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Data for the 2023 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 6

New Zealand Fisheries Assessment Report 2024/19

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TABLE OF CONTENTS

Plain language summary

The red rock lobster supports the most valuable inshore commercial fishery in New Zealand. This fishery has been managed with catch quotas in nine Quota Management Areas (QMAs), which are usually treated as independent populations or stocks.

To estimate those quotas, a stock assessment is done for each QMA approximately every five years. These stock assessments include a review of the previous stock assessments and data inputs, the addition of new data, data processing, and development of a new stock assessment model.

This document describes the collation and review of inputs for the 2023 stock assessment of CRA 6 (the Chatham Islands).

EXECUTIVE SUMMARY

Webber, D.N.[1]; Roberts, J.O.[2]; Starr, P.J.[3]; Rudd, M.B.[4]; Pons, M.[3] (2024). Data for the 2023 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 6.

***New Zealand Fisheries Assessment Report 2024/19.* 73 p.**

This document describes the covariates and data used in the 2023 stock assessment of rock lobsters (*Jasus edwardsii*) in CRA 6, including catch estimates for all sectors of the CRA 6 fishery, seasonal catch-per-unit-effort (CPUE) indices, standardised length frequency (LF) distributions and sex ratios, standardised proportions of mature females that were in berry (egg-bearing), and tag-recapture data.

Annual catch estimates were provided for the commercial, recreational, customary, and illegal fisheries by six-month season (spring/summer [SS] and autumn/winter [AW]) for the period 1965 to 2022 (i.e., the 2022–23 fishing year). The only recreational catch estimate that was available for CRA 6 was a 2008–09 Chatham Island census recall survey. Fixed estimates of 4.7 t/year for recreational catch and 2 t/year for customary catch were assumed. Illegal catch estimates were based on fixed proportions of the commercial catch (5% before 1990 and 2% beginning in 1990), under the assumption that large amounts of unreported catch were unlikely to occur given the isolation and remoteness of this fishery. The stock assessment assumed that these removals were in addition to commercial fishery removals, consequently these catches were added to the annual totals rather than being eventually attributed to the legal fishery.

Statutory paper form (Catch Effort Landing Return, CELR) CPUE was standardised for the AW and SS seasons. The 'F2' algorithm, which uses a truncated distribution of 'vessel correction factors' to adjust estimated catches to final catch, was used to prepare the catch and effort data collected since 1989 up to 2019 AW. The destination codes 'X' (discarded at sea) and 'F' (section 111 recreational catches) were added to the destination code 'L' (landed to a Licensed Fish Receiver) to obtain the final catch total for scaling the estimated catches. The CPUE standardisation procedure included a vessel explanatory variable for data beginning in 1989. Standardised CPUE based on the earlier Fisheries Statistics Unit data (1979–1988) was estimated separately and also used a vessel explanatory variable. Based on an evaluation of the data, the Rock Lobster Working Group concluded that the switch to electronic reporting (ERS) from the previous CELR reporting has fundamentally changed the reporting of rock lobster potting data, breaking the continuity in the previous CELR series. The previous CPUE analysis determined that an equivalent analysis could be done for CRA 2 using the voluntary logbook (LB) data (1990–2021) collected for catch composition by length. A CPUE analysis for the period 2014 to 2022 was done for this stock assessment to replace the statutory catch and effort data used previously.

The use of the early observer catch sampling (CS) LF data required the estimation of tail width-carapace length relationships because these data had been collected in terms of carapace length rather than tail width. The same conversion was required to process the early tag-recapture growth information.

Size and sex composition data were available from both the observer catch sampling and voluntary logbook programmes. Early (1966, 1982, and the period 2001 to 2012) LF data used in the 2018 CRA 6 stock assessment were rejected because it was concluded that these data were likely to be unrepresentative of the fishery. This document describes how the LF data were combined into catch-weighted distributions for use in the stock assessment model and into catch-weighted sex proportions, also for use in the assessment model.

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[2] Anemone Consulting Ltd, Wellington, New Zealand.
[3] Independent consultant.
[4] Scaleability LLC, USA.

Few CRA 6 tag-recapture data were adequate to provide reliable growth rate estimates by sex. The 2018 CRA 6 stock assessment explored the inclusion of tagging data from other CRA QMAs, resulting in the selection of Fiordland (CRA 8 statistical areas 926, 927, and 928) tagging data, to augment the tagging data set. Tagging data from Fiordland statistical areas were selected because they had similar size structure to that observed for CRA 6, the growth increments were similar to those from the sparse CRA 6 tag-recapture data, and the sea temperatures were broadly similar when comparing these two regions.

1. INTRODUCTION

The CRA 6 Quota Management Area (QMA) for red rock lobster (*Jasus edwardsii*, CRA) surrounds the Chatham Islands, including the two main islands (Chatham and Pitt) (Figure 1). There are four rock lobster statistical areas (940, 941, 942, and 943) that roughly divide the Chatham Islands rock lobster habitat into four quadrants.

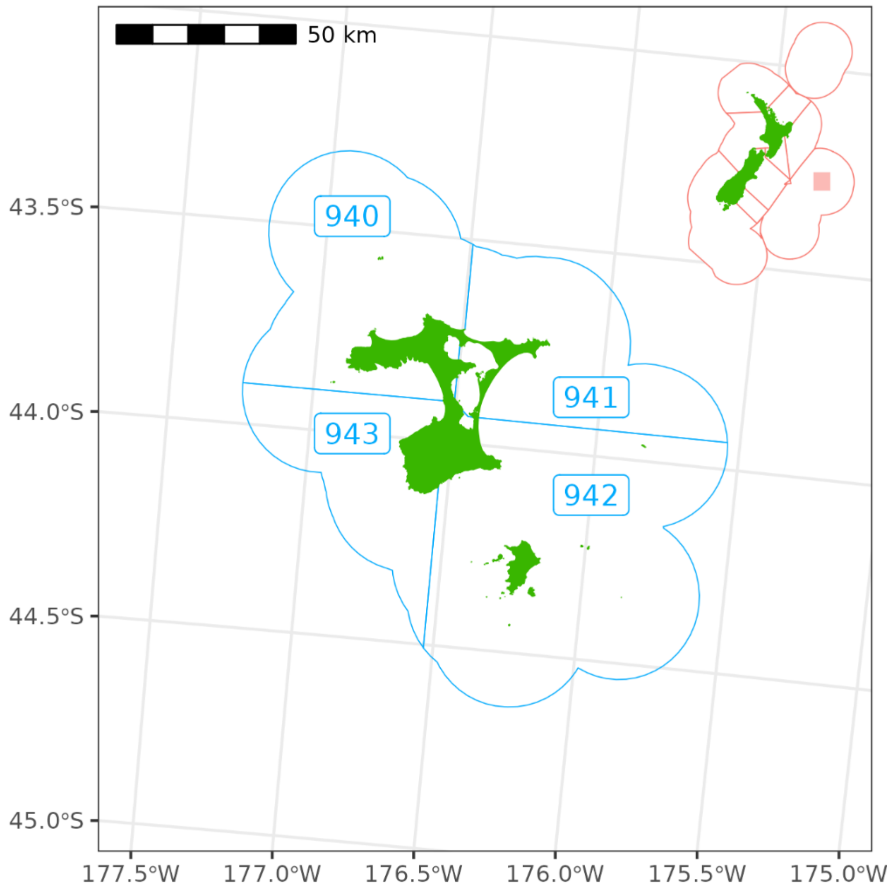

Figure 1: Map of the Chatham Islands, showing the spatial bounds of CRA 6 and its statistical areas.

The previous stock assessment for CRA 6 was developed in 2018 (Rudd et al. 2019), with Starr et al. (2019) describing the input covariates and data. The National Rock Lobster Management Group (NRLMG) decided that an updated stock assessment for CRA 6 should be done in 2023. This document describes all covariates and data used by this stock assessment, including: annual catch histories (commercial, recreational, customary, and illegal) from 1965 to 2022[5], catch-per-unit-effort (CPUE), length frequency (LF) and sex ratio (SR) data, seasonal estimates of the proportion of mature females that were in berry, and tag-recapture data. The CRA 6 stock assessment was completed during a workshop in May and June 2023. Decisions on data and modelling choices were discussed and approved by the Rock Lobster Working Group (RLWG). The stock assessment was presented to and approved by the Fisheries New Zealand mid-year Plenary meeting on 16–17 October 2023 (Fisheries New Zealand 2023).

CRA 6 entered the QMS on 1 April 1990 with a total allowable commercial catch (TACC) of 518 t, which was reduced in three steps to 360 t by 1998–99, with no change since. A total allowable catch (TAC) of 480 t was established for the first time in 1997–98, but was promptly reduced to 370 t in the following year (1998–99) when the TACC was also dropped. The only allowance in the current TAC is

[5] The 1 April–31 March red rock lobster statutory fishing year is denoted with the initial year of the pair in this document.

10 t for ‘other sources of mortality’, which includes illegal fishing and handling mortality. There are no allowances in the current TAC for customary or recreational catches.

The RLWG concluded that the continuity of the commercial catch CPUE series used to inform CRA 6 stock assessments had been lost when paper Catch Effort Landing Return (CELR) forms were replaced by electronic reporting (see section 1.1.1 of the 2023 plenary chapter titled Introduction, Red Rock Lobsters in Fisheries New Zealand 2024, for an explanation of the reasoning for this decision). Consequently, a new CPUE series was developed based on the voluntary logbook data collected by the CRA 6 rock lobster industry for the purpose of monitoring the biological characteristics of the catch (Webber & Starr 2022). This programme has been implemented in most New Zealand QMAs and involves fishers monitoring a sub-sample of their effort (see Sections 3.4 and 4 for a description of this programme).

LF and SR data are key inputs for New Zealand red rock lobster stock assessments, where their purpose is to inform the model of the range of sizes and the proportions of each sex that are removed by the commercial catch and to indirectly provide information about growth and recruitment. Commercial LFs and SRs (and associated uncertainty) were modelled using data from the voluntary logbook (LB) programme reported by commercial fishers (Walker & Mackay 2002) and the observer catch sampling (CS) programme (Mackay & George 2002). The LFs and SRs were scaled by the commercial catch data (see Sections 4.1 and 4.2). This methodology was developed to create a unified standardised LF series by sex for each season/year stratum and to predict appropriate LF distributions for strata that had not been sampled by either sampling methodology (Webber 2022).

An analysis of the seasonal proportion of mature female lobsters that were carrying visible eggs (in berry and not therefore in a vulnerable state that may be landed by fishers) was done for all QMAs including CRA 6 (see Section 4.3).

Growth increments from tag-recapture data were used to inform the estimation of size specific growth rates by sex within the stock assessment model. Due to the lack of tag-recapture observations for CRA 6 and, following the approach of Rudd et al. (2019), these data were supplemented with tag-recapture data from the Fiordland region of CRA 8, which were jointly processed for use by the CRA 6 stock assessment (described in Section 5).

2. CATCH

2.1 Commercial catch

The CRA 6 stock assessment assumed seasonal catches (with the autumn/winter (AW) season comprising April to September and the spring/summer (SS) comprising October to March) from the first model year of 1965 to the most recent year of data in 2022. The statutory fishing year is April to March and is designated with the first year of the pair (Ministry for Primary Industries 2016). Monthly catch estimates from Annala & King (1983) were summarised by season to determine the commercial catches for fishing years 1965 to 1973. Catch estimates for 1974–1978 were only available by calendar year (Annala & Esterman 1986). These catch estimates were converted to seasonal catch within an April–March fishing year by dividing the monthly catch totals from 1972, 1973, 1979, and 1980 into three-month quarterly periods and applying the average quarterly proportions to the 1974–1978 Annala & Esterman (1986) catch statistics. The first quarter in each year was added to the final three quarters of the preceding year to derive catch statistics for respective fishing years by season.

From 1 January 1979 to 31 March 1986, catch totals were taken from monthly data summarised by fishing year from data collected by the Fisheries Statistics Unit (FSU), a version of which is now held by Fisheries New Zealand as part of the Ministry of Primary Industries (MPI).

From 1 April 1986 to 31 March 1988, reported monthly catch totals from all of New Zealand were obtained from Quota Management Returns (QMRs) maintained by MPI, without the corresponding separation into QMAs. Because catch estimates for individual QMAs were not available for this period, the total New Zealand catch statistics were divided into QMA catch estimates based on the proportional landings reported on FSU forms. From 1 April 1988 to 30 September 2001, catch estimates were summarised from monthly QMRs from each QMA. The QMRs were replaced by Monthly Harvest Returns (MHRs) on 1 October 2001, but the same information is available from these new forms (Table 1, Figure 2).

2.2 Recreational catch

A Chatham Islands recreational harvest survey was done in the late 2000s (Davey et al. 2011). This study estimated 2811 kg rock lobster caught in the 2008 fishing year, mainly taken by local residents. In 2018, the RLWG agreed to a constant 6.03 tonne recreational catch per year, which was made up of 5 tonnes of recreational catch and a maximum section 111 catch of 1.03 tonnes.

For the 2023 CRA 6 stock assessment, the RLWG lowered the constant value used for recreational catch from 5 tonnes/year to 3 tonnes/year. In the fishing year immediately following the 2018 stock assessment, the section 111[6] catch was 1.68 tonnes, making this the highest section 111 catch during the CELR period. Therefore, the RLWG settled on a combined total of 4.68 tonnes of recreational catch for the 2023 stock assessment, under the agreement that the highest value for section 111 catches would be added to the recreational catch estimate for all years. The 2023 CRA 6 stock assessment assumed 90% of recreational catch to have been taken in the SS and the balance in the AW (Figure 2, Table 1).

2.3 Illegal catch

Recent red rock lobster stock assessments have assumed that the annual illegal catch should be defined as a fixed percentage (usually 10% to 20%) of the commercial catch before 1990 when rock lobsters were brought into the QMS, which was then dropped to a lower level in 1990 in recognition of the impact of the introduction to the QMS. The lower percentage for the years since the introduction of the QMS was assumed because of the greater control over the sale and receipt of lobsters once they became a tradeable asset. In line with these decisions, the RLWG chose to set the 1965–1989 illegal catch to 5% of annual commercial catch, which was then reduced to 2% of the annual commercial catch between 1990 and 2022, for the 2023 CRA 6 stock assessment. These assumed illegal catch percentages for CRA 6 were lower than those assumed for other QMAs, because of the remoteness of the Chatham Islands and the consequent difficulty of exporting unreported catch.

The 2018 CRA 6 stock assessment assumed some portion of illegal catch was subsequently reported as legally reported catch, and therefore this reported illegal catch was subtracted from the reported commercial catches to avoid double counting catch. The RLWG decided that the 2023 stock assessment would no longer assume there was reported illegal catch. This meant that all illegal catch was treated as unreported and added to the total annual catch.

The seasonal split of illegal catch was assumed to be the same as for reported commercial catches (Figure 2, Table 1).

2.4 Customary catch

For the 2023 CRA 6 stock assessment, the RLWG lowered the assumed constant value used for customary catch from 4 t/year to 2 t/year. The 2023 CRA 6 stock assessment assumed 90% of customary catch to have been taken in the SS and the balance in the AW (Figure 2, Table 1).

[6] Section of the Fisheries Act that allows fishers to keep lobsters for personal use. These are declared as 'F' disposals on landing forms.

Table 1: CRA 6 seasonal (AW and SS) catches (tonnes) (commercial, recreational including s 111, illegal and customary) from 1965 to 2022 by statistical area and summed for all CRA 6. The non-commercial catches in this table reflect the RLWG agreements described in Sections 2.2, 2.3, and 2.4.

Fishing	Commercial		Recreational		Illegal		Customary		CRA 6	
year	AW	SS	AW	SS	AW	SS	AW	SS	AW	SS
1965	0.0	250.6	0.5	4.2	0.0	12.5	0.2	1.8	0.7	269.1
1966	670.0	1 204.9	0.5	4.2	33.5	60.2	0.2	1.8	704.2	1 271.2
1967	1 584.4	3 027.6	0.5	4.2	79.2	151.4	0.2	1.8	1 664.3	3 185.0
1968	2 477.7	3 686.1	0.5	4.2	123.9	184.3	0.2	1.8	2 602.3	3 876.4
1969	1 234.5	1 937.3	0.5	4.2	61.7	96.9	0.2	1.8	1 296.9	2 040.2
1970	388.1	862.7	0.5	4.2	19.4	43.1	0.2	1.8	408.2	911.8
1971	304.5	692.6	0.5	4.2	15.2	34.6	0.2	1.8	320.4	733.2
1972	239.3	672.2	0.5	4.2	12.0	33.6	0.2	1.8	251.9	711.8
1973	200.4	496.8	0.5	4.2	10.0	24.8	0.2	1.8	211.0	527.7
1974	121.0	397.0	0.5	4.2	6.1	19.8	0.2	1.8	127.8	422.8
1975	77.3	253.7	0.5	4.2	3.9	12.7	0.2	1.8	81.9	272.4
1976	91.4	299.6	0.5	4.2	4.6	15.0	0.2	1.8	96.6	320.6
1977	70.8	232.2	0.5	4.2	3.5	11.6	0.2	1.8	75.0	249.8
1978	92.9	304.7	0.5	4.2	4.6	15.2	0.2	1.8	98.2	325.9
1979	113.9	286.4	0.5	4.2	5.7	14.3	0.2	1.8	120.2	306.8
1980	84.1	271.8	0.5	4.2	4.2	13.6	0.2	1.8	88.9	291.4
1981	105.5	359.8	0.5	4.2	5.3	18.0	0.2	1.8	111.5	383.8
1982	136.2	335.5	0.5	4.2	6.8	16.8	0.2	1.8	143.6	358.3
1983	139.0	408.7	0.5	4.2	7.0	20.4	0.2	1.8	146.7	435.1
1984	95.0	372.4	0.5	4.2	4.7	18.6	0.2	1.8	100.4	397.0
1985	130.4	473.2	0.5	4.2	6.5	23.7	0.2	1.8	137.6	502.9
1986	88.6	491.7	0.5	4.2	4.4	24.6	0.2	1.8	93.7	522.3
1987	73.2	375.3	0.5	4.2	3.7	18.8	0.2	1.8	77.5	400.1
1988	75.1	375.1	0.5	4.2	3.8	18.8	0.2	1.8	79.5	399.8
1989	69.2	249.1	0.5	4.2	3.5	12.5	0.2	1.8	73.3	267.6
1990	55.0	314.7	0.5	4.2	1.1	6.3	0.2	1.8	56.7	327.0
1991	62.3	326.0	0.5	4.2	1.2	6.5	0.2	1.8	64.2	338.6
1992	78.3	251.1	0.5	4.2	1.6	5.0	0.2	1.8	80.6	262.1
1993	79.4	262.4	0.5	4.2	1.6	5.2	0.2	1.8	81.6	273.7
1994	66.6	245.9	0.5	4.2	1.3	4.9	0.2	1.8	68.6	256.9
1995	73.8	241.6	0.5	4.2	1.5	4.8	0.2	1.8	75.9	252.4
1996	106.1	272.2	0.5	4.2	2.1	5.4	0.2	1.8	108.9	283.7
1997	117.4	221.3	0.5	4.2	2.3	4.4	0.2	1.8	120.4	231.7
1998	96.2	238.1	0.5	4.2	1.9	4.8	0.2	1.8	98.8	248.9
1999	98.4	224.0	0.5	4.2	2.0	4.5	0.2	1.8	101.0	234.5
2000	113.5	229.2	0.5	4.2	2.3	4.6	0.2	1.8	116.4	239.8
2001	89.9	238.7	0.5	4.2	1.8	4.8	0.2	1.8	92.4	249.5
2002	94.7	241.6	0.5	4.2	1.9	4.8	0.2	1.8	97.3	252.5
2003	78.0	212.4	0.5	4.2	1.6	4.2	0.2	1.8	80.2	222.7
2004	96.3	226.7	0.5	4.2	1.9	4.5	0.2	1.8	98.9	237.2
2005	100.7	251.0	0.5	4.2	2.0	5.0	0.2	1.8	103.4	262.0
2006	117.5	234.6	0.5	4.2	2.3	4.7	0.2	1.8	120.5	245.3
2007	111.6	244.4	0.5	4.2	2.2	4.9	0.2	1.8	114.5	255.3
2008	96.8	258.6	0.5	4.2	1.9	5.2	0.2	1.8	99.4	269.7
2009	73.4	271.7	0.5	4.2	1.5	5.4	0.2	1.8	75.6	283.2
2010	100.2	257.2	0.5	4.2	2.0	5.1	0.2	1.8	102.9	268.4
2011	83.3	276.4	0.5	4.2	1.7	5.5	0.2	1.8	85.6	287.9
2012	64.5	291.4	0.5	4.2	1.3	5.8	0.2	1.8	66.5	303.3
2013	77.6	266.0	0.5	4.2	1.6	5.3	0.2	1.8	79.8	277.3
2014	78.1	256.4	0.5	4.2	1.6	5.1	0.2	1.8	80.3	267.6
2015	79.7	273.6	0.5	4.2	1.6	5.5	0.2	1.8	82.0	285.0
2016	108.8	250.7	0.5	4.2	2.2	5.0	0.2	1.8	111.6	261.8
2017	117.1	242.0	0.5	4.2	2.3	4.8	0.2	1.8	120.1	252.8
2018	122.3	237.6	0.5	4.2	2.4	4.8	0.2	1.8	125.5	248.4
2019	107.1	221.5	0.5	4.2	2.1	4.4	0.2	1.8	109.9	232.0
2020	112.7	278.2	0.5	4.2	2.3	5.6	0.2	1.8	115.6	289.8
2021	108.2	251.8	0.5	4.2	2.2	5.0	0.2	1.8	111.0	262.8
2022	90.9	268.2	0.5	4.2	1.8	5.4	0.2	1.8	93.4	279.5

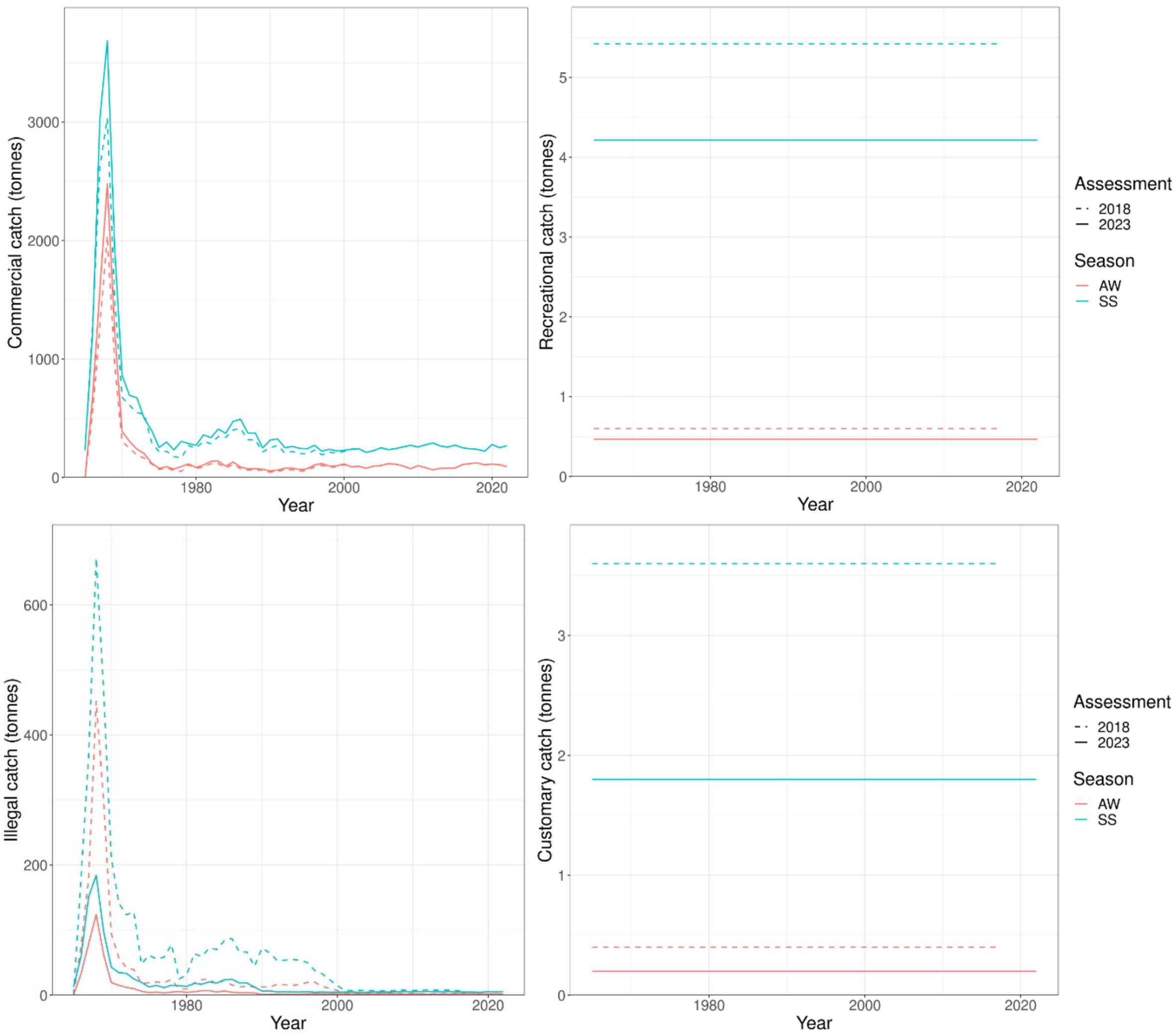

Figure 2: CRA 6 commercial, recreational, illegal, and customary catch (tonnes) by season from the start year of 1965 to the final model year 2022. The dashed line shows the catches used in the 2018 assessment and the solid line shows the catches used in the 2023 assessment (see Table 1 for annual seasonal catches by sector).

3. CATCH PER UNIT EFFORT (CPUE)

CPUE indices provide the stock assessment with a relative measure of abundance, which is assumed to reflect the underlying vulnerable biomass over time. Six different CPUE index series were available for the CRA 6 stock assessment:

1. 1965–1973 historical catch rate (CR) series;
2. 1979–80 to 1988–89 series based on commercial catch data collected by the Fisheries Statistics Unit (FSU);
3. 1989–90 to 2019–20 series based on the statutory commercial catch data (CELR) collected on paper forms by Fisheries New Zealand;
4. 2019–20 SS to 2022–23 series of statutory commercial catch data collected by Fisheries New Zealand under the electronic reporting system (ERS); and
5. 2014–15 to 2022–23 series based on the voluntary logbook data collected by the CRA 6 fishing industry.

Each of these CPUE series are described below. The ERS data were not used by the CRA 6 assessment due to inconsistencies with data collection under the CELR system (see appendix B of Starr 2024 for a supporting analysis). In addition, the ERS data could not be used as an independent series because there were only 4 years of data at the time of analysis.

3.1 CR CPUE

Monthly catch and effort (days fishing) data for 1965–1973 were summarised by Annala & King (1983) and were used to calculate a CPUE series based on the unstandardised catch per day for each calendar year and season from 1965 to 1973 (Table A.1, Figure 3).

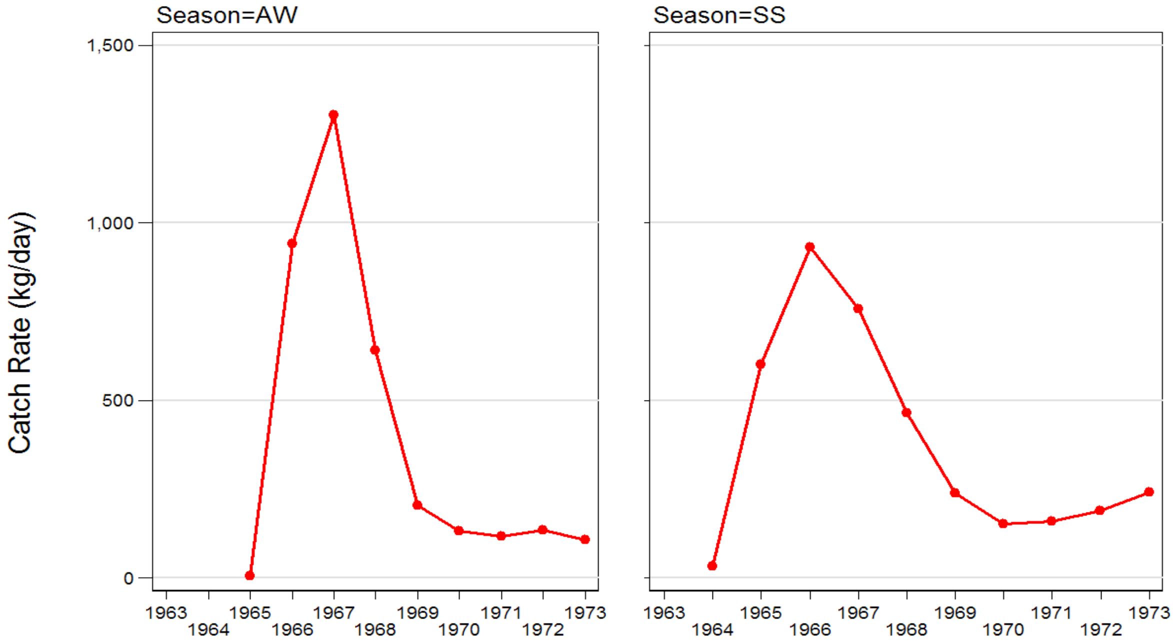

Figure 3: Unstandardised catch rate (CR) CPUE indices (kg/day) by calendar year and season for CRA 6 (derived from Annala & King 1983).

3.2 FSU CPUE

The FSU CPUE series covers the period from 1979–80 to 1989–90 AW and was based on data from the FSU database. These data represent the entire fishery in the early years, with a reduction in participation after the programme was officially ended in 1986. The data were aggregated by fishing year, season, month, statistical area, and vessel. FSU CPUE was defined as the sum of the catch of legal lobsters divided by the number of pots lifted per stratum. These data are used by the stock assessment model as an index of abundance for legal lobsters (i.e., does not include berried females or lobsters below the minimum legal size, MLS). An adequate number of records were available for this analysis in each vessel, season, and statistical area stratum (Table A.2).

Explanatory variables offered to the CRA 6 FSU CPUE standardisation model included:

1. period (i.e., a fishing year/season) specified as a population-level parameter (analogous to fixed effects);
2. month as a group-level effect (analogous to random effects);
3. vessel as a group-level effect;
4. statistical area as a population-level effect; and
5. a period/statistical area interaction term specified as a group-level effect.

A lognormal distribution was assumed. Modelling was done using *brms* in *R* (Bürkner 2017, R Core Team 2022) and the leave-one-out information criterion (LOO IC) and Bayesian R^2 were used for model selection (Vehtari et al. 2017). The *brms* package is a wrapper for Stan (Stan Development Team 2018) that facilitates running MCMC using the Hamiltonian Monte Carlo (HMC) algorithm. The best model according to the LOO IC and Bayesian R^2 was the most complex model that included all of the terms listed above. The Markov chain Monte Carlo (MCMC) for the best model mixed well (Figure A.1), and the lognormal assumption was met adequately (Figure A.2). The FSU CPUE series indicated a gradually declining stock from 1979–80 to 1989–90 AW, but showed relatively little contrast (Table A.1, Figure 4).

