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Tini a Tangaroa

Data for the 2022 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2

New Zealand Fisheries Assessment Report 2023/42

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EXECUTIVE SUMMARY

Roberts, J.¹; Webber, D.N.²; Starr, P.J.³; Rudd, M.B.⁴; Pons, M.³; Goeden, Z.³ (2023). Data for the 2022 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2.

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This document describes the covariates and data used in the 2022 stock assessment of red rock lobster (*Jasus edwardsii*) in CRA 2, including: catch estimates for all sectors of the CRA 2 fishery, seasonal catch-per-unit-effort (CPUE) indices, standardised length frequency distributions (LFs) and sex-ratios (SRs), tag-recapture data, and the proportion of mature females that were in berry (egg bearing).

Catch estimates were provided for the commercial, recreational, customary, and illegal fisheries, collated by year to 1978 and then by six-month season (autumn/winter [AW] and spring/summer [SS]) to 2021 (i.e., the 2021–22 fishing year). The methods for deriving the catch histories for non-commercial fisheries were developed in agreement with the Rock Lobster Working Group. From 1979 to 2018, the recreational fishery catch trajectory was derived from the SS seasonal CPUE series (FSU and CELR for 1979–1992, logbook series for 1992–2018), fitted to survey-based estimates of recreational catch. Recreational catch was assumed to be equal to scaled survey estimates for 2019, 2020, and 2021. Recreational catches before 1979 were interpolated from a low value (equal to 20% of 1979) in 1945 to the 1979 value. Before the introduction of rock lobster to the Quota Management System in 1990, illegal catches were assumed to be 20% of the summed commercial catch for 1945–1989 (depending on the model run), and since 1990 were assumed to be 10% of the total 1990–2021 commercial catch. Customary catches were assumed to be 5 tonnes annually.

Three standardised CPUE index series of relative abundance were developed, all of which were used in the stock assessment model and with each series separated into the AW and SS seasons: (1) a 1979–1988 series based on commercial catch data collected by the Fisheries Statistics Unit; (2) a 1989–2019 series based on the statutory commercial catch data collected by Fisheries New Zealand; and (3) a 1993–2021 series based on the voluntary logbook data collected by the CRA 2 fishing industry primarily for the purpose of providing biological data from the fishery. The two latter series, with overlapping periods, gave consistent temporal patterns in catch rate. The series based on the statutory commercial catch data was terminated at the end of the 2019 AW season, at the point of transition from paper forms to electronic reporting, because of the concern that the replacement electronic data were no longer comparable to the previously collected paper form data. Unstandardised daily catch rate data for each calendar year for 1963–73 were also used for one of the stock assessment model runs.

Length frequency (LF) and sex ratio (SR) data were available from both the observer catch sampling and voluntary logbook programmes, collated by fishing year, season, and sex. Standardised LFs and SRs by fishing year were predicted from models fitted to these data, along with associated uncertainty. The tag-recapture data described in this document provide information on sex-specific individual growth rate. An analysis of the seasonal proportion of mature female lobsters carrying visible eggs (in berry) in CRA 2 is provided in an appendix to this document, because this information was newly incorporated into the CRA 2 stock assessment. An analysis of SST in the CRA 2 region, is described in another appendix. While the SST data were not used in the base case stock assessment, they were investigated as potential environmental covariates in sensitivity analyses.

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1. INTRODUCTION

The CRA 2 Quota Management Area (QMA) for red rock lobster (*Jasus edwardsii*, CRA) extends from Te Arai Point, south of Whangarei, to East Cape at the easternmost end of the Bay of Plenty (Figure 1 and Figure 2). This QMA includes the Hauraki Gulf, both sides of the Coromandel and all of the Bay of Plenty. CRA 2 also includes the Great and Little Barrier islands.

The previous stock assessment for CRA 2 was developed in 2017 (Webber et al. 2018), with Starr & Webber (2018) describing the input covariates and data. An earlier CRA 2 stock assessment, current to the 2011–12 fishing year, was done in 2013 (Starr et al. 2014b) with the data used in that stock assessment documented by Starr et al. (2014a). The first CRA 2 stock assessment was conducted in 2002 and was current to the 2000–01 fishing year (Starr et al. 2003).

The National Rock Lobster Management Group (NRLMG) decided that a new stock assessment for CRA 2 should be done in 2022. This document describes all data and covariates used by this stock assessment, including: catches (commercial, recreational, customary, and illegal) from 1945 to 2021, catch-per-unit-effort (CPUE), length frequency (LF) and sex ratio (SR) data, tag-recapture data, the proportion of mature females that were in berry, and sea surface temperature indices. The CRA 2 stock assessment was completed during a workshop in September and October 2022. 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 on 31 October 2022 (Fisheries New Zealand 2022).

CRA 2 (Figure 2) entered the QMS on 1 April 1990 with a total allowable commercial catch (TACC) of 250 tonnes, which was reduced in three steps to 215 tonnes by 1993. The TACC was raised to 236 tonnes in 1997–98 in response to CPUE increases observed at the time. A total allowable catch (TAC) of 453 tonnes was established for the first time in the same year, with allowances of 16.5 tonnes for customary fisheries, 140 tonnes for recreational catch, and 60 tonnes for other mortalities. The TACC was dropped to 200 tonnes in 2014–15, based on the first operation of a newly adopted management procedure (MP) developed during the 2013 stock assessment (Figure 3). The non-commercial allowances remained unchanged, resulting in a TAC of 416.5 t. The TACC for CRA 2 continued to be controlled by MPs until 2019, when the collection of the statutory commercial catch and effort data, which were used to calculate the CPUE that informed the MP, was switched from a paper form to electronic reporting. The MP was discontinued because of concern that the continuity with the previous reporting system had been lost. In response to low biomass levels, the CRA 2 industry voluntarily shelved 25 tonnes of the 200 tonne TACC in 2015–16, even though the operation of the CRA 2 MP at the time did not require a reduction. The amount of shelving was increased to 49 tonnes for 2016–17 and 2017–18. After the 2017 stock assessment (Webber et al. 2018), the TAC was reduced for 2018–19 from 416.5 tonnes to 173.1 tonnes and comprised: an 80 tonne TACC, 34 tonnes for recreational catch, 16.5 tonnes for customary harvest, and 42.5 tonnes for ‘other fishing mortality’.

As mentioned in the previous paragraph, it was concluded by the RLWG that the continuity of the underlying commercial catch CPUE series used to inform CRA 2 stock assessments had been lost when paper forms were replaced by electronic reporting⁵. Consequently, a new CPUE series was developed based on the logbook data collected by the CRA 2 rock lobster industry for the purpose of monitoring the biological characteristics of the catch (Webber & Starr 2022). The CRA 2 industry had made a strong commitment to the voluntary logbook programme when it was first introduced in 1993. Because this programme had been in continuous operation and employed a consistent design, these data were available for the development of a CPUE series. Webber & Starr (2022) presented a detailed description of this analysis, as well as a comparison with the previous paper form CPUE series and an additional series whereby all pots for 15–20 fishers were fully enumerated. The documentation for the updated series used in the 2022 CRA 2 stock assessment is presented in Section 3.4.

⁵ This issue is discussed in the Rock Lobster introductory chapter of Fisheries New Zealand (2022). The contributing data analyses are presented in appendix B of Starr (2022).

Section 4 describes the application of a new methodology that predicts commercial LFs and SRs and associated uncertainty for New Zealand red rock lobster stocks, using data from the voluntary logbook (LB) data collected by commercial fishers (Walker & Mackay 2002), from the observer catch sampling (CS) programme (Mackay & George 2002), and the commercial catch data. 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). This procedure was also applied to the SR data collected by the same programmes. 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 SRs that are removed by the commercial catch and to indirectly provide information about growth and recruitment.

Fishery tag-recapture based growth increment data were used to inform the estimation of size specific growth rates by sex in the stock assessment model. For CRA 2, tag-recapture data from the period 1983–84 to 2021–22 were processed for use in the stock assessment and are described in Section 5.

Appendix A documents a data request to Fisheries New Zealand for non-commercial catch information. No formal response was received from Fisheries New Zealand, but a recreational catch time series was developed and discussed in a MAFWG meeting, which was used to inform a RLWG discussion on 15 September 2022 about non-commercial catch estimates during an early stage of this assessment.

An analysis of the seasonal proportion of female lobsters that were carrying visible eggs (in berry) in CRA 2 is described in Appendix B. The outputs of this analysis were used in the CRA 2 stock assessment (Rudd et al. 2023).

Earlier work indicated that sea surface temperature (SST) data may be useful for predicting recruitment to the CRA 3 and CRA 4 stocks (Breen & Starr 2010), although that work did not include CRA 2 in the analysis. Appendix F presents an analysis deriving two alternative SST time series for CRA 2. Note that these series were not included in the base case model, but were used in sensitivity runs as exploratory inputs to the assessment model to see if they could serve as possible covariates (Rudd et al. 2023).

For definitions of technical terms used here see the Glossary in the CRA 2 stock assessment report (Rudd et al. 2023).

2. CATCH

2.1 Legal commercial catch

The fishing year and calendar year were the same before 1979. From 1979 onwards, the statutory fishing year has been an April to March year (Ministry for Primary Industries 2016). Reported annual commercial catches for 1945–1978, summarised by calendar year, were obtained from sources described by Bentley et al. (2005). From 1 January 1979 to 31 March 1986, catches were taken from monthly data summarised by fishing year from data collected by the Fisheries Statistics Unit (FSU), a version of which is now held by Fisheries New Zealand. The three months of catch from January to March 1979 were added to the 1978 annual total to ensure that no catch was lost when switching from calendar year to fishing year.

From 1 April 1986 to 30 March 1988, monthly reported catch totals from all of New Zealand's commercial rock lobster fisheries were obtained from Quota Management Returns (QMRs), maintained by Fisheries New Zealand, without the corresponding separation into QMAs. Because catch estimates for individual QMAs were not available for this period, the total New Zealand catches were divided into QMA catches based on the proportional landings reported on FSU forms. From 1 April 1988 through 30 September 2001, catches 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.

Commercial fishing in CRA 2 is primarily confined to the Bay of Plenty, extending from the eastern side of the Coromandel Peninsula to East Cape (Figure 2). Between the mid-1990s and 2017–18 the number of vessels operating in the CRA 2 fishery was typically in the 30s, but this decreased abruptly to 18 vessels with the drop in TACC in 2018–19 and the fleet has remained around this size since (Starr 2022). This fishery supports processing and export operations primarily in Tauranga, Whitianga, and Auckland.

Commercial catches in CRA 2 averaged 196 tonnes/year before 1979, with a short period in the late 1960s when catches exceeded 300 tonnes/year (Table 1 and Figure 3). CRA 2 commercial catches increased in the period leading up to the introduction of rock lobster into the QMS (1979–1988), with catches peaking at 445 tonnes in 1980–81 and averaging just over 300 tonnes/year during that decade. Commercial catches in CRA 2 have generally closely matched the TACC since the introduction of rock lobster into the QMS in 1990–91 (Table 2 and Figure 4), except for a period in the early-2000s, and another the period from 2015–16 to 2017–18 when the commercial catch was reduced due to voluntary shelving of quota.

Annual FSU CPUE declined during the entire period of high catches in the 1980s (Figure 4). CELR CPUE began to rise from about 1994 and had more than doubled by 1997 and 1998. This increase in CPUE mirrored similar increases in CPUE over the same period in CRA 1, CRA 3, CRA 4, and CRA 5 (Starr 2022). CPUE dropped rapidly from 1999 to 2002 and then declined further until 2017. While CPUE calculated from the statutory catch and effort data after 2019 is no longer comparable with earlier CELR data, the logbook CPUE (see Section 3.4) has retained comparability across years. That series showed an increasing trend in CPUE from the lowest point in 2017 to 2021, corroborating the observed 2018 increase in the statutory CPUE (Figure 4). CRA 2 generally has the lowest CPUE of the all the CRA QMAs (Starr 2022).

There has been increased use of intermediate destination/disposal codes (see appendix B.2 of Starr 2022 for the definitions of these codes) in many of the CRA QMAs, a practice which allows operators to wait for favourable market conditions for selling their catch. This practice has affected the analysis of commercial catch and effort data by breaking the link between the effort used to catch the lobsters and the validated landing information (see Fisheries New Zealand 2022 for a discussion of this problem). However, Starr & Webber (2018) showed that the extent of this practice in CRA 2 was relatively minor compared to some other QMAs. Also, they did not find evidence of high levels of legal discarding in CRA 2 and consequently little use is made of the destination ‘X’ code.

There is uncertainty in the quality of the catch estimates in the years before the FSU system began in 1979, but there is confidence in the quality of the commercial catch estimates from the FSU system. Catch estimates generated from the FSU data available to the stock assessment team are consistent with published historical catch estimates from the FSU system.

2.2 Recreational catch

Eleven recreational survey catch estimates are available for CRA 2 (Table 3). The 1994 and 1996 surveys, conducted by researchers at the University of Otago, were considered biased in a review of the available recreational surveys (unpublished minutes, Recreational Technical Working Group [NIWA, Auckland, 10–11 June 2004]) because the interview questions likely underestimated fisher participation rates by allowing for an easy exit from the interview (‘soft refusal’ bias). For this reason, these two surveys were not included in the 2022 recreational catch estimation process. Estimates from the two Kingett Mitchell national telephone diary surveys (Boyd et al. 2004, Boyd & Reilly 2004) were not accepted by the RLWG for the 2013 CRA 2 stock assessment (Starr et al. 2014a), because these estimates were considered implausibly high for CRA 2. Both the Kingett Mitchell and the Otago telephone diary surveys were also potentially biased high because survey participants were not closely supervised and may have included fishing activity in their reported logbooks that occurred outside of the reporting period (‘telescoping’ bias). The much higher harvest estimates in the Kingett Mitchell surveys were a result of high participation rates in marine fishing obtained through the initial screening

survey. These participation rates were considered to be biased high through the use of poor survey interview technique.

A large-scale population-based diary/interview survey, known as the National Panel Survey (NPS), was conducted under contract for the Ministry for Primary Industries from 1 October 2011 to 30 September 2012 (Wynne-Jones et al. 2014). The NPS was repeated from 1 October 2017 to 30 September 2018 using directly comparable methods (Wynne-Jones et al. 2019). The reliability of the NPS method was confirmed for more commonly caught finfish species (e.g., snapper and kahawai), for which fully independent and concurrent aerial-access survey estimates were available in 2011–12 and 2017–18 (Hartill et al. 2019). Both surveys were designed to estimate annual catches by Fisheries Management Area (FMA) and QMA for all important finfish and non-fish species harvested by recreational fishers (Heinemann et al. 2015). These surveys used ‘mesh block’ mapped information on the location and number of dwellings in small scale strata throughout the country, to probabilistically survey over 30 000 households throughout the country. This screening survey was used to estimate how many potential fishers there were in New Zealand and to recruit participants who were asked to report their catch for an entire year. A structured and carefully designed Computer Assisted Telephone Interview (CATI) method was used to regularly record harvest in detail from those who had fished. The 2011–12 survey results were thought to be plausible for CRA 2, with 69 fishers providing 168 interviews (see table 60 of Wynne-Jones et al. 2014) with a relatively low CV (0.24). The 2017–18 survey was not as successful in recruiting CRA 2 CATI participants, with only 33 fishers supplying 79 interviews resulting in a higher overall CV (0.36) (see table 57 of Wynne-Jones et al. 2019). Both surveys provided estimates of the distribution of fishing platforms used to take lobsters in CRA 2, with motorboats accounting for about three quarters of the effort in 2011–12, which rose to 85% in 2017–18 (Table 4). Land based fishing accounted for 13% of the CRA 2 catch in 2011–12, which dropped to 8% in 2017–18 (Table 4). The primary capture method used to take rock lobster in CRA 2 was diving (83% in 2011–12, rising to 95% in 2017–18). Potting is not used much in CRA 2, with only 16% of the 2011–12 catch and 5% of the 2017–18 catch (Table 4).

For both NPS surveys, panellists provided data in terms of number of fish. Mean recreational catch weights for the most important finfish and non-fish species QMAs were estimated in parallel projects (Hartill & Davey 2015, Davey et al. 2019).

A recreational catch vector from 1979 to 2018 was developed by assuming that recreational catch had been proportional to the CRA 2 spring/summer (SS) abundance, as reflected by the SS FSU and CELR CPUE to 1992 and the logbook CPUE to 2018. By agreement in the RLWG, the recreational catch vector was based on four of the eleven survey estimates (in tonnes – see Table 3)—from Holdsworth (2010), Holdsworth (2011), and the 2011–12/2017–18 NPS surveys. The two NPS surveys were assumed to be the least biased and most precise so the estimated CV for each survey (0.24 and 0.36) were assumed. The CVs for the two remaining surveys were assumed to be 50% higher than that of the 2011–12 NPS survey. A scalar quantity q was estimated by obtaining the best fit to these survey estimates when minimising a lognormal likelihood using the CVs indicated in Table 3:

$$\begin{aligned} W_t &= w_t N_t \\ W_t &\sim \text{lognormal}(\hat{q} I_t) \end{aligned}$$

Equation 1:

where t are the four recreational catch surveys for CRA 2 (Holdsworth 2010, 2011, Wynne-Jones et al. 2014, 2019), w_t is the mean SS weight of lobsters at or above the minimum legal size (MLS) in year/survey t , N_t is the mean number of lobsters in year/survey t , W_t is the surveyed recreational catch in tonnes, I_t is the SS standardised CPUE in years with surveys, and $\hat{q}$ is the estimated parameter that relates the CPUE index and estimated recreational catch by year.

Recreational catch was estimated as follows:

Equation 2:

$$\begin{aligned}\hat{W}_y &= \hat{q}I_y \quad \text{if } 1979 \leq y < 2019 \\ \hat{W}_{1945} &= 0.2\hat{W}_{1979} \\ \hat{W}_y &= \hat{W}_{y-1} + \frac{\hat{W}_{1979} - \hat{W}_{1945}}{1979 - 1945} \quad \text{if } 1945 < y < 1979\end{aligned}$$

The onsite surveys referred to above were commissioned by Fisheries New Zealand for monitoring recreational catch in CRA 2 as part of the rebuilding plan implemented in 2018–19, as a response to the poor stock status estimated by the 2017 stock assessment. Boat ramp surveys were conducted at 11 sites across CRA 2 in 2019–20, 2020–21, and 2021–22, spanning the period October to February in each year, with the intent of scaling the summer survey information with the total catch estimates obtained by the NPS (Hartill et al. 2022). This work had not been completed by September 2022, but interim scaled catch estimates were used in the 2022 CRA 2 stock assessment. By agreement in the RLWG, these estimates were used without any additional scaling because the scaling procedure described in Equation 1 and Equation 2 resulted in recreational catch estimates that were considered implausibly high.

The recreational catch trajectory matched the 2011–12 NPS and the 2010/2011 Holdsworth estimates reasonably well but missed the 2017–18 NPS survey (Figure 5). The recreational catch vector accounted for 1730 tonnes of catch from 1979 to 2021. The procedure used to estimate recreational catch for the 2022 CRA 2 stock assessment returned very similar estimates to those used for the 2017 CRA 2 stock assessment but scaled down to better fit the Holdsworth surveys and NPS estimates. The updated procedure used for the 2022 assessment reduced the 1979–2018 total recreational catch from 1634 to 1556 tonnes. The Hartill et al. (2022) model MLE estimates were used as the recreational catch estimates for 2019, 2020, and 2021. Recreational catches were split between seasons, with 90% assumed taken in the SS and the balance in the autumn/winter (AW).

For assessments conducted since 2006, the RLWG has included recreational landings made by commercial vessels under section 111 of the Fisheries Act. Greenweight landings with destination code ‘F’ were extracted from the CRACE database (Bentley et al. 2005), which showed a maximum annual value of 2.036 tonnes for CRA 2 occurring in 2014–15 (Table 3). The RLWG has agreed to add the maximum catch estimate to the estimated recreational catch in each year beginning with 1979 (Figure 5), increasing the total 1979–2021 recreational catch in the model to 1818 tonnes.

2.3 Customary catch

For the 2017 CRA 2 stock assessment, the RLWG lowered the constant value used for this catch category from 10 t/year to 5 t/year in recognition that some customary catch is included in the recreational catch estimate and advice that 10 t/year was likely to be too high (Starr & Webber 2018). The 2022 CRA 2 stock assessment continued to use 5 t/year for customary catch, with 90% assumed to have been taken in the SS and the balance in the AW.

2.4 Illegal catch

Recent red rock lobster stock assessments have opted to use a fixed percentage (usually 10% to 20%) of the commercial catch before 1990 (the year that rock lobsters were brought into the QMS). The percentage was dropped to a lower level in 1990 in recognition of the impact of the introduction to the QMS, including greater control over the sale and receipt of lobsters once they became a tradable asset. In line with these decisions, the RLWG chose to set the 1945–1989 illegal catch to 20% of the commercial catch from this period, which was then dropped to 10% of the summed commercial catch from 1990 to 2021 for the 2022 CRA 2 stock assessment. The annual totals were scaled to the annual CPUE rather than to apply a constant level of illegal catch in every year. This change in approach resulted in a considerable reduction in the overall illegal catch when compared with the totals used in the 2017 CRA 2 stock assessment: the total illegal catch used in the stock assessment over the period 1979 to 2016 dropped from 2200 tonnes to 985 tonnes. The sum of the 1979–2021 illegal catch used in

the 2022 CRA 2 stock assessment was 1100 tonnes. Illegal catches were split between seasons using the split returned by the commercial catch in the respective year. The updated estimated illegal catch history is compared with that used for the 2017 stock assessment in Figure 6.

2.5 Total catch

The total estimated catch for the size-limited (legal commercial and recreational) and non-size-limited (illegal and customary) fisheries is shown in Figure 7, disaggregated by fishing year and season.

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 biomass over time. Six different CPUE index series were potentially available for the CRA 2 stock assessment:

1. 1963–1973 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 AW series based on the statutory commercial catch data (CELR) collected by Fisheries New Zealand;
4. 1993–94 to 2021–22 series based on the voluntary logbook data collected by the CRA 2 fishing industry primarily for the purpose of providing biological data from the fishery;
5. 2009–10 to 2021–22 ‘fine scale’ series based on the complete enumeration of every pot set by a subset of CRA 2 fishers; and
6. 2019 SS to 2021–22 series of statutory commercial catch data collected by Fisheries New Zealand under the electronic reporting system (ERS).

The first four of these CPUE series are described below while the fine scale series, described by Webber & Starr (2022), was not used in the 2022 CRA 2 stock assessment. The ERS data were also not used by the CRA 2 assessment due to inconsistencies with data collection under the CELR system (see appendix B of Starr 2022 for a supporting analysis). In addition, the ERS could not be used as an independent series due to the short time period over which the data were collected.

3.1 CR CPUE indices

Monthly catch and effort (days fishing) data from Annala & King (1983) historical statistical areas 3 and 4 were available for the period January 1963 to December 1973. Historical statistical area 3 comprised the Hauraki Gulf and approximates the modern statistical area 905 (Figure 2). Statistical area 4 encompassed all of the Bay of Plenty west of statistical area 3 up to Cape Runaway. This coverage approximates the remaining CRA 2 statistical areas 906, 907, and 908. These data were summarised to calculate a CPUE series based on the unstandardised catch per day for each calendar year from 1963 to 1973 (Table 5, Figure 8).

3.2 FSU CPUE indices

The FSU CPUE series covers 1979–80 to 1989–90 AW and was based on data from the FSU database. The data were aggregated by fishing year, season, month, statistical area, and vessel. The number of records is provided in Table 6. FSU CPUE was the sum of the catch of legal lobsters divided by the number of pots lifted per stratum, thus the series is an index of legal lobsters (i.e., does not include berried females or lobsters below the MLS). Variables offered to the CRA 2 FSU 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 leave-one-out information criterion (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 the terms listed above. The Markov chain Monte Carlo (MCMC) for the best model mixed well (Figure D.1), and the lognormal assumption was adequate (Figure D.2). The FSU CPUE series covers 1979–80 to 1989–90 AW and indicates a declining stock during this time (Table 7, Figure 9).

3.3 CELR CPUE indices

The CELR CPUE series covers 1990–91 to 2019–20 AW and was described in sections 2.1 and 3.1 of Webber & Starr (2022). As there were no new data available for this series since that publication was completed, it is unnecessary to repeat the documentation of this series here. This series only includes core vessels which were defined as those vessels that have operated within the CRA 2 fishery for a least 5 years (46% of vessels and 86% of records). The number of records was provided in Table 6. The model used for the final series had catch weight/pots as the dependent variable and included explanatory variables for a period/statistical area interaction term, month, vessel (all group level parameters), and also period and statistical area (both population level parameters). A lognormal distribution was assumed. This resulting CPUE series (Table 7, Figure 10) is an index of the catch rate (weight per pot) of legal lobsters (i.e., does not include berried females or lobsters below the MLS).

3.4 Logbook CPUE indices

The logbook CPUE series covers the period 1993–94 AW to 2021–22 SS. The logbook CPUE analysis for CRA 2 was first 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 all lobsters above the MLS (i.e., includes berried females) and has units in numbers per potlift (rather than weight per potlift). The number of records is provided in Table 6. A negative binomial distribution was assumed.

The model used in the stock assessment was the pot-by-pot series, with the number of lobsters caught per pot specified as the dependent variable and included the explanatory terms: period, month, vessel, statistical area, and a period/statistical area interaction term. The resulting CPUE series (the green line and shaded ribbon in Figure 10) was essentially identical to the series generated by Webber & Starr (2022) using the same model structure (not shown in this figure) with two additional data points for AW and SS of 2021–22. The MCMC for the best model mixed well (Figure D.3), and the negative binomial assumption fitted the data adequately (Figure D.4). The trend in logbook CPUE differed among the four statistical areas but was generally similar (Figure D.5, Figure D.6).

The temporal pattern in this CPUE series is very similar to the series derived from the logbook data when specifying estimated catch weight per pot as the dependent variable (instead of numbers per pot) and also agreed well with the CELR-derived CPUE series in the years of overlap (Table 7, Figure 10).

4. LENGTH FREQUENCY DISTRIBUTIONS & SEX RATIOS

Length structured stock assessment models predict the numbers at length in the population for each model time step (i.e., year/season). Such predictions are informed by data that consist of the relative numbers at length each year, either in the population or in the catch. New Zealand rock lobster stock assessments are informed by data collected from the commercial potting fishery through sampling programmes which use on-board observers (catch sampling or CS) or through voluntary fisher logbooks

(LB). The relative numbers at length each year in the CS and LB are related to the underlying population through a selectivity function.

This section describes how the CS and LB data were used by models to derive LF and SR data sets for use in the CRA 2 stock assessment. The subscripts that are used in the description of these two models are provided in Table 8.

4.1 Length frequency/sex ratio data

The CS (relog 14506) and LB data (J. Olver, Fishserve, pers. comm.) for CRA 2 were extracted in July and August 2022, comprising data from the 1986–87 to 2021–22 fishing years. The design of the logbook catch sampling programme requires participating fishers to measure every lobster in each of 3–5 marked pots each day up to a maximum of 25 lobsters. Additional lobsters are enumerated with respect to size above or below the MLS. This design results in good spatial and temporal representation of the catch assuming that the participating fishers are representative of the wider fishing fleet. This goal is likely to have been achieved in CRA 2, with a high rate of participation in the voluntary logbook programme since its commencement in 1993 (Table 9). Approximately 12–13 days/year of dedicated observer coverage has been provided by the CS programme since 1999, and these data have been used to corroborate the voluntary logbook programme (Table 9). This sampling project measures and sexes all lobsters in as many pots as feasible during a day’s fishing for the vessel being observed.

The extracted data contain 25 years of data for the CS programme from 1986 to 2021 and 29 years of data for the LB programme from 1993 to 2021. The first three fishing years (1986, 1990, and 1991) were dropped from the data set because there were too few vessels, days, trips, pots, and lobsters sampled by the CS programme and no LB samples (Table 9) and, during those years, there were no samples in statistical areas 905 and 906 (Table 10), when only the SS season was sampled.

These are large data sets, with almost 300 CS sampling days, including nearly 20 000 pots lifted and over 61 000 lobsters measured (Table 9, Table 11). The equivalent numbers for the LB programme were 5600 days, 59 500 pots lifted, and almost 182 000 lobsters measured.

4.2 Predicting length frequencies of lobsters

The CS and LB data were aggregated to the trip (j) level and a LF model was fitted to the trip-by-trip data. For a given fishing year (y), month (m), statistical area (a), data source (LB or CS) (d), and trip (j), and counts of the number of lobsters measured by sex category (s) and length bin (l) were generated and arranged as vectors by length bin (l):

$$n_{y,m,a,d,j,l}^{\text{LF}} = \mathbf{n}_{y,m,a,d,j}^{\text{LF}} \in [0, \infty]$$

The sex category subscript has been dropped from the equations for clarity and because LF models are fitted separately for each sex category. Often there were few lobsters below a certain size or above a certain size, so each end of the LF was aggregated into the first or final bin, respectively (Table 12).

The predictor term (η) for each length bin (l) during fishing year (y), month (m), and statistical area (a) was:

Equation 3: $\eta_{y,m,a,l} = \boldsymbol{\eta}_{y,m,a} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}\boldsymbol{\mu} = \beta_l^0 + X^y\beta_l^y + X^m\beta_l^m + X^a\beta_l^a + Z^{y,a}\mu_l^{y,a}$

In this equation, $\boldsymbol{\beta}$ and $\boldsymbol{\mu}$ are the coefficients at the population level (analogous to fixed effects) and group level (analogous to random effects), respectively, $\mathbf{X}$ and $\mathbf{Z}$ are the corresponding design matrices, β_l^0 is the intercept for each length, β_l^y are coefficients accounting for each fishing year, β_l^m are coefficients accounting for each month, β_l^a are coefficients for each statistical area, $\mu_l^{y,a}$ are coefficients

for an interaction term by fishing year and statistical area. The fishing year, month, and statistical area terms are treated as population-level effects and the fishing year by statistical area interaction term is treated as a group-level effect.

The model predicted the proportion ($\mathbf{p}$) within each tail width (TW) bin (l) by fishing year, month, and statistical area:

Equation 4: $\mathbf{p}_{y,m,a} = \text{logit}(\boldsymbol{\eta}_{y,m,a})$ where $\mathbf{p}_{y,m,a} \in (0,1)$ and $\sum \mathbf{p}_{y,m,a} = 1 \forall y, m, a$

Counts of individuals within each TW bin at the trip level were fitted to using a multinomial distribution:

Equation 5: $\mathbf{n}_{y,m,a,d,j}^{\text{LF}} \sim \text{multinomial}(n, \mathbf{p}_{y,m,a})$

and the following priors were used:

Equation 6:

$$\begin{aligned}\beta_l^0 &\sim N(0, 10^2) \\ \beta_l^y &\sim N(0, 1^2) \\ \beta_l^m &\sim N(0, 1^2) \\ \beta_l^a &\sim N(0, 1^2) \\ \mu_l^{y,a} &\sim N\left(0, (\sigma_l^{y,a})^2\right) \\ \sigma_l^{y,a} &\sim \text{student}(3, 0, 2.5)\end{aligned}$$

Bayesian inference was done using the R package *brms* (Bürkner 2017, R Core Team 2022). The *brms* package is a wrapper for doing mixed effects models using Stan (Stan Development Team 2018) for MCMC. Full Bayesian inference was done using the Hamiltonian Monte Carlo (HMC) algorithm.

Model fits to the LF data were not presented at the level to which they were fitted (i.e., by trip). Instead, the data were aggregated to the two levels described below with model predictions made at these aggregated levels:

1. By fishing year, month, data source, and length bin separately for each statistical area and sex category:

Equation 7: $\mathbf{n}_{y,m,a,d,s} = \sum_j \mathbf{n}_{y,m,a,d,j,s}$

1. By fishing year, season, and length bin separately for each sex category:

Equation 8: $\mathbf{n}_{y,t,s} = \sum_{a,m \in t,d,j} \mathbf{n}_{y,m,a,d,j,s}$

Only the latter (i.e., Equation 8) is presented in this document. Predictions at any of the two levels above (done using the fitted function in the *brms* package) also produce a standard deviation (SD, σ) for each bin. The total SD across bins, associated with Equation 7 can, for example, be calculated using:

Equation 9: $\sigma_{y,m,a,s} = \sqrt{\sum_l \sigma_{y,m,a,s,l}^2}$

The catch (tonnes) in each fishing year, month, and statistical area was calculated from the commercial catch and effort data, denoted $C_{y,m,a}$. The fitted LF models were used to simulate the predicted LF by region, year, month, statistical area, and for each sex category from the posterior distribution (using the *posterior_epred*⁶ function in the *brms* package). The fitted sex ratio model was used to simulate the predicted sex ratio by year, month, and statistical area from the posterior distribution or posterior predictive distribution. The simulated LFs were scaled by the catch and aggregated by posterior sample (i), region, fishing year, season (t), sex category, and length bin then converted to proportions using:

Equation 10:
$$P_{y,t,s,i} = \sum_{a \in r, m \in t} C_{y,m,a} x_{y,m,a,i} p_{y,m,a,s,i} / \sum_{a \in r, m \in t, s} C_{y,m,a} x_{y,m,a,i} p_{y,m,a,s,i}$$

From Equation 10, the mean and SD by fishing year, season, sex category, and length bin were calculated from either the posterior or posterior predictive distribution:

Equation 11:
$$P_{y,t,s,l} = P_{y,t,s} \text{ and } \sigma_{y,t,s,l} = \sigma_{y,t,s}$$

Finally, the data set weight for each fishing year, season, and sex category was calculated from the posterior or posterior predictive SD as:

Equation 12:
$$\omega_{y,t,s}^{\text{LF}} = \frac{1}{\sqrt[2]{\sum_l \sigma_{y,t,s,l}^2}}$$

Because there were few male and immature female lobsters below 36 mm TW measured, all male and immature female lobsters from 30 to 36 mm TW were added to the [36, 38) bin (Table 12). There were few mature females below 42 mm TW, so all mature females from 30 to 42 mm were added to the [42, 44) bin. Likewise, there were few immature females above 70 mm TW, so all immature females greater than 70 mm TW were added to the [68, 70) bin.

In the past, dropping fishing years and aggregating TW bins was usually done after the empirical LFs were produced but before they were input into the stock assessment (e.g., see Starr et al. 2022). However, initial model runs that included all years and attempted to fit to all TW bins took a long time to run and resulted in inadequate MCMC mixing (not shown). When the years and TW bins with sparse data were aggregated, MCMC mixing was adequate for all model runs and the run time was reasonable (Figure E.1, Figure E.2, Figure E.3).

For all three sex categories, the model intercept parameters (β_l^0) increased from low values for the smallest TW bins, peaked near the MLS, then began to decline (Figure E.4). The fishing year population level effects (i.e., fixed effects) for each TW bin varied by year, with some obvious positive correlation comparing TW bins of a similar size (Figure E.5). For example, the fishing year coefficients were very similar for the 75 and 79 mm TW bins for males and mature females (Figure E.5). The population level effects for month suggested seasonal differences in length for CRA 2 (Figure E.6) and the population level effects for statistical area were different among the four statistical areas (Figure E.7).

The conditional effect of a particular explanatory variable within a model is the effect of that variable conditioned on the remaining explanatory variables fixed at a reference value (the reference value used for all models was the parameter associated with the smallest TW bin, the first fishing year, April, and statistical area 905 or 906). Conditional effects for fishing year illustrate how the underlying LFs (i.e.,

⁶ The *posterior_epred* function computes posterior draws of the expected value/mean of the posterior predictive distribution. This can be done for the data used to fit the model (i.e., posterior predictive checks) or for new data. By definition, these predictions have smaller variance than the posterior predictions performed by the *posterior_predict* method. This is because only the uncertainty in the mean is incorporated in the draws computed by *posterior_epred* while any residual error is ignored. However, the estimated means of both methods averaged across draws should be very similar.

the mean across all months and statistical areas) have changed through time (Figure E.8). There does not appear to be any persistent changes in the conditional effects for fishing year in CRA 2. The conditional effects for month suggest some minor variability in the LFs within each month (Figure E.9). The conditional effects for statistical area in CRA 2 are unusual in that non-adjacent areas were more similar (i.e., statistical areas 906 and 908 were similar to each other, and statistical areas 905 and 907 were similar to each other) (Figure E.10).

Scaled predicted LFs for CRA 2 are presented in Appendix F (Figure E.11 to Figure E.19). When the sample sizes were high, the LF standardisation generally didn't alter the raw LFs very much, but at low sample sizes or when sampling appeared to be non-representative, the procedure corrected the LFs considerably. Scaling the LFs by the catch generally did very little to alter the LFs. This is because the CS programme is adjusted each year so that the samples are approximately proportional to the catch by statistical area, while the LB programme design mimics fishing and the data set is self-weighting. The standardised LFs of the catch are summarised by fishing year and sex in Figure 11 and the LF effective sample sizes are provided in Table 13.

