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Data for the 2019 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1

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EXECUTIVE SUMMARY

Starr, P.J.; Webber, D.N.; Rudd, M.B.; Large, K.; Roberts, J. (2020). Data for the 2019 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1.

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This document describes the data used in the 2019 CRA 1 stock assessment. Data sets described in this report include catch estimates for all sectors of the CRA 1 fisheries, seasonal standardised CPUE indices, length frequency distributions, and tag-recapture data.

Catch estimates are provided for the commercial, recreational, customary, and illegal fisheries, collated by year to 1978 and then by six-month season (spring-summer [SS] and autumn-winter [AW]), and by size-limited and non-size-limited fisheries. Recreational catch estimates were available from older telephone/diary surveys, from two recent large-scale multi-species surveys conducted using a population-based survey methodology, and a single interview-based creel survey conducted in the two east coast CRA 1 statistical areas. The survey catch estimates were fitted, assuming a log-normal distribution, to the SS standardised CPUE for 1994, 1996, 2011, 2013, and 2017. The estimated scaling coefficient was then used to estimate a recreational catch series from 1979 based on the full series of standardised SS commercial CPUE. Recreational catches before 1979 were interpolated from a low value in 1945 to the 1979 value.

CPUE was standardised for the SS and AW seasons. The F2 algorithm, which uses a truncated distribution of "vessel correction factors" to adjust estimated catches to final catch, was used to prepare the catch and effort data. The destination codes "X" (discarded at sea) and "F" (Section 111 recreational catches) were added to the destination code "L" (landed to a Licensed Fish Receiver [LFR]) to obtain the final catch total for scaling the estimated catches. The CPUE standardisation procedure was updated by the inclusion of a vessel explanatory variable for data beginning in 1989 and Bayesian inference was used to better represent the uncertainty. Earlier data were excluded because vessel codes were not consistent before 1989; this effectively split the CPUE series. Frequentist inference was used for these early data without using a vessel explanatory variable.

Length frequency data were available from both observer catch sampling and voluntary logbook programmes. These were collated by data source and by season, and the document describes how the individual records were weighted. Tag-recapture data provide information on sex-specific growth rates, and the document describes the data set. The CRA 1 tag data set was augmented by tag recoveries from the two adjacent western statistical areas in CRA 2.

1. INTRODUCTION

This work addressed parts of Objectives 3 and 4 of the Fisheries New Zealand contract CRA2018-01. This one-year contract, which began in April 2019, was awarded to New Zealand Rock Lobster Industry Council Ltd. (NZ RLIC Ltd.), who sub-contract Objectives 3 and 4 to the authors of this report.

Objective 3 - CPUE and decision rules: To update the standardised CPUE analysis from all lobster QMAs and report on the operation of current decision rules.

Objective 4 - Stock assessment: To estimate biomass and sustainable yields for rock lobster stocks.

The National Rock Lobster Management Group (NRLMG) decided that CRA 1 and CRA 3 should be assessed in 2019. Data were compiled for both stocks by a team comprising Paul Starr, D'Arcy Webber, Merrill Rudd, Kath Large, and Jim Roberts. CRA 1 was then assessed by Merrill Rudd and Kath Large, and CRA 3 was assessed by D'Arcy Webber and Jim Roberts, with Paul Starr supporting both teams. This document is limited to the data for CRA 1 and describes catches – including commercial, recreational, customary and illegal catches – CPUE, length frequencies, and tag-recapture data. Appendix A documents formal data requests to Fisheries New Zealand for non-commercial catch information and the associated Fisheries New Zealand response is provided in Appendix B. Rudd et al. (in press) present the stock assessment based on the data in this report.

The previous stock assessment of CRA 1, including the development of operational management procedures, was in 2014 (Webber & Starr 2015). The data used in that stock assessment were described by Starr et al. (2015). Decisions on data and modelling choices were discussed and approved by the Rock Lobster Fishery Assessment Working Group (RLFAWG).

CRA 1 extends from Kaipara Harbour on the west coast to the Waipu River, south of Bream Bay and Whangarei on the east coast (Figure 1). This QMA includes the Three Kings Islands, designated as Statistical Area 901. Commercial fishing occurs on both sides of the North Island, as well as at the Three Kings. The first TAC for CRA 1 was set at 273.062 t for the 2015–16 fishing year as a result of the 2015 stock assessment, with the CRA 1 TACC remaining unchanged at 131.062 t. This TAC comprises a customary allowance of 20 t, a 50 t recreational allowance, and a 72 t allowance for "other mortalities". Commercial landings have remained at or near the 131 t TACC since the early 1990s. In the 2017–18 fishing year, there were 12 vessels operating in CRA 1, a total that has remained relatively unchanged since the early 2000s (Starr 2019). There is significant iwi involvement in quota share ownership and fishing and rock lobsters have great cultural significance to local Māori. The commercial harvest has an approximate landed value of $11.1 million based on an average port price of $84,500/tonne (D. Sykes, NZ RLIC, pers. comm.). CRA 1 rock lobsters are landed to Totara North and Leigh and shipped to two Auckland locations for packing and live export. In the 2019–20 fishing year there were 35 CRA 1 quota share owners (D. Sykes, NZ RLIC, pers. comm.).

The available biological and CPUE data were examined for internal evidence of differences between regions of CRA 1, given that the two East Northland Statistical Areas 903 and 904 have much lower absolute CPUE (in terms of kg/potlift) than the other three CRA 1 statistical areas. However, when the available data were examined in detail (see Appendix C), the stock assessment team concluded that, although the regional CPUE series differed in terms of absolute CPUE, the series looked remarkably similar as relative series (see Figure C.6). There did not appear to be sufficient evidence to justify performing separate independent stock assessments on these two regions (see Section C.3), particularly considering limitations in the amount of length frequency data available for Statistical Areas 903 and 904 (see Table C.1).

2. CRA 1 CATCH DATA

2.1 Commercial catch

For commercial catches, the fishing year and calendar year were the same before 1979. From 1979 onwards, the fishing year has been from 1 April to 31 March. Reported annual commercial catches from 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 the Fisheries Statistics Unit (FSU), a version of which is now held by Fisheries New Zealand. The three months of catch from January through 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.

For 1 April 1986 through to 31 March 1988, monthly reported catch totals from all New Zealand were obtained from Quota Management Returns (QMRs), maintained by Fisheries New Zealand. Because catch estimates for individual QMAs were not available for this period, these total New Zealand catches were divided into QMA catches based on the proportional landings reported on FSU forms. From 1 April 1988 to 30 September 2001, catches were summarised from monthly QMRs from each QMA. The QMRs were replaced by Monthly Harvest Returns (MHRs) on 1 October 2001, but the same information is available from these newer forms.

There has been increased use of destination codes that report intermediate holding of catch in many of the CRA QMAs (see Appendix D), a practice which allows operators to wait for favourable market conditions before selling their catch. However, this practice has also affected the analysis of commercial catch and effort data by breaking the link between the effort used to take the lobsters and the validated landing information (see Fisheries New Zealand 2019 for a discussion of this problem). The landing information was examined to see the extent of this practice in CRA 1, which appears to use intermediate holding pots (destination code “P”, see Figure D.1). However, little use is made of Destination “X” (discarding of legal lobsters) in CRA 1 (Figure D.1). It is not known if this indicates that there is very little discarding of legal lobsters or whether discarded legal lobsters are not being recorded.

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

Annual commercial catches in CRA 1 averaged 130 t/year between 1945 and 1978, with a 9-year period in the late 1960s and early 1970s when catches ranged from 190 t to 356 t (Figure 2). CRA 1 commercial catches were also high (174–232 t) in the period leading up to the introduction of rock lobster into the QMS (1980–1989), with catches peaking at 232 t in 1983–84 and averaging 200 t/year during that decade. Commercial catches in CRA 1 were less than the TACC until 1993–94, when the TACC was reduced to its current level. Landings have since closely matched the TACC (Figure 3).

2.2 Recreational catch

Seven annual recreational survey catch estimates are available for CRA 1 (Table 1). Estimates from the two Kingett Mitchell National Surveys (Boyd et al. 2004; Boyd & Reilly 2002) were not accepted by the RLFAWG for the 2014 CRA 1 stock assessment (Starr et al. 2015) because these survey estimates were considered implausibly high for CRA 1. The earlier 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 [Auckland NIWA, 10–11 June 2004]) because the interview questions possibly underestimated fisher participation rates by allowing for an easy exit from the interview (“soft refusal” bias). These two early surveys continue to be used by the RLFAWG despite this advice because the estimates are plausible and no other recreational information is available for these years. Both the Boyd and the Otago surveys were potentially biased high because recreational logbook participants were not closely supervised and may not have accurately recorded their fishing activity. The much higher harvest estimates in the Boyd surveys were a result of higher claimed participation in saltwater fishing over the previous 12 months in the initial screening survey.