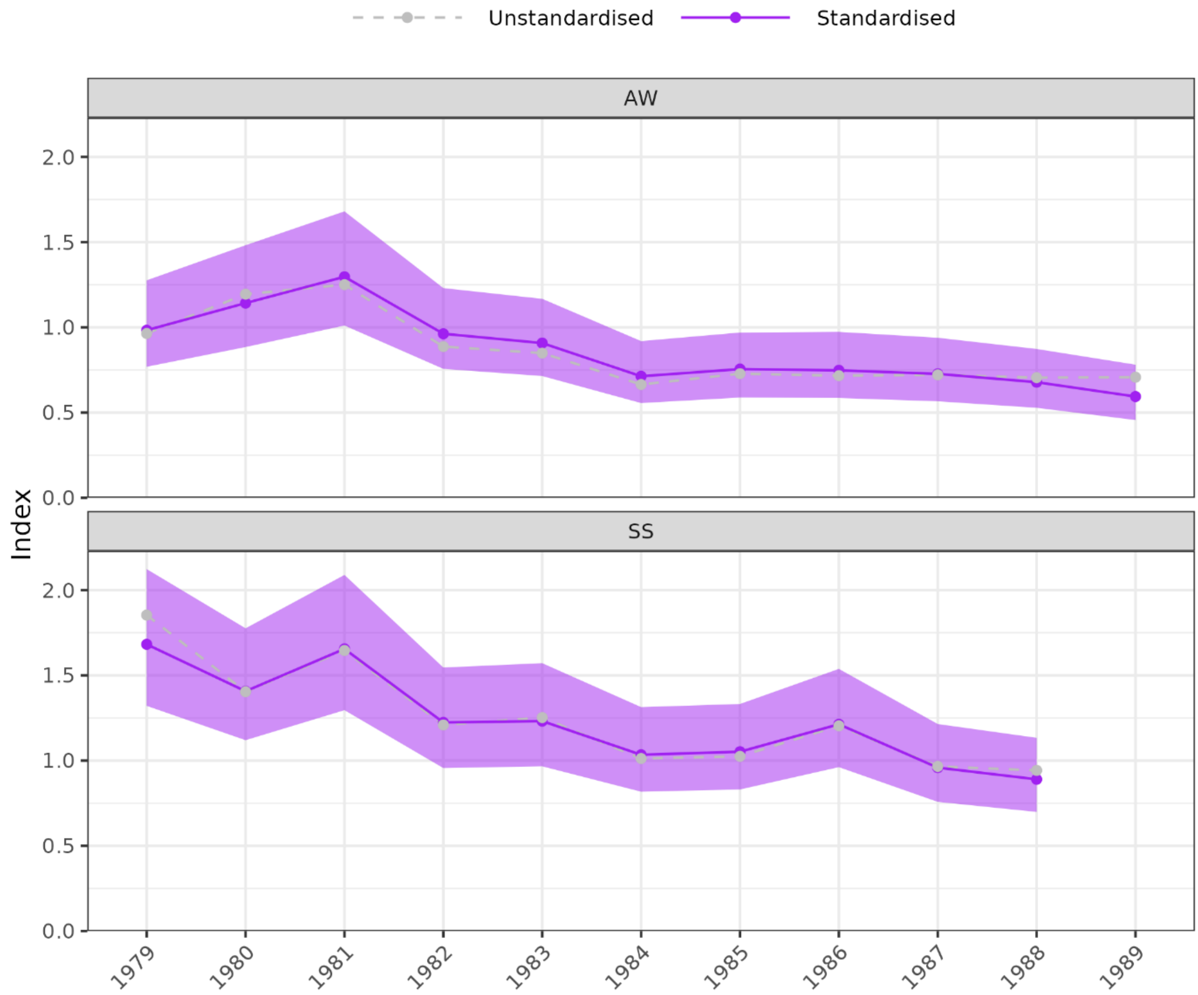

Figure 4: Standardised FSU CPUE indices (kg/potlift) by fishing year and season (AW = autumn/winter, SS = spring/summer) for CRA 6. Plot shows the posterior median (points) connected by lines and the 95% credible interval (shaded region).

3.3 CELR CPUE

The CELR CPUE series covered the period from 1989–90 SS to 2019–20 AW. This series only included core vessels, which were defined as those vessels that operated within the CRA 6 fishery for at least five years. The CELR (paper form) data comprise the statutory reporting of all catch for each vessel. Therefore, the CELR CPUE series is representative of the commercial catch and effort for each year and is used by the stock assessment model as an index of abundance for legal lobsters (i.e., it does not include berried females or lobsters below the MLS). An adequate number of records were available for this analysis in each vessel, season, and statistical area stratum (Table A.2).

Explanatory variables offered to the CRA 6 CELR CPUE standardisation model included:

1. period (i.e., a fishing year/season), specified as a population-level parameter (analogous to fixed effects);

2. month, as a group-level effect (analogous to random effects);
3. vessel, as a group-level effect;
4. statistical area, as a population-level effect; and
5. a period/statistical area interaction term, specified as a group-level effect.

A lognormal distribution was assumed. Modelling was done in *brms* and the LOO IC and Bayesian R^2 were used for model selection. The best model according to the LOO IC and Bayesian R^2 was the most complex model that included all of the terms listed above. The MCMC for the best model mixed well (Figure A.3), and the lognormal assumption was met adequately (Figure A.4). The resulting CELR CPUE series suggested an increasing stock from the mid-1990s to 2019–20 AW (Table A.1, Figure 5).

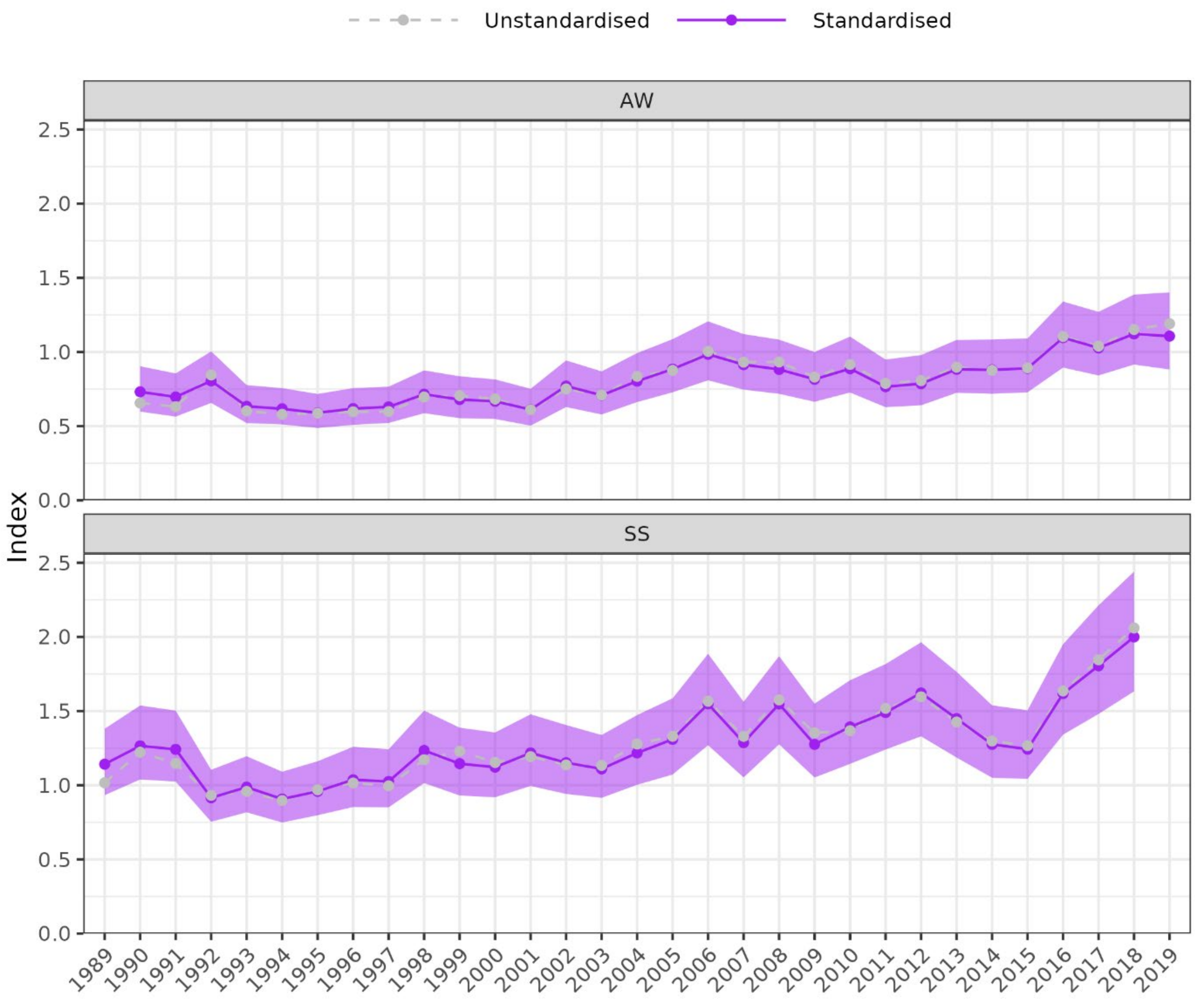

Figure 5: Standardised CELR CPUE indices (number/potlift) by fishing year and season (AW = autumn/winter, SS = spring/summer) for CRA 6. Plot shows the posterior median (points) connected by lines and the 95% credible interval (shaded region).

3.4 Logbook CPUE

The methods used for the logbook CPUE analysis for CRA 6 were comparable with those used for CRA 2 (described in sections 2.2 and 3.2 of Webber & Starr 2022). Logbook CPUE is different to CR, FSU, and CELR CPUE in that it is an index of abundance for all lobsters above the MLS (i.e., includes berried females) and has units in numbers per potlift (rather than kg per potlift).

The logbook programme in CRA 6 was initiated in 2001–02, but the logbook CPUE series used for this assessment was limited to the period from 2014–15 AW to 2022–23 SS, because the logbook data were considered to be non-representative before 2014 and were consequently not used. In statistical areas 940 and 941, there was an adequate number of records available for this analysis in each vessel, season, and statistical area stratum (Table A.2). However, there were missing seasonal strata in statistical areas 942 and 943, possibly reflecting a lack of representative coverage in these statistical areas even after 2014 (Table A.2).

The proportion of pots containing no lobsters declined after 2019–20, suggesting either that abundance increased, or that the reporting of pots containing zero lobsters had become less reliable (Figure 6). The former explanation seems more plausible because there is a trend in this statistic, with the expectation that a reporting issue would be more variable between years.

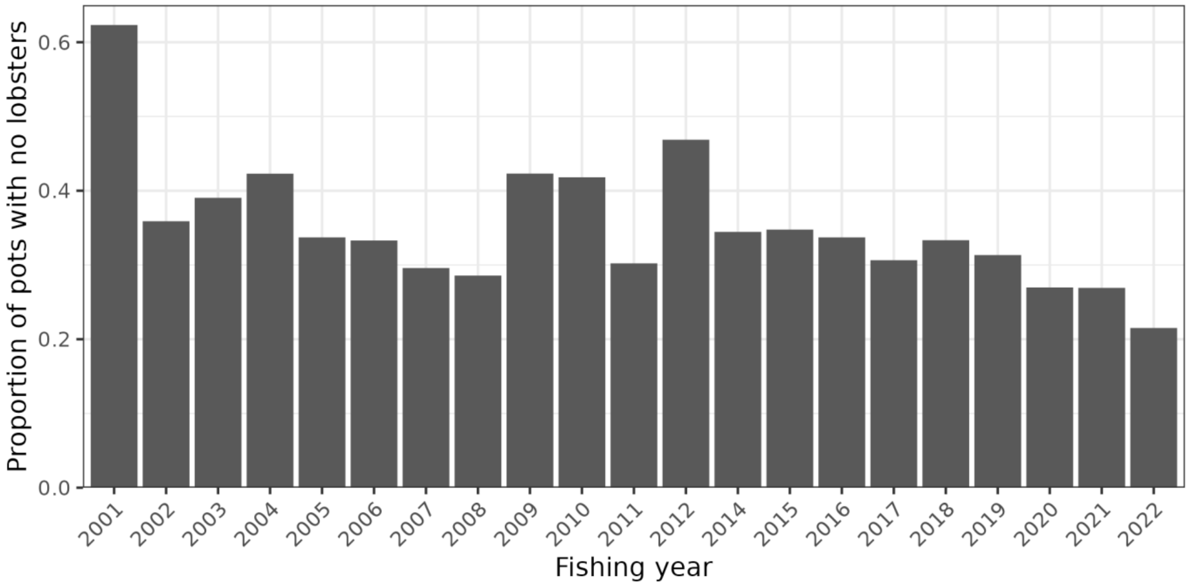

Figure 6: Proportion of logbook pots containing no lobsters in CRA 6. Note that the RLWG did not accept the data before 2014–15 as being representative of the fishery.

Two different models were explored, with one model assuming a negative binomial distribution and the other a hurdle negative binomial distribution, where the probability of a non-zero catch was modelled using a binomial distribution and positive catch was modelled using the negative binomial distribution. The number of lobsters caught per pot was specified as the dependent variable and the model included the following explanatory variables: period, month, vessel, statistical area, and a period/statistical area interaction term for both the hurdle and positive catch components.

The hurdle negative binomial model was selected as the better model by the LOO IC (14 570 units for the negative binomial and 14 475 units for the hurdle negative binomial, where lower is better). The MCMC for the hurdle model mixed well (Figure A.5) and represented the observed distribution of the data better than the negative binomial model (Figure A.6). However, there was still some indication that the number of pots containing a single lobster was not being modelled well. Note that there was little difference in the resulting CPUE series when comparing the negative binomial and a hurdle negative binomial models, indicating that this was not a serious problem (Figure 7). The temporal pattern in this CPUE series agreed well with the CELR-derived CPUE series in overlapping years (Table A.1, Figure 8). The standardisation reduced the AW CPUE in recent years, relative to the unstandardised series, but had little influence on the SS series (Figure 9).

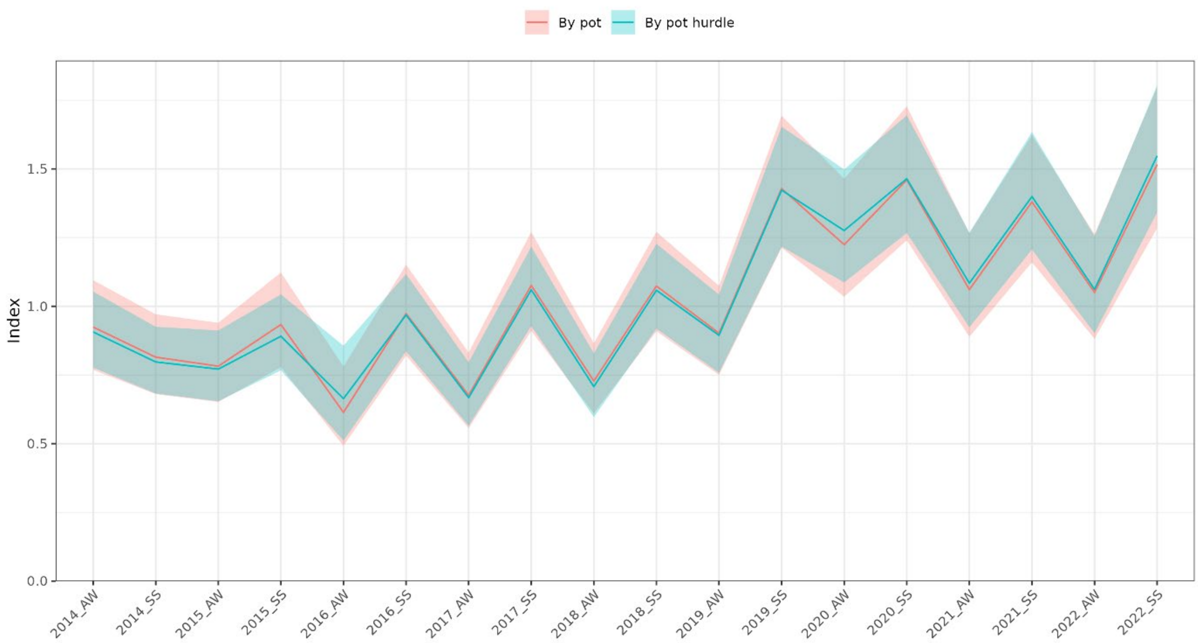

Figure 7: Standardised logbook CPUE indices (number/potlift) by season and fishing year for CRA 6. Plot shows the posterior median (points) connected by lines and the 95% credible interval (shaded region).

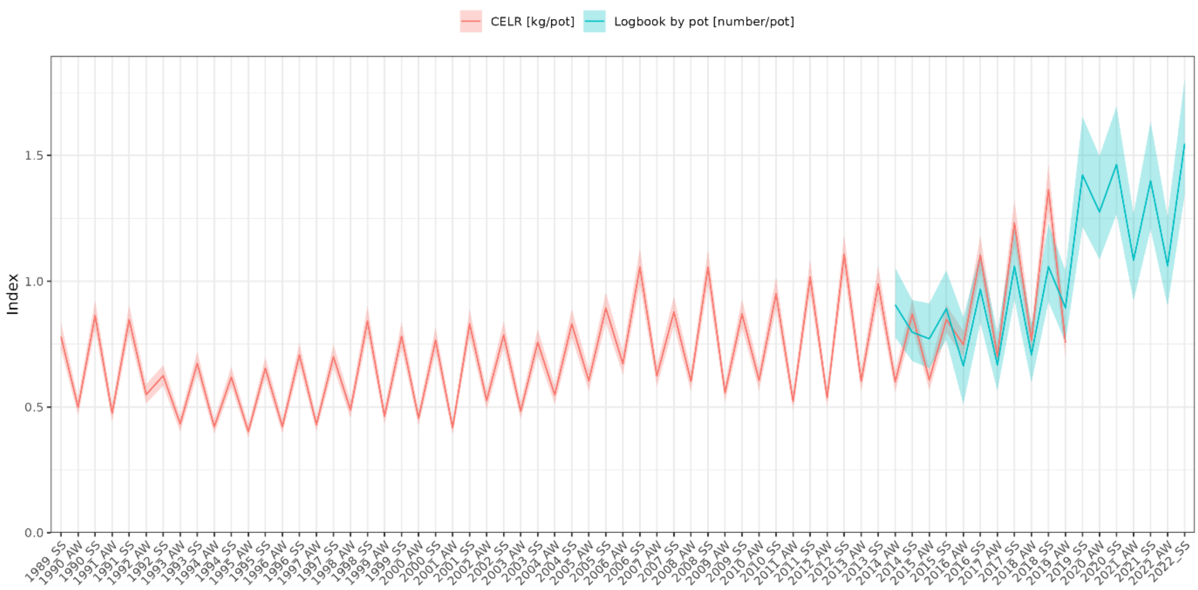

Figure 8: Standardised CELR and logbook CPUE indices by fishing year and season for CRA 6. Plot shows the posterior median (points) connected by lines and the 95% credible interval (shaded region). The series are rescaled to have the same geometric mean for overlapping years.

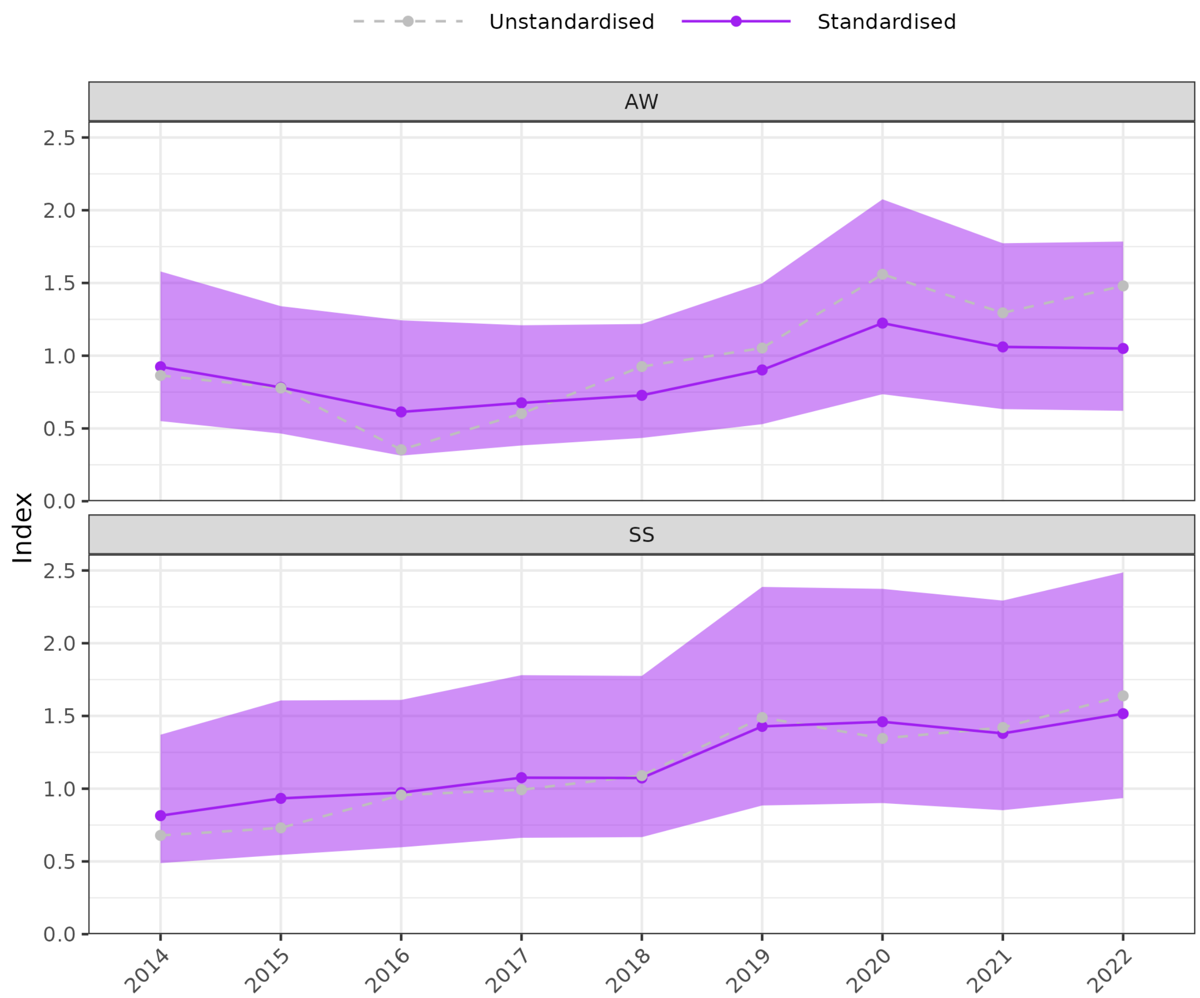

Figure 9: Standardised logbook CPUE indices (number/potlift) by season and fishing year for CRA 6. Plot shows the posterior median (points) connected by lines and the 95% credible interval (shaded region).

4. COMPOSITION OF THE CATCH

Catch must be further stratified by sex category (males, immature females, mature females) and length bin before it can be removed from the modelled stock. Splitting the catch in this way was informed by the sex ratio data, the length frequency data, and the proportion of mature females in berry covariate. These inputs were derived from available observer catch sampling and the voluntary logbook data sets and standardisation models were developed for all three types of data/covariate.

The design of the voluntary logbook (LB) catch sampling programme required participating fishers to measure every lobster in 3–5 marked pots for every fishing day up to a maximum of 25 lobsters per pot. Additional lobsters beyond the 25-pot limit were enumerated with respect to size above or below the MLS. This design results in a good spatial and temporal representation of the catch if the participating fishers are representative of the wider fishing fleet, select representative pots for monitoring, and record the catch information accurately. This outcome was not achieved in CRA 6 in many years, with a low rate of participation in the logbook programme since its beginning in 2001 and there was evidence of poor reporting (Table 2). The CRA 6 LB programme started in 2001 with two participants, rapidly expanded to 17 participants by 2005, and then declined to 5 to 10 participants in the years from 2012 to 2022. The LB data appeared to be highly variable between years, leading to the conclusion that some years were likely to be unrepresentative of the fishery, and there was internal evidence of excessive rounding of measurements. A ‘Shannon entropy’ (Shannon 1948) test was applied to these LFs, in an attempt to identify those years where data did not match either the preceding or succeeding sample years. This analysis was premised on the assumption that year-to-year variation in LF distribution should be relatively minor and that large shifts were evidence of unrepresentative sampling. The RLWG agreed, after reviewing this analysis, that all logbook data collected before 2014 would be discarded. However, data for the years 2001 to 2014 were retained for the sex ratio modelling.

The observer catch sampling programme (CS) places trained observers on participating vessels who are charged with measuring and sexing all lobsters in every pot that is hauled in a day of fishing. This goal is often difficult to achieve if the fishing is productive. Consequently, observers are allowed to skip pots after recording the total number of lobsters in the skipped pot (including both legal and sub-legal lobsters). Historically, some CS was done in 1982, 1989, and from 1993 to 1997, followed by a hiatus until the programme was restarted in 2020. However, no sampling took place in 2021 because of COVID-19, with sampling resuming in 2022 (Table 2). A problem with the CRA 6 catch sampling data is the limited coverage within the year, given the remoteness of the Chatham Islands, resulting in coverage mainly restricted to the spring and summer months within a year.

Table 2: Number of vessels, skippers, trips, days sampled, pots lifted, and lobsters measured in the observer catch sampling (CS) and voluntary logbook (LB) programmes each fishing year. The fishing years shaded grey were not included in the LF and SR models.

Fishing	Observer catch sampling					Voluntary logbook				
year	Vessels	Days	Trips	Pots	Lobsters	Vessels	Days	Trips	Pots	Lobsters
1982	1	3	4	4	287	–	–	–	–	–
1989	9	13	13	559	1 472	–	–	–	–	–
1993	9	12	13	345	648	–	–	–	–	–
1994	11	12	12	343	666	–	–	–	–	–
1995	22	18	53	1 237	2 550	–	–	–	–	–
1996	27	27	51	1 860	7 503	–	–	–	–	–
1997	18	17	36	1 044	2 707	–	–	–	–	–
2001	–	–	–	–	–	2	35	42	52	122
2002	–	–	–	–	–	6	93	128	255	599
2003	–	–	–	–	–	8	126	221	379	1 170
2004	–	–	–	–	–	6	133	178	354	938
2005	–	–	–	–	–	18	200	416	821	3 251
2006	–	–	–	–	–	11	169	326	647	2 268
2007	–	–	–	–	–	15	182	382	696	2 793
2008	–	–	–	–	–	12	166	332	620	2 345
2009	–	–	–	–	–	3	84	106	181	542
2010	–	–	–	–	–	9	93	139	281	993
2011	–	–	–	–	–	13	153	266	553	1 995
2012	–	–	–	–	–	5	87	107	203	630
2014	–	–	–	–	–	5	114	165	299	1 223
2015	–	–	–	–	–	5	83	104	214	876
2016	–	–	–	–	–	6	64	82	130	475
2017	–	–	–	–	–	8	81	108	175	819
2018	–	–	–	–	–	10	114	175	305	1 395
2019	–	–	–	–	–	8	67	81	149	810
2020	2	4	4	305	3 065	8	120	201	345	1 966
2021	–	–	–	–	–	7	112	153	266	1 474
2022	8	16	16	966	5 720	10	88	137	293	1 804

The CS (replog 15070) and LB (J. Olver, Fishserve, pers. comm.) data for CRA 6 were extracted in May and June 2023. The extracted data contained nine years of data for the CS programme between 1982 and 2022 and 21 years of data for the LB programme from 2001 to 2022. The 1982 fishing year was dropped from the data set because there were no females in the data set, rendering its reliability questionable. The LB data from 2001 to 2012 were dropped from the LF data set as described above; however, data for these years were retained for the sex ratio modelling.

Bayesian inference for the sex ratio, length frequency, and proportion in berry models was done using the R package *brms*.

4.1 Sex ratio of the catch

A model was constructed where the predictor term for each sex category estimated the sex ratio (SR) for each fishing year, month, statistical area, and fishing vessel (similar to the methods outlined by Webber 2022). The explanatory variables included: fishing year, month, statistical area, vessel, 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 fishing year by statistical area interaction terms were treated as group-level 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 were generated and arranged as vectors by sex category (i.e., data source and trips were replicates). Note that the 2001–2012 LB data which were excluded from the LF analysis were included in this analysis. 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).

The SR model was then used to simulate the SR by year, month, and statistical area from the posterior distribution. This model-based approach also predicted the SR if there was catch in a stratum but no catch sampling from either data source and combined the available SR data from both data sources if both were present in the stratum.

The catch (tonnes) in each fishing year, month, and statistical area was calculated from the catch and effort database. The simulated SRs were scaled by the monthly catch in each statistical area and aggregated by posterior sample, fishing year, season, and sex category then converted to proportions (i.e., month and statistical area were rolled up). The mean and SD (i.e., uncertainty) by fishing year, season, and sex category were calculated from this distribution of sex ratios. Finally, the SR data set weight for each fishing year and season was calculated from the posterior SD (see Webber 2022).

The standardisation and the catch scaling did little to alter the time series of raw sex ratios by fishing year and season (Figure 10).