4.3 Predicting sex ratios (SR) of lobsters

A model was constructed where the predictor term (η) for each sex category (s) estimated the sex ratio (SR) for each fishing year (y), month (m), and statistical area (a):

$$\text{Equation 13: } \eta_{y,m,a,s}^{\text{SR}} = \eta_{y,m,a}^{\text{SR}} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}\boldsymbol{\mu} = \beta_l^0 + X^y\beta_l^y + X^m\beta_l^m + X^a\beta_l^a + Z^{y,a}\mu_l^{y,a}$$

where $\boldsymbol{\beta}$ and $\boldsymbol{\mu}$ are the coefficients at the population level (analogous to fixed effects) and group level (analogous to random effects), respectively, $\mathbf{X}$ and $\mathbf{Z}$ are the corresponding design matrices, β_l^0 is the intercept for each sex, β_l^y are coefficients accounting for each fishing year, β_l^m are coefficients accounting for each month, β_l^a are coefficients for each statistical area, $\mu_l^{y,a}$ are coefficients for an interaction term by fishing year and statistical area. The fishing year, month, and statistical area terms were treated as population-level effects and the fishing year by statistical area interaction term is treated as a group-level effect.

The model predicted the proportion (p) within each sex category (s) by fishing year, month, and statistical area:

$$\text{Equation 14: } p_{y,m,a,s}^{\text{SR}} = p_{y,m,a}^{\text{SR}} = \text{logit}(\eta_{y,m,a}^{\text{SR}}) \text{ where } \sum p_{y,m,a}^{\text{SR}} = 1 \forall y, m, a$$

For a given fishing year (y), month (m), statistical area (a), data source (LB or CS) (d), and trip (j), counts of the number of lobsters measured by sex category (s) were generated and arranged as vectors by sex category:

$$n_{y,m,a,d,j,s}^{\text{SR}} = \mathbf{n}_{y,m,a,d,j}^{\text{SR}} \in [0, \infty]$$

Counts of lobsters by sex category were fitted using a multinomial distribution (i.e., data source and trips were replicates):

$$\text{Equation 15: } \mathbf{n}_{y,m,a,d,j}^{\text{SR}} \sim \text{multinomial}(n, \mathbf{p}_{y,m,a}^{\text{SR}})$$

and the following priors were used:

Equation 16:

$$\begin{aligned}\mu_l^{y,a} &\sim N\left(0, (\sigma_l^{y,a})^2\right) \\ \sigma_l^{y,a} &\sim \text{student}(3, 0, 2.5)\end{aligned}$$

Bayesian inference was done using the R package *brms* (Bürkner 2017, R Core Team 2022). MCMC mixing was excellent (Figure E.20).

The catch (tonnes) in each fishing year, month, and statistical area was calculated from the catch and effort database and denoted $C_{y,m,a}$. The fitted SR model was used to simulate the predicted SR by year, month, and statistical area from the posterior distribution (using the *posterior_epred* function in the *brms* package). The simulated SRs were scaled by the catch and aggregated by posterior sample (i), fishing year, season, and sex category then converted to proportions using

Equation 17:

$$P_{y,t,s,i} = \sum_{a,m \in t} C_{y,m,a} p_{y,m,a,s,i}^{\text{SR}} / \sum_{a,m \in t,s} C_{y,m,a} p_{y,m,a,s,i}^{\text{SR}}$$

The mean and SD by fishing year, season, and sex category were calculated from the Equation 17 posterior distribution:

Equation 18:

$$\begin{aligned}P_{y,t,s} &= \mathbf{P}_{y,t} \\ \sigma_{y,t,s} &= \boldsymbol{\sigma}_{y,t}\end{aligned}$$

Finally, the SR data set weight for each fishing year and season was calculated from the posterior SD as:

Equation 19:

$$\omega_{y,t}^{\text{SR}} = \frac{1}{\sqrt{\sum_s \sigma_{y,t,s}^2}}$$

The standardisation did little to alter the time series of SR by fishing year and season (Figure 12).

Mean tail width by sex category was calculated (Figure 13). The logbook data showed an increase in the AW and SS mean size in the late 1990s for both males and mature females, followed by a drop in the mean size, reaching a low point around 2010 for both males and mature females and in both seasons. Mean size then increased up to the end of the series. An equivalent pattern in the catch sampling data is less clear. Both periods of increased mean size were coincident with increases in CPUE over a similar period (Figure 10).

5. TAG RECAPTURES

This section describes tag-recapture data that were used to inform growth in the stock assessment of rock lobster stocks (Haist et al. 2009). These data were also useful for informing decisions about stock structure and movement. Tag recapture data for all QMAs were obtained in August 2022 from Fisheries New Zealand (replog 14522).

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 unique release-recapture event for a tag to be linked to form a single record while tags with no recaptures were discarded. Processing, linking, and formatting were done using purpose-built software written in the R statistical computing language.

The tag processing code implemented the following:

1. remove duplicate records
2. remove records with no date
3. remove records that are missing both tail width and carapace length
4. remove releases with no corresponding recapture
5. iteratively match captures with recaptures
6. if sex is missing at capture but not recapture, then infer sex and vice versa
7. remove matched records that change sex
8. remove matched records that do not have a sex code of 1 or 2
9. if statistical area is not 901 to 943 then set to NA
10. Determine statistical areas of tag release and recovery using latitude and longitude. Where these are not reported, instead use the fisher-reported statistical areas of release and recapture.
11. if the option [qma_method] = "area", then determine the quota management area (i.e., CRA 1, ..., CRA 9) from the statistical area, unless the statistical area is NA, then set the QMA using the project ID (this option was used). Otherwise, determine the quota management area from the project ID, unless the project ID is NA then set the QMA using the statistical area
12. if the calendar year > 1992 and the source = 2 (catch sampling) then add 0.5 to the tail width measurement (this step is required because of the measurement instructions provided to the observers doing the catch sampling)
13. if there is no recorded tail width, then calculate this from the carapace length using the relationships given by Breen et al. (1988)
14. remove records where tail width is less than 20 mm
15. remove records where tail width is greater than 150 mm
16. calculate the time at liberty in days
17. remove those records that are at liberty for less than 1 day
18. remove those records that are at liberty for greater than 10 years
19. calculate the growth increment as the difference in tail widths
20. remove records with a growth increment less than -40 mm or greater than 40 mm.

Data were then rearranged into the format used by the model:

- sex (1 for males and 2 for females)
- year and month of release, extracted from release date
- year and month of recovery, extracted from recovery date
- days at liberty, obtained by subtracting release from recovery dates
- TW at release
- TW at recovery
- number of re-releases
- statistical areas of release and recovery.

During the initial phase of data preparation for CRA 2, it was found that the reported latitude and longitude data for tag releases and recoveries had been processed incorrectly for the three preceding stock assessments (CRA 1 and CRA 3 in 2019, CRA 4 and CRA 5 in 2020, and CRA 7&8 in 2021). This error caused some tag events to be attributed with the wrong statistical areas. These data were processed correctly for the 2022 CRA 2 assessment. A brief comparison of the tag data extracts using the incorrect and correct methods for parsing latitude and longitude data is given in Appendix F.

5.2 Tag data summaries: all QMAs

5.2.1 Comparison with previous extract

A comparison was done to ensure that new data extracts were not missing records that were available in previous years and to see how many new data records are available (Table 14 and Table 15). This comparison showed an overall increase in the number of usable recoveries of around 150 tags compared with the same total from last year (Table 14), with nearly all usable recaptures coming from recaptures after 2018–19 (Table 15).

5.2.2 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 (0.299) and the lowest rate in CRA 9 (0.020) (Table 16). There were 35 564 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 21 881 were males and the remaining 13 683 were females (Table 17). The CRA QMA with most recovered tags was CRA 8, and the fewest recaptured tags came from CRA 6 and CRA 9, both of which had fewer than 250 recoveries (Table 17).

Tagged lobsters are generally recaptured in the QMA or statistical area of release, but, for a small proportion of recaptures, it appears that some individuals moved much greater distances (Table 18). It seems likely that many of these large-scale movements (e.g., between CRA 3 and CRA 8 – see Table 18) may be due to data errors, which will be investigated in the future.

5.2.3 Growth patterns

The observed growth increment (mm) by TW (mm) at release was generally greater in smaller individuals, but this relationship was highly variable by QMA (Figure 14, Figure 15). 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 15). The relationship between observed 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 16, Figure 17). This observation holds true for all QMAs with an adequate amount of data (Figure 17).

5.3 Tag data summaries: CRA 2

The CRA 2 stock tagging information includes data from releases in statistical area 906 since 1983–84, and all statistical areas since 1996–97. Since then, pulses of tagging effort occurred in the mid-to-late 1990s, the early and late 2000s, and in fishing years since 2014–15, with similar temporal patterns in effort across all statistical areas (Table 19). The total number of CRA 2 tag recoveries consisted of 4877 recaptures (2460 males and 2417 females) (Table 19). Table 20 shows the same data except summarised by year of recapture. The peak months of recovered tag releases (at least 400 events) were in the period from July to November, in which 79% of the recovered tags were released. There were comparatively few (< 150 recaptures) in the period from February to April (Table 21), when the commercial fishing effort in CRA 2 has been minimal (Starr 2022).

Most CRA 2 recaptures were made in the statistical area of release (Table 22). There was some evidence of movement between areas 905 and 906, although these comprised a relatively small percentage (< 10%) of all those released in these statistical areas (Table 22). There was little evidence for large-scale movements, such as between CRA 2 and the adjacent QMAs (CRA 1 and CRA 3) (Table 18). This was still the case when using a subset of individuals spending at least 2 years at liberty (Table 23).

The distributions of sizes at release and recapture by sex are shown in Figure 18. The modal size class of the males was close the MLS for this sex (54 mm TW), but with a broad right-hand distribution extending to above 80 mm TW. The female distribution is less broad than for males, with a mode of

around about 58 mm TW (the female MLS in CRA 2 is 60 mm) and a similar shaped right-hand of the size distribution compared with the males (Figure 18). The size distribution at recapture for males and females is right-shifted relative to the size distribution at release (Figure 18), consistent with growth between release and recapture.

Times at liberty varied from 1 day to 2171 days (5.9 years) for males and from 1 day to 3350 days (9.2 years) for females (Table 24). Note that data processing step 17 (above) dropped potential recoveries that were at liberty for more than 10 years. The medians were 261 days for males and 350 days for females (Table 24). A few males were re-released seven to eleven-times, and from five to eight-times for females (Table 25). Forty-one percent of the male recoveries came from re-releases while the equivalent percentage for females was 27%.

Growth increments (mm) ranged from -37 to 28 mm TW (males) and -24 to 25 mm TW (females) (Table 26). The observed growth increment in CRA 2 was generally greater in smaller individuals (Figure 19, Figure 20). The relationship between observed growth increment and time at liberty (years) was somewhat tighter (Figure 21, Figure 22), although both relationships were highly variable.

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 run much faster because there are 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.
- The first three fishing years (1986, 1990, and 1991) were dropped from the LF/SR data set because there were too few vessels, days, trips, pots, and lobsters sampled by the CS programme and no LB samples (Table 9) and, during these years, there were no samples in statistical areas 905 and 906 (Table 10) and only the SS season was sampled. However, the SR model does not require as much data as the LF models and therefore these three years could potentially be retained in future SR models.
- The proportion of mature females in berry should be estimated using a model that standardises for temporal effects and accounts for catch, rather than just averaging across all the data for each season. Ideally, the standardisation model(s) should account for variation with respect to sex and QMA/statistical area.
- When processing the tagging data, the relationships used to predict TW from CL, where the former is missing, were based on a much smaller sample of paired measurements than is currently available. Predictive models of this relationship should be developed, ideally for each sex and QMA, and fitting to as much of the available data as possible, so that TW can more accurately be predicted from CL.

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.

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9. REFERENCES

- Annala, J.H.; King, M.R. (1983). The 1963–73 New Zealand rock lobster landings by statistical area. *Fisheries Research Division Occasional Publication, Data Series 11*. 20 p.
- Bentley, N.; Starr, P.J.; Walker, N.; Breen, P.A. (2005). Catch and effort data for New Zealand rock lobster stock fisheries. *New Zealand Fisheries Assessment Report 2005/49*. 49 p.
- Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC2000-01 held by Fisheries New Zealand, Wellington.) 92 p.
- Boyd, R O; Reilly, J L (2004) 1999/2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand, Wellington.) 28 p.
- Bradford, E. (1997). Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993–94. New Zealand Fisheries Assessment Research Document 97/7. (Unpublished report held by NIWA library, Wellington.) 16 p.
- Bradford, E. (1998). Harvest estimates from the 1996 national marine recreational fishing surveys. New Zealand Fisheries Assessment Research Document 98/16. (Unpublished report held by NIWA library, Wellington.) 27 pp.
- Breen, P.A.; Booth, J.D.; Tyson, P.J. (1988). Feasibility of a minimum size limit based on tail width for the New Zealand rock lobster *Jasus edwardsii*. *New Zealand Fisheries Technical Report No. 6*. 16 p.
- Breen, P.A.; Starr, P.J. (2010). Exploration of the utility of puerulus settlement and other indices for predicting future states of rock lobster stocks (*Jasus edwardsii*). (Unpublished Final Research Report for CRA2006–01, 2009–10, Objective 5, produced for the Ministry for Primary Industries). 41 p.
- Bürkner, P. (2017). brms: An R Package for Bayesian Multilevel Models Using Stan. *Journal of Statistical Software* 80: 1–28. doi: 10.18637/jss
- Copernicus (2022). ERA5 monthly averaged data on single levels from 1959 to present. Extracted September 2022. URL: <https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels-monthly-means>
- Davey, N.; Hartill, B.; Carter, M. (2019). Mean weight estimates for recreational fisheries in 2017–18. *New Zealand Fisheries Assessment Report 2019/25*. 32 p.
- Fisheries New Zealand (2022). *Fisheries Assessment Plenary, November 2022: stock assessments and stock status*. Compiled by the Fisheries Science Team, Fisheries New Zealand, Wellington, New Zealand. 684 p.
- Forman, J.S.; McKenzie, A.; Stotter, D.R. (2022). Red rock lobster (*Jasus edwardsii*) settlement indices for the 2020 fishing year. *New Zealand Fisheries Assessment Report 2022/14*. 52 p.

- Haist, V.; Breen, P.A.; Starr, P.J. (2009). A new multi-stock length-based assessment model for New Zealand rock lobsters (*Jasus edwardsii*). *New Zealand Journal of Marine and Freshwater Research* 43(1): 355–371.
- Hartill, B.; Bian, R.; Rush, N.; Armiger, H. (2019). Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017–18. *New Zealand Fisheries Assessment Report 2019/23*. 39 p.
- Hartill, B.; Davey, N. (2015). Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25*. 37 p.
- Hartill, B.; Evans, O.; Taylor, R.; Armiger, H.; Marsh, C. (2022). Creel survey monitoring of trends in recreational landings from CRA 2 – update for 2021–22. (Unpublished Research Progress Report produced for Fisheries New Zealand.) 26 p.
- Heinemann, A.; Wynne-Jones, J.; Gray, A.; Hill, L. (2015). National Panel Survey of Marine Recreational Fishers 2011–12 Rationale and Methods. *New Zealand Fisheries Assessment Report 2015/48*. 94 p.
- Holdsworth, J.C. (2016). Amateur harvest estimates from an access point survey of marine fishers in the western Bay of Plenty, New Zealand in 2010–11 and 2011–12. *New Zealand Fisheries Assessment Report 2016/30*. 46 p.
- Luo, B.; Minnett, P.J. (2020). Evaluation of the ERA5 Sea Surface Skin Temperature with Remotely-Sensed Shipborne Marine-Atmospheric Emitted Radiance Interferometer Data. *Remote Sensing*, 12: 1873.
- Mackay, K.A. & George, K. (2002). Database documentation: rcls. NIWA Internal Report. 53 p.
- Ministry for Primary Industries (2016). *Fisheries Assessment Plenary, November 2016: stock assessments and stock status*. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 459 p.
- R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: <https://www.R-project.org/>.
- Roberts, J.; Webber, D.N. (2021). Characterisation, catch-per-unit-effort, and stock assessment of packhorse rock lobster (*Sagmariasus verreauxi*) in New Zealand. *New Zealand Fisheries Assessment Report 2021/78*. 63 p.
- Roberts, J.; Webber, D.N. (2022). Growth of juvenile red rock lobster (*Jasus edwardsii*) in New Zealand and implications for stock assessment. *New Zealand Fisheries Assessment Report 2022/45*. 59 p.
- Rudd, M.B.; Pons, M.; Roberts, J.; Webber, D.N.; Starr, P.J. (2021a). The 2020 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 4. *New Zealand Fisheries Assessment Report 2021/80*. 112 p.
- Rudd, M.B.; Pons, M.; Webber, D.N.; Starr, P.J.; Roberts, J.; Goeden Z.D. (2023). The 2022 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2023/43*. 108 p.
- Rudd, M.B.; Roberts, J.; Large, K.; Webber, D.N.; Starr, P.J. (2021b). The 2019 stock assessment of rock lobsters (*Jasus edwardsii*) in CRA 1. *New Zealand Fisheries Assessment Report 2021/04*. 101 p.
- Stan Development Team (2018). RStan: the R interface to Stan. R package version 2.17.3. <http://mc-stan.org/>
- Starr, P.J. (2022). Rock lobster catch and effort data: 1979–80 to 2021–22. *New Zealand Fisheries Assessment Report 2022/42*. 151 p.
- Starr, P.J.; Bentley, N.; Breen, P.A.; Kim, S.W. (2003). Assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1 and CRA 2 in 2002. *New Zealand Fisheries Assessment Report 2003/35*. 112 p.
- Starr, P.J.; Breen, P.A.; Edwards, C.T.T.; Haist, V. (2014a). Data for the 2013 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2014/18*. 54 p.

- Starr, P.J.; Haist, V.; Breen, P.A.; Edwards, C.T.T.E. (2014b). The 2013 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2 and development of management procedures. *New Zealand Fisheries Assessment Report 2014/19*. 76 p.
- Starr, P.J.; Webber, D.N. (2018). Data for the 2017 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2018/31*. 75 p.
- Starr, P.J.; Webber, D.N.; Rudd, M.B.; Pons, M.; Roberts, J. (2022). Data for the 2021 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 7&8. *New Zealand Fisheries Assessment Report 2022/16*. 140 p.
- Walker, N.; Mackay, K.A. (2002). Database documentation: rlcs (B) Logbook schema. NIWA Internal Report (revised 5 September 2002). (Unpublished report held in NIWA library, Wellington.) 26 p.
- Webber, D.N. (2022). Modelling the length frequency of red rock lobsters (*Jasus edwardsii*) in New Zealand. *New Zealand Fisheries Assessment Report 2022/30*. 261 p.
- Webber, D.N.; Roberts, J.; Rudd, M.B.; Starr, P.J.; Large, K. (2020). The 2019 stock assessment of rock lobsters (*Jasus edwardsii*) in CRA 3. *New Zealand Fisheries Assessment Report 2020/42*. 93 p.
- Webber, D.N.; Starr, P.J. (2022). Catch per unit effort of red rock lobsters (*Jasus edwardsii*) in CRA 2 (1990–2021). *New Zealand Fisheries Assessment Report 2022/47*. 118 p.
- Webber, D.N.; Starr, P.J.; Haist, V.; Rudd, M.; Edwards, C.T.T. (2018). The 2017 stock assessment and management procedure evaluation for rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2018/17*. 87 p.
- Webber, D.N.; Starr, P.J.; Roberts, J.; Rudd, M.B.; Pons, M. (2021). The 2020 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 5. *New Zealand Fisheries Assessment Report 2021/62*. 91 p.
- Webber, D.N.; Starr, P.J.; Rudd, M.B.; Roberts, J.; Pons, M. (2022). The 2021 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 7 and CRA 8. *New Zealand Fisheries Assessment Report 2022/17*. 113 p.
- Wynne-Jones, J.; Gray, A.; Hill, L.; Heinemann, A. (2014). National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.
- Wynne-Jones, J.; Gray, A.; Heinemann, A.; Hill, L.; Walton, L. (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

10. TABLES

Table 1: CRA 2 catch (t) (commercial, recreational including section 111, customary, and illegal) by calendar year for 1945–1978. Note that the assessment model does not use two seasons until 1979; annual estimates are therefore provided before 1979.

Calendar year	Commercial	Recreational	Illegal	Customary
1945	136.8	11.9	45.2	5.0
1946	116.9	13.0	45.2	5.0
1947	129.7	14.2	45.2	5.0
1948	212.3	15.3	45.2	5.0
1949	198.2	16.5	45.2	5.0
1950	209.1	17.6	45.2	5.0
1951	191.2	18.8	45.2	5.0
1952	178.9	20.0	45.2	5.0
1953	190.9	21.1	45.2	5.0
1954	149.9	22.3	45.2	5.0
1955	155.2	23.4	45.2	5.0
1956	159.9	24.6	45.2	5.0
1957	126.0	25.7	45.2	5.0
1958	155.0	26.9	45.2	5.0
1959	192.3	28.1	45.2	5.0
1960	167.0	29.2	45.2	5.0
1961	198.9	30.4	45.2	5.0
1962	203.2	31.5	45.2	5.0
1963	217.3	32.7	45.2	5.0
1964	260.5	33.8	45.2	5.0
1965	252.2	35.0	45.2	5.0
1966	300.5	36.1	45.2	5.0
1967	330.2	37.3	45.2	5.0
1968	307.8	38.5	45.2	5.0
1969	297.3	39.6	45.2	5.0
1970	201.5	40.8	45.2	5.0
1971	178.0	41.9	45.2	5.0
1972	202.7	43.1	45.2	5.0
1973	185.4	44.2	45.2	5.0
1974	155.0	45.4	45.2	5.0
1975	138.0	46.6	45.2	5.0
1976	144.0	47.7	45.2	5.0
1977	199.0	48.9	45.2	5.0
1978 ¹	239.9	50.0	45.2	5.0

¹ includes January–March 1979 catches.

Table 2: CRA 2 catch (t) (commercial, recreational including section 111, customary, and illegal) by fishing season since 1979–80. AW = autumn/winter; SS = spring/summer.

Fishing year	Commercial		Recreational		Illegal		Customary	
	AW	SS	AW	SS	AW	SS	AW	SS
1979	86.4	206.3	5.1	46.1	15.9	37.9	0.5	4.5
1980	168.2	272.9	5.5	49.4	25.2	40.8	0.5	4.5
1981	120.5	270.5	5.2	47.0	16.6	37.2	0.5	4.5
1982	109.5	217.1	4.2	38.2	15.2	30.2	0.5	4.5
1983	84.0	190.6	3.6	32.1	11.3	25.7	0.5	4.5
1984	92.1	178.1	3.3	30.0	12.8	24.7	0.5	4.5
1985	88.5	249.1	4.0	35.6	10.8	30.3	0.5	4.5
1986	82.4	192.5	3.5	31.1	11.1	25.9	0.5	4.5
1987	81.0	173.4	3.3	29.3	10.5	22.5	0.5	4.5
1988	79.4	142.8	3.3	29.8	12.8	23.0	0.5	4.5
1989	72.9	179.8	4.3	38.3	7.8	19.3	0.5	4.5
1990	96.7	140.9	5.2	46.8	9.0	13.0	0.5	4.5
1991	94.5	135.1	4.5	40.1	8.0	11.4	0.5	4.5
1992	72.7	117.5	3.7	33.2	6.4	10.3	0.5	4.5
1993	101.8	113.1	4.0	35.9	8.5	9.4	0.5	4.5
1994	126.3	86.5	5.3	47.6	13.5	9.3	0.5	4.5
1995	162.3	50.2	7.1	63.5	24.8	7.7	0.5	4.5
1996	189.7	23.4	7.6	68.6	32.5	4.0	0.5	4.5
1997	208.6	25.8	8.3	74.6	34.2	4.2	0.5	4.5
1998	202.3	30.0	9.7	87.4	34.7	5.1	0.5	4.5
1999	178.0	57.1	5.7	51.0	20.4	6.6	0.5	4.5
2000	133.7	101.7	4.8	43.3	12.4	9.4	0.5	4.5
2001	119.2	105.7	4.7	42.3	10.7	9.5	0.5	4.5
2002	72.9	132.8	2.7	24.5	4.3	7.8	0.5	4.5
2003	68.8	127.2	3.9	35.5	5.9	10.9	0.5	4.5
2004	77.0	120.4	3.5	31.7	5.8	9.1	0.5	4.5
2005	82.4	142.8	3.7	33.4	5.6	9.7	0.5	4.5
2006	90.6	135.9	3.7	32.9	6.5	9.7	0.5	4.5
2007	88.7	141.0	3.7	33.1	6.1	9.7	0.5	4.5
2008	87.9	144.4	3.4	30.4	6.1	10.0	0.5	4.5
2009	85.8	149.3	3.0	27.3	4.5	7.8	0.5	4.5
2010	74.0	150.8	3.5	31.4	4.8	9.7	0.5	4.5
2011	62.1	166.9	3.1	27.9	3.6	9.6	0.5	4.5
2012	88.1	146.2	2.9	26.5	4.9	8.2	0.5	4.5
2013	83.2	152.5	2.9	25.8	4.4	8.1	0.5	4.5
2014	63.0	135.6	2.8	25.5	3.7	7.9	0.5	4.5
2015	51.4	123.3	2.4	21.4	2.8	6.7	0.5	4.5
2016	38.2	104.4	2.4	21.7	2.6	7.0	0.5	4.5
2017	42.0	100.8	3.1	27.6	3.4	8.1	0.5	4.5
2018	32.5	47.5	5.1	46.3	8.6	12.6	0.5	4.5
2019	45.6	30.5	3.4	30.7	15.6	10.4	0.5	4.5
2020	37.6	46.3	3.5	31.7	12.6	15.5	0.5	4.5
2021	47.5	32.5	3.3	29.8	16.2	11.1	0.5	4.5

Table 3: Recreational catch estimates used to model recreational catch for CRA 2. The Holdsworth (2016) survey estimates are described by Starr & Webber (2018). Survey estimates for 2019, 2020, and 2021 are preliminary from a project that is ongoing. ‘–’: not available.

Survey	Numbers	Mean weight (kg)	Catch weight (t)	CV
1994 (Otago: Bradford 1997)	142 000	0.672 ¹	95.42	not used
1996 (Otago: Bradford 1998)	223 000	0.672 ¹	149.86	not used
2000 (Boyd & Reilly 2004)	324 000	–	235.9 ²	not used
2001 (Boyd et al 2004)	331 000	–	241.4 ²	not used
2010 (Holdsworth 2016)	55 260	0.741	40.9	1.5×0.24
2011 (Holdsworth 2016)	31 602	0.700	22.1	1.5×0.24
2011–12 (NPS: Wynne-Jones et al 2014)	58 413	0.701 ³	40.86	0.24 ⁴
2017–18 (NPS: Wynne-Jones et al 2019)	19 123	0.743 ⁵	14.21	0.36 ⁶
2019–20 (Hartill et al. 2022)	–	–	32.1	0.37
2020–21 (Hartill et al. 2022)	–	–	33.2	0.38
2021–22 (Hartill et al. 2022)	–	–	31.1	0.37
Maximum reported section 111 landings (tonnes) (in 2014–15)			2.036	

¹ SS (spring/summer) mean weight (kg) calculated from commercial sampling data from 1994–96 assuming recreational minimum legal sizes (Starr et al 2003).

² As reported by Boyd & Reilly (2004) and Boyd et al. (2004).

³ Hartill & Davey (2015).

⁴ Estimate provided by Wynne-Jones et al. (2014).

⁵ Using data from Davey et al. (2019).

⁶ Estimate provided by Wynne-Jones et al. (2019).

Table 4: Fishing platform and capture method categories for CRA 2 estimated by the two National Panel Surveys: 2011–12 (Wynne-Jones et al. 2014) and 2017–18 (Wynne-Jones et al. 2019). The final line shows the CRA 2 total estimates. CV is the standard error of the estimate, which does not include error associated with the estimate of mean weight.

Category	Numbers		CV		Catch (t)		CV		Distribution (%)	
	2011	2017	2011	2017	2011	2017	2011	2017	2011	2017
Platform										
Trailer motor boat	36 489	13 285	0.27	0.45	25.49	9.98	0.27	0.45	62	70
Larger motor boat or launch	8 231	3 040	0.46	0.45	5.76	2.12	0.46	0.45	14.1	15
Trailer yacht	0	0	–	–	0	0	–	–	0	0
Larger yacht or keeler	3 891	0	0.75	–	2.73	0	0.75	–	7	0
Kayak canoe or rowboat	1 771	1 231	0.69	0.78	1.24	0.93	0.69	0.78	3	6.5
Off land including beach rocks or jetty	7 855	1 568	0.28	0.46	5.49	1.18	0.28	0.46	13	8
Something else	218	0	1.01	–	0.15	0	1.01	–	0.4	0
Capture method										
Rod or line (not longline)	0	0	–	–	0	0	–	–	0	0
Longline including set line kontiki or kite	0	0	–	–	0	0	–	–	0	0
Net (not including landing net used if caught by line)	0	0	–	–	0	0	–	–	0	0
Pot (e.g., for crayfish)	9 106	1 312	0.60	0.70	6.38	0.77	0.60	0.70	16	5.4
Dredge grapple or rake	0	0	–	–	0	0	–	–	0	0
Hand gather or floundering from shore	635	0	0.94	–	0.44	0	0.94	–	1.1	0
Hand gather by diving	48 714	17 812	0.37	0.38	34.03	13.44	0.37	0.38	83	94.6
Spearfishing	0	0	–	–	0	0	–	–	0	0
Some other method	0	0	–	–	0	0	–	–	0	0
Total	58 455	19 124	0.24	0.36	40.86 ¹	14.21 ²	0.24	0.36	100	100

¹ Uses mean weight estimate of 701 g (Hartill & Davey 2015).

² Uses mean weight estimate of 754 g (Davey et al. 2019).

Table 5: Catch rate from the potlift and days fishing data in Annala & King (1983) calculated for CRA 2 from the combined data for Annala/King areas 3 and 4 (equivalent to statistical areas 905 to 908).

Calendar year	Catch rate (kg/day)
1963	38.2
1964	39.9
1965	37.2
1966	38.8
1967	41.6
1968	32.7
1969	24.4
1970	24.0
1971	25.1
1972	25.5
1973	24.0

Table 6: Number of vessel/statistical area/month records in the data set used to calculate the CRA 2 seasonal CPUE time series for both the FSU, CELR, and logbook data sets. Data are provided by statistical area, fishing year (designated by the first year of the pair), and 6-month season. (Continued next page)

Fishing year	AW					SS				
	905	906	907	908	Total	905	906	907	908	Total
FSU data										
1979–80	65	104	37	69	275	84	182	75	146	487
1980–81	51	154	64	98	367	70	193	82	129	474
1981–82	75	135	61	91	362	102	206	67	151	526
1982–83	79	132	54	91	356	100	187	64	135	486
1983–84	80	114	59	81	334	97	187	64	118	466
1984–85	67	124	56	85	332	73	194	70	129	466
1985–86	61	116	56	73	306	79	180	78	119	456
1986–87	48	110	42	61	261	67	175	71	126	439
1987–88	41	111	55	75	282	51	172	65	98	386
1988–89	47	87	46	35	215	49	151	56	66	322
1989–90	20	48	22	16	106	–	–	–	–	–
Total	634	1 235	552	775	3 196	772	1 827	692	1 217	4 508
CELR data										
1990–91	14	33	19	4	70	16	63	19	9	107
1991–92	23	46	23	7	99	21	63	27	14	125
1992–93	23	50	19	13	105	27	83	19	22	151
1993–94	29	61	12	26	128	22	75	14	30	141
1994–95	29	75	8	26	138	16	46	15	24	101
1995–96	21	74	15	33	143	8	29	2	15	54
1996–97	24	69	12	22	127	1	16	1	5	23
1997–98	29	76	20	23	148	5	22	1	4	32
1998–99	34	62	15	26	137	16	26	3	6	51
1999–00	27	61	21	22	131	9	21	7	6	43
2000–01	22	69	17	26	134	19	42	11	12	84
2001–02	28	62	22	24	136	33	54	17	16	120
2002–03	20	62	17	24	123	36	64	17	29	146
2003–04	33	49	17	25	124	31	60	27	45	163
2004–05	20	54	13	23	110	21	55	19	41	136
2005–06	32	45	18	26	121	46	58	21	40	165
2006–07	35	54	17	21	127	42	65	17	37	161
2007–08	30	50	11	23	114	45	64	16	38	163

Fishing year	AW					SS				
	905	906	907	908	Total	905	906	907	908	Total
2008–09	29	45	15	21	110	41	57	13	29	140
2009–10	40	47	17	23	127	49	70	16	34	169
2010–11	30	37	15	24	106	48	63	18	42	171
2011–12	24	40	15	22	101	43	74	17	39	173
2012–13	28	43	16	26	113	42	69	16	37	164
2013–14	31	45	17	28	121	39	74	15	40	168
2014–15	19	43	15	26	103	26	71	15	33	145
2015–16	26	42	14	27	109	30	67	20	36	153
2016–17	22	36	15	16	89	42	51	20	33	146
2017–18	37	33	16	17	103	46	49	14	29	138
2018–19	13	23	7	8	51	12	19	5	21	57
2019–20	10	20	8	11	49	–	–	–	–	–
Total	782	1 506	466	643	3 397	832	1 570	422	766	3 590
Logbook data										
1993–94	269	2 117	451	906	3 743	70	1 997	416	845	3 328
1994–95	933	2 092	790	842	4 657	190	894	242	262	1 588
1995–96	171	1 964	738	587	3 460	–	361	19	94	474
1996–97	174	1 996	592	553	3 315	–	84		93	177
1997–98	84	1 643	685	475	2 887	–	3	7	56	66
1998–99	357	1 770	257	496	2 880	15	–	–	156	171
1999–00	252	1 595	790	565	3 202	63	326	85	8	482
2000–01	233	1 453	628	598	2 912	15	605	151	104	875
2001–02	106	255	456	447	1 264	169	1 190	203	84	1 646
2002–03	165	1 677	396	580	2 818	226	1 303	403	264	2 196
2003–04	244	631	354	183	1 412	122	1 575	273	428	2 398
2004–05	243	1 563	128	314	2 248	170	1 765	–	494	2 429
2005–06	192	1 373	301	426	2 292	92	2 156	628	706	3 582
2006–07	88	1 500	308	409	2 305	24	881	405	555	1 865
2007–08	–	874	314	537	1 725	6	1 143	341	1 059	2 549
2008–09	43	1 035	250	711	2 039	44	1 479	305	1 207	3 035
2009–10	17	913	330	459	1 719	46	1 390	430	1 111	2 977
2010–11	66	745	377	449	1 637	229	1 785	287	1 266	3 567
2011–12	293	583	398	487	1 761	200	2 186	317	624	3 327
2012–13	229	855	405	639	2 128	93	1 826	446	1 268	3 633
2013–14	287	906	464	839	2 496	153	1 724	684	930	3 491
2014–15	147	932	852	143	2 074	165	1 794	463	495	2 917
2015–16	309	649	779	394	2 131	503	1 509	515	630	3 157
2016–17	214	424	426	68	1 132	342	724	667	454	2 187
2017–18	337	439	366	345	1 487	234	786	348	447	1 815
2018–19	126	482	278	24	910	3	308	226	259	796
2019–20	184	426	441	226	1 277	36	115	62	230	443
2020–21	84	436	410	74	1 004	139	270	133	358	900
2021–22	104	476	573	66	1 219	–	124	96	361	581
Total	5 951	31 804	13 537	12 842	64 134	3 349	30 303	8 152	14 848	56 652

Table 7: Seasonal standardised CPUE index series used in the CRA 2 stock assessment, showing median estimated standardised indices and standard error derived from separate analyses using the FSU data (1979–80 AW to 1989–90 AW), the CELR data (1990–91 AW to 2019–20 AW), and the logbook data (1993–94 AW to 2021–22 SS).

