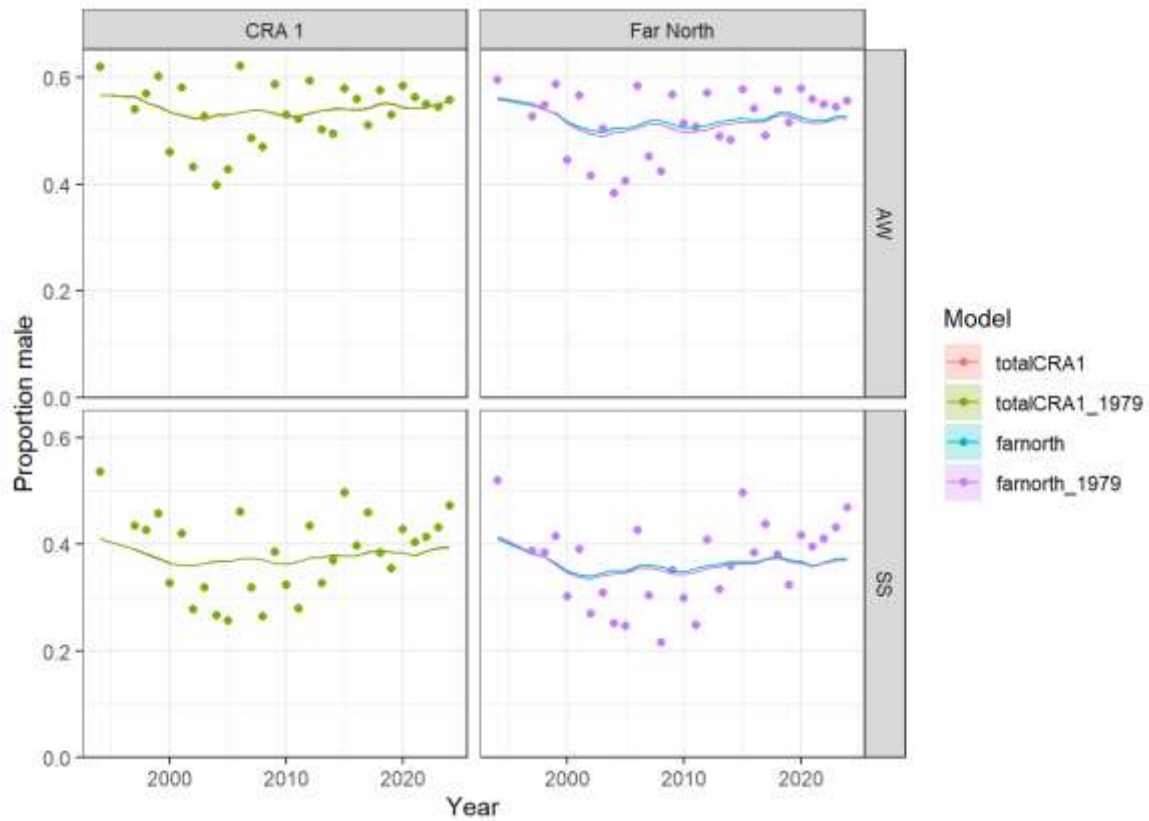


Figure 46: Comparison of sex ratio fits for model sensitivity runs.

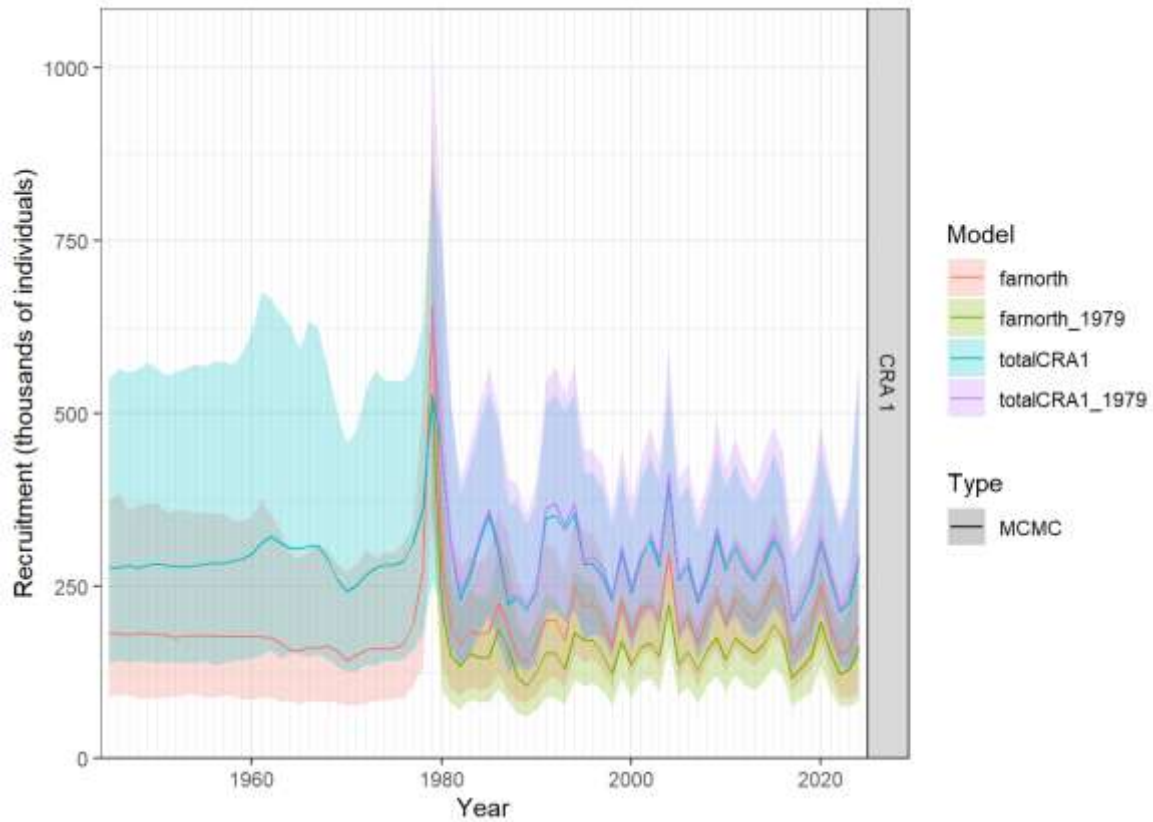


Figure 47: Comparison of recruitment by fishing year for farnorth and totalCRA1 models starting in 1945 and 1979.

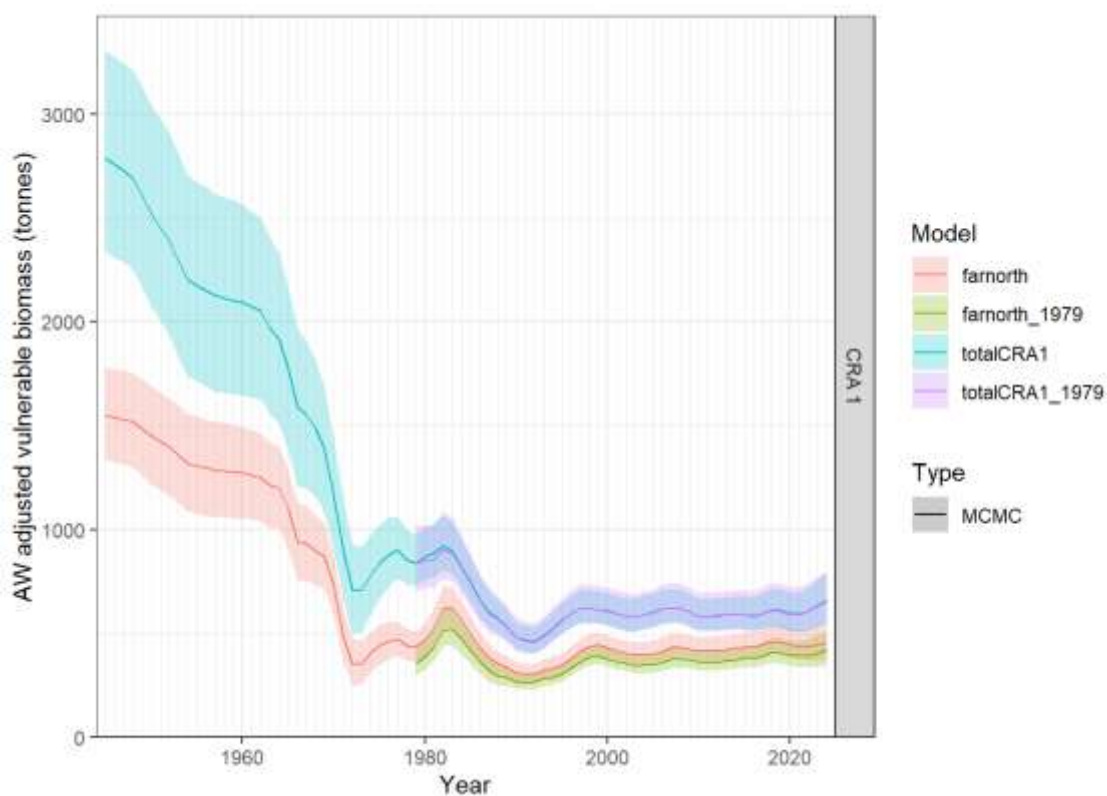


Figure 48: Comparison of AW adjusted vulnerable biomass by fishing year for farnorth and totalCRA1 models starting in 1945 and 1979.

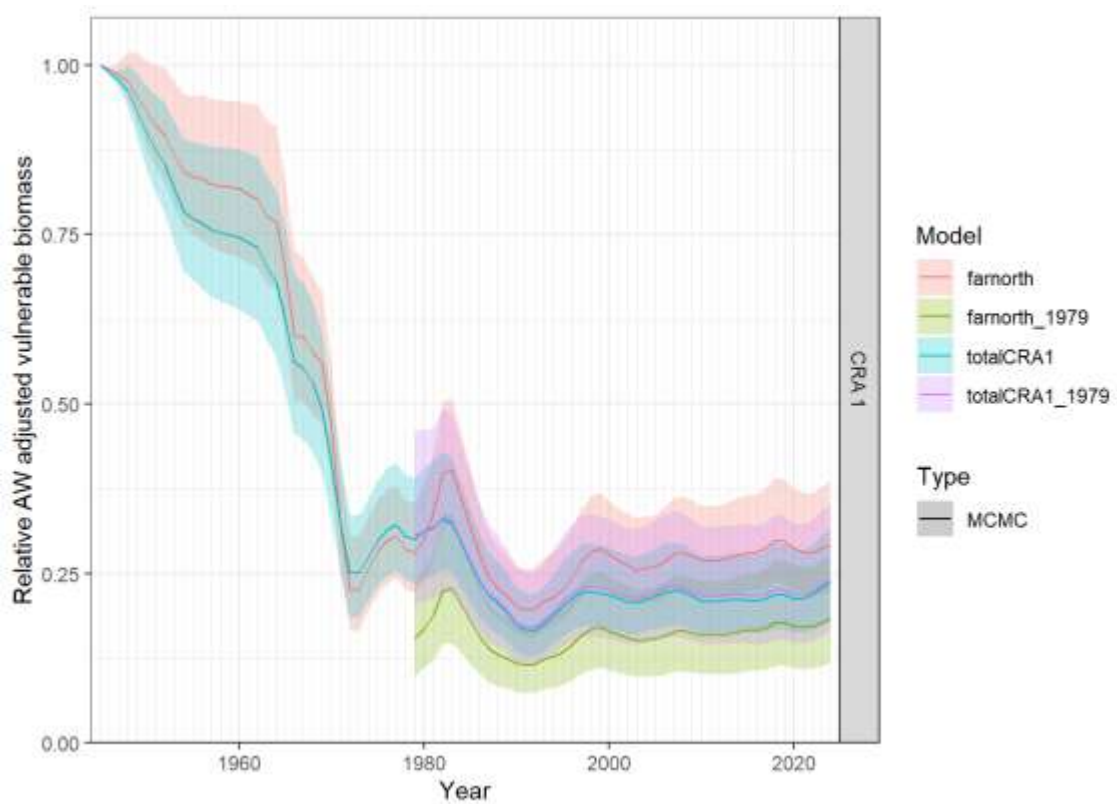


Figure 49: Comparison of relative AW adjusted vulnerable biomass by fishing year for farnorth and totalCRA1 models starting in 1945 and 1979.

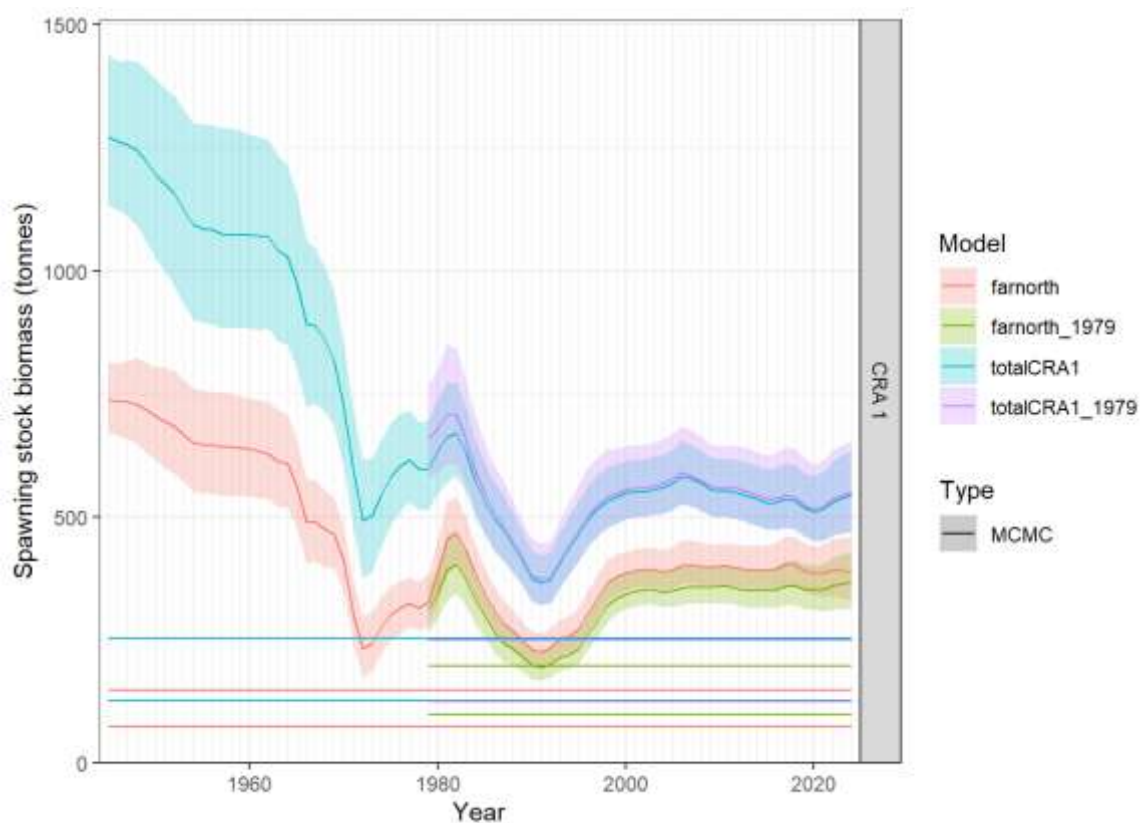


Figure 50: Comparison of spawning stock biomass by fishing year for farnorth and totalCRA1 models starting in 1945 and 1979.

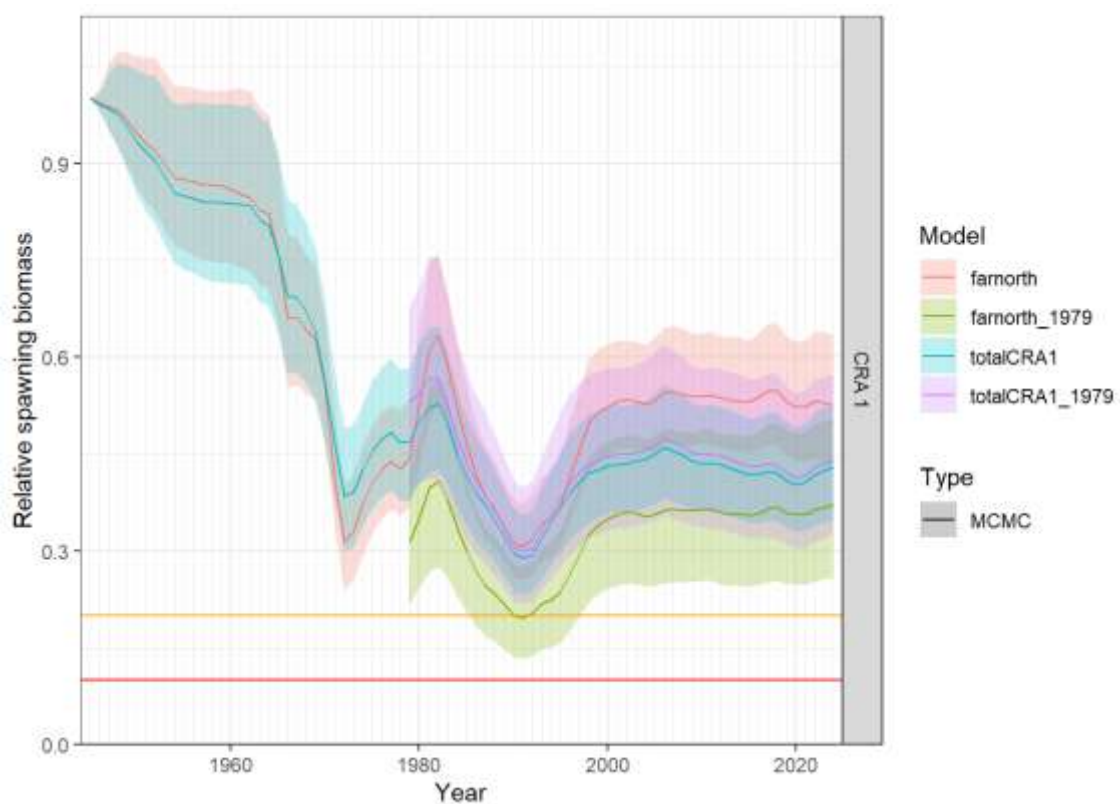


Figure 51: Comparison of relative spawning stock biomass (SSB) by fishing year for the Far North (farnorth) and totalCRA1 models starting in 1945 and 1979.