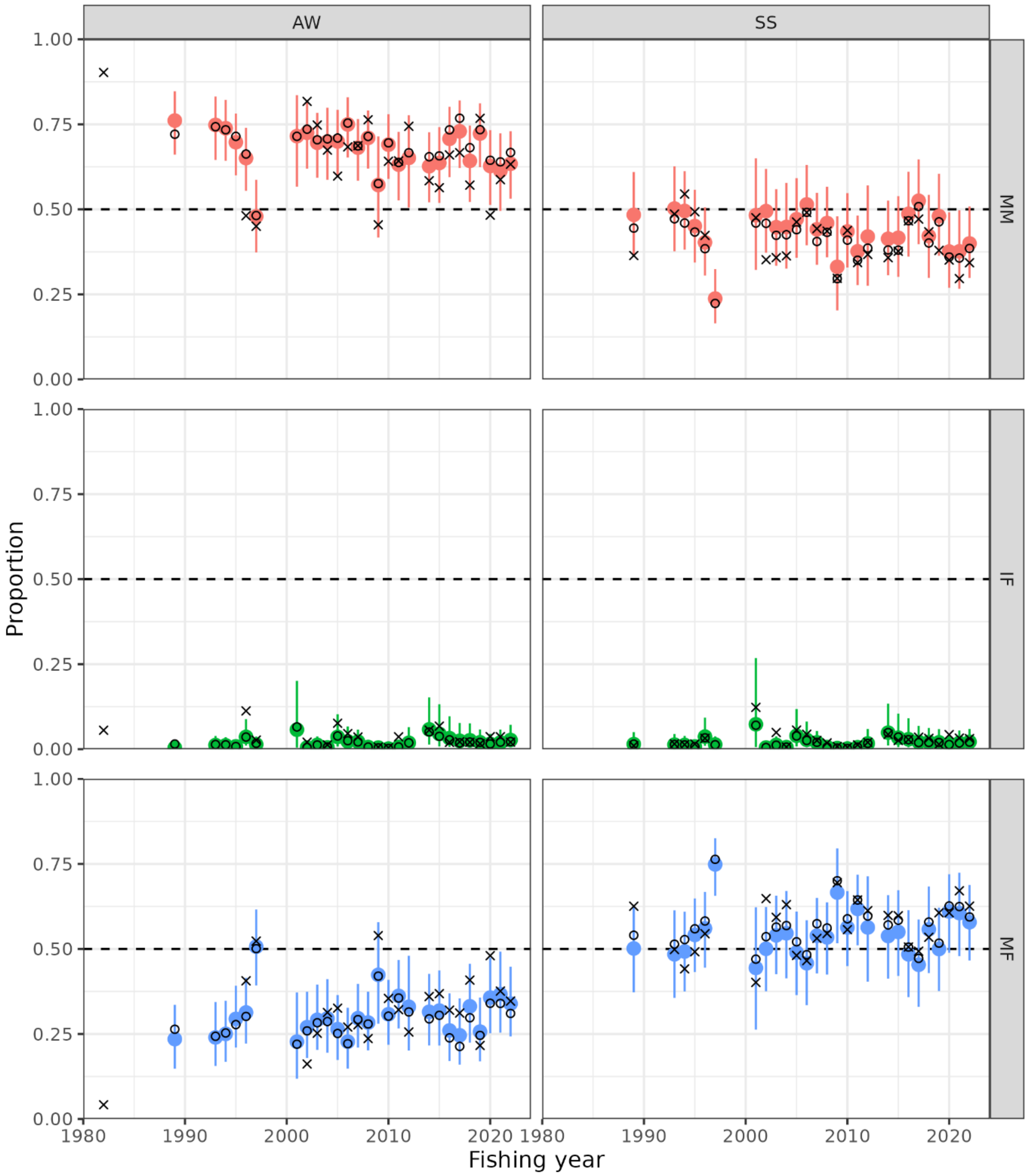

Figure 10: Sex ratios (SRs) by fishing year and season, showing raw SRs (black crosses), predicted SRs (open black circles), and scaled SRs (closed circles with error bars representing 95% credible intervals) for males (MM), immature females (IF), and mature females (MF) by fishing year and season (AW = autumn/winter, SS = spring/summer).

4.2 Length frequency of the catch

A model was constructed that estimated the proportion at length for each fishing year, month, and statistical area (see Webber 2022 and Roberts et al. 2023). The explanatory variables included: fishing year, month, statistical area, 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 fishing year by statistical area interaction term was treated as a group-level effect.

For a given sex category, fishing year, month, statistical area, data source (LB or CS), and trip, 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). Note that the 2001–2012 LB data were excluded from the LF analysis. 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 excellent (Figure B.2).

The fitted LF models were used to simulate the predicted LF by sex category, 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 and combined the available LF data from both data sources if both were present in the stratum.

The catch (tonnes) in each fishing year, month, and statistical area was calculated from the commercial catch and effort data. 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.

When the sample sizes were reasonably high, the LF standardisation (i.e., the scaled predicted LFs) predicted very similar LFs to those produced from the raw data (e.g., 1995 SS for mature females and males), but at low sample sizes or when sampling appeared to be non-representative (i.e., saw toothed), the procedure corrected the LFs considerably (Figure B.3, Figure B.4, Figure B.5). 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 approximately proportional to the catch by statistical area, while the LB programme design attempts to mimic fishing patterns and results in a data set that is essentially self-weighting. In general, the standardised CRA 6 LFs did not look as good as the LFs for other QMAs (compare Figure 11 with Webber 2022).

The mean tail width by sex category and season was highly variable during the AW season but appeared to have declined during the SS in both the CS and LB data sets (Figure 12).

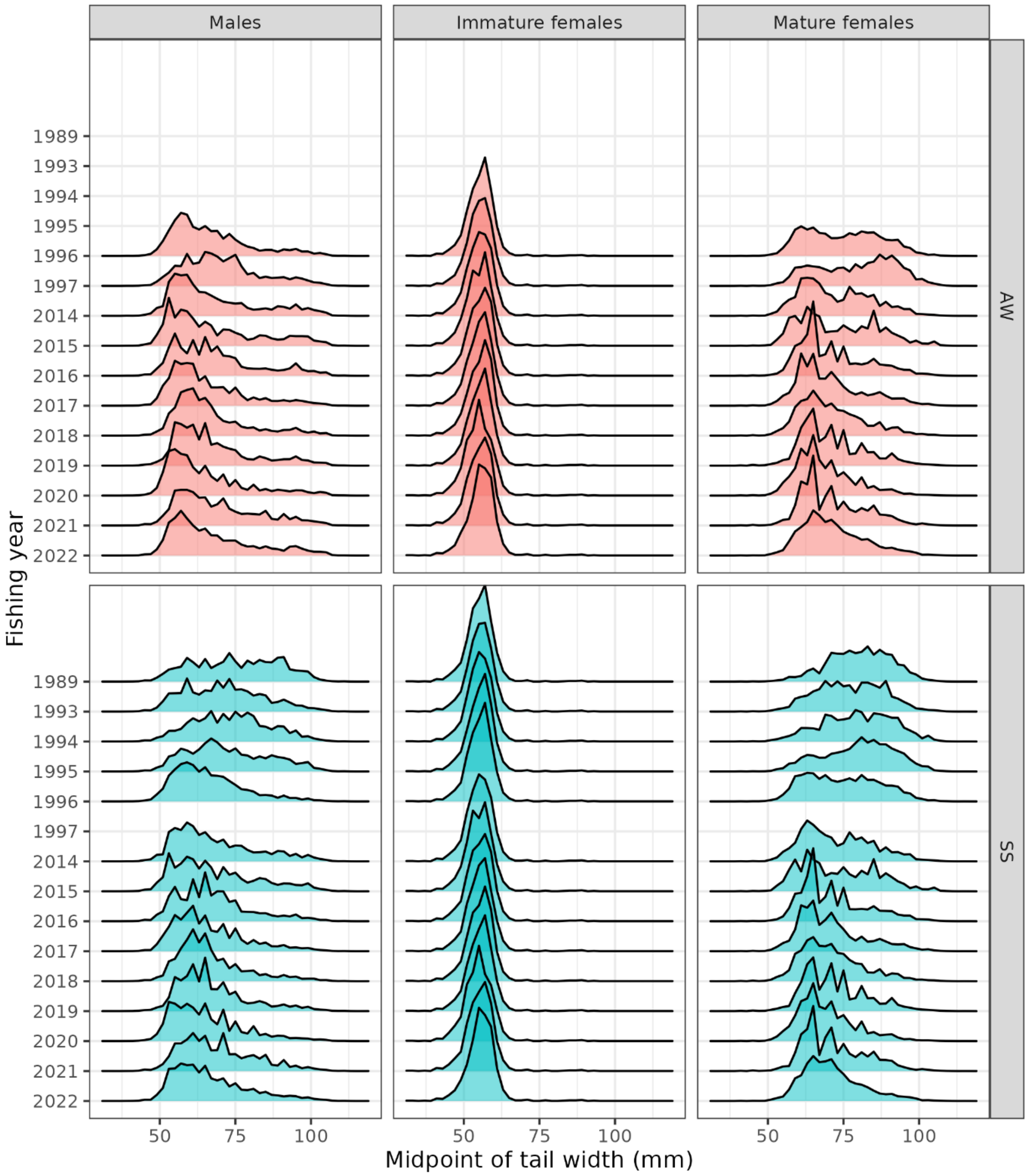

Figure 11: Expected standardised LFs by fishing year (from 1989 to 2022), season (AW = autumn/winter, SS = spring/summer), TW bin, and sex. See Figures B3 to B5 for a comparison of raw and standardised LF distributions by year, season, and sex.

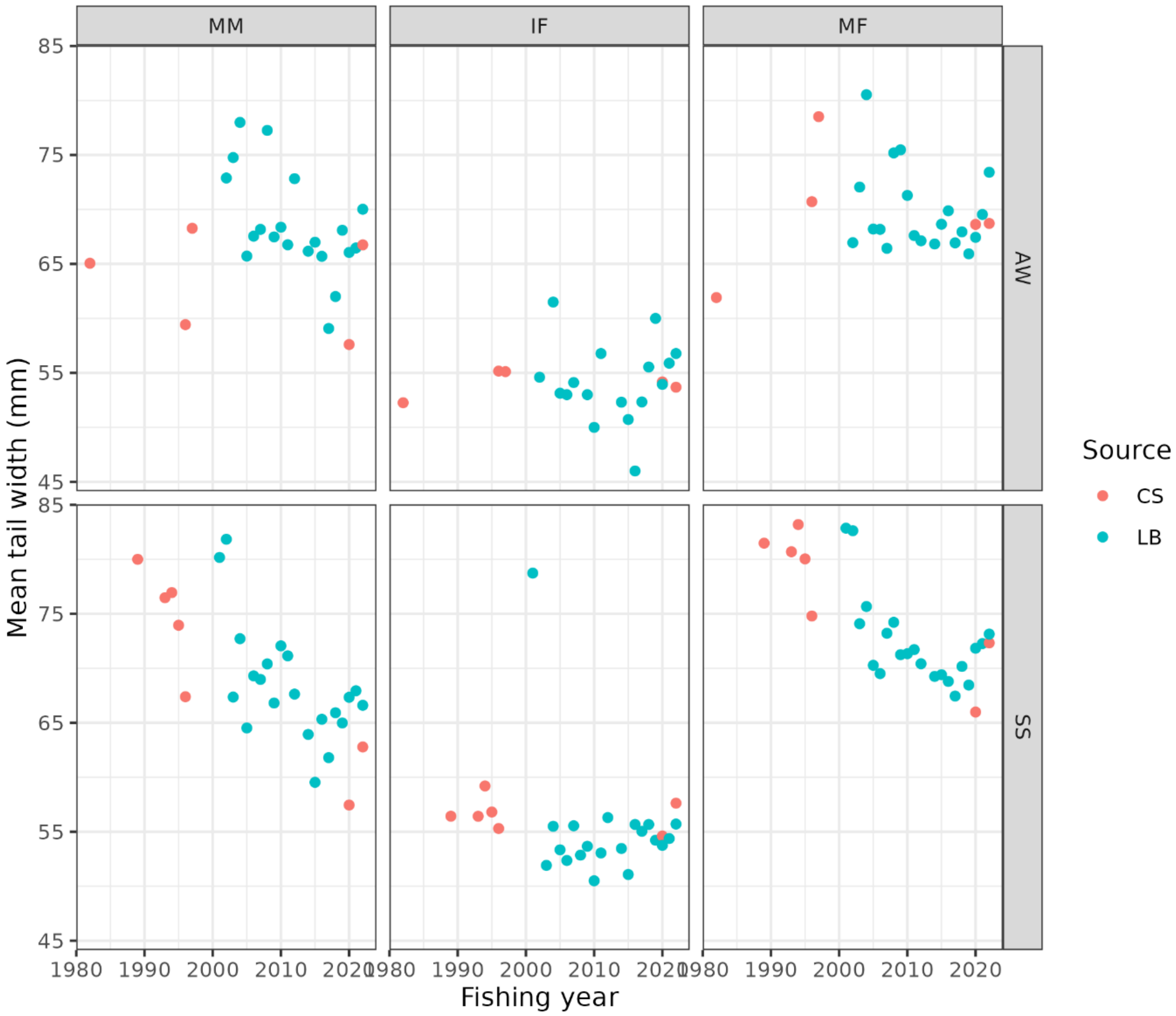

Figure 12: Mean tail width (mm) by fishing year, sex category (MM = males, IF = immature females, MF =mature females), season (AW = autumn/winter, SS = spring/summer), and data source (CS = observer catch sampling, LB = voluntary logbook).

4.3 Historical length frequency data

Kensler (1969) plotted a frequency histogram of 1152 male and 1339 female lobsters measured in October 1966. These plots were converted to LFs for use as input data to the 2018 stock assessment model, as were four 1982 LF samples found in the *rlcs* (observer) database. However, both of these datasets were dropped from the 2023 stock assessment. The 1966 LF data were rejected because it was unclear how well an isolated solitary undocumented sample would be able to inform the stock assessment and the 1982 LF data were rejected on the basis that they were likely to be unrepresentative of the fishery, because they consisted almost entirely of males.

4.4 Proportion of mature females in berry

The proportion of mature females in berry by year and season is a covariate in the stock assessment, which excludes this category from the catch in the size-limited fishery. A model-based approach was used to estimate the seasonal and annual proportions of mature females in berry for CRA 6. This analysis also estimated proportions in berry for the other assessed QMAs/stock regions, which are shown here for completeness.

Of a total of 2 122 502 individual lobsters in the LB extract, 1 095 380 were males, 169 775 were immature females, 4032 were unidentified stage females, and 1689 had no sex stage information.

Excluding these resulted in total sample of 851 646 mature female lobsters. In addition, 9061 records lacked information of statistical area of sampling, so were also excluded, yielding a total sample of 842 585 mature females that were used by this analysis.

Berried females were defined as having sex code = 4 (‘berried female’) or sex code = 5 (‘spent female’). Using this definition, 494 203 were assumed to be berried and 348 382 were not. The total number of records of mature females there were available for this analysis is summarised by berried status and QMA/stock assessment region in Table 3, and by the month of sampling in Table C.1.

There were two stages to the analysis that generated the proportion in berry estimates:

1. a model-based standardisation was used to produce predictions of the proportion of mature females that were berried/not berried by statistical area, fishing year, and month; then
2. using the reported catch in each (area/fishing year/month) stratum, catch-weighted values of the proportion of mature females in berry were produced for each stock-region and season and (as required) fishing year.

A binomial distribution was assumed, and models were fitted to the total number of mature females that were in berry (‘successes’), given the total number of mature females sampled (‘trials’) within each stratum. Explanatory variables offered to the model included:

1. month (*month*), specified as a group-level parameter (analogous to random effects);
2. fishing year (*fyear*) as a group-level effect;
3. island (i.e., North Island or South Island, with CRA 6 included in South Island) as a population-level effect (analogous to fixed effects);
4. statistical area (*area*) as a group-level effect; and
5. QMA/stock assessment region (*qma_region*), as a group-level effect.

Furthermore, interaction terms were offered between month fished and stock assessment region or statistical area, as well as between fishing year and stock assessment region or statistical area, to allow the month and year effects to vary in space.

Table 3: Sample size of mature females by berried status and QMA/stock assessment region.

QMA/stock assessment region	Non-berried	Berried
CRA 1	6 259	5 444
CRA 2	56 512	58 144
CRA 3_R1	5 264	3 191
CRA 3_R2	3 504	8 671
CRA 4	23 033	14 099
CRA 5_R1	52 065	118 016
CRA 5_R2	50 331	78 413
CRA 6	**10 141**	**4 018**
CRA 78_Fiordland	130 154	180 854
CRA 78_Southland	2 724	8 459
CRA 9	8 395	14 894

A series of different model structures was considered by this analysis (Table 4). Note that the model structure which included statistical area (*fit10*) was not comparable with other models using the LOO IC, because this model was fitted to data aggregated by statistical area and comprised more data points than models aggregated by stock assessment region (although comprised the same total number of ‘trials’).

For the models not including statistical area, the best model according to the LOO IC and Bayesian R^2 was the most complex model, which included: month fished, fishing year, and stock assessment region as main effects, as well as interactions terms between month fished/fishing year and stock assessment region (*fit9* , see Table 4). The MCMC for model *fit10* mixed well (Figure C.1) with no divergent transitions. The model fit to the data was excellent (Figure C.2). The posteriors of the estimated parameters of model *fit10* were summarised (Table C.2).

A summary of the predicted proportions of mature females in berry by QMA/stock assessment region and month is given in Figure C.3. These outputs indicate the timing of the reproductive cycle of female lobsters is broadly consistent across the assessed QMAs, including CRA 6, although with perhaps a slightly later onset of egg-bearing females in the northernmost QMAs—CRA 1, CRA 2, and CRA 9 (around June)—compared with the other QMAs (May). The more anomalous QMA regions (e.g., CRA 3 region 2 and CRA 7&8 Southland) had relatively sparse sampling of mature females in some months (Table C.1).

The predicted proportions for each QMA/stock assessment region were also shown for each season (Table C.3 and Figure C.4), noting that differences comparing assessment regions reflected differences in the monthly catch distribution as well as the reproductive cycle of females. Also, for CRA 6, the predicted proportions which were summarised by season and fishing year (Table C.4 and Figure C.5), indicated some variability when comparing across fishing years, although no obvious long-term trends.

The CRA 6 stock assessment used three alternative sets of outputs from this analysis of the proportion of mature females in berry:

- the unstandardised and non-catch-weighted seasonal averages, pooled across all individuals sampled in each period (i.e., AW = 0.866, SS = 0.142);
- the mean values of the model-estimated catch-weighed seasonal posteriors of mature females in berry across all fishing years (i.e., AW = 0.818, SS = 0.116); and
- the mean model-estimated values for each season and fishing year (see Table C.4 and Figure C.5).

Table 4: Summary of models used to predict the proportion of mature females in berry. The model *fit10* was not comparable with the others in terms of LOO IC, although is placed at the top of the table since one was the final model used for making predictions.

Label	Explanatory variables	Bayesian R^2	δ-LOO IC	SE LOO IC
fit10	(1|month) + (1|area) + (1|fyear) + (1|month:area) + (1|fyear:area)	0.988 (0.987–0.988)	–	–
fit9	(1|month) + (1|qma_region) + (1|fyear) + (1|month:qma_region) + (1|fyear:qma_region)	0.991 (0.990–0.991)	0	495
fit8	(1|month) + (1|qma_region) + (1|fyear) + (1|month:qma_region) + (1|fyear:island)	0.988 (0.987–0.988)	2 802	651
fit7	(1|month) + (1|qma_region) + (1|fyear) + (1|month:qma_region)	0.984 (0.984–0.985)	3 913	709
fit6	(1|month) + (1|qma_region) + (1|fyear) + (1|month:island)	0.977 (0.976–0.977)	10 239	941
fit5	(1|month) + (1|qma_region) + (1|fyear)	0.973 (0.973–0.974)	13 201	1 097
fit4	(1|month) + (1|qma_region)	0.959 (0.959–0.959)	15 479	1 198
fit3	(1|month) + island	0.950 (0.950–0.950)	19 952	1 343
fit2	(1|month) + (1|fyear)	0.962 (0.962–0.962)	21 688	1 441
fit1	(1|month)	0.948 (0.948–0.948)	22 186	1 453

5. TAG RECAPTURES

This section describes tag-recapture data that were used to inform growth in the stock assessment of rock lobster stocks (Webber et al. 2023). These data were also useful for informing decisions about stock structure and movement. Tag-recapture data for all QMAs were obtained in August 2023 from Fisheries New Zealand (replog 15053).

5.1 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 that every release-recapture event for a tag was linked to create a single record while all tags with no recaptures were discarded. Processing, linking, and formatting were done using purpose-built software written in the *R* statistical computing language (see section 5.1 of Starr et al. 2019 for a description of these preparatory steps).

It was determined during the tag data preparation for the CRA 2 stock assessment in 2022 that the relationships provided by Breen et al. (1988) to predict TW from CL (carapace length, used when TW measurements were missing) were based on much less information than is currently available and appeared to be unrealistic for some QMAs (Roberts et al. 2023). These relationships were updated for the current stock assessment and were used to process the tag-recapture data for the CRA 6 assessment. A description of the analysis used to generate updated CL-TW relationships for all QMAs is given in Appendix D. The tag data summary given below was informed by these updated CL-TW relationships.

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 (Table 5, Table 6). This comparison showed an overall increase in the number of usable recoveries of 326 tags for all New Zealand compared with the same total from last year, with nearly all the new usable recaptures coming from recaptures made after 2020–21 (Table 6).

Table 5: Comparison of the number of records by Project ID in the new (2023) tag data extract with the number of records in the extract made for the 2022 CRA 2 assessment (Roberts et al. 2023), i.e., the next most recent red rock lobster stock assessment.

Project ID	Previous	Current	Difference
CRA_Akaroa	227	227	–
CRA_CCampb	44	44	–
CRA_Gis70s	2 240	2 240	–
CRA_Gisb	48	48	–
CRA_ReefPt	573	573	–
CRA_StewIs	1 614	1 614	–
CRA01Gisb	1 179	1 179	–
CRA1_TAG	1 622	1 647	25
CRA2_EBOP	5	5	–
CRA2_TAG	4 744	4 776	32
CRA2_WBOP	268	268	–
CRA3_TAG	2 110	2 190	80
CRA4_TAG	3 134	3 138	4
CRA4_Wair	10	10	–
CRA5_Kaik	1 176	1 176	–
CRA5_TAG	6 104	6 107	3
CRA6_TAG	247	250	3
CRA7_TAG	686	703	17
CRA7rs	199	202	3
CRA8_Fiord	1 714	1 714	–
CRA8_TAG	7 260	7 419	159
CRA8rs	233	233	–
CRA9_TAG	127	127	–
Total	35 564	35 890	326

Table 6: Comparison of the number of records by recapture year in the new (2023) tag data extract with the number of records in the extract for the 2022 CRA 2 stock assessment (Roberts et al. 2023), i.e., the next most recent red rock lobster stock assessment.

Calendar year	Previous	Current	Difference	Calendar year	Previous	Current	Difference
1966	53	53	–	1998	2 944	2 944	–
1967	28	28	–	1999	2 486	2 486	–
1968	7	7	–	2000	1 585	1 585	–
1969	2	2	–	2001	1 377	1 377	–
1971	1	1	–	2002	1 571	1 571	–
1975	115	115	–	2003	1 121	1 121	–
1976	1 268	1 268	–	2004	2 079	2 079	–
1977	2 091	2 091	–	2005	2 386	2 386	–
1978	886	886	–	2006	975	975	–
1979	1 081	1 081	–	2007	481	482	1
1980	1 112	1 112	–	2008	366	366	–
1981	593	593	–	2009	304	304	–
1982	332	332	–	2010	237	237	–
1983	273	273	–	2011	548	548	–
1984	1 071	1 071	–	2012	425	425	–
1985	394	394	–	2013	510	510	–
1986	76	76	–	2014	778	778	–
1987	18	18	–	2015	875	875	–
1988	4	4	–	2016	525	525	–
1989	2	2	–	2017	565	565	–
1991	1	1	–	2018	362	363	1
1992	1	1	–	2019	202	203	1
1994	39	39	–	2020	254	271	17
1995	72	72	–	2021	110	254	144
1996	423	423	–	2022	–	140	140
1997	2 555	2 558	3	2023	–	19	19
				Total	35 564	35 890	326

5.2 Tag data summaries: all QMAs

5.2.1 Summaries of all data (with paired tag release and recovery records)

Recovery rates (tags returned relative to numbers released) varied by QMA, with the highest rate occurring in CRA 8 (30.3%) and the lowest rate in CRA 9 (2.0%) (Table 7). There were 35 890 complete release/recovery records (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 22 128 were males and the remaining 13 762 were females (Table 8). The CRA QMA with most recovered tags was CRA 8, and the fewest recaptured tags came from CRA 6 and CRA 9, which had 250 recoveries and 129 recoveries, respectively (Table 8).

Tagged lobsters were primarily recaptured in the QMA or statistical area of release, but there was evidence that some individuals moved much greater distances (Table 9). It seems likely that many of the large-scale movements (e.g., between CRA 3 and CRA 8, see Table 9) were due to data errors, which will be investigated in the future.

Table 7: 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	19 716	2 210	17 506	11.2%
CRA 2	29 197	4 909	24 288	16.8%
CRA 3	43 888	5 807	38 081	13.2%
CRA 4	42 732	3 148	39 584	7.4%
CRA 5	43 748	7 554	36 194	17.3%
CRA 6	9 807	250	9 557	2.5%
CRA 7	12 409	890	11 519	7.2%
CRA 8	36 262	10 993	25 269	30.3%
CRA 9	6 581	129	6 452	2.0%

Table 8: 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	953	1 257	2 210
CRA 2	2 471	2 438	4 909
CRA 3	4 444	1 363	5 807
CRA 4	2 427	721	3 148
CRA 5	5 233	2 321	7 554
CRA 6	59	191	250
CRA 7	432	458	890
CRA 8	6 075	4 918	10 993
CRA 9	34	95	129
Total	22 128	13 762	35 890

Table 9: 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	Recovery QMA									
QMA	CRA 1	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8	CRA 9	Total
CRA 1	2 180	–	30	–	–	–	–	–	–	2 210
CRA 2	1	4 898	10	–	–	–	–	–	–	4 909
CRA 3	–	14	5 732	8	1	–	–	52	–	5 807
CRA 4	–	–	–	3 141	7	–	–	–	–	3 148
CRA 5	–	–	–	2	7 546	–	6	–	–	7 554
CRA 6	–	–	–	–	–	250	–	–	–	250
CRA 7	–	–	6	–	–	–	839	45	–	890
CRA 8	–	1	121	–	–	–	1	10 867	3	10 993
CRA 9	–	–	–	–	–	–	–	–	129	129
Total	2 181	4 913	5 899	3 151	7 554	250	846	10 964	132	35 890

5.2.2 Growth patterns

The observed growth increment (mm) by TW (mm) at release was generally greater for smaller individuals, but this relationship was highly variable by QMA (Figure 13, Figure 14). Apparent growth rates from these data differed by QMA, with CRA 3 and CRA 4 having fewer large individuals sampled compared with most of the other QMAs (Figure 14). The relationship between the recorded growth increment (mm) and time at liberty (years) appeared to be less variable than for growth increment and TW, with both relationships highly variable (Figure 15, Figure 16). This observation held true for all QMAs for which there were adequate numbers of observations (Figure 16).

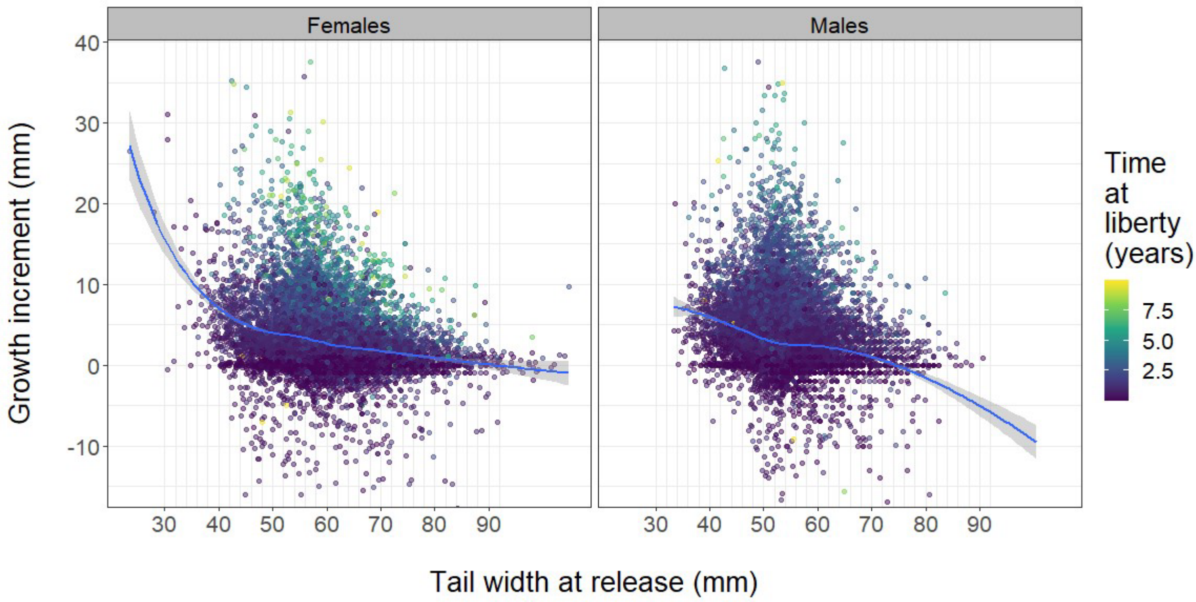

Figure 13: Growth increments (mm) by size at release (mm) and sex for all combined tag recoveries. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

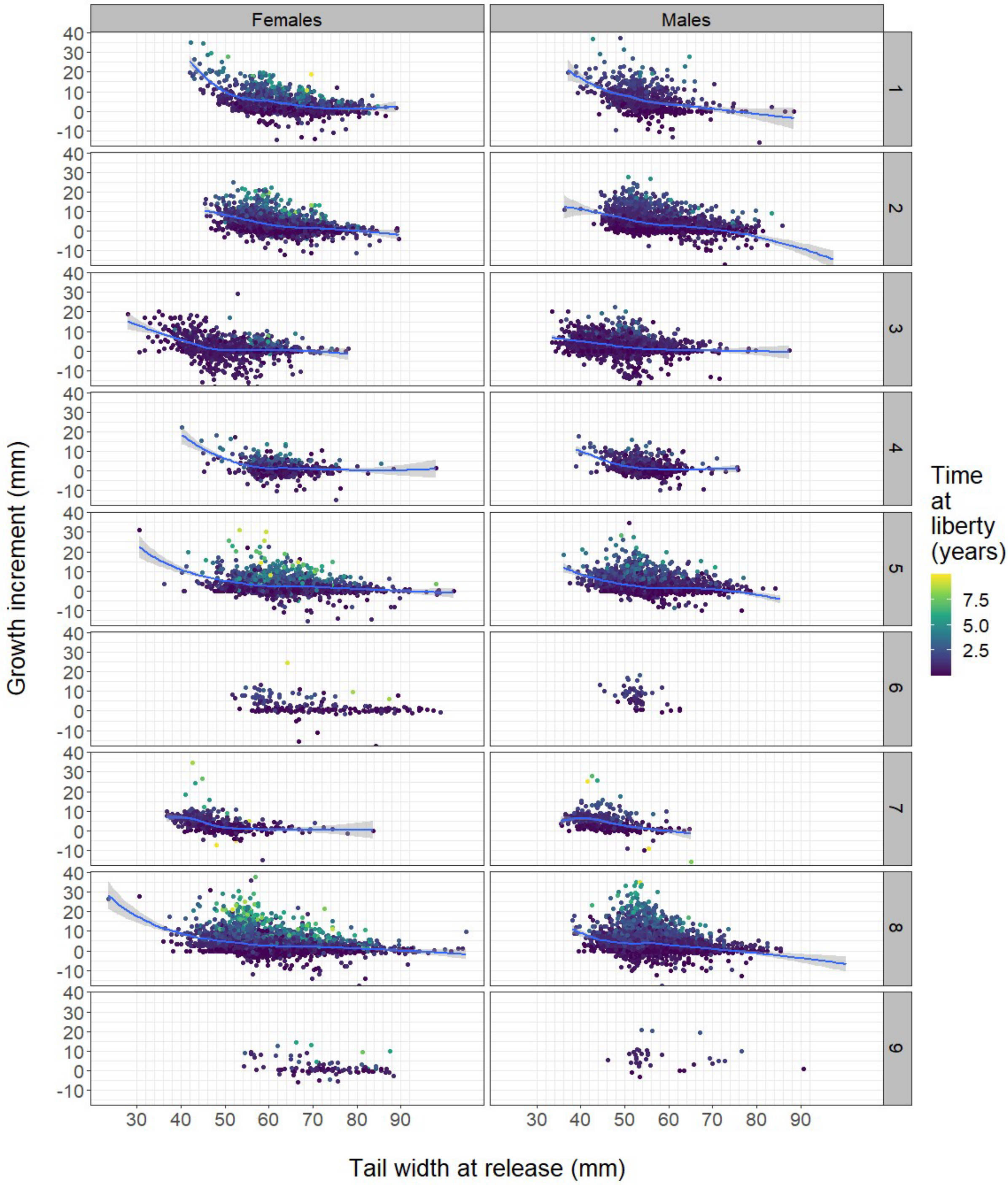

Figure 14: Growth increments (mm) by size at release (mm), sex, and QMA. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