Fishing year	AW		SS		AW		SS	
	Index	SE	Index	SE	Index	SE	Index	SE
FSU series								
1979–80	1.123	0.122	1.448	0.155				
1980–81	1.597	0.172	1.561	0.166				
1981–82	1.088	0.114	1.485	0.158				
1982–83	0.979	0.103	1.194	0.128				
1983–84	0.776	0.081	0.996	0.107				
1984–85	0.867	0.092	0.925	0.099				
1985–86	0.856	0.092	1.110	0.116				
1986–87	0.804	0.087	0.958	0.104				
1987–88	0.676	0.072	0.903	0.098				
1988–89	0.794	0.086	0.918	0.099				
1989–90	0.647	0.074	–	–				
CELR series								
1990–91	0.980	0.167	1.469	0.240				
1991–92	0.913	0.151	1.258	0.200				
1992–93	0.831	0.134	1.032	0.162				
Logbook series								
1993–94	0.925	0.146	1.184	0.186	1.036	0.185	0.968	0.182
1994–95	1.080	0.176	1.475	0.237	1.233	0.217	1.412	0.254
1995–96	1.579	0.253	1.615	0.277	1.477	0.263	1.858	0.398
1996–97	1.912	0.308	2.793	0.561	2.050	0.363	1.812	0.437
1997–98	2.144	0.339	2.552	0.466	1.903	0.346	1.927	0.530
1998–99	2.177	0.344	2.575	0.440	1.698	0.304	2.255	0.588
1999–00	1.401	0.219	2.373	0.409	1.650	0.290	2.053	0.408
2000–01	1.173	0.186	1.839	0.293	1.204	0.218	1.595	0.310
2001–02	0.907	0.144	1.340	0.211	0.959	0.173	1.000	0.181
2002–03	0.618	0.097	1.125	0.175	0.757	0.135	0.797	0.144
2003–04	0.714	0.113	0.964	0.148	0.802	0.146	0.963	0.173
2004–05	0.803	0.128	1.135	0.179	0.795	0.140	0.902	0.176
2005–06	0.714	0.113	1.043	0.160	0.738	0.132	0.816	0.147
2006–07	0.831	0.130	1.248	0.192	0.805	0.141	0.948	0.175
2007–08	0.860	0.137	1.153	0.177	0.905	0.184	0.912	0.174
2008–09	0.874	0.138	1.159	0.179	0.982	0.182	0.935	0.172
2009–10	0.792	0.124	1.042	0.162	0.637	0.118	0.788	0.143
2010–11	0.695	0.110	0.923	0.142	0.829	0.154	1.038	0.182
2011–12	0.554	0.089	0.931	0.143	0.814	0.145	0.769	0.134
2012–13	0.692	0.110	0.851	0.130	0.807	0.146	0.729	0.136
2013–14	0.590	0.093	0.825	0.127	0.780	0.141	0.757	0.140
2014–15	0.523	0.083	0.740	0.115	0.632	0.117	0.734	0.132
2015–16	0.393	0.062	0.639	0.098	0.592	0.110	0.594	0.108
2016–17	0.426	0.069	0.637	0.100	0.476	0.087	0.616	0.112
2017–18	0.425	0.068	0.620	0.097	0.557	0.103	0.743	0.132
2018–19	0.629	0.106	1.018	0.167	1.114	0.211	1.229	0.246
2019–20	0.941	0.159	–	–	1.161	0.215	1.462	0.282
2020–21	–	–	–	–	1.282	0.238	1.647	0.294
2021–22	–	–	–	–	1.394	0.257	1.311	0.268

Table 8: Summary of subscripts used throughout this document.

Subscript	Variable	Support
<i>y</i>	Fishing year	1986–2020
<i>m</i>	Month	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
<i>t</i>	Season	AW = autumn/winter, SS = spring/summer
<i>a</i>	Statistical Area	905, 906, 907, 908
<i>s</i>	Sex category	Males, immature females, mature females
<i>d</i>	Data source	CS = catch sampling, LB = logbook
<i>j</i>	Trip	–
<i>i</i>	Pot	–
<i>l</i>	Length bin	[30,32), [32,34), ..., [88,90), [90, ∞)
<i>x</i>	Posterior sample/iteration	–

Table 9: CRA 2: number of vessels, skippers, trips, days sampled, pots lifted, and lobsters measured in the catch sampling (CS) and logbook (LB) programmes each fishing year. The fishing years indicated in grey were not included in the LF and SR models.

Fishing year	Catch sampling (CS)					Logbook (LB)					
	vessels	days	trips	pots	lobsters	vessels	skippers	days	trips	pots	lobsters
1986	2	3	3	159	562	–	–	–	–	–	–
1990	2	3	3	127	364	–	–	–	–	–	–
1991	1	2	2	115	918	–	–	–	–	–	–
1993	–	–	–	–	–	26	23	253	1 915	4 494	18 092
1994	–	–	–	–	–	30	25	254	1 613	4 307	18 133
1995	–	–	–	–	–	26	21	176	1 048	2 809	11 657
1996	–	–	–	–	–	21	19	187	902	2 508	12 522
1997	–	–	–	–	–	19	16	169	766	2 111	9 224
1998	–	–	–	–	–	21	17	191	781	2 199	9 172
1999	12	12	12	917	3 073	20	17	153	949	2 642	10 323
2000	13	13	13	1 002	3 022	16	16	198	950	2 568	9 186
2001	10	11	11	859	3 014	13	13	268	743	1 787	5 893
2002	12	13	14	724	2 274	18	18	267	1 197	2 738	8 269
2003	12	12	12	737	1 898	13	13	289	979	2 440	7 445
2004	12	12	12	530	1 353	14	14	319	1 144	2 730	8 532
2005	10	12	12	752	2 303	18	18	301	1 442	3 563	10 748
2006	9	12	12	772	1 964	17	17	251	1 057	2 765	8 836
2007	11	12	12	828	2 237	14	13	245	1 088	2 678	9 008
2008	7	12	12	874	2 568	15	15	257	1 281	3 302	10 415
2009	8	11	14	881	2 769	15	14	240	1 195	2 861	8 662
2010	12	13	13	783	1 926	16	16	274	1 471	3 518	12 003
2011	12	14	17	857	2 175	17	19	252	1 357	3 177	8 831
2012	11	13	13	835	2 465	17	17	256	1 502	3 696	11 636
2013	9	10	12	864	2 868	19	18	284	1 585	3 853	11 976
2014	8	12	12	882	2 666	15	16	266	1 373	3 147	8 016
2015	8	13	13	768	1 450	16	17	274	1 342	2 921	6 315
2016	9	13	13	763	2 005	15	16	223	859	1 829	3 658
2017	9	14	14	873	2 652	14	14	235	928	1 971	4 234
2018	9	11	12	965	2 785	11	11	176	453	1 230	4 374
2019	–	–	–	–	–	13	14	196	470	1 318	4 273
2020	10	16	19	1 551	5 174	15	15	174	526	1 490	5 072
2021	12	18	18	1 458	6 870	13	13	228	496	1 325	4 050

Table 10: CRA 2: number of vessels and trips by statistical area in either the catch sampling (CS) or logbook (LB) programmes each fishing year. The fishing years indicated in grey were not included in the LF models.

Fishing year	905		906		907		908	
	vessels	trips	vessels	trips	vessels	trips	vessels	trips
1986	—	—	—	—	1	2	1	1
1990	—	—	—	—	—	—	2	3
1991	—	—	—	—	—	—	1	2
1993	3	80	15	1 187	3	191	5	457
1994	8	271	15	805	6	262	6	275
1995	1	43	12	635	6	194	7	176
1996	2	43	9	537	7	154	3	168
1997	1	21	10	431	6	181	3	133
1998	3	102	11	454	4	67	3	158
1999	4	89	11	499	6	231	3	142
2000	3	63	11	534	5	189	3	177
2001	2	71	8	382	4	167	4	134
2002	3	90	10	704	5	195	5	222
2003	2	91	8	582	3	159	4	159
2004	2	97	10	811	3	34	5	214
2005	1	70	11	872	4	236	5	276
2006	1	30	9	606	3	186	6	247
2007	2	3	8	504	2	183	8	410
2008	1	22	9	628	2	144	5	499
2009	1	20	8	577	3	200	6	412
2010	3	96	9	717	5	185	7	486
2011	2	132	11	722	3	185	5	335
2012	2	91	8	699	4	208	5	517
2013	1	118	9	680	4	304	6	495
2014	1	93	9	728	7	361	3	203
2015	2	162	8	565	5	332	4	296
2016	2	119	6	294	6	301	4	158
2017	2	143	7	309	4	220	6	270
2018	2	30	5	206	4	141	4	88
2019	1	66	4	136	3	127	5	141
2020	1	59	6	189	4	146	6	151
2021	1	28	10	177	3	174	4	135

Table 11: Number of lobsters measured by fishing year, sex, and season for CRA 2 by the observer catch sampling and the logbook programmes for 1987–2021. Samples marked in grey were dropped from the stock assessment. ‘–’: no data. (Continued next page)

Fishing year	Catch sampling (CS)				Logbook (LB)			
	Male	Immature female	Mature female	Total	Male	Immature female	Mature female	Total
Season=AW								
1993	–	–	–	–	5 191	1 378	3 932	10 501
1994	–	–	–	–	6 773	1 155	4 932	12 860
1995	–	–	–	–	5 901	500	3 500	9 901
1996	–	–	–	–	6 944	373	4 507	11 824
1997	–	–	–	–	5 285	67	3 672	9 024
1998	–	–	–	–	4 579	45	4 095	8 719
1999	1 200	24	1 849	3 073	3 937	41	4 685	8 663
2000	1 051	15	1 214	2 280	3 010	104	3 487	6 601
2001	826	36	624	1 486	1 667	51	1 285	3 003
2002	872	19	954	1 845	2 322	99	2 291	4 712
2003	748	131	879	1 758	1 216	212	1 080	2 508
2004	237	53	219	509	2 269	261	1 443	3 973
2005	696	48	397	1 141	2 111	447	1 487	4 045
2006	274	35	160	469	2 902	545	1 433	4 880
2007	666	56	355	1 077	1 798	215	1 273	3 286
2008	403	22	424	849	2 790	285	1 586	4 661
2009	429	55	425	909	1 622	82	1 060	2 764
2010	296	7	261	564	1 928	145	1 202	3 275
2011	233	4	133	370	1 450	245	1 375	3 070
2012	73	1	103	177	2 510	312	1 497	4 319
2013	133	8	164	305	2 791	292	1 626	4 709
2014	498	7	330	835	1 591	112	1 360	3 063
2015	80	2	120	202	1 409	189	1 195	2 793
2016	137	19	88	244	596	109	316	1 021
2017	670	15	692	1 377	789	196	688	1 673
2018	502	5	335	842	1 270	291	592	2 153
2019	–	–	–	–	1 936	176	804	2 916
2020	1 417	26	448	1 891	1 278	74	782	2 134
2021	1 025	73	880	1 978	1 473	123	898	2 494
Total	12 466	661	11 054	24 181	44 665	4 606	33 445	82 716

Fishing year	Catch sampling (CS)				Logbook (LB)			
	Male	Immature female	Mature female	Total	Male	Immature female	Mature female	Total
Season=SS								
1986	287	49	226	562	—	—	—	—
1990	131	14	219	364	—	—	—	—
1991	516	113	289	918	—	—	—	—
1993	—	—	—	—	3 489	814	3 288	7 591
1994	—	—	—	—	2 177	470	2 626	5 273
1995	—	—	—	—	775	142	839	1 756
1996	—	—	—	—	374	10	314	698
1997	—	—	—	—	56	—	144	200
1998	—	—	—	—	233	1	219	453
1999	—	—	—	—	330	8	1 322	1 660
2000	180	15	547	742	777	33	1 775	2 585
2001	446	57	1 025	1 528	1 052	67	1 771	2 890
2002	89	17	323	429	1 160	109	2 288	3 557
2003	42	2	96	140	2 421	376	2 140	4 937
2004	381	101	362	844	2 416	315	1 828	4 559
2005	614	123	425	1 162	3 153	717	2 833	6 703
2006	689	108	698	1 495	1 927	360	1 669	3 956
2007	532	51	577	1 160	2 690	435	2 597	5 722
2008	878	142	699	1 719	2 631	258	2 865	5 754
2009	689	82	1 089	1 860	2 365	314	3 219	5 898
2010	476	55	831	1 362	4 203	477	4 048	8 728
2011	738	79	988	1 805	2 559	476	2 726	5 761
2012	1 013	231	1 044	2 288	3 838	752	2 727	7 317
2013	1 045	156	1 362	2 563	3 347	589	3 331	7 267
2014	584	46	1 201	1 831	1 933	294	2 726	4 953
2015	526	60	662	1 248	1 495	203	1 824	3 522
2016	991	135	635	1 761	1 149	220	1 268	2 637
2017	848	123	304	1 275	1 127	436	998	2 561
2018	969	88	886	1 943	1 068	198	955	2 221
2019	—	—	—	—	728	68	561	1 357
2020	1 294	68	1 921	3 283	1 349	103	1 486	2 938
2021	4 005	49	838	4 892	742	23	791	1 556
Total	17 963	1964	17 247	37 174	51 564	82 68	55 178	114 810

Table 12: Bin limits for CRA 2 indicated in grey.

Length bin	Midpoint	Bin	MM	IF	MF
[30, 32)	31	1			
[32, 34)	33	2			
[34, 36)	35	3			
[36, 38)	37	4			
[38, 40)	39	5			
[40, 42)	41	6			
[42, 44)	43	7			
[44, 46)	45	8			
[46, 48)	47	9			
[48, 50)	49	10			
[50, 52)	51	11			
[52, 54)	53	12			
[54, 56)	55	13			
[56, 58)	57	14			
[58, 60)	59	15			
[60, 62)	61	16			
[62, 64)	63	17			
[64, 66)	65	18			
[66, 68)	67	19			
[68, 70)	69	20			
[70, 72)	71	21			
[72, 74)	73	22			
[74, 76)	75	23			
[76, 78)	77	24			
[78, 80)	79	25			
[80, 82)	81	26			
[82, 84)	83	27			
[84, 86)	85	28			
[86, 88)	87	29			
[88, 90)	89	30			
[90, ∞)	91	31			

Table 13: Effective sample size for each LF record by fishing year, season, and sex category.

Fishing year	AW			SS		
	Male	Immature female	Mature female	Male	Immature female	Mature female
1993–94	68.1	38.0	52.6	83.5	40.8	74.4
1994–95	96.9	40.7	88.1	87.7	36.1	82.6
1995–96	77.5	22.5	60.9	66.7	22.0	54.8
1996–97	82.0	20.0	64.3	68.1	17.5	56.6
1997–98	70.2	8.6	59.3	58.2	8.1	52.0
1998–99	67.3	7.2	62.6	59.2	7.1	57.6
1999–00	73.5	9.0	86.4	59.4	8.6	74.3
2000–01	69.8	13.6	78.7	61.5	13.0	71.9
2001–02	62.4	15.5	66.1	57.2	15.6	66.4
2002–03	66.9	16.3	74.8	63.4	16.1	72.8
2003–04	63.9	27.3	62.3	66.2	27.9	63.2
2004–05	62.5	25.1	51.9	63.8	24.5	53.2
2005–06	70.2	32.2	62.3	75.5	35.3	67.0
2006–07	71.8	28.7	59.1	72.9	30.2	61.0
2007–08	64.8	20.7	55.0	63.2	20.3	53.3
2008–09	59.6	19.8	58.1	63.8	21.7	63.7
2009–10	63.0	21.2	64.3	65.7	23.1	71.2
2010–11	70.4	22.1	63.3	71.3	23.9	68.8
2011–12	65.8	27.4	66.9	70.5	28.8	72.1
2012–13	77.8	31.0	65.0	85.8	35.7	72.0
2013–14	75.8	29.2	72.4	81.8	33.4	80.3
2014–15	63.0	20.1	67.8	66.7	22.4	74.4
2015–16	57.9	21.9	59.5	57.7	22.3	60.7
2016–17	54.6	22.8	48.2	55.7	23.8	49.7
2017–18	58.8	26.9	51.6	60.1	30.2	53.0
2018–19	56.7	23.7	49.1	54.0	23.0	47.8
2019–20	50.6	16.6	36.0	50.5	16.3	37.8
2020–21	64.8	16.7	61.1	71.7	17.9	70.5
2021–22	58.8	15.2	47.3	62.4	14.3	50.9

Table 14: Comparison of the number of records by Project ID in the new tag data extract with the number of records in the extract made for the 2021 CRA 7&8 assessment (Starr et al. 2022), 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	1 622	—
CRA2_EBOP	5	5	—
CRA2_TAG	4 694	4 744	50
CRA2_WBOP	268	268	—
CRA3_TAG	2 110	2 110	—
CRA4_TAG	3 132	3 134	2
CRA4_Wair	10	10	—
CRA5_Kaik	1 176	1 176	—
CRA5_TAG	6 082	6 104	22
CRA6_TAG	219	247	28
CRA7_TAG	678	686	8
CRA7rs	200	199	-1
CRA8_Fiord	1 714	1 714	—
CRA8_TAG	7 223	7 260	37
CRA8rs	233	233	—
CRA9_TAG	127	127	—
Total	35 418	35 564	146

Table 15: Comparison of the number of records by recapture year in the new tag data extract with the number of records in the extract for the 2021 CRA 7&8 stock assessment (Starr et al. 2022), i.e., the next most recent red rock lobster stock assessment.

Calendar year	Previous	Current	Difference	Calendar year	Previous	Current	Difference
1966	53	53	—	1997	2 562	2 555	-7
1967	28	28	—	1998	2 945	2 944	-1
1968	7	7	—	1999	2 486	2 486	—
1969	2	2	—	2000	1 585	1 585	—
1971	1	1	—	2001	1 377	1 377	—
1975	115	115	—	2002	1 572	1 571	-1
1976	1 268	1 268	—	2003	1 121	1 121	—
1977	2 091	2 091	—	2004	2 079	2 079	—
1978	886	886	—	2005	2 389	2 386	-3
1979	1 081	1 081	—	2006	975	975	—
1980	1 112	1 112	—	2007	481	481	—
1981	593	593	—	2008	366	366	—
1982	332	332	—	2009	304	304	—
1983	273	273	—	2010	237	237	—
1984	1 071	1 071	—	2011	548	548	—
1985	394	394	—	2012	425	425	—
1986	76	76	—	2013	510	510	—
1987	18	18	—	2014	777	778	1
1988	4	4	—	2015	875	875	—
1989	2	2	—	2016	524	525	1
1991	1	1	—	2017	565	565	—
1992	1	1	—	2018	362	362	—
1994	39	39	—	2019	145	202	57
1995	72	72	—	2020	239	254	15
1996	423	423	—	2021	26	110	84
				Total	35 418	35 564	146

Table 16: 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	Proportion recaptured
CRA 1	19 494	2 185	17 309	0.112
CRA 2	29 190	4 877	24 313	0.167
CRA 3	43 866	5 727	38 139	0.131
CRA 4	42 729	3 144	39 585	0.074
CRA 5	43 748	7 551	36 197	0.173
CRA 6	8 812	247	8 565	0.028
CRA 7	11 410	876	10 534	0.077
CRA 8	36 161	10 828	25 333	0.299
CRA 9	6 581	129	6 452	0.020

Table 17: 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	948	1 237	2 185
CRA 2	2 460	2 417	4 877
CRA 3	4 371	1 356	5 727
CRA 4	2 427	717	3 144
CRA 5	5 233	2 318	7 551
CRA 6	57	190	247
CRA 7	420	456	876
CRA 8	5 931	4 897	10 828
CRA 9	34	95	129
Total	21 881	13 683	35 564

Table 18: Number of tags released by QMA (rows) and recaptured by QMA (columns). Note that the row totals are not always the same as in previous tables because some records could not be assigned to a QMA.

Release QMA	Recovery QMA									Total
	CRA 1	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8	CRA 9	
CRA 1	2 155	—	30	—	—	—	—	—	—	2 185
CRA 2	1	4 866	10	—	—	—	—	—	—	4 877
CRA 3	—	14	5 652	8	1	—	—	52	—	5 727
CRA 4	—	—	—	3 137	7	—	—	—	—	3 144
CRA 5	—	—	—	2	7 543	—	6	—	—	7 551
CRA 6	—	—	—	—	—	247	—	—	—	247
CRA 7	—	—	6	—	—	—	834	36	—	876
CRA 8	—	1	121	—	—	—	—	10 703	3	10 828
CRA 9	—	—	—	—	—	—	—	—	129	129
Total	2 155	—	30	—	—	—	—	—	—	2 185

Table 19: Number of tag recaptures by calendar year of release and sex for each statistical area in CRA 2. 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 year	Statistical area of release					Sex		Total
	905	906	907	908	Unknown	Females	Males	
1983	–	190	–	–	–	112	78	190
1984	–	60	–	–	1	36	25	61
1985	–	18	–	–	–	8	10	18
1996	37	748	251	189	–	539	686	1 225
1997	2	396	67	129	–	129	465	594
1998	4	266	21	17	–	71	237	308
1999	1	44	17	6	–	32	36	68
2000	–	2	–	–	–	2	–	2
2001	–	10	–	–	–	8	2	10
2002	18	224	12	23	–	202	75	277
2003	67	460	102	39	–	423	245	668
2004	6	93	23	1	–	63	60	123
2005	2	35	5	6	–	35	13	48
2006	–	1	3	–	–	4	–	4
2007	–	–	3	2	–	4	1	5
2008	5	61	20	66	–	100	52	152
2009	1	14	2	25	2	18	26	44
2010	–	13	2	5	–	17	3	20
2011	–	2	–	1	–	2	1	3
2012	9	–	–	1	–	7	3	10
2014	23	60	103	186	27	207	192	399
2015	–	8	77	65	–	87	63	150
2016	4	42	143	29	1	154	65	219
2017	1	17	72	13	1	66	38	104
2018	1	1	7	3	–	9	3	12
2019	–	–	84	38	1	61	62	123
2020	–	1	29	3	2	19	16	35
2021	–	1	4	–	–	2	3	5
Total	181	2 767	1 047	847	35	2 417	2 460	4 877

Table 20: Number of tag recaptures by calendar year of recapture and sex for each statistical area in CRA 2. 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 year	Statistical area of recapture					Sex		Total
	905	906	907	908	Unknown	Females	Males	
1983	–	3	–	–	–	1	2	3
1984	–	180	–	–	–	101	79	180
1985	–	77	–	–	1	47	31	78
1986	–	8	–	–	–	7	1	8
1996	–	–	2	–	–	–	2	2
1997	14	640	157	202	–	285	728	1 013
1998	20	547	86	84	–	223	514	737
1999	5	206	79	38	–	174	154	328
2000	–	3	–	5	–	4	4	8
2001	3	38	27	–	–	52	16	68
2002	3	63	2	25	–	67	26	93
2003	46	308	21	9	–	226	158	384
2004	34	302	77	9	–	257	165	422
2005	10	136	26	25	–	149	48	197
2006	2	21	12	3	–	36	2	38
2007	–	5	10	7	–	21	1	22
2008	–	34	8	12	–	39	15	54
2009	5	28	5	66	–	49	55	104
2010	1	28	9	15	2	46	9	55
2011	–	10	5	6	–	16	5	21
2012	–	–	–	4	–	4	–	4
2013	–	–	2	–	–	2	–	2
2014	19	43	45	136	23	130	136	266
2015	8	20	82	56	3	79	90	169
2016	6	10	121	56	2	133	62	195
2017	3	43	129	34	–	144	65	209
2018	2	9	16	10	–	30	7	37
2019	–	–	23	1	1	1	24	25
2020	–	4	74	43	3	81	43	124
2021	–	1	29	1	–	13	18	31
Total	181	2 767	1 047	847	35	2 417	2 460	4 877

Table 21: Number of tag releases by sex and release month for CRA 2 by release statistical area and for all of CRA 2.

Release month	Statistical area of release					Sex		Total
	905	906	907	908	Unknown	Females	Males	
Jan	2	30	73	81	1	123	64	187
Feb	7	27	64	30	–	72	56	128
Mar	–	31	8	1	1	21	20	41
Apr	–	78	40	–	–	22	96	118
May	–	166	1	–	–	15	152	167
Jun	1	79	6	141	1	88	140	228
Jul	54	380	75	149	2	303	357	660
Aug	25	352	338	121	10	368	478	846
Sep	63	657	162	200	7	586	503	1089
Oct	16	478	223	76	9	524	278	802
Nov	13	385	35	25	1	207	252	459
Dec	–	104	22	23	3	88	64	152
Total	181	2 767	1 047	847	35	2 417	2 460	4 877

Table 22: Number of tag recaptures by release and recovery statistical areas for CRA 2 releases, summed across all years. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Release statistical area	Recovery statistical area							
	Unknown	904	905	906	907	908	909	Total
Unknown	33	–	–	1	–	1	–	35
905	1	1	169	10	–	–	–	181
906	5	–	29	2 730	2	–	1	2 767
907	1	–	12	–	1 031	2	1	1 047
908	70	–	1	3	13	752	8	847
Total	110	1	211	2 744	1 046	755	10	4 877

Table 23: Number of tag recaptures by release and recovery statistical areas for CRA 2 releases, summed across all years, using a subset of individuals spending at least two years at liberty. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Release statistical area	Recovery statistical area							
	Unknown	904	905	906	907	908	909	Total
Unknown	1	–	–	–	–	1	–	94
905	2	–	87	6	–	–	–	942
906	1	–	14	925	1	–	–	399
907	4	–	7	–	389	1	1	230
908	4	–	–	–	8	215	3	5
Total	12	–	108	931	398	217	4	1 670

Table 24: Days-at-liberty statistics for recaptures of CRA 2 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	23	2	3	68	452	620
	Females	12	6	9	102	575	711
905	Males	25	17	23	308	720	1 053
	Females	156	1	25	374	1 050	3 288
906	Males	1 518	1	7	242	683	2 171
	Females	1 249	1	20	355	1 142	3 350
907	Males	479	1	3	313	765	1 836
	Females	568	1	5	360	1 528	3 006
908	Males	415	1	9	281	690	2 002
	Females	432	1	14	301	1 317	3 099
CRA 2	Males	2 460	1	5	261	722	2 171
	Females	2 417	1	13	350	1 243	3 350

Table 25: Number of tag re-releases in CRA 2, by sex and statistical area of release. Re-release event code= 0 means the first release-recapture event.

Re-release event	Statistical area of release											
	905						CRA 2					
	N	Cum Prop	N	Cum Prop	N	Cum Prop	N	Cum Prop	N	Cum Prop	N	Cum Prop
Males												
0	21	0.84	852	0.56	291	0.61	297	0.72	0	0.00	1 461	0.59
1	4	1.00	339	0.78	94	0.80	74	0.89	17	0.74	528	0.81
2	0	1.00	170	0.90	45	0.90	26	0.96	4	0.91	245	0.91
3	0	1.00	88	0.95	25	0.95	11	0.98	2	1.00	126	0.96
4	0	1.00	38	0.98	14	0.98	4	0.99	0	1.00	56	0.98
5	0	1.00	15	0.99	5	0.99	2	1.00	0	1.00	22	0.99
6	0	1.00	8	0.99	3	1.00	0	1.00	0	1.00	11	1.00
7	0	1.00	3	1.00	1	1.00	0	1.00	0	1.00	4	1.00
8	0	1.00	2	1.00	1	1.00	1	1.00	0	1.00	4	1.00
9	0	1.00	1	1.00	0	1.00	0	1.00	0	1.00	1	1.00
10	0	1.00	1	1.00	0	1.00	0	1.00	0	1.00	1	1.00
11	0	1.00	1	1.00	0	1.00	0	1.00	0	1.00	1	1.00
Females												
0	134	0.86	918	0.73	385	0.68	337	0.78	0	0.00	1 774	0.73
1	18	0.97	219	0.91	104	0.86	68	0.94	11	0.92	420	0.91
2	3	0.99	74	0.97	38	0.93	19	0.98	1	1.00	135	0.96
3	1	1.00	27	0.99	19	0.96	6	1.00	0	1.00	53	0.99
4	0	1.00	9	1.00	10	0.98	2	1.00	0	1.00	21	0.99
5	0	1.00	2	1.00	4	0.99	0	1.00	0	1.00	6	1.00
6	0	1.00	0	1.00	3	0.99	0	1.00	0	1.00	3	1.00
7	0	1.00	0	1.00	3	1.00	0	1.00	0	1.00	3	1.00
8	0	1.00	0	1.00	2	1.00	0	1.00	0	1.00	2	1.00

Table 26: Statistics for tail width growth increments (mm) for recaptures of CRA 2 releases. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Release statistical area	Sex	N	Minimum	5%	Median	95%	Maximum
Unknown	Males	23	-2.00	-1.00	0.00	2.90	19.00
	Females	12	-1.00	-0.45	1.00	5.00	5.00
905	Males	25	-1.00	0.10	5.00	15.50	15.70
	Females	156	-4.00	-0.05	2.00	11.03	20.70
906	Males	1 518	-37.00	-1.00	3.00	12.70	27.70
	Females	1 249	-19.30	-1.30	2.12	10.30	20.70
907	Males	479	-23.00	-0.30	3.00	15.70	26.70
	Females	568	-24.30	-1.00	3.20	14.66	24.70
908	Males	415	-9.30	-0.33	2.40	10.70	18.00
	Females	432	-22.30	-1.30	1.70	10.33	20.50
CRA 2	Males	2 460	-37.00	-1.00	2.82	13.23	27.70
	Females	2 417	-24.30	-1.22	2.30	11.30	24.70

11. FIGURES

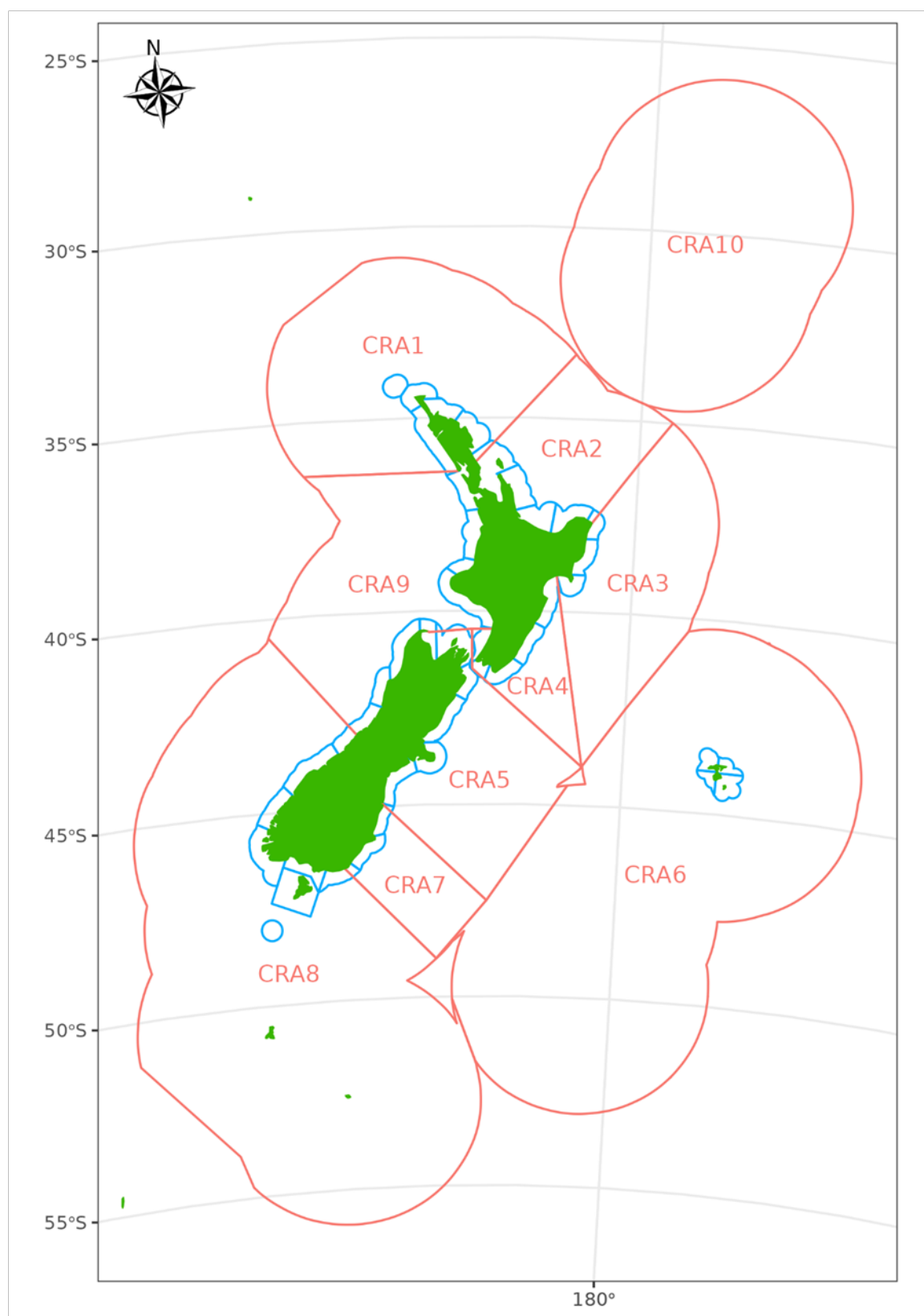


Figure 1: New Zealand red rock lobster Quota Management Area (QMA) boundaries (red lines) and statistical area boundaries (blue lines).

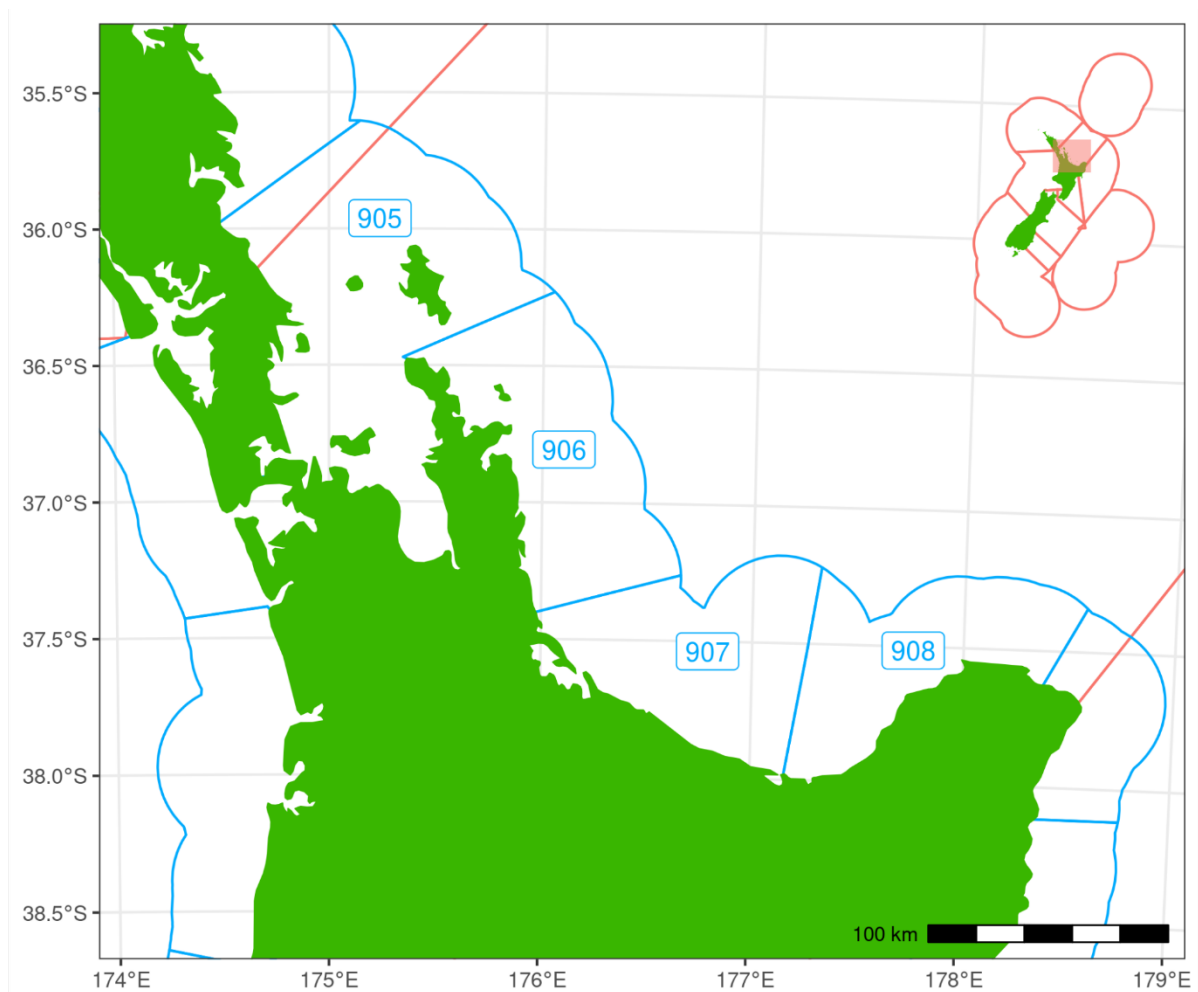


Figure 2: Map of the upper North Island, showing the spatial bounds of CRA 2 and its statistical areas.