4 DISCUSSION

The 2025 assessment made several improvements over the previous assessment of CRA 1 (Rudd et al. 2021b), including:

- Covariate and data input improvements:
 - fitted to an updated logbook CPUE index of relative abundance from 2015 to 2024;
 - fitted to standardised length frequencies and proportions male, with more defensible data weightings for these observation types resulting in improvements in model fits to these data;
 - improved assumptions about the magnitude of historical recreational and illegal catches;
 - used an externally estimated maturity ogive;
 - used an externally estimated proportion berried at length ogive to describe female egg bearing dynamics;
 - excluded tag release-recovery pairs that were at liberty for less than six months in order to reduce or eliminate bias in growth estimation resulting from recoveries of lobsters that had not yet moulted,
 - represented the Far North region as a primary model with the total CRA 1 area as a secondary model, to better represent recent and future dynamics in resource utilisation of CRA 1, given the current closure of the eastern Statistical Areas 903, 904, and northern 905 to all forms of red rock lobster harvesting until at least 1 April 2031.
- Model structure improvements:
 - by introducing the new RTMB *decamod* model, the 2025 stock assessment moved from modelling three sexes in the previous lobster stock dynamics (LSD) model to two sexes using *decamod*;
 - *decamod* also modelled recruitment deviates as a random effect along with estimating recruitments in the final four years constrained using an order 1 autoregressive (AR1) model. This manner of handling recruitments in the final reconstruction years is preferable to returning recruitments to a fixed value, usually R_0 ;
 - introduced length-varying natural mortality, a more plausible representation for a length-based model;
 - estimated the *Galpha* parameter at 30 mm TW to obtain sensible estimates of M_a ,
 - implemented effort “creep” (or learning) in all CPUE series;
 - simplifying vulnerability to take advantage of the reduction in the number of *decamod* sex categories: assumed to be one for males in the AW season, then estimating the relative female vulnerabilities in both seasons and the SS male vulnerability, with all estimated vulnerabilities allowed to exceed one.

The new *decamod* model improved the capacity to quickly and easily run, save, compare, and communicate models using RTMB, with better optimisation over the previous LSD model run with Stan (see Section 3.4.1). However, there was difficulty estimating the *Galpha* parameter at 50 mm TW, allowing growth to be unrealistically fast at smaller sizes and natural mortality M_a to be unrealistically high in order to kill off those individuals with fast growth. To solve this, *Galpha* was estimated at 30 mm TW, using a prior that was developed based on juvenile growth analyses derived from dive observations, to keep *Galpha* and M_a at more realistically levels. This approach worked for CRA 1, although it did not improve *Galpha* estimation for CRA 2 (Rudd et al. 2026). Despite the higher estimate of *Galpha* for females, the model was considered to have done a reasonable job at representing the CRA 1 stock.

This assessment describes a stock that was initially fished at a relatively low level through the 1950s, increasing during the 1960s (Figure 31). The SS exploitation rate peaked in the 1970s and 1980s before

levelling off by the 2000s. The AW exploitation rate rose from the 1960s to its highest level in the late 1990s and early 2000s and has been relatively stable since (Figure 31). This pattern of increasing exploitation rates resulted in a declining trend in vulnerable biomass through the mid-1970s to the late 1990s and has remained relatively stable since then (Figure 34). The stable vulnerable biomass can also be attributed to relatively stable recruitment with a lack of large peaks or troughs since the start of length frequency data collection (Figure 30). This stability has resulted in relatively constant catches for almost 20 years (Figure 28) and a maintenance of vulnerable biomass above the reference level (Figure 34) and well above the soft limit (Figure 36).

5 POTENTIAL RESEARCH

Potential research considerations relating directly to the stock assessment model include:

- explore the apparent influence of proportion male in the catch informing R_0 (as identified from likelihood profiles) in the CRA 1 assessment;
- review the validity of the prior for M ;
- allow different fisheries within the same region (i.e., the ‘areas as fisheries’ concept using different selectivities; this would enable different selectivities for any of the Statistical Areas with CRA 1);
- investigate the influence of growth priors where the posteriors are substantially different from the prior (e.g., *Gobs* and perhaps also *Gshape* for males) to determine whether these priors are appropriate and influential, and/or whether the growth meta-analysis needs to be redone;
- further explore the growth function, including possible separation by season; and
- explore alternative selectivity functions.

Future research considerations relating to the development of stock assessment inputs include:

- explore representativeness of the logbook pot and catch sampling data using fine scale position data;
- explore the feasibility of a fishery independent potting survey to develop an abundance index for key areas within CRA 1 (Statistical Areas 903 and 904), where commercial fishing activity has declined considerably;
- consider further analysing the potential for a bias in the estimation of growth that could result from the timing of tagging with respect to the timing of moulting;
- investigate alternative methods for collecting growth information across the vulnerable size range, such as direct ageing;
- develop a CPUE index series based on electronic reporting data as soon as possible;
- investigate alternative handling mortality assumptions; and
- further investigate the development of climate covariates, including SST series, for predicting temporal recruitment variability, as experienced by the fishery.

6 FULFILMENT OF BROADER OUTCOMES

Whakapapa links all people back to the land, sea, and sky, and our obligations to respect the physical world. This research aims to ensure the long-term sustainability of red rock lobster stocks, for the good of the wider community (including stakeholders and the public) and the marine ecosystems that lobsters inhabit. This project supports both Māori and regional businesses and our research is inextricably linked to the moana from the work it carries out and the tangata whenua it supports.

To support the wider fisheries science community and enable more value to be extracted from the limited resources (time and money) available for fisheries research we make as much code as possible open source (i.e., publicly available). Furthermore, this project has built capacity and capability in fisheries science and stock assessment by employing researchers with a range of experience so that

those with a long history of working in fisheries science can pass on their knowledge. This approach has meant that rock lobster stock assessments have consisted of a team with some members that have been involved for many years and some newer team members. This approach further mitigates risk associated with team members not being able to participate any longer.

7 ACKNOWLEDGEMENTS

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APPENDIX A. LOGBOOK CPUE DIAGNOSTICS

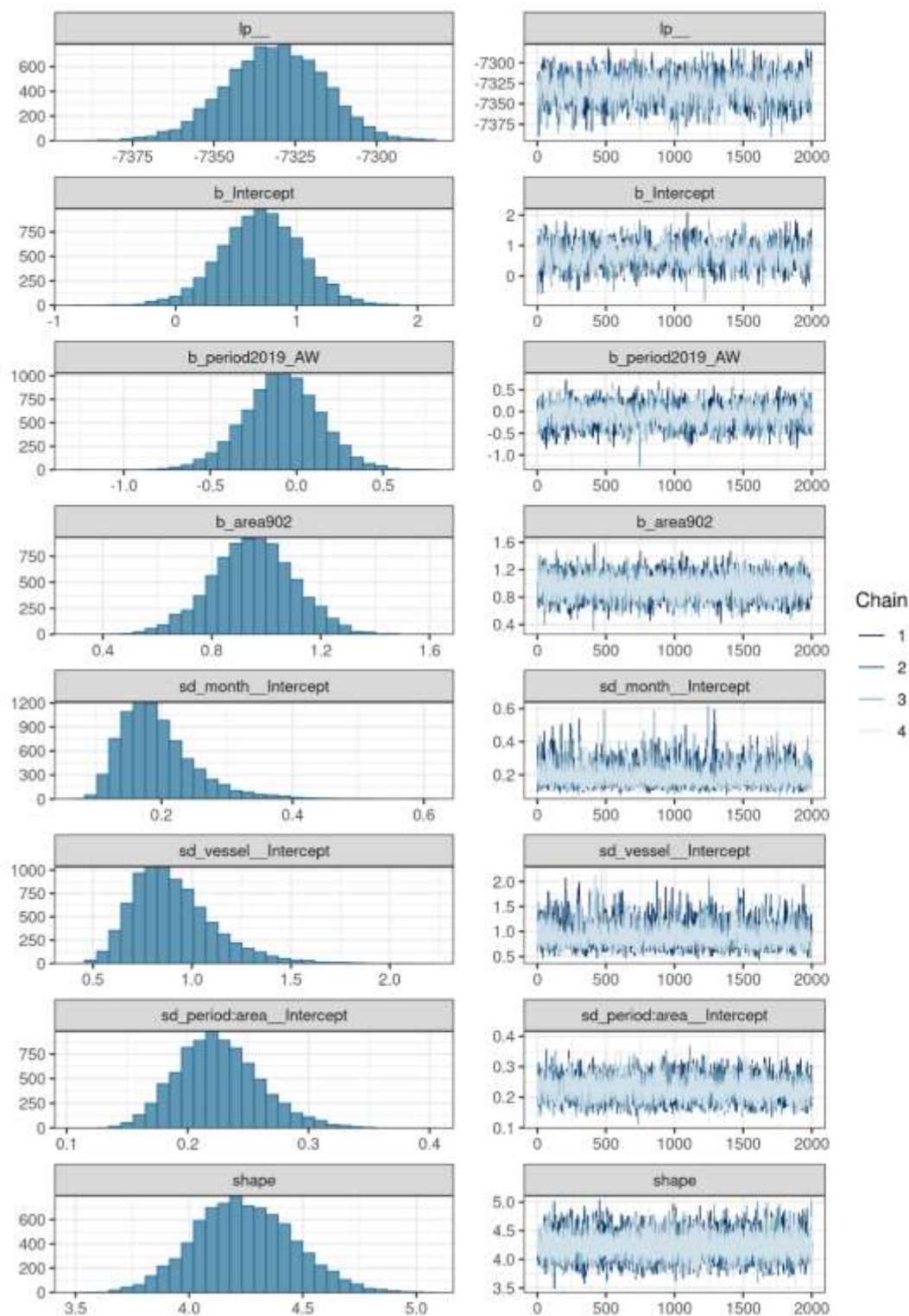


Figure A.1: MCMC trace plots for a subset of model parameters from the legal status logbook CPUE model.

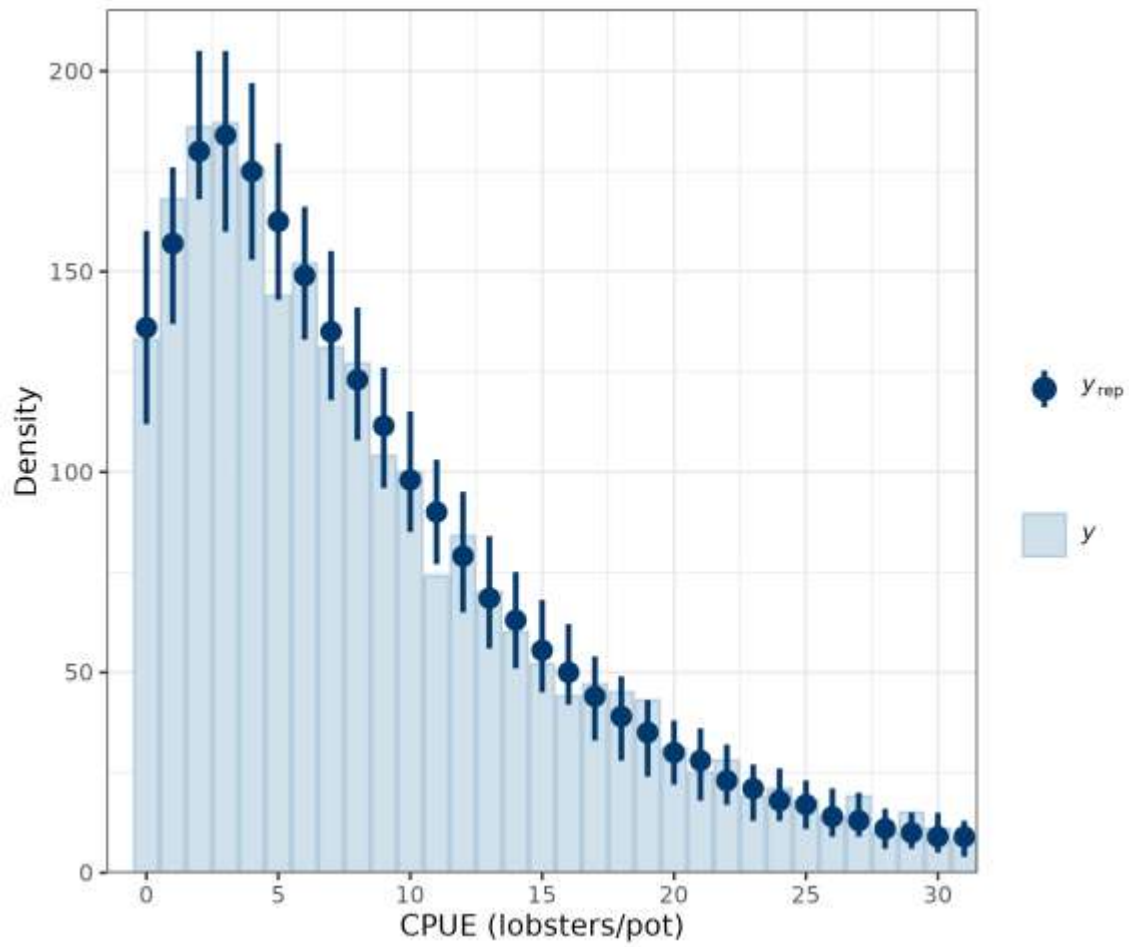


Figure A.2: Posterior predictive check plot for the legal status logbook CPUE model.

APPENDIX B. CATCH COMPOSITION ANALYSIS ADDITIONAL OUTPUTS

Table B.1: Summary of the catch sampling data from CRA 1 by the number of vessels, days, trips, pots and lobsters sampled under the catch sampling and logbook programmes. The data from fishing year-source strata shaded grey in this table were obtained from few vessels, so were excluded from the catch composition analysis.

Fishing year	Observer catch sampling (CS)					Voluntary logbook sampling (LB)					
	Vessels	Days	Trips	Pots	Lobsters	Vessels	Skippers	Days	Trips	Pots	Lobsters
1975	1	2	2	15	47	–	–	–	–	–	–
1976	2	8	8	142	427	–	–	–	–	–	–
1993	–	–	–	–	–	1	1	24	24	55	172
1994	–	–	–	–	–	2	2	59	64	142	475
1995	–	–	–	–	–	1	1	42	42	109	486
1996	–	–	–	–	–	–	–	–	–	–	–
1997	5	17	17	714	2 456	–	–	–	–	–	–
1998	3	9	9	504	2 633	–	–	–	–	–	–
1999	11	24	24	1 233	6 882	–	–	–	–	–	–
2000	9	15	15	895	4 605	–	–	–	–	–	–
2001	8	12	12	730	2 774	–	–	–	–	–	–
2002	6	15	15	897	4 655	–	–	–	–	–	–
2003	8	16	16	909	4 758	–	–	–	–	–	–
2004	6	15	15	748	4 046	–	–	–	–	–	–
2005	4	20	20	828	4 952	–	–	–	–	–	–
2006	6	15	15	878	4 789	–	–	–	–	–	–
2007	4	16	16	497	2 918	–	–	–	–	–	–
2008	6	15	15	704	3 677	–	–	–	–	–	–
2009	7	16	16	858	4 806	–	–	–	–	–	–
2010	9	16	16	845	4 078	–	–	–	–	–	–
2011	6	16	16	750	3 522	1	2	21	21	67	363
2012	4	15	15	1 005	6 912	1	1	16	16	53	464
2013	4	16	16	916	4 571	1	1	14	15	42	297
2014	4	18	18	744	3 994	2	2	32	33	97	420
2015	4	13	13	601	1 917	5	5	155	199	580	3 216
2016	4	18	18	963	5 911	6	6	160	225	548	2 803
2017	5	15	15	617	1 824	7	7	156	210	498	2 791
2018	4	18	18	920	3 460	7	7	147	246	568	3 148
2019	6	18	18	925	4 412	8	8	149	194	421	2 118
2020	5	19	19	850	4 160	8	8	142	199	522	2 415
2021	4	16	18	915	3 924	7	7	155	258	634	2 923
2022	5	19	19	1 219	7 886	8	8	170	290	902	4 460
2023	3	11	11	637	4 285	10	10	144	301	923	5 206
2024	4	16	16	766	5 905	8	8	129	205	662	3 856

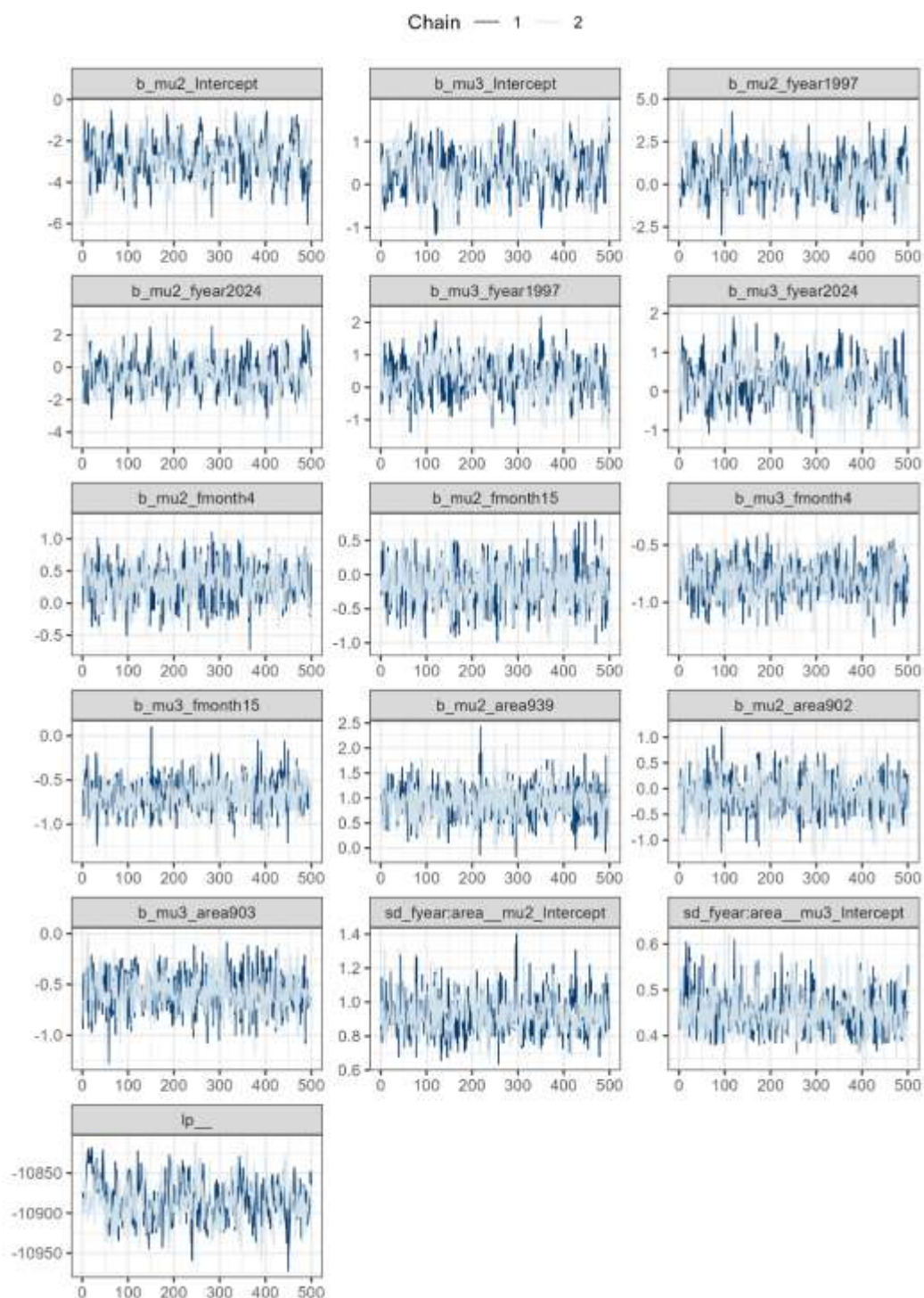


Figure B.1: MCMC trace plots for a subset of model parameters from the proportion male model.