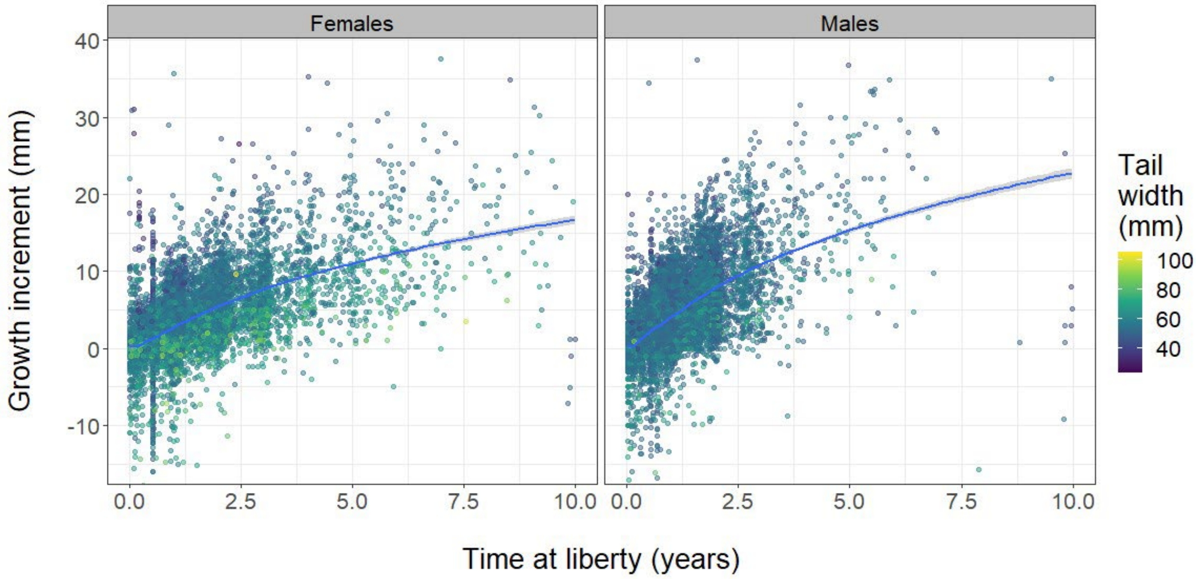

Figure 15: Growth increments (mm) by time at liberty (years) and sex for all combined tag recoveries. The colour of each point represents the size at release (mm). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

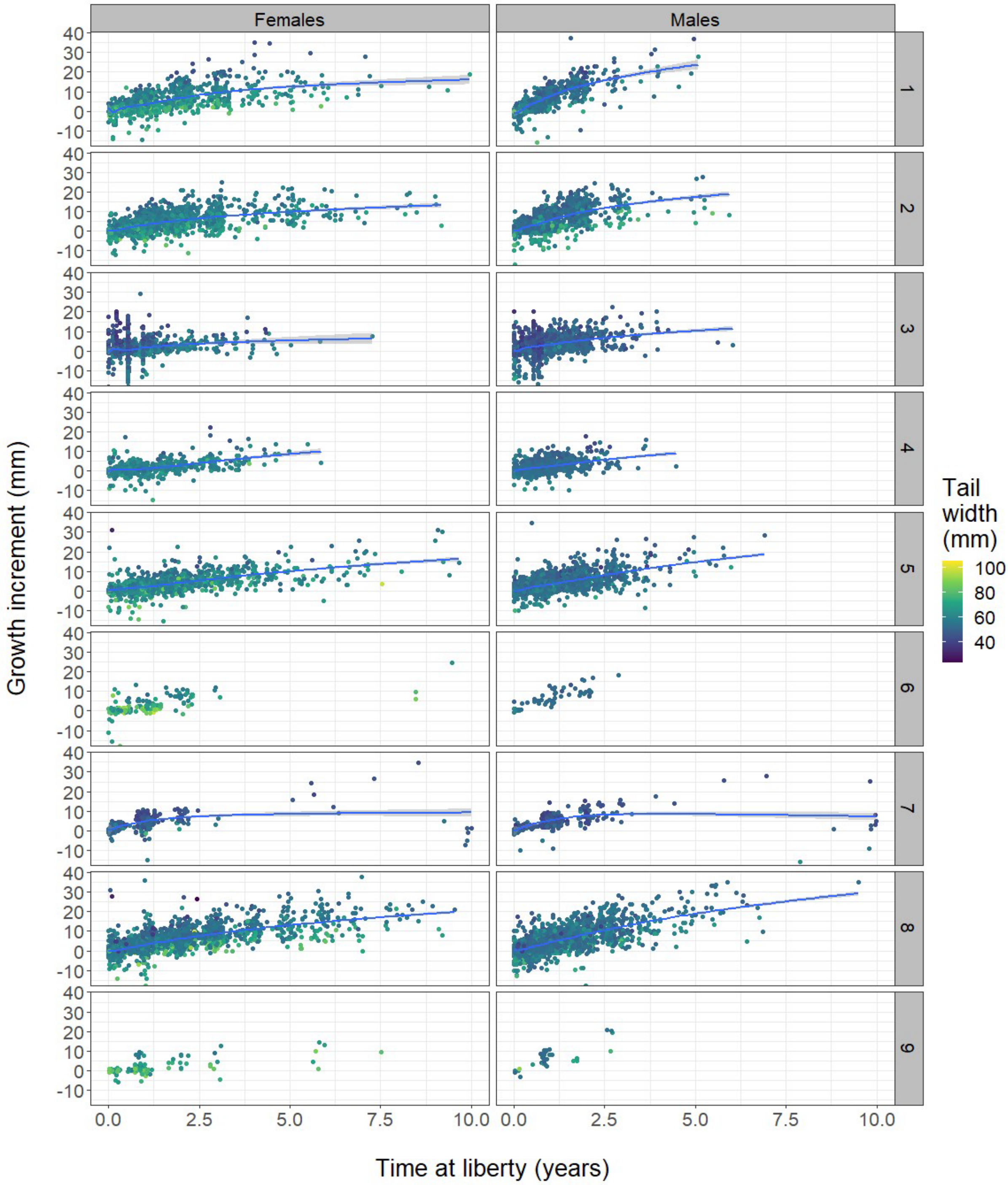

Figure 16: Growth increments (mm) by time at liberty (years), sex, and QMA. The colour of each point represents the size at release (mm). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

5.3 Tag data summaries: CRA 6 (including CRA 8 (Fiordland))

The CRA 6 tagging information included data from releases in 1995–96 to 1998–99 and from 2018–19. The total number of CRA 6 tag recoveries consisted of 250 recaptures (59 males and 191 females) (Table 8, Table 10, Table 11). Therefore, following the approach used for the 2018 CRA 6 stock assessment (Rudd et al. 2019), the tag data from CRA 6 were supplemented with tag data from the Fiordland region of CRA 8 (statistical areas 926, 927, and 928). All subsequent summaries of the tag data included the combined CRA 6 and CRA 8 Fiordland data (where the water temperature regime was considered to be comparable).

Table 10: Number of tag recaptures by calendar year of <u>release</u> and sex for each statistical area in CRA 6 and CRA 8 Fiordland. 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	Statistical area of release							Sex		
year	926	927	928	940	941	942	Unknown	Females	Males	Total
1978	–	299	–	–	–	–	–	169	130	299
1979	–	639	–	–	–	–	–	416	223	639
1980	–	1	–	–	–	–	–	1	–	1
1981	–	207	–	–	–	–	–	111	96	207
1984	53	–	–	–	–	–	–	26	27	53
1993	35	–	–	–	–	–	–	15	20	35
1994	6	3	–	–	–	–	–	4	5	9
1995	6	159	53	–	2	–	–	117	103	220
1996	2	–	83	14	81	10	1	134	57	191
1997	209	974	140	62	–	3	–	1 065	323	1 388
1998	371	703	86	8	–	–	–	528	640	1 168
1999	100	380	26	–	–	–	–	249	257	506
2000	7	234	5	–	–	–	–	131	115	246
2001	1	55	–	–	–	–	–	38	18	56
2002	4	57	1	–	–	–	–	40	22	62
2003	503	641	93	–	–	–	–	23	1 214	1 237
2004	132	378	47	–	–	–	–	18	539	557
2005	11	219	11	–	–	–	–	12	229	241
2006	–	135	6	–	–	–	–	11	130	141
2007	1	35	–	–	–	–	–	3	33	36
2008	–	27	1	–	–	–	–	4	24	28
2009	–	9	–	–	–	–	–	2	7	9
2010	1	4	–	–	–	–	–	2	3	5
2011	–	8	–	–	–	–	–	7	1	8
2012	–	1	–	–	–	–	–	1	–	1
2018	–	1	–	2	13	14	–	18	12	30
2019	21	–	–	–	–	29	–	14	36	50
2020	28	57	–	–	–	9	1	16	79	95
2021	4	66	1	–	–	1	–	4	68	72
2022	–	19	–	–	–	–	–	2	17	19
Total	1 495	5 311	553	86	96	66	2	3 181	4 428	7 609

Table 11: Number of tag recaptures by calendar year of <u>recapture</u> and sex for each statistical area in CRA 6 and CRA 8 Fiordland. 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	Statistical area of recapture							Sex		
year	926	927	928	940	941	942	Unknown	Females	Males	Total
1978	–	8	–	–	–	–	–	3	5	8
1979	–	333	–	–	–	–	–	187	146	333
1980	–	373	–	–	–	–	–	208	165	373
1981	–	139	–	–	–	–	–	102	37	139
1982	–	226	–	–	–	–	–	144	82	226
1983	–	27	–	–	–	–	–	20	7	27
1984	2	22	–	–	–	–	–	18	6	24
1985	48	10	–	–	–	–	–	31	27	58
1986	1	6	–	–	–	–	–	6	1	7
1987	–	1	–	–	–	–	–	1	0	1
1989	1	1	–	–	–	–	–	2	0	2
1991	1	–	–	–	–	–	–	1	0	1
1993	1	–	–	–	–	–	–	0	1	1
1994	22	1	–	–	–	–	–	9	14	23
1995	17	79	8	–	–	–	–	55	49	104
1996	5	68	98	3	59	10	1	147	97	244
1997	42	234	88	42	23	1	–	354	76	430
1998	157	822	104	32	–	–	–	689	426	1 115
1999	313	650	52	7	–	–	–	500	522	1 022
2000	92	400	25	–	–	–	–	265	252	517
2001	23	136	10	–	–	–	–	113	56	169
2002	17	89	4	–	–	–	–	72	38	110
2003	16	38	2	–	–	–	–	39	17	56
2004	490	656	110	–	–	–	–	42	1 214	1 256
2005	132	386	32	–	1	2	–	44	509	553
2006	40	259	15	–	–	–	–	27	287	314
2007	8	82	3	–	–	–	–	15	78	93
2008	8	57	–	–	–	–	–	6	59	65
2009	3	29	–	–	–	–	–	7	25	32
2010	3	13	1	–	–	–	–	3	14	17
2011	–	16	–	–	–	–	–	12	4	16
2012	–	5	–	–	–	–	–	4	1	5
2013	–	1	–	–	–	–	–	0	1	1
2016	–	1	–	–	–	–	–	1	0	1
2019	1	–	–	–	–	–	–	0	1	1
2020	9	3	–	2	13	38	1	28	38	66
2021	33	101	1	–	–	14	–	19	130	149
2022	10	39	–	–	–	1	–	7	43	50
Total	1 495	5 311	553	86	96	66	2	3 181	4 428	7 609

The peak months for tag recoveries (at least 500 events) were in February or the period from August to November. There were comparatively few (< 200 recaptures) in the period from March to April (Table 12), when the fishing effort in CRA 8 was relatively low (Starr 2024). Most recaptures in CRA 6 and CRA 8 Fiordland were made in the statistical area of release (Table 13). There was some evidence of movement between the statistical areas of CRA 6, although these comprised a relatively small percentage (< 5%) of all those recaptured in these statistical areas (Table 13), and there was no evidence for large-scale movements between CRA 6 and the other QMAs (Table 9).

Table 12: Number of tag releases by sex, release month, and release statistical area for CRA 6 and CRA 8 Fiordland.

Release	Statistical area of release							Sex		
month	926	927	928	940	941	942	Unknown	Females	Males	Total
Jan	4	341	25	3	–	–	–	191	182	373
Feb	9	830	53	–	3	–	–	507	388	895
Mar	2	69	15	1	–	–	–	18	69	87
Apr	1	92	1	1	–	–	–	3	92	95
May	5	172	4	–	–	1	–	28	154	182
Jun	10	318	25	–	–	–	–	54	299	353
Jul	52	277	40	52	57	1	–	183	296	479
Aug	216	1 263	69	6	19	8	–	908	673	1 581
Sep	300	700	123	1	4	42	–	727	443	1 170
Oct	611	237	40	14	13	9	1	304	621	925
Nov	83	832	123	5	–	5	1	163	886	1 049
Dec	202	180	35	3	–	–	–	95	325	420
Total	1 495	5 311	553	86	96	66	2	3 181	4 428	7 609

Table 13: Number of tag recaptures by release and recovery statistical areas for CRA 6 and CRA 8 Fiordland releases, summed across all years. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

	Unknown	906	922	923	924	926	927	928	929	940	941	942	943	Total
Unknown	1	–	–	–	–	–	–	–	–	–	–	–	1	2
926	2	–	1	15	5	1 224	195	50	3	–	–	–	–	1 495
927	1 286	1	–	–	2	14	3 984	24	–	–	–	–	–	5 311
928	30	–	–	–	1	2	3	517	–	–	–	–	–	553
940	–	–	–	–	–	–	–	–	–	83	1	1	1	86
941	8	–	–	–	–	–	–	–	–	–	87	1	–	96
942	7	–	–	–	–	–	–	–	–	–	2	56	1	66
Total	1 334	1	1	15	8	1 240	4 182	591	3	83	90	58	3	7 609

The distributions of sizes at release and recapture by sex are shown in Figure 17. The modal size classes of both the males and females were close to the respective MLS values for each sex in CRA 8, from where most of the tag data originate (54 mm TW for males and 57 mm TW for females), but with a broad right-hand distribution extending to above 80 mm TW for both sexes. The size distribution at recapture for males and females was right-shifted relative to the size distribution at release (Figure 17), consistent with growth between release and recapture.

Times at liberty in the processed tag data varied from 1 day to slightly less than 3500 days (~10 years) for both sexes (Table 14), noting that data processing procedure dropped recoveries that were at liberty for more than 10 years. The median periods at liberty were 270 days for males and 345 days for females (Table 14). A few males were re-released seven to ten-times, and from seven to thirteen-times for females (Table 15). Thirty-six percent of male recoveries came from re-releases while the equivalent percentage for females was 30%.

Growth increments (mm) ranged from -13 to +35 mm TW for males and from -21 to +31 mm TW for females (Table 16). The observed growth increment was generally greater for smaller individuals (Figure 18, Figure 19). The relationship between observed growth increment and time at liberty (years) was somewhat tighter (Figure 20, Figure 21), although both relationships were highly variable.

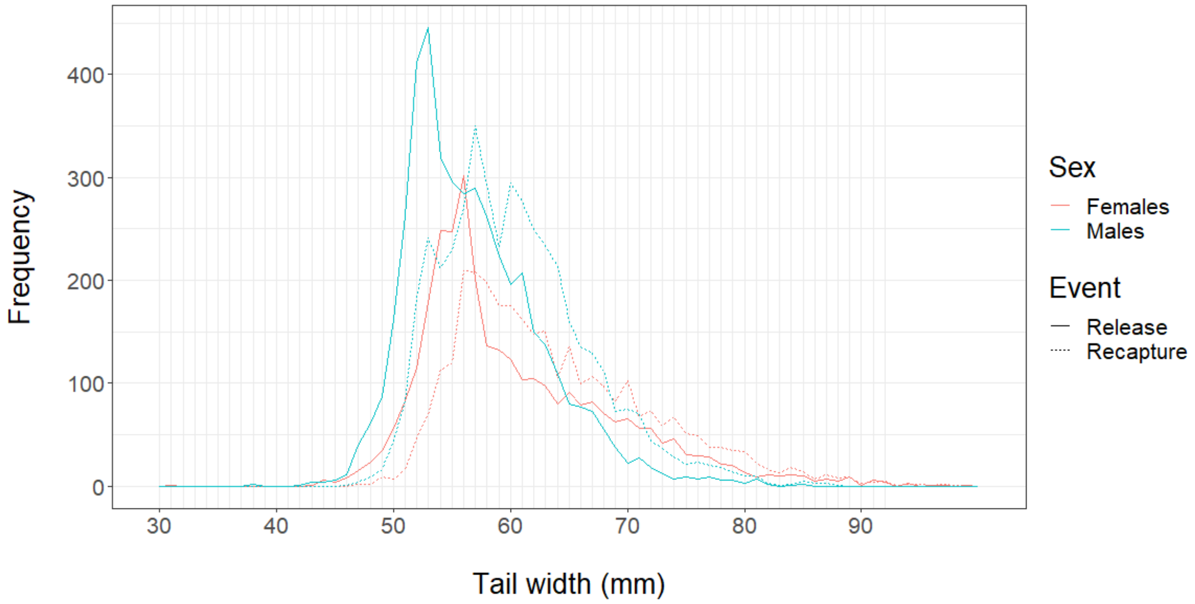

Figure 17: CRA 6 and CRA 8 Fiordland combined size at release (solid lines) and recapture (dashed lines) distributions by sex. A bin width of 1 mm was used.

Table 14: Days at liberty statistics for recaptures of CRA 6 and CRA 8 Fiordland releases. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Statistical area of release	Sex	N	Minimum	5%	Median	95%	Maximum
Unknown	Males	1	14	14	14	14	14
	Females	1	9	9	9	9	9
926	Males	1 109	1	8	296	981	3 473
	Females	386	1	11	394	2148	3 260
927	Males	2 964	1	5	251	866	2 468
	Females	2 347	1	9	343	1 317	3 363
928	Males	296	1	7	234	654	1 992
	Females	257	1	5	160	945	2 908
940	Males	4	56	108	543	781	798
	Females	82	1	26	155	834	1 126
941	Males	21	1	2	207	758	781
	Females	75	8	30	202	797	3 462
942	Males	33	4	162	410	758	1 056
	Females	33	1	8	383	1 883	3 096
CRA 6 &	Males	4 428	1	6	270	893	3 473
CRA 8 Fiordland	Females	3 181	1	9	345	1 396	3 462

Table 15: Number of tag re-releases in CRA 6 and CRA 8 Fiordland, by sex, and statistical area of release. Re-release event code = 0 means the first release-recapture event.

Re-release event	926		927		928		940		941		942		Unknown		CRA 6 & CRA 8 Fiordland	
	N	Cum Prop	N	Cum Prop	N	Cum Prop	N	Cum Prop	N	Cum Prop	N	Cum Prop	N	Cum Prop	N	Cum Prop
Males																
0	864	0.78	1 709	0.58	199	0.67	4	1.00	20	0.95	31	0.94	0	0.00	2 827	0.64
1	178	0.94	564	0.78	59	0.87	0	1.00	1	1.00	2	1.00	1	1.00	805	0.83
2	41	0.98	305	0.88	26	0.96	0	1.00	0	1.00	0	1.00	0	1.00	372	0.91
3	14	0.99	159	0.93	9	0.99	0	1.00	0	1.00	0	1.00	0	1.00	182	0.95
4	9	1.00	82	0.96	2	1.00	0	1.00	0	1.00	0	1.00	0	1.00	93	0.97
5	1	1.00	47	0.98	1	1.00	0	1.00	0	1.00	0	1.00	0	1.00	49	0.99
6	1	1.00	29	0.99	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	30	0.99
7	1	1.00	18	0.99	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	19	1.00
8	0	1.00	11	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	11	1.00
9	0	1.00	3	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	3	1.00
10	0	1.00	1	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	1	1.00
Females																
0	316	0.82	1 551	0.66	196	0.76	69	0.84	75	1.00	33	1.00	0	0.00	2 240	0.70
1	53	0.96	408	0.83	47	0.95	9	0.95	0	1.00	0	1.00	1	1.00	518	0.87
2	13	0.99	193	0.92	11	0.99	2	0.98	0	1.00	0	1.00	0	1.00	219	0.94
3	3	1.00	107	0.96	3	1.00	1	0.99	0	1.00	0	1.00	0	1.00	114	0.97
4	1	1.00	47	0.98	0	1.00	1	1.00	0	1.00	0	1.00	0	1.00	49	0.99
5	0	1.00	17	0.99	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	17	0.99
6	0	1.00	10	0.99	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	10	1.00
7	0	1.00	3	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	3	1.00
8	0	1.00	2	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	2	1.00
9	0	1.00	2	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	2	1.00
10	0	1.00	3	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	3	1.00
11	0	1.00	2	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	2	1.00
12	0	1.00	1	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	1	1.00
13	0	1.00	1	1.00	0	1.00	0	1.00	0	1.00	0	1.00	0	1.00	1	1.00

Table 16: Statistics for tail width growth increments (mm) for recaptures of CRA 6 and CRA 8 Fiordland releases. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Statistical area of release	Sex	N	Minimum	5%	Median	95%	Maximum
Unknown	Males	1	0	0	0	0	0
	Females	1	-0.5	-0.5	-0.5	-0.5	-0.5
926	Males	1 109	-10	-0.56	3.7	14.6	35
	Females	386	-14.2	-0.5	3.46	19.22	30.5
927	Males	2 964	-13	-0.3	2.72	11	26.7
	Females	2 347	-21.1	-0.7	2.3	11.58	29
928	Males	296	-10	-1.5	2.8	9.9	27.9
	Females	257	-9.1	-2.5	1	11.04	30.9
940	Males	4	0	0.63	10	16.74	16.9
	Females	82	-17.8	-1	0.75	8.1	10.6
941	Males	21	-0.5	0.4	5	9.6	10.3
	Females	75	-15.5	-0.5	0.7	9.42	24.4
942	Males	33	0.8	1.54	8.9	14.16	18.1
	Females	33	-10.9	-2.7	1.2	11.22	11.9
CRA 6 &	Males	4 428	-13	-0.5	3	12	35
CRA 8 Fiordland	Females	3 181	-21.1	-1	2.27	12.11	30.9

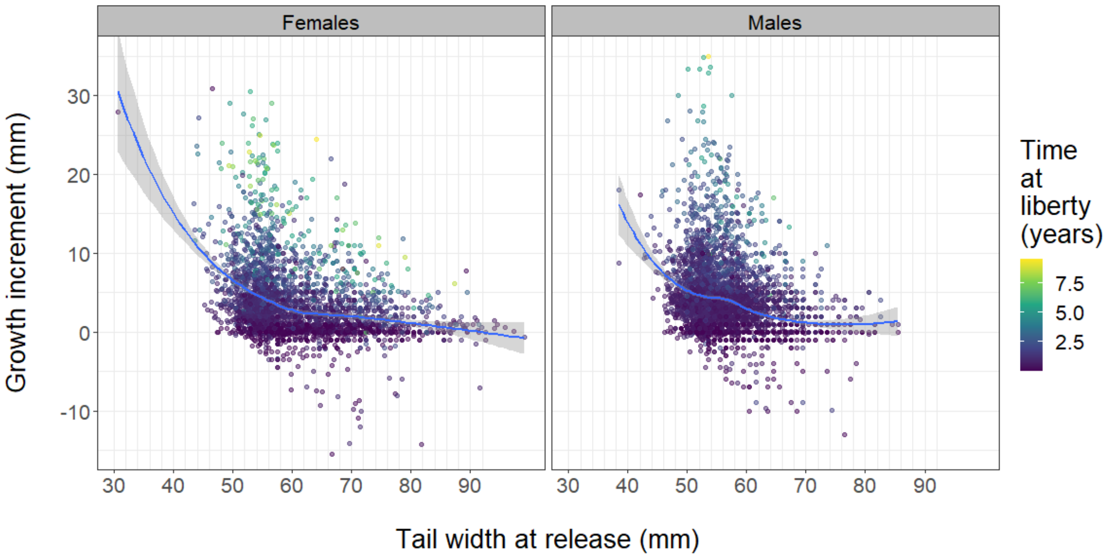

Figure 18: Growth increments (mm) by size at release (mm) and sex for all tags included in the CRA 6 stock assessment (includes CRA 8 Fiordland tags). The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) are also shown.

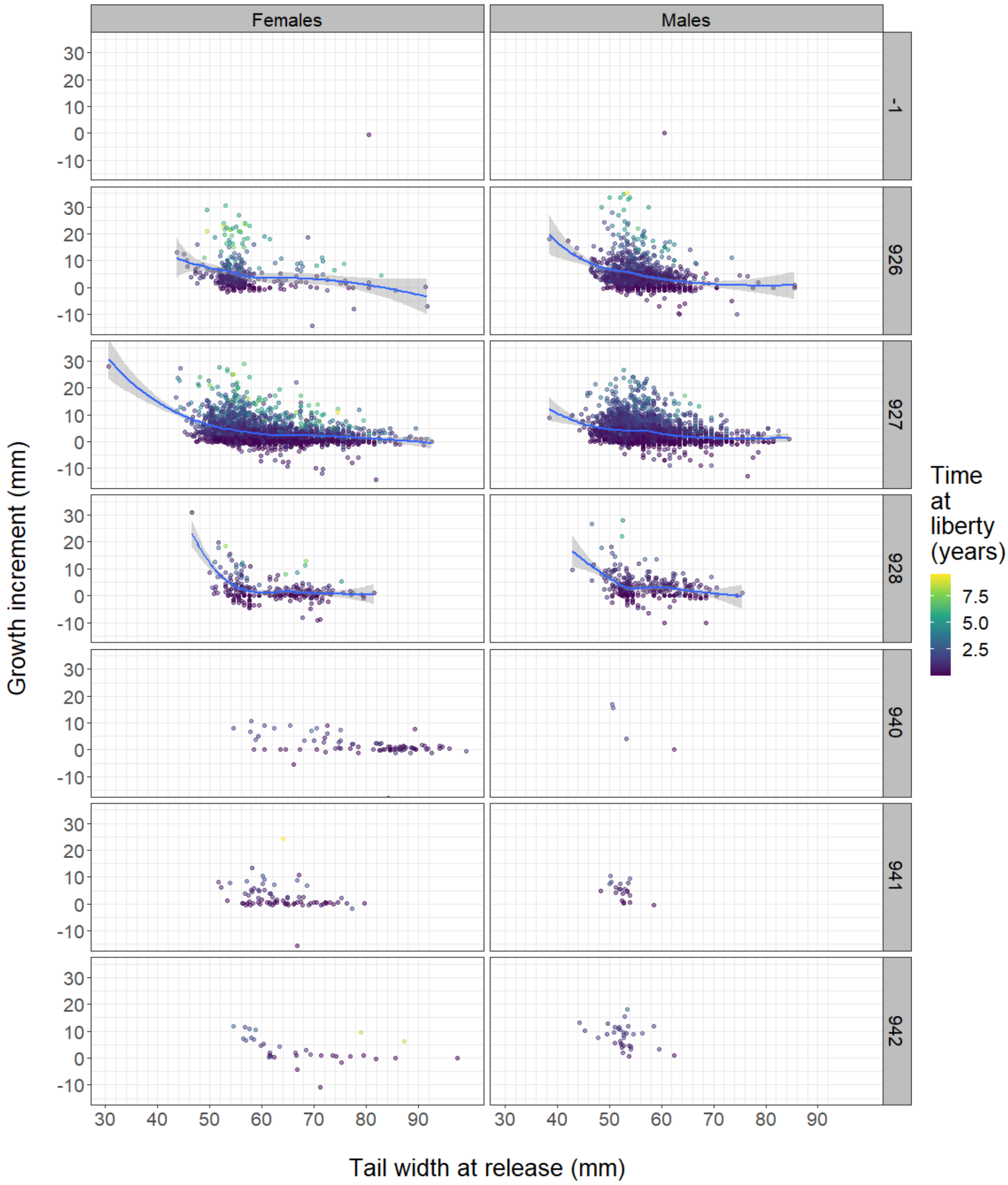

Figure 19: CRA 6 and CRA 8 Fiordland growth increments (mm) by size at release (mm) and sex in each release statistical area of release. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval (grey shading) about this smoother are also shown. -1: unknown statistical area.

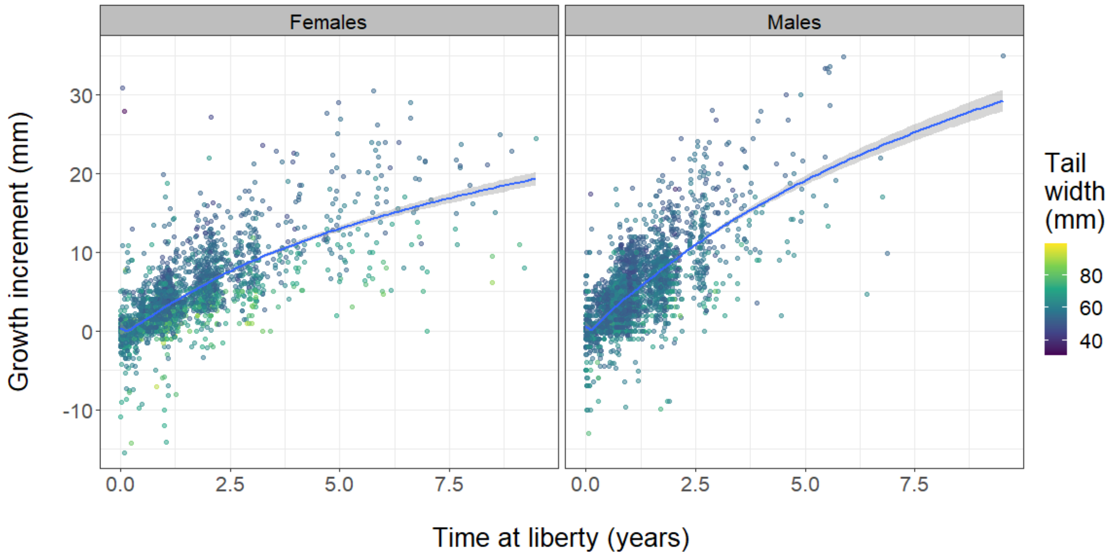

Figure 20: CRA 6 and CRA 8 Fiordland growth increments (mm) by time at liberty (years) and sex for all tags included in the stock assessment. The colour of each point represents the tail width (mm). A loess (blue line) and the 95% confidence interval (grey shading) about this smoother is also shown.