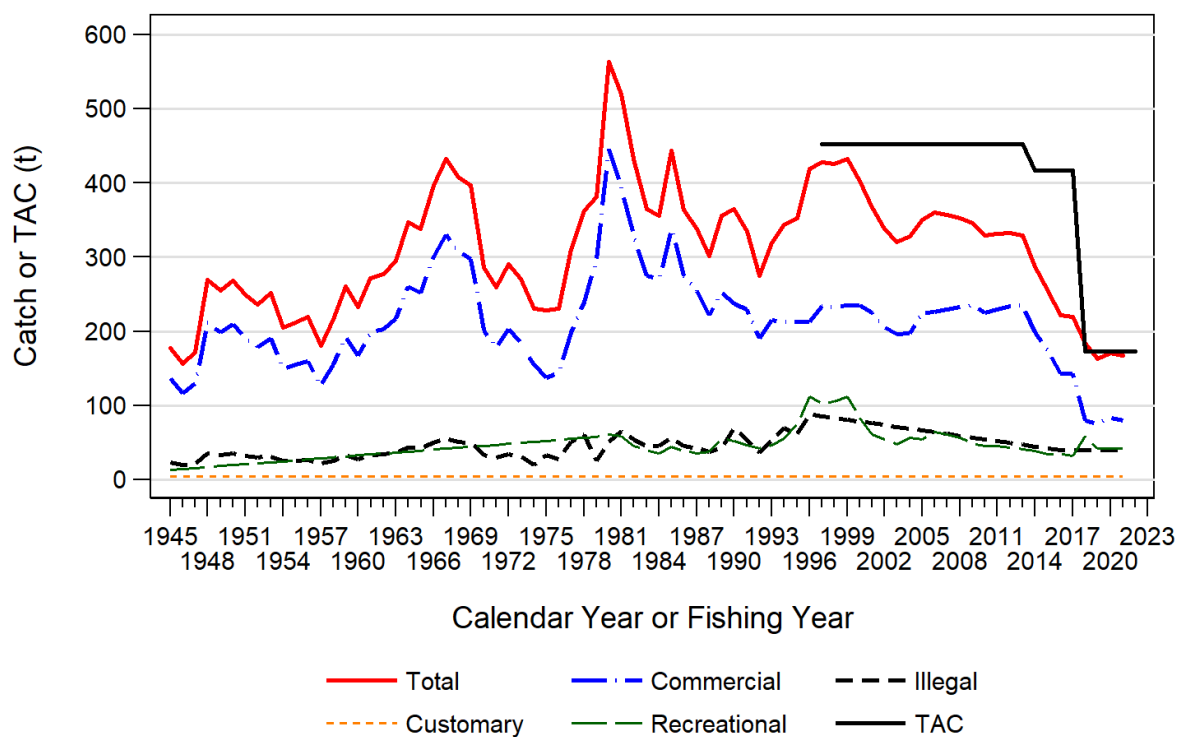


Figure 3: CRA 2 catches by fishery from 1945 to 2021–22. Also showing the TAC from 1996–97 to 2022–23.

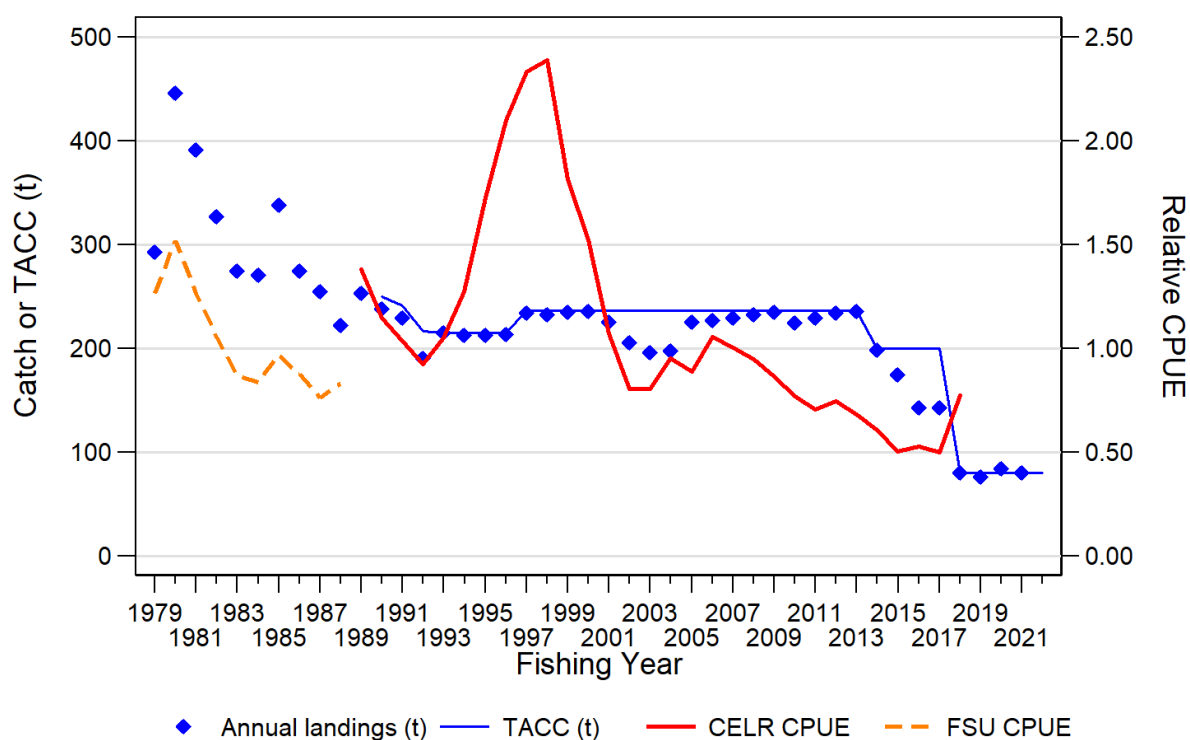


Figure 4: CRA 2 annual commercial catch from 1979 to 2021, TACC from 1990 to 2022, and annual standardised commercial CPUE (FSU: 1979–1988; CELR: 1989–2018) (not used in the stock assessment). Both CPUE series have a geometric mean of 1.

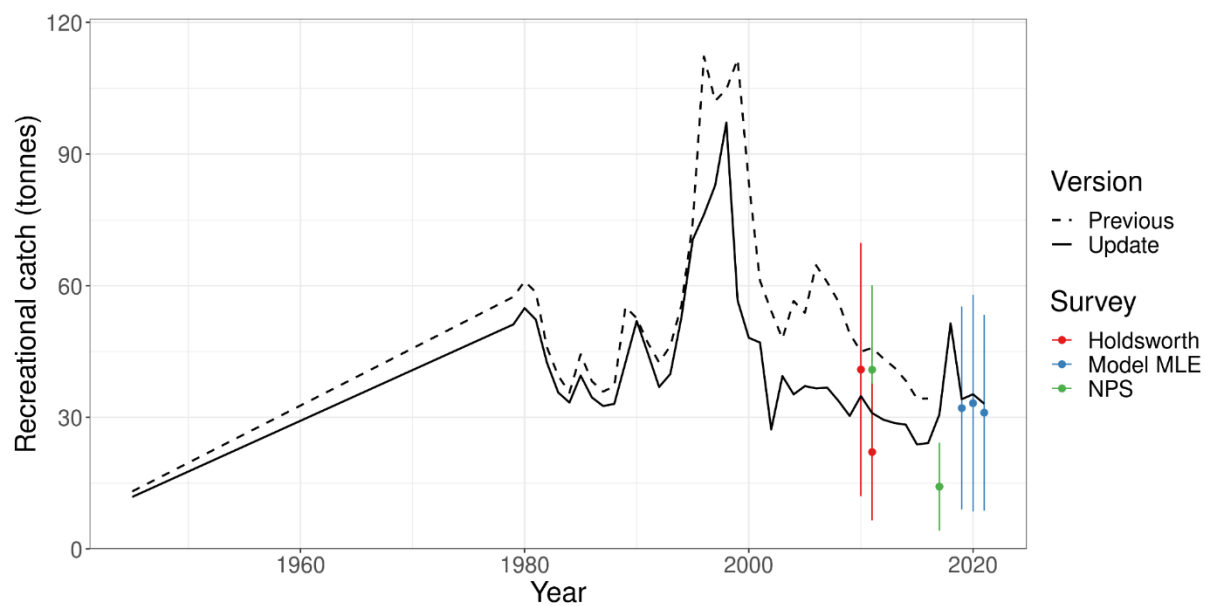


Figure 5: CRA 2 recreational catch (tonnes) trajectory (solid line) based on the SS seasonal CELR CPUE series fitted to four recreational catch surveys (Table 3). Error bars are ± 2 SE, assuming a lognormal distribution. The new series is compared with what was assumed for the 2017 assessment (dashed line).

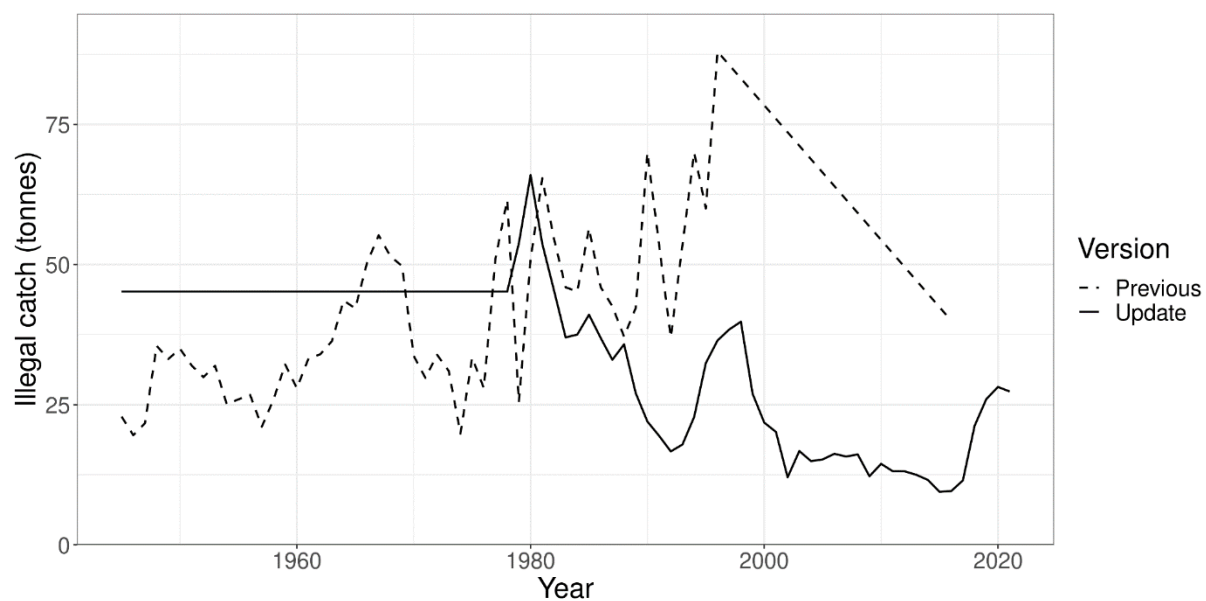


Figure 6: CRA 2 illegal catch (tonnes) trajectory for the 2022 stock assessment (solid line), compared with what was assumed for the 2017 assessment (dashed line).

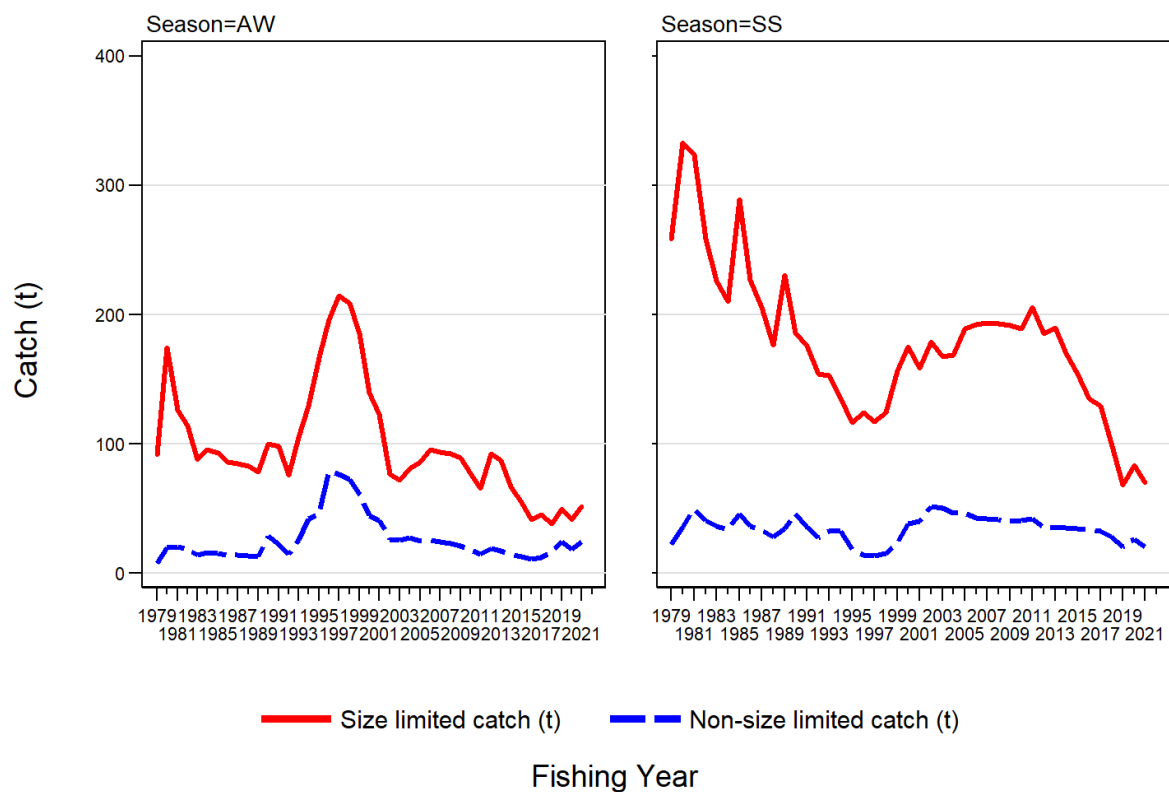


Figure 7: CRA 2 seasonal size limited (SL, solid red line) and non-size limited (NSL, dashed blue line) catches (tonnes).

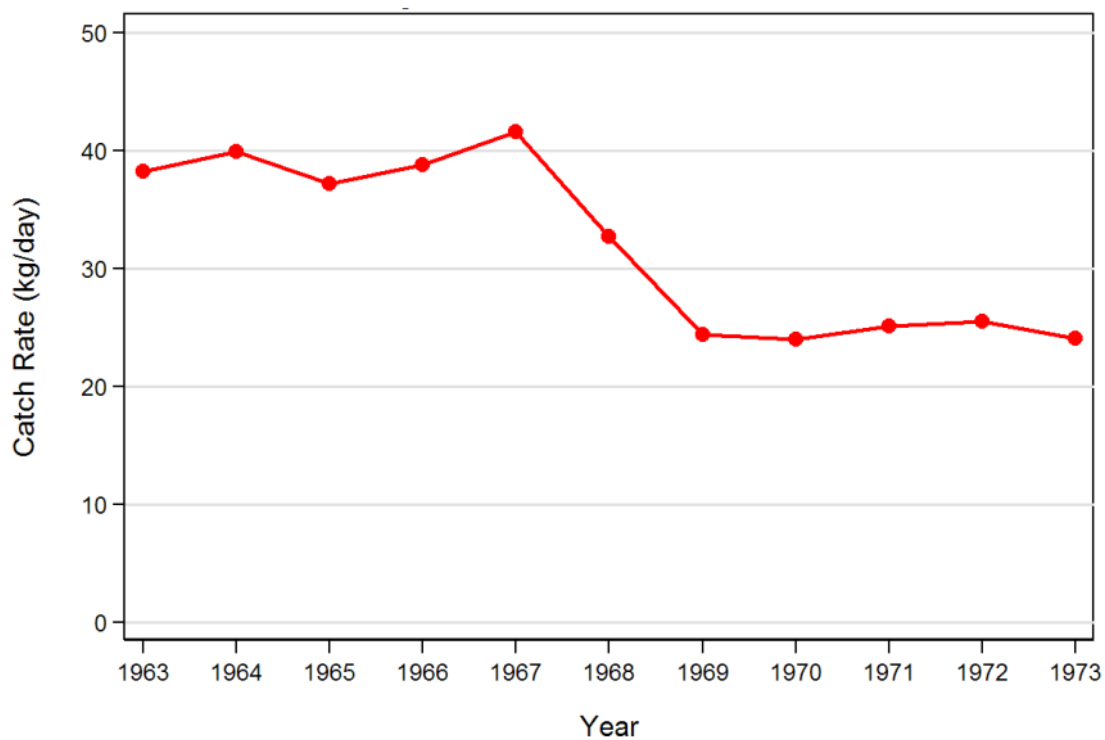


Figure 8: CRA 2 historical catch rate (CR) (kg/day) CPUE series by calendar year from Annala & King (1983).

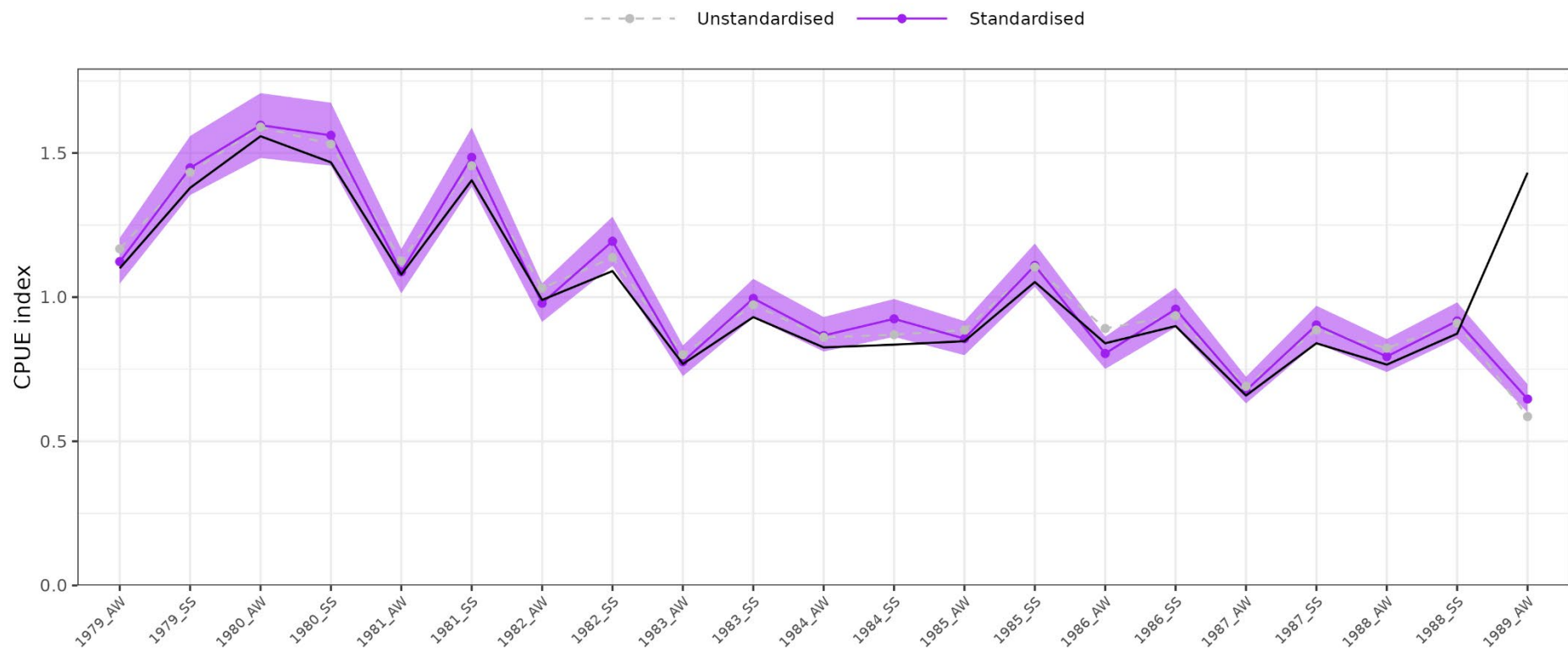


Figure 9: Standardised CPUE indices (kg/potlift) by season and fishing year for CRA 2 FSU. Plot shows the posterior median (points) connected by lines and the 95% credible interval (shaded purple). The FSU CPUE series used in the previous CRA 2 stock assessment is shown as a black line.

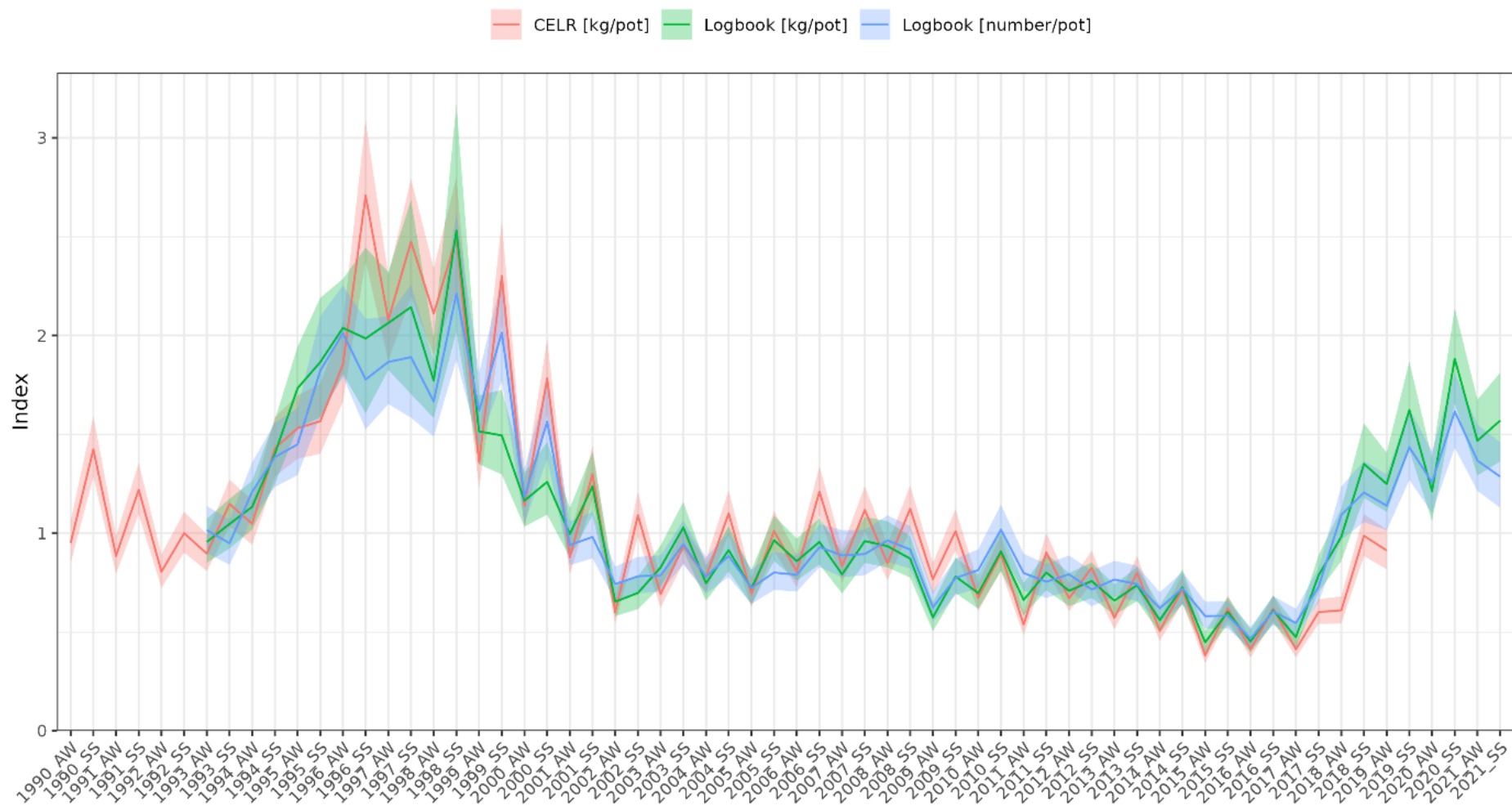


Figure 10: Standardised CPUE indices (kg/potlift) by season and fishing year for CRA 2 from the final CPUE models fitted to CELR data in kg/pot (red), logbook data in kg/pot (green), logbook data in number/pot (blue). Plot shows the posterior medians (lines) and the 95% credible interval (shaded regions).

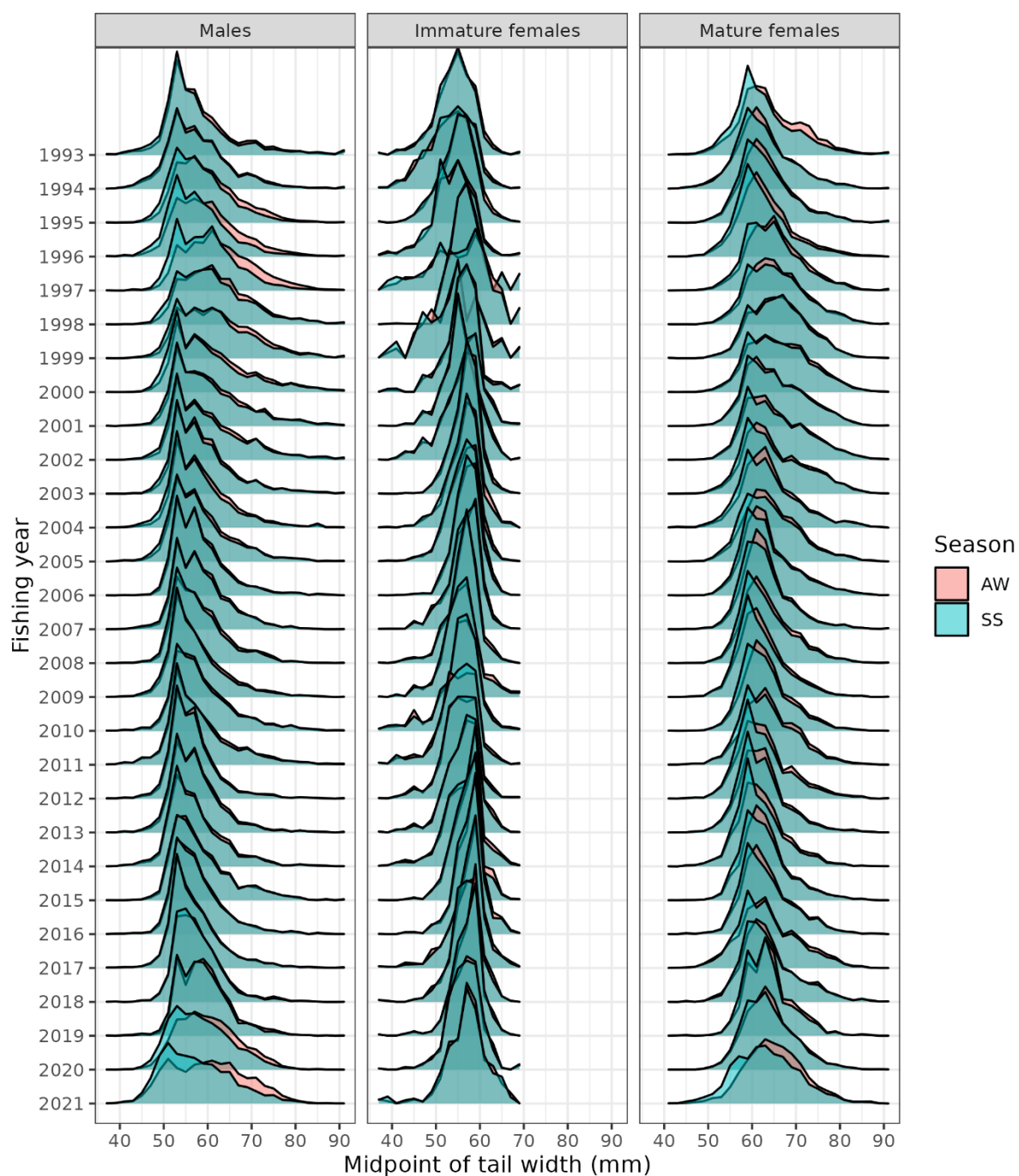


Figure 11: CRA 2 standardised length frequency distributions of the catch, by sex category, fishing year, and season (AW = autumn/winter, SS = spring/summer).

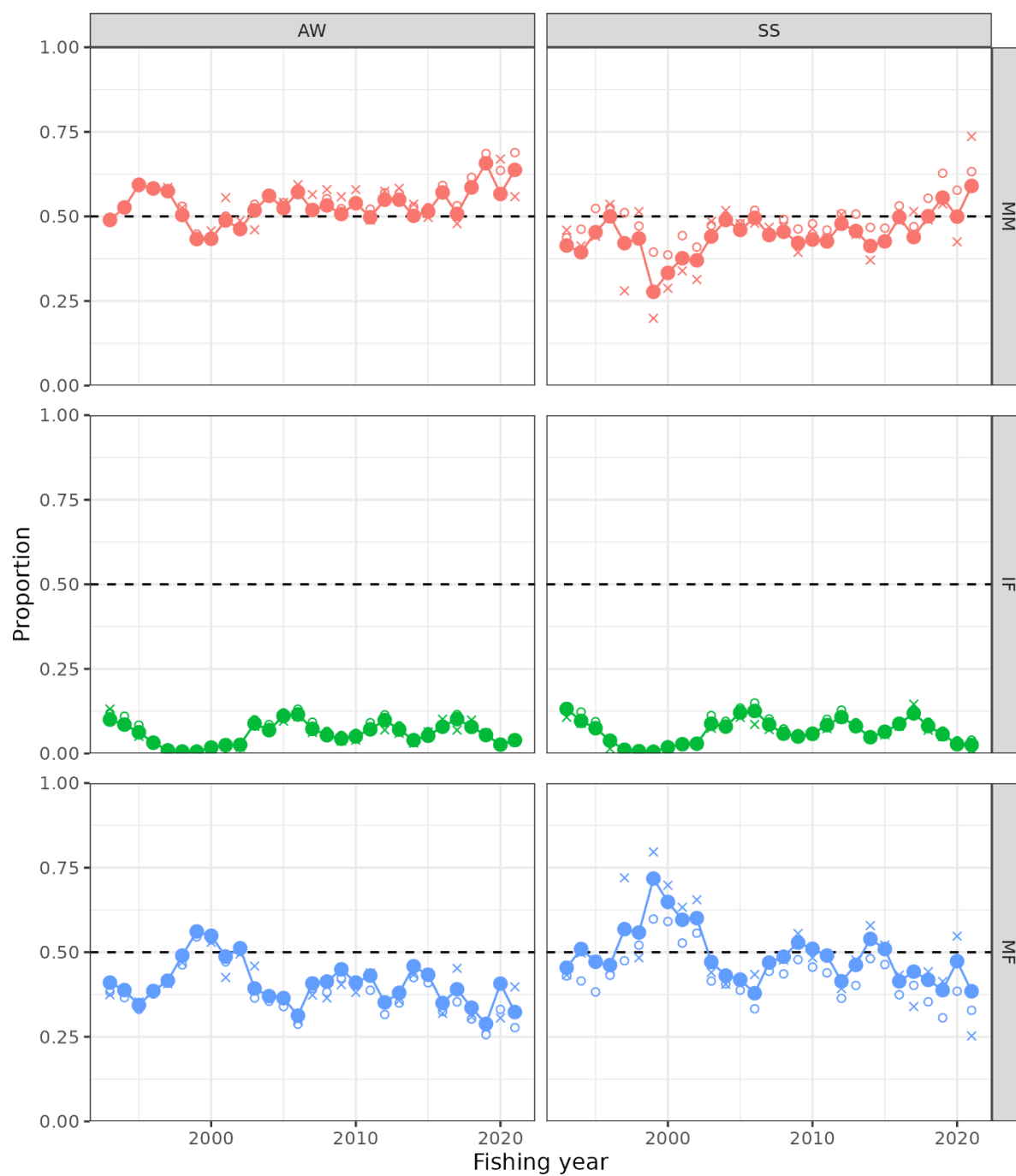


Figure 12: CRA 2 sex ratios (SRs) by fishing year and season, showing raw SRs (crosses), predicted SRs (open circles), and scaled SRs (closed circles) for males (MM), immature females (IF), and mature females (MF). The 95% credible intervals for the scaled proportions are plotted but cannot be seen behind the points.

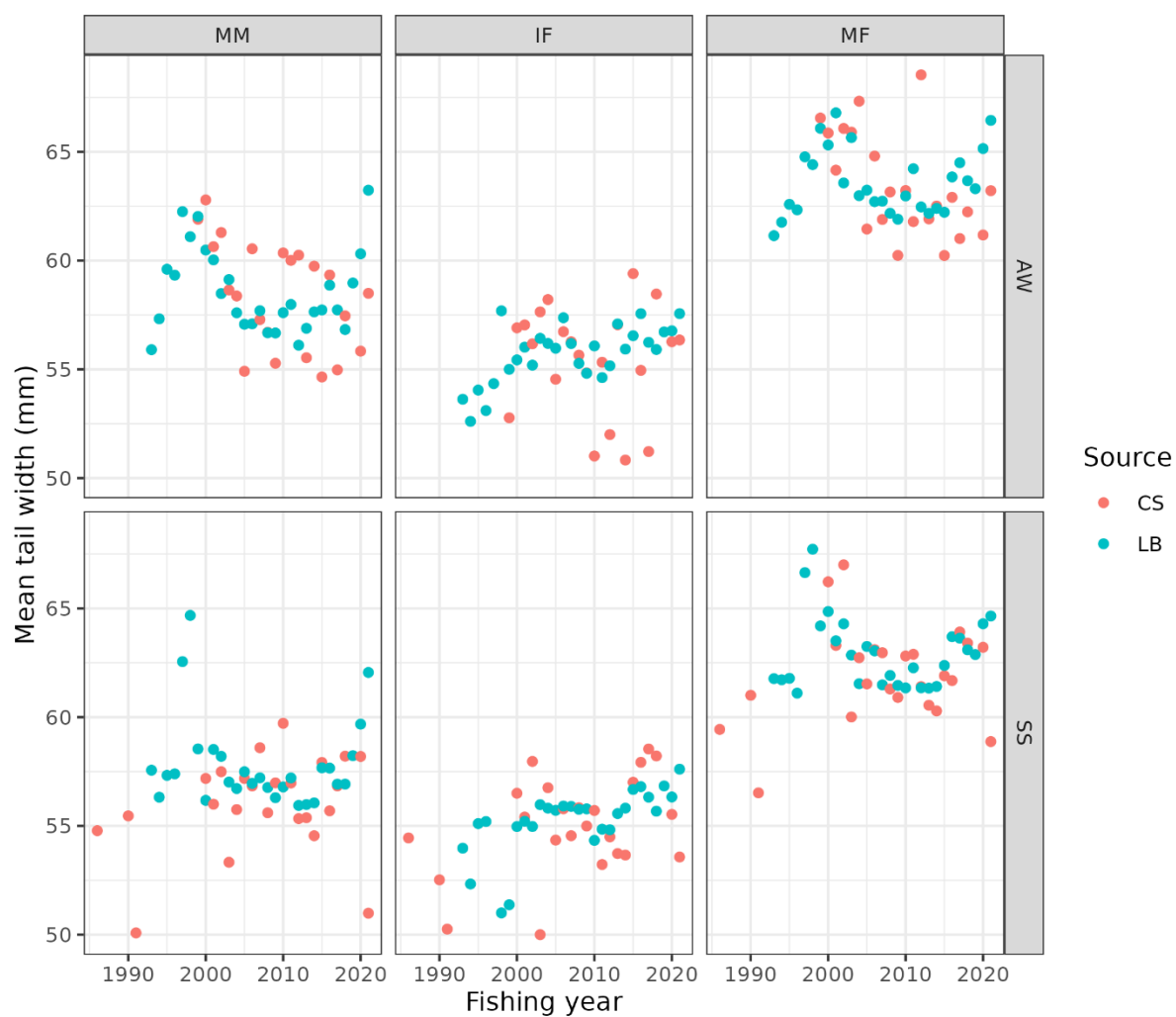


Figure 13: CRA 2 mean tail width (mm) by fishing year, season, sex category, and sampling source.