Two large-scale population-based diary/interview surveys (National Panel Survey or NPS) have been conducted under contract for Fisheries New Zealand from 1 October 2011–30 September 2012 (Wynne-Jones et al. 2014) and from 1 October 2017–30 September 2018 (Wynne-Jones et al. 2019), with the intention of estimating FMA- and QMA-specific annual catches for all major finfish and non-finfish species (Heinemann et al. 2015). This survey was based on a design that resembled the New Zealand national census, making use of the census population strata ("mesh blocks") of dwellings as the basis for identifying recreational fishers. A door-to-door survey of households in randomly selected strata was used to select participants who would report their catch for an entire year. A structured and carefully designed Computer Assisted Telephone Interview method was used to record harvest in detail from those who had fished. The survey results were thought to be plausible for CRA 1, with 32 (2011–12) and 34 (2017–18) fishers providing 90 and 65 interviews for each survey year (see table 60 in Wynne-Jones et al. 2014 and table 51 in Wynne-Jones et al. 2019). These estimates have relatively high CVs (0.30 in 2011 and 0.47 in 2019, Table 2). The 2011–12 survey provided estimates of the distribution of fishing platforms used to take lobsters in CRA 1, with large and small motor boats accounting for about three quarters of the catch and only 15% coming from land (Table 2). The primary capture method used to take rock lobster in CRA 1 was diving (87%), followed by potting (11%) (Table 2). NPS survey results from logbook participants were in terms of number of fish. Mean recreational catch weight for the most important finfish and non-finfish species QMAs was estimated by a parallel project (Hartill & Davey 2015).

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

A recreational catch vector was developed by assuming that recreational catch has been proportional to the CRA 1 spring-summer (SS) abundance, as reflected in the unstandardised (geometric mean) SS CPUE from Statistical Areas 903 and 904. These areas were used because the majority of the recreational fishery takes place in these statistical areas, located off the east coast of the North Island (about 70% of the total QMA– Holdsworth 2014). These areas have lower commercial CPUE than the remaining three CRA 1 statistical areas and do not show a large increase in CPUE, from the early 2000s, seen in the other statistical areas. The unstandardised SS CPUE vector was calculated for combined Statistical Areas 903 and 904 using data prepared with the F2-LFX algorithm (see Starr 2019). By agreement in the RLFAWG, the recreational catch vector was based on five of the seven survey estimates (in tonnes – see Table 1) from the 1994 (Otago), 1996 (Otago), the 2011–12 and 2017–18 NPS surveys and the 2013 Holdsworth survey. The two NPS surveys and the Holdsworth survey were assumed to be less biased, so the estimated survey CVs were used. The CVs for the two Otago surveys were assumed to be 50% higher than that of the mean of the two NPS surveys. A scalar quantity q (Eq. 1) was estimated by obtaining the best fit to these survey estimates when minimising a log-normal distribution using the CVs indicated in Table 1:

Eq. 1

$$\boldsymbol{W_t = w_t N_t}$$
$$\boldsymbol{\widehat{W}_t = \widehat{q} CPUE_t}$$
$$\mathbf{LL} = \sum_{t=1}^{5} \left(\frac{\left(LN(W_t) - LN(\widehat{W}_t) \right)^2}{2\sigma_t^2} \right)$$

where

t subscripts five recreational survey estimates in Table 1:
1=1994 Otago; 2=1996, Otago; 3=2011–12 NPS; 4=2103 Holdsworth; 5=2017–18 NPS

$w_t =$ mean spring/summer weight >= MLS for sampled lobster in year/survey t for CRA 1

$N_t =$ mean number lobsters in year/survey t for CRA 1

$CPUE_t =$ Area 903/904 mean spring/summer unstandardised CPUE in year t

$\hat{W}_t =$ CRA 1 estimated recreational catch (tonnes) for year t

The estimated recreational catch trajectory (Eq. 2) based on the q estimated in Eq. 1 matches the 2013 Holdsworth observation but overshoots the 2011–12 and 2017–18 NPS surveys and underestimates the two Otago observations (Figure 4). The q parameter was estimated to be 37 tonnes/CPUE-unit and the recreational catch vector accounted for about 1000 tonnes of historical catch from 1979 to 2018.

Eq. 2

$$\widehat{W}_y = \hat{q}CPUE_y \text{ if } y \geq 1979$$
$$\widehat{W}_{1945} = 0.2\widehat{W}_{1979}$$
$$\widehat{W}_y = \widehat{W}_{y-1} + \frac{\widehat{W}_{1979} - \widehat{W}_{1945}}{1979 - 1945} \text{ if } 1945 < y < 1979$$

For assessments since 2006, the RLFAWG 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 5015 kg for CRA 1, occurring in 2006–07. The RLFAWG has agreed to add the maximum catch estimate to the estimated recreational catch in each year since 1979 (Figure 4), increasing the total 1979 to 2018 recreational catch in the model to 1195 t.

2.3 Customary catch

Fisheries New Zealand were asked to provide estimates of current and historical customary catches, and an appreciation of their uncertainty (see Appendix A and Appendix B). Fisheries New Zealand advised that a constant customary catch of 10 t should be assumed. This was split between seasons, with 90% assumed taken in the SS.

2.4 Illegal catch

Fisheries New Zealand were asked to provide estimates of current and historical illegal catches, and an appreciation of their uncertainty (see Appendix A and the response in Appendix B).

When this was initially discussed by the RLFAWG, the meeting rejected using the estimates of illegal catch provided by MPI Compliance Services because these had not been adequately documented. The meeting agreed to use the early estimates generated using the ‘export-discrepancy’ methodology (described below) up to 1980. After that year, the meeting agreed to use a fixed percentage of the total commercial catch summed over the period 1981–2018, scaled by the annual standardised CRA 1 CPUE.

The following procedure was used to estimate illegal catch up to 1980:

- Starting with the estimates of export discrepancies for all of New Zealand for 1974–80 (McKoy, unpublished data), the CRA 1 illegal catches for each of these seven years were estimated from the ratio of the reported commercial catch in CRA 1 relative to the total New Zealand reported commercial catch for the same years.
- The average ratio of the export discrepancy catch to the reported commercial catch was calculated for the period 1974–80. This ratio was used to generate an illegal catch estimate for all years with no data (1945 to 1973 and 1981 to 1989) by multiplying the reported catch by the average ratio. This approach was agreed by the RLFAWG on 15 Aug 2002.

In the past, estimates for illegal catch from MPI Compliance Services have frequently been provided in two categories (“reported” or “R” and “not reported” or “NR”). The category of “commercial illegal reported” or “reported” (equals “R” in Table 3) was assumed to represent illegal commercial catch that was eventually reported to the QMS as legitimate catch. Table 3 indicates that the “R" category is not present among the CRA 1 illegal catch estimates; consequently, consideration of this category was not applicable for CRA 1.

We assumed that annual illegal catches were distributed between seasons in the same proportion as the commercial catch for each year. The illegal catch estimates are shown in Figure 5.

2.5 Time series of CRA 1 annual and seasonal catches

Annual catches for CRA 1 from 1945 to 1978, followed by seasonal catches from 1979 to 2018, are presented for commercial, recreational, customary, and illegal categories in Table 4.

2.6 Size-limited and non-size-limited catch

The size-limited (SL) catch is taken under the Minimum Legal Size (MLS) regulations and the restriction on landing berried females; it is the sum of the commercial and recreational catches minus the reported illegal catches (of which there are none for CRA 1). The non-size-limited (NSL) catch is taken without regard to those restrictions; it is the sum of reported and unreported illegal catches and the customary catches. Annual commercial catches were divided into seasons beginning in 1979 based on the seasonal distribution of the FSU and QMR/MHR data (Figure 6). Illegal catches were divided between seasons in the same proportions as commercial catches.

2.7 Seasonal proportion of catch

It was assumed that 90% of the customary and recreational catches were taken in SS. These catches are shown in Figure 2 and Table 4. The proportion of the commercial catch taken in the autumn-winter (AW) season increased to near 80% in the late 1990s and early 2000s, and then dropped to around 40–50% (Figure 7).

3. CATCH RATE INFORMATION

3.1 Seasonal standardised CPUE indices

3.1.1 Introduction and methods

Catch and effort data from the Catch Effort Landing Return (CELR) forms were obtained from Fisheries New Zealand in September 2019 (Replog 12557) and processed using standard error checks (Bentley et al. 2005). Data spanned the period from 1 July 1989 to 31 March 2019. Data for the period 1 April 1979 to 30 June 1989 came from the FSU database, a static copy of which is held by the rock lobster stock assessment team.

Preparation of the CELR data used the F2_LFX procedure (Starr 2019). The F2 algorithm scales the monthly estimated catch taken by a vessel in a statistical area using a "vessel correction factor" (*vcf*) which is the ratio of landed catch to estimated catch for one vessel in one year (Starr 2019). Vessels with a *vcf* less than 0.8 or greater than 1.2 are discarded from the analysis. The F2_LFX procedure scales the estimated catches to the combined "L" (LFR), "X" (discarded to sea), and "F" (Section 111 recreational catch) destination codes (destination codes are defined in Appendix D; number of records in the CPUE data set are provided in Table 5).