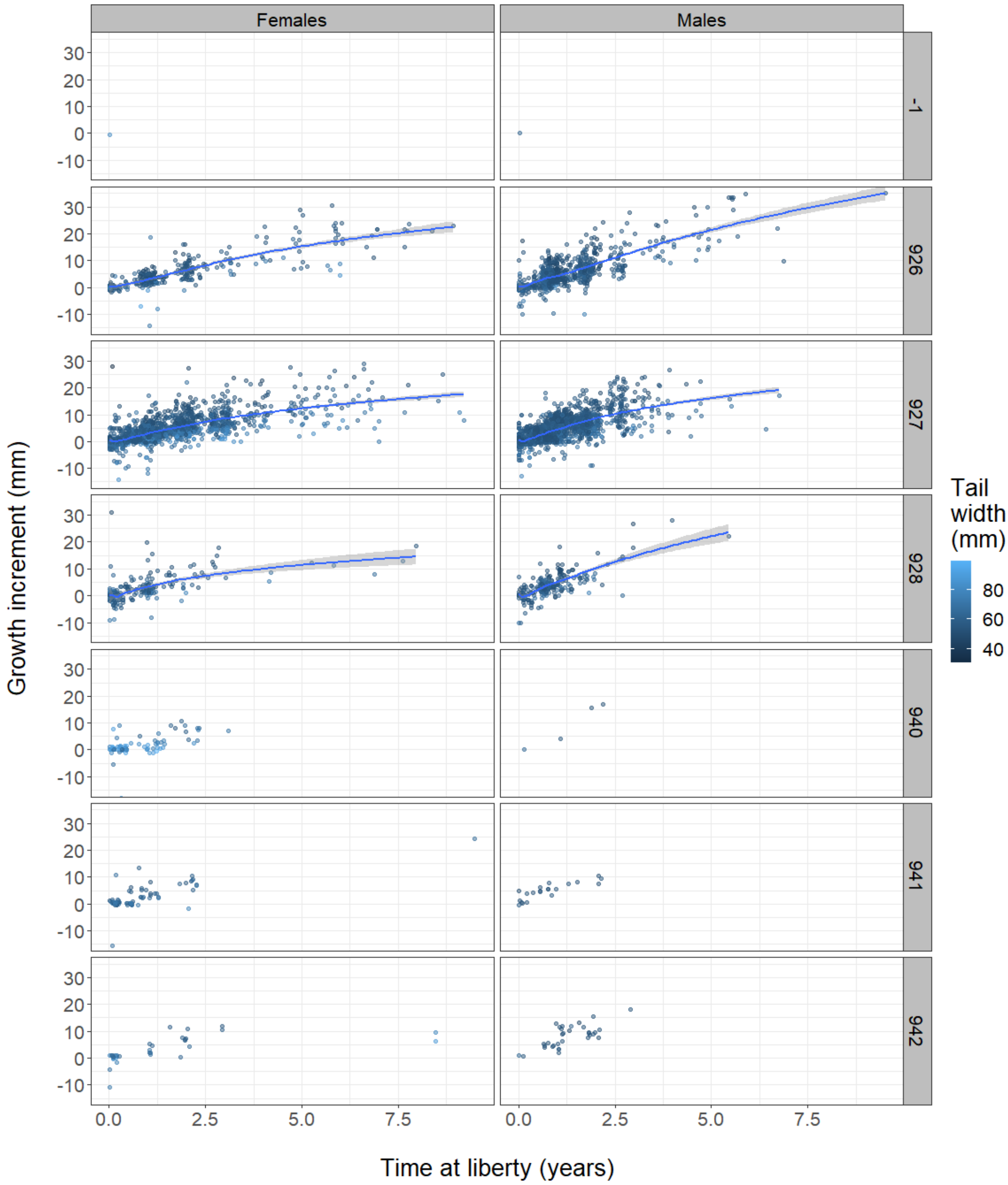

Figure 21: CRA 6 and CRA 8 Fiordland growth increments (mm) by time at liberty (years) and sex in each release statistical area. The colour of each point represents the tail width (mm). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown. -1: unknown statistical area.

6. POTENTIAL RESEARCH

- In the LF standardisation models, it was necessary to fit to trip level data so that the MCMC runs for these models finished within a reasonable timeframe. The SR models were also fitted to trip level data. However, the SR models ran much faster because there were only three sex categories and therefore only three categories in the multinomial distribution. In future, SR models could be fitted to pot-level data rather than to trip-level data.
- Consider dropping the sex ratio from 2001–2012 (as was done for the LFs).
- Options for increasing the tag recovery rate in CRA 6 (which is an order of magnitude lower than for some other QMAs) should be explored so that there is less reliance on growth information from QMAs.
- Investigate the utility of the current growth model and alternative models using a meta-analysis approach.

7. FULFILLMENT 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.

8. ACKNOWLEDGEMENTS

We thank Fisheries New Zealand who awarded the contract CRA2022-01 to Quantifish Ltd. We thank Bruce Hartill (chair) and the members of the Rock Lobster Working Group for their peer review and constructive discussion throughout the development of this stock assessment. We also thank the CRA 6 fishers for their input and ongoing commitment to the fishery.

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Appendix A. Catch-per-unit-effort diagnostics

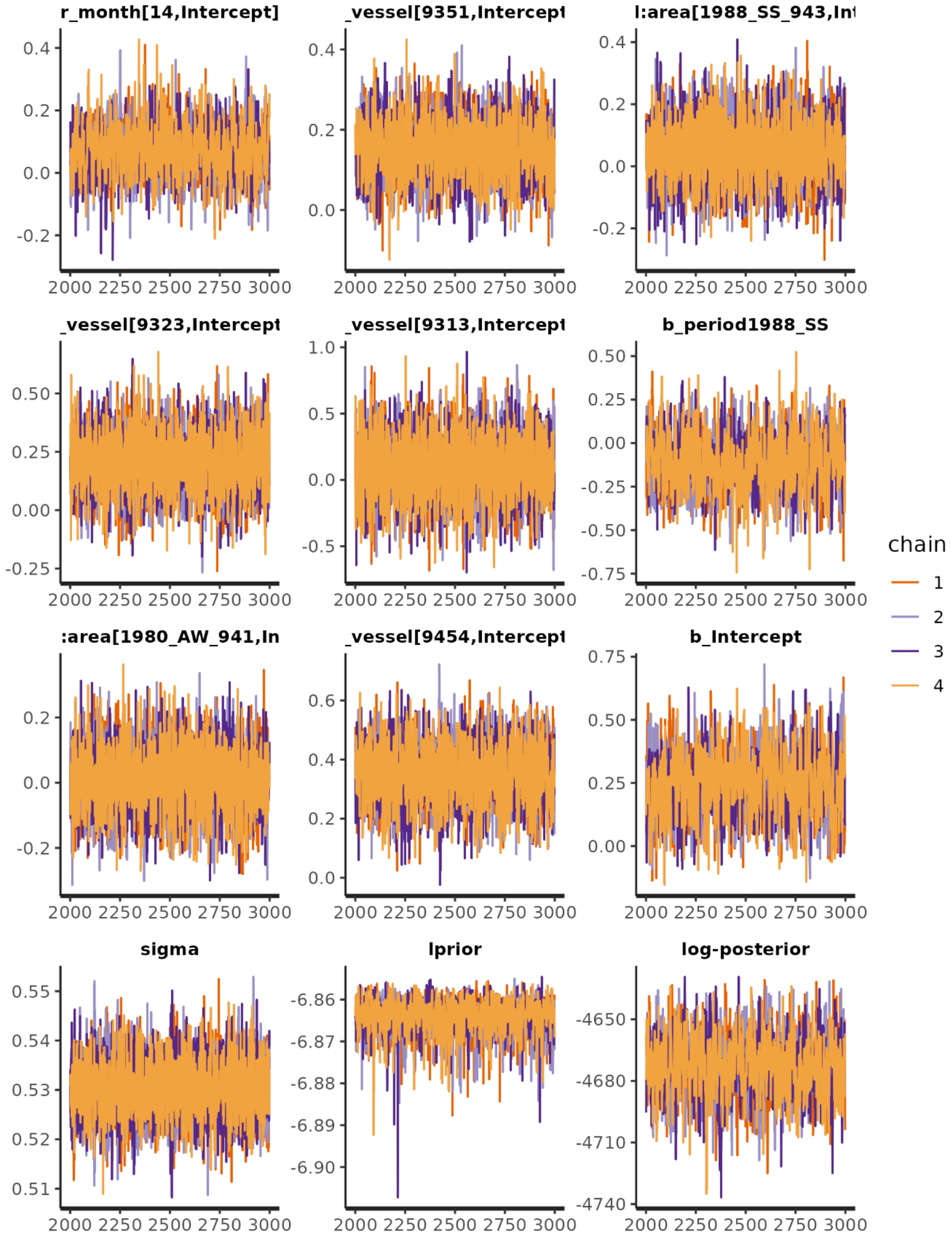


Figure A.1: MCMC trace plots for a subset of model parameters from the FSU standardised GLMM model.

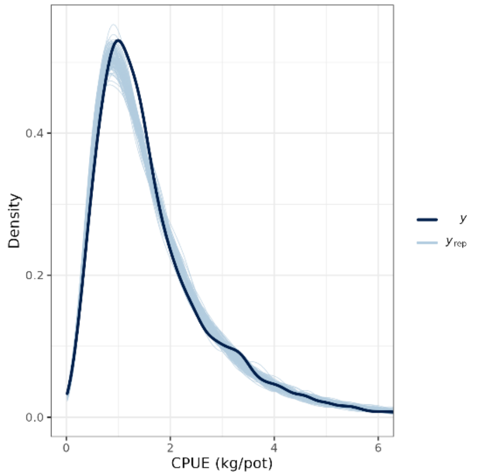


Figure A.2: CRA 6 FSU posterior predictive density overlay.

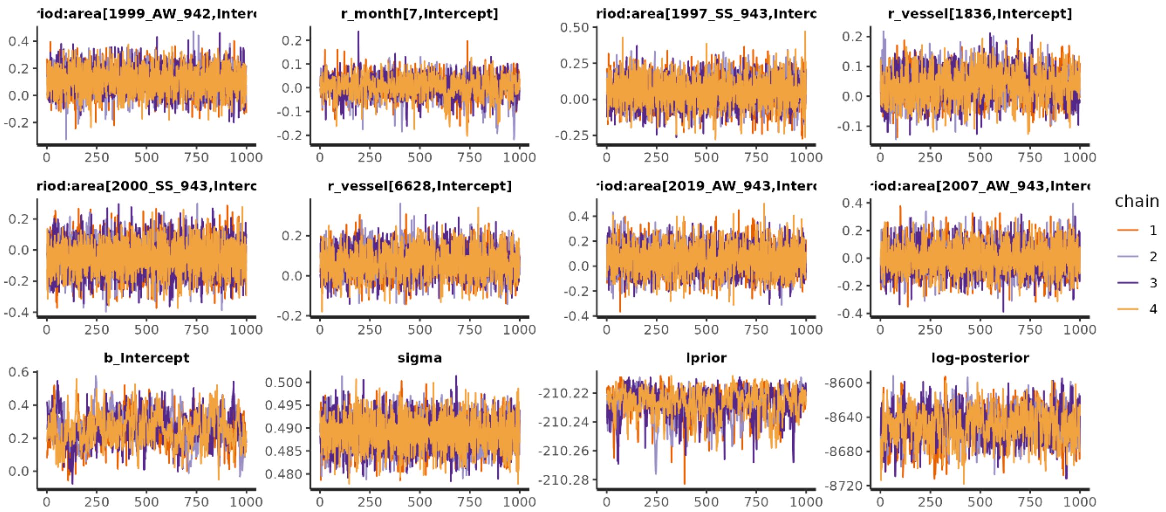


Figure A.3: MCMC trace plots for a subset of model parameters from the CELR standardised GLMM model.

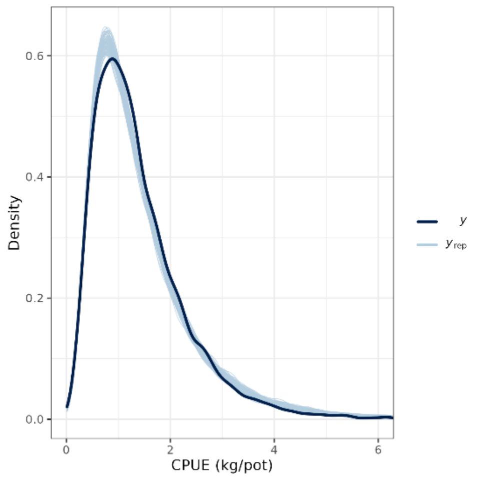


Figure A.4: CRA 6 CELR posterior predictive density overlay.

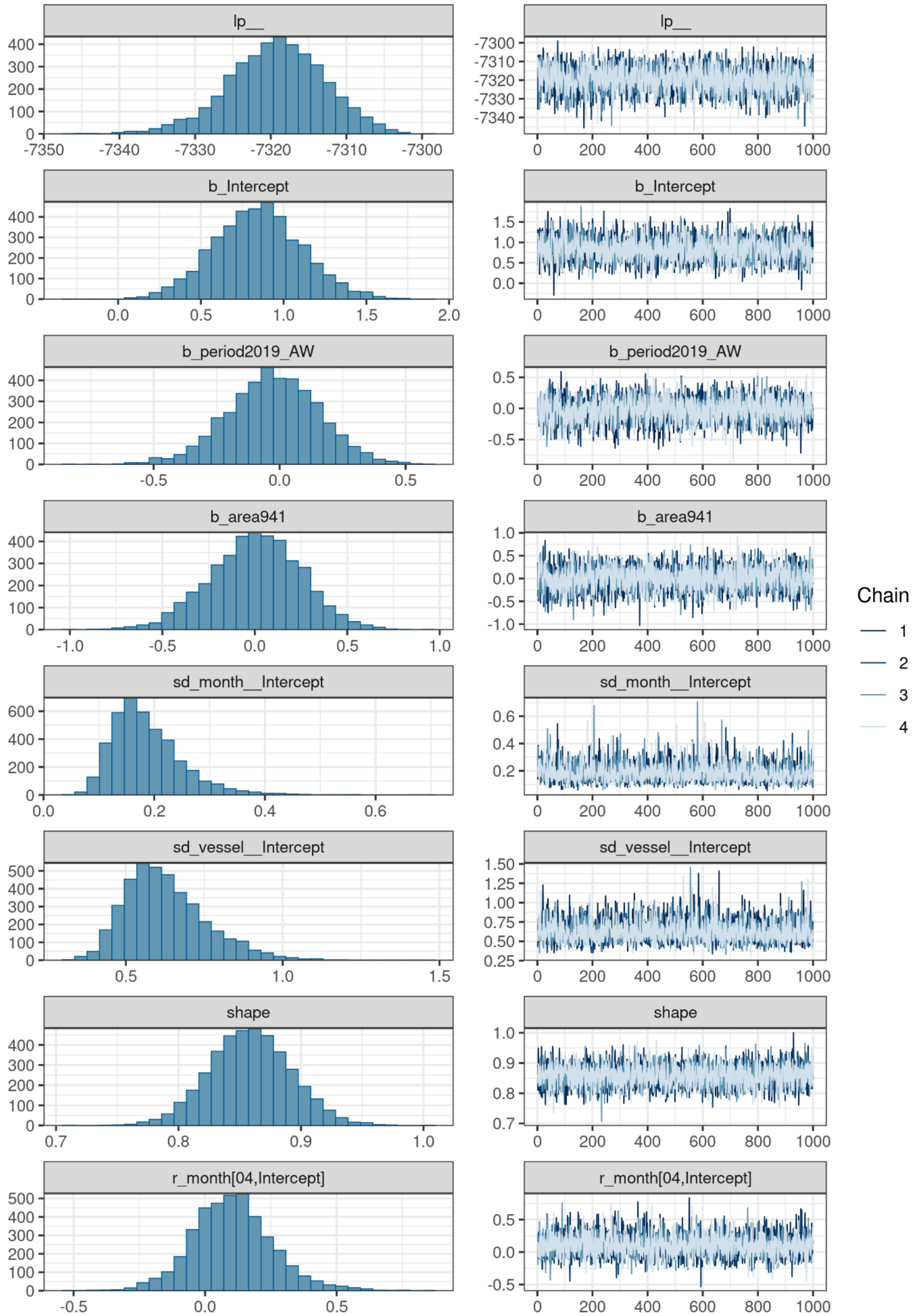
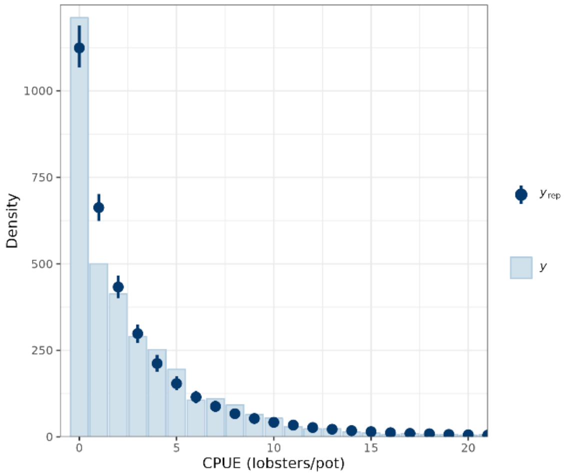


Figure A.5: MCMC trace and density plots for a subset of model parameters from the logbook standardised CPUE GLMM model.



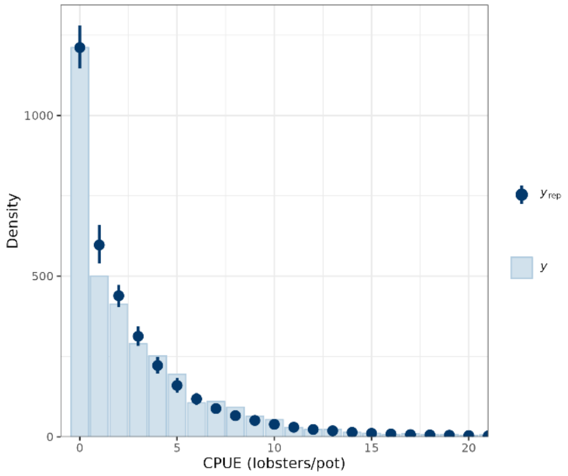


Figure A.6: CRA 6 logbook posterior predictive density overlay. Negative binomial model on left and hurdle negative binomial model on right.

Table A.1: Median indices and standard deviations (SD) by fishing year and season for the four CRA 6 CPUE series used in the 2023 stock assessment. '–': value not available. (Continued next page)

Data source	Fishing year	AW Index	AW SD	SS Index	SS SD
CR	1965	–	–	600.9	0.3
	1966	939.7	0.3	930.5	0.3
	1967	1,304.0	0.3	756.7	0.3
	1968	640.2	0.3	464.1	0.3
	1969	204.8	0.3	238.9	0.3
	1970	131.4	0.3	150.4	0.3
	1971	116.1	0.3	160.1	0.3
	1972	133.8	0.3	188.3	0.3
	1973	107.7	0.3	241.8	0.3
FSU	1979	0.983	0.125	1.682	0.206
	1980	1.142	0.152	1.407	0.171
	1981	1.297	0.169	1.655	0.200
	1982	0.963	0.119	1.224	0.149
	1983	0.908	0.115	1.232	0.150
	1984	0.713	0.091	1.034	0.126
	1985	0.755	0.095	1.052	0.127
	1986	0.748	0.096	1.213	0.147
	1987	0.727	0.093	0.959	0.116
	1988	0.678	0.087	0.890	0.109
	1989	0.594	0.082	–	–
CELR	1989	–	–	1.142	0.112
	1990	0.731	0.077	1.266	0.127
	1991	0.697	0.074	1.242	0.122
	1992	0.805	0.086	0.915	0.088
	1993	0.634	0.065	0.987	0.096
	1994	0.617	0.062	0.907	0.086
	1995	0.590	0.058	0.959	0.092
	1996	0.618	0.063	1.037	0.101
	1997	0.630	0.061	1.026	0.099
	1998	0.715	0.074	1.234	0.124
	1999	0.680	0.071	1.145	0.115

Data source	Fishing year	AW Index	AW SD	SS Index	SS SD
CELR	2000	0.667	0.068	1.122	0.111
	2001	0.612	0.063	1.218	0.122
	2002	0.771	0.081	1.152	0.117
	2003	0.708	0.073	1.110	0.109
	2004	0.803	0.083	1.217	0.120
	2005	0.885	0.091	1.309	0.131
	2006	0.984	0.100	1.548	0.157
	2007	0.915	0.094	1.287	0.129
	2008	0.882	0.092	1.547	0.150
	2009	0.816	0.084	1.275	0.126
	2010	0.887	0.093	1.393	0.142
	2011	0.766	0.080	1.490	0.145
	2012	0.786	0.083	1.622	0.160
	2013	0.883	0.092	1.450	0.147
	2014	0.880	0.092	1.276	0.123
	2015	0.890	0.093	1.243	0.121
	2016	1.097	0.114	1.618	0.159
	2017	1.027	0.108	1.806	0.186
	2018	1.122	0.120	2.000	0.205
	2019	1.107	0.133	–	–
Logbook	2014	2.307	0.564	2.030	0.481
	2015	1.963	0.525	2.268	0.550
	2016	1.690	0.715	2.465	0.561
	2017	1.699	0.479	2.698	0.573
	2018	1.801	0.461	2.694	0.618
	2019	2.277	0.554	3.621	0.897
	2020	3.247	0.823	3.727	0.863
	2021	2.759	0.685	3.562	0.856
	2022	2.702	0.692	3.939	0.921

Table A.2: Number of records by fishing year, season and statistical area for the three CRA 6 standardised CPUE series used in the 2023 stock assessment. Records for the FSU and CELR series reflect the fishing year, vessel, statistical area, and monthly stratification while the logbook strata are by vessel, statistical area, and potlift. '–': value not available. (Continued next page)

		940		941		942		943	
Data source	Fishing year	AW	SS	AW	SS	AW	SS	AW	SS
FSU	1979	34	40	53	39	39	68	29	30
	1980	27	54	35	46	45	52	9	42
	1981	25	34	51	59	40	80	23	50
	1982	23	48	74	57	70	93	36	48
	1983	28	42	59	61	73	115	32	35
	1984	34	51	54	65	71	107	34	29
	1985	42	50	52	59	51	104	37	51
	1986	45	62	37	42	42	85	29	52
	1987	30	64	37	56	51	94	19	49
	1988	41	45	33	38	53	81	19	27
	1989	15	–	11	–	31	–	11	–

Data source	Fishing year	940		941		942		943	
		AW	SS	AW	SS	AW	SS	AW	SS
CELR	1989	–	45	–	41	–	56	–	18
	1990	27	40	33	38	33	61	15	16
	1991	24	46	37	57	46	92	10	16
	1992	27	45	25	47	65	114	11	14
	1993	48	43	39	51	82	100	19	29
	1994	48	58	44	53	83	92	35	40
	1995	52	47	41	36	81	95	41	39
	1996	62	60	28	31	80	83	19	25
	1997	69	53	31	31	84	77	32	27
	1998	45	40	26	23	52	45	16	18
	1999	29	28	29	34	51	57	14	15
	2000	45	45	31	30	61	56	16	14
	2001	43	39	33	31	45	47	12	16
	2002	30	38	33	36	34	44	14	15
	2003	33	42	30	35	42	49	21	23
	2004	40	40	30	36	52	55	13	15
	2005	37	43	45	45	65	68	20	21
	2006	36	37	33	40	54	53	22	22
	2007	35	35	37	50	45	53	17	23
	2008	39	39	34	42	55	67	19	19
	2009	28	34	21	35	54	65	18	28
	2010	29	32	24	30	53	53	25	25
	2011	32	37	28	33	52	74	20	27
	2012	29	31	17	26	62	79	20	25
	2013	30	36	20	20	58	92	15	27
	2014	31	42	23	29	65	82	24	27
	2015	45	44	25	35	54	85	12	26
	2016	34	32	27	27	60	79	21	26
	2017	32	33	21	21	55	62	22	24
	2018	36	36	18	22	52	69	18	22
	2019	15	–	3	–	33	–	8	–
Logbook	2014	31	56	116	114	11	–	25	86
	2015	19	27	88	87	–	12	–	60
	2016	17	66	11	45	–	36	–	–
	2017	21	64	44	82	2	22	–	–
	2018	49	94	77	87	83	39	–	–
	2019	84	29	151	59	57	3	8	20
	2020	30	152	42	100	41	80	–	4
	2021	42	118	26	74	58	35	–	–
	2022	44	57	33	69	23	39	2	35

Appendix B. Size and sex composition diagnostics

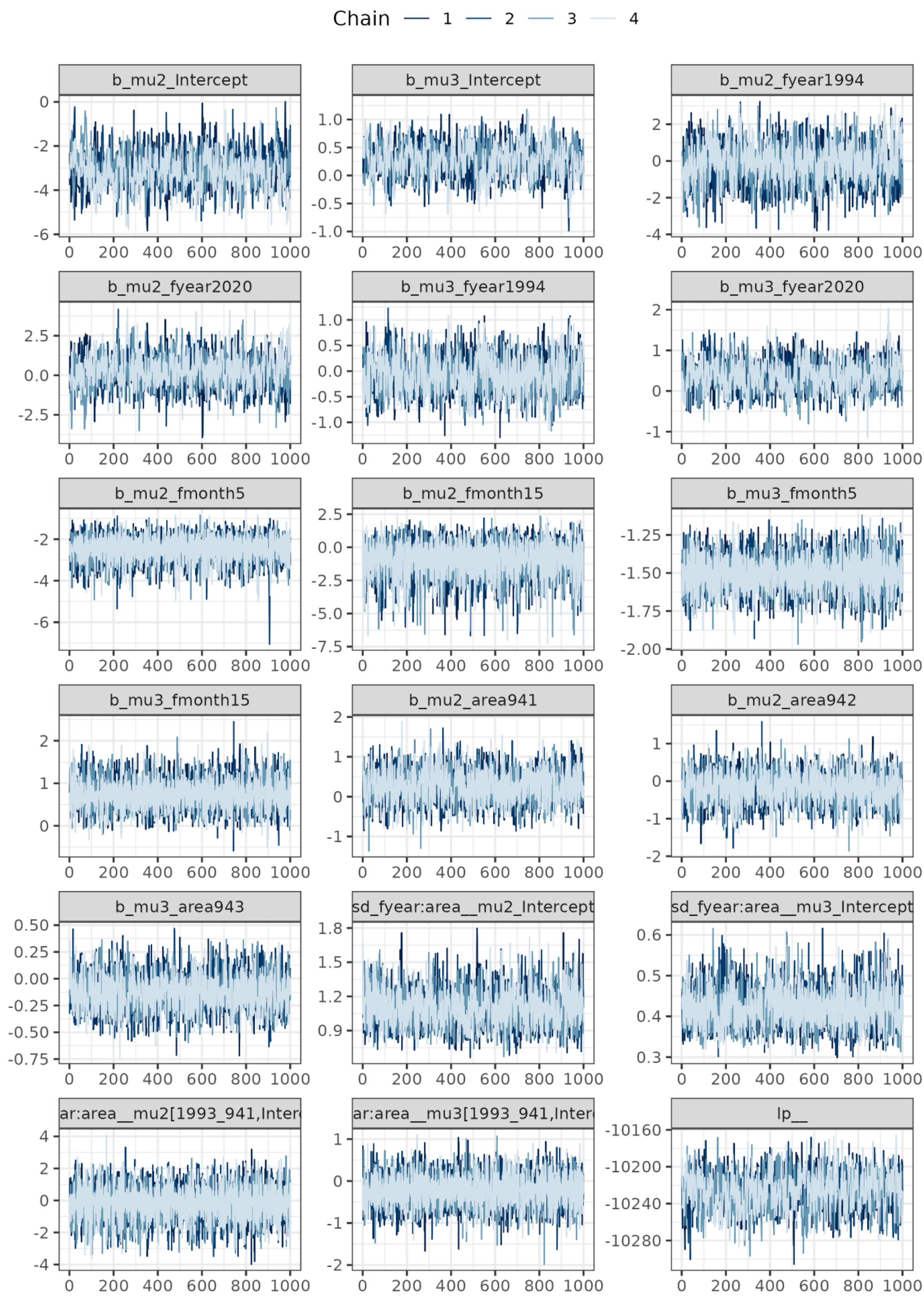


Figure B.1: MCMC trace plots for a subset of model parameters from the sex ratio model.