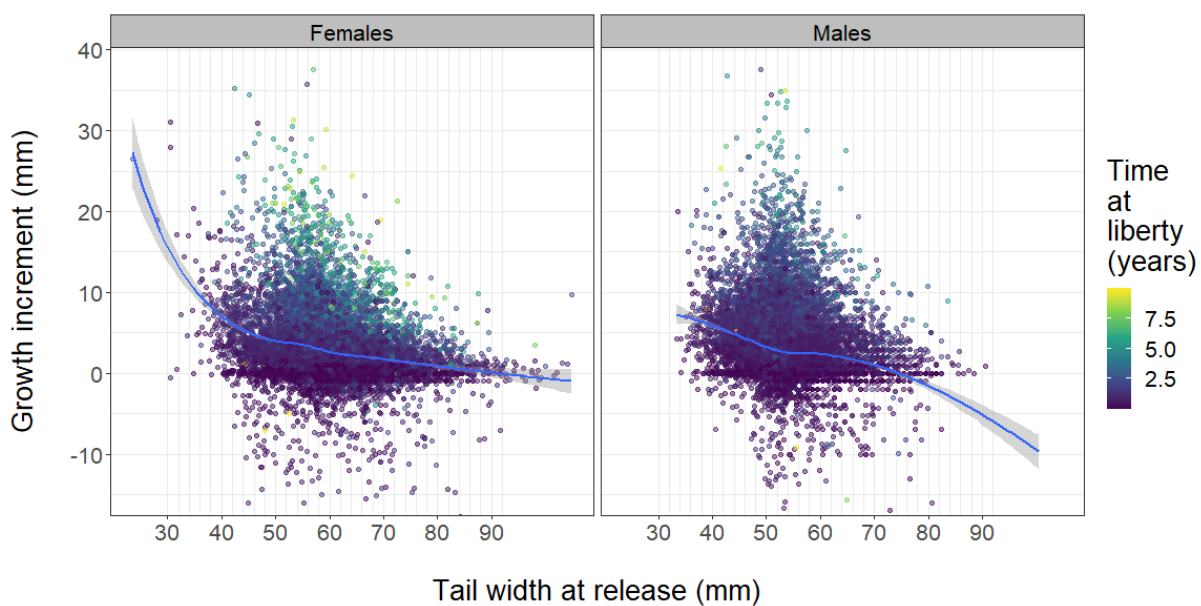


Figure 14: Growth increments (mm) by size at release (mm) and sex for all combined tag recoveries. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

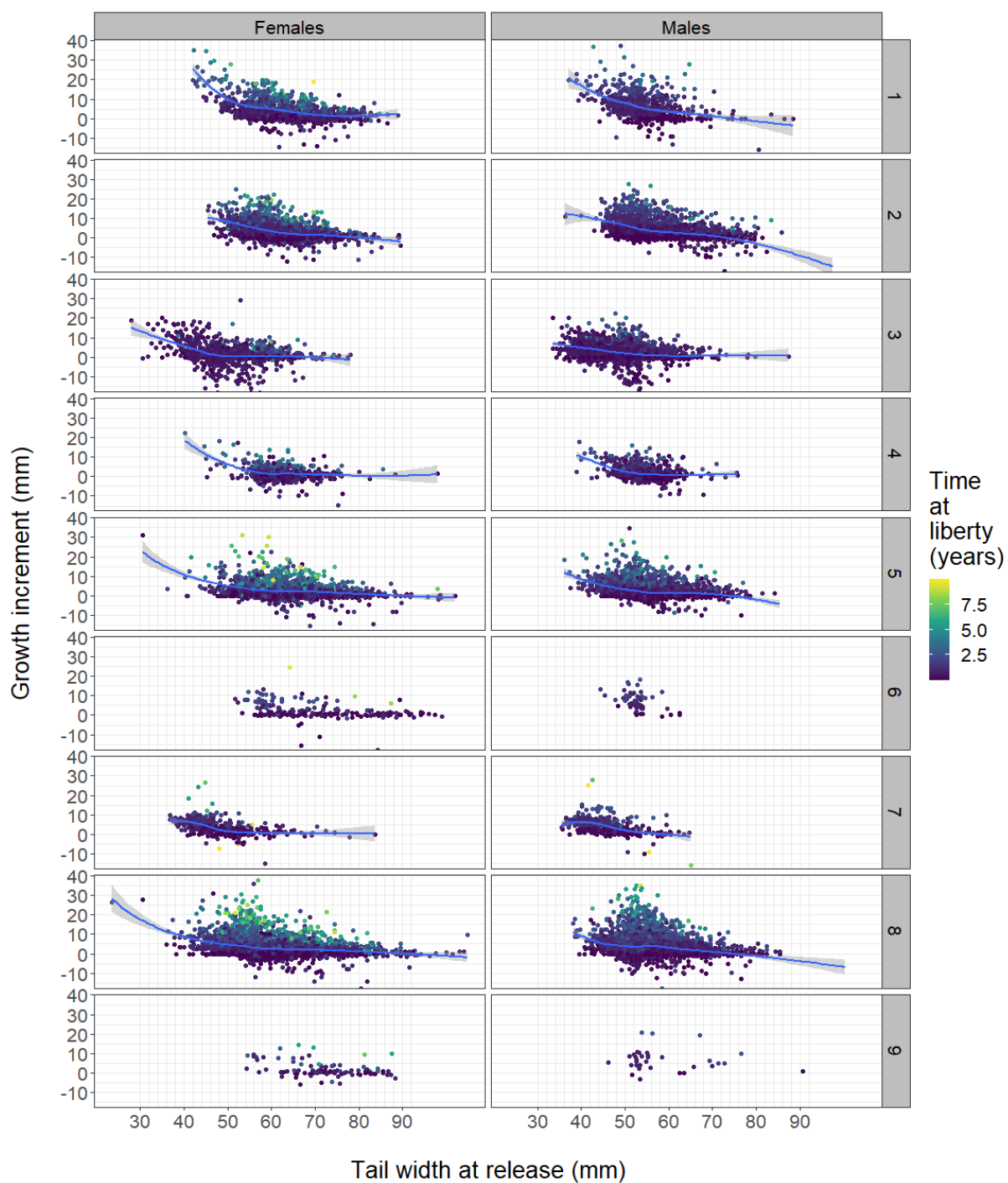


Figure 15: Growth increments (mm) by size at release (mm), sex, and QMA. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.



Figure 16: 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.

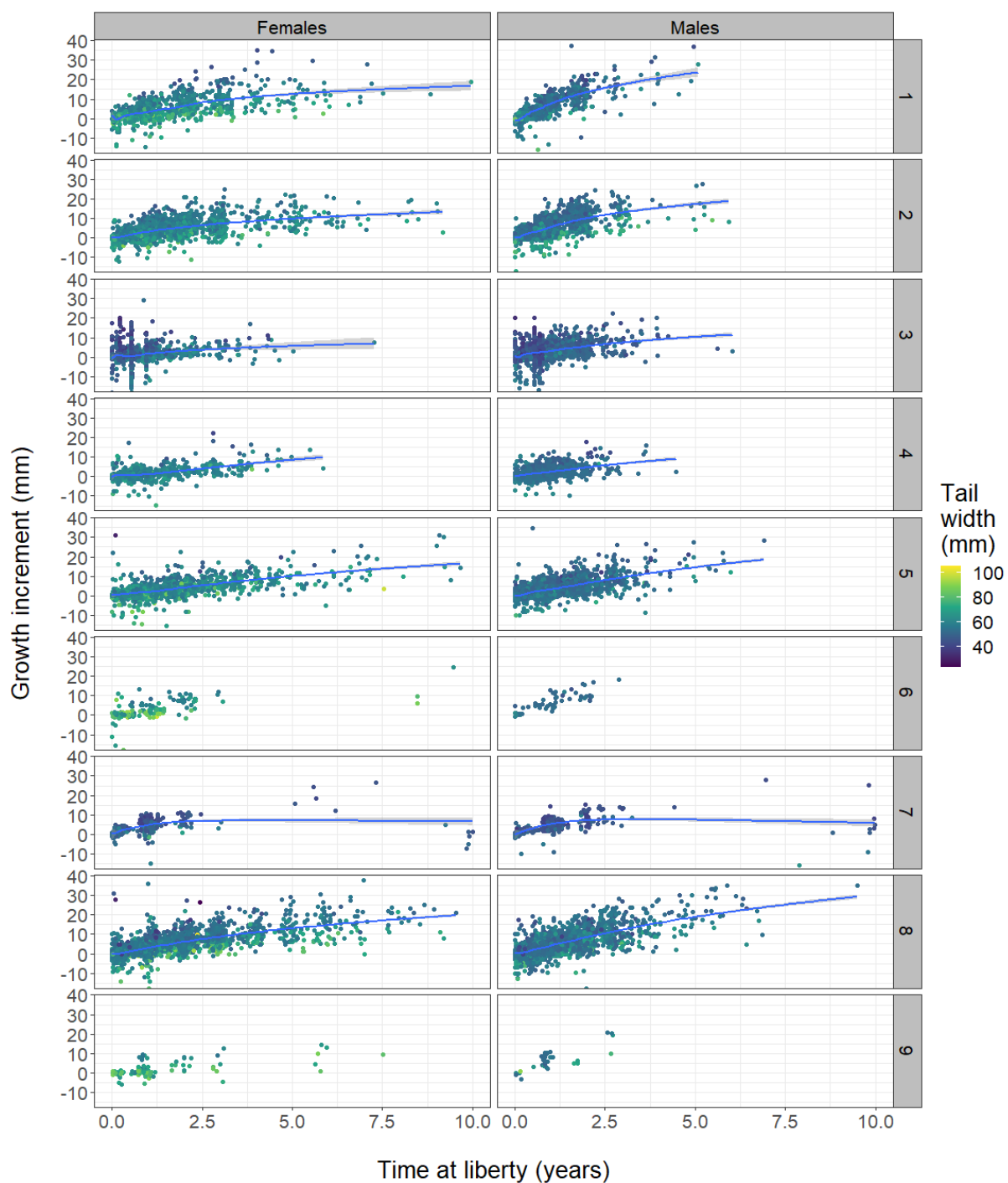


Figure 17: Growth increments (mm) by time at liberty (years), sex, and QMA. The colour of each point represents the size at release (mm). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

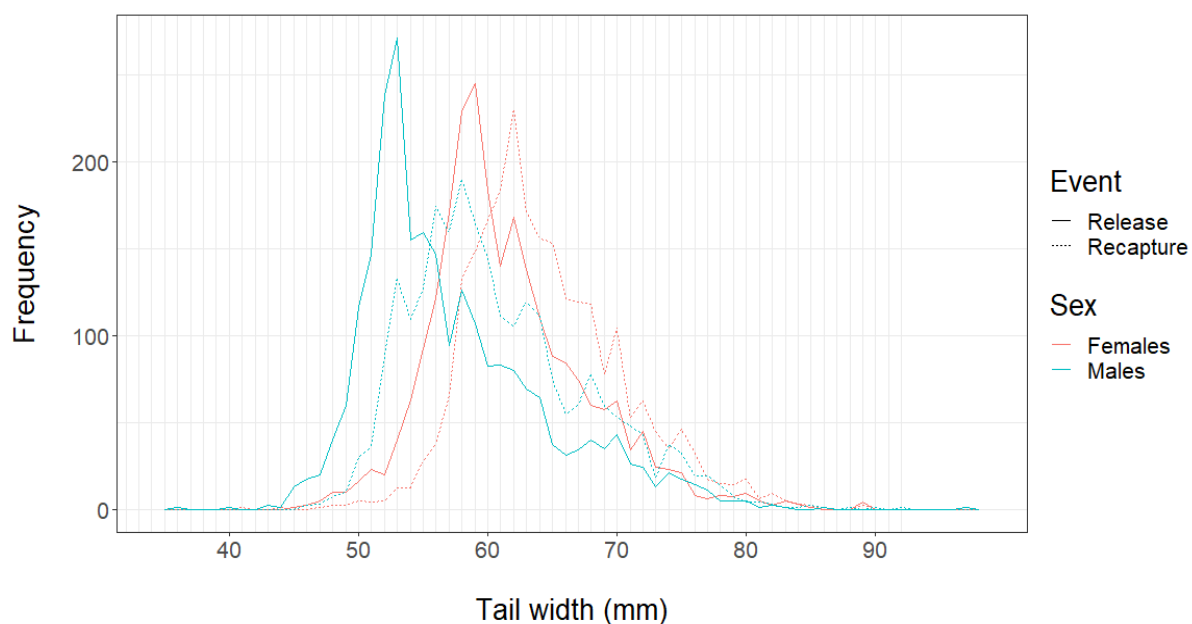


Figure 18: CRA 2 distribution of size at release (solid lines) and recapture (dashed lines) by sex. A bin width of 1 mm was used.

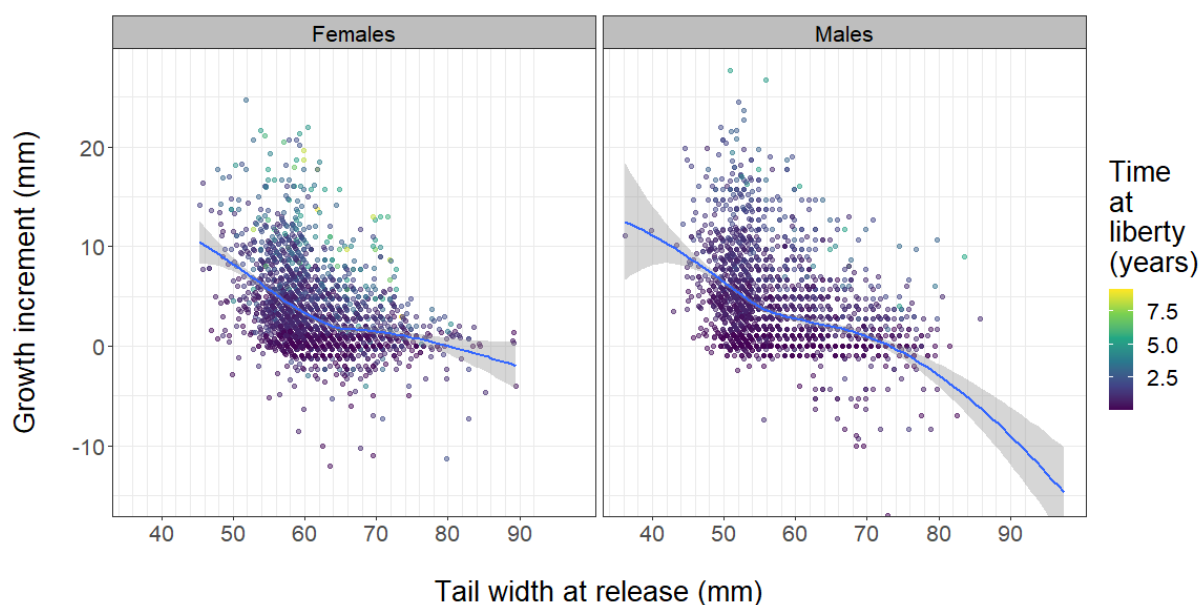


Figure 19: Growth increments (mm) by size at release (mm) and sex for all tags included in the CRA 2 stock assessment. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) are also shown.

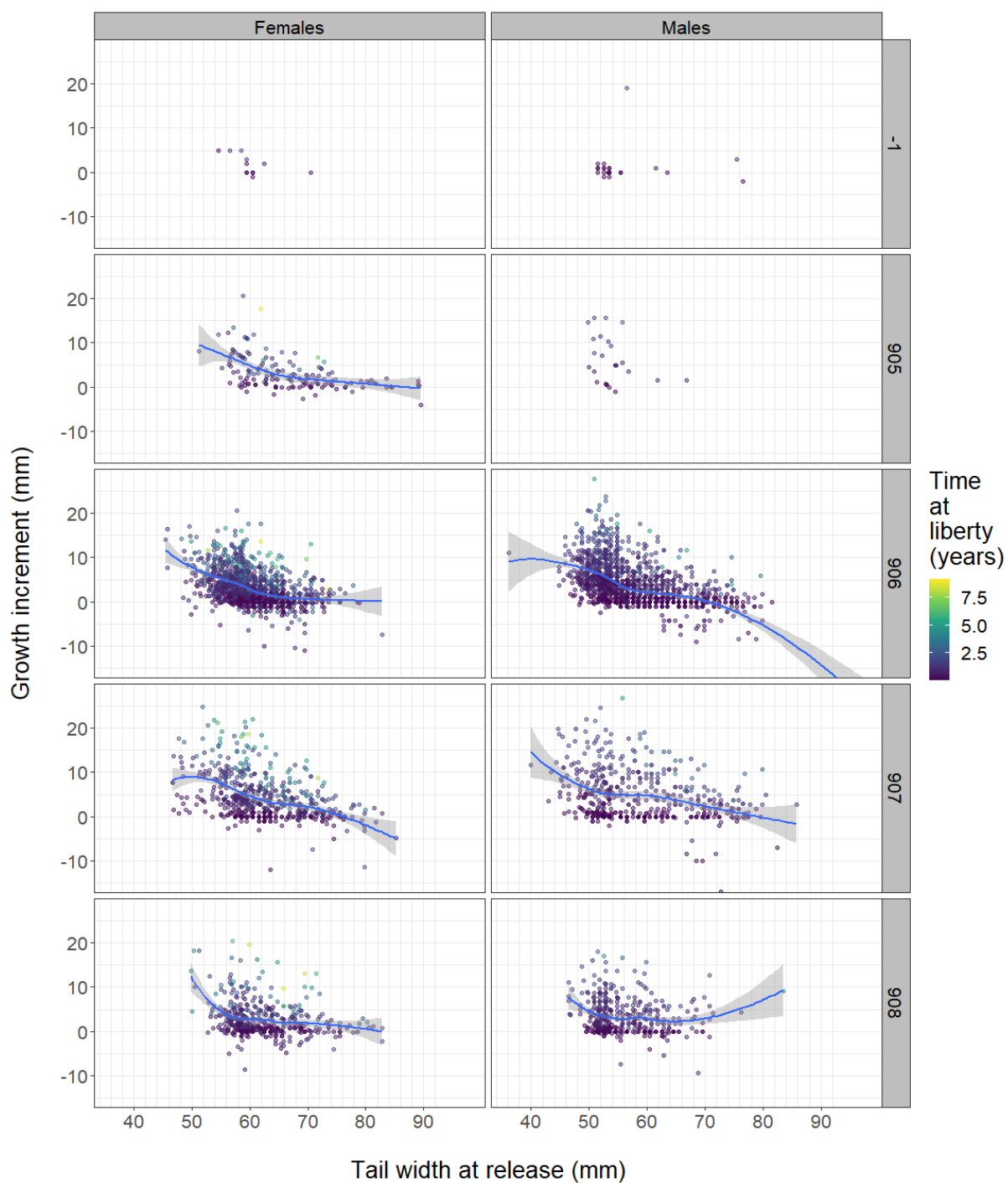


Figure 20: CRA 2 growth increments (mm) by size at release (mm) and sex in each release statistical area of release. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval (grey shading) about this smoother are also shown. -1: unknown statistical area.

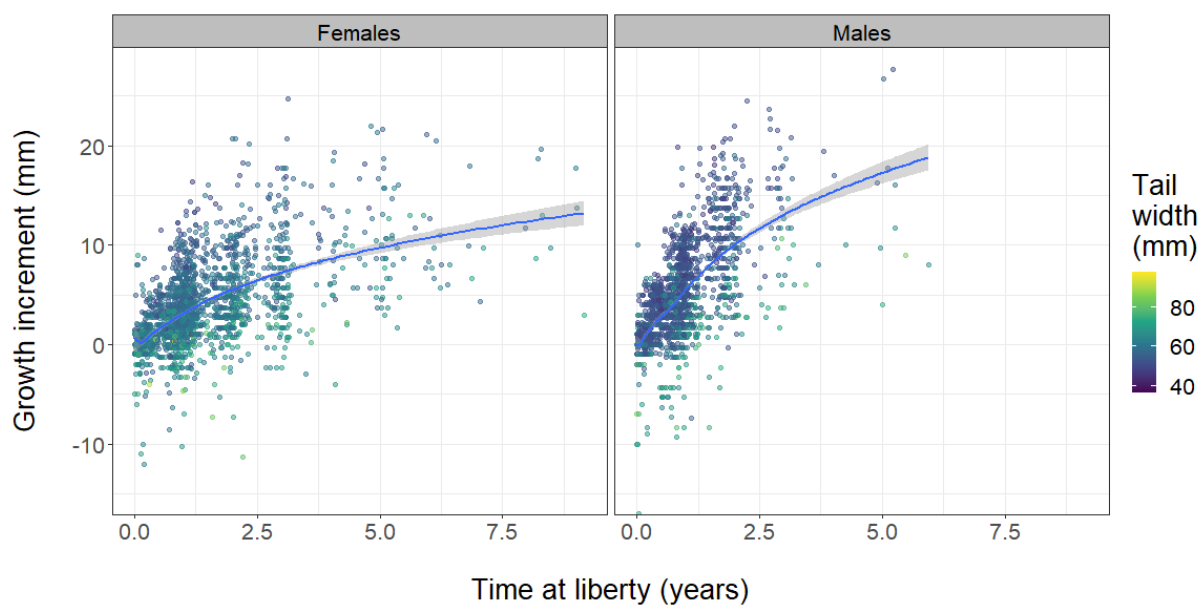


Figure 21: CRA 2 growth increments (mm) by time at liberty (years) and sex for all tags included in the stock assessment. The colour of each point represents the tail width (mm). A loess (blue line) and the 95% confidence interval (grey shading) about this smoother is also shown.

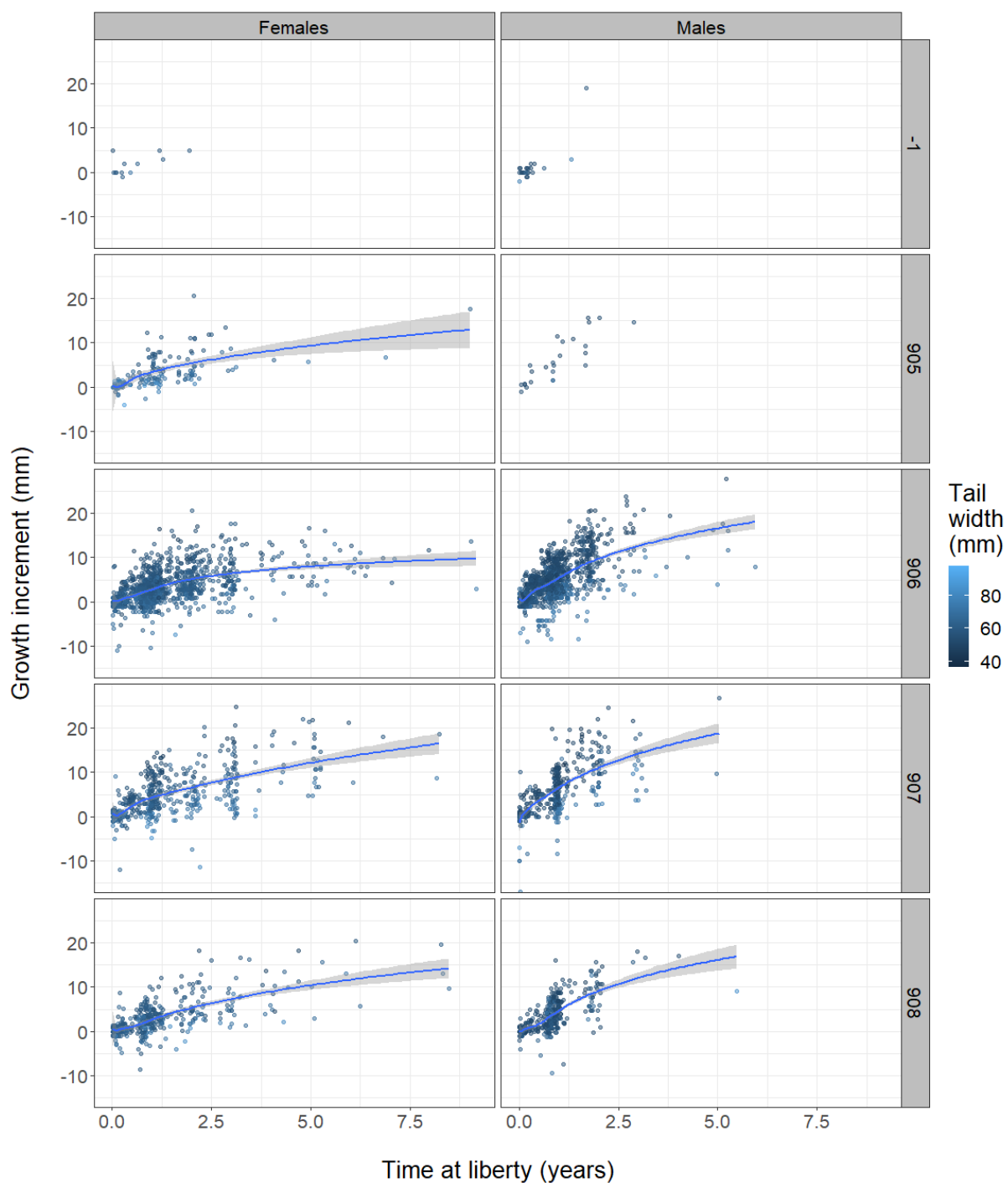


Figure 22: CRA 2 growth increments (mm) by time at liberty (years) and sex in each release statistical area. The colour of each point represents the tail width (mm). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown. -1: unknown statistical area.

Appendix A. Request to Fisheries New Zealand for non-commercial catch estimates



✉ darcy@quantifish.co.nz

🌐 www.quantifish.co.nz

📍 72 Haukore Street
Hairini
Tauranga 3112
New Zealand

☎ 021 0233 0163

25 July 2022

RE: non-commercial data request for New Zealand red rock lobster stock assessments in 2022

By email: Clifford.Baird@mpi.govt.nz
Carbon copy: Leyla.Knittweis@mpi.govt.nz
Ian.Tuck@mpi.govt.nz
William.Gibson@mpi.govt.nz
merrillrudd@gmail.com
paul@starrfish.co.nz
pons.maite@gmail.com
jimroberts@gmail.com

Dear Clifford,

Specific Objective 6 in the Fisheries New Zealand contract CRA2022-01 is to:

Carry out full stock assessments for around two rock lobster stocks annually including estimating biomass and sustainable yields, the status of the stock in relation to management reference points, and future projections of stock status as required to support management.

From August through November of this year, the rock lobster stock assessment team will be working on the CRA 2 stock assessment. To complete this objective, the stock assessment team will require estimates of non-commercial catch components for lobsters, including customary, illegal, and recreational catches. The team has no access to customary or illegal catch data. In the past, Fisheries New Zealand provided estimates of illegal catches, but these were highly uncertain and, since 2004, only estimates in response to requests for the stock(s) being assessed in each year have been made available.

The stock assessment cannot ignore the current and historical non-commercial catches because doing so would cause stock productivity to be underestimated. It is likely that the RLWG will

request sensitivity analyses to catch series that are alternatives to the base case non-commercial catches, but the responsibility for providing the base case non-commercial catches lies with Fisheries New Zealand.

The assessment team needs to know the following information for **CRA 2**:

1. the Fisheries New Zealand estimates of current and recent **illegal** catches, historical catch trends, and an appreciation of the uncertainty;
2. the Fisheries New Zealand estimates of current and recent **customary** catches, historical catch trends, and an appreciation of the uncertainty; and
3. the Fisheries New Zealand estimates of current and recent **recreational** catches, historical catch trends, and an appreciation of the uncertainty.

Without these estimates from Fisheries New Zealand, it will not be possible to produce acceptable stock assessments. These Fisheries New Zealand estimates of non-commercial catches are required by COB **5 September 2022**. Can you please confirm your understanding of this written request? To assist the task, I will be happy to answer any questions you may have.

Sincerely,

A handwritten signature in black ink, appearing to read 'D'Arcy Webber'.

D'Arcy Webber

Director / Fisheries Scientist
Quantifish Limited

Appendix B. Analysis of the proportion of mature females in berry

Background

The proportion of mature females with visible eggs (e.g., in berry) is used as input data in the red rock lobster stock assessment models in order to exclude this category of lobsters from the catch in the size-limited (SL) fishery (i.e., the legal commercial and recreational fisheries). For all recent New Zealand red rock lobster stock assessments, including the previous CRA 2 assessment (Webber et al. 2018), it was assumed that all mature females were in berry in the autumn/winter (AW) period, and that none were in berry during spring/summer (SS) season. However, it is likely that the stock assessment model seasons do not perfectly align with the periods that females are in berry. It is also possible that some smaller mature females, based on the presence of setae, may not yet be reproductive, e.g., as is known to be the case for packhorse rock lobster (*Sagmariasus verreauxi*) around New Zealand (Roberts & Webber 2021).

For the new CRA 2 stock assessment, the lobster stock dynamics (LSD) model was modified to allow these proportions to be set to user-defined values between zero (none assumed to be berried) and one (all berried) (Rudd et al. 2023) by year and season. This appendix describes an empirical analysis that estimated the proportion of mature females by year and season that were in berry for use in the stock assessment.

Method and results

This analysis used the voluntary logbook data collected by commercial fishers in CRA 2 to estimate unstandardised proportions of mature females berried for the AW and SS seasons in CRA 2 (Table B.1). The data included all mature female lobsters sampled from 1993–94 to 2021–22 and excluded any lobsters for which the sex was unknown (Table B.2). Berried lobsters were defined as those with ‘Sex’ = ‘4’ (berried female) or ‘5’ (spent female) in the data base. The proportion berried was then calculated as the number of berried females within a given time period (i.e., by season across all fishing years, by season within each fishing year, as well as by individual month) as a proportion of the number of mature females sampled in the respective period (Table B.3). This simple analysis did not account for the relative catch in each time period.

The proportion of mature females in berry varied strongly by fishing month, being below 0.15 in months from November to May, and above 0.85 from June to August (Table B.3). There was also some evidence for variability in the proportion of mature females in berry by fishing year during the autumn/winter period, although some of this variability could have been driven by temporal gaps in sampling, e.g., during April and May, when the proportion berried was generally quite low (Table B.1) or observational variability resulting from sampling variation. Across all fishing years, the overall proportion of mature females that were berried was 0.82 in the AW period, and 0.18 in the SS period (Table B.3).

Implications and future research

The unstandardised values from this empirical analysis (i.e., 82% of mature females were berried in AW and 18% were berried in SS) were assumed by the CRA 2 base case run. These values are likely to be representative of the true catch proportions and an improvement on the previous simplifying assumption of all mature females in berry during the AW and none in the SS. However, there were gaps in the logbook coverage for some fishing year-month combinations, particularly in the period Dec–May, when the proportion berried was low, that could bias the resulting values relative to the true values from the entire catch (Table B.1).

This could be addressed by using a model-based approach to estimate standardised values of the proportions of mature females berried by season, weighted by the catch in each time period. This could

also allow the estimation of year-specific values for each season, which could be included in future model runs, and would also allow the evaluation of potential changes in reproductive biology over time.

Given the large difference in the empirical values derived from this analysis compared with the assumption made by all previous red rock lobster stock assessments and the effect this change had on the CRA 2 stock assessment (Rudd et al. 2023), it is recommended that future stock assessments of other New Zealand red rock lobster stocks should also include this provision, assuming that appropriate data are available.

Table B.1: Logbook: Number of pots on which lobsters were measured by fishing year, season, and month. An en dash (–) indicates that no logbook sampling occurred in that respective year-month combination.

Fishing year	AW							SS						
	Apr	May	Jun	Jul	Aug	Sep	Apr-Sep	Oct	Nov	Dec	Jan	Feb	Mar	Oct-Mar
1993	–	–	35	464	537	477	1 513	534	338	265	223	67	15	1 442
1994	20	15	209	680	649	453	2 026	573	169	75	30	33	–	880
1995	5	24	158	457	506	359	1 509	280	7	–	–	–	–	287
1996	16	101	175	653	346	240	1 531	91	22	–	–	–	–	113
1997	46	27	131	569	299	222	1 294	50	–	–	–	–	–	50
1998	24	67	187	463	326	328	1 395	31	32	25	–	–	–	88
1999	–	2	62	608	479	502	1 653	336	6	–	–	–	–	342
2000	43	64	59	279	463	436	1 344	490	115	–	–	2	–	607
2001	26	16	40	106	96	241	525	290	224	49	28	81	109	781
2002	71	19	29	289	290	259	957	543	183	64	32	72	69	963
2003	28	2	8	111	171	220	540	345	221	132	160	79	58	995
2004	49	24	39	246	162	178	698	307	226	110	122	94	77	936
2005	31	25	4	94	278	298	730	475	311	156	227	205	93	1 467
2006	7	–	5	302	292	246	852	399	164	92	121	79	14	869
2007	1	–	–	86	289	249	625	408	265	160	133	140	44	1 150
2008	9	–	–	120	336	329	794	475	349	166	231	89	46	1 356
2009	–	–	7	137	168	275	587	529	323	258	220	47	10	1 387
2010	5	–	5	150	226	218	604	521	379	286	277	209	106	1 778
2011	–	–	3	116	224	319	662	380	323	278	233	147	51	1 412
2012	–	–	5	181	302	295	783	434	412	312	208	76	11	1 453
2013	10	2	38	265	248	309	872	574	411	293	246	50	34	1 608
2014	2	–	12	265	196	254	729	481	379	268	202	37	40	1 407
2015	7	4	14	221	250	187	683	315	362	225	163	29	31	1 125
2016	–	–	1	37	65	105	208	271	183	172	120	45	6	797
2017	5	–	5	106	157	176	449	237	159	119	110	37	1	663
2018	5	10	–	23	107	138	283	245	71	43	42	–	11	412
2019	61	15	9	80	108	170	443	110	57	12	72	–	–	251
2020	3	9	–	45	96	213	366	336	167	51	25	–	–	579
2021	136	36	14	50	40	143	419	111	68	30	93	21	1	324
Overall	610	462	1 254	7 203	7 706	7 839	25 074	10 171	5 926	3 641	3 318	1 639	827	25 522

Table B.2: Logbook: Number of mature female lobsters measured by fishing year, season, and month. An en dash (–) indicates that no logbook sampling occurred in that respective year-month combination.

Fishing year	AW							SS						
	Apr	May	Jun	Jul	Aug	Sep	Apr-Sep	Oct	Nov	Dec	Jan	Feb	Mar	Oct-Mar
1993	–	–	66	1 035	1 518	1 316	3 935	1 474	710	473	468	144	19	3 288
1994	33	26	499	1 670	1 657	1 047	4 932	1 919	440	151	49	67	–	2 626
1995	10	42	375	1 003	1 152	918	3 500	823	16	–	–	–	–	839
1996	24	238	442	2 052	1 002	749	4 507	267	47	–	–	–	–	314
1997	119	43	304	1 689	742	776	3 673	144	–	–	–	–	–	144
1998	63	162	445	1 431	829	1 165	4 095	104	49	66	–	–	–	219
1999	–	3	138	1 516	1 206	1 823	4 686	1 304	18	–	–	–	–	1 322
2000	161	140	146	673	1 118	1 249	3 487	1 430	343	–	–	2	–	1 775
2001	55	38	89	251	189	663	1 285	739	527	111	56	161	177	1 771
2002	148	28	99	741	674	601	2 291	1 497	343	156	46	118	128	2 288
2003	40	2	10	209	300	519	1 080	770	430	270	445	141	84	2 140
2004	66	34	67	543	309	424	1 443	689	439	202	205	162	131	1 828
2005	52	41	5	173	565	651	1 487	1 054	523	244	434	420	158	2 833
2006	14	–	5	493	501	420	1 433	813	305	157	242	132	20	1 669
2007	1	–	–	173	579	520	1 273	1 007	516	355	340	301	78	2 597
2008	19	–	–	242	696	629	1 586	1 108	690	297	540	148	82	2 865
2009	–	–	7	227	281	545	1 060	1 325	722	510	571	74	17	3 219
2010	7	–	10	301	444	440	1 202	1 295	871	603	618	437	227	4 051
2011	–	–	6	202	468	700	1 376	844	600	488	441	280	73	2 726
2012	–	–	6	302	545	644	1 497	937	727	573	367	103	20	2 727
2013	20	2	71	453	441	640	1 627	1 216	928	548	464	115	60	3 331
2014	5	–	16	486	326	528	1 361	1 087	668	467	389	64	51	2 726
2015	8	5	21	395	447	319	1 195	502	611	367	270	43	35	1 828
2016	–	–	1	50	89	176	316	476	257	250	214	62	9	1 268
2017	6	–	5	145	229	303	688	358	243	169	160	67	1	998
2018	5	13	–	29	186	359	592	639	124	88	82	–	22	955
2019	103	21	24	179	161	316	804	184	138	21	218	–	–	561
2020	6	19	–	66	154	537	782	913	415	83	75	–	–	1 486
2021	240	62	43	144	89	322	900	293	173	77	207	41	1	792
Overall	1 205	919	2 900	16 873	16 897	19 299	58 093	25 211	11 873	6 726	6 901	3 082	1 393	55 186

Table B.3: Logbook: proportion of mature females that were in berry (i.e., carrying eggs of spent) measured by fishing year, season, and month. An en dash (–) indicates that no logbook sampling occurred in that respective year-month combination. The bolded values were used by the CRA 2 stock assessment.