The 2019 stock assessment included two standardised CPUE series calculated from generalised linear models (GLMs) that used sequential six-month periods as forced explanatory variables (see section 2.5 of Starr (2019) for a description of this procedure). One CPUE series was based on the early FSU data and the second series used the more recent CELR data. Three explanatory variables were available for both analyses in addition to the sequential [`period`] variable: [`month`] of capture, statistical [`area`] of capture, and an identification code for each fishing [`vessel`]. There is a discontinuity between the two series; the FSU series ends with the 1 October 1988–31 March 1989 sequential period and the 1 April 1989–30 September 1989 series starts on 1 July 1989 when the CELR data collection began (Bentley et al. 2005).

The variable [`vessel`] is not used in the FSU GLM. However, an analysis that included a vessel effect was done and this made no perceivable difference so was dropped: the FSU indices extracted from this analysis for use in the 2019 stock assessment are provided in Table E.3. The FSU GLM estimated relative [`month`] effects in each half-year period, using the [`month`] in each period with the lowest standard error as the reference [`month`].

The CELR model used a [`vessel`] explanatory variable, filtered for vessels with at least five years of data. The CELR GLM estimated [`month`], [`vessel`], and a [`period:area`] interaction as group-level effects and [`period`] as a population-level effect. Bayesian inference was used to estimate parameter uncertainty in the CELR GLM. This was done using the R package *brms*, which is a wrapper for doing GLMs coded using the Stan language. Stan uses gradient-based Markov chain Monte Carlo (MCMC), specifically the Hamiltonian Monte Carlo (HMC) algorithm, for Bayesian inference. Four thousand samples from the posterior distribution were obtained by combining samples across four chains, with each chain consisting of a warm-up period of 2000 discarded iterations followed by sampling the next 1000 iterations.

The null model, which only includes coefficients for the sequential period (*t*), and is roughly equivalent to the unstandardised series, is defined as:

Eq. 3 $$\log\left(\frac{C_i}{E_i}\right) = \mathrm{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon_i} = \boldsymbol{\beta_0} + \boldsymbol{T\beta_t} + \boldsymbol{\varepsilon_i}$$

where

$$\varepsilon_i \sim N(0, \sigma^2)$$
$$\sigma \sim \text{student}(3,1,10)$$
$$\beta_0 \sim N(0,100)$$
$$\beta_t \sim N(0,10)$$

where C_i is the catch (tonnes) for record *i*, and E_i is the effort (number of pot lifts) for record *i*. There are two time periods (*t*) each fishing year. The periods are referred to as spring-summer (SS) and autumn-winter (AW) when two (seasonal) time periods are specified. For $\boldsymbol{t}$ = (1, 2, 3, …, n), then $\boldsymbol{t}$ = (AW, SS, AW, …, SS), where SS = October to March.

The status quo model is similar to the model used in previous CPUE analyses for New Zealand rock lobster fisheries (Starr 2019) and included population-level effects for time period (*t*), and group-level effects for month (*m*), statistical area (*a*), and vessel (*v*):

Eq. 4 $$\log\left(\frac{C_i}{E_i}\right) = X\boldsymbol{\beta} + \boldsymbol{\varepsilon_i} = \boldsymbol{\beta_0} + \boldsymbol{T\beta_t} + \boldsymbol{M\beta_m} + \boldsymbol{A\beta_a} + \boldsymbol{V\beta_v} + \boldsymbol{\varepsilon_i}$$

where

$$\begin{aligned}
&\varepsilon_i \sim N(0,\sigma^2)\\
&\sigma \sim student(3,1,10)\\
&\beta_0 \sim N(0,100)\\
&\beta_t \sim N(0,10)\\
&\beta_m \sim N(0,10)\\
&\beta_a \sim N(0,10)\\
&\beta_v \sim N(0,10)
\end{aligned}$$

The interaction model includes population-level effects for time period (*t*), and group-level effects for month (*m*), and vessel (*v*), and a time period+statistical area interaction term (*a*):

Eq. 5 $$\log\left(\frac{C_i}{E_i}\right) = X\boldsymbol{\beta} + \boldsymbol{\varepsilon_i} = \boldsymbol{\beta_0} + \mathbf{T}\boldsymbol{\beta_t} + \mathbf{AT}\boldsymbol{\beta_{a,t}} + \mathbf{M}\boldsymbol{\beta_m} + \mathbf{V}\boldsymbol{\beta_v} + \boldsymbol{\varepsilon_i}$$

where

$$\begin{aligned}
&\varepsilon_i \sim N(0,\sigma^2)\\
&\sigma \sim student(3,1,10)\\
&\beta_0 \sim N(0,100)\\
&\beta_t \sim N(0,10)\\
&\beta_m \sim N(0,10)\\
&\beta_a \sim N(0,10)\\
&\beta_{a,t} \sim N\left(0,\sigma^2_{\beta_{a,t}}\right)\\
&\sigma_{\beta_{a,t}} \sim student(3,1,10)
\end{aligned}$$

3.1.2 CRA 1 CELR Seasonal Standardised Series

Pareto smoothed importance-sampling, leave-one-out cross-validation (PSIS-LOO) was used for model checking and model comparison (Vehtari et al. 2017). This method compares a matrix of log-likelihood values for each data point and MCMC sample between models. The calculated leave-one-out information criterion (LOOIC) indicates the best fit (lowest LOOIC value) for the interaction model at 4134 compared with 4516 for the status quo model and 7491 for the null model (Table 6). PSIS-LOO diagnostics (for model checking) also indicate reliability of the PSIS-LOO analysis with tail shape (Pareto shape parameter k) estimates for each point's contribution to the model comparison below the preferred threshold of $k < 0.7$, with the majority of estimates at $k < 0.5$ which is considered ideal (Figure 8).

Trace plots of the MCMC samples of the posterior from the interaction model appear well mixed with no indication of lack of convergence (Figure 9). Vessel coefficients (Figure 10) show a wide range of values with many vessels having non-overlapping posterior distributions. The AW month coefficients in May and June are much smaller than the other coefficients, suggesting lower catch rates during these months (Figure 11).

There is a gradual but variable overall increasing trend from the mid 1990s in both the AW and SS series (Table 7, Figure 12). Catch rates are generally higher in the SS series compared with those in the AW (Figure 13), an observation made in all CRA QMAs because ovigerous females cannot be taken legally during the AW months. The 2017–18 AW CPUE is the highest catch rate in the AW series and the 2018–19 SS CPUE is the highest in the SS series.

3.2 CRA 1 FSU/CELR seasonal standardised series

The seasonal model (Appendix E), fitted to the FSU/CELR data set without using a [vessel] explanatory variable (see Eq. 3 of Starr 2019), explained 43% of the model deviance (Table E.2). Standardised model residuals show good conformity with the underlying lognormal distribution assumption (Figure E.1). There was little contrast in the [month] coefficients and the contrast in the [statistical_area] coefficients, though greater than for the [month] variable, was still relatively small (Figure E.2). Only the first ten seasonal indices were included in the CRA 1 stock assessment (coloured cells: Table E.3).

3.3 Historical catch rate (CR) data

Monthly catch and effort (days fishing) data from 1963 to 1973 were summarised by Annala & King (1983) and used to calculate unstandardised catch per day for each calendar year from 1963 to 1973 (Figure 14).

4. LENGTH FREQUENCY DISTRIBUTIONS (LFS)

Data were extracted for CRA 1 in August/September 2019, comprising both observer and voluntary logbook catch sampling from the 1975–76 to 2018–19 fishing years. The pre-1980 length measurements used carapace length (CL) which were converted to tail width (TW) using an unpublished relationship for CRA 2 because there are no published relationships for either CRA 1 or CRA 2[1]. Each data record used for input to the model represented a weighted sum of the length measurements for a season and sampling source for each year of sampling. The design of the logbook catch sampling requires participating fishers to measure every lobster (up to 25 individuals) in each of 3–5 marked pots each day. This design results in good spatial and temporal representation of the catch if the participating fishers are representative of the wider fishing population. This goal is not likely to have been achieved in CRA 1 until after 2014, with only intermittent participation in the voluntary logbook programme from 1993 to 2014. After 2014, participation in the logbook programme improved considerably (Table 8). The primary sampling method in CRA 1 has been observer sampling, whereby dedicated observers are placed on vessels, assigned according to availability and distributed on the basis of the previous year fishery catches. This sampling procedure measures and sexes all lobsters from as many pots as is feasible during a day's fishing for the vessel being observed. Approximately 15 to 20 days of sampling effort have been directed at CRA 1 in each year since 1997 (Table 8).

Record fields in the data set included the following information:

- fishing year
- season (coded 1 for AW, 2 for SS)
- source (coded 1 for logbooks, 2 for observers)
- a relative weight field for the record (w), described below
- the total number of lobsters measured
- 36 fields, representing the relative proportion (see below) of males measured by sex class within the sizes classes {[30, 32), [32, 34), …, [98, 100), [100, ∞)} mm tail width (TW)
- 36 fields for immature female numbers measured
- 36 fields for mature female numbers measured

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[1] $TW = a + bCL$
where
$a = -0.14; b = 0.54504$ (males)
$a = -6.03; b = 0.68834$ (females)

The choice of the accumulator bin (100 mm instead of 90 mm) was larger than in other North Island lobster QMAs because about 3% of the measured lobsters were greater than 90 mm in this QMA.