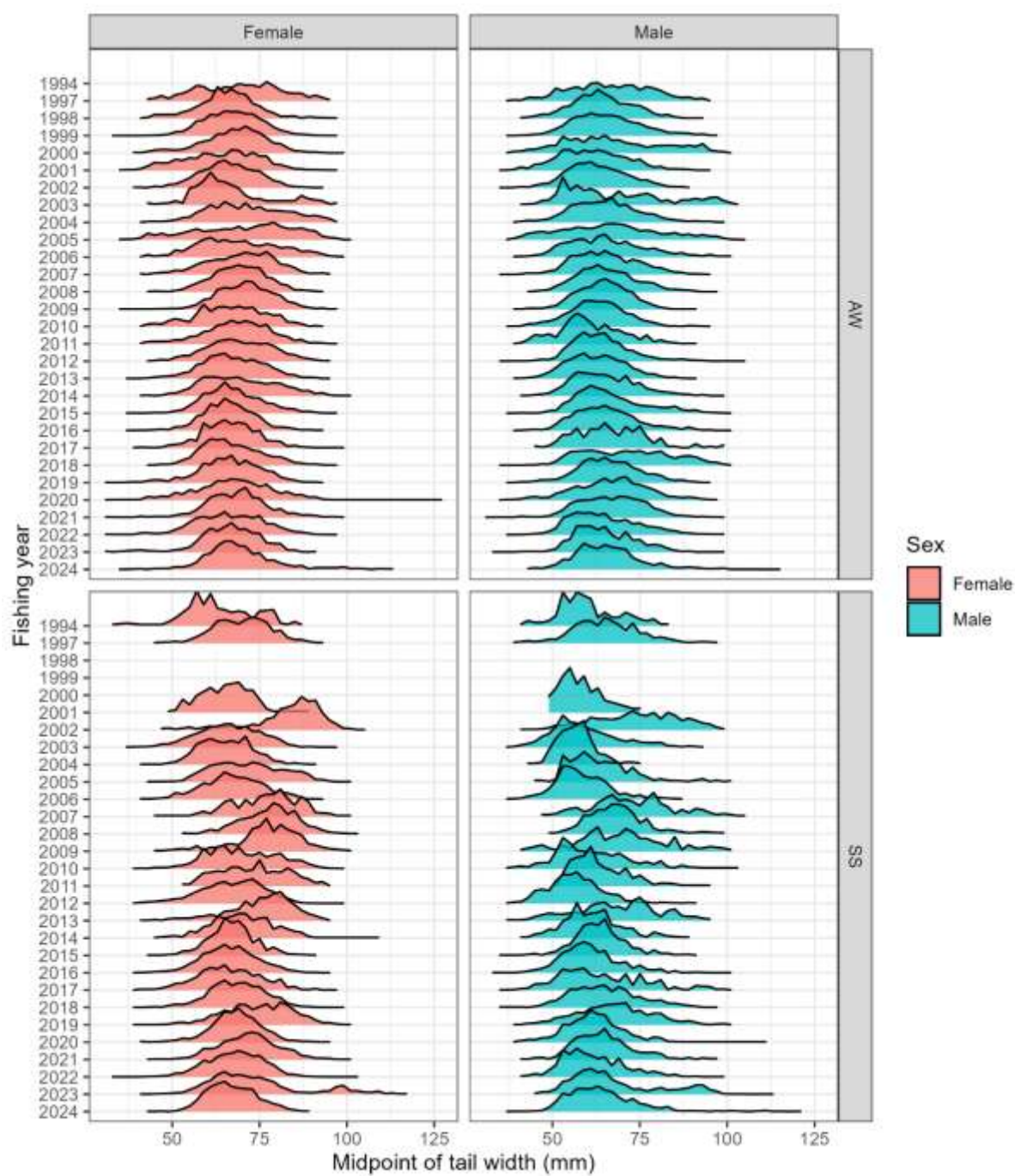


Figure B.2: Observed length frequencies by sex, season, and fishing year.

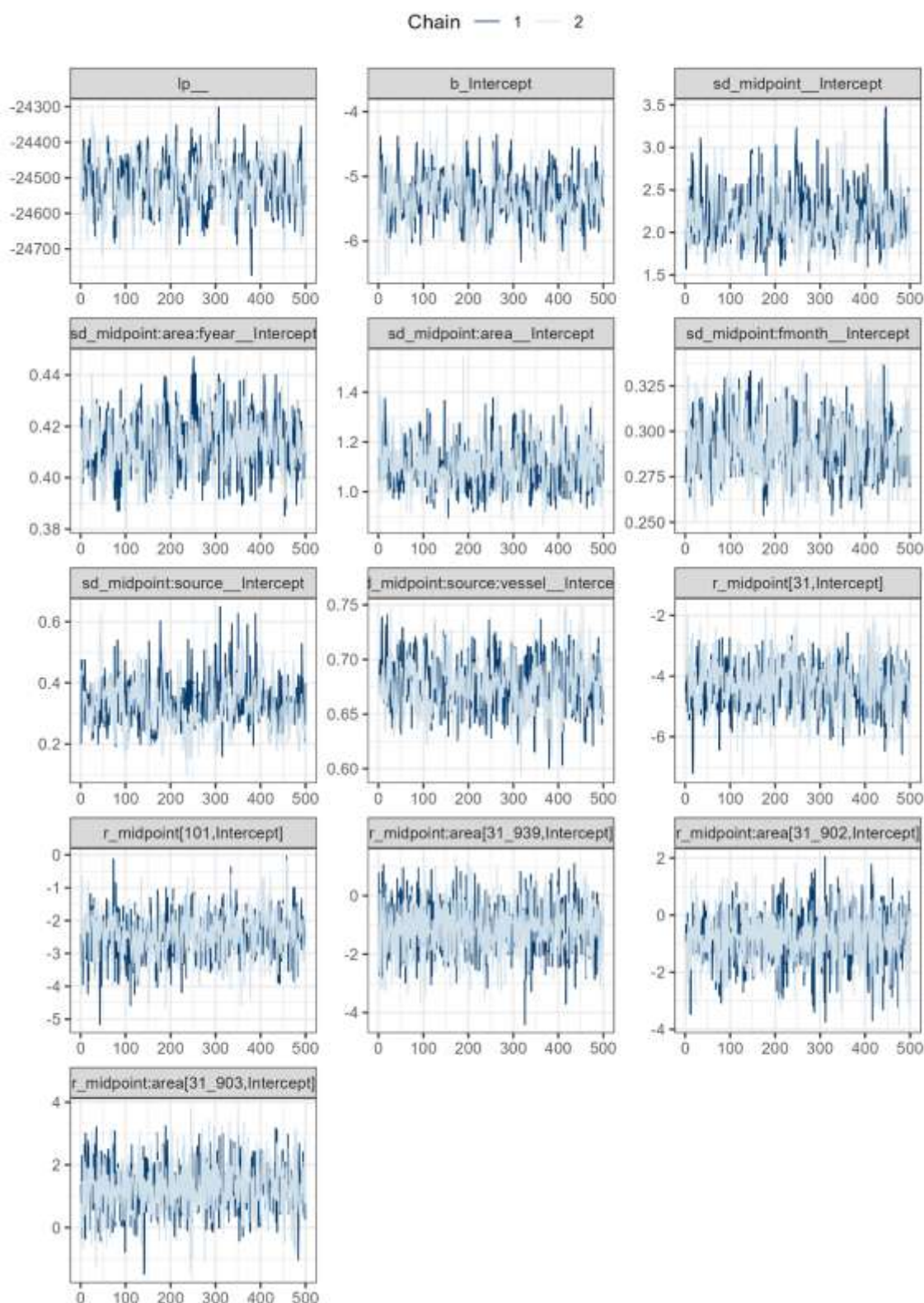


Figure B.3: MCMC trace plots for a subset of model parameters from the male LF model.

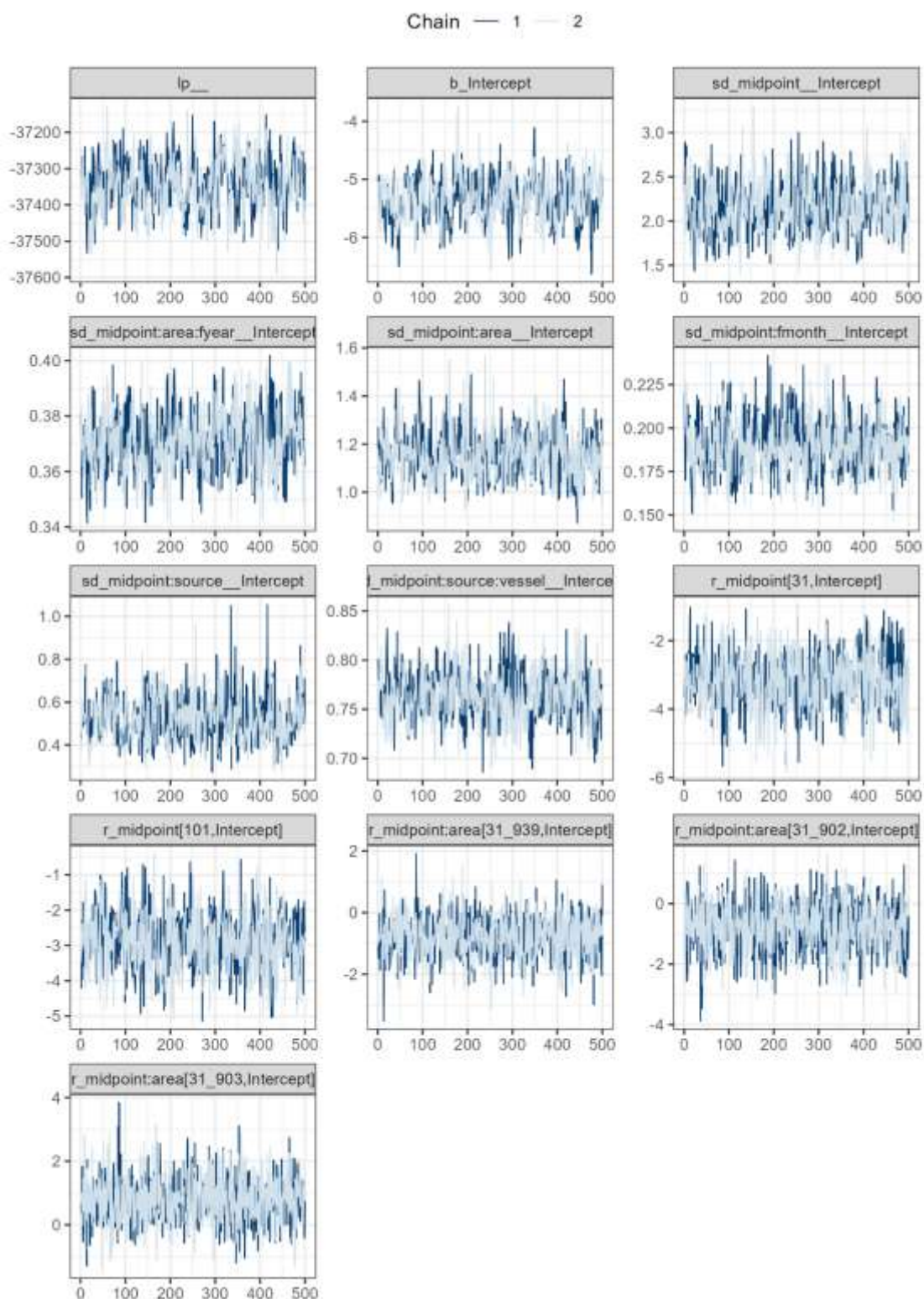


Figure B.4: MCMC trace plots for a subset of model parameters from the female LF model.

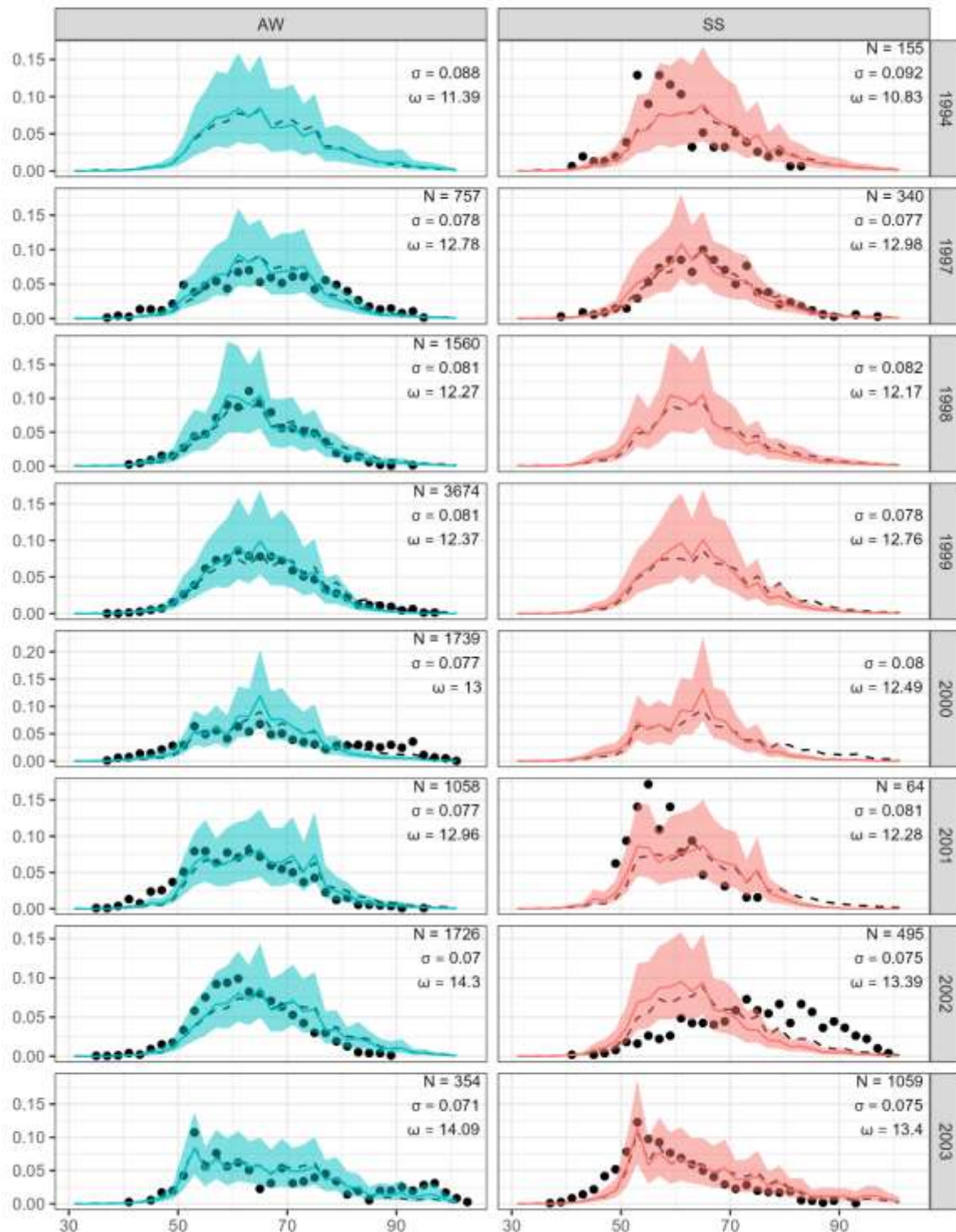


Figure B.5: CRA 1 Far North LFs for males by fishing year (from 1994 to 2003), season (AW = autumn/winter, SS = spring/summer), and TW bin. The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF distributions. The aggregated data (points) and unscaled predictions of the LF (dashed line) for the same stratum are also shown. Each panel also includes text which provides the number of lobsters measured (N), the SD of the predicted LF for each stratum (σ), and the data set weight for each stratum (ω).

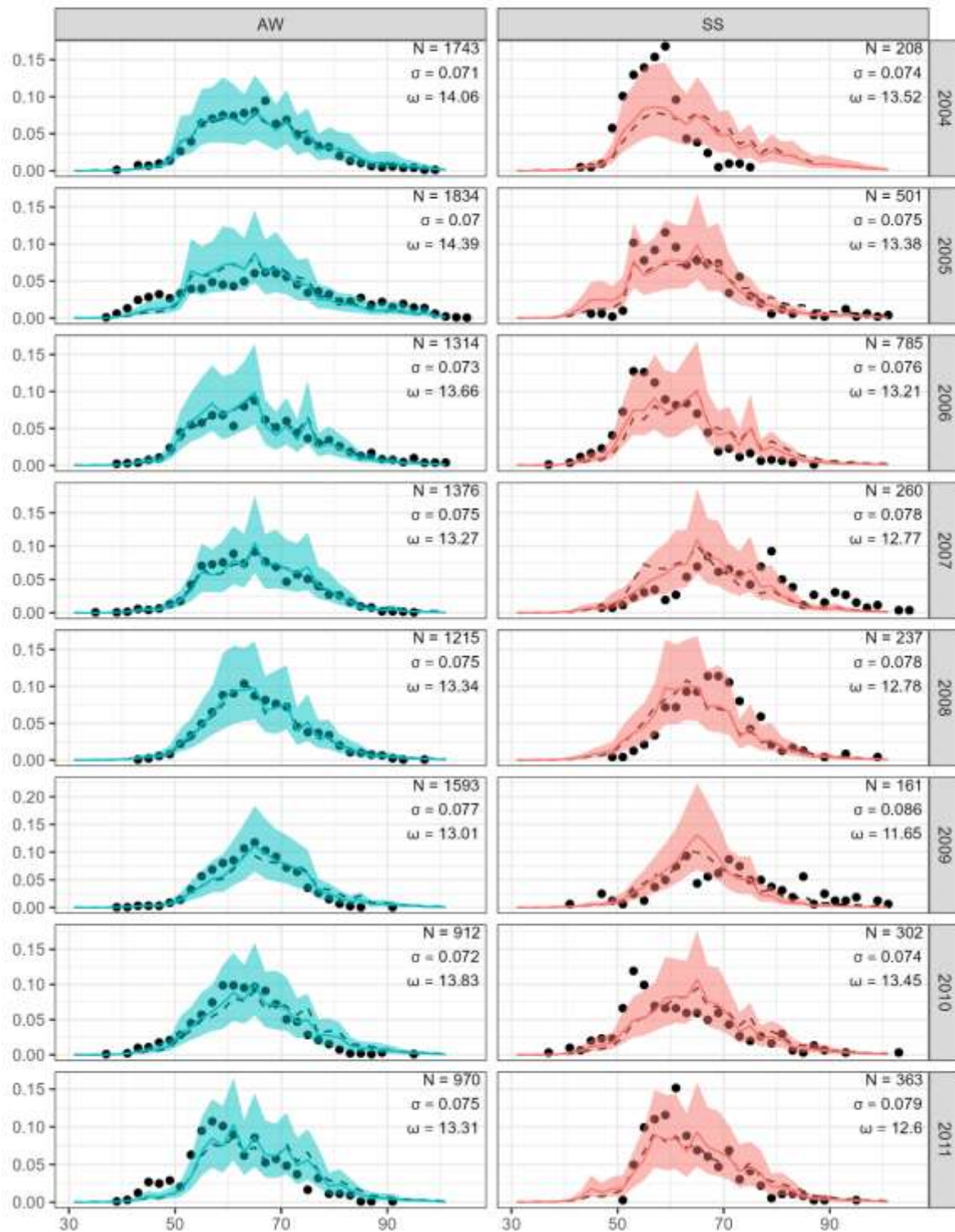


Figure B.6: CRA 1 Far North LFs for males by fishing year (from 2004 to 2011), season (AW = autumn/winter, SS = spring/summer), and TW bin. The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF distributions. The aggregated data (points) and unscaled predictions of the LF (dashed line) for the same stratum are also shown. Each panel also includes text which provides the number of lobsters measured (N), the SD of the predicted LF for each stratum (σ), and the data set weight for each stratum (ω).