Fishing year	AW							SS						
	Apr	May	Jun	Jul	Aug	Sep	Apr-Sep	Oct	Nov	Dec	Jan	Feb	Mar	Oct-Mar
1993	–	–	0.970	0.938	0.904	0.793	0.877	0.465	0.372	0.135	0.241	0.465	0.000	0.363
1994	0.000	0.038	0.932	0.971	0.955	0.780	0.910	0.386	0.193	0.437	0.102	0.000	–	0.341
1995	0.000	0.143	0.827	0.970	0.977	0.828	0.907	0.508	0.938	–	–	–	–	0.516
1996	0.000	0.172	0.876	0.992	0.980	0.868	0.909	0.768	0.064	–	–	–	–	0.662
1997	0.000	0.093	0.908	0.996	0.961	0.584	0.852	0.229	–	–	–	–	–	0.229
1998	0.000	0.093	0.807	0.987	0.896	0.492	0.758	0.010	0.000	0.000	–	–	–	0.005
1999	–	0.000	0.804	0.976	0.951	0.668	0.844	0.278	0.000	–	–	–	–	0.275
2000	0.006	0.029	0.623	0.975	0.978	0.660	0.765	0.403	0.376	–	–	0.000	–	0.398
2001	0.000	0.158	0.865	0.964	0.942	0.641	0.722	0.093	0.004	0.000	0.000	0.050	0.006	0.045
2002	0.000	0.071	0.859	0.957	0.926	0.772	0.822	0.371	0.187	0.006	0.000	0.000	0.023	0.273
2003	0.000	0.000	0.500	0.885	0.870	0.520	0.668	0.222	0.079	0.007	0.002	0.000	0.000	0.097
2004	0.000	0.000	0.896	0.961	0.958	0.726	0.822	0.266	0.057	0.000	0.000	0.000	0.000	0.114
2005	0.000	0.195	1.000	0.954	0.906	0.550	0.705	0.162	0.017	0.004	0.000	0.000	0.000	0.064
2006	0.000	–	1.000	0.961	0.950	0.614	0.846	0.220	0.023	0.000	0.000	0.000	0.000	0.111
2007	0.000	–	–	0.948	0.945	0.633	0.817	0.174	0.099	0.003	0.000	0.000	0.000	0.087
2008	0.000	–	–	0.901	0.904	0.727	0.822	0.262	0.059	0.003	0.000	0.000	0.000	0.116
2009	–	–	1.000	0.974	0.943	0.794	0.874	0.321	0.039	0.004	0.000	0.000	0.000	0.141
2010	0.000	–	0.600	0.934	0.955	0.527	0.785	0.258	0.098	0.035	0.005	0.062	0.286	0.132
2011	–	–	1.000	0.946	0.929	0.513	0.720	0.289	0.098	0.002	0.005	0.000	0.000	0.112
2012	–	–	0.833	0.980	0.958	0.472	0.753	0.128	0.034	0.007	0.003	0.000	0.000	0.055
2013	0.000	0.000	0.746	0.960	0.923	0.605	0.788	0.243	0.034	0.015	0.000	0.000	0.000	0.101
2014	0.000	–	0.750	0.928	0.908	0.519	0.759	0.179	0.055	0.011	0.005	0.000	0.000	0.088
2015	0.000	0.000	0.905	0.947	0.924	0.878	0.909	0.386	0.185	0.134	0.278	0.070	0.200	0.241
2016	–	–	1.000	0.900	0.876	0.511	0.677	0.155	0.214	0.148	0.173	0.145	0.000	0.167
2017	0.000	–	1.000	0.986	0.952	0.601	0.797	0.240	0.111	0.195	0.238	0.343	0.000	0.207
2018	0.000	0.000	–	0.966	0.882	0.838	0.833	0.574	0.379	0.011	0.268	–	0.000	0.458
2019	0.000	0.000	0.875	0.955	0.938	0.851	0.761	0.543	0.254	0.000	0.459	–	–	0.419
2020	0.000	0.000	–	1.000	0.987	0.585	0.680	0.212	0.147	0.000	0.000	–	–	0.172
2021	0.004	0.032	0.907	1.000	0.966	0.745	0.569	0.212	0.006	0.000	0.029	0.000	0.000	0.087
Overall	0.002	0.097	0.853	0.969	0.941	0.667	0.821	0.298	0.112	0.044	0.059	0.044	0.055	0.177

Appendix C. Sea surface temperature analysis

Background

Previous stock assessments of New Zealand red rock lobster have trialled the inclusion of annual puerulus settlement indices as a covariate of model estimated annual recruitment deviations (e.g., Webber et al. 2022). This step was made to predict annual recruitment strength several years in advance of the fishery data being informative, given that it typically takes at least four years for newly settled pueruli to recruit to the fishery (Roberts & Webber 2022). However, the available puerulus settlement indices (Forman et al. 2022) have not been found to correspond well with the fishery-based recruitment information, given stock assessment model estimates of size-based growth and natural mortality. This has resulted in the cessation of using puerulus indices the base case model runs for any assessed New Zealand stock (Rudd et al. 2021a, Webber et al. 2020, 2021, 2022). Furthermore, long-running, ongoing puerulus settlement indices are not available for all the assessed stocks, including CRA 2, as well as CRA 1 and CRA 6.

Breen & Starr (2010) assessed the correlation of assessment recruitment deviates for the CRA 3, CRA 4, CRA 5, CRA 7, and CRA 8 with coastal sea surface temperature (SST), southern oscillation index (SOI), Kidson weather type, and other climate indices. Breen & Starr (2010) did not identify any conclusive predictors of recruitment, given the available data, although relatively strong correlations (Spearman correlation coefficient of < -0.5 for CRA 3, and of around 0.5 for CRA 8) were obtained between sea surface temperature (SST) and recruitment to the model (at around 32 mm tail width (TW)) when using short time lags, i.e., relating SST indices from 0 to 1 years prior to recruitment to the model. This implies that the relative recruitment strength may be influenced by processes affecting the mortality of juvenile lobsters sometime after settlement as pueruli. Note that Breen & Starr (2010) did not attempt to relate to recruitment indices for CRA 2.

This Appendix describes an analysis that prepared SST indices for fishing years from 1960–61 to 2021–22, that were ultimately offered to the latest CRA 2 assessment as covariates of model estimated annual recruitment deviations. First there is a description of methods used for processing the SST data and then the resulting indices are presented.

Extraction and processing of SST data

Sea surface temperature data were extracted from the ‘ERA5 monthly averaged data on single levels from 1959 to present’ climate data reanalysis data set developed by the European Centre for Medium-Range Weather Forecasts (Copernicus 2022) and downloaded from Copernicus data portal (Copernicus 2022). The SST data from this product are known to be an accurate representation of *in situ* SST (Luo & Minnett 2020).

The SST data extract had a quarter degree and monthly resolution for all months from April 1960 to March 2022. These data were extracted as a ‘gridded binary’ or ‘general regularly-distributed information in binary form’ (GRIB) files. The data were then converted into a raster brick for further processing in *R* (R Core Team 2022). The SST rasters were then reprojected to an equal area projection (CRS = ‘+proj=aea +lat_0=-40 +lon_0=175 +lat_1=-30 +lat_2=-50 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs’) with a 250 m grid cell resolution. Grid cells were then masked out if they were: on land, outside the bounds of CRA 2, or over seafloor deeper than 100 m depth. This depth threshold was arbitrarily selected to exclude deeper seafloor areas that juvenile lobsters would be unlikely to use.

Spatial plots of the resulting SST data are shown for two example months (January of 1979 and 2018) in Figure C.1. From these plots it was apparent that SST was relatively uniform across the spatial domain of the data subset. The arithmetic mean of all grid cells for each monthly raster was used to generate a monthly SST time series.

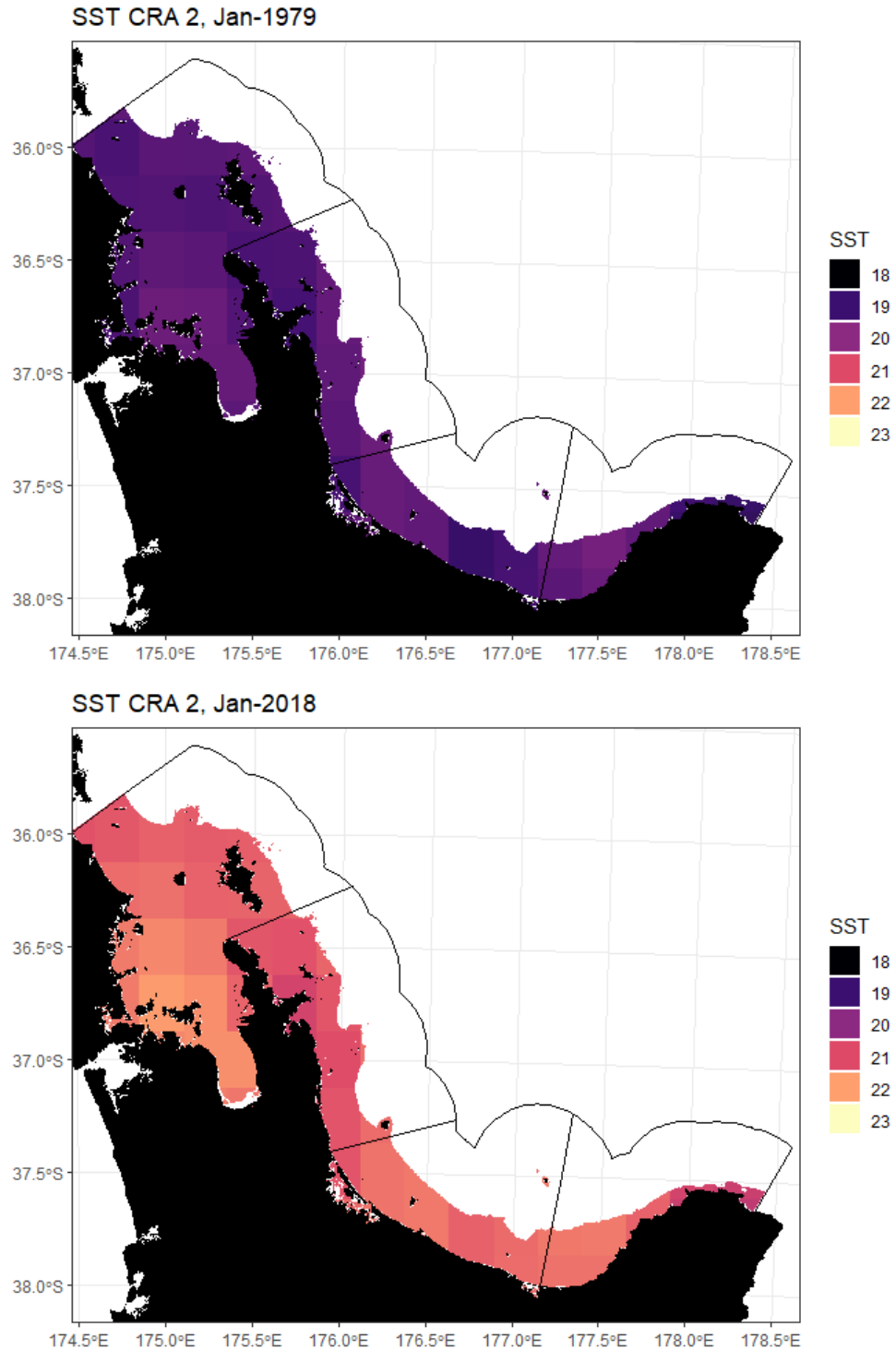


Figure C.1: Sea surface temperature extracted from the ERA5 reanalysis (Copernicus 2022) for the CRA 2 region and two example months (top - January 1979, and bottom – January 2018), masking out grid cells over seafloor deeper than 100 m depth. Note that the same colour scale was used for both plots.

Development of SST time series

The monthly SST values were then assembled for use as a potential covariate of annual deviations from the mean recruitment estimated by the stock assessment model. The first step was to average the monthly SST values for each red rock lobster fishing year for which there was a full 12 months of data (i.e., 1960–61 to 2021–22). This was achieved by taking the arithmetic mean of the SST values for all months within a respective fishing year. Two alternative SST indices were produced and trialled by the updated CRA 2 stock assessment:

- one index (**sst_1yr**) that simply used the SST values for each fishing year and which was related to model-based recruitment in the respective fishing year; and
- another index (**sst_3yr**) that took the running mean of the SST observation centred on the observed fishing year and averaged across the period from one year before to one year following.

The resulting SST indices for CRA 2 were then normalised to the mean value across all years and are plotted in Figure C.2. A 20% coefficient of variation was arbitrarily assigned to each SST index value and the values were inverted (multiplied by -1) for the purposes of model fitting, given the tentative negative correlation obtained between model-based recruitment in CRA 3 and SST from the prior analysis by Breen & Starr (2010).

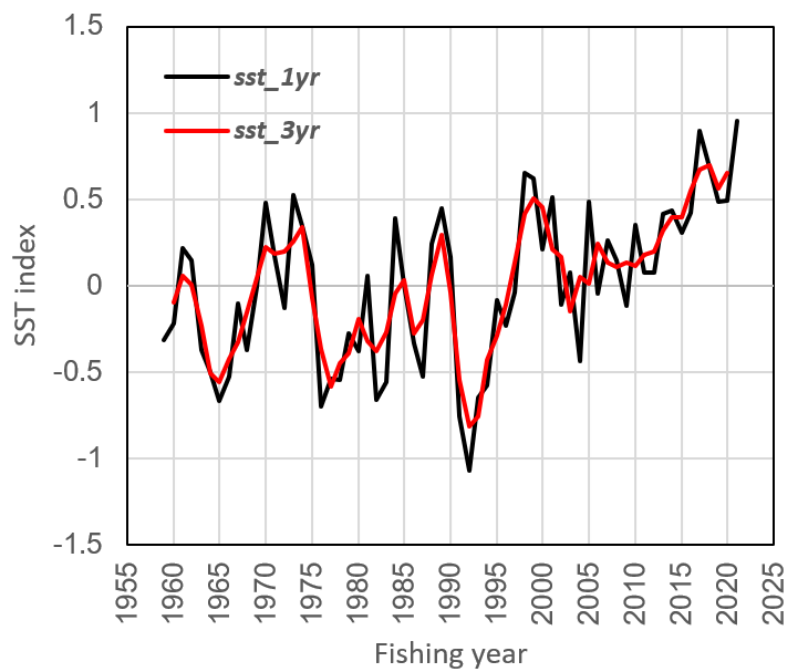


Figure C.2: Annual sea surface temperature indices produced for CRA 2.

Appendix D. Supplementary plots from CPUE analyses

D.1 FSU MCMC

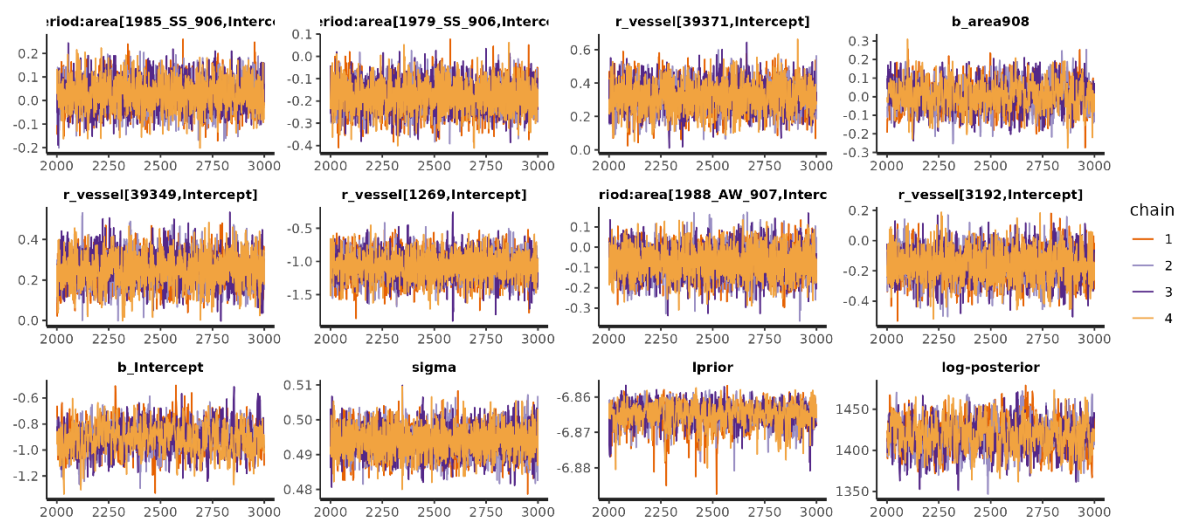


Figure D.1: CRA 2 FSU CPUE MCMC trace plots.

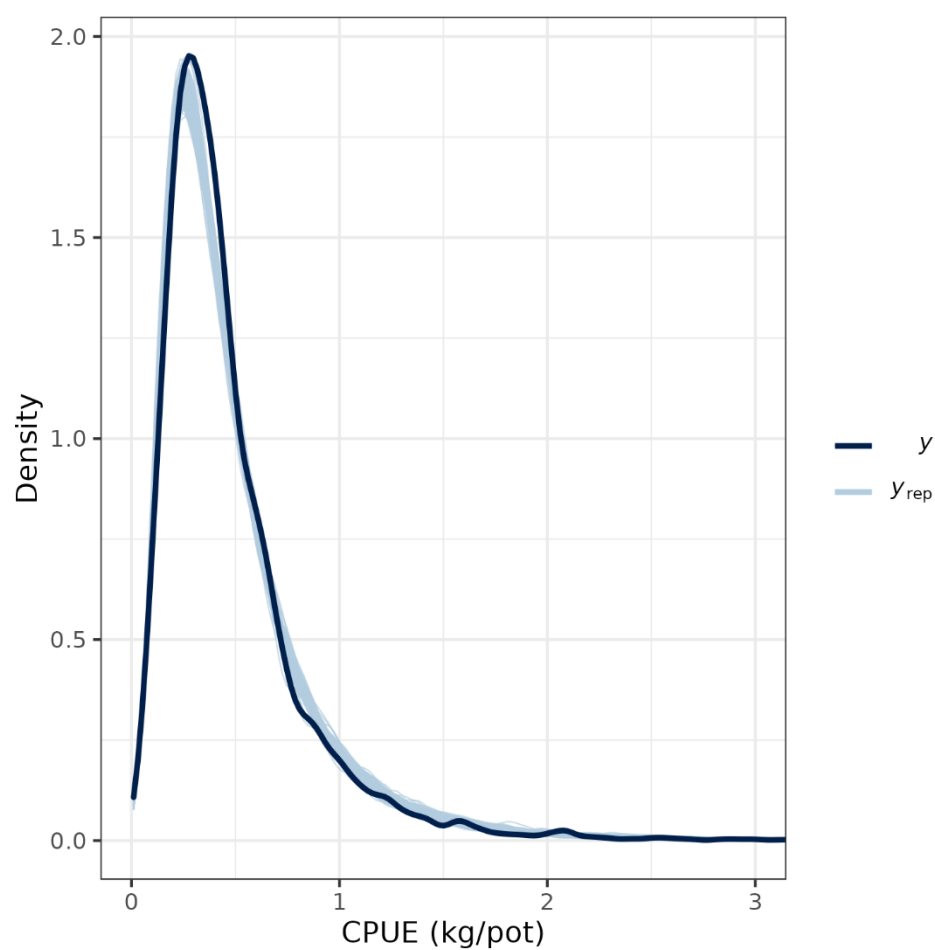


Figure D.2: CRA 2 FSU posterior predictive density overlay.

D.2 CRA 2 logbook CPUE

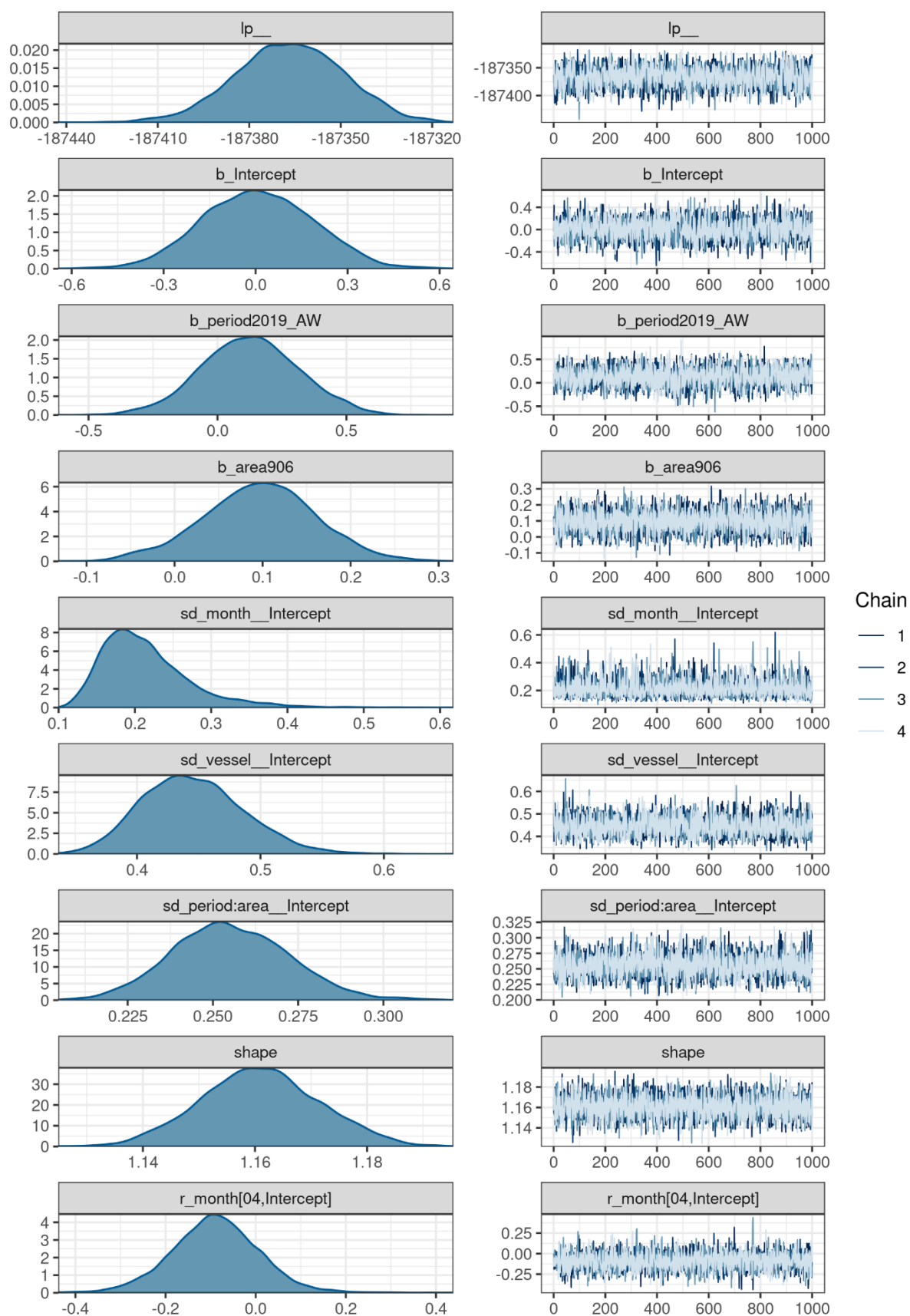


Figure D.3: CRA 2 logbook CPUE MCMC trace plots.

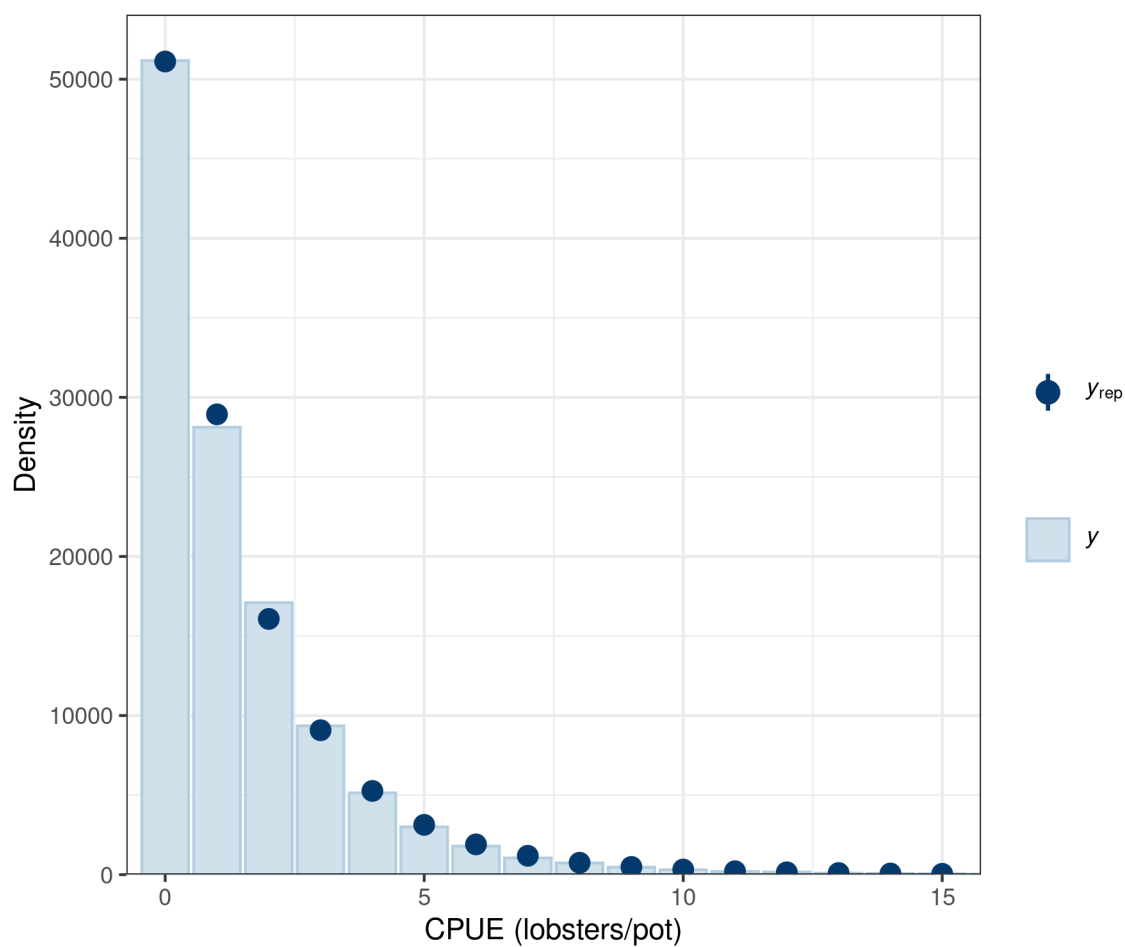


Figure D.4: CRA 2 logbook CPUE distribution assumptions good.

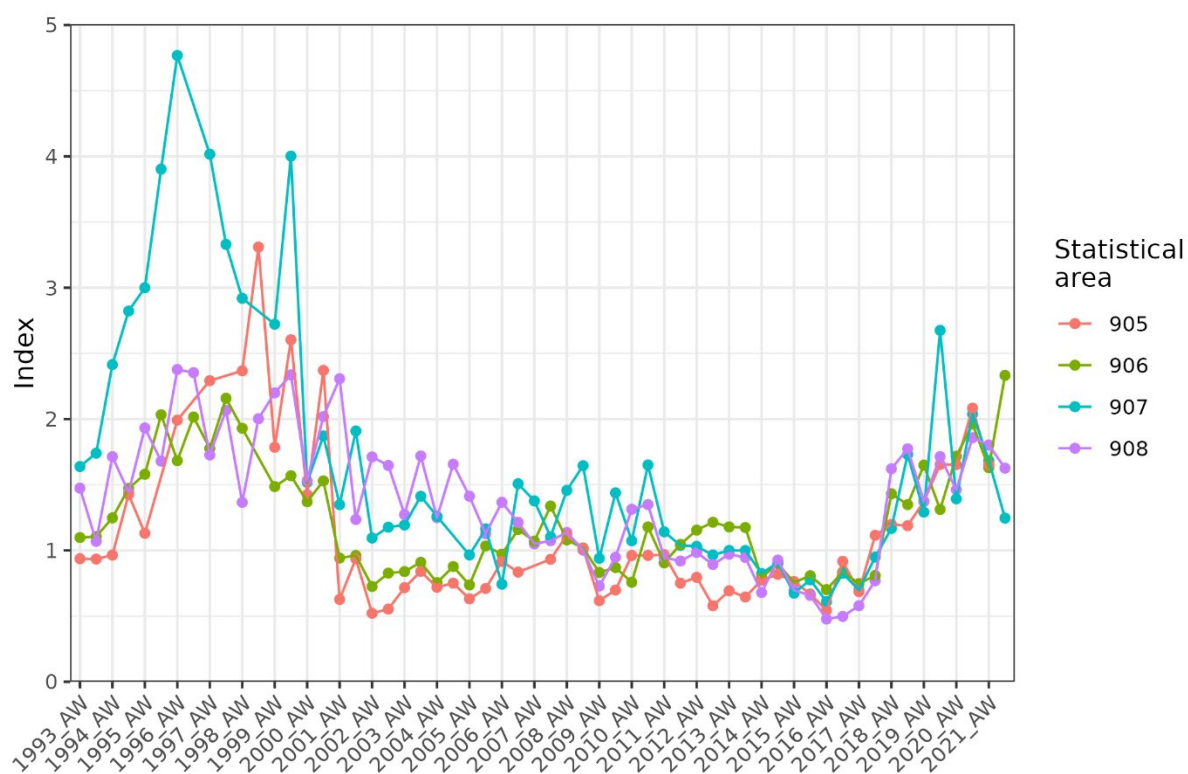


Figure D.5: CRA 2 logbook CPUE by statistical area showing the median.

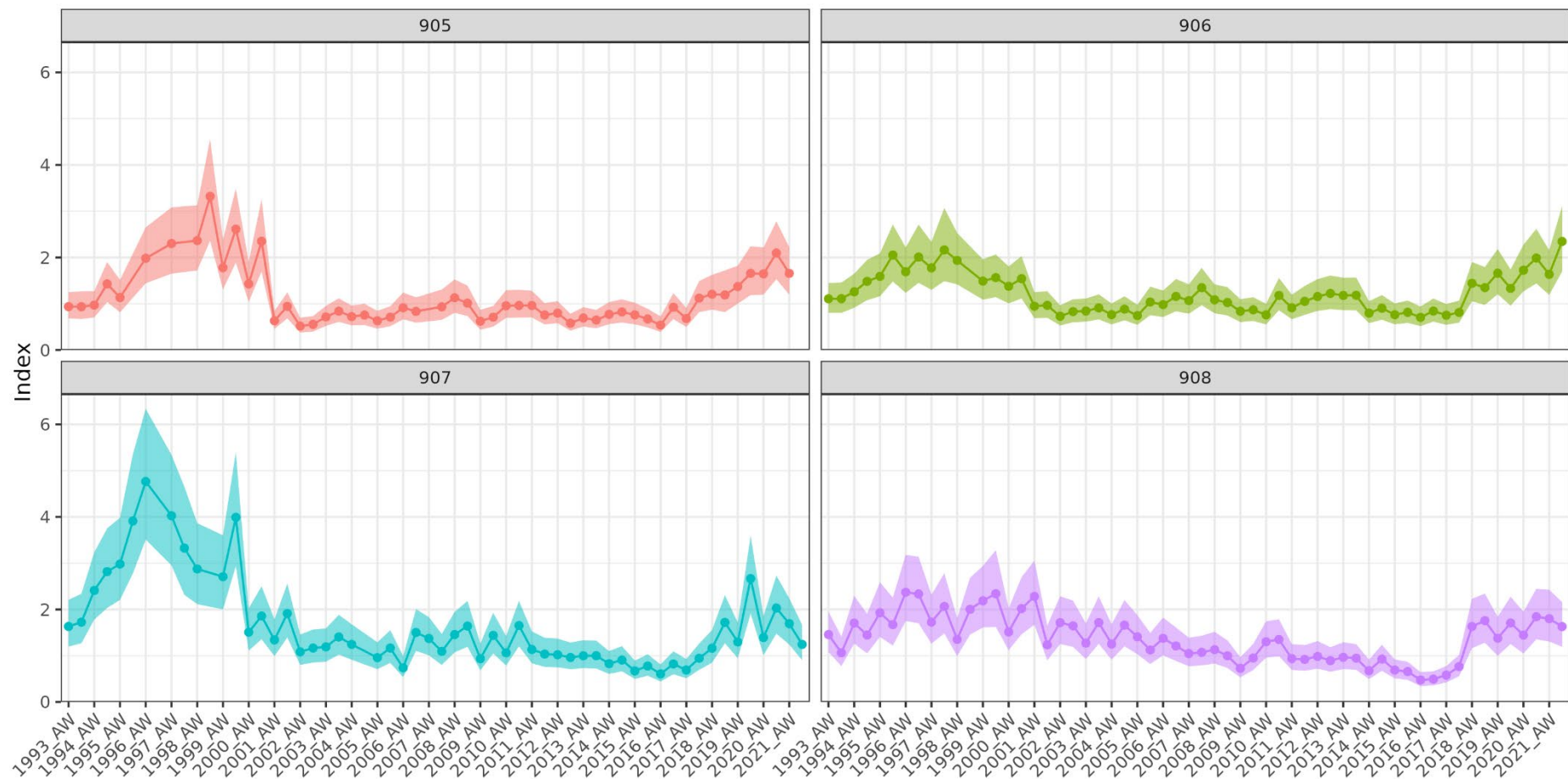


Figure D.6: CRA 2 logbook CPUE by statistical area showing the median and 50% credible interval.

Appendix E. Supplementary plots from LF and sex ratio analyses

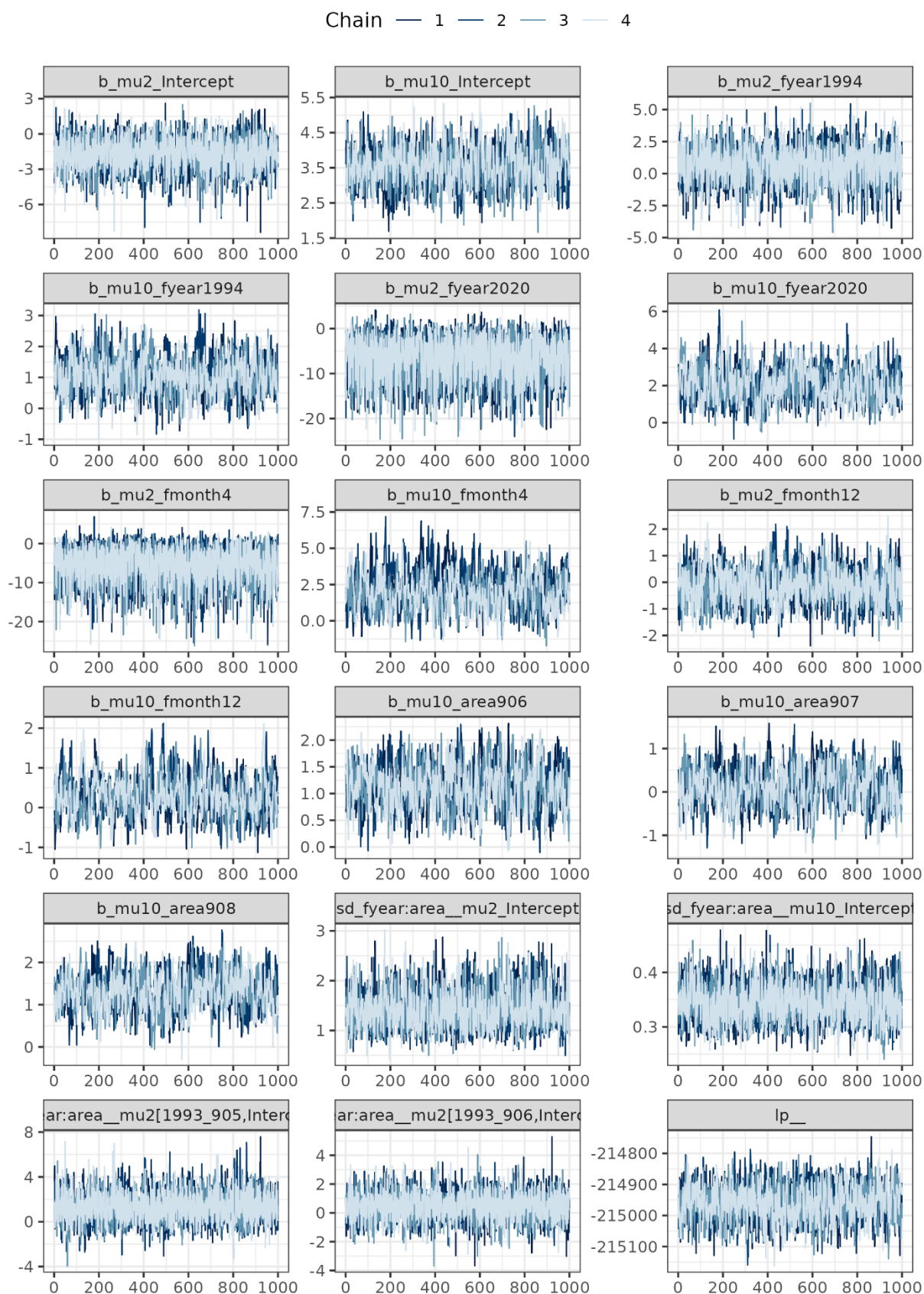


Figure E.1: CRA 2 male LF MCMC trace plots.