Each data record comprised pooled measurements taken from various months within the season and from various statistical areas within the QMA. For each month/area stratum, the numbers-at-length were summed for each sex, and the proportion-at-sex was calculated as:

Eq. 6 $$\boldsymbol{p}_{g,m,a,s} = \frac{\boldsymbol{N}_{g,m,a,s}}{\sum_s \boldsymbol{N}_{g,m,a,s}}$$

where g indexes sex, s indexes size group, m indexes month, a indexes statistical area, and $N_{g,m,a,s}$ represents the number-at-length for each sex in the month/area/length bin cell.

Proportions-at-length from the month/area cells were combined to form a record, based on their "representativeness", i.e., using the catch in the month/area cell ($C_{m,a}$) compared with the total catch for the season:

Eq. 7 $$\boldsymbol{P}_{g,s} = \frac{\sum_m \sum_a (\boldsymbol{C}_{m,a} \boldsymbol{p}_{g,m,a,s})}{\sum_m \sum_a \sum_s (\boldsymbol{C}_{m,a} \boldsymbol{p}_{g,m,a,s})}$$

where $P_{g,s}$ was the relative proportion-at-length for each sex in the record. The model re-normalised these to sum to 1 across each sex.

As well as the relative weight assigned to the overall LF dataset, a relative weight for each sex (w_s) was assigned to each data record within the dataset which combined the representativeness of each month/area cell, the cube root of the number of fish measured ($N_{m,a,s}$), and the cube root of the number of days sampled ($D_{m,a}$):

Eq. 8 $$\boldsymbol{w}_s = \sum_m \sum_a \frac{\boldsymbol{C}_{m,a} \sqrt[3]{\boldsymbol{N}_{m,a,s}} \sqrt[3]{\boldsymbol{D}_{m,a}}}{\sum_m \sum_a \boldsymbol{C}_{m,a}}$$

This approach of applying the relative weight by sex represented a change from past stock assessments which used a single weight for the total record, after applying a truncation rule to the weights so that single records did not have exceptional influence (see Starr et al. 2014, for instance). This rule truncated weights to a maximum value of 10 while raising weights less than 1.0 to 1.0. Because of the change to using weights by sex category, the stock assessment team decided to use the length frequency records without applying the truncation rule. Applying relative weights by sex in this way is more practical if there are few (or no) immature female individuals measured but there are male and mature female records. Using the previous methodology, these records would have received the same weight (across all three sex categories) and the size class with few or no measured individuals would have been inappropriately up-weighted, given the small amount of data.

The CRA 1 LF data set comprised 64 records from 1986 to 2018, spanning two seasons: 21 were logbook samples and the remaining 43 were observer samples. Four of the logbook samples and two of the observer samples were dropped because they had less than 100 measurements. The logbook samples for 1993, 1995, 2011, 2012, and 2013 were also dropped because there was only one participant, and thus these samples were unlikely to be representative of the entire fishery (Table 8). This accounted for another 7 records, leaving 10 logbook records and 41 observer records, for a total of 51 records for use in the stock assessment. The logbook records ranged from 357 to 1842 lobsters measured in both seasons and the observer samples ranged from 436 to 6882 lobsters measured in both seasons (Table 9). The logbook sampling record weights by sex (Eq. 8) ranged from 0.066 to 6.35 for the accepted samples whereas the observer catch sampling record weights ranged from 0.0006 to 4.09 (Table 10). All the very low weights corresponded to samples with very few observed immature females, giving an appropriate low weight to the poorly represented sex category.

Sex proportions were calculated from normalised data records (Figure 15, Table 11). There were relatively few immature females (mean about 5%), with females in this QMA usually reaching maturity below the MLS of 60 mm TW. The sex ratios of males and mature females showed little systematic pattern over time in either the logbook data or the catch sampling data. The sex proportions estimated by both sampling programmes show similar trends.

Mean length was also calculated from the data records (Figure 16, Table 12). There was no trend in male or mature female mean length in either the AW or SS for either sampling programme.

Although the model contains size bins in the range 30–100+ mm TW, few fish as small as 30 mm were measured, especially for immature females, leading to many cells with zero observations (Figure 17, Table 13). For sex/size bins with few observations, the model would be comparing many zero observations with zero or very small predictions, resulting in a large number of very small residuals that would distort the diagnostics and waste computing time. Bins at both ends of the range for each sex were therefore combined into accumulator "plus" and "minus" bins. Table 13 shows the number of year, season, sampling category records for each 2 mm TW bin by sex category. This table also shows the number of these records where the year, season, sampling category proportion within a sex category is less than 0.001 (an arbitrary threshold) and the calculated proportion of records greater than 0.001 in the bin. This information is useful to select appropriate accumulator bins for each sex category. Past experience has shown that model results were not very sensitive to the chosen threshold value.

The distributions of the LF data by sex are shown for each data record included in the stock assessment, where a "data record" represents the normalised frequency by sex class in a sequential six-month season by data source (logbook or observer catch sampling). Length frequency distributions by year are shown for AW logbook sampling (Figure F.1), SS logbook sampling (Figure F.2), AW observer catch sampling (Figure F.3), and SS observer catch sampling (Figure F.4).

5. TAG DATA

This section describes tag-recapture data that are used to inform growth in the stock assessment of rock lobster stocks (Haist et al. 2009). These data will also be useful for informing decisions about stock structure and movement. Tag data for all CRA areas were extracted in August 2019.

5.1 Data processing

Before the tag data were summarised to inform growth in stock assessments, they were pre-processed (i.e., obvious errors were corrected and records that cannot be used were removed). As part of this procedure, every release-recapture event was linked to form a single record. These steps of processing, linking, and formatting were done using purpose-built software written in the R statistical computing language.

The tag processing software implements the following rules:

- remove duplicate records
- remove records with no date
- remove records that are missing both tail width and carapace length
- remove releases with no corresponding recapture
- iteratively match captures with recaptures
- if sex is missing at capture but not recapture, then infer sex and vice versa
- remove matched records that change sex
- remove matched records that do not have a sex code of 1 or 2
- if statistical area is not 901 to 943 then set to NA

- 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
- 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)
- if there is no recorded tail width, then calculate this from the carapace length using the relationships given by Breen et al. (1988)
- remove records where tail width is less than 20 mm
- remove records where tail width is greater than 150 mm
- calculate the time at liberty in days
- remove those records that are at liberty for less than 1 day
- remove those records that are at liberty for greater than 10 years
- calculate the growth increment as the difference in tail widths
- remove records with a growth increment less than -40 mm or greater than 40 mm

Data are then rearranged into the format used by the model:
- sex (1 for males and 2 for females)
- year of release, extracted from release date
- year 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

5.2 Tag data summaries: all QMAs

5.2.1 Comparison with previous extract

A comparison is done to ensure that new data extracts are not missing records that were available in previous years and to see how many new data records are available (Table 14 and Table 15). There was an increase in the number of release-recovery pairs in CRA 1 (in anticipation of this CRA 1 stock assessment) and increases in CRA 3, CRA 4, and CRA 5 (Table 14). As would be expected, almost all the increases in tag recaptures occurred during the years 2015 to 2018 (Table 15).

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

Recovery rates (tags turned in relative to number released) vary by QMA, with the highest rate occurring in CRA 5 (0.208) and the lowest rate in CRA 9 (0.020) (Table 16). There are a total of 34 691 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 (Table 17). The CRA QMA with the majority of recovered tags has been CRA 8, and the fewest recaptured tags have come from CRA 6 and CRA 9 (Table 17).

Tagged lobsters are generally recaptured in the QMA or statistical area of release, but there are a number of recaptures where it appears that tagged individuals have moved much greater distances (Table 18). However, it seems more likely that many of these large scale movements (e.g., from CRA 8 to CRA 3 and from CRA 3 to CRA 8 – see Table 18) may be due to data errors, which will be investigated in the future.

5.2.3 Summary for QMAs: growth patterns

The observed growth increment (mm) by tail width (mm) at release was generally greater in smaller individuals, but this relationship is very messy (Figure 18 and Figure 19). Growth rates differ among QMAs, with CRA 1 showing fewer smaller individuals compared with most of the other QMAs (Figure 19). The relationship between observed growth increment (mm) and time at liberty (years) appears to be less variable (Figure 20 and Figure 21). This observation holds true for all the QMAs with an adequate amount of data (Figure 21).

5.3 CRA 1: tag data summaries

The total number of CRA 1 tag recoveries consisted of about 2100 events, most (about 1500) of which came from Statistical Area 939, off the west coast of North Cape (see Figure C.1). Consequently, the stock assessment team decided to augment the CRA 1 tag data set with tag recoveries from the western statistical areas of CRA 2: Statistical Area 905 (Great Barrier Island and Coromandel) and Statistical Area 906 (western Bay of Plenty) (see Figure 1). It was reasoned that tags from these two areas would be representative of the two East Northland (CRA 1) statistical areas (903 and 904), neither of which have much representation in the CRA 1 tag data set. All the tables in this section keep the totals from these two tag regions separate, allowing for comparisons.