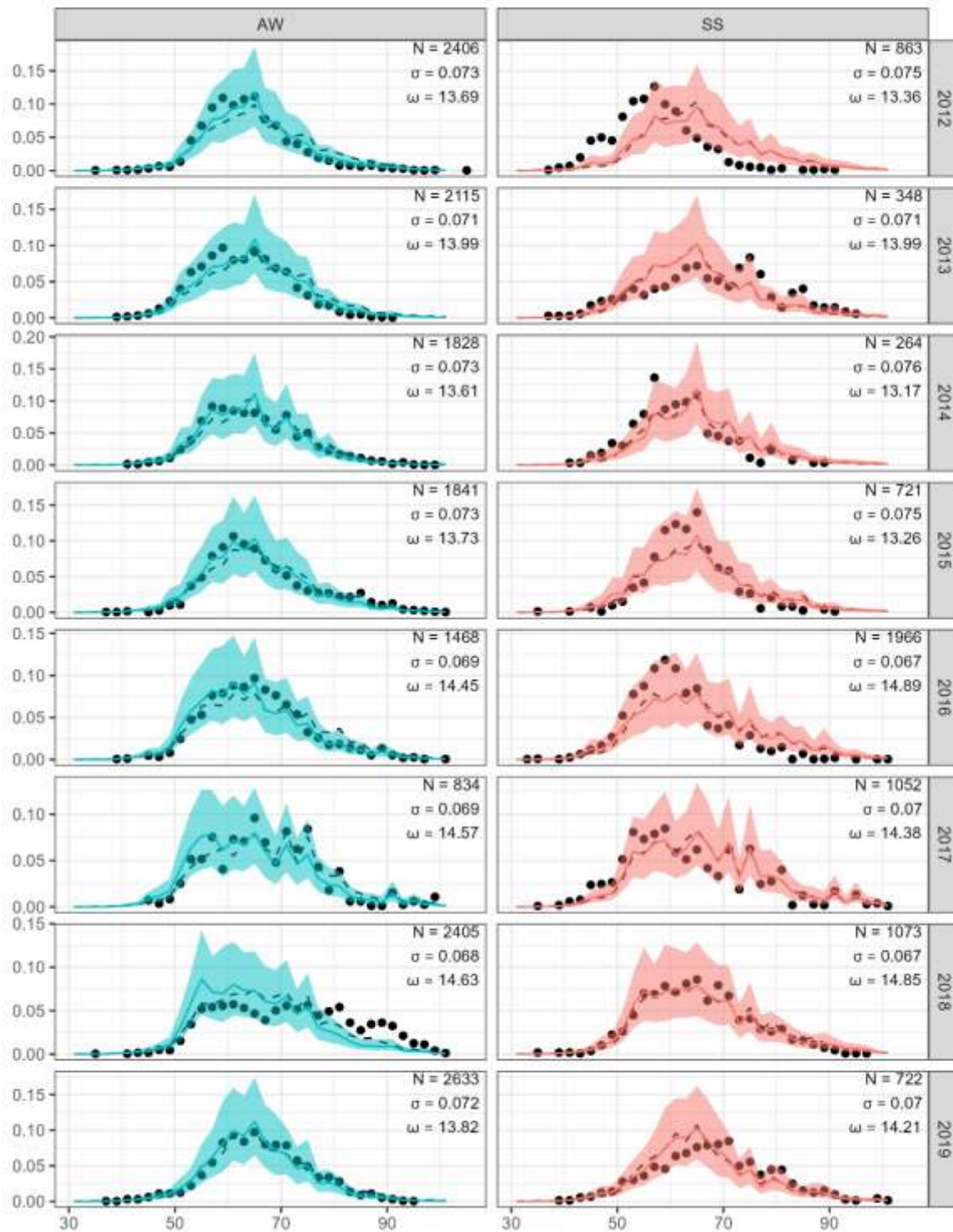


Figure B.7: CRA 1 Far North LFs for males by fishing year (from 2012 to 2019), season (AW = autumn/winter, SS = spring/summer), and TW bin. The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF distributions. The aggregated data (points) and unscaled predictions of the LF (dashed line) for the same stratum are also shown. Each panel also includes text which provides the number of lobsters measured (N), the SD of the predicted LF for each stratum (σ), and the data set weight for each stratum (ω).

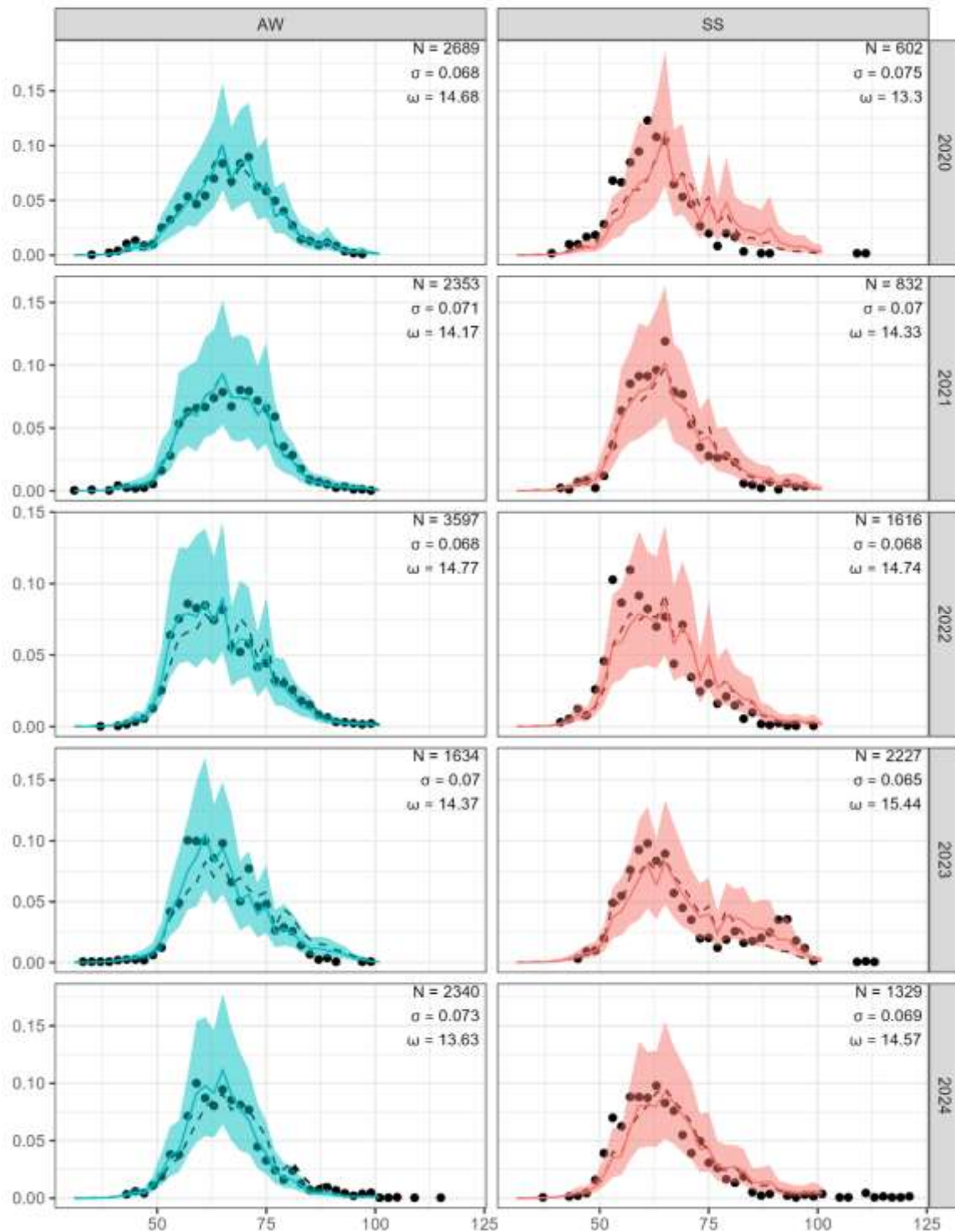


Figure B.8: CRA 1 Far North LFs for males by fishing year (from 2020 to 2024), season (AW = autumn/winter, SS = spring/summer), and TW bin. The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF distributions. The aggregated data (points) and unscaled predictions of the LF (dashed line) for the same stratum are also shown. Each panel also includes text which provides the number of lobsters measured (N), the SD of the predicted LF for each stratum (σ), and the data set weight for each stratum (ω).

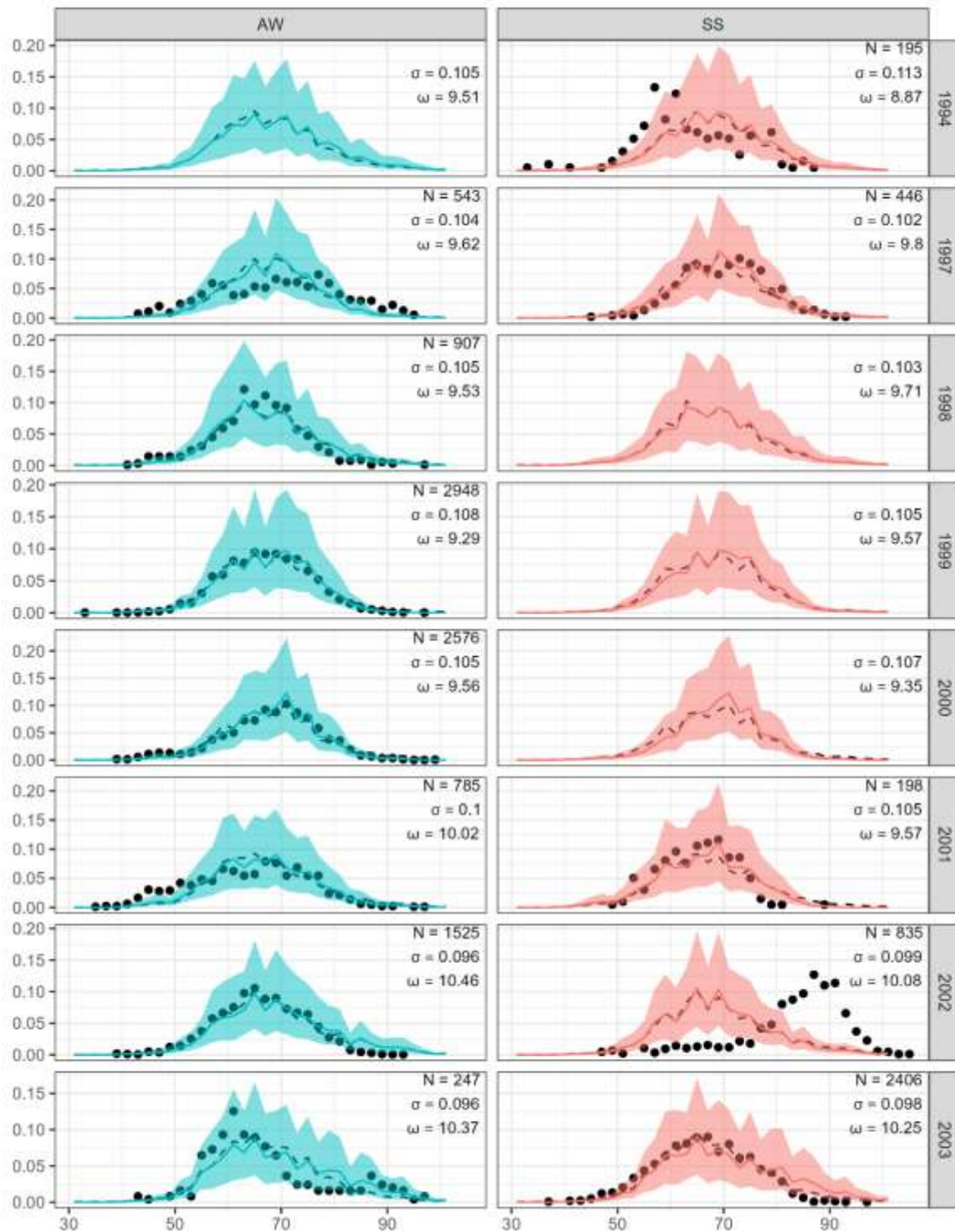


Figure B.9: CRA 1 Far North LFs for females by fishing year (from 1994 to 2003), season (AW = autumn/winter, SS = spring/summer), and TW bin. The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF distributions. The aggregated data (points) and unscaled predictions of the LF (dashed line) for the same stratum are also shown. Each panel also includes text which provides the number of lobsters measured (N), the SD of the predicted LF for each stratum (σ), and the data set weight for each stratum (ω).

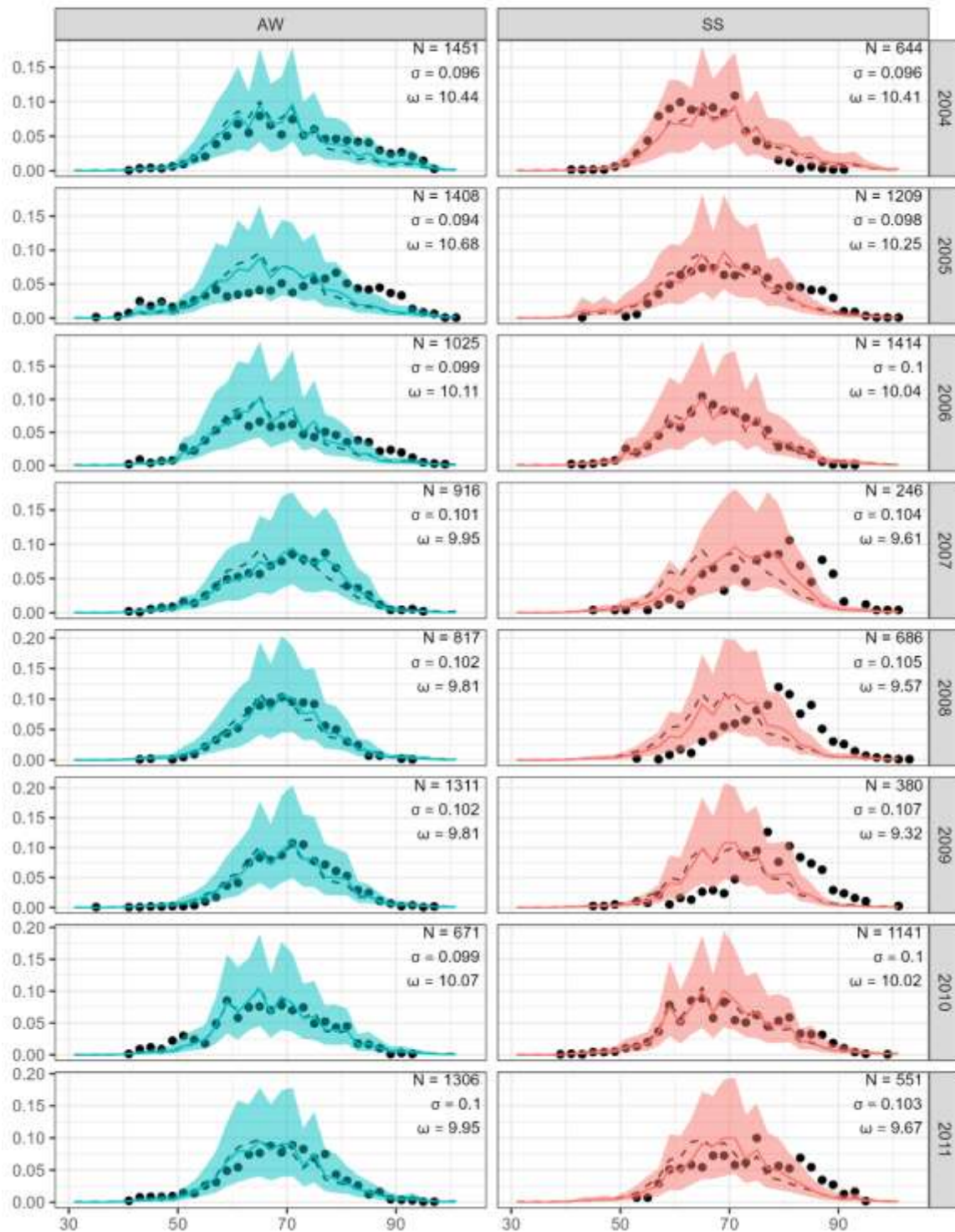


Figure B.10: CRA 1 Far North LFs for females by fishing year (from 2004 to 2011), season (AW = autumn/winter, SS = spring/summer), and TW bin. The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF distributions. The aggregated data (points) and unscaled predictions of the LF (dashed line) for the same stratum are also shown. Each panel also includes text which provides the number of lobsters measured (N), the SD of the predicted LF for each stratum (σ), and the data set weight for each stratum (ω).