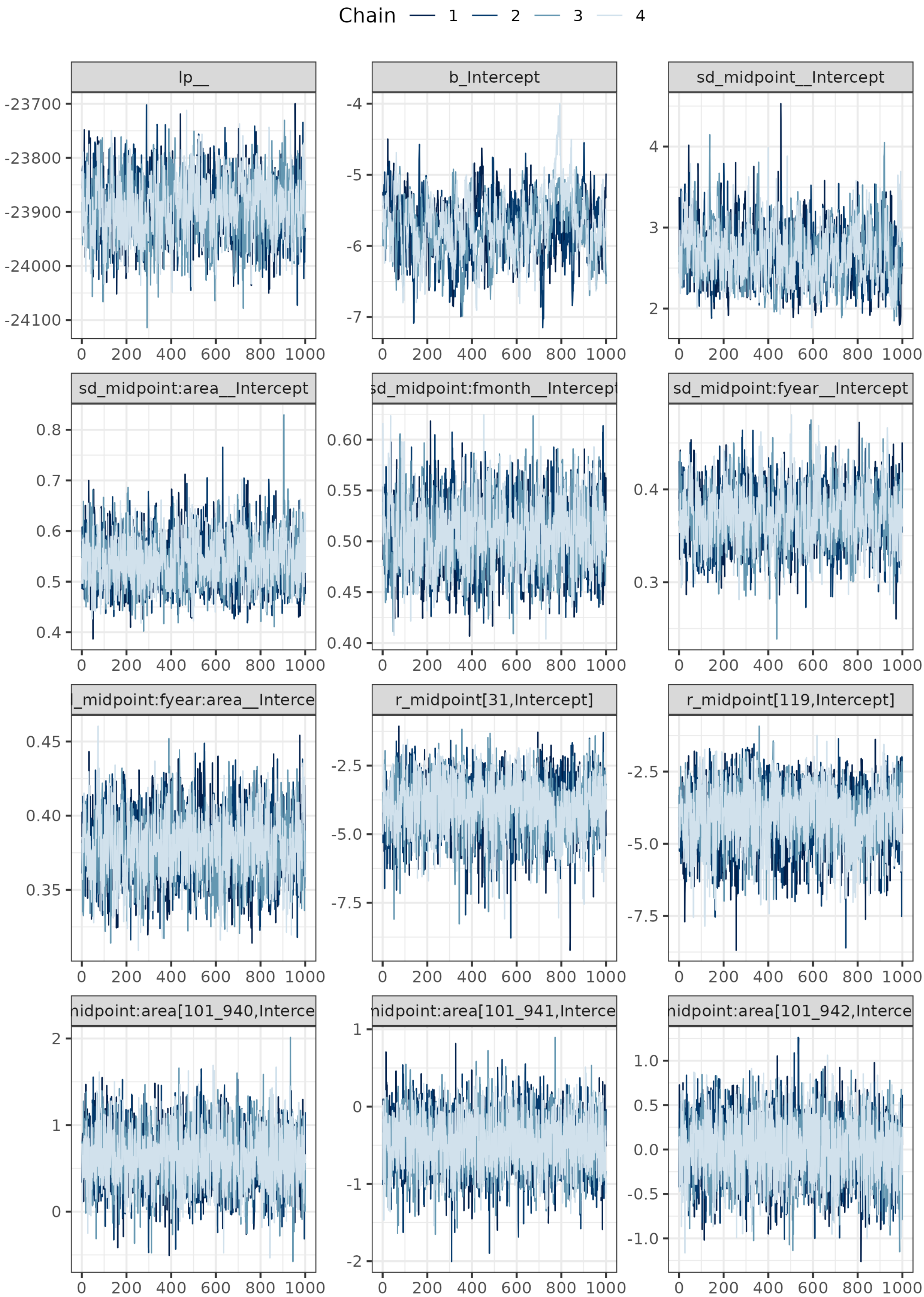


Figure B.2: MCMC trace plots for a subset of model parameters from the LF model.

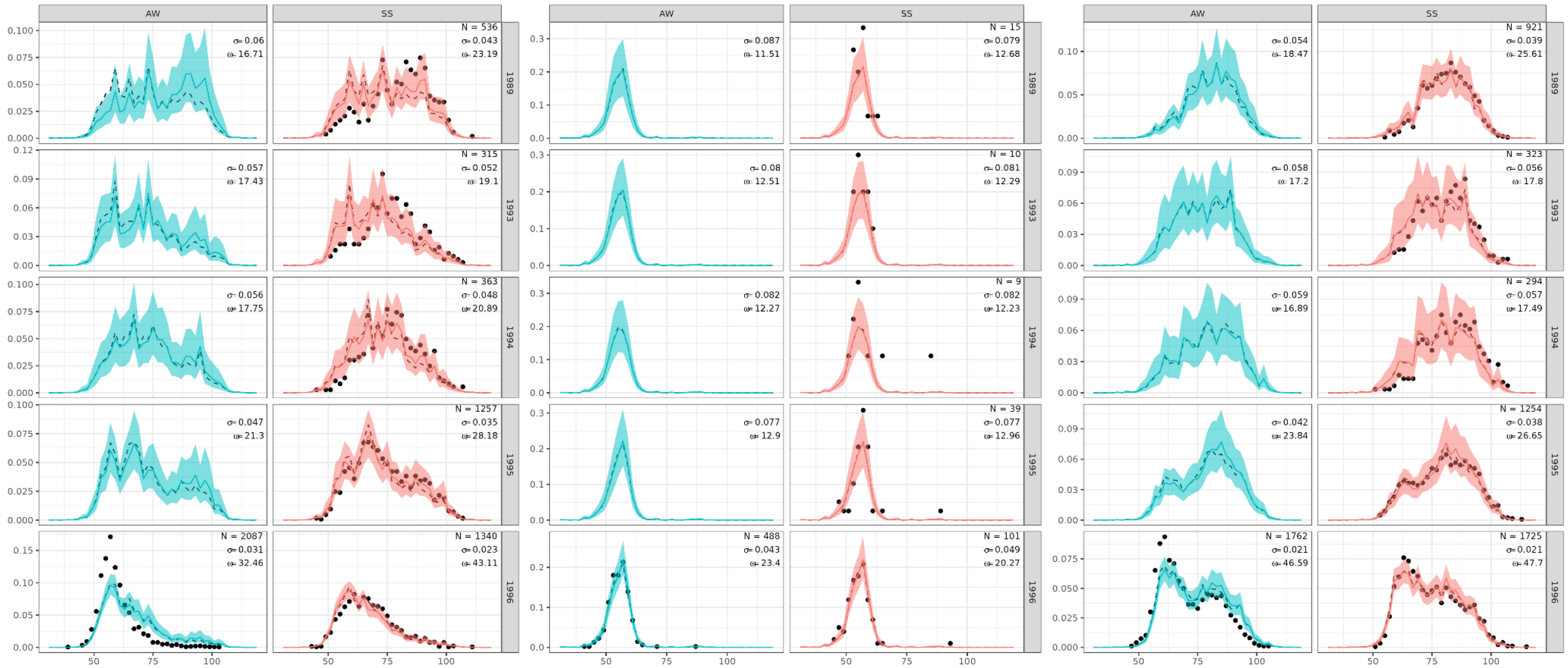


Figure B.3: CRA 6 LFs by fishing year (from 1989 to 1996), season (AW = autumn/winter, SS = spring/summer), TW bin, and sex (males left panel, immature females middle panel, and mature females right panel). The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF 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; the SD of the predicted LF for each stratum; and the data set weight for each stratum.

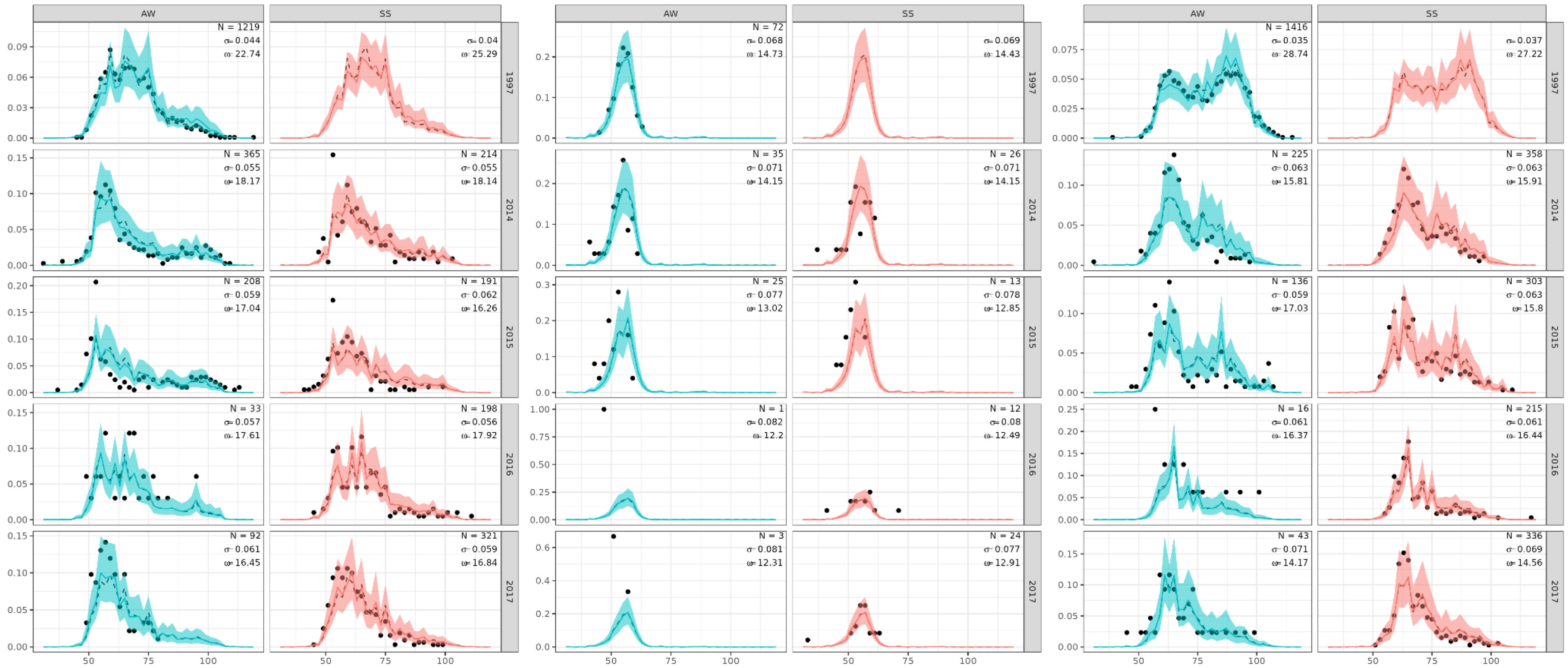


Figure B.4: CRA 6 LFs by fishing year (from 1997 to 2017), season (AW = autumn/winter, SS = spring/summer), TW bin, and sex (males left panel, immature females middle panel, and mature females right panel). The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF 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; the SD of the predicted LF for each stratum; and the data set weight for each stratum.

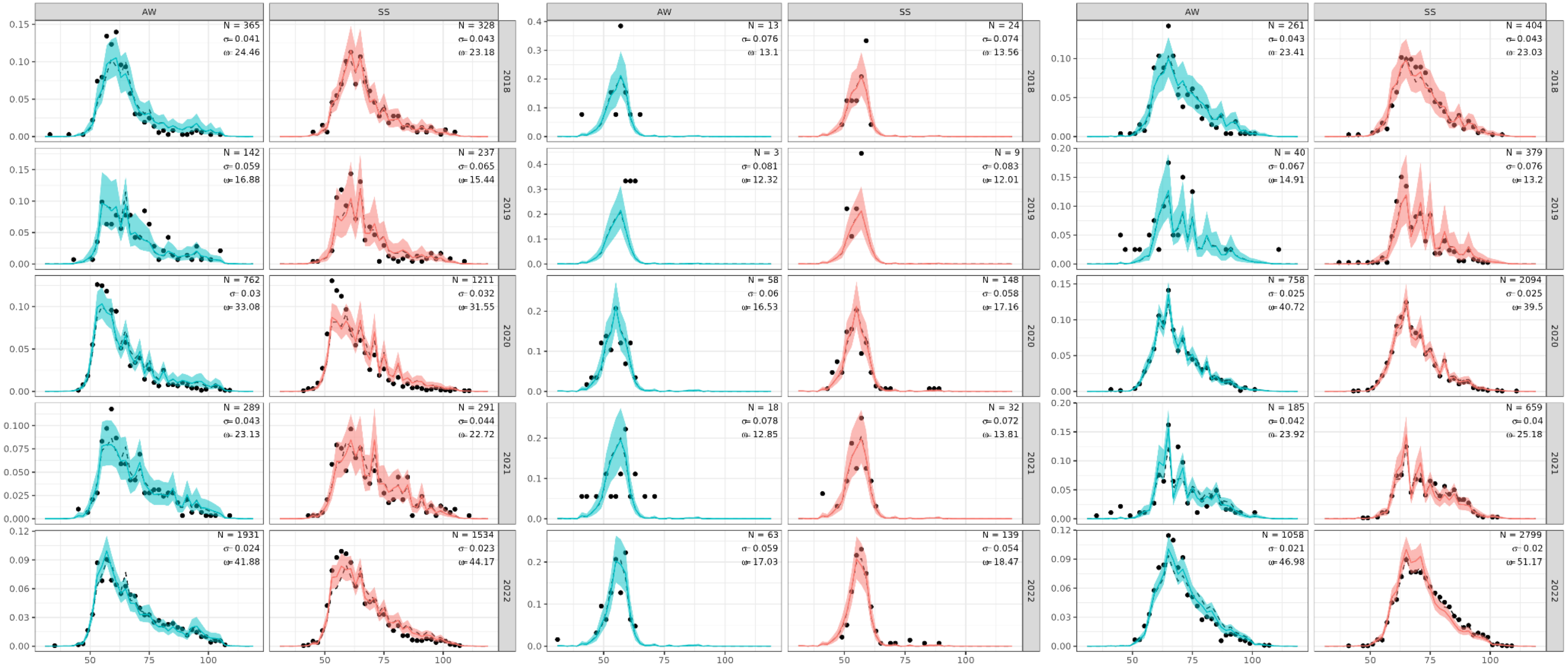


Figure B.5: CRA 6 LFs by fishing year (from 2018 to 2022), season (AW = autumn/winter, SS = spring/summer), TW bin, and sex (males left panel, immature females middle panel, and mature females right panel). The solid line is the mean and the shaded region is the 95% credible interval of the scaled LF 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; the SD of the predicted LF for each stratum; and the data set weight for each stratum.

Appendix C. Proportion in berry analysis

Table C.1: Sample size of mature females by month and QMA/stock assessment region.

QMA/stock assessment region	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
CRA 1	459	277	202	680	1 244	2 761	3 165	1 548	475	460	182	250	11 703
CRA 2	1 376	979	2 900	16 873	17 130	19 760	25 479	12 001	6 782	6 901	3 082	1 393	114 656
CRA 3_R1	271	26	1 052	1 431	900	89	169	550	426	1 341	1 685	515	8455
CRA 3_R2	459	549	892	1 161	855	1 441	2 278	427	423	1 371	1 696	623	12 175
CRA 4	82	1 293	3 253	3 607	2 672	4 494	5 619	4 593	3 810	5 673	1 806	230	37 132
CRA 5_R1	17 819	35 631	20 641	11 365	9 930	15 482	15 623	16 494	13 458	12 705	595	338	170 081
CRA 5_R2	6 872	19 563	20 121	12 948	10 462	16 065	14 548	8 419	5 522	13 037	1 084	103	128 744
CRA 6	**0**	**99**	**318**	**549**	**562**	**1 243**	**3 458**	**3 056**	**1 997**	**1 821**	**1 011**	**45**	**14 159**
CRA 7&8_Fiordland	11 093	38 624	32 384	28 725	37 616	63 057	25 010	15 790	6 267	28 915	14 464	9 063	311 008
CRA 7&8_Southland	142	1 368	823	854	1 862	3 079	2 146	485	128	129	135	32	11 183
CRA 9	383	332	1 681	4 207	4 471	5 542	4 138	1 253	139	171	435	537	23 289

Table C.2: Summary of parameter estimates of final model for predicting the proportion of mature females in berry (*fit10*). This tables excludes parameters relating to interaction terms. (Continued on next 2 pages)

Parameter label	Mean	SD	2.50%	Median	97.50%
b_Intercept	-0.670	0.714	-2.181	0.741	0.687
sd_area__Intercept	1.117	0.186	0.810	0.194	1.572
sd_fmonth__Intercept	2.452	0.500	1.670	0.568	3.905
sd_fmonth:area__Intercept	1.334	0.069	1.202	0.072	1.481
sd_fyear__Intercept	0.086	0.062	0.006	0.056	0.214
sd_fyear:area__Intercept	0.869	0.032	0.807	0.032	0.936
r_area[901,Intercept]	-0.283	0.531	-1.321	0.523	0.711
r_area[902,Intercept]	-0.322	0.597	-1.424	0.596	0.858
r_area[903,Intercept]	1.165	0.550	0.086	0.567	2.349
r_area[904,Intercept]	0.180	0.646	-1.079	0.656	1.456
r_area[905,Intercept]	-0.622	0.441	-1.482	0.456	0.306
r_area[906,Intercept]	-0.465	0.421	-1.328	0.440	0.430
r_area[907,Intercept]	-0.867	0.448	-1.754	0.453	0.009
r_area[908,Intercept]	0.092	0.441	-0.787	0.441	0.928
r_area[909,Intercept]	-1.818	0.553	-2.933	0.554	-0.736
r_area[910,Intercept]	-1.441	0.499	-2.471	0.512	-0.466
r_area[911,Intercept]	1.322	0.442	0.479	0.450	2.246
r_area[912,Intercept]	-0.812	0.557	-1.904	0.547	0.286
r_area[913,Intercept]	-0.677	0.516	-1.644	0.500	0.275
r_area[914,Intercept]	-0.406	0.458	-1.340	0.467	0.504
r_area[915,Intercept]	0.411	0.442	-0.484	0.470	1.379
r_area[916,Intercept]	0.286	0.426	-0.562	0.442	1.181
r_area[917,Intercept]	1.024	0.427	0.201	0.431	1.884
r_area[918,Intercept]	0.760	0.486	-0.185	0.484	1.657

Parameter label	Mean	SD	2.50%	Median	97.50%
r_area[920,Intercept]	-3.471	0.978	-5.635	1.002	-1.640
r_area[922,Intercept]	0.110	0.698	-1.241	0.704	1.549
r_area[923,Intercept]	1.159	0.580	0.030	0.619	2.488
r_area[924,Intercept]	1.670	0.468	0.769	0.469	2.610
r_area[925,Intercept]	1.224	0.737	-0.203	0.732	2.685
r_area[926,Intercept]	0.831	0.433	-0.055	0.438	1.654
r_area[927,Intercept]	-0.177	0.425	-1.021	0.432	0.642
r_area[928,Intercept]	0.399	0.412	-0.459	0.420	1.180
r_area[930,Intercept]	-0.646	0.649	-1.867	0.639	0.643
r_area[931,Intercept]	0.633	0.468	-0.290	0.475	1.594
r_area[932,Intercept]	0.315	1.003	-1.692	1.056	2.570
r_area[933,Intercept]	-0.093	0.450	-0.917	0.448	0.792
r_area[934,Intercept]	0.091	0.772	-1.436	0.778	1.634
r_area[935,Intercept]	0.622	0.492	-0.382	0.505	1.573
r_area[936,Intercept]	0.957	0.518	-0.044	0.508	1.956
r_area[937,Intercept]	-0.052	0.898	-1.771	0.897	1.701
r_area[939,Intercept]	-0.783	0.485	-1.752	0.498	0.219
r_area[940,Intercept]	0.000	0.474	-0.923	0.483	0.980
r_area[941,Intercept]	0.330	0.474	-0.601	0.480	1.284
r_area[942,Intercept]	-0.397	0.475	-1.339	0.484	0.522
r_area[943,Intercept]	-0.527	0.571	-1.589	0.572	0.619
r_fmonth[4,Intercept]	-1.546	0.740	-2.967	0.761	-0.017
r_fmonth[5,Intercept]	0.845	0.728	-0.668	0.756	2.328
r_fmonth[6,Intercept]	3.052	0.747	1.614	0.755	4.584
r_fmonth[7,Intercept]	3.449	0.729	2.039	0.747	4.962
r_fmonth[8,Intercept]	2.894	0.714	1.499	0.746	4.431
r_fmonth[9,Intercept]	1.372	0.725	-0.082	0.745	2.825
r_fmonth[10,Intercept]	0.041	0.719	-1.396	0.749	1.544
r_fmonth[11,Intercept]	-1.154	0.713	-2.640	0.744	0.289
r_fmonth[12,Intercept]	-2.155	0.725	-3.571	0.758	-0.639
r_fmonth[13,Intercept]	-2.773	0.758	-4.224	0.770	-1.148
r_fmonth[14,Intercept]	-2.856	0.742	-4.396	0.779	-1.288
r_fmonth[15,Intercept]	-2.370	0.723	-3.910	0.773	-0.811
r_fyear[1993,Intercept]	-0.030	0.076	-0.310	0.107	0.120
r_fyear[1994,Intercept]	-0.002	0.061	-0.186	0.087	0.173
r_fyear[1995,Intercept]	0.035	0.076	-0.108	0.105	0.314
r_fyear[1996,Intercept]	0.019	0.068	-0.118	0.097	0.280
r_fyear[1997,Intercept]	-0.003	0.066	-0.213	0.091	0.180
r_fyear[1998,Intercept]	-0.001	0.066	-0.217	0.094	0.185
r_fyear[1999,Intercept]	-0.024	0.069	-0.284	0.099	0.110
r_fyear[2000,Intercept]	0.025	0.070	-0.124	0.099	0.291
r_fyear[2001,Intercept]	-0.014	0.068	-0.250	0.093	0.131
r_fyear[2002,Intercept]	0.032	0.075	-0.097	0.102	0.314
r_fyear[2003,Intercept]	-0.009	0.062	-0.233	0.089	0.148
r_fyear[2004,Intercept]	0.047	0.078	-0.070	0.111	0.371
r_fyear[2005,Intercept]	0.026	0.072	-0.112	0.097	0.281

Parameter label	Mean	SD	2.50%	Median	97.50%
r_fyear[2006,Intercept]	-0.004	0.063	-0.214	0.093	0.184
r_fyear[2007,Intercept]	0.017	0.067	-0.121	0.095	0.267
r_fyear[2008,Intercept]	0.005	0.062	-0.155	0.084	0.203
r_fyear[2009,Intercept]	0.023	0.068	-0.123	0.096	0.281
r_fyear[2010,Intercept]	0.003	0.061	-0.176	0.089	0.200
r_fyear[2011,Intercept]	-0.019	0.063	-0.268	0.091	0.107
r_fyear[2012,Intercept]	-0.022	0.065	-0.272	0.094	0.126
r_fyear[2013,Intercept]	-0.008	0.063	-0.213	0.088	0.153
r_fyear[2014,Intercept]	-0.013	0.060	-0.238	0.087	0.135
r_fyear[2015,Intercept]	0.021	0.065	-0.110	0.090	0.255
r_fyear[2016,Intercept]	-0.009	0.060	-0.208	0.084	0.152
r_fyear[2017,Intercept]	-0.001	0.059	-0.168	0.080	0.177
r_fyear[2018,Intercept]	-0.024	0.065	-0.264	0.091	0.103
r_fyear[2019,Intercept]	0.011	0.065	-0.135	0.089	0.239
r_fyear[2020,Intercept]	-0.013	0.062	-0.223	0.086	0.141
r_fyear[2021,Intercept]	-0.022	0.064	-0.249	0.087	0.101
r_fyear[2022,Intercept]	-0.038	0.069	-0.285	0.093	0.092

Table C.3: Summary of posteriors of predicted proportion of mature females in berry by stock assessment QMA/Region and season (*fit10*).

Season	QMA/Region	Mean	SD	2.5%	Median	97.5%
Autumn/Winter	CRA 1	0.718	0.090	0.554	0.720	0.874
	CRA 2	0.759	0.083	0.498	0.758	0.896
	CRA 3_R1	0.765	0.109	0.519	0.783	0.932
	CRA 3_R2	0.852	0.086	0.603	0.868	0.958
	CRA 4	0.782	0.067	0.641	0.786	0.899
	CRA 5_R1	0.885	0.036	0.801	0.893	0.940
	CRA 5_R2	0.815	0.057	0.707	0.815	0.948
	CRA 6	**0.818**	**0.075**	**0.633**	**0.826**	**0.931**
	CRA 7&8_Fiordland	0.693	0.097	0.473	0.701	0.843
	CRA 7&8_Southland	0.549	0.116	0.335	0.555	0.754
	CRA 9	0.834	0.074	0.656	0.849	0.937
Spring/Summer	CRA 1	0.226	0.078	0.116	0.208	0.420
	CRA 2	0.198	0.090	0.090	0.168	0.395
	CRA 3_R1	0.013	0.023	0.001	0.006	0.072
	CRA 3_R2	0.470	0.218	0.049	0.471	0.858
	CRA 4	0.097	0.054	0.036	0.080	0.245
	CRA 5_R1	0.281	0.085	0.132	0.279	0.479
	CRA 5_R2	0.128	0.066	0.057	0.105	0.309
	CRA 6	**0.116**	**0.043**	**0.049**	**0.110**	**0.213**
	CRA 7&8_Fiordland	0.292	0.111	0.143	0.283	0.526
	CRA 7&8_Southland	0.539	0.159	0.180	0.556	0.770
	CRA 9	0.287	0.125	0.085	0.280	0.529

Table C.4: Summary of posteriors of predicted proportion of mature females in berry in CRA 6 by season and fishing year (*fit10*).

	Autumn/Winter					Spring/Summer				
Fishing year	Mean	SD	2.5%	Median	97.5%	Mean	SD	2.5%	Median	97.5%
1993	0.828	0.067	0.666	0.836	0.928	0.094	0.036	0.042	0.087	0.184
1994	0.825	0.065	0.662	0.833	0.924	0.094	0.035	0.042	0.088	0.179
1995	0.808	0.075	0.618	0.820	0.917	0.151	0.049	0.071	0.144	0.264
1996	0.825	0.069	0.656	0.837	0.926	0.153	0.047	0.074	0.147	0.259
1997	0.819	0.072	0.638	0.832	0.922	0.117	0.040	0.055	0.112	0.209
1998	0.821	0.069	0.642	0.831	0.924	0.142	0.049	0.066	0.134	0.257
1999	0.819	0.069	0.657	0.829	0.923	0.131	0.046	0.057	0.124	0.237
2000	0.800	0.081	0.599	0.814	0.921	0.145	0.053	0.064	0.137	0.270
2001	0.816	0.077	0.635	0.829	0.928	0.118	0.042	0.056	0.112	0.218
2002	0.738	0.046	0.640	0.742	0.821	0.056	0.014	0.034	0.055	0.088
2003	0.812	0.035	0.738	0.815	0.870	0.107	0.016	0.079	0.107	0.139
2004	0.873	0.024	0.821	0.875	0.913	0.116	0.016	0.087	0.115	0.148
2005	0.882	0.017	0.847	0.883	0.912	0.119	0.012	0.096	0.119	0.145
2006	0.792	0.026	0.738	0.793	0.838	0.092	0.013	0.069	0.091	0.120
2007	0.927	0.011	0.904	0.927	0.946	0.145	0.013	0.122	0.144	0.172
2008	0.811	0.027	0.754	0.812	0.859	0.101	0.011	0.081	0.101	0.125
2009	0.833	0.054	0.708	0.842	0.914	0.070	0.025	0.038	0.065	0.134
2010	0.759	0.041	0.676	0.762	0.832	0.076	0.014	0.052	0.075	0.106
2011	0.637	0.041	0.556	0.635	0.715	0.058	0.007	0.045	0.058	0.074
2012	0.830	0.068	0.662	0.842	0.929	0.098	0.031	0.057	0.091	0.175
2013	0.794	0.072	0.627	0.804	0.908	0.132	0.046	0.064	0.125	0.244
2014	0.823	0.052	0.701	0.830	0.903	0.099	0.023	0.063	0.096	0.151
2015	0.905	0.031	0.829	0.912	0.950	0.117	0.025	0.077	0.114	0.175
2016	0.804	0.048	0.692	0.810	0.884	0.126	0.033	0.071	0.124	0.196
2017	0.805	0.050	0.689	0.811	0.883	0.148	0.036	0.086	0.144	0.226
2018	0.748	0.033	0.680	0.749	0.810	0.100	0.015	0.076	0.099	0.131
2019	0.839	0.062	0.691	0.847	0.929	0.153	0.039	0.095	0.146	0.248
2020	0.898	0.017	0.861	0.900	0.928	0.169	0.018	0.135	0.169	0.207
2021	0.799	0.031	0.733	0.801	0.856	0.101	0.015	0.075	0.100	0.133
2022	0.855	0.023	0.807	0.856	0.896	0.151	0.018	0.120	0.150	0.190

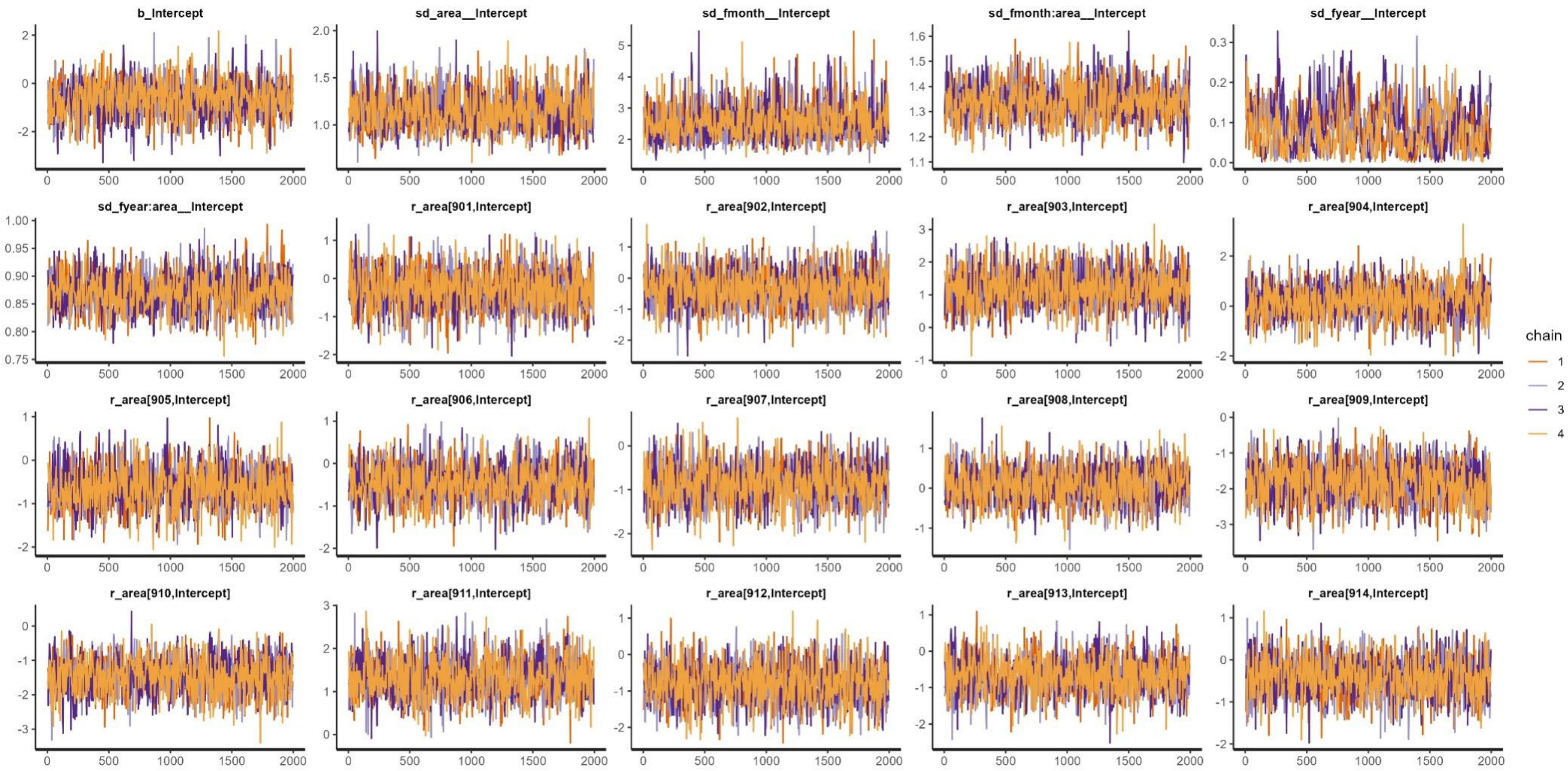


Figure C.1: MCMC traces of a sample of estimated parameters of the final model used to predict the proportion of mature females in berry (*fit10*).