The screened data extract for CRA 1 comprised 2124 records for the ‘901–904, 939’ tag region (922 males and 1202 females) and 2869 records for the ‘905, 906’ tag region (1521 males and 1348 females) (Table 19). If the data are confined to tags which had been at liberty for at least 365 days (see Webber et al. 2020, Appendix 1 for a discussion of the reasons for this option), the number of tag recoveries drops considerably: to 821 and 1002 recoveries for both sexes in the ‘901–904, 939’ and ‘905, 906’ tag regions respectively (Table 19). The distributions of sizes at release and recapture by sex are shown in Figure 22, with most of the tagged males just below the 54 mm TW whereas the females show a broader distribution of tagged individuals. Note that the recapture polygons for both sexes in this plot are shifted well to the right of the release polygons, indicating a degree of growth during the period at liberty.

About 25% of the ‘901–904, 939’ tag region release/recovery pairs, and none of the ‘905, 906’ tag region data, derive from tagging done in the 1970s and 1980s, with the remainder of the tag recovery data coming later. Tagging commenced in the ‘905, 906’ tag region in the mid 1990s and did not resume in the ‘901–904, 939’ tag region until the early 2000s (Table 20). All the pre-1985 releases used western rock lobster tags, with size recorded in carapace length, and all the post-1996 releases used Hallprint tags, with size recorded in tail width.

Statistical Area 939 was the most prevalent statistical area of release and recovery in the ‘901–904, 939’ tag region, and Statistical Area 906 was the most important statistical area in the ‘905, 906’ tag region (Table 21). Most recaptures were made in the statistical area of release in both tag regions, with little evidence of large-scale movement.

5.3.1 CRA 1: times at liberty

Times at liberty in the ‘901–904, 939’ tag region varied from 1 day to 1855 days (5.1 years) for males and from 1 day to 3634 days (10 years) for females (Table 22). The equivalent statistics for the ‘905, 906’ tag region are 1 to 2171 days (5.9 years) for males and 1 to 3350 days (9.2 years) for females. The medians were 277.5 days for males and 357 days for females in the ‘901–904, 939’ tag region and 246 days for males and 356 days for females in the 905, 906 tag region (Table 22). The percentages of recaptures at liberty for less than one year in the ‘901–904, 939’ tag region are 74% and 51% for males and females, respectively. Recaptures at liberty are similar in the ‘905, 906’ tag region, with 77% (males) and 52% (females) at liberty for less than one year. The number of times an individual is re-released is also monitored with several females re-released 5–7 times in the ‘901–904, 939’ tag region and some males re-released up to 11 times in the ‘905, 906’ tag region (Table 23). Re-releases were more important in ‘905, 906’ tag region, with 43% of males and 24% of females re-released; the equivalent percentages for the ‘901–904, 939’ tag region were 18% for males and 17% for females.

5.3.2 CRA 1: GROWTH INCREMENTS

Growth increments ranged from -25.8 to 37.5 mm (males) and -29.7 to 35.2 mm (females) for the ‘901–904, 939’ tag region (Table 24) and from -37.0 to 27.7 mm (males) and -9.3 to 20.7 mm (females) for the ‘905, 906’ tag region (Table 24). As with the overall QMA summaries, the observed growth increment (mm) in CRA 1 by tail width at release is generally greater in smaller individuals, even when viewed by statistical area (Figure 23). Similarly, the relationship between observed growth increment (mm) and time at liberty (years) is somewhat tighter, even when viewed by statistical area (Figure 24).

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Table 1: Information used to estimate recreational catch for CRA 1.

Survey	Numbers	Mean weight (kg)	Catch weight (t)	Assumed CV
1994 (Otago: Bradford 1997)	56 000	0.717[1]	40.15	1.5*(0.3+0.47)/2
1996 (Otago: Bradford 1998)	74 000	0.717[1]	53.06	1.5*(0.3+0.47)/2
2000 (Boyd & Reilly 2002)	107 000[2]	–	102.3	not used
2001 (Boyd et al. 2004)	161 000[2]	–	153.5	not used
2011–12 (NPS: Wynne-Jones et al. 2014)	29 739[3]	0.81	23.98	0.30
2013 (Holdsworth 2014)	50 430	0.78	37.30	0.17
2017–18 (NPS: Wynne-Jones et al. 2019)	19 350[4]	0.82	15.91	0.47
Section 111 reported landings				
Maximum reported landings (t) (in 2006–07)			5.015	

[1] SS (spring-summer) mean weight (kg) calculated from commercial sampling data from 1994 to 1996 assuming recreational minimum legal sizes (Starr et al. 2015)
[2] as reported by Boyd & Reilly (2002) and Boyd et al. (2004)
[3] estimate provided by Wynne-Jones et al. (2014)
[4] estimate provided by Wynne-Jones et al. (2019)

Table 2: Fishing platform and capture method categories for CRA 1 during 2011–12 estimated by the national NPS recreational survey (Wynne-Jones et al. 2014). The final line shows the 2011–12 CRA 1 total estimates. CV=standard error of the estimate, which does not include error associated with the estimate of mean weight.

Category	Numbers	CV	Catch (t)[1]	CV	% of Total catch weight
Platform (Appendix table 27.1, Wynne-Jones et al. 2014)					
Trailer motor boat	54 322	0.25	39.87	0.25	65
Larger motor boat or launch	9 520	0.48	6.80	0.47	11
Trailer yacht	0		0.00		0
Larger yacht or keeler	5 016	1.00	3.63	0.57	6
Kayak canoe or rowboat	1 980	0.00	1.41	0.46	2
Off land including beach rocks or jetty	12 280	0.26	9.06	0.26	15
Something else	218	1.01	0.15	1.01	0
Capture method (Appendix table 27.2, Wynne-Jones et al. 2014)					
Rod or line (not long line)	0		0.00		0
Long-line including set line kontiki or kite	0		0.00		0
Net (not including landing net used if caught by line)	0		0.00		0
Pot (e.g. for crayfish)	9 727	0.62	6.89	0.62	11
Dredge grapple or rake	0		0.00		0
Hand gather or floundering from shore	1 398	0.56	1.06	0.55	2
Hand gather by diving	72 212	0.18	52.98	0.18	87
Spearfishing	0		0.00		0
Some other method	0		0.00		0
Total	83 337	0.20	60.93	0.20	100

[1] uses mean weight estimate of 801 grams (Hartill & Davey 2015).

Table 3: Available estimates of illegal catches (tonnes) by CRA QMA from 1990, as provided by MPI Compliance Services over a number of years. R (reported): illegal catch that will eventually be processed though the legal catch/effort system; NR (not reported): illegal catch outside the catch/effort system. Cells without data or missing rows have been deliberately left blank or filled with dashes. Years without any MPI Compliance Services estimates in any QMA have been suppressed in this table.

Fishing	CRA 1		CRA 2		CRA 3		CRA 4		CRA 5		CRA 6		CRA 7		CRA 8		CRA 9	
Year	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR
1990	–	38	–	70	–	288.3	–	160.1	–	178	–	85	34	9.6	25	5	–	12.8
1992	–	11	–	37	–	250	–	30	–	180	–	70	34	5	60	5	–	31
1994	–	15	–	70	5	37	–	70	–	70	–	70	–	25	–	65	–	18
1995	–	15	–	60	0	63	–	64	–	70	–	70	–	15	–	45	–	12
1996	0	72	5	83	20	71	0	75	0	37	70	–	15	5	30	28	0	12
1997	–	–	–	–	4	60	–	–	–	–	–	–	–	–	–	–	–	–
1998	–	–	–	–	4	86.5	–	–	–	–	–	–	–	–	–	–	–	–
1999	–	–	–	–	0	136	–	–	–	–	–	–	–	23.5	–	54.5	–	–
2000	–	–	–	–	3	75	–	64	–	40	–	–	–	–	–	–	–	–
2001	–	72	–	88[1]	0	75	–	–	–	–	–	10	–	–	–	–	–	1
2002	–	–	–	–	0	75	9	51	5	47	–	–	–	1	–	18	–	–
2003	–	–	–	–	0	89.5	–	–	–	–	–	–	–	–	–	–	–	–
2004	–	–	–	–	–	–	10	30	–	–	–	–	–	–	–	–	–	–
2011	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	3	–	–
2014	–	–	–	–	–	–	–	–	–	30	–	–	–	–	–	–	–	–
2015	–	–	–	–	–	–	–	40	–	–	–	–	–	–	–	–	–	–
2016	–	–	–	40[2]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2018	–	40	–	–	–	50	–	–	–	–	–	–	–	–	–	–	–	–

[1] this value discarded by RLFAWG agreement.
[2] this value is not an estimate: it is assumed by agreement by the RLFAWG.