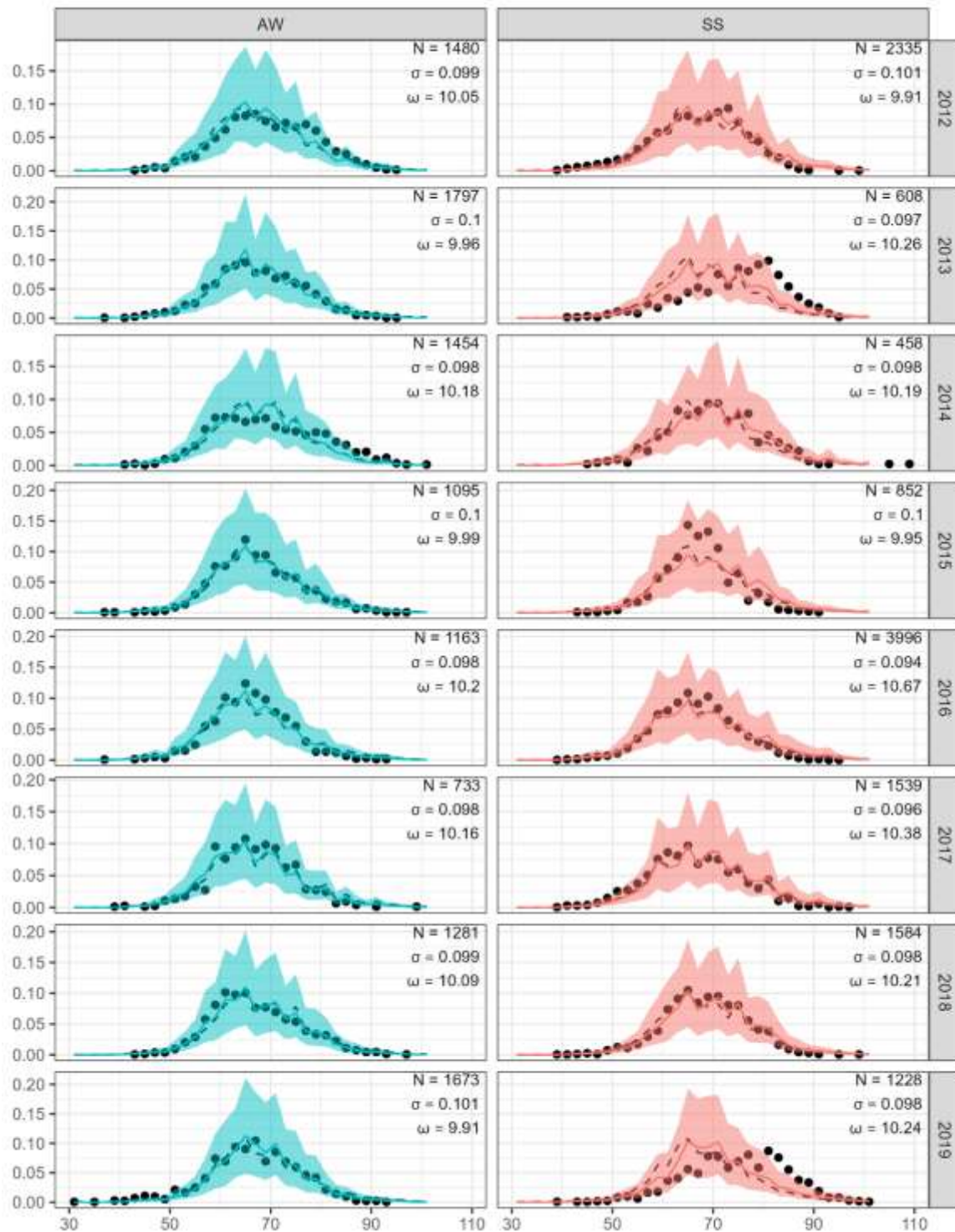


Figure B.11: CRA 1 Far North LFs for females by fishing year (from 2012 to 2019), season (AW = autumn/winter, SS = spring/summer), and TW bin. The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF distributions. The aggregated data (points) and unscaled predictions of the LF (dashed line) for the same stratum are also shown. Each panel also includes text which provides the number of lobsters measured (N), the SD of the predicted LF for each stratum (σ), and the data set weight for each stratum (ω).

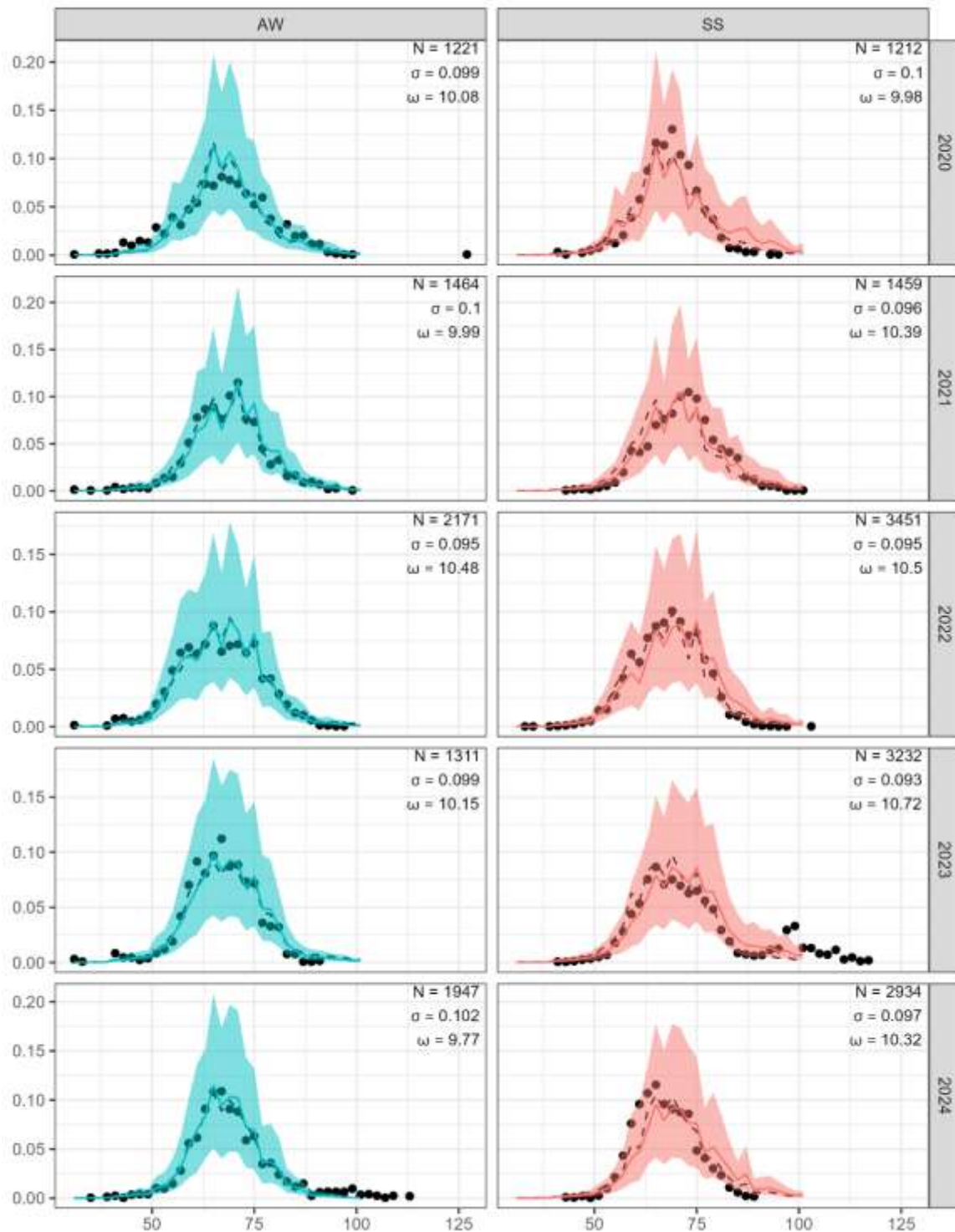


Figure B.12: CRA 1 Far North LFs for females by fishing year (from 2020 to 2024), season (AW = autumn/winter, SS = spring/summer), and TW bin. The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF distributions. The aggregated data (points) and unscaled predictions of the LF (dashed line) for the same stratum are also shown. Each panel also includes text which provides the number of lobsters measured (N), the SD of the predicted LF for each stratum (σ), and the data set weight for each stratum (ω).

APPENDIX C. TAG RECAPTURE DATA

Table C.1: Number of tags released, including tags that were never recaptured, compared with the number and proportion recaptured, by QMA.

QMA	Number released	Number recaptured	Number not recaptured	Percent recaptured
CRA 1	19 744	2 259	17 485	11.4
CRA 2	29 163	5 033	24 130	17.3
CRA 3	43 858	5 801	38 057	13.2
CRA 4	42 622	3 159	39 463	7.4
CRA 5	44 699	7 613	37 086	17.0
CRA 6	10 802	269	10 533	2.5
CRA 7	12 999	913	12 086	7.0
CRA 8	36 253	11 028	25 225	30.4
CRA 9	6 575	129	6 446	2.0

Table C.2: Number of complete tagging release/recovery records by sex and QMA. Note that the row totals are not always consistent with other tables because some records could not be assigned to a sex category.

QMA	Male	Female	Total
CRA 1	974	1 285	2 259
CRA 2	2 548	2 485	5 033
CRA 3	4 436	1 365	5 801
CRA 4	2 438	721	3 159
CRA 5	5 281	2 332	7 613
CRA 6	62	207	269
CRA 7	445	468	913
CRA 8	6 085	4 943	11 028
CRA 9	34	95	129
Total	22 303	13 901	36 204

Table C.3: Number of tags released by QMA (rows) and recaptured by QMA (columns). Note that the row totals are not always the same as in previous tables because some records could not be assigned to a QMA.

Release QMA	Recapture QMA									Total
	CRA1	CRA2	CRA3	CRA4	CRA5	CRA6	CRA7	CRA8	CRA9	
CRA 1	2 229	–	30	–	–	–	–	–	–	2 259
CRA 2	1	5 027	5	–	–	–	–	–	–	5 033
CRA 3	–	5	5 735	8	1	–	–	52	–	5 801
CRA 4	–	–	–	3 152	7	–	–	–	–	3 159
CRA 5	–	–	–	2	7 605	–	6	–	–	7 613
CRA 6	–	–	–	–	–	269	–	–	–	269
CRA 7	–	–	6	–	–	–	861	46	–	913
CRA 8	–	1	121	–	–	–	1	10 902	3	11 028
CRA 9	–	–	–	–	–	–	–	–	129	129
Total	2 230	5 033	5 897	3 162	7 613	269	868	11 000	132	36 204

**Table C.4: Proportion of tags that were recaptured outside of the statistical area of release.
Proportions based on fewer than ten recaptures were left blank.**

QMA	Statistical Area	Total recaptured	Proportion in new area
CRA 1	901	326	0.009
	902	2	—
	903	22	0.000
	904	—	—
	939	1 902	0.050
CRA 2	905	191	0.037
	906	2 778	0.012
	907	1 081	0.015
	908	947	0.023
CRA 3	909	1 020	0.002
	910	3 464	0.016
	911	1 304	0.011
CRA 4	912	386	0.000
	913	1 079	0.025
	914	1 283	0.047
	915	408	0.029
	934	3	—
CRA 5	917	2 891	0.000
	918	238	0.029
	919	—	—
	916	3 177	0.005
	932	—	—
CRA 6	933	1 123	0.006
	940	91	0.055
	941	101	0.010
	942	75	0.040
	943	—	—
CRA 7	920	530	0.160
	921	383	0.073
CRA 8	922	34	0.794
	923	239	0.460
	924	2 608	0.067
	925	20	0.300
	926	1 505	0.182
	927	5 333	0.009
	928	542	0.011
CRA 9	938	—	—
	937	—	—
	936	19	0.000
	935	98	0.000
	931	10	0.000
	930	—	—
	929	2	—

Table C.5: Number of recaptured lobsters for CRA 1 releases (supplemented with releases from Statistical Areas 905 and 906 for the CRA 1 assessment), by fishing year of release, sex, and statistical area. Tags were classified to statistical area based on the reported location and then the reported statistical area of release. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Release fishing year	Recaptured lobsters by Statistical Area of release							By sex		
	Unknown	939	901	902	903	905	906	Males	Females	Total
1975	–	73	–	–	–	–	–	35	38	73
1976	–	305	–	–	–	–	–	139	166	305
1977	–	81	–	–	–	–	–	24	57	81
1978	–	58	–	–	–	–	–	39	19	58
1979	–	56	–	–	–	–	–	24	32	56
1983	–	–	–	–	–	–	190	112	78	190
1984	–	–	–	–	–	–	60	36	24	60
1985	–	–	–	–	–	–	18	8	10	18
1996	–	–	–	–	–	38	750	364	424	788
1997	–	–	–	–	–	2	399	68	333	401
1998	–	–	–	–	–	5	273	61	217	278
1999	–	–	–	–	–	1	45	20	26	46
2000	–	310	161	–	3	–	2	303	173	476
2001	–	95	18	–	–	–	10	66	57	123
2002	–	155	39	2	–	18	223	325	112	437
2003	–	265	22	–	9	67	460	465	358	823
2004	–	61	–	–	1	6	94	66	96	162
2005	–	19	–	–	1	2	35	40	17	57
2006	–	7	–	–	1	–	1	8	1	9
2007	–	2	–	–	2	–	–	3	1	4
2008	–	–	–	–	–	5	61	49	17	66
2009	–	49	–	–	2	2	13	46	20	66
2010	–	42	30	–	2	–	13	61	26	87
2011	1	22	1	–	–	–	2	16	10	26
2012	–	110	9	–	1	9	–	54	75	129
2013	5	53	41	–	–	–	–	65	34	99
2014	–	12	–	–	–	25	58	54	41	95
2015	–	6	3	–	–	–	8	10	7	17
2016	–	1	–	–	–	8	38	36	11	47
2017	–	48	–	–	–	2	16	44	22	66
2018	–	2	–	–	–	1	1	4	–	4
2019	–	24	–	–	–	–	–	20	4	24
2020	–	2	–	–	–	–	1	2	1	3
2021	1	24	–	–	–	–	7	20	12	32
2022	–	20	2	–	–	–	–	12	10	22
2023	–	73	–	–	–	–	–	–	–	–

Table C.6: Number of tag releases by sex, release month, and release statistical area for CRA 1 (supplemented with releases from Statistical Areas 905 and 906 for the CRA 1 assessment).

Release month	By Statistical Area of release							By sex		
	Unknown	939	901	902	903	905	906	Males	Females	Total
Jan	–	1	–	–	–	2	30	17	16	33
Feb	–	34	–	–	–	7	27	35	33	68
Mar	1	131	–	–	–	–	31	69	94	163
Apr	–	303	–	–	–	–	78	121	260	381
May	–	39	–	–	–	–	168	23	184	207
Jun	–	27	92	–	–	1	80	113	87	200
Jul	–	367	47	2	–	57	385	437	421	858
Aug	2	114	56	15	–	29	348	308	256	564
Sep	2	415	118	1	–	65	665	725	541	1266
Oct	2	354	11	–	2	16	478	551	312	863
Nov	–	79	2	4	–	14	384	216	267	483
Dec	–	38	–	–	–	–	104	84	58	142

Table C.7: Days-at-liberty statistics for recaptures of CRA 1 (supplemented with releases from Statistical Areas 905 and 906 for the CRA 1 assessment). Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Statistical area of release	Sex	N at liberty		Days at liberty				
		N	> 6 months	Minimum	5%	Median	95%	Maximum
Unknown	Male	5	3	8	15	220	241	245
	Female	2	1	29	46	195	344	361
939	Male	867	563	1	10	260	719	3 281
	Female	1 035	753	1	18	320	1 317	3 634
901	Male	96	82	10	41	366	797	1 810
	Female	230	204	1	39	477	1 513	3 415
902	Male							
	Female	2	2	316	357	723	1 089	1 130
903	Male	6	6	346	359	693	1 268	1 458
	Female	16	14	26	133	1050	2 147	2 157
905	Male	27	17	17	26	308	710	1 053
	Female	164	114	1	25	374	1 061	3 288
906	Male	1 528	887	1	7	242	683	2 171
	Female	1 250	948	1	20	355	1 148	3 350
Total	Male	2 529	1 558	1	8	259	707	3281
	Female	2 699	2 036	1	21	355	1 314	3 634

Table C.8: Growth increment statistics (in mm tail-width) for recaptures of CRA 1 releases (supplemented with releases from Statistical Areas 905 and 906 for the CRA 1 assessment). Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Statistical area of release	Sex	N	Tail width growth increment (mm)				
			Minimum	5%	Median	95%	Maximum
Unknown	Male	5	0.00	0.20	6.00	7.00	7.00
	Female	2	0.00	0.05	0.50	0.95	1.00
939	Male	867	-21.52	-0.13	4.30	15.48	37.50
	Female	1 035	-25.37	-1.00	3.00	14.00	35.20
901	Male	96	-9.40	-1.65	7.90	19.52	36.80
	Female	230	-29.70	-1.41	3.10	15.60	24.30
902	Male	—	—	—	—	—	—
	Female	2	1.50	2.35	10.00	17.65	18.50
903	Male	6	0.00	1.18	7.50	17.15	19.90
	Female	16	-2.00	-1.40	2.95	17.48	18.30
905	Male	54	-1.00	0.00	4.90	15.70	15.70
	Female	328	-4.00	-0.20	2.00	11.00	20.70
906	Male	3 056	-37.00	-1.00	3.00	12.70	27.70
	Female	2 500	-19.30	-1.30	2.16	10.30	20.70
Total	Male	4 084	-37.00	-1.00	3.53	13.70	37.50
	Female	4 113	-29.70	-1.30	2.60	11.70	35.20

APPENDIX D. BASE CASE DIAGNOSTICS

The following diagnostics are for the primary Far North model run which excludes Statistical Areas 903 and 904.

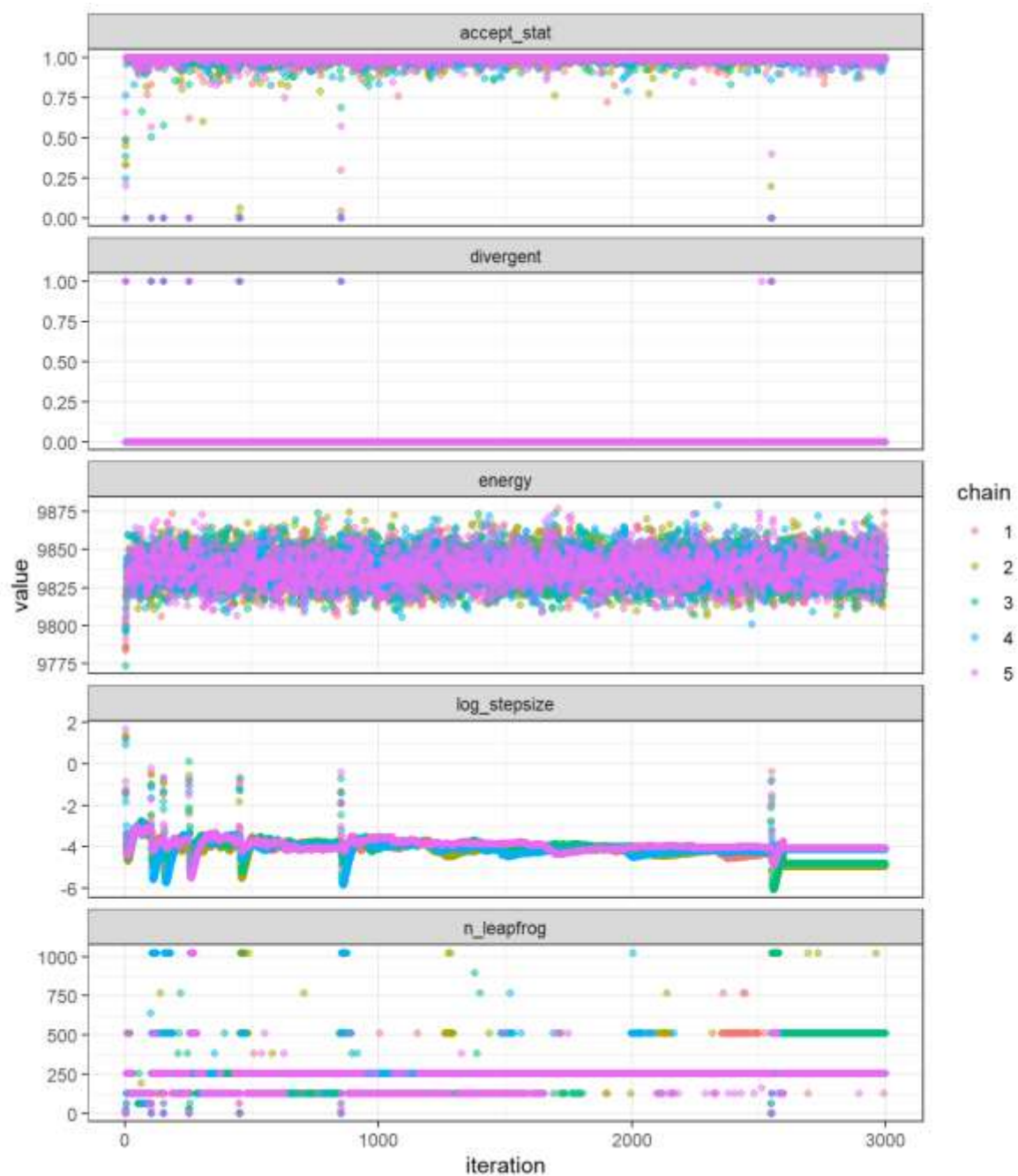


Figure D.1: Adaptation metrics for the Far North MCMC.