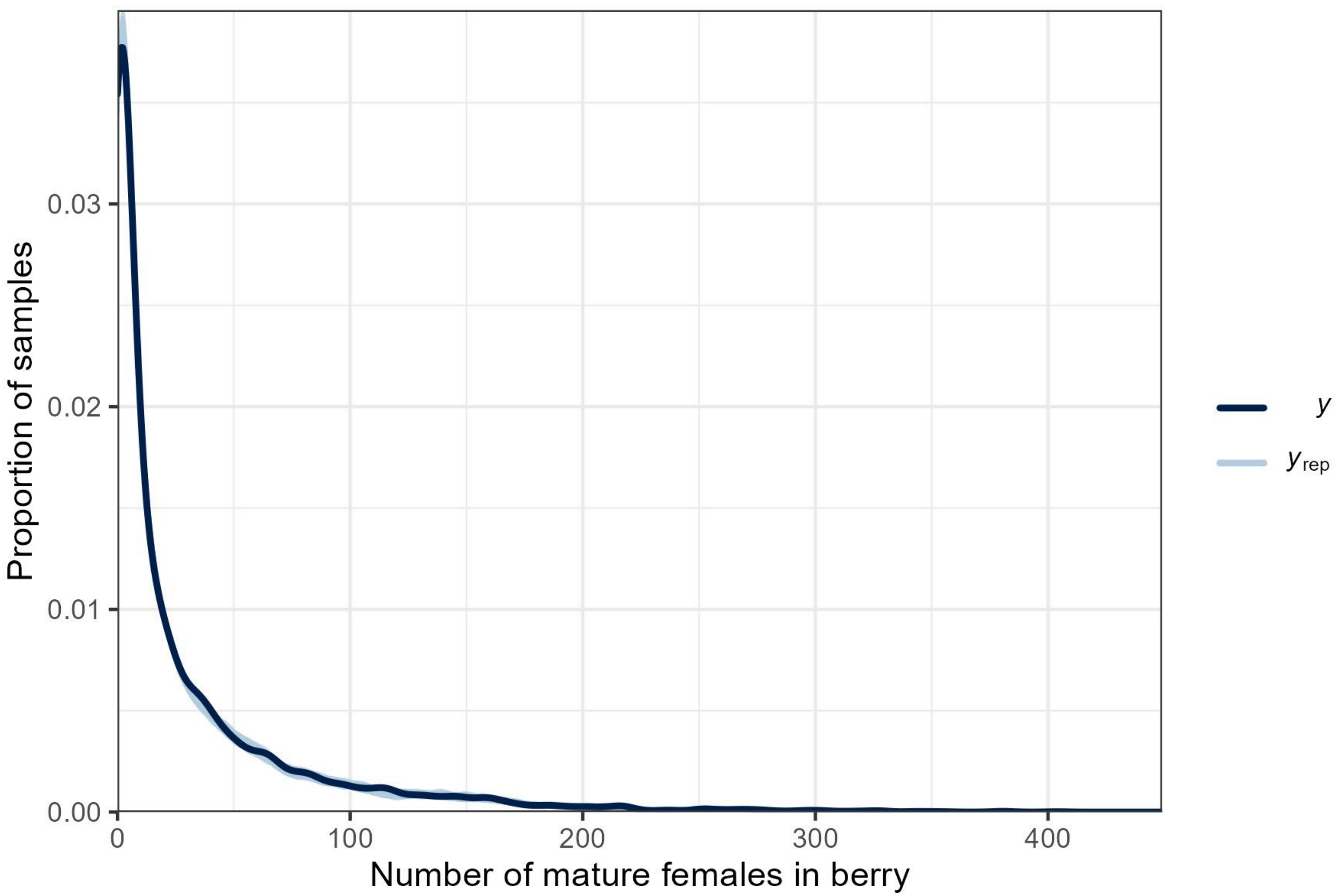


Figure C.2: Comparison of observed (dark blue line) versus predicted (light blue lines) density of the number of mature females in berry from the posterior predictive distribution of the final model used to predict the proportion of mature females in berry (*fit10*).

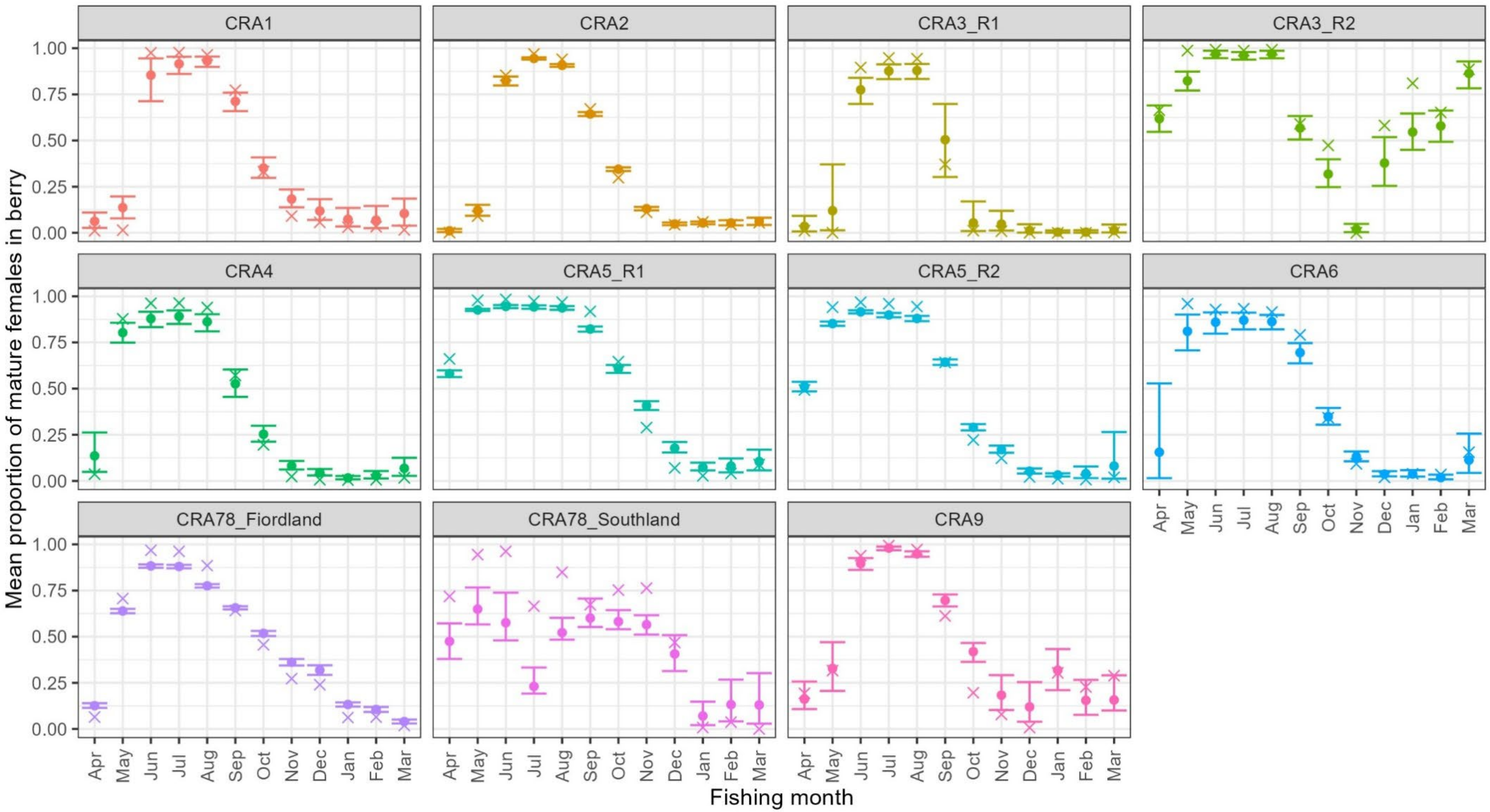


Figure C.3: Catch-weighted posteriors of the proportion of mature females in berry by stock assessment QMA/region and fishing month from the final model (*fit10*). Closed points are mean values; bars are the 95% credible intervals; and the non-catch-weighted proportions are represented by crosses.

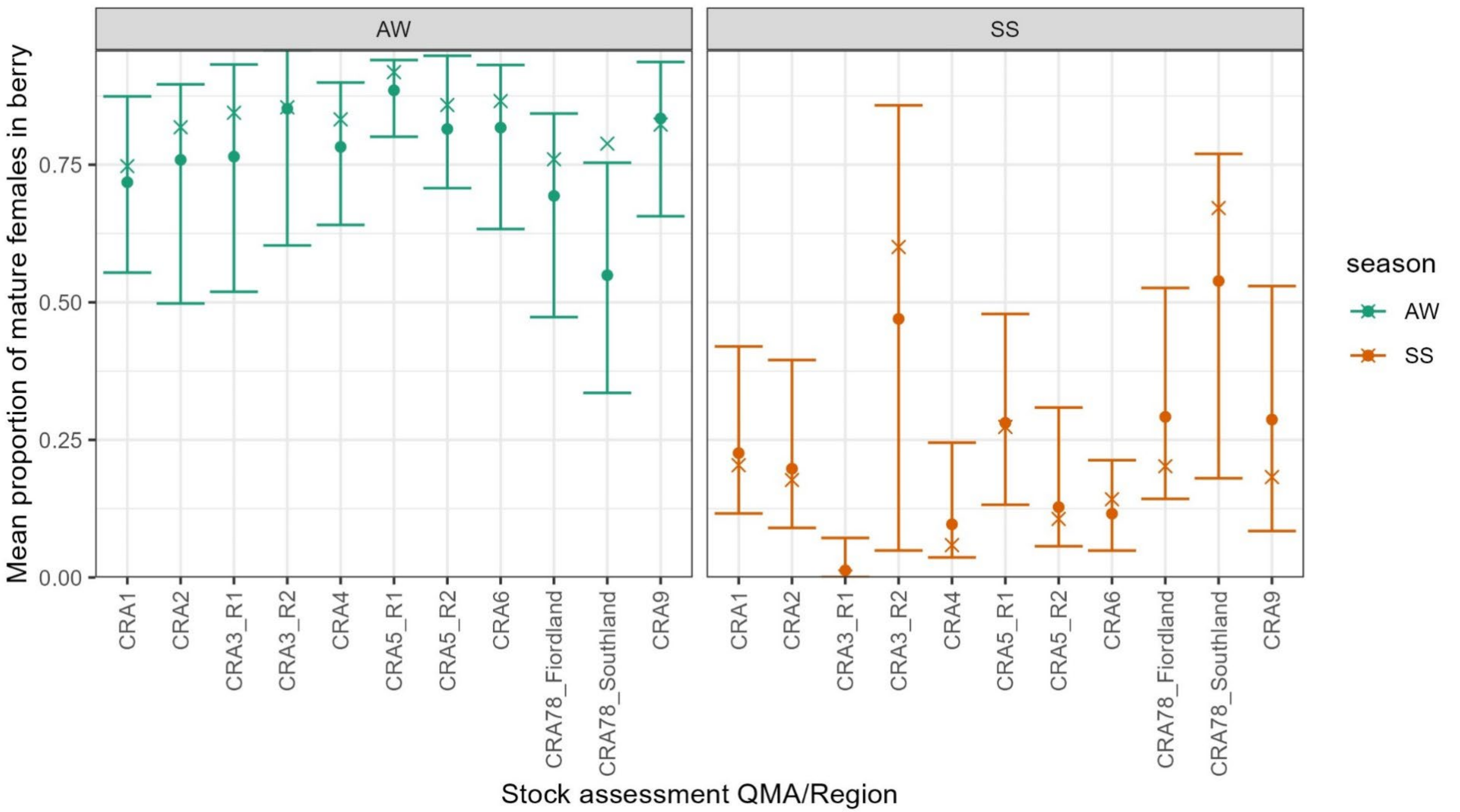


Figure C.4: Catch-weighted posterior of the proportion of mature females in berry by stock assessment QMA/region and season from the final model (*fit10*). Closed points are mean values; bars are the 95% credible intervals; and the non-catch-weighted proportions are represented by crosses.

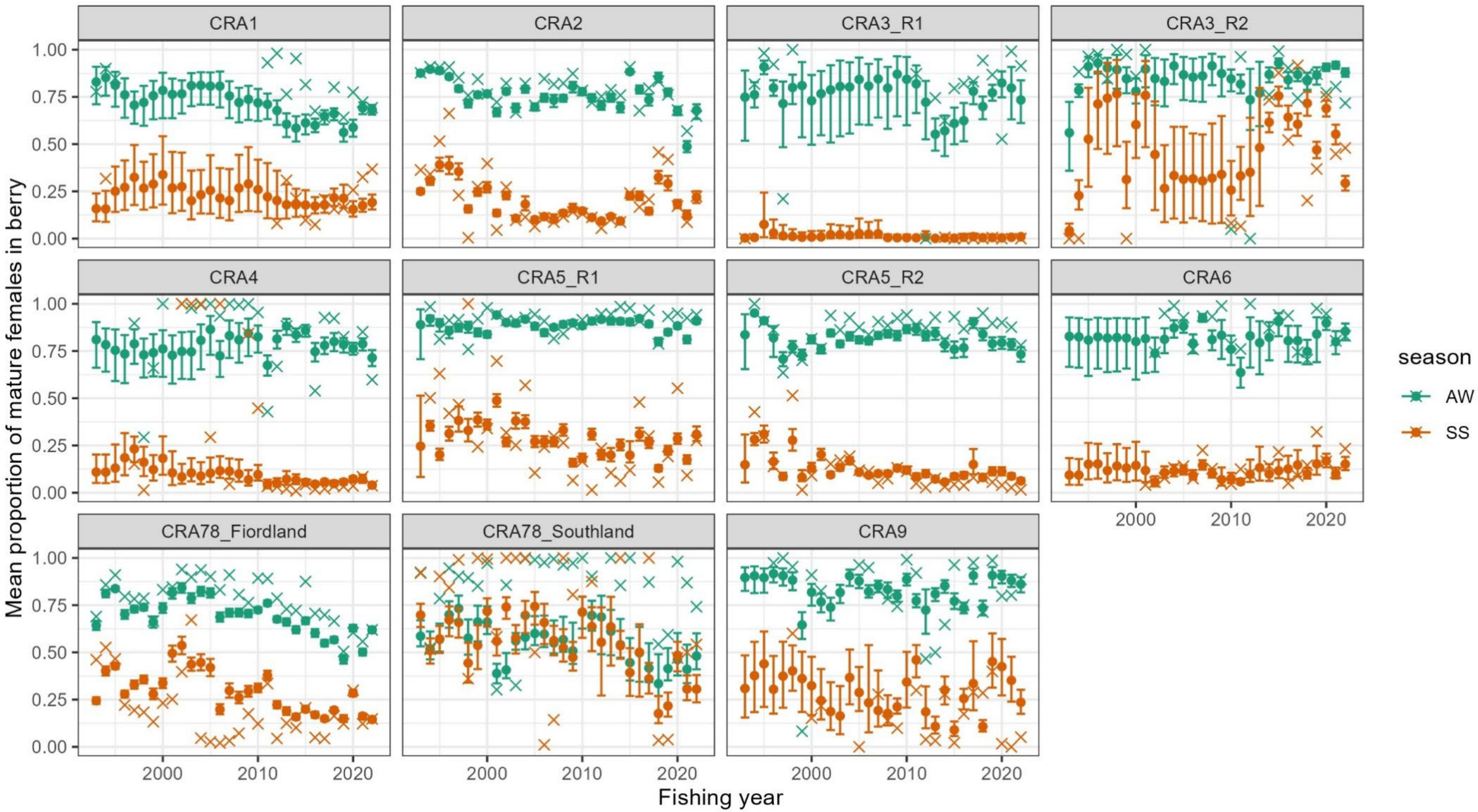


Figure C.5: Catch-weighted posteriors of the proportion of mature females in berry by stock assessment QMA/region and fishing year from the final model (*fit10*). Closed points are mean values; bars are the 95% credible intervals; and the non-catch-weighted proportions are represented by crosses.

Appendix D. Updated carapace length-tail width relationships

The tag-recapture based estimation of growth by rock lobster stock assessment models is dependent on the accurate measurement of lobsters. All New Zealand red rock lobster assessments use tail width (TW), whereas, prior to the late-1980s, most measurements of tagged and recaptured lobsters were of carapace length (CL). This necessitated the use of a model to derive TW estimates for lobsters for which only a CL measurement was available. Prior to the current assessment of CRA 6, the sex and QMA-specific CL-TW relationships provided by Breen et al. (1988) were used for making this conversion. However, that analysis had much less data than are now available, and the derived relationships appeared to be inaccurate for some QMA-sex combinations based on a comparison with the currently available sample of paired CL-TW measurements (Figure D.1). For example, for those stocks with an adequate sample of larger tagged lobsters, non-linear relationships between CL and TW were more consistent with the data, particularly for females.

The analysis presented in this Appendix updates previous CL-TW relationships for each sex-QMA combination for which there are adequate data (i.e., all except CRA 1 and CRA 9). These updated relationships were then used to process the tag growth data used by the CRA 6 assessment (Section 5.1).

Methods & Results

Models predicting TW from CL were fitted to TW measurements from a June 2023 extract of the *rlcs* database (replog 15070). The available sample sizes of paired CL-TW measurements for males and females were greatest for CRA 3, CRA 4, CRA 5, and CRA 8 (each with more than 10 000 samples), and were smallest for CRA 2 (with fewer than 1 000 samples). There were no samples in CRA 9 and effectively no samples in CRA 1 (Table D.1).

Initial data exploration indicated non-linear CL-TW relationships for females in those QMAs with an adequate sample of larger lobsters (Figure D.1), which is likely to reflect an increase in TW around the size at maturation. Non-linear models using splines were explored (Wood 2011), implemented as *brms* models in *R* (Bürkner 2017, R Core Team 2023).

During initial model development, it became apparent that the use of splines resulted in prohibitively slow model run times when fitting to the full dataset of observations. Because of this limitation, it was decided to fit separate models for males and females, using a subset of observations. This was done by a taking a random sample, without replacement, of up to 50 lobsters per 1 cm CL bin within each QMA-sex stratum. This reduced the fitted sample of observations to approximately one-tenth of its original size (Table D.1), while maintaining an even spread of information across the full size range for each sex.

Models were fitted to logged individual measurements of TW. The following candidate explanatory variables were offered to the model:

1. log(CL);
2. a spline on log(CL), for which the initial basis dimension value was set to $k = 4$, to constrain the wiggliness of the spine; and
3. QMA, including CRA 2 to CRA 8 (i.e., not CRA 1 or CRA 9, which were data deficient).

All parameters were trialled as population-level effects (analogous to fixed effects). Normal and Student *t* distributions were trialled, with a full set of candidate models (listed in Table D.3).

Leave-one-out information criterion (LOO IC) and Bayesian R^2 statistics were used to guide model selection. The optimal model was checked by the visual assessment of MCMC trace plots and also by the comparison of observed versus simulated densities of TW measurements.

For both sexes, the best model in terms of LOO IC and Bayesian R^2 statistics was the most complex model structure, assuming the Student *t* distribution (*fit_f4* for females and *fit_m4* for males). The trace plots for the optimal models for each sex indicated good MCMC mixing (Figure D.2 and Figure D.3). The optimal model fit to the data was better for males than it was for females (Figure D.4), however there were no obvious residual patterns with respect to observed and predicted tail width for either sex (Figure D.5). The conditional smooths for the spline on log(CL) were shaped differently for males and females, with a sigmoidal shape for females and a slight curvature for males (Figure D.6).

The predicted CL-TW width relationships showed good overall agreement between the optimal models and the observations (Figure D.7, Figure D.8). Mean predicted TW values, tabulated at 5 mm carapace length intervals for each sex and QMA, indicated that CRA 7 and CRA 8 females had a slightly different morphology compared with the other QMAs, with a narrower TW for a given CL (Table D.6, Table D.7). Males had a consistently smaller TW for a given CL compared with females at all sizes, with this difference being more apparent with increasing body size.

Conclusions

The CL-TW relationships produced by the optimal models were deemed by the RLWG to be a good representation of the relationships for males and females in each QMA. These updated relationships were used to process the tagging data summarised in Section 5.1.

Table D.1: Number of lobsters with both carapace length (CL) and tail width (TW) measurements by QMA and sex (source: *rlcs* database). The reduced sample sizes shown in the final two columns were made to speed up model fitting by selecting up to 50 lobsters randomly by sex and QMA without replacement from every 1 cm CL bin.

	Number of lobsters in *rlcs* database with both measurements		Sample used for model fitting	
QMA	Female	Male	Female	Male
CRA 1	4	2	–	–
CRA 2	910	934	861	901
CRA 3	22 491	53 526	1 881	2 570
CRA 4	36 771	51 955	2 674	2 851
CRA 5	12 868	10 131	2 566	2 609
CRA 6	4 788	3 146	3 399	3 123
CRA 7	7 483	6 640	2 135	2 485
CRA 8	80 128	62 679	3 980	4 105
Total	165 443	189 013	17 496	18 644

Table D.2: Number of lobsters with both carapace length and tail width measurements by QMA and fishing year of measurement (source: *rlcs* database). There were no paired measurements in the *rlcs* database prior to 1986–87.

Fishing year of measurement	CRA 1	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8
1986	–	562	483	276	–	–	–	–
1987	–	–	–	2 748	–	–	–	1 855
1988	–	–	–	3 822	–	–	2 523	1 146
1989	–	–	5 172	8 265	3 312	1 463	1 238	18 463
1990	–	364	13 490	25 020	5 307	–	2 411	31 052
1991	–	918	14 384	18 640	4 963	–	1 835	37 710
1992	–	–	13 152	18 050	3 017	–	2 103	30 766
1993	–	–	28 633	11 903	6 400	645	1 978	21 760
1994	–	–	–	–	–	–	–	55
1995	–	–	–	–	–	2 529	–	–
1996	–	–	26	–	–	3 198	–	–
1997	–	–	669	–	–	99	–	–
1998	–	–	–	–	–	–	–	–
1999	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–
2001	–	–	3	–	–	–	–	–
2002	–	–	2	–	–	–	–	–
2003	–	–	–	–	–	–	–	–
2004	–	–	–	–	–	–	–	–
2005	–	–	–	–	–	–	–	–
2006	–	–	–	–	–	–	–	–
2007	–	–	1	–	–	–	–	–
2008	–	–	–	–	–	–	–	–
2009	–	–	–	2	–	–	–	–
2010	–	–	–	–	–	–	–	–
2011	–	–	–	–	–	–	–	–
2012	–	–	–	–	–	–	–	–
2013	–	–	–	–	–	–	–	–
2014	3	–	–	–	–	–	–	–
2015	–	–	–	–	–	–	–	–
2016	–	–	2	–	–	–	2 035	–
2017	3	–	–	–	–	–	–	–
2018	–	–	–	–	–	–	–	–
2019	–	–	–	–	–	–	–	–
2020	–	–	–	–	–	–	–	–
2021	–	–	–	–	–	–	–	–
2022	–	–	–	–	–	–	–	–
Total	6	1 844	76 017	88 726	22 999	7 934	14 123	142 807

Table D.3: Comparison of candidate models for predicting the tail width of male and female red rock lobsters given carapace length (CL).

Label	Model structure	Distribution	Bayesian R^2	δ-LOO IC	SE LOO IC
Female models					
fit_f1	log(*CL*)	Normal	0.957 (0.957–0.958)	6 690	775
fit_f2	log(*CL*) + *qma*	Normal	0.961 (0.961–0.962)	4 950	841
fit_f3	s(log(*CL*), k = 4) + *qma*	Normal	0.963 (0.963–0.963)	4 162	672
fit_f4	s(log(*CL*), k = 4) + *qma*	Student *t*	0.963 (0.963–0.964)	0	259
Male models					
fit_m1	log(*CL*)	Normal	0.965 (0.965–0.966)	9 044	1 244
fit_m2	log(*CL*) + *qma*	Normal	0.970 (0.970–0.970)	6 460	1 377
fit_m3	s(log(*CL*), k = 4) + *qma*	Normal	0.970 (0.970–0.971)	6 198	1 343
fit_m4	s(log(*CL*), k = 4) + *qma*	Student *t*	0.971 (0.971–0.971)	0	270

Table D.4: Summary of parameter estimates of final model for predicting the tail width of females (*fit_f4*) given carapace length.

Parameter label	Mean	SD	2.50%	Median	97.50%
b_Intercept	4.0854	0.0014	4.0827	4.0854	4.0882
b_qmaCRA3	0.0176	0.0017	0.0142	0.0176	0.0207
b_qmaCRA4	0.0200	0.0016	0.0167	0.0200	0.0229
b_qmaCRA5	0.0090	0.0016	0.0059	0.0090	0.0121
b_qmaCRA6	0.0047	0.0016	0.0016	0.0047	0.0079
b_qmaCRA7	-0.0271	0.0016	-0.0302	-0.0271	-0.0239
b_qmaCRA8	-0.0145	0.0015	-0.0177	-0.0145	-0.0115
bs_slogcl_1	2.4929	0.0388	2.4180	2.4930	2.5684
sds_slogcl_1	0.5278	0.3349	0.1964	0.7514	2.6258
sigma	0.0340	0.0003	0.0334	0.0340	0.0346
nu	4.8080	0.1546	4.5012	4.8086	5.1118
s_slogcl_1[1]	-0.3767	0.0201	-0.4162	-0.3765	-0.3381
s_slogcl_1[2]	0.2543	0.0226	0.2098	0.2543	0.3009

Table D.5: Summary of parameter estimates of final model for predicting the tail width of males (*fit_m4*).

Parameter label	Mean	SD	2.50%	Median	97.50%
b_Intercept	3.9929	0.0010	3.9910	3.9929	3.9948
b_qmaCRA3	-0.0197	0.0012	-0.0221	-0.0197	-0.0174
b_qmaCRA4	-0.0188	0.0012	-0.0211	-0.0187	-0.0164
b_qmaCRA5	-0.0029	0.0011	-0.0051	-0.0029	-0.0007
b_qmaCRA6	0.0302	0.0012	0.0279	0.0302	0.0326
b_qmaCRA7	0.0081	0.0011	0.0059	0.0081	0.0103
b_qmaCRA8	0.0044	0.0011	0.0022	0.0045	0.0067
bs_slogcl_1	2.9283	0.0237	2.8827	2.9283	2.9758
sds_slogcl_1	0.2094	0.1497	0.0651	0.3495	1.6970
sigma	0.0263	0.0002	0.0259	0.0263	0.0267
nu	4.7004	0.1414	4.4256	4.7033	5.0139
s_slogcl_1[1]	0.1356	0.0151	0.1058	0.1354	0.1652
s_slogcl_1[2]	-0.0650	0.0119	-0.0886	-0.0653	-0.0430

Table D.6: Predicted mean tail width of females by carapace length and QMA (*fit_f4*).

Carapace	Predicted mean tail width (mm)						
length (mm)	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8
35	22.1	22.5	22.6	22.3	22.2	21.5	21.8
40	24.8	25.2	25.3	25.0	24.9	24.1	24.4
45	27.4	27.9	28.0	27.7	27.6	26.7	27.0
50	30.1	30.7	30.7	30.4	30.3	29.3	29.7
55	32.9	33.5	33.5	33.2	33.0	32.0	32.4
60	35.7	36.4	36.4	36.0	35.9	34.8	35.2
65	38.7	39.4	39.5	39.1	38.9	37.7	38.1
70	41.8	42.6	42.7	42.2	42.0	40.7	41.2
75	45.1	45.9	46.0	45.5	45.3	43.9	44.4
80	48.5	49.3	49.5	48.9	48.7	47.2	47.8
85	52.0	52.9	53.0	52.4	52.2	50.6	51.2
90	55.5	56.5	56.7	56.0	55.8	54.0	54.7
95	59.1	60.2	60.3	59.7	59.4	57.6	58.3
100	62.7	63.9	64.0	63.3	63.0	61.1	61.8
105	66.3	67.5	67.7	66.9	66.6	64.5	65.4
110	69.8	71.1	71.3	70.5	70.2	68.0	68.8
115	73.3	74.6	74.8	74.0	73.7	71.4	72.3
120	76.7	78.1	78.3	77.4	77.1	74.7	75.6
125	80.1	81.5	81.7	80.8	80.5	78.0	78.9
130	83.4	84.9	85.1	84.2	83.8	81.2	82.2
135	86.6	88.2	88.4	87.4	87.0	84.3	85.4
140	89.8	91.4	91.6	90.6	90.3	87.4	88.5
145	93.0	94.6	94.8	93.8	93.4	90.5	91.6
150	96.1	97.8	98.0	97.0	96.5	93.5	94.7
155	99.2	100.9	101.2	100.1	99.6	96.5	97.7
160	102.2	104.0	104.3	103.1	102.7	99.5	100.7
165	105.3	107.1	107.4	106.2	105.8	102.4	103.7
170	108.3	110.2	110.5	109.3	108.8	105.4	106.7
175	111.3	113.3	113.5	112.3	111.8	108.3	109.7
180	114.3	116.3	116.6	115.3	114.8	111.2	112.6
185	117.3	119.4	119.6	118.3	117.8	114.1	115.6
190	120.3	122.4	122.7	121.4	120.8	117.1	118.5
195	123.3	125.4	125.7	124.4	123.8	120.0	121.5

Table D.7: Predicted mean tail width of males by carapace length and QMA (*fit_m4*).