Table 4: Estimated CRA 1 catches (commercial, recreational including Section 111, illegal, and customary) by season. Note that the model does not use two seasons until 1979. Annual estimates are provided in the AW column before 1979. (Continued on next page)

	Commercial		Recreational		Illegal		Customary		Total	
Year	AW	SS	AW	SS	AW	SS	AW	SS	AW	SS
1945	22.1	–	8.8	–	4.2	–	10	–	45.0	–
1946	22.8	–	9.2	–	4.3	–	10	–	46.2	–
1947	40.0	–	9.7	–	7.5	–	10	–	67.1	–
1948	90.7	–	10.1	–	17.1	–	10	–	127.9	–
1949	104.2	–	10.5	–	19.6	–	10	–	144.3	–
1950	92.4	–	11.0	–	17.4	–	10	–	130.8	–
1951	85.0	–	11.4	–	16.0	–	10	–	122.4	–
1952	133.7	–	11.9	–	25.1	–	10	–	180.6	–
1953	131.2	–	12.3	–	24.7	–	10	–	178.2	–
1954	72.0	–	12.7	–	13.5	–	10	–	108.3	–
1955	64.0	–	13.2	–	12.0	–	10	–	99.2	–
1956	75.2	–	13.6	–	14.1	–	10	–	113.0	–
1957	60.7	–	14.1	–	11.4	–	10	–	96.1	–
1958	62.0	–	14.5	–	11.7	–	10	–	98.2	–
1959	62.2	–	15.0	–	11.7	–	10	–	98.9	–
1960	75.1	–	15.4	–	14.1	–	10	–	114.6	–
1961	81.0	–	15.8	–	15.2	–	10	–	122.0	–
1962	135.5	–	16.3	–	25.5	–	10	–	187.3	–
1963	111.2	–	16.7	–	20.9	–	10	–	158.9	–
1964	190.8	–	17.2	–	35.9	–	10	–	253.8	–
1965	249.0	–	17.6	–	46.8	–	10	–	323.4	–
1966	238.4	–	18.0	–	44.8	–	10	–	311.3	–

	Commercial		Recreational		Illegal		Customary		Total	
Year	AW	SS	AW	SS	AW	SS	AW	SS	AW	SS
1967	135.2	–	18.5	–	25.4	–	10	–	189.1	–
1968	235.2	–	18.9	–	44.2	–	10	–	308.3	–
1969	335.6	–	19.4	–	63.1	–	10	–	428.0	–
1970	327.8	–	19.8	–	61.6	–	10	–	419.2	–
1971	356.4	–	20.3	–	67.0	–	10	–	453.7	–
1972	213.4	–	20.7	–	40.1	–	10	–	284.2	–
1973	70.9	–	21.1	–	13.3	–	10	–	115.3	–
1974	45.0	–	21.6	–	5.8	–	10	–	82.3	–
1975	78.0	–	22.0	–	18.9	–	10	–	128.9	–
1976	99.0	–	22.5	–	19.2	–	10	–	150.7	–
1977	182.0	–	22.9	–	46.7	–	10	–	261.6	–
1978	149.2	–	23.3	–	38.3	–	10	–	220.8	–
1979	25.3	89.7	2.4	21.4	2.2	7.8	1	9	30.9	127.9
1980	32.4	147.4	2.6	23.1	3.7	16.8	1	9	39.7	196.3
1981	32.5	150.8	2.8	25.1	6.1	28.3	1	9	42.4	213.2
1982	44.1	178.8	2.5	22.5	8.3	33.6	1	9	55.8	244.0
1983	57.0	174.7	2.4	22.0	10.7	32.8	1	9	71.2	238.6
1984	49.6	162.0	2.4	21.4	9.3	30.5	1	9	62.3	222.9
1985	53.6	165.2	2.6	23.6	10.1	31.0	1	9	67.2	228.8
1986	62.2	149.2	2.7	24.2	11.7	28.0	1	9	77.6	210.4
1987	40.3	147.4	2.6	23.6	7.6	27.7	1	9	51.5	207.6
1988	55.0	123.6	2.2	19.6	10.3	23.2	1	9	68.5	175.4
1989	43.5	130.5	2.4	21.8	8.2	24.5	1	9	55.1	185.9
1990	38.4	92.6	2.5	22.2	11.1	26.9	1	9	53.1	150.7
1991	33.6	94.7	2.1	18.9	6.4	18.1	1	9	43.1	140.6
1992	27.6	82.9	2.0	17.6	2.7	8.3	1	9	33.3	117.7
1993	32.5	94.9	2.0	17.8	3.3	9.7	1	9	38.8	131.4
1994	42.1	87.9	2.7	23.9	4.9	10.1	1	9	50.6	130.9
1995	65.3	61.5	3.6	32.0	7.7	7.3	1	9	77.6	109.8
1996	79.0	50.4	2.8	25.1	44.0	28.0	1	9	126.8	112.5
1997	96.7	32.6	3.1	27.5	53.8	18.2	1	9	154.6	87.3
1998	95.6	33.1	3.0	26.9	53.5	18.5	1	9	153.1	87.5
1999	100.5	25.2	2.0	18.2	57.5	14.5	1	9	161.1	66.9
2000	91.1	39.9	3.5	31.5	50.1	21.9	1	9	145.6	102.3
2001	98.0	32.6	3.1	27.9	54.0	18.0	1	9	156.1	87.5
2002	81.9	48.9	2.6	23.3	43.9	26.2	1	9	129.3	107.5
2003	63.2	65.5	2.2	19.7	33.5	34.7	1	9	100.0	128.9
2004	72.7	58.1	3.0	27.3	36.9	29.5	1	9	113.7	123.8
2005	69.8	60.7	3.8	33.8	34.5	30.0	1	9	109.0	133.5
2006	81.3	49.5	5.6	50.5	38.9	23.7	1	9	126.8	132.7
2007	79.2	50.7	4.4	39.7	37.0	23.7	1	9	121.6	123.1
2008	87.6	43.4	4.1	36.7	39.3	19.5	1	9	132.0	108.5
2009	83.0	47.9	3.6	32.7	36.1	20.8	1	9	123.8	110.4
2010	71.5	59.4	3.3	29.6	30.1	25.0	1	9	105.8	123.0
2011	66.6	63.9	3.8	34.6	27.1	26.0	1	9	98.5	133.5
2012	54.9	76.0	3.9	35.5	21.5	29.8	1	9	81.4	150.2
2013	67.9	62.4	4.1	37.0	25.8	23.7	1	9	98.8	132.0
2014	61.4	68.8	3.2	29.2	22.4	25.1	1	9	88.1	132.1
2015	66.1	63.2	3.5	31.9	23.3	22.3	1	9	94.0	126.4
2016	60.0	70.6	2.3	20.4	20.1	23.6	1	9	83.4	123.7
2017	54.7	69.5	3.1	27.6	18.4	23.4	1	9	77.2	129.6
2018	68.0	62.6	3.1	28.3	20.8	19.2	1	9	93.0	119.1

Table 5: Number of vessel/statistical area/month records in the dataset used to calculate the CRA 1 seasonal CPUE time series after excluding vessels with less than five years data in the fishery.

Fishing	Autumn-Winter						Spring-Summer					
year	901	902	903	904	939	Total	901	902	903	904	939	Total
89/90	1	4	6	4	4	19	1	12	9	18	21	61
90/91	10	8	7	13	17	55	21	11	12	19	25	88
91/92	5	8	18	16	22	69	5	13	17	38	37	110
92/93	3	5	11	24	25	68	6	16	14	27	38	101
93/94	3	3	16	28	23	73	5	7	19	28	30	89
94/95	3	4	16	28	14	65	5	5	21	31	20	82
95/96	5	4	15	19	23	66	6	7	16	17	14	60
96/97	6	8	13	23	4	54	3	11	20	18	1	53
97/98	8	7	17	18	6	56	1	4	12	16	1	34
98/99	5	7	11	21	23	67	1	4	9	20	5	39
99/00	13	4	6	17	20	60	3	3	8	17	8	39
00/01	17	4	12	16	23	72	8	3	12	19	4	46
01/02	18	8	11	14	27	78	7	1	11	12	12	43
02/03	19	13	10	10	20	72	12	7	8	13	14	54
03/04	6	10	3	15	18	52	4	13	6	16	13	52
04/05	9	13	4	4	15	45	8	12	7	5	11	43
05/06	11	10	8	4	18	51	11	9	6	5	13	44
06/07	13	10	10	4	15	52	13	5	12	5	8	43
07/08	18	13	15	5	11	62	12	15	21	8	3	59
08/09	16	14	8	4	15	57	8	7	8	4	3	30
09/10	16	18	10	8	15	67	14	4	12	9	4	43
10/11	18	9	9	6	14	56	16	11	13	10	5	55
11/12	18	12	10	8	12	60	12	9	12	12	5	50
12/13	15	8	6	11	8	48	21	14	11	15	5	66
13/14	18	5	11	11	14	59	12	12	13	16	7	60
14/15	18	4	2	8	14	46	20	7	2	18	7	54
15/16	20	4	8	10	9	51	21	5	8	12	3	49
16/17	12	3	7	4	8	34	12	7	9	3	3	34
17/18	12	4	8	3	8	35	17	8	8	6	4	43
18/19	11	9	8	3	8	39	10	9	7	6	4	36
Total	347	233	296	359	453	1 688	295	251	343	443	328	1 660

Table 6: CRA 1 standardised seasonal CPUE models: the number of model parameters (p), the Bayesian LOO estimate of the expected log pointwise predictive density (elpd_loo), estimated effective number of parameters (p_loo), and the leave-one-out information criterion (LOOIC). The standard error (SE) for each value is provided in parenthesis. Lower LOOIC indicates a better fit, and, in a well specified model, the estimated effective number of parameters (p_loo) should be smaller than, or similar to, the total number of parameters in the model.