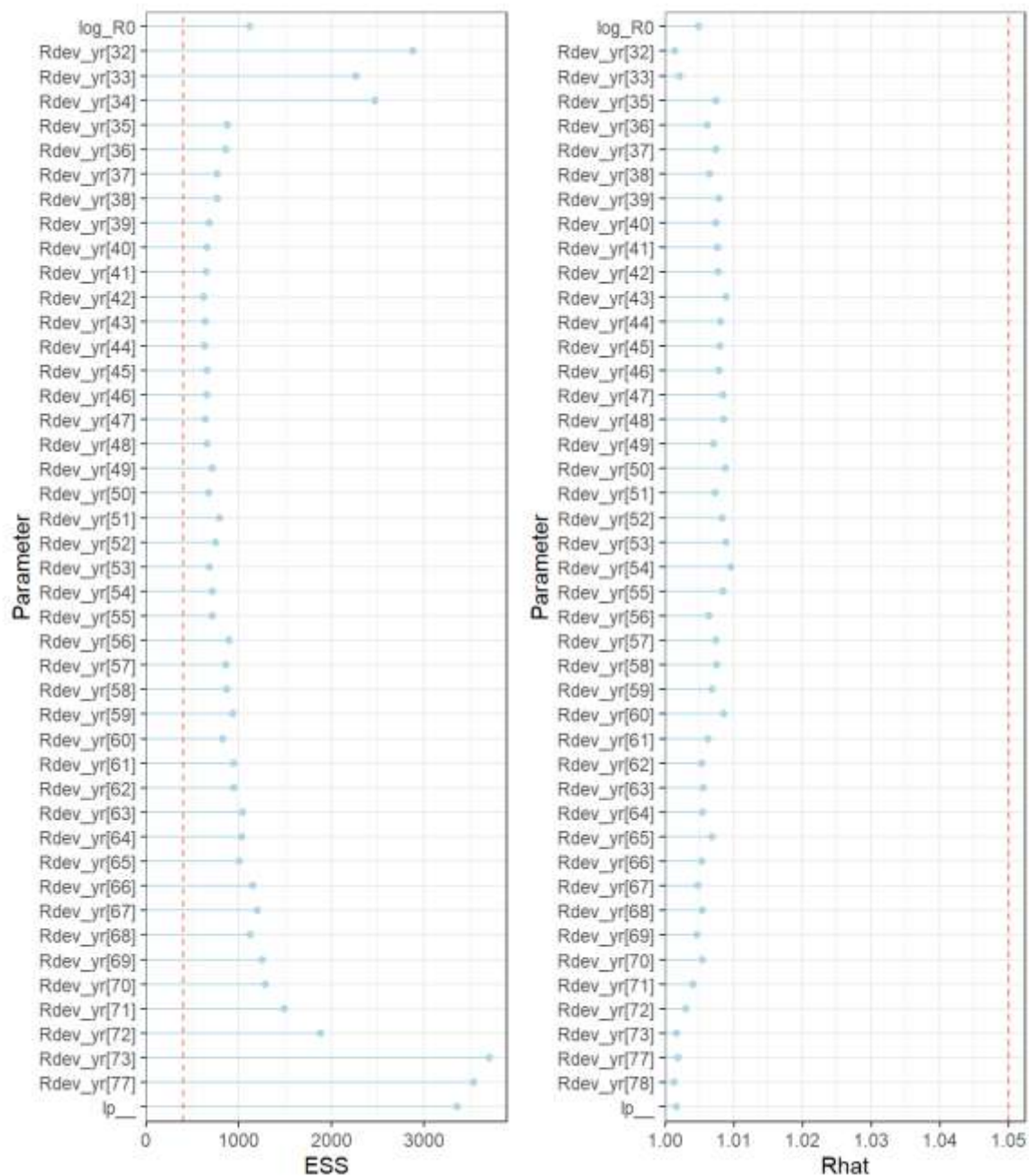


Figure D.2: Effective sample size (ESS) and Rhat for the worst 45 parameters of the Far North model.

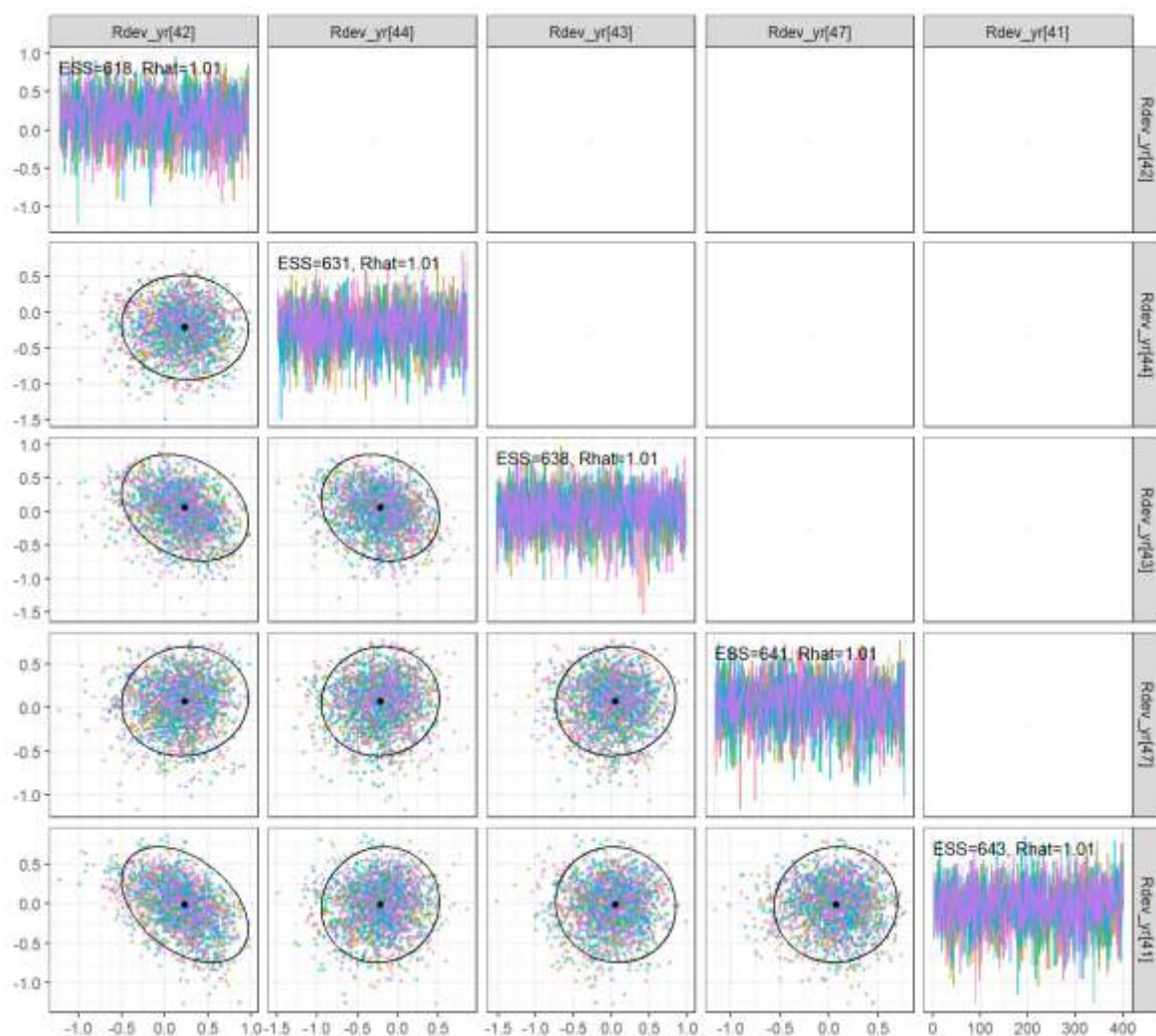


Figure D.3: Pairwise scatterplots of samples for the slowest mixing parameters. Plots show MLE (ellipses) and MCMC samples (points) for each comparison.

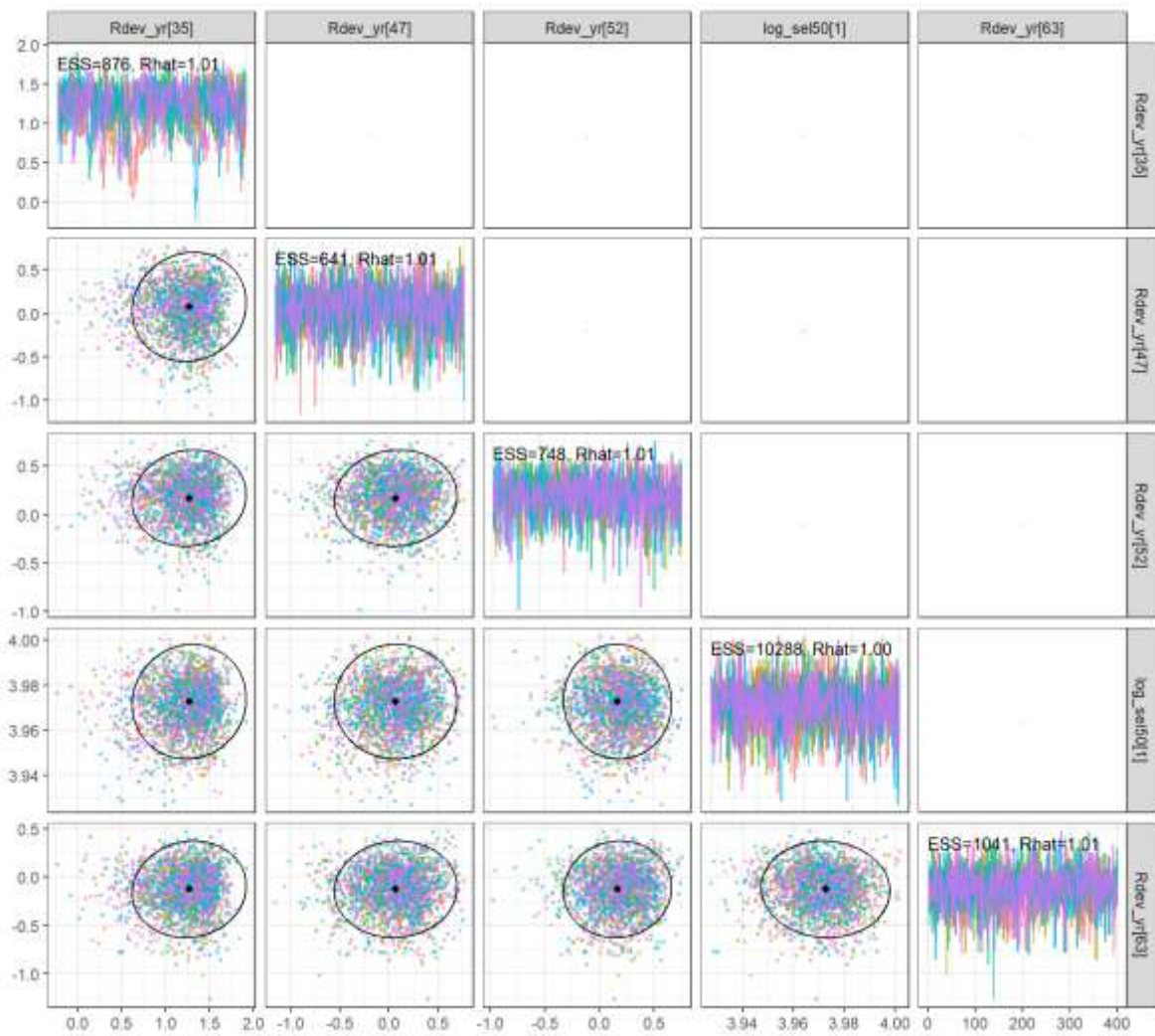


Figure D.4: Pairwise scatterplots of samples for the parameters with greatest mismatch between MLE (ellipses) and MCMC samples (points).

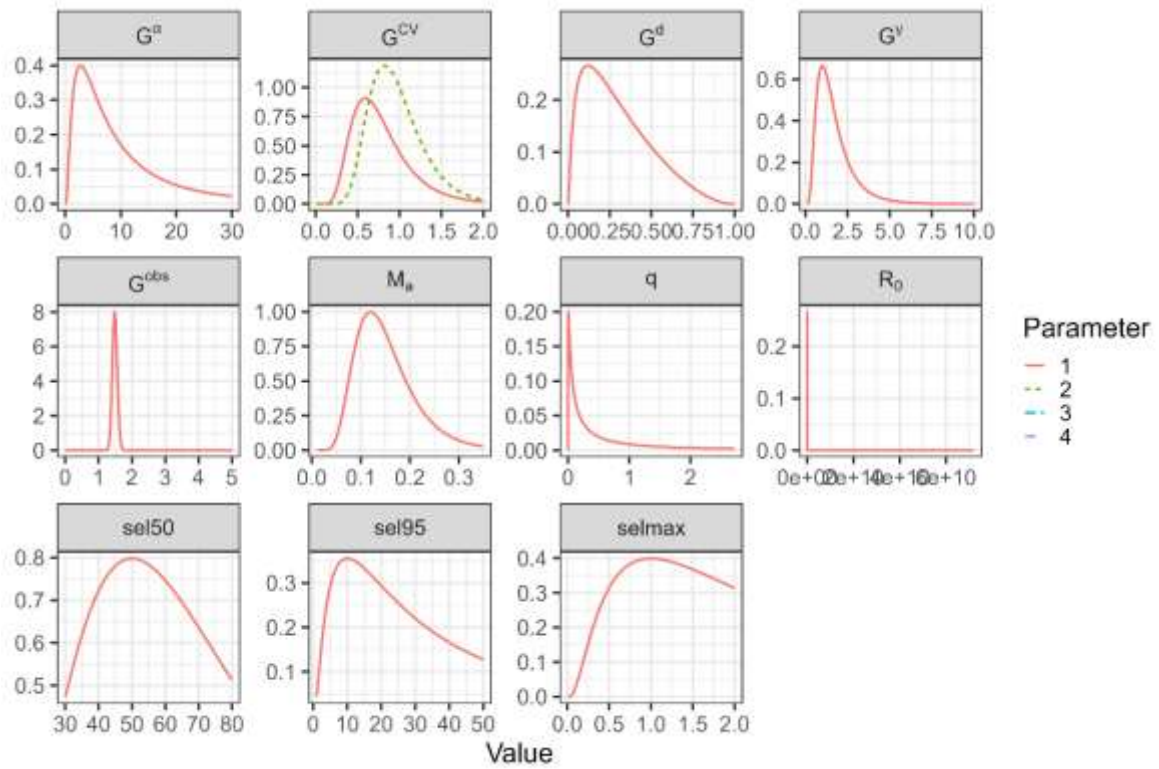


Figure D.5: Assumed prior distributions.

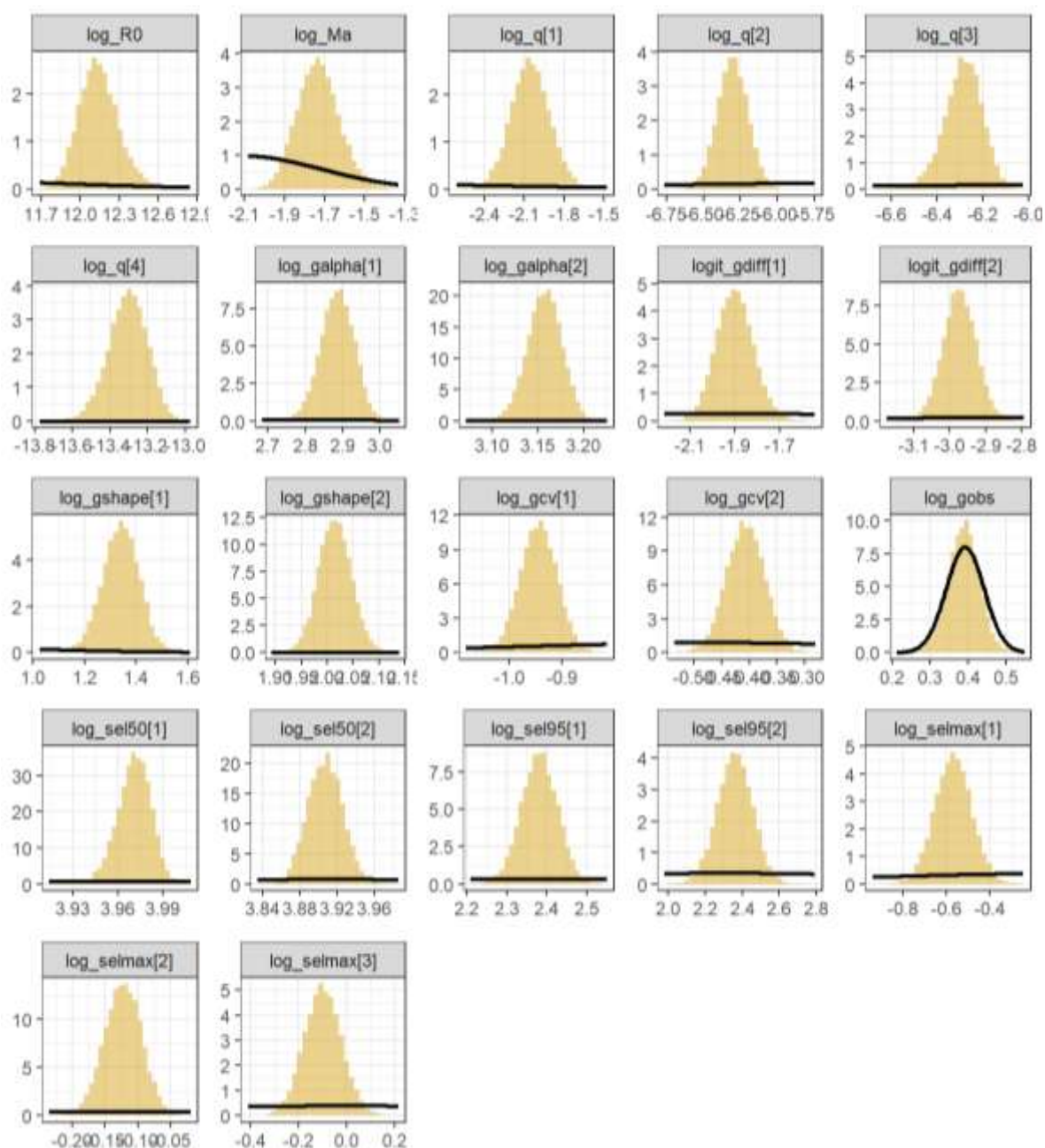


Figure D.6: Posterior distributions for key model parameters (bars) compared with prior distributions (black lines). The x-axis for each panel was set by posterior minimum and maximum).