Carapace length (mm)	Predicted mean tail width (mm) CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8
35	20.6	20.2	20.2	20.5	21.2	20.8	20.7
40	23.3	22.8	22.8	23.2	24	23.4	23.4
45	25.9	25.4	25.4	25.8	26.7	26.1	26.0
50	28.5	28.0	28.0	28.5	29.4	28.8	28.7
55	31.2	30.5	30.6	31.1	32.1	31.4	31.3
60	33.8	33.1	33.1	33.7	34.8	34	33.9
65	36.3	35.6	35.7	36.2	37.5	36.6	36.5
70	38.9	38.2	38.2	38.8	40.1	39.2	39.1
75	41.5	40.7	40.7	41.4	42.8	41.8	41.7
80	44.0	43.2	43.2	43.9	45.4	44.4	44.2
85	46.6	45.7	45.7	46.5	48	47	46.8
90	49.1	48.2	48.2	49	50.6	49.5	49.3
95	51.6	50.6	50.7	51.5	53.2	52	51.9
100	54.1	53.1	53.1	54	55.8	54.6	54.4
105	56.6	55.5	55.5	56.4	58.3	57	56.8
110	59.0	57.9	57.9	58.8	60.8	59.5	59.3
115	61.4	60.2	60.3	61.2	63.3	61.9	61.7
120	63.8	62.6	62.6	63.6	65.8	64.3	64.1
125	66.1	64.8	64.9	65.9	68.2	66.7	66.4
130	68.4	67.1	67.2	68.2	70.5	69.0	68.8
135	70.7	69.3	69.4	70.5	72.9	71.3	71.0
140	73	71.5	71.6	72.8	75.2	73.6	73.3
145	75.2	73.7	73.8	75	77.5	75.8	75.5
150	77.4	75.9	75.9	77.2	79.8	78.0	77.7
155	79.6	78.0	78.1	79.3	82.0	80.2	79.9
160	81.7	80.1	80.2	81.5	84.2	82.4	82.1
165	83.8	82.2	82.3	83.6	86.4	84.5	84.2
170	85.9	84.2	84.3	85.7	88.6	86.6	86.3
175	88.0	86.3	86.4	87.8	90.7	88.7	88.4
180	90.1	88.3	88.4	89.8	92.8	90.8	90.5
185	92.1	90.3	90.4	91.9	95.0	92.9	92.5
190	94.2	92.3	92.4	93.9	97.1	94.9	94.6
195	96.2	94.3	94.4	95.9	99.2	97.0	96.6
200	98.2	96.3	96.4	97.9	101.2	99.0	98.7
205	100.2	98.3	98.4	99.9	103.3	101.0	100.7
210	102.2	100.2	100.3	101.9	105.4	103.1	102.7
215	104.2	102.2	102.3	103.9	107.4	105.1	104.7
220	106.2	104.1	104.2	105.9	109.4	107.1	106.7
225	108.2	106.0	106.2	107.8	111.5	109.0	108.6
230	110.1	108.0	108.1	109.8	113.5	111.0	110.6

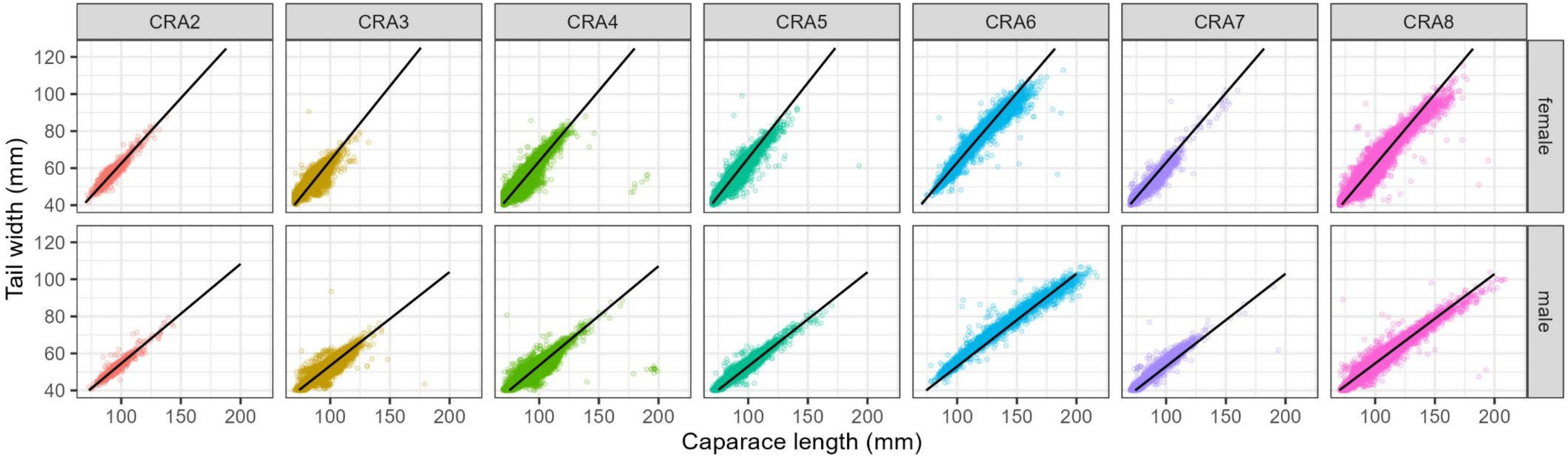


Figure D.1: Sex and QMA-specific morphometric relationships (black lines) from Breen et al. (1988) used by previous tag data analyses for deriving tail width (TW) values for red rock lobsters for which only carapace length (CL) measurements were taken. The currently available sample of paired measurements of CL and TW are represented by open circles (source *rlcs* database).

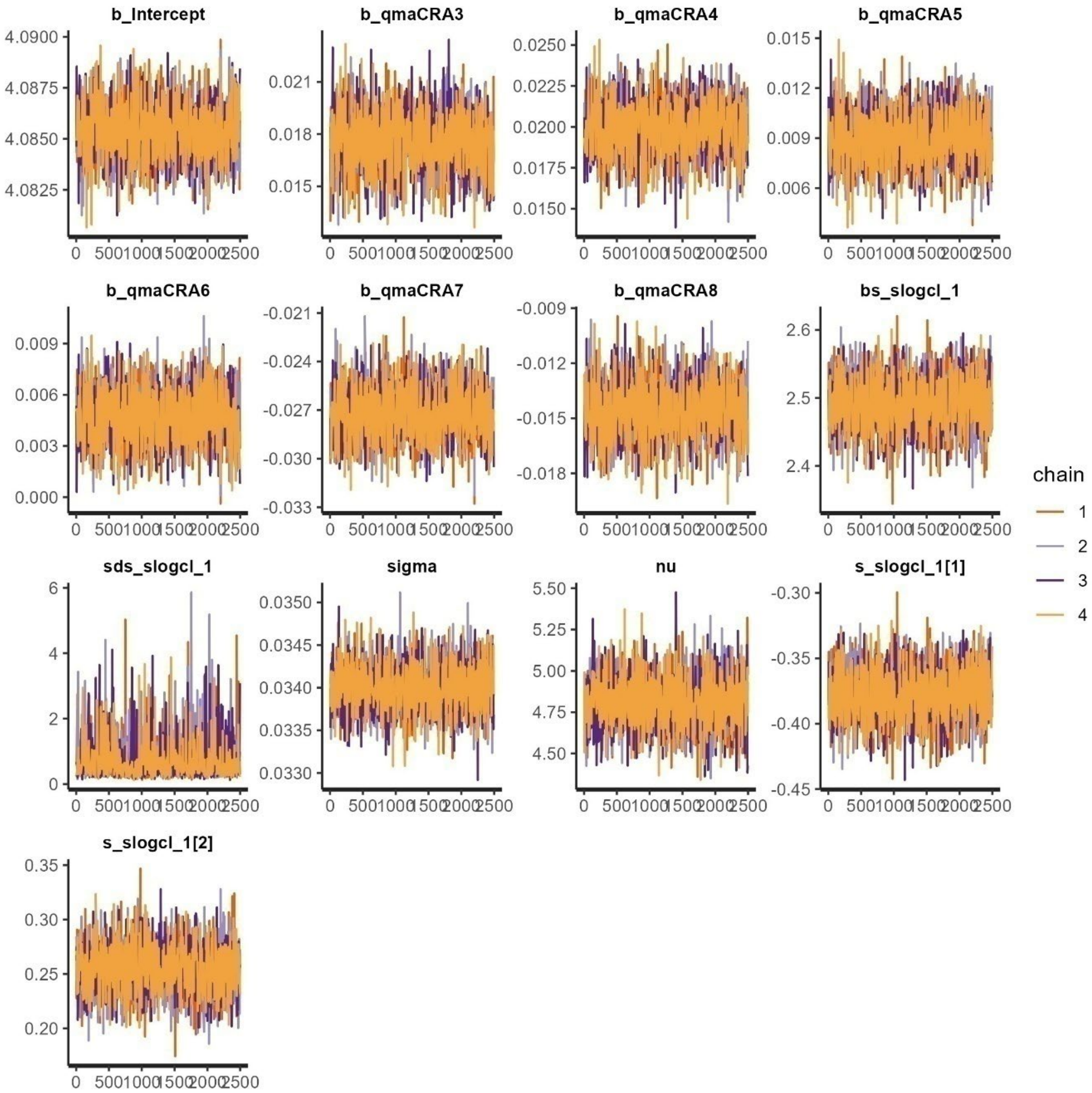


Figure D.2: Trace plots for all estimated model parameters of the optimal modal for predicting tail width (TW) from carapace length (CL) for female lobsters (*fit_f4*).

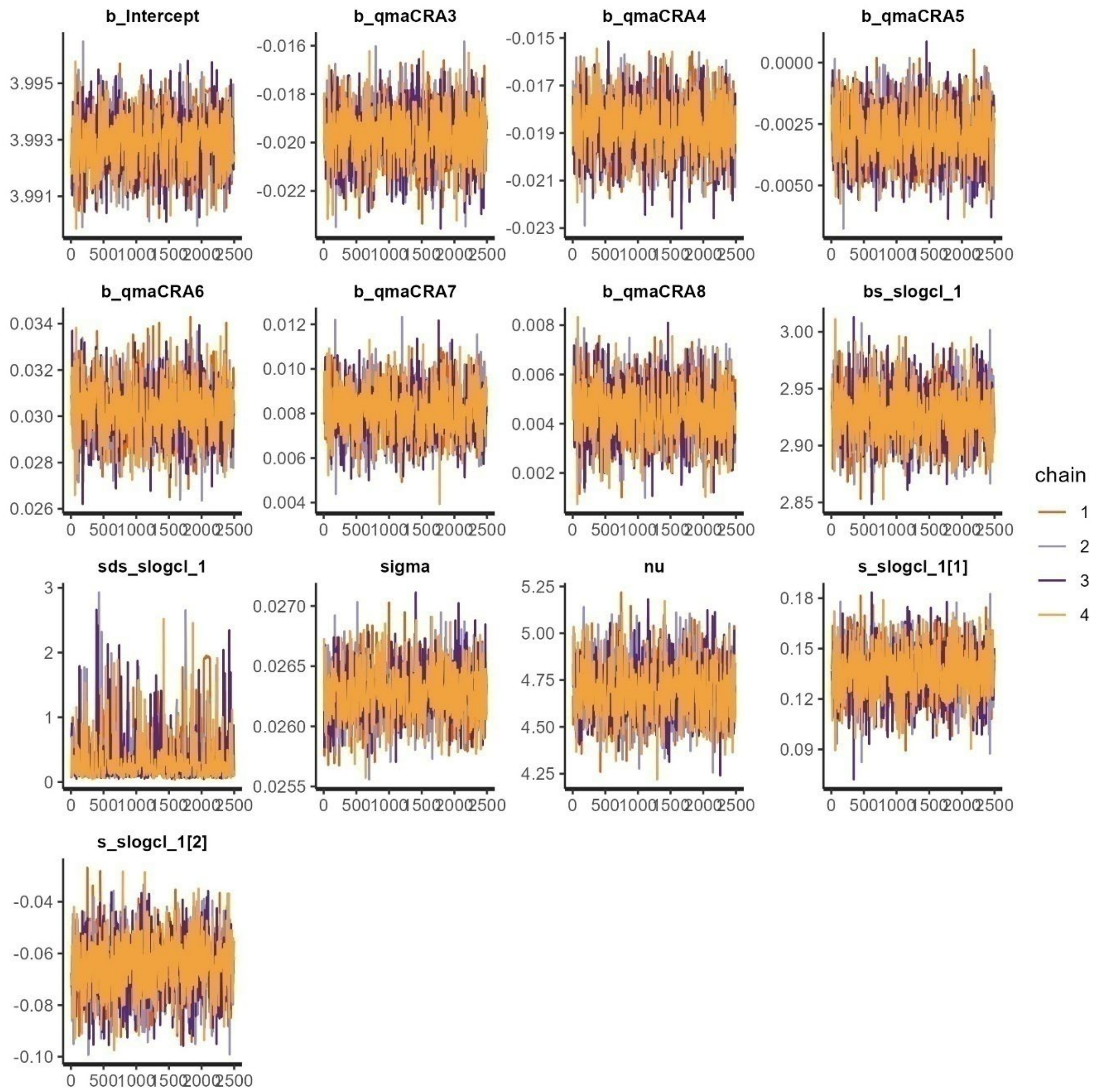


Figure D.3: Trace plots for all estimated model parameters of the optimal modal for predicting tail width (TW) from carapace length (CL) for male lobsters (*fit_m4*).

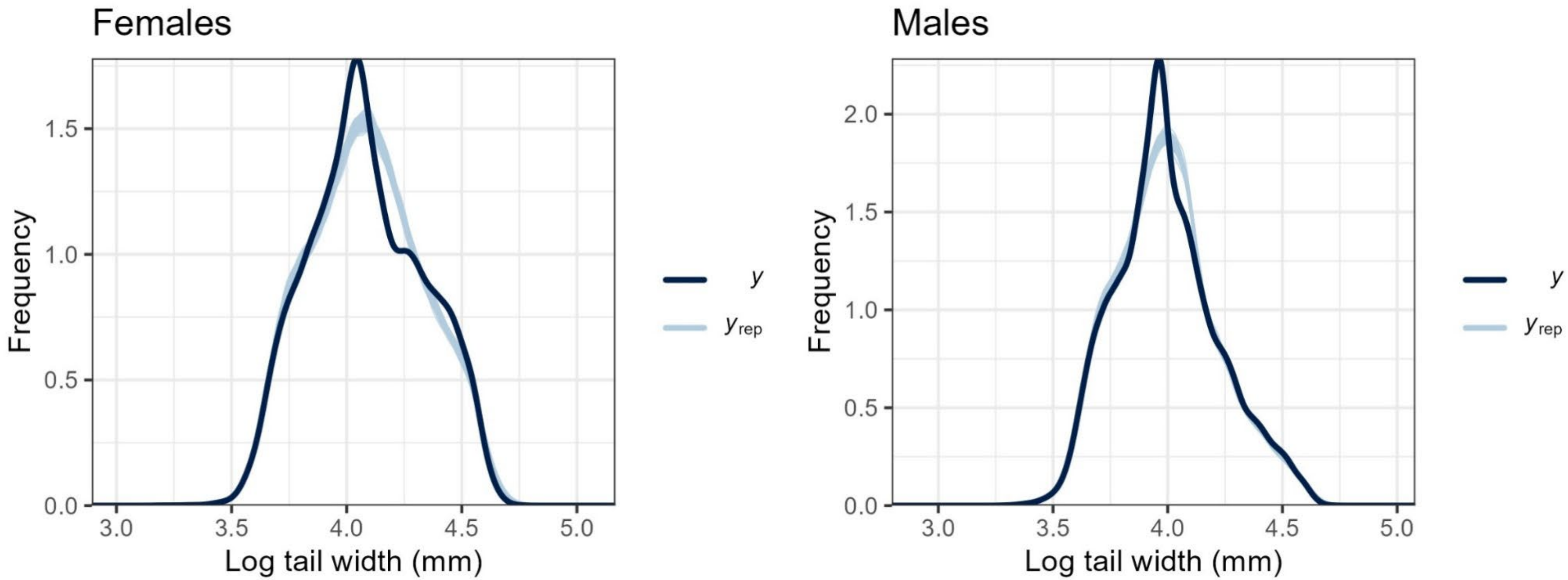


Figure D.4: Comparison of observed (dark blue lines) versus simulated (light blue lines) density of log(tail width) from the posterior predictive distribution of the final models used to predict the tail width of females (*fit_f4*) and males (*fit_m4*) given carapace length measurements.

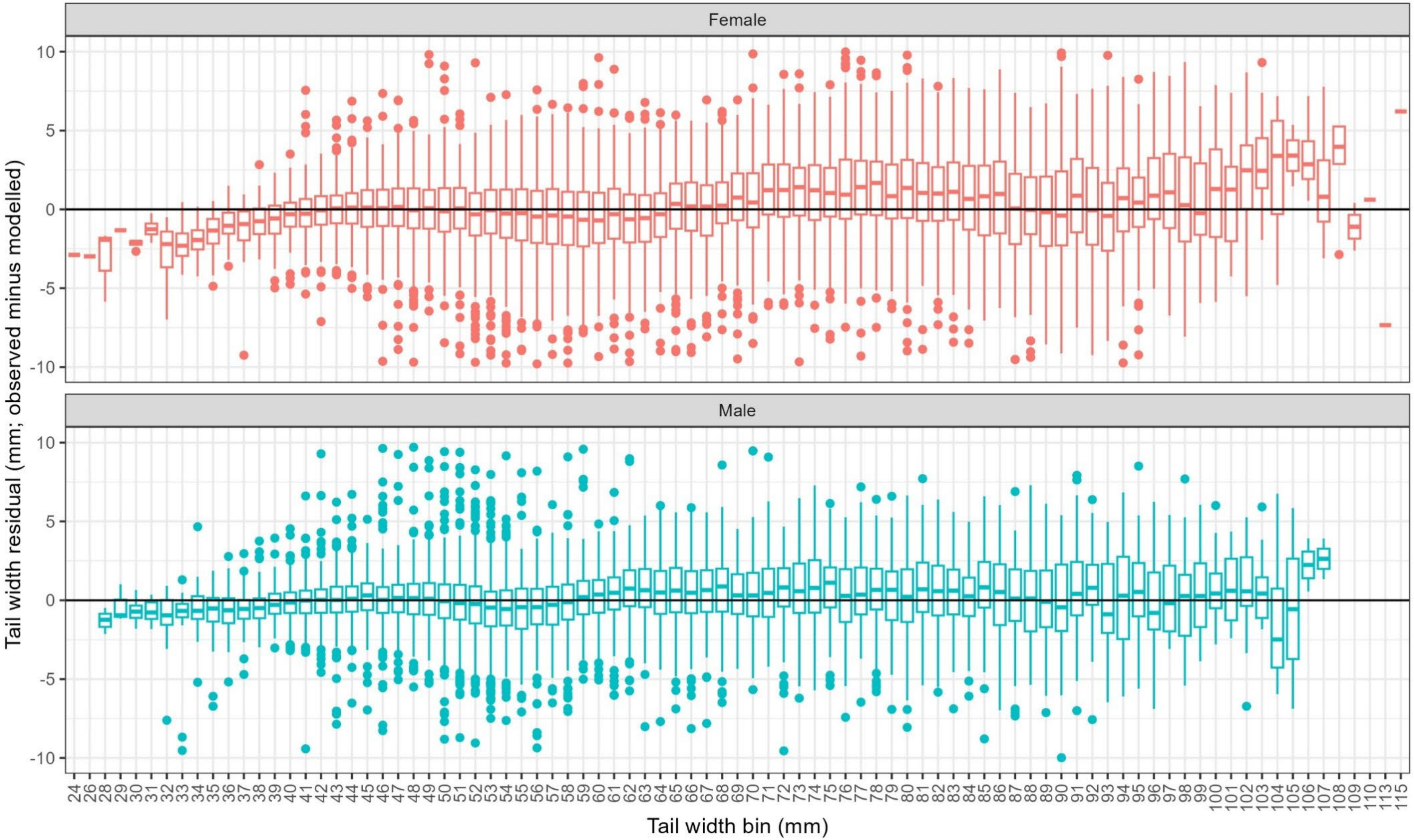


Figure D.5: Plot of model residuals by 1 mm TW bin for the final models used to predict the tail width of females (*fit_f4*) and males (*fit_m4*) from carapace length frequency data.

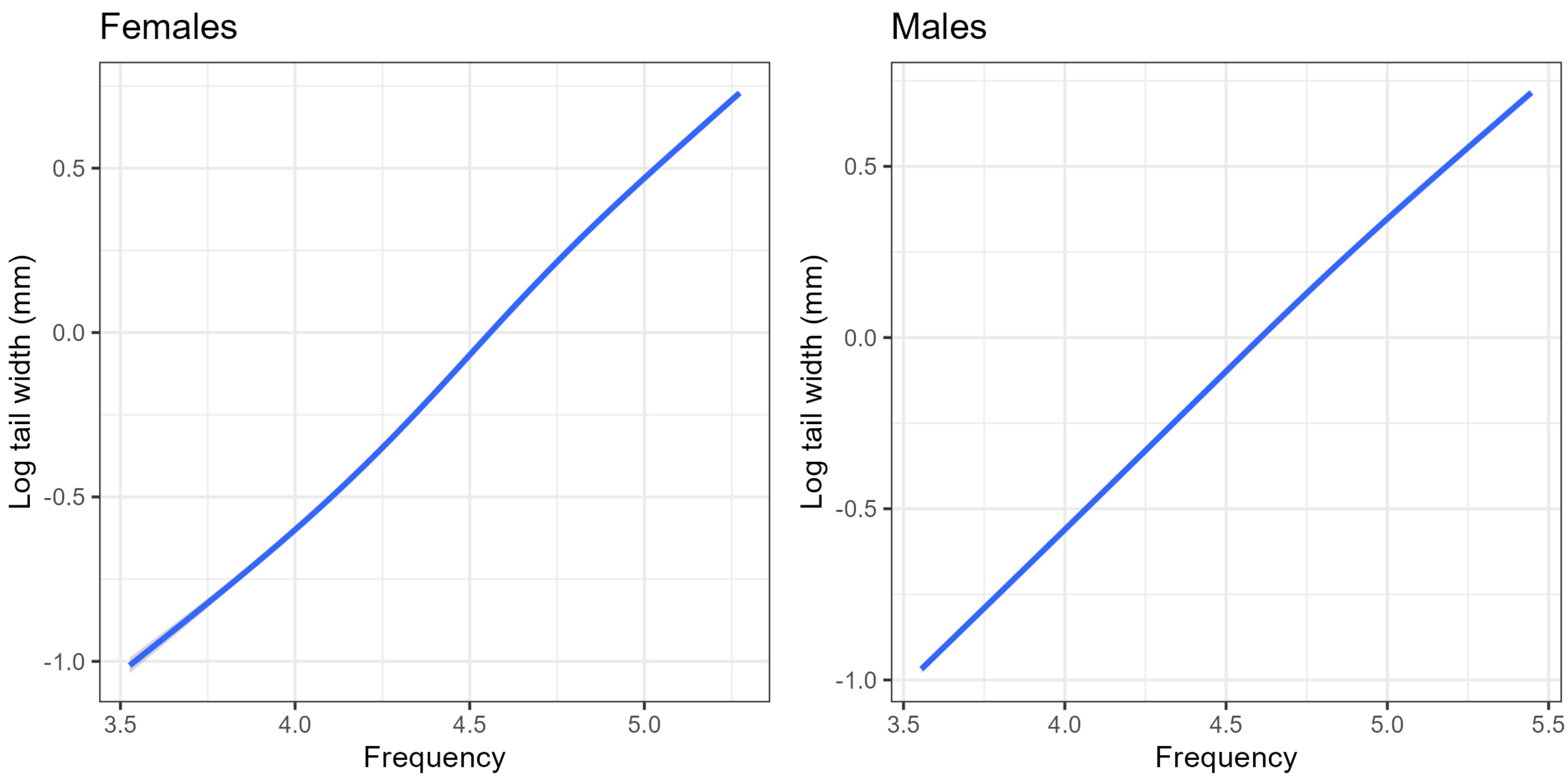


Figure D.6: Conditional smoothers for the effect of log(carapace length) on the mean of log(tail width) from the final models used to predict the tail width of females (*fit_f4*) and males (*fit_m4*). Blue lines represent medians and shaded areas represent the 95% credible interval.

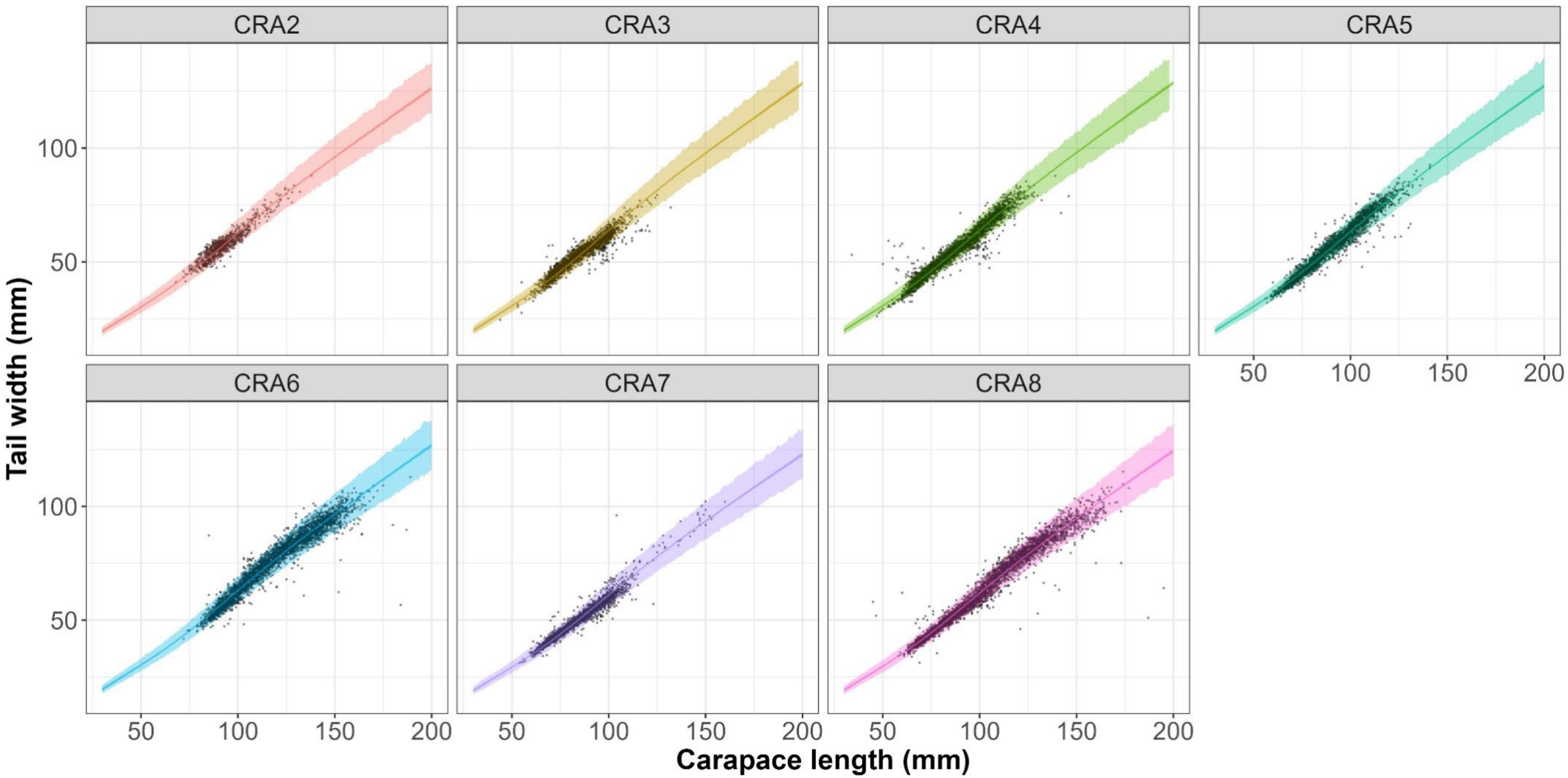


Figure D.7: Predicted tail width of female red rock lobsters relative to carapace length by QMA of model *fit_f4* (lines represent the mean and shaded regions represent the 95% credible intervals) and the observations fitted to by this model (open circles).

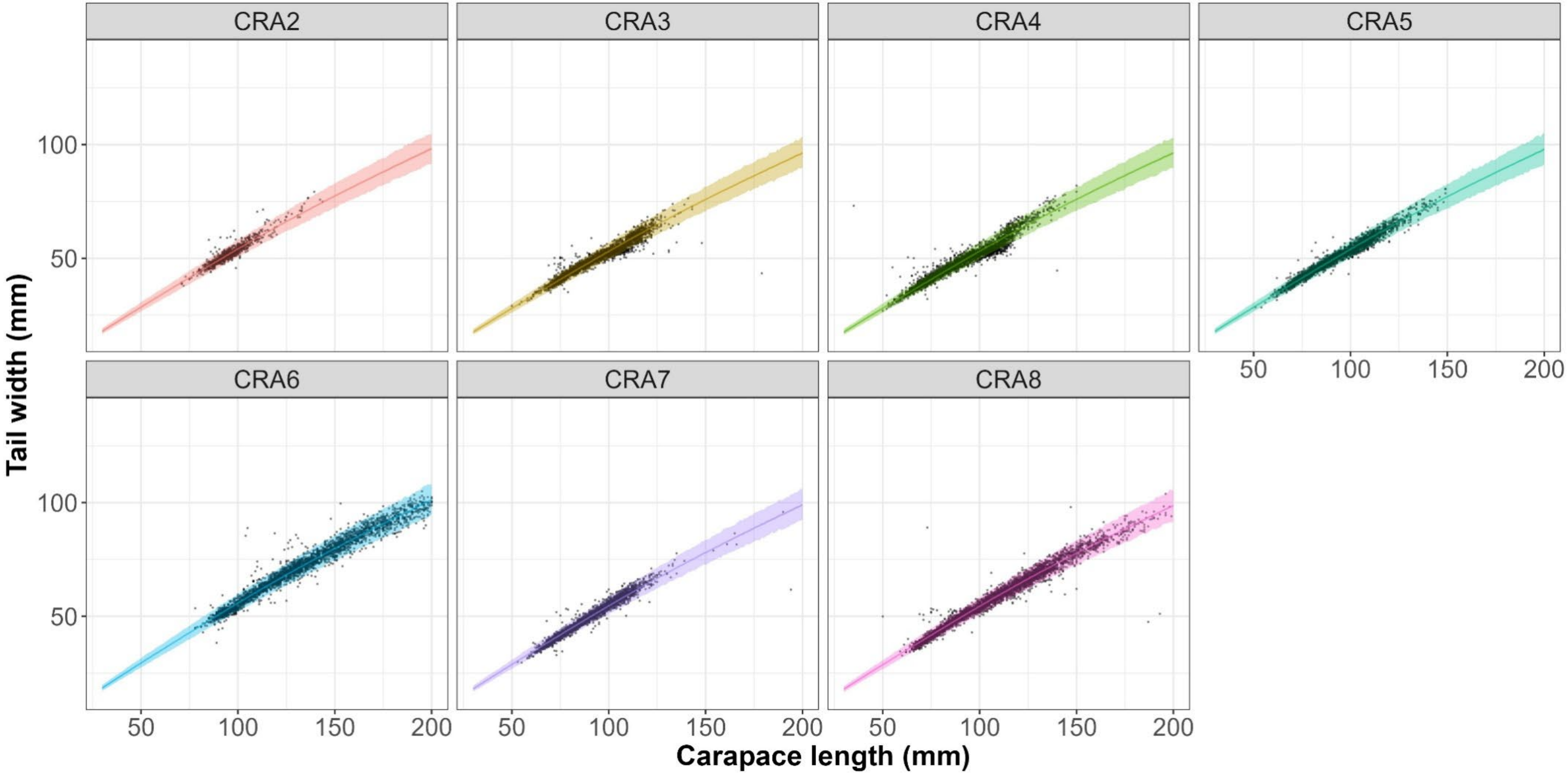


Figure D.8: Predicted tail width of male red rock lobsters relative to carapace length by QMA of model *fit_m4* (lines represent the mean and shaded regions represent the 95% credible intervals) and the observations fitted to by this model (open circles).