Model	p	elpd_loo (SE)	p_loo (SE)	LOOIC (SE)
interaction	406	-2067. 1 (88.8)	263.6 (11.9)	4134.1 (177.6)
status-quo	114	-2257.9 (84.7)	110.6 (4.8)	4515.9 (169.4)
null	60	-3745.0 (70.4)	61.7 (2.0)	7490.8 (140.7)

Table 7: CRA 1 the interaction model: seasonal CPUE indices. Calculated from the analysis of catch and potlift data including a vessel explanatory variable based on vessels with at least five years of data in the database.

	Autumn-winter		Spring-Summer	
Fishing year	Standardised Index	Standard Error	Standardised Index	Standard Error
89/90	–	–	0.965	0.185
90/91	0.699	0.135	0.958	0.183
91/92	0.709	0.135	0.959	0.182
92/93	0.628	0.124	0.847	0.159
93/94	0.647	0.125	0.963	0.188
94/95	0.703	0.136	1.056	0.202
95/96	0.958	0.182	1.264	0.249
96/97	0.916	0.179	1.334	0.262
97/98	1.052	0.200	1.125	0.239
98/99	1.029	0.195	1.315	0.277
99/00	0.875	0.168	1.157	0.231
00/01	0.971	0.183	1.722	0.342
01/02	1.049	0.198	1.251	0.253
02/03	0.960	0.182	1.335	0.260
03/04	0.923	0.177	1.346	0.266
04/05	0.959	0.191	1.374	0.267
05/06	0.956	0.184	1.347	0.265
06/07	0.887	0.173	1.298	0.259
07/08	1.030	0.196	1.718	0.336
08/09	0.997	0.191	1.721	0.354
09/10	1.212	0.235	1.692	0.339
10/11	0.961	0.183	1.341	0.250
11/12	0.871	0.164	1.234	0.236
12/13	1.129	0.220	1.498	0.283
13/14	1.048	0.200	1.512	0.290
14/15	1.172	0.228	1.479	0.295
15/16	1.019	0.199	1.382	0.276
16/17	1.110	0.223	1.295	0.261
17/18	1.272	0.250	1.505	0.304
18/19	1.168	0.233	1.725	0.343

Table 8: Sampling intensity by fishing year in CRA 1 by the logbook and observer catch sampling programme from 1975. "Lobsters" are the number of individuals measured. Number of active vessels in CRA 1 is included to show the level of participation in the logbook programme. Cells marked in grey were not used in the stock assessment because there was only a single participant.

Fishing	Logbooks				Observer catch sampling			
year	N vessels[1]	Fishermen	Potlifts	Lobsters	Vessels	Days	Potlifts	Lobsters
1975	–	–	–	–	0	2	39	47
1976	–	–	–	–	1	8	306	436
1993	27	1	129	179	–	–	–	–
1994	22	2	251	484	–	–	–	–
1995	23	1	170	486	–	–	–	–
1997	26	–	–	–	5	17	1 252	2 458
1998	21	–	–	–	3	9	668	2 635
1999	19	–	–	–	11	24	1 722	6 883
2000	20	–	–	–	9	15	1 256	4 625
2001	18	–	–	–	8	12	1 110	2 779
2002	18	–	–	–	6	15	1 245	4 665
2003	17	–	–	–	8	16	1 321	4 763
2004	16	–	–	–	6	15	1 013	4 047
2005	15	–	–	–	4	20	1 132	4 964
2006	15	–	–	–	6	15	1 315	4 797
2007	13	–	–	–	4	16	780	2 924
2008	13	–	–	–	6	15	994	3 678
2009	13	–	–	–	7	16	1 177	4 807
2010	13	–	–	–	9	16	1 237	4 086
2011	14	1	69	363	6	16	1 053	3 523
2012	13	1	60	464	4	15	1 217	6 912
2013	14	1	45	297	4	16	1 241	4 571
2014	14	2	116	425	4	18	1 202	3 995
2015	14	5	639	2 974	5	15	1 086	1 917
2016	13	6	744	2 975	4	18	1 277	5 912
2017	13	7	593	2 820	5	15	1 138	1 826
2018	12	7	701	3 107	4	19	1 266	3 460
Total	–	–	3 517	14 574	–	353	25 702	90 227

[1] from Starr (2019).

Table 9: Number of lobsters measured by the observer and logbook catch sampling programmes by fishing year, sex category, and season. '–': no data. Cells marked in grey were not used in the stock assessment either due to a single participant or less than 100 size measurements.

	Logbooks				Observer catch sampling			
Fishing year	Male	Immature female	Mature female	Total	Male	Immature female	Mature female	Total
Season=AW								
1993	107	2	63	172	–	–	–	–
1994	4	–	10	14	–	–	–	–
1995	333	63	86	482	–	–	–	–
1997	–	–	–	–	962	100	608	1 670
1998	–	–	–	–	1 681	82	870	2 633
1999	–	–	–	–	3 848	228	2 806	6 882
2000	–	–	–	–	1 888	234	2 460	4 582
2001	–	–	–	–	1 225	170	697	2 092
2002	–	–	–	–	1 726	119	1 406	3 251
2003	–	–	–	–	572	22	498	1 092
2004	–	–	–	–	1 743	127	1 324	3 194
2005	–	–	–	–	1 834	217	1 191	3 242
2006	–	–	–	–	1 498	172	920	2 590
2007	–	–	–	–	1 440	73	899	2 412
2008	–	–	–	–	1 595	33	976	2 604
2009	–	–	–	–	2 200	39	1 699	3 938
2010	–	–	–	–	1 488	9	1 117	2 614
2011	232	15	116	363	786	45	1 136	1 967
2012	192	7	103	302	2 214	123	1 247	3 584
2013	117	7	51	175	1 998	118	1 621	3 737
2014	119	48	190	357	1 787	185	1 263	3 235
2015	697	151	716	1 564	1 356	62	499	1 917
2016	495	76	390	961	987	27	682	1 696
2017	511	71	441	1 023	541	62	246	849
2018	990	159	655	1 804	1 526	78	529	2 133
Total	3 797	599	2 821	7 217	34 895	2 325	24 694	61 914
Season=SS								
1975	–	–	–	–	44	–	3	47
1976	–	–	–	–	245	56	135	436
1994	204	68	189	461	–	–	–	–
1995	3	1	–	4	–	–	–	–
1997	–	–	–	–	340	45	401	786
2000	–	–	–	–	14	1	8	23
2001	–	–	–	–	203	18	461	682
2002	–	–	–	–	505	44	855	1 404
2003	–	–	–	–	1 110	143	2 413	3 666
2004	–	–	–	–	208	69	575	852
2005	–	–	–	–	501	82	1 127	1 710
2006	–	–	–	–	785	125	1 289	2 199
2007	–	–	–	–	260	21	225	506
2008	–	–	–	–	287	25	761	1 073
2009	–	–	–	–	249	22	597	868
2010	–	–	–	–	308	5	1 151	1 464
2011	–	–	–	–	561	–	994	1 555
2012	66	9	87	162	903	190	2 235	3 328
2013	36	5	81	122	312	26	496	834
2014	17	4	42	63	275	24	460	759
2015	753	132	767	1 652	–	–	–	–
2016	696	132	1 014	1 842	1 295	87	2 833	4 215
2017	761	179	828	1 768	365	10	600	975
2018	594	47	703	1 344	481	9	837	1 327
Total	3 130	577	3 711	7 418	9 251	1 002	18 456	28 709

Table 10: Sample weight (Eq. 8) calculated for each LF sampling record given in Table 9. '–': no data. Cells marked in grey were not used in the stock assessment either due to a single participant or less than 100 size measurements.