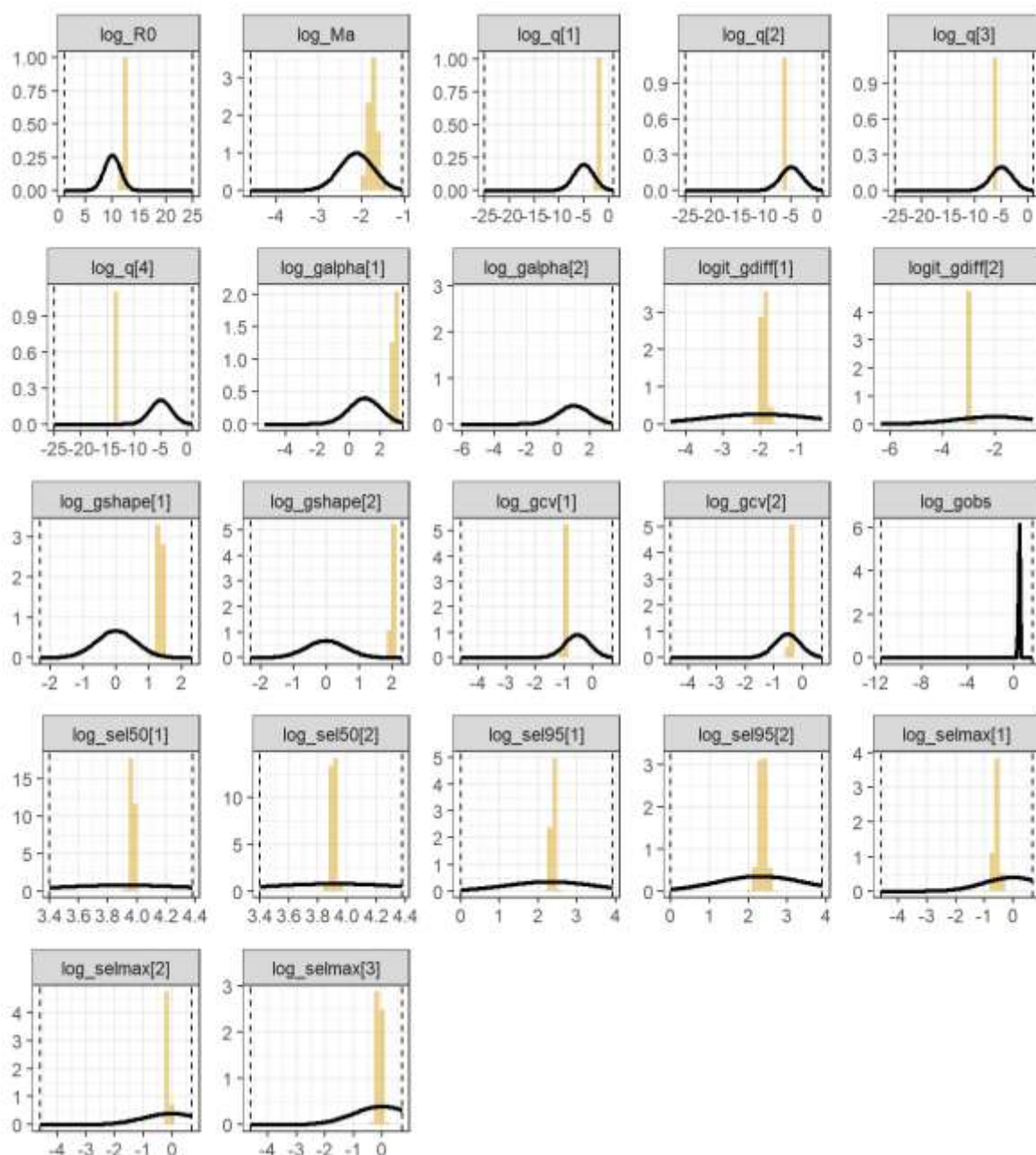


Figure D.7: Posterior distributions for key model parameters (bars) compared with prior distributions (black lines). The x-axis for each panel was set by parameter bounds).

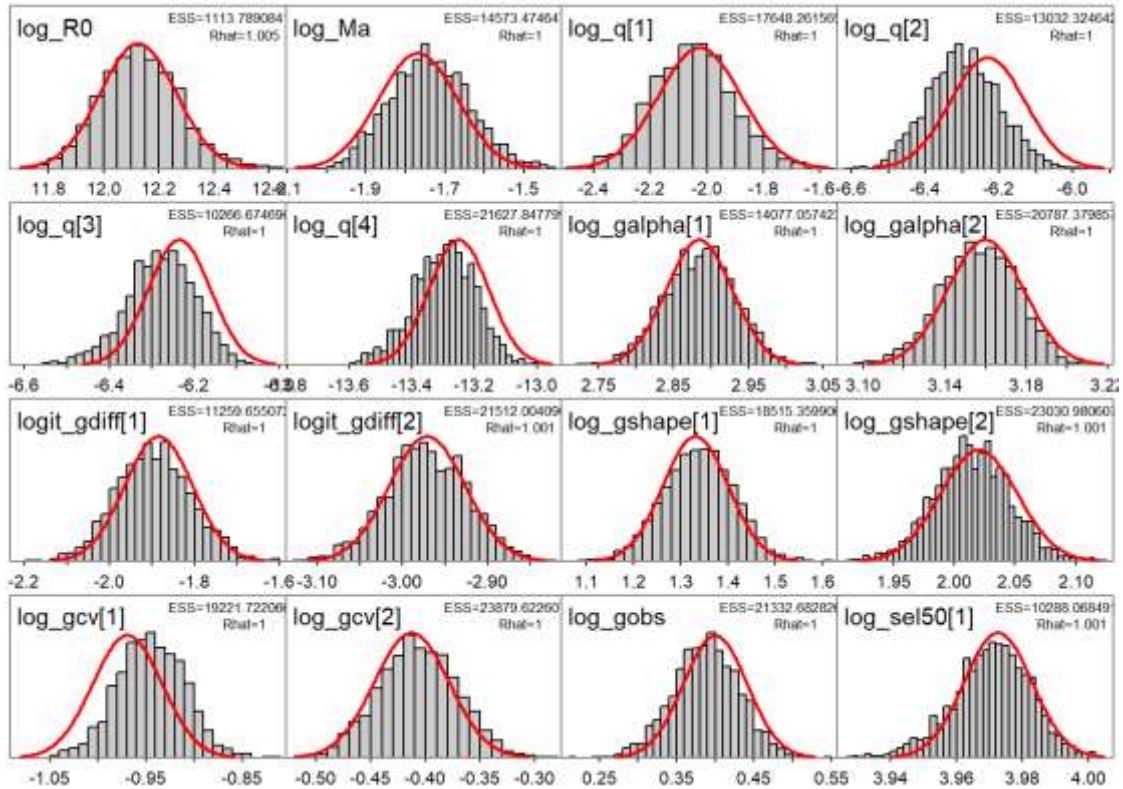


Figure D.8: Posterior distributions for a subset of model parameters (grey bars) and the asymptotic uncertainty derived from the MLE (red lines).

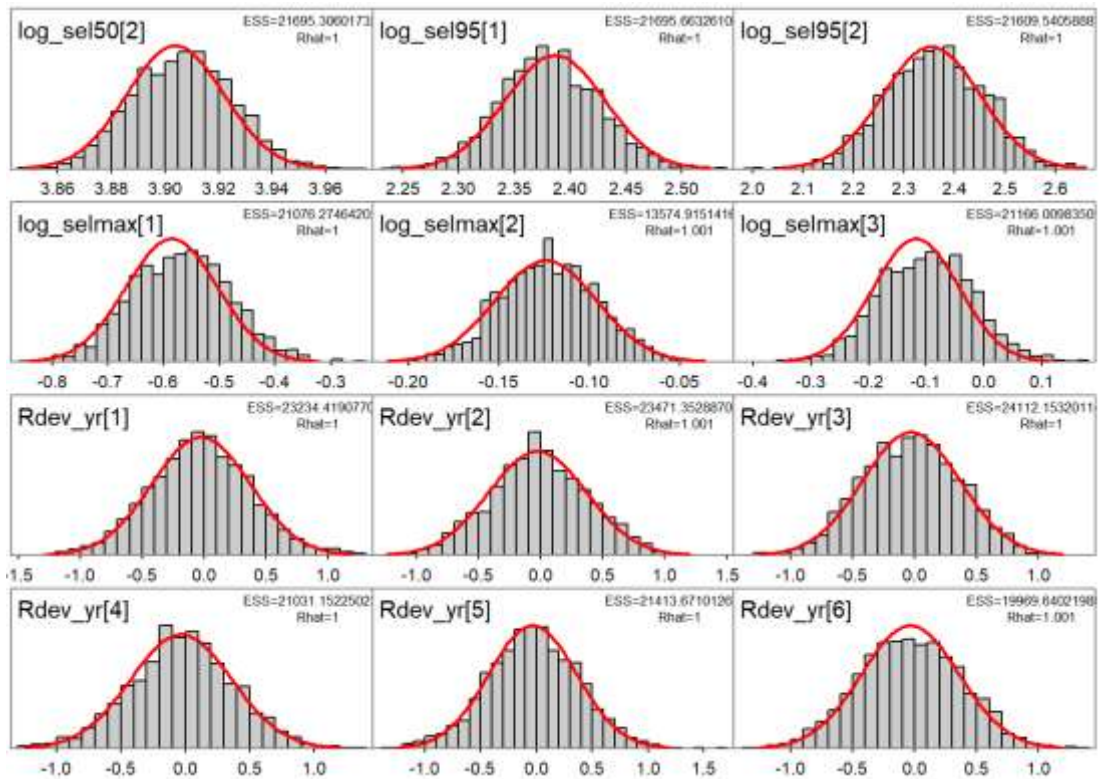


Figure D.9: Posterior distributions for a subset of model parameters (grey bars) and the asymptotic uncertainty derived from the MLE (red lines).

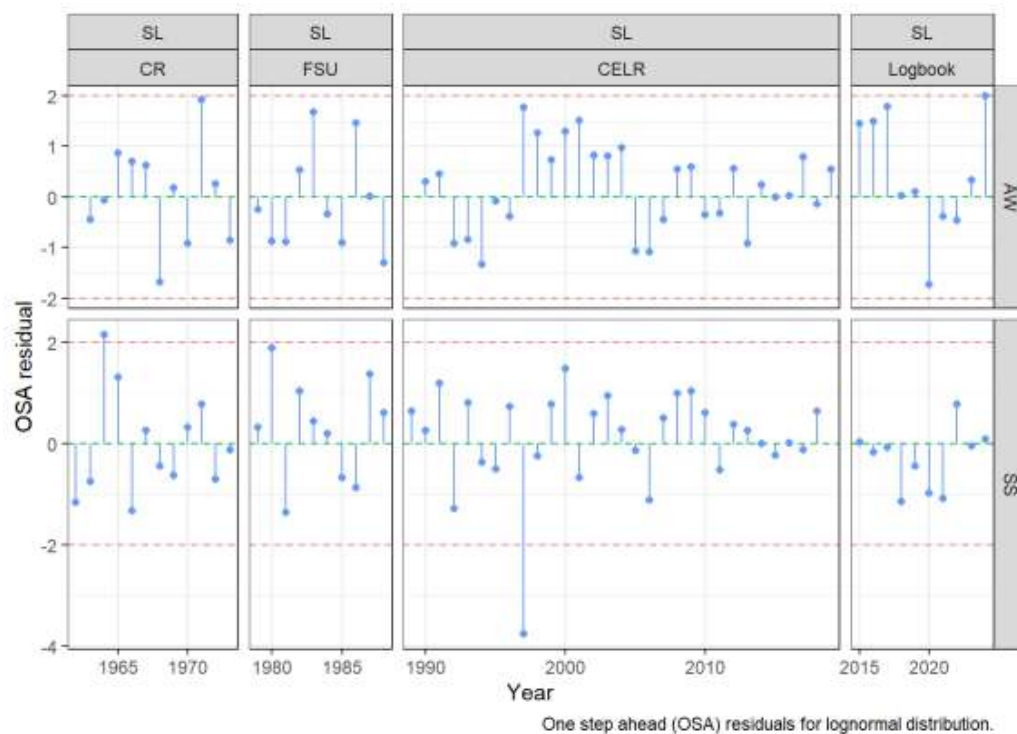


Figure D.10: CPUE one step ahead residuals for the Far North model.

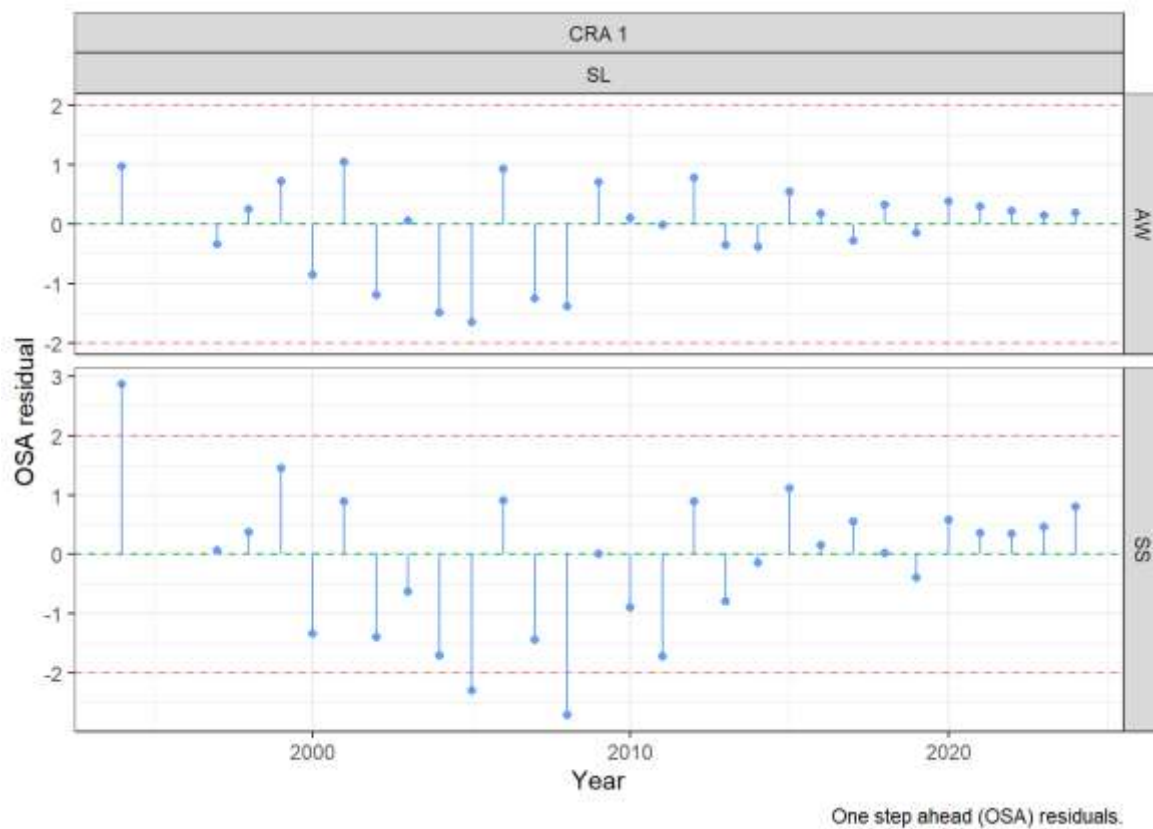


Figure D.11: Sex ratio one step ahead residuals for the Far North model.

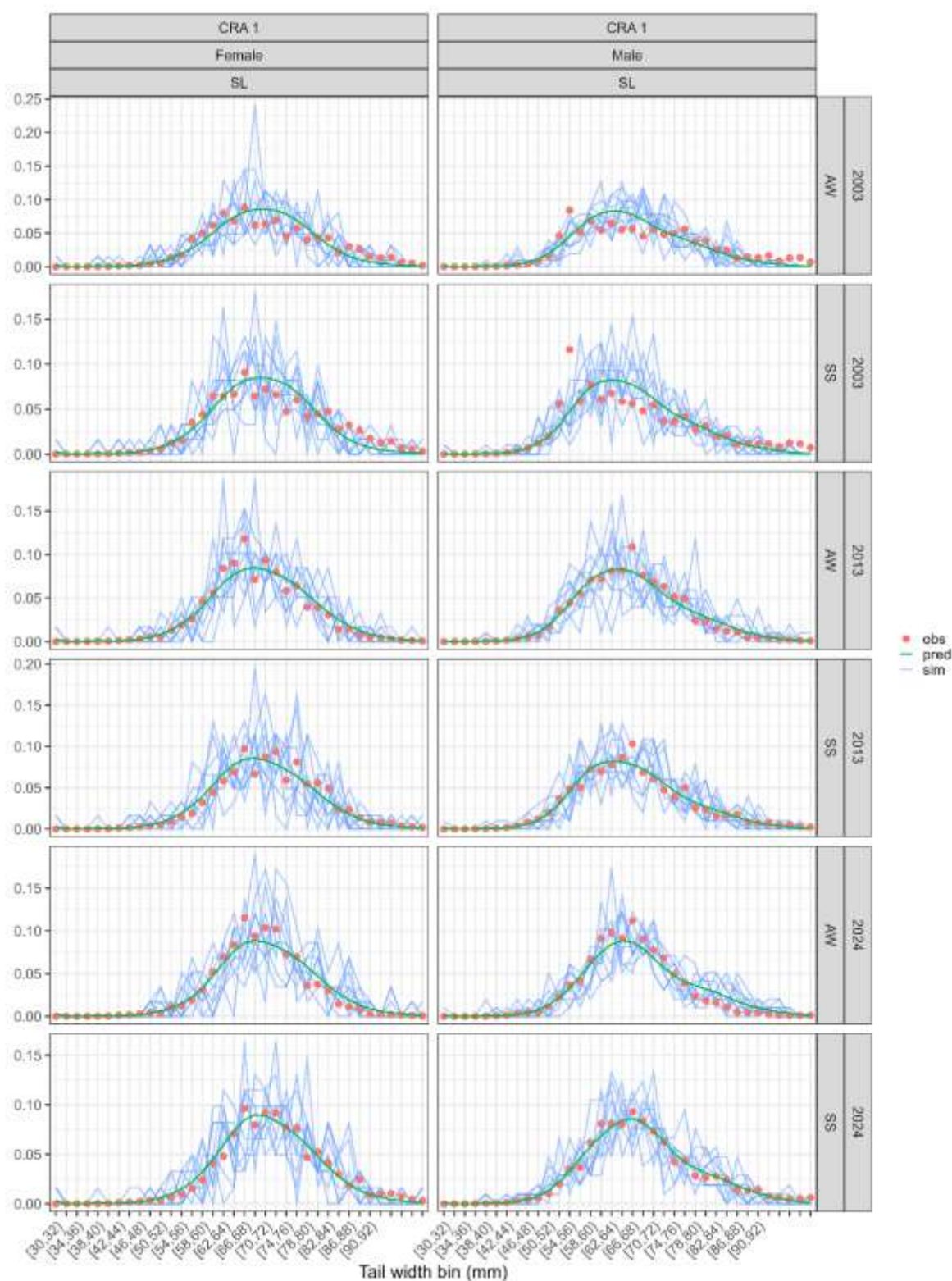


Figure D.12: Model fits to length-frequency (LF) observations (green), with simulations to demonstrate the range of uncertainty (blue) for a subset of years for the Far North model.