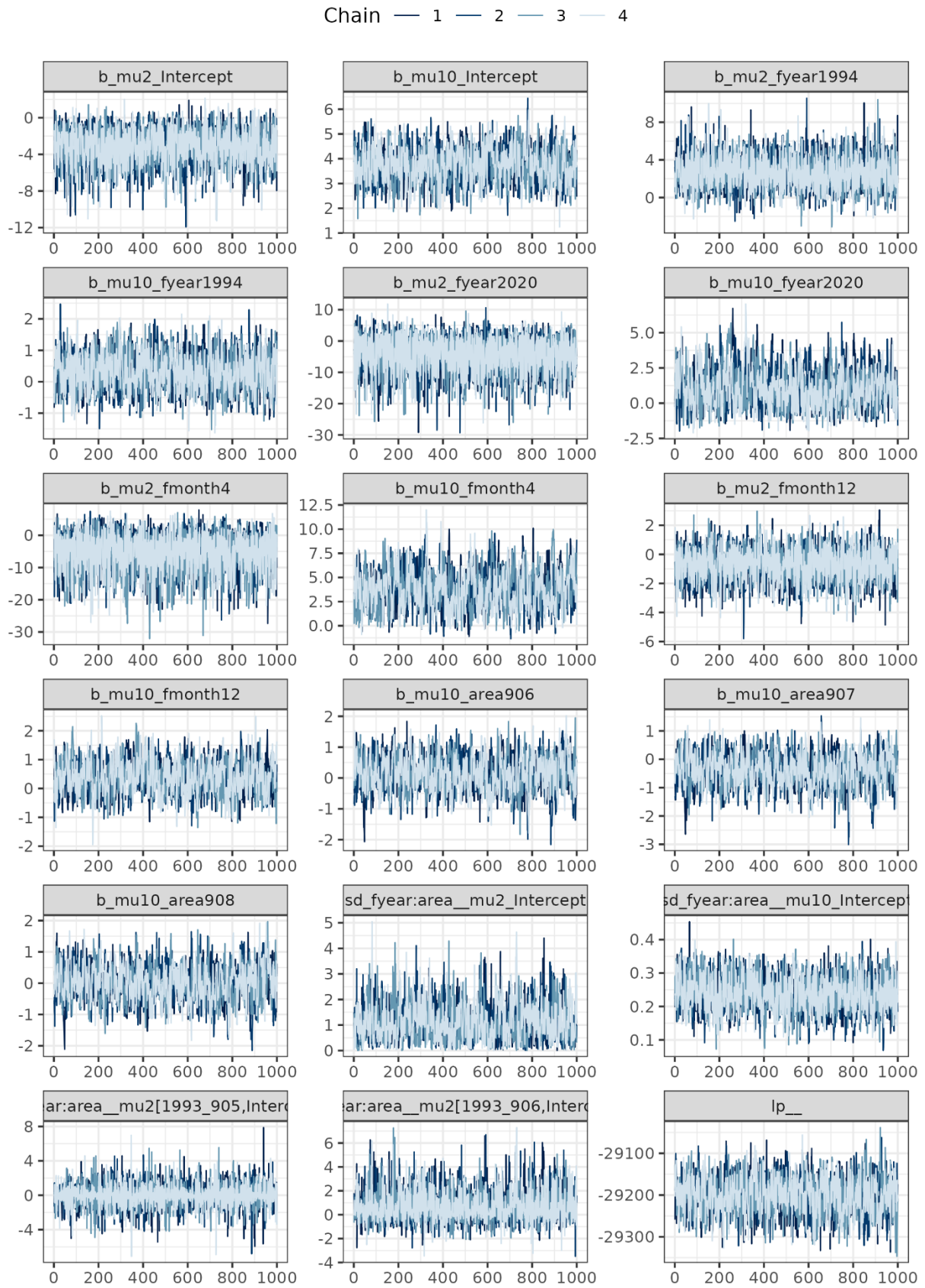


Figure E.2: CRA 2 immature female LF MCMC trace plots.

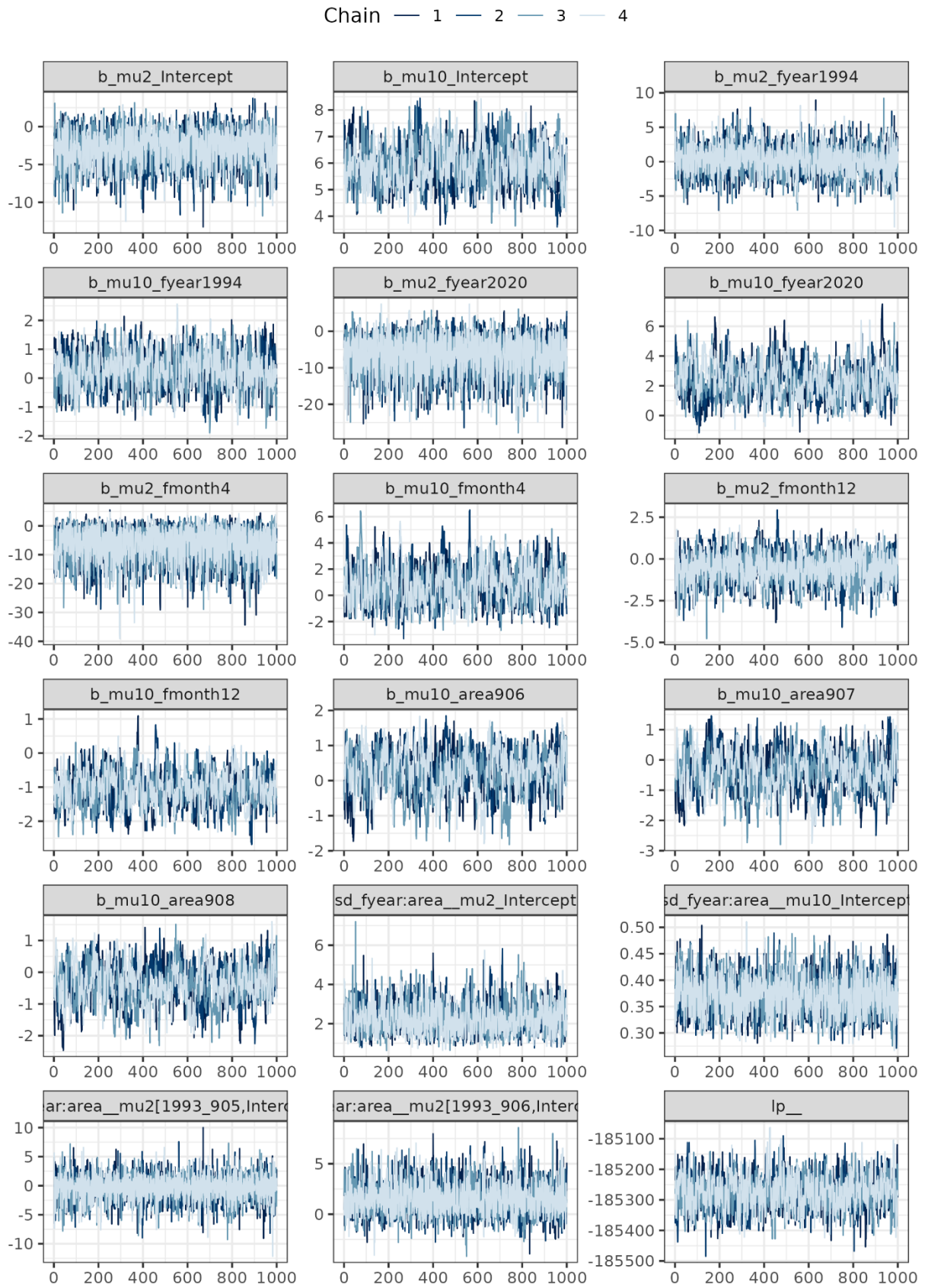


Figure E.3: CRA 2 mature female LF MCMC trace plots.

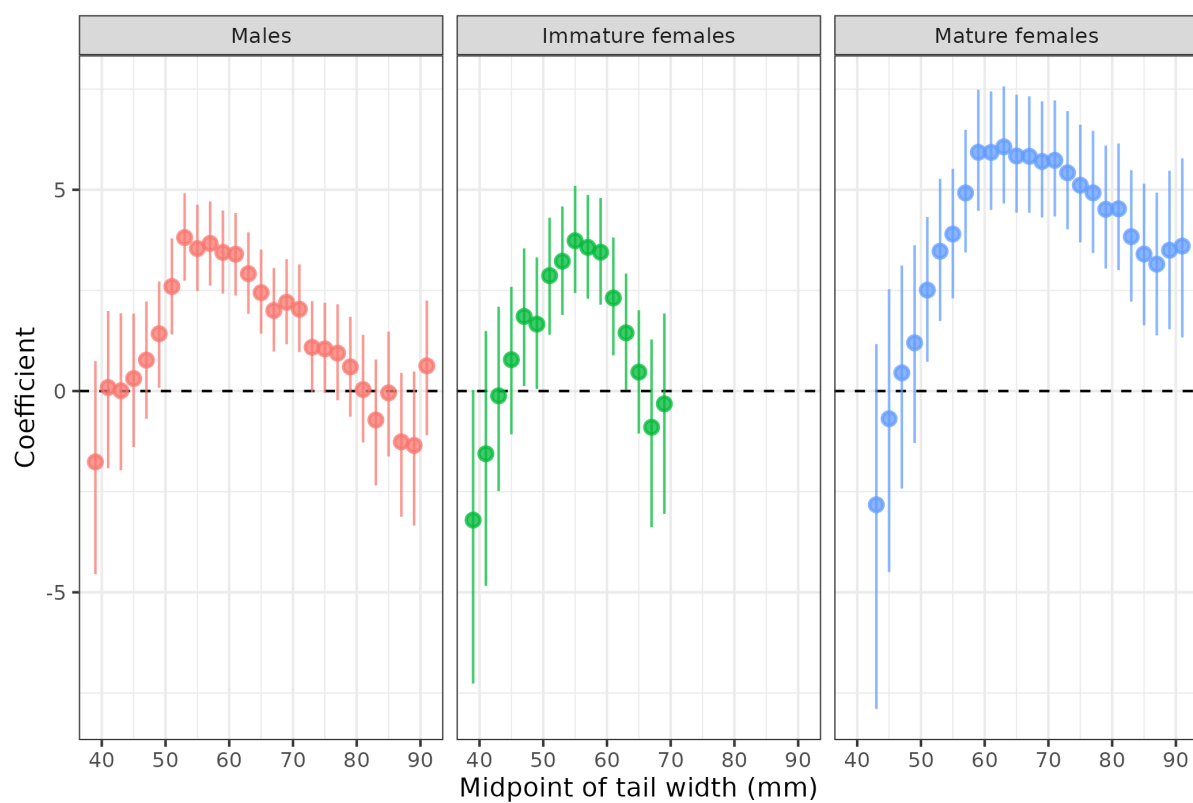


Figure E.4: The population level effect of intercept by TW bin for each sex category, showing the mean and 95% credible intervals.

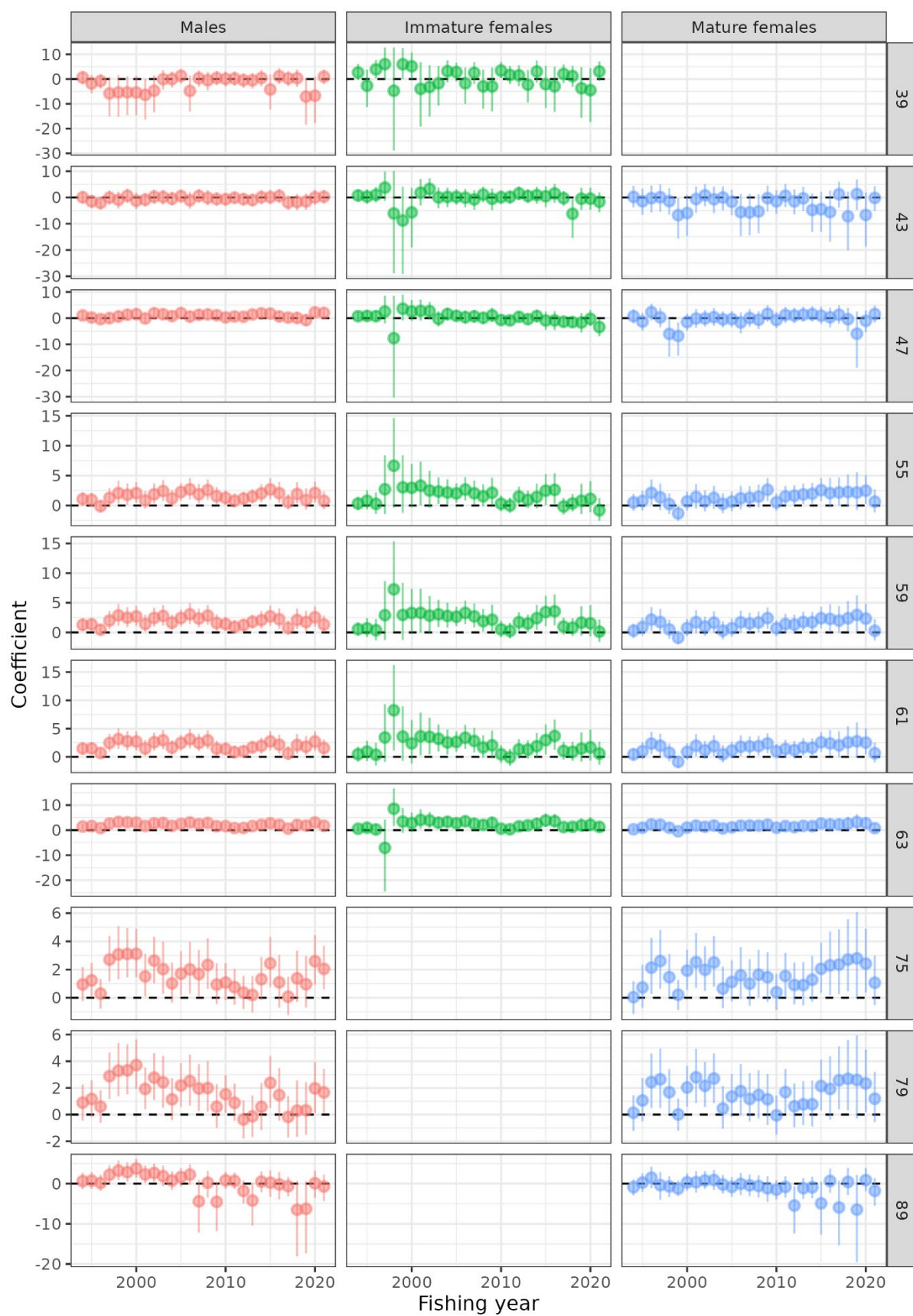


Figure E.5: The population level effect of fishing year by TW bin for each sex category, showing the mean and 95% credible intervals.

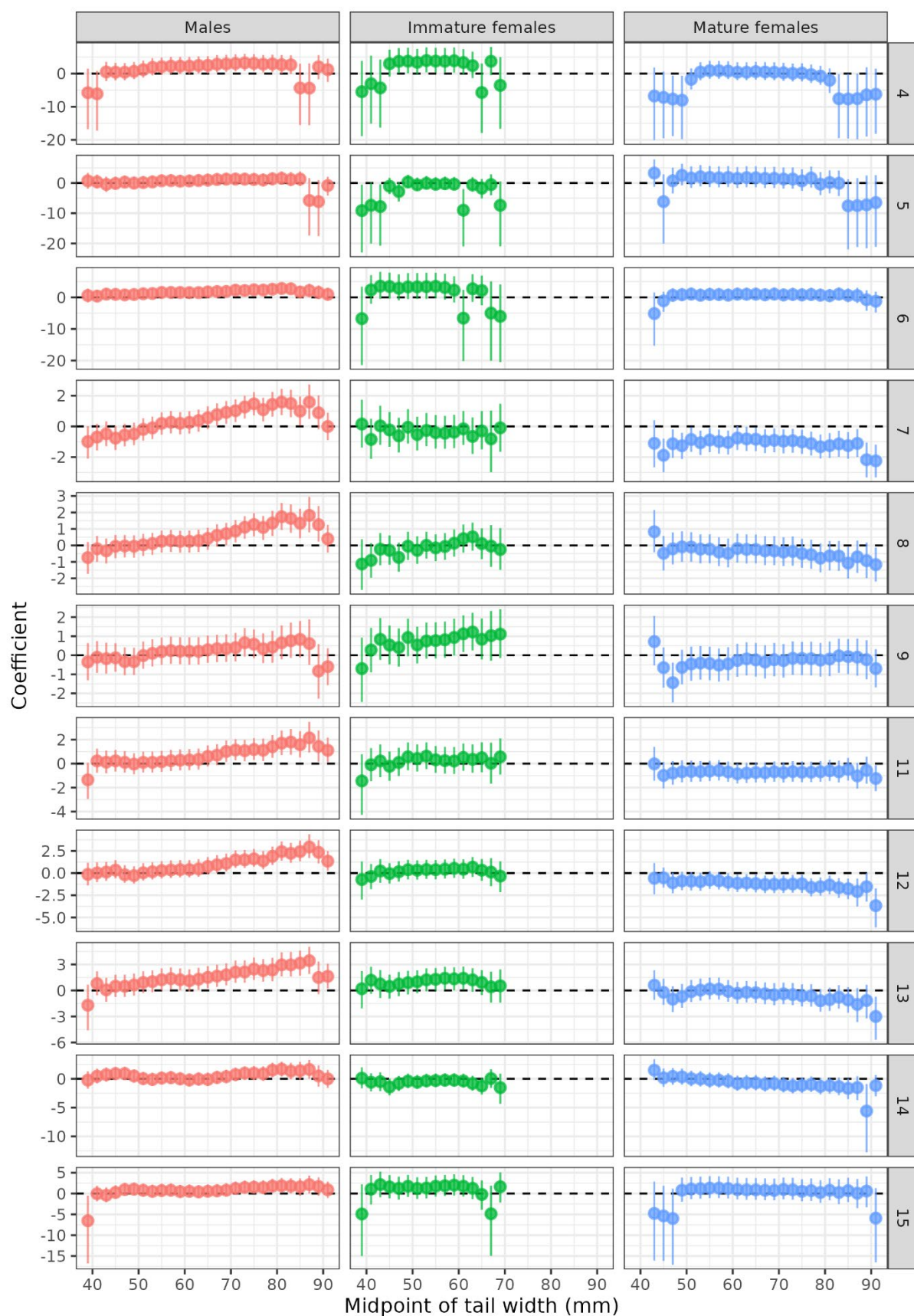


Figure E.6: The population level effect of fishing month (4 = April, 15 = March) by TW bin for each sex category, showing the mean and 95% credible intervals.

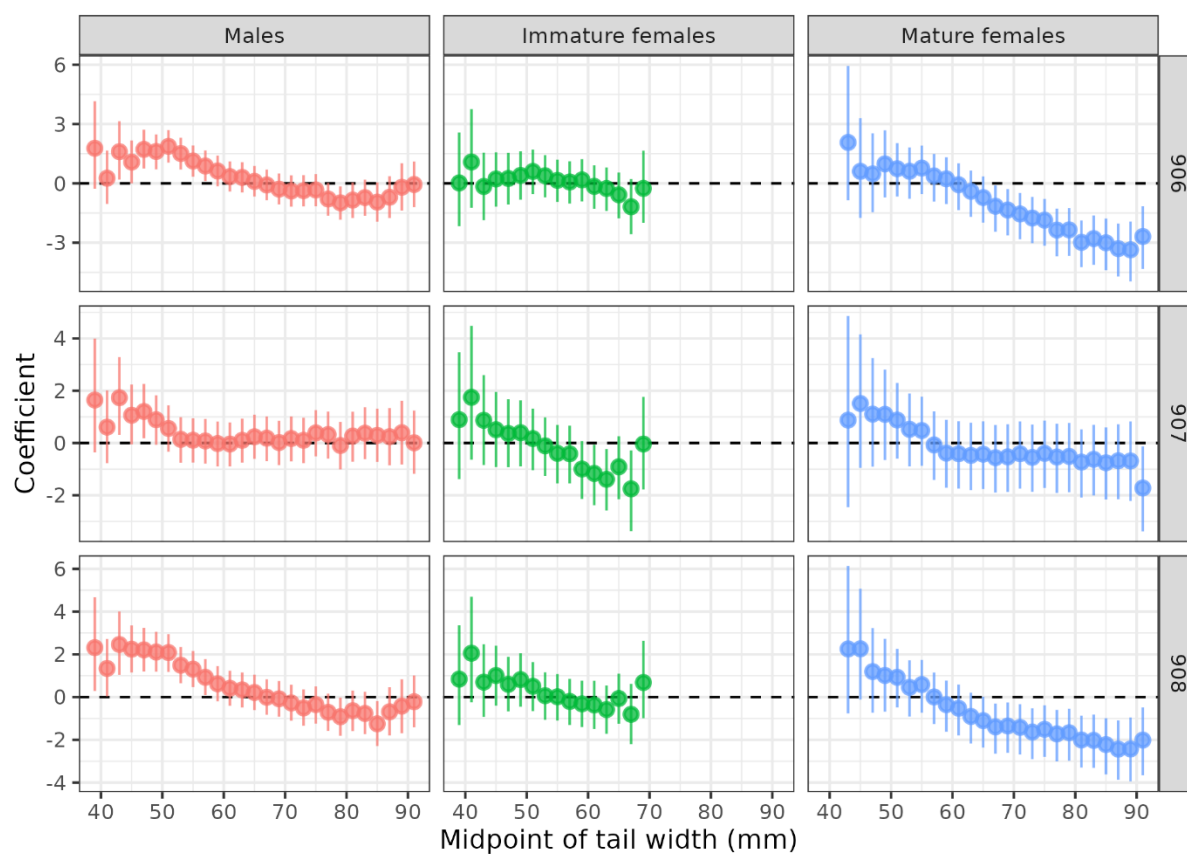


Figure E.7: The population level effect of statistical area by TW bin for each sex category, showing the mean and 95% credible intervals. Statistical area 905 is not shown as it is the reference level.

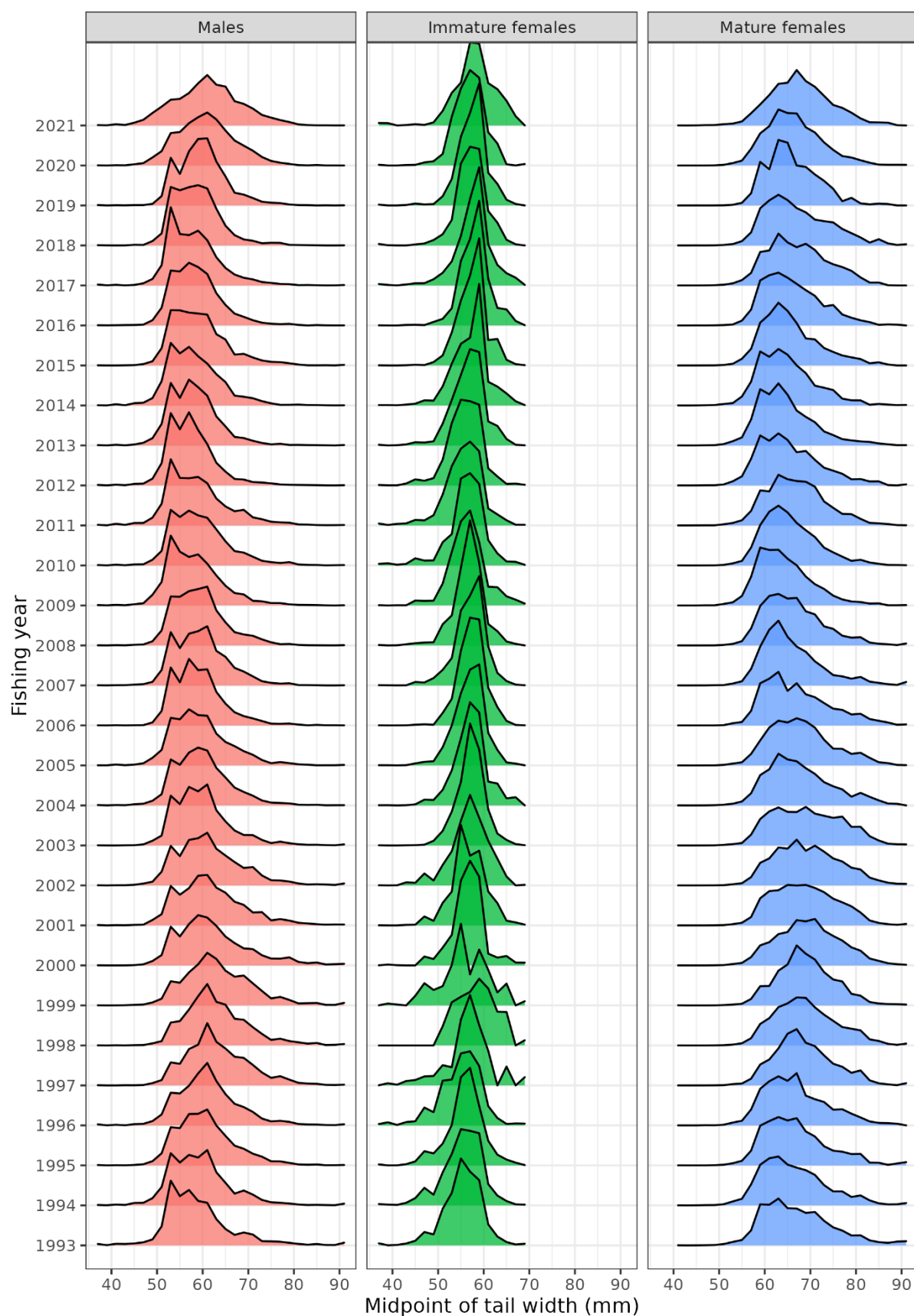


Figure E.8: The conditional effect of fishing year by TW bin for each sex category.

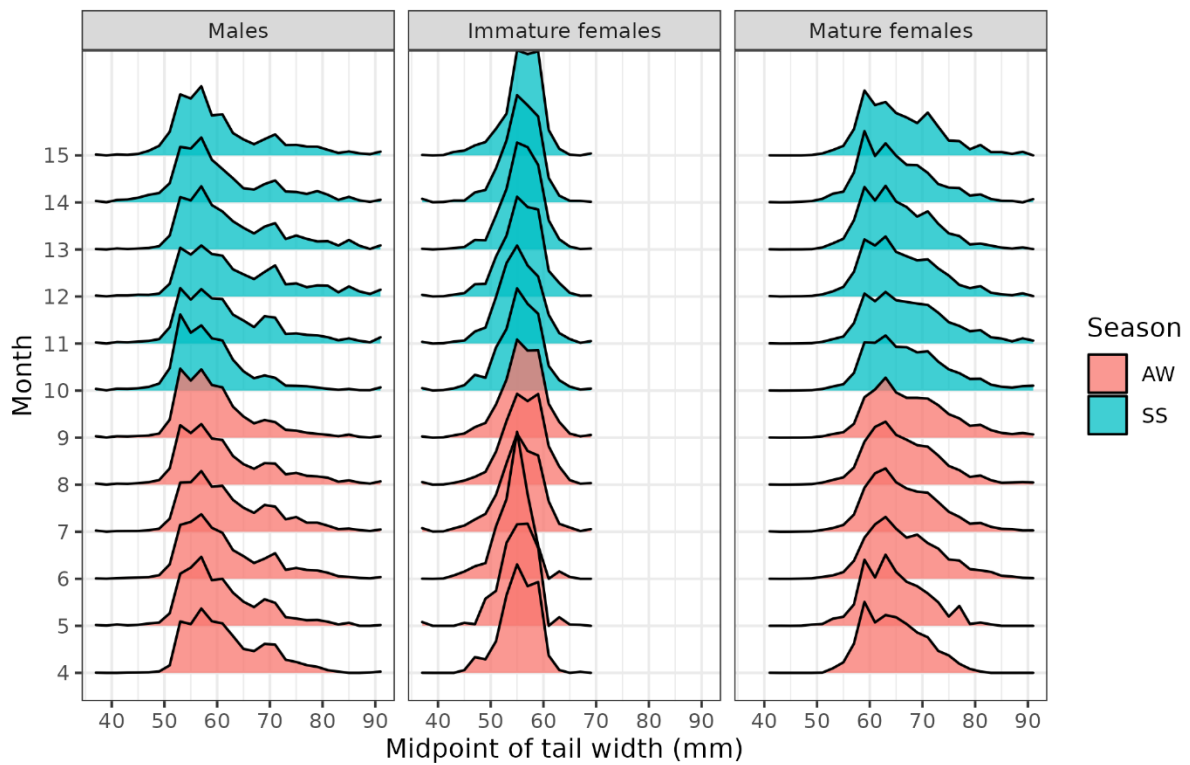


Figure E.9: The conditional effect of fishing month (4 = April, 15 = March) by TW bin for each sex category.

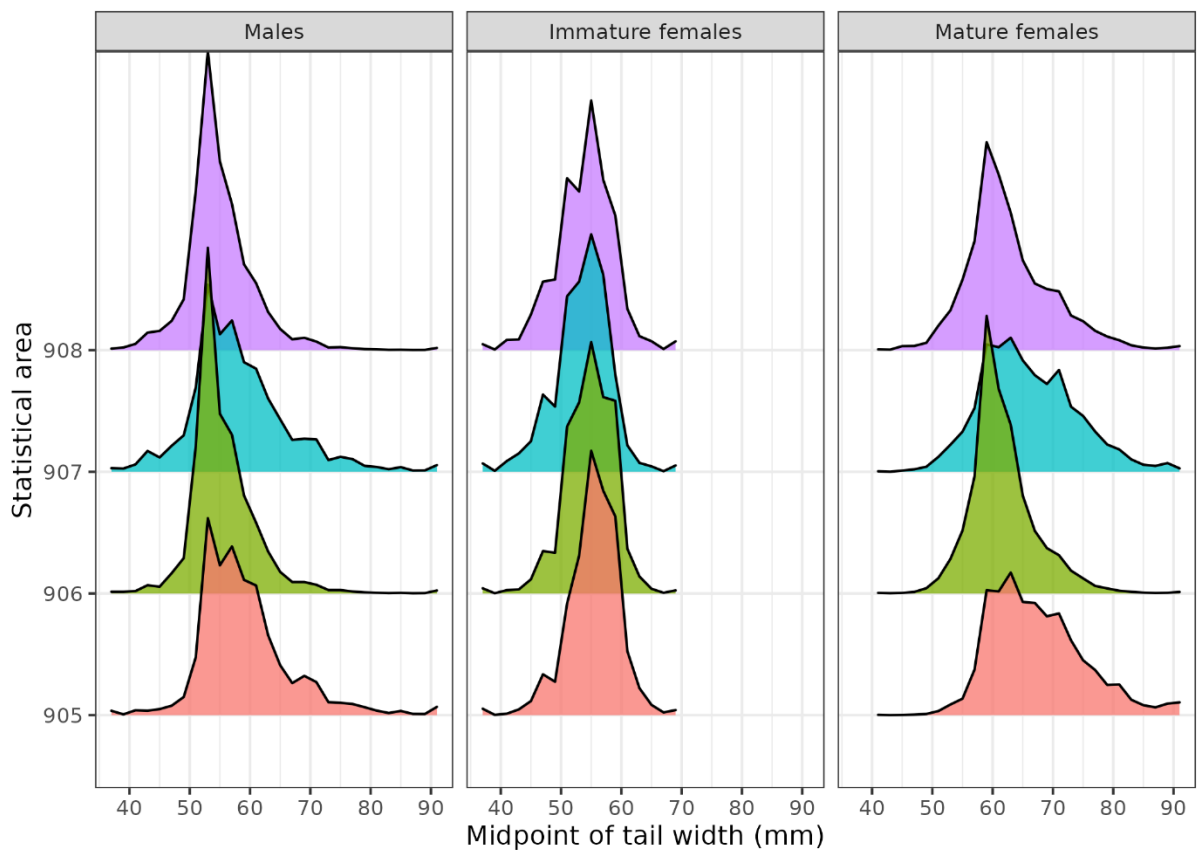


Figure E.10: The conditional effect of statistical area by TW bin for each sex category.

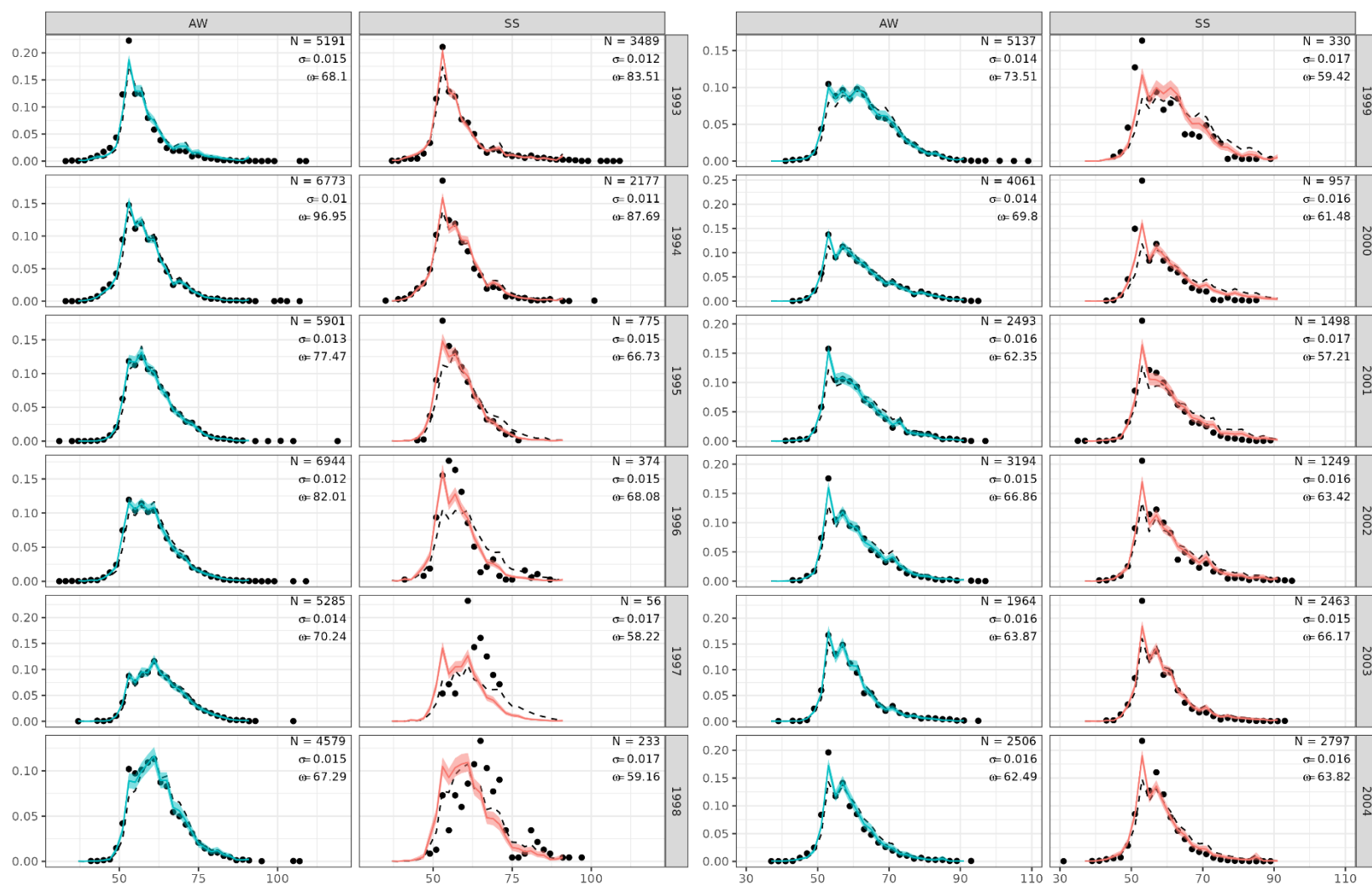


Figure E.11: Males 1993 to 2004: scaled LF distributions by fishing year, season, and TW bin (Equation 11) where the solid line is the mean and the shaded region is the 95% credible interval of the posterior distribution of the mean. The aggregated data (points, Equation 8) and unscaled predictions of 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 (Equation 11); and the data set weight for each stratum (Equation 12).

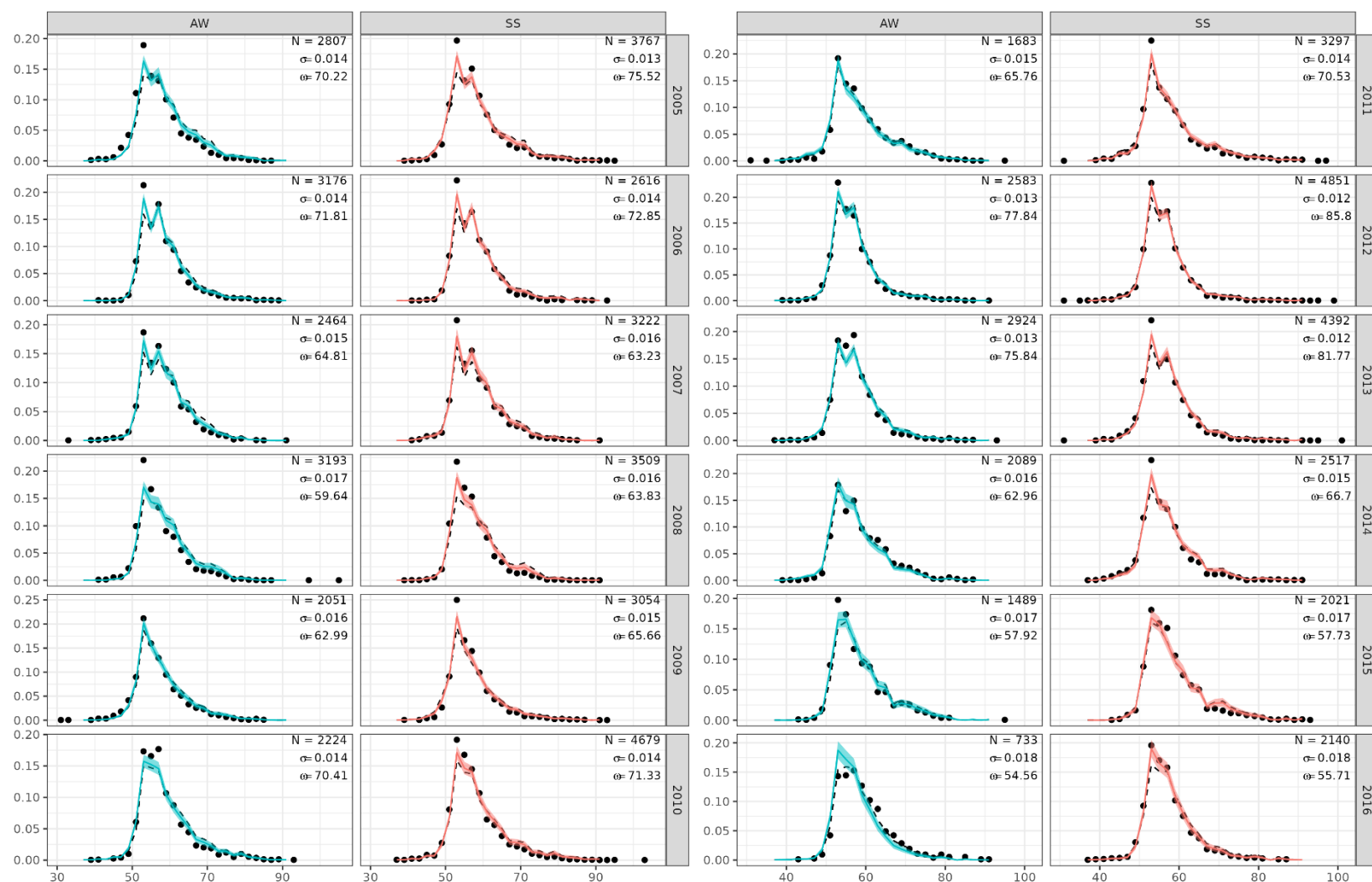


Figure E.12: Males 2005 to 2016: scaled LF distributions by fishing year, season, and TW bin (Equation 11) where the solid line is the mean and the shaded region is the 95% credible interval of the posterior distribution of the mean. The aggregated data (points, Equation 8) and unscaled predictions of 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 (Equation 11); and the data set weight for each stratum (Equation 12).

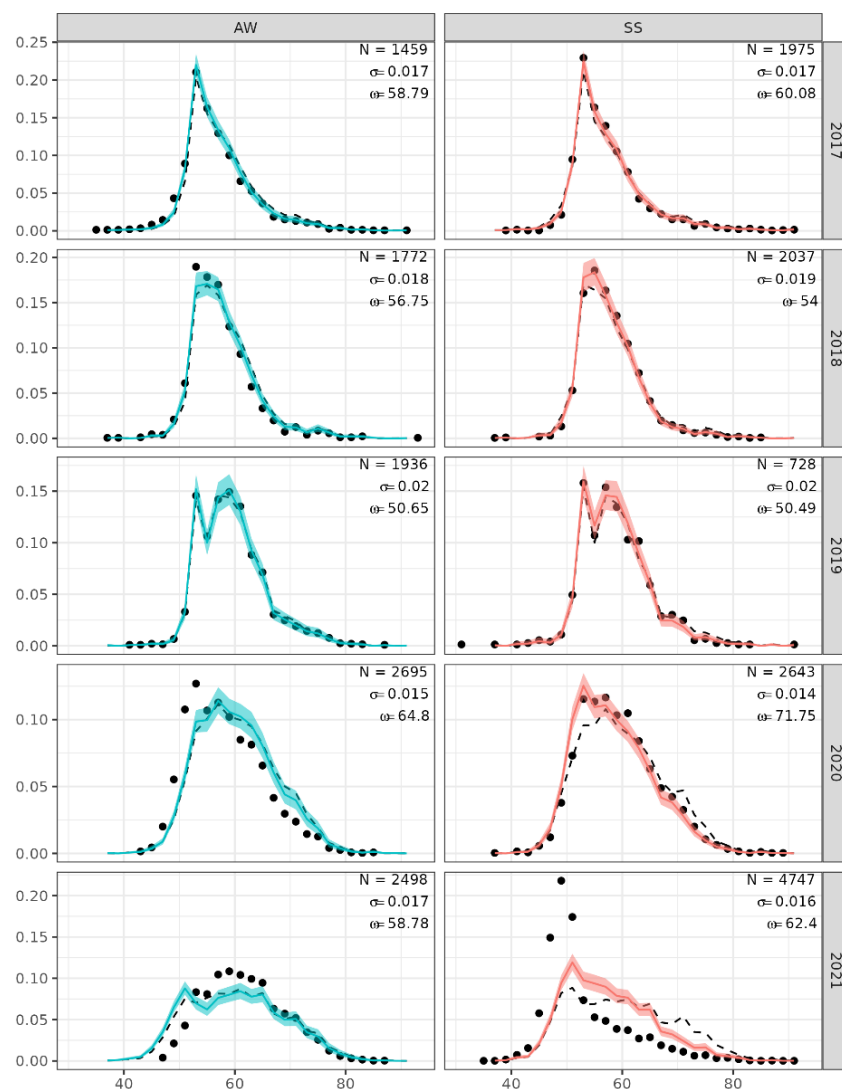


Figure E.13: Males 2017 to 2021: scaled LF distributions by fishing year, season, and TW bin (Equation 11) where the solid line is the mean and the shaded region is the 95% credible interval of the posterior distribution of the mean. The aggregated data (points, Equation 8) and unscaled predictions of 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 (Equation 11); and the data set weight for each stratum (Equation 12).

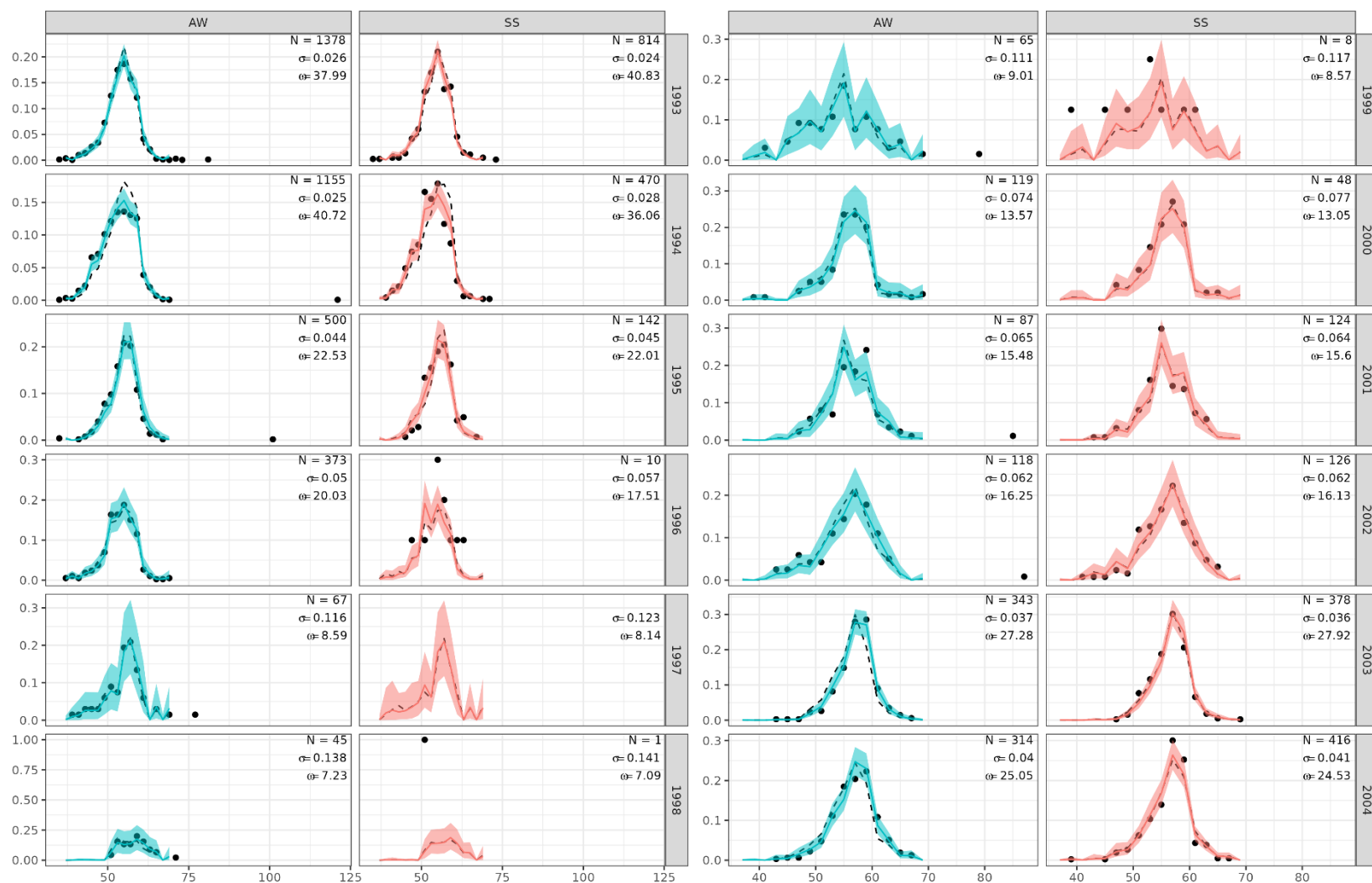


Figure E.14: Immature females 1993 to 2004: scaled LF distributions by fishing year, season, and TW bin (Equation 11) where the solid line is the mean and the shaded region is the 95% credible interval of the posterior distribution of the mean. The aggregated data (points, Equation 8) and unscaled predictions 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 (Equation 11); and the data set weight for each stratum (Equation 12).

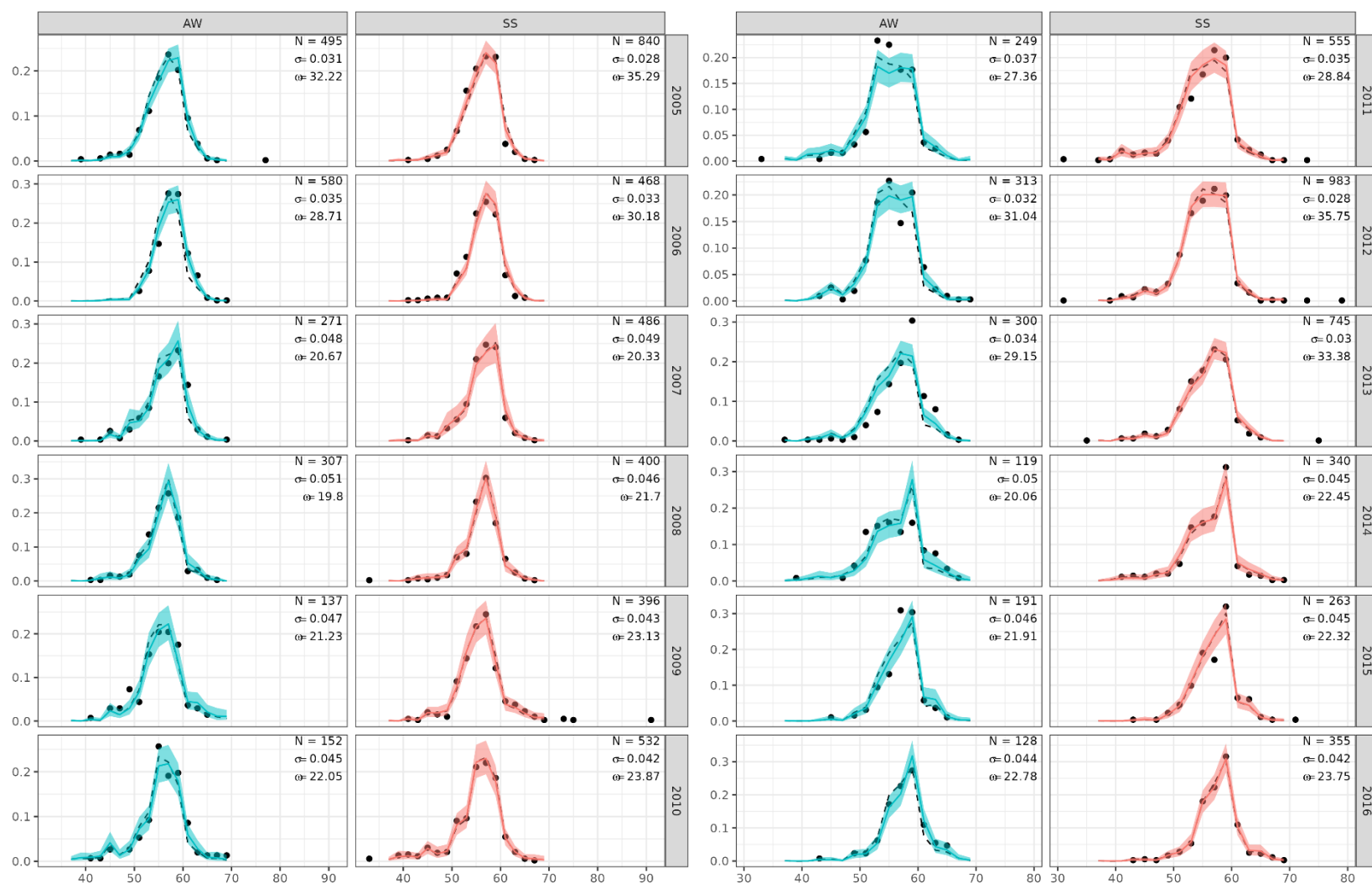


Figure E.15: Immature females 2005 to 2016: scaled LF distributions by fishing year, season, and TW bin (Equation 11) where the solid line is the mean and the shaded region is the 95% credible interval of the posterior distribution of the mean. The aggregated data (points, Equation 8) and unscaled predictions 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 (Equation 11); and the data set weight for each stratum (Equation 12).

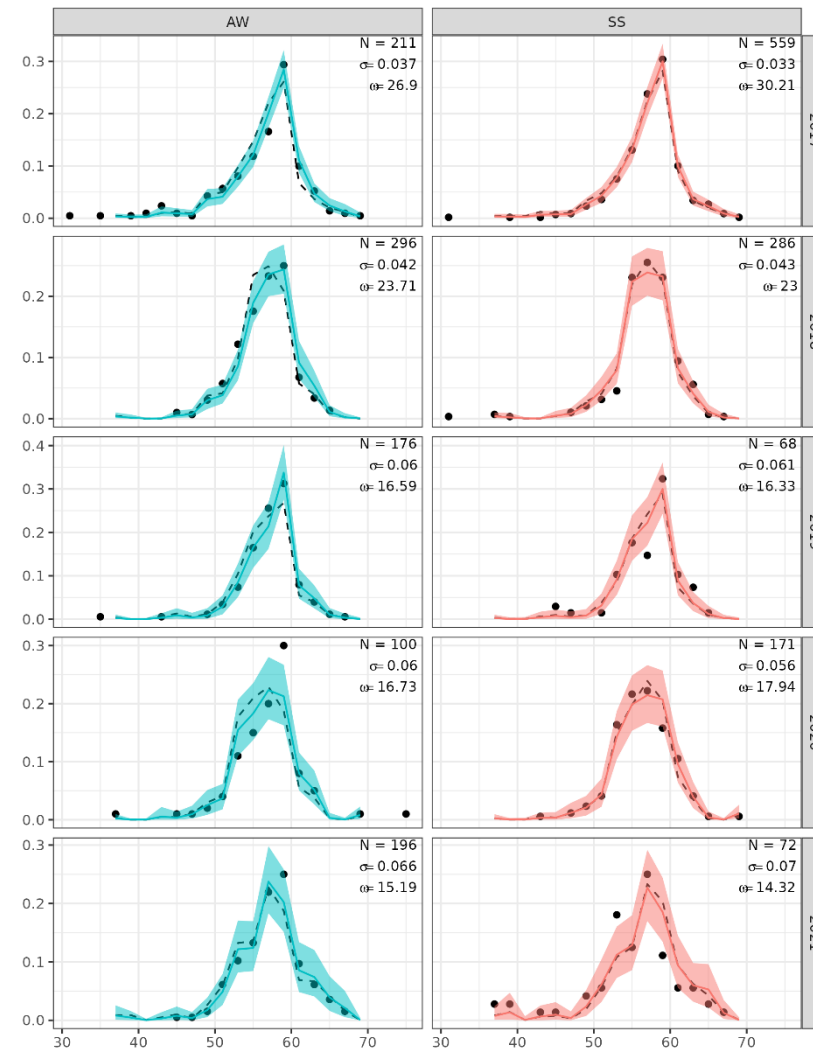


Figure E.16: Immature females 2017 to 2021: scaled LF distributions by fishing year, season, and TW bin (Equation 11) where the solid line is the mean and the shaded region is the 95% credible interval of the posterior distribution of the mean. The aggregated data (points, Equation 8) and unscaled predictions 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 (Equation 11); and the data set weight for each stratum (Equation 12).

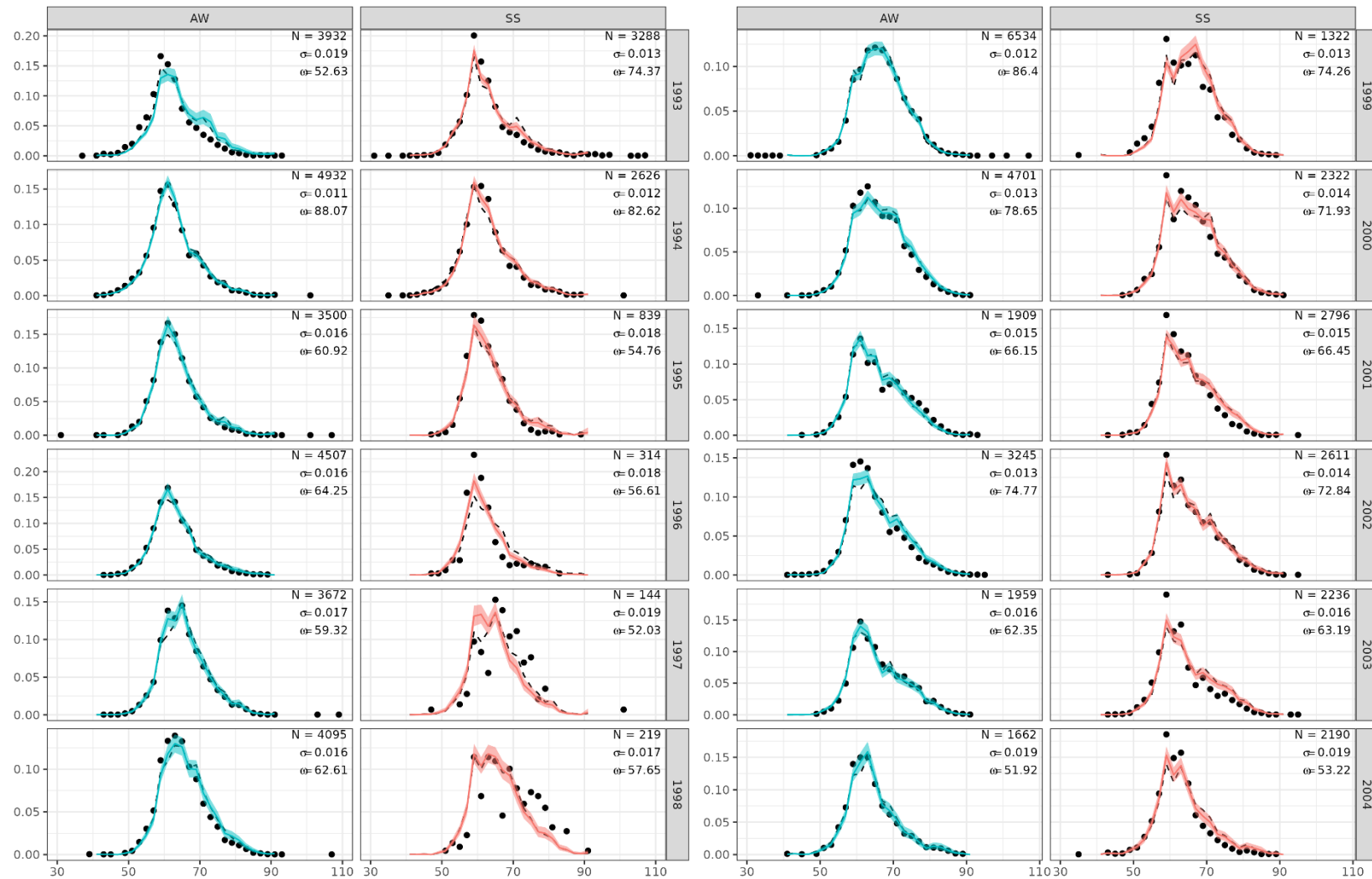


Figure E.17: Mature females 1993 to 2004: scaled LF distributions by fishing year, season, and TW bin (Equation 11) where the solid line is the mean and the shaded region is the 95% credible interval of the posterior distribution of the mean. The aggregated data (points, Equation 8) and unscaled predictions 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 (Equation 11); and the data set weight for each stratum (Equation 12).

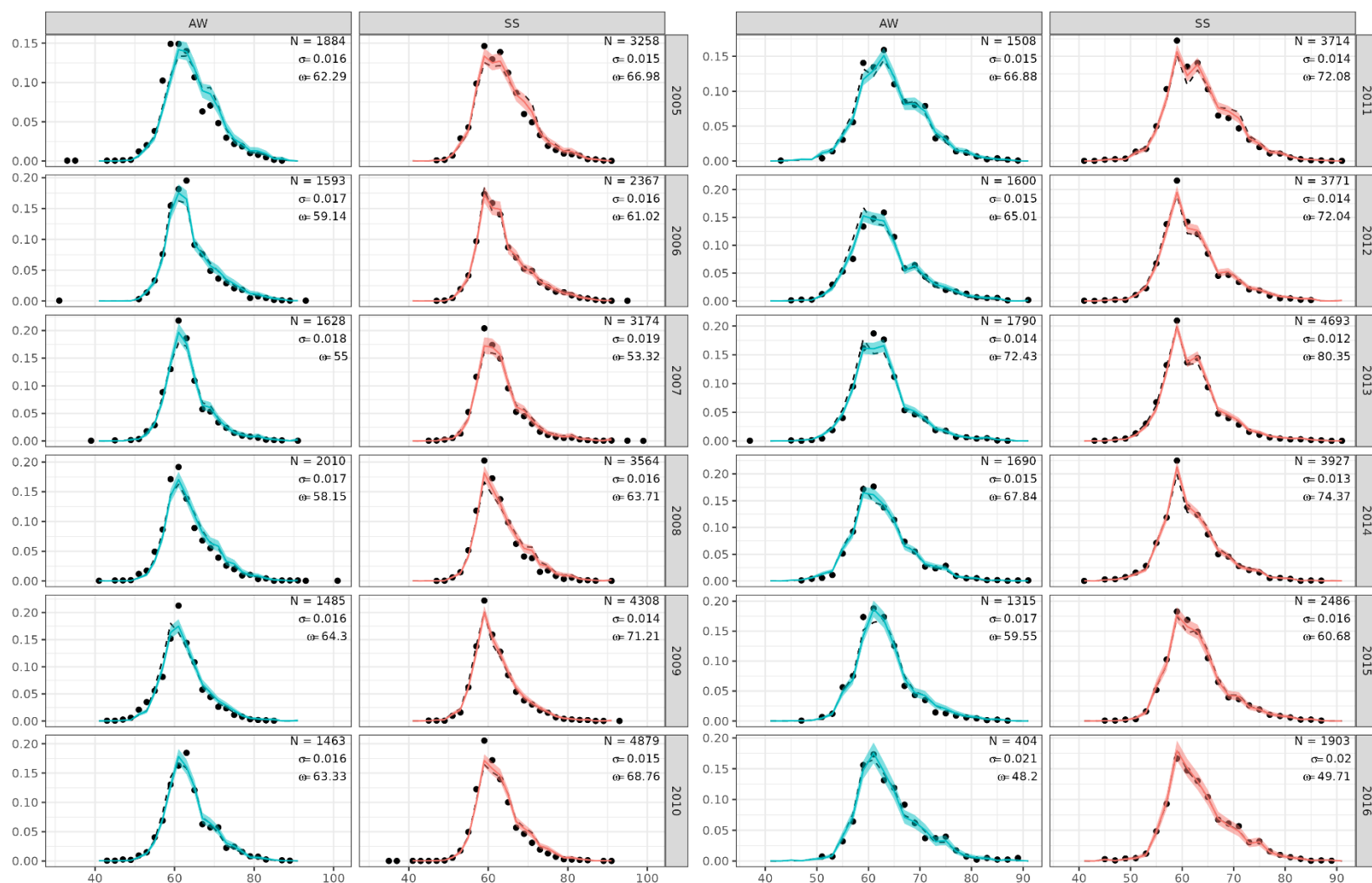


Figure E.18: Mature females 2005 to 2016: scaled LF distributions by fishing year, season, and TW bin (Equation 11) where the solid line is the mean and the shaded region is the 95% credible interval of the posterior distribution of the mean. The aggregated data (points, Equation 8) and unscaled predictions 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 (Equation 11); and the data set weight for each stratum (Equation 12).

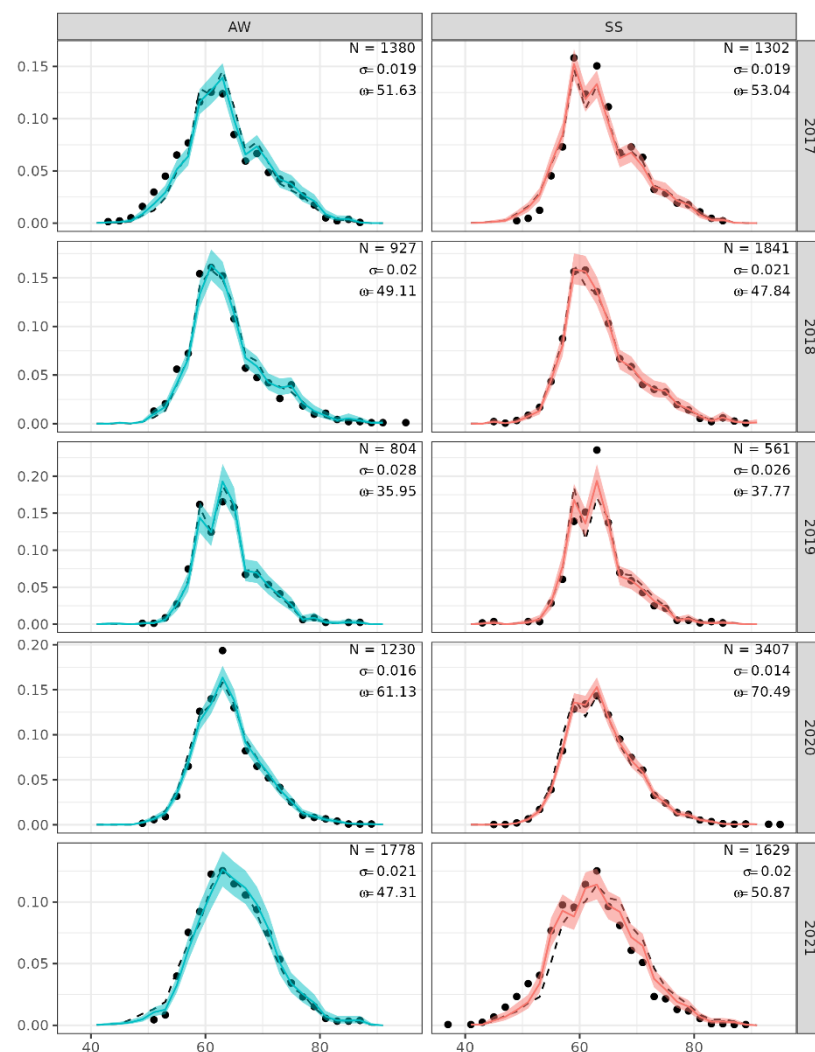


Figure E.19: Mature females 2017 to 2021: scaled LF distributions by fishing year, season, and TW bin (Equation 11) where the solid line is the mean and the shaded region is the 95% credible interval of the posterior distribution of the mean. The aggregated data (points, Equation 8) and unscaled predictions 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 (Equation 11); and the data set weight for each stratum (Equation 12).

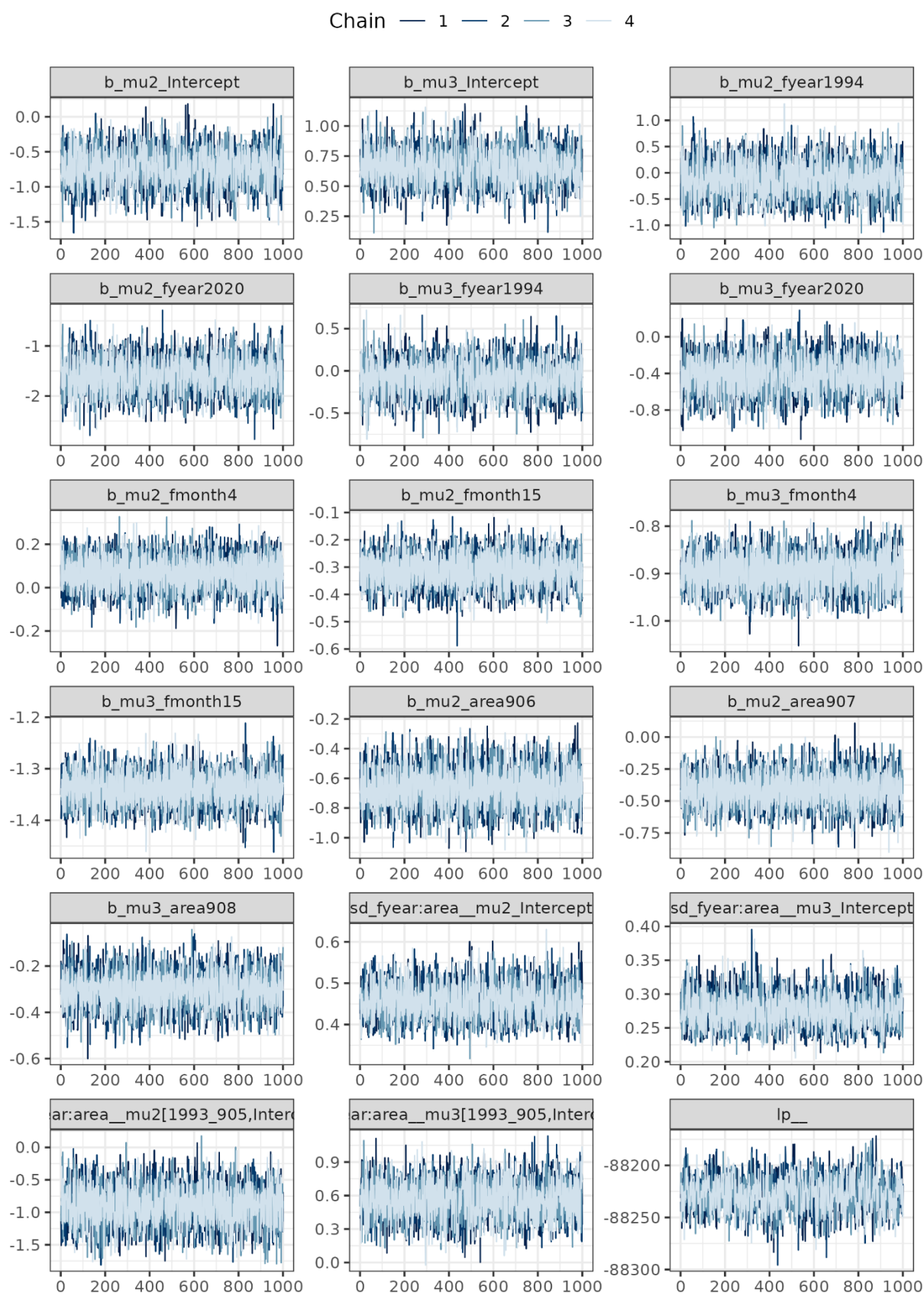


Figure E.20: CRA 2 sex ratio MCMC trace plots.

Appendix F. Update to processing of tag record locations

The method used to assign tag releases and recaptures to specific statistical areas has changed through time:

- for all assessments done prior to 2019, only the fisher-reported statistical area was used;
- for all assessments since 2019, this was based on the reported latitude and longitude, where these were reported, otherwise the reported statistical area was used.

During the 2022 assessment of CRA 2, it was discovered that the reported tag locations had previously been processed incorrectly (minutes were incorrectly assumed to be decimal). This issue was corrected part way through the 2022 assessment of CRA 2, so that this assessment used the correct allocation of statistical areas.

For a subset of tag records for which latitude and longitude were reported, the assigned QMA and statistical area of release when the correct or incorrect methods for processing reported locations were used is shown in Table F.1 and Table F.2. Generally, tag releases that were allocated to the wrong statistical area when using the incorrect method were a relatively small proportion of the sample for each area. For example, in statistical area 911 (in CRA 3), only 1 of a total of 443 for which location data were provided were misallocated (to area 910). However, the proportion that were misallocated is higher for some other statistical areas, e.g., 52 out of 181 in area 905 (CRA 2), and 90 out of 1029 in area 909 (CRA 3), both of which involved misallocations between QMAs.

The most recent assessments for CRA 1, CRA 3, CRA 4, CRA 5, and CRA 7&8 (Rudd et al. 2021a, 2021b; Webber et al. 2020, 2021, 2022) will have used the incorrect method for processing tag locations. The effects of using the correct method may need to be explored by the next assessments of these stocks, although the effects on assessment outcomes are likely to be small, given the relatively low rate of misallocations for nearly all statistical areas in these QMAs (Table F.1 and Table F.2).

Table F.1: Tag records by area of release when using the correct method to process reported location data (rows) and the incorrect method (columns). This table only includes tag events for which a latitude and longitude were reported (CRA 1–5). Cells shaded grey and red, respectively, highlight numbers of tag recaptures that did not and did change areas, comparing methods for processing location data.

Statistical area of release when using the <u>correct</u> method to process location data			Statistical area of release when using the <u>incorrect</u> method to process location data																							
QMA	Statistical area	CRA 1					CRA 2				CRA 3			CRA 4					CRA 5							
		939	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	934	932	933	916	917	918	919		
CRA 1	939	1255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	901	0	322	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	902	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	903	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	904	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
CRA 2	905	0	0	0	0	11	129	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	906	0	0	0	0	0	51	2423	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	907	0	0	0	0	0	0	36	1010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	908	0	0	0	0	0	0	0	1	782	21	0	0	0	0	0	0	0	0	0	0	0	0	0		
CRA 3	909	0	0	0	0	0	0	0	0	90	939	0	0	0	0	0	0	0	0	0	0	0	0	0		
	910	0	0	0	0	0	0	0	0	0	992	0	0	0	0	0	0	0	0	0	0	0	0	0		
	911	0	0	0	0	0	0	0	0	0	1	442	0	0	0	0	0	0	0	0	0	0	0	0		
CRA 4	912	0	0	0	0	0	0	0	0	0	0	0	382	0	1	0	0	0	0	0	0	0	0	0		
	913	0	0	0	0	0	0	0	0	0	0	0	0	1004	2	0	0	0	0	0	0	0	0	0		
	914	0	0	0	0	0	0	0	0	0	0	0	4	18	1175	0	0	0	0	0	0	0	0	0		
	915	0	0	0	0	0	0	0	0	0	0	0	0	0	0	402	0	0	0	4	0	0	0	0		
	934	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0		
CRA 5	932	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	933	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1106	2	0	0	0	0		
	916	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3126	0	0	0	0		
	917	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	1736	0	0	0		
	918	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	919	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Table F.2: Area of release when using the correct method to process reported location data (rows) and the incorrect method (columns). This table only includes tag events for which a latitude and longitude were reported (CRA 6–9). Cells shaded grey and red respectively highlight numbers of tag recaptures that did not and did change areas, comparing methods for processing location data.

Statistical area of release when using the correct method to process location data		Statistical area of release when using the incorrect method to process location data																			
		CRA 7&8										CRA 9								CRA 6	
QMA	Statistical area	920	921	922	923	924	925	926	927	928	929	930	931	935	936	937	938	940	941	942	943
CRA 7&8	920	509	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	921	1	315	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	922	0	0	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	923	0	0	0	180	26	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
	924	0	0	0	2	924	0	19	1	0	0	0	0	0	0	0	0	0	0	0	0
	925	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	926	0	0	0	5	0	2	1422	12	1	0	0	0	0	0	0	0	0	0	0	0
	927	0	0	0	0	0	0	37	3964	3	0	0	0	0	0	0	0	0	0	0	0
	928	0	0	0	0	0	0	0	5	462	0	0	0	0	0	0	0	0	0	0	0
CRA 9	929	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	930	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	931	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
	935	0	0	0	0	0	0	0	0	0	0	0	0	60	38	0	0	0	0	0	0
	936	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0
	937	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	938	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	940	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	84	1	0	1
CRA 6	941	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96	0	0
	942	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	0
	943	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	943	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0