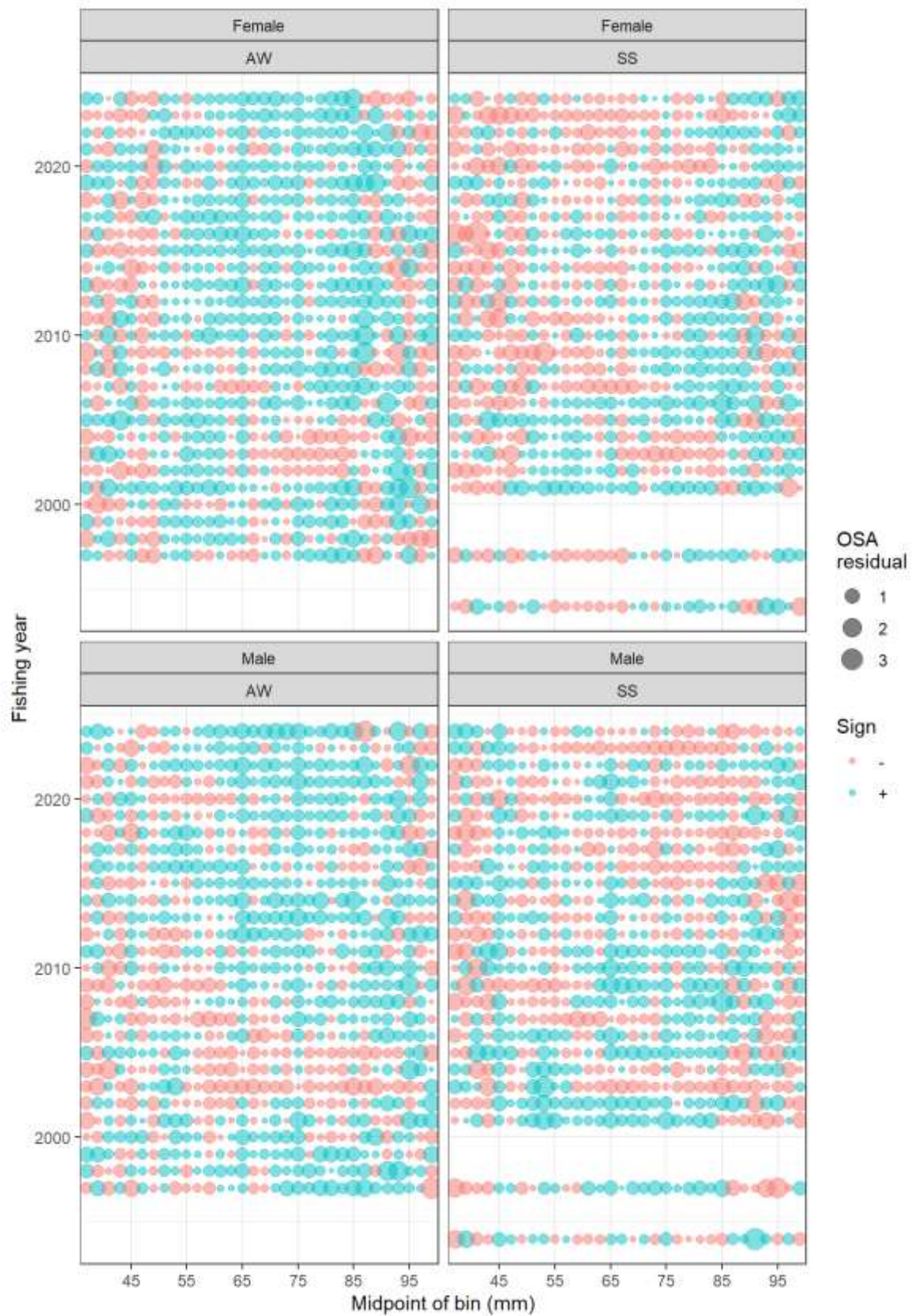


Figure D.13: One step ahead (OSA) LF residuals by size, year, sex, and season for the Far North model.

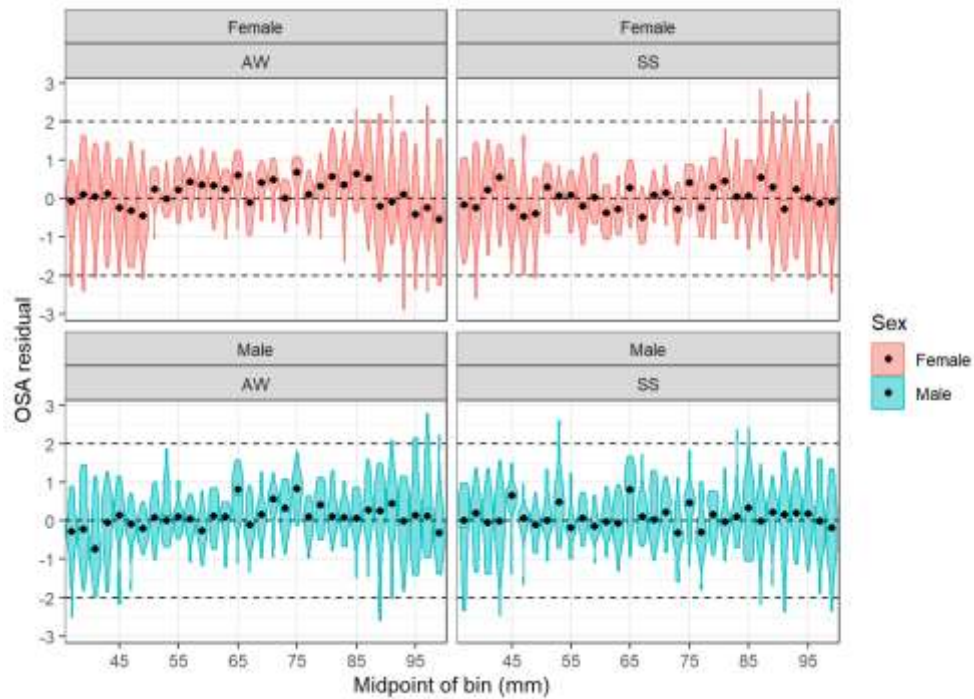


Figure D.14: One step ahead (OSA) LF residuals by size, sex, and season for the Far North model.

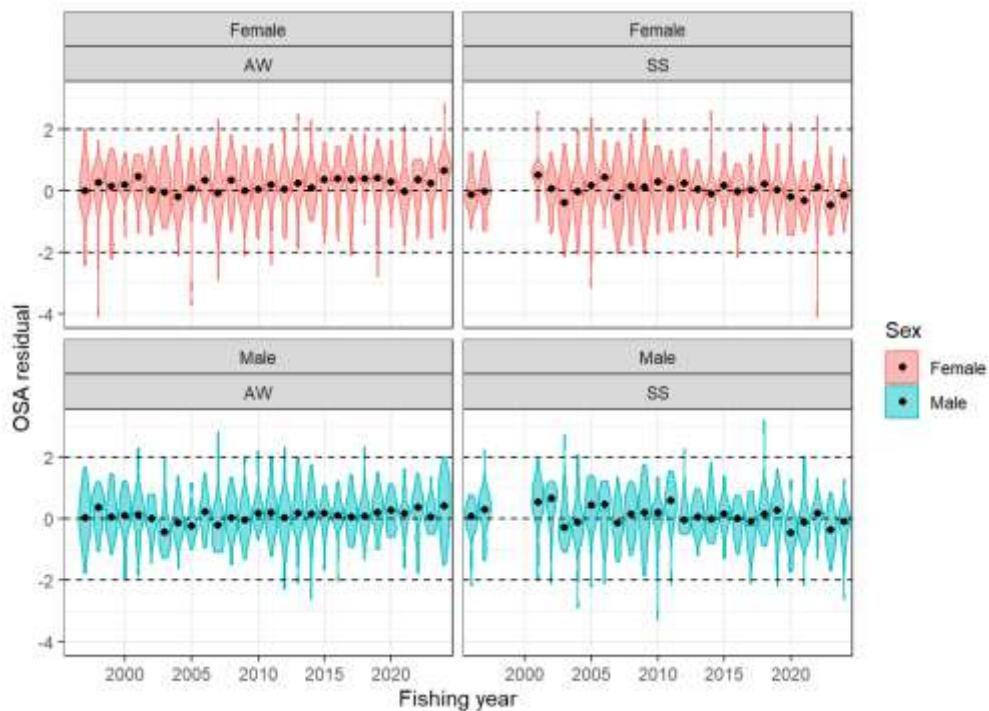


Figure D.15: One step ahead (OSA) LF residuals by year, sex, and season for the Far North model.

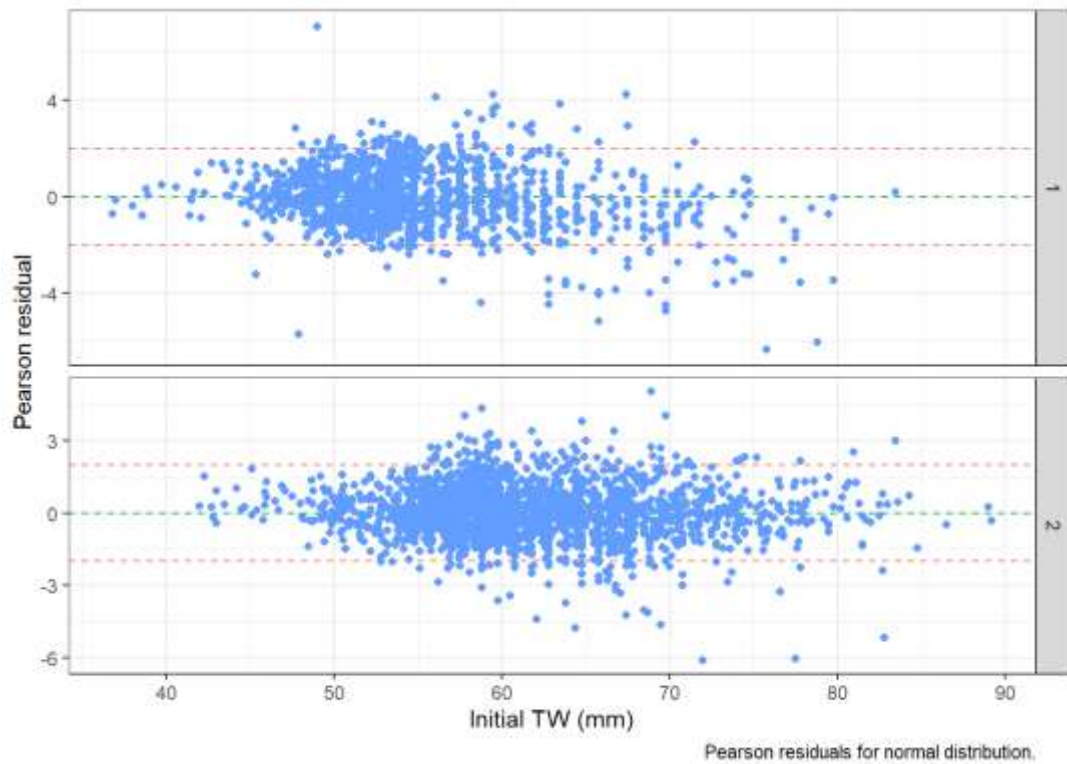


Figure D.16: Pearson tag residuals by tail-width (TW) at release for the Far North model. Note: tags from Statistical Areas 903 and 904 were still included.

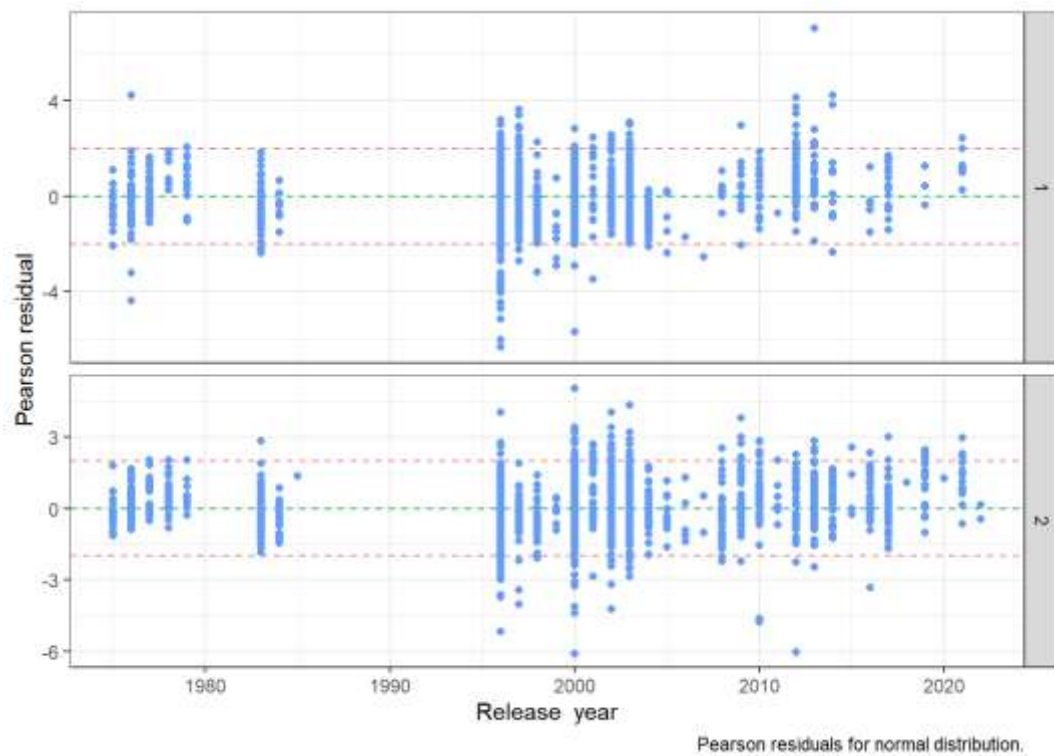


Figure D.17: Pearson tag residuals by release year for the Far North model. Note: tags from Statistical Areas 903 and 904 were still included.

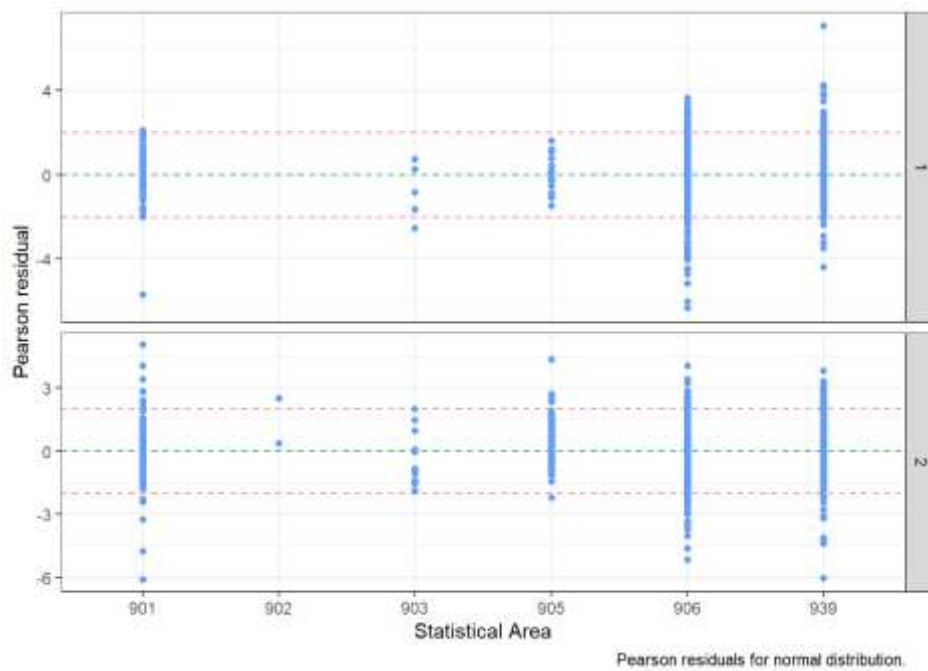


Figure D.18: Pearson tag residuals by statistical area for the Far North model. Note: tags from Statistical Areas 903 and 904 were still included.

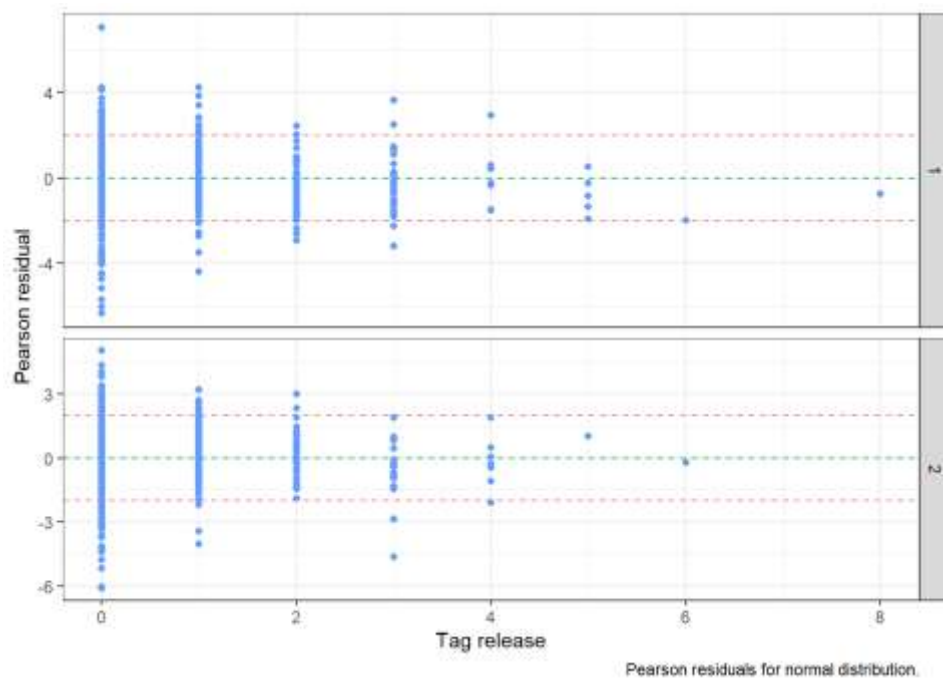


Figure D.19: Pearson tag residuals by tag release number for the Far North model. Note: tags from Statistical Areas 903 and 904 were still included.