	Logbooks				Observer catch sampling			
Fishing year	Male	Immature female	Mature female	Total	Male	Immature female	Mature female	Total
Season=AW								
1993	0.832	0.016	0.477	1.325	–	–	–	–
1994	0.025	–	0.064	0.089	–	–	–	–
1995	2.138	0.443	0.574	3.155	–	–	–	–
1997	–	–	–	–	0.973	0.080	0.720	1.772
1998	–	–	–	–	1.064	0.049	0.504	1.617
1999	–	–	–	–	4.092	0.201	3.210	7.503
2000	–	–	–	–	2.040	0.289	3.300	5.629
2001	–	–	–	–	1.872	0.263	0.940	3.076
2002	–	–	–	–	2.364	0.142	1.920	4.427
2003	–	–	–	–	1.036	0.041	0.652	1.729
2004	–	–	–	–	2.354	0.181	1.824	4.359
2005	–	–	–	–	1.910	0.258	1.204	3.372
2006	–	–	–	–	0.849	0.096	0.485	1.430
2007	–	–	–	–	2.584	0.117	1.591	4.292
2008	–	–	–	–	2.682	0.025	1.381	4.087
2009	–	–	–	–	1.929	0.028	1.584	3.541
2010	–	–	–	–	1.593	0.010	1.170	2.773
2011	1.525	0.100	0.749	2.374	0.686	0.036	0.921	1.644
2012	0.824	0.030	0.442	1.296	1.870	0.105	1.045	3.021
2013	0.869	0.053	0.397	1.320	2.022	0.118	1.564	3.703
2014	0.959	0.279	0.840	2.077	2.401	0.199	1.703	4.302
2015	2.788	0.718	3.190	6.696	1.677	0.083	0.507	2.267
2016	3.753	0.616	3.004	7.372	1.645	0.044	1.227	2.917
2017	4.144	0.600	3.760	8.505	1.104	0.155	0.557	1.817
2018	6.347	0.922	3.433	10.703	2.247	0.183	1.035	3.465
Season=SS								
1975	–	–	–	–	0.269	–	0.018	0.287
1976	–	–	–	–	0.652	0.191	0.355	1.198
1994	0.965	0.349	0.669	1.983	–	–	–	–
1995	0.012	0.004	–	0.016	–	–	–	–
1997	–	–	–	–	0.519	0.068	0.584	1.172
2000	–	–	–	–	0.106	0.008	0.060	0.173
2001	–	–	–	–	0.381	0.042	0.931	1.354
2002	–	–	–	–	1.046	0.091	1.756	2.893
2003	–	–	–	–	0.582	0.083	1.350	2.015
2004	–	–	–	–	0.463	0.154	1.281	1.898
2005	–	–	–	–	0.756	0.121	1.643	2.520
2006	–	–	–	–	1.131	0.184	1.790	3.105
2007	–	–	–	–	0.007	0.001	0.006	0.013
2008	–	–	–	–	0.242	0.021	0.647	0.910
2009	–	–	–	–	0.305	0.038	0.821	1.164
2010	–	–	–	–	0.209	0.001	0.741	0.951
2011	–	–	–	–	0.591	–	1.177	1.768
2012	0.185	0.025	0.244	0.455	1.061	0.226	2.718	4.005
2013	0.172	0.024	0.387	0.582	0.609	0.052	0.963	1.624
2014	0.137	0.066	0.428	0.631	0.452	0.042	1.021	1.515
2015	2.599	0.474	3.254	6.327	–	–	–	–
2016	3.881	0.533	5.202	9.615	1.410	0.107	2.899	4.415
2017	3.498	0.672	3.858	8.028	0.704	0.018	1.117	1.839
2018	4.212	0.216	5.165	9.593	0.469	0.009	0.816	1.293

Table 11: Statistics for the proportion-at-sex for each season, summarised across all records for a season using the weights in Table 10.

	Autumn-Winter			Spring-Summer		
Statistic	Male	Immature Female	Mature Female	Male	Immature Female	Mature Female
Maximum	0.678	0.140	0.714	0.750	0.250	0.779
Minimum	0.286	0.004	0.182	0.220	0.001	0.338
Mean	0.554	0.055	0.391	0.373	0.050	0.577

Table 12: Statistics for mean tail width (mm) by sex for each season, summarised across all records for a season using the weights in Table 10.

	Autumn-Winter			Spring-Summer		
Statistic	Male	Immature Female	Mature Female	Male	Immature Female	Mature Female
Maximum mean TW	70.0	60.0	72.5	73.8	61.2	82.7
Minimum mean TW	48.0	46.7	53.0	55.9	41.4	64.1
Mean TW	63.9	53.4	68.0	63.2	52.6	69.1

Table 13: Number of year, season, sampling category records by 2 mm tail width bin for each sex category. Also shown are the number of these records where the year, season, sampling category proportion within a sex category is less than 0.001 and the calculated proportion of records greater than 0.001. Bold grey cells indicate accumulator bins. (Continued on next page)

	Males			Immature Females			Mature Females		
Bin	N records	N records<0.001	Prop >0.001	N records	N records<0.001	Prop >0.001	N records	N records<0.001	Prop >0.001
[30,32)	1	0	1.00	3	0	1.00	1	0	1.00
[32,34)	2	1	0.50	8	3	0.63	3	1	0.67
[34,36)	**12**	**8**	**0.33**	**4**	**2**	**0.50**	**3**	**2**	**0.33**
[36,38)	16	12	0.25	8	4	0.50	0		
[38,40)	26	17	0.35	12	7	0.42	3	1	0.67
[40,42)	38	15	0.61	27	13	0.52	8	4	0.50
[42,44)	35	5	0.86	35	11	0.69	12	7	0.42
[44,46)	47	7	0.85	42	10	0.76	16	6	0.63
[46,48)	49	1	0.98	41	8	0.80	20	10	0.50
[48,50)	51	3	0.94	45	4	0.91	38	16	0.58
[50,52)	56	0	1.00	45	5	0.89	40	7	0.83
[52,54)	60	0	1.00	50	4	0.92	47	4	0.91
[54,56)	60	0	1.00	51	4	0.92	52	3	0.94
[56,58)	58	0	1.00	50	3	0.94	56	1	0.98
[58,60)	60	0	1.00	52	6	0.88	59	0	1.00
[60,62)	60	0	1.00	46	10	0.78	57	0	1.00
[62,64)	60	0	1.00	41	14	0.66	60	0	1.00
[64,66)	58	0	1.00	30	10	0.67	60	0	1.00
[66,68)	60	0	1.00	27	15	0.44	60	0	1.00
[68,70)	59	0	1.00	19	11	0.42	59	0	1.00
[70,72)	60	0	1.00	12	9	0.25	60	0	1.00
[72,74)	58	0	1.00	**3**	**3**	**0.00**	60	0	1.00
[74,76)	58	0	1.00	5	5	0.00	60	0	1.00
[76,78)	55	1	0.98	4	4	0.00	59	0	1.00
[78,80)	53	3	0.94	1	1	0.00	57	0	1.00
[80,82)	49	3	0.94	1	1	0.00	57	0	1.00
[82,84)	47	1	0.98	1	1	0.00	56	0	1.00

	Males			Immature Females			Mature Females		
	N	N	Prop	N	N	Prop	N	N	Prop
Bin	records	records<0.001	>0.001	records	records<0.001	>0.001	records	records<0.001	>0.001
[84,86)	46	6	0.87	1	1	0.00	54	0	1.00
[86,88)	44	11	0.75	0			54	3	0.94
[88,90)	42	11	0.74	0			49	11	0.78
[90,92)	32	8	0.75	0			42	7	0.83
[92,94)	33	12	0.64	0			34	13	0.62
[94,96)	28	9	0.68	0			28	12	0.57
[96,98)	20	8	0.60	0			19	13	0.32
[98,100)	18	6	0.67	0			11	7	0.36
[100,∞)	**15**	**10**	**0.33**	0			**8**	**4**	**0.50**

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 2018 CRA 6 stock assessment (Starr et al. 2019).

Project_ID	Previous	Current	Difference
CRA_Akaroa	227	227	0
CRA_CCampb	44	44	0
CRA_Gis70s	2 243	2 244	1
CRA_Gisb	48	48	0
CRA_ReefPt	573	573	0
CRA_StewIs	1 615	1 622	7
CRA01Gisb	1 191	1 179	-12
CRA1_TAG	1 486	1 592	106
CRA2_EBOP	5	5	0
CRA2_TAG	4 309	4 364	55
CRA2_WBOP	268	268	0
CRA3_TAG	1 777	2 070	293
CRA4_TAG	2 616	3 128	512
CRA4_Wair	10	10	0
CRA5_Kaik	1 176	1 176	0
CRA5_TAG	5 629	5 946	317
CRA6_TAG	183	183	0
CRA7_TAG	589	632	43
CRA7rs	199	199	0
CRA8_Fiord	1 714	1 714	0
CRA8_TAG	7 295	7 295	0
CRA8rs	236	236	0
CRA9_TAG	73	126	53

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 2018 CRA 6 stock assessment (Starr et al. 2019).

Year	Previous	Current	Difference	Year	Previous	Current	Difference
1966	53	53	0	1998	2 949	2 950	1
1967	29	29	0	1999	2 494	2 494	0
1968	7	7	0	2000	1 593	1 593	0
1969	2	2	0	2001	1 378	1 378	0
1971	1	1	0	2002	1 576	1 576	0
1975	115	115	0	2003	1 122	1 122	0
1976	1 268	1 275	7	2004	2 083	2 083	0
1977	2 094	2 096	2	2005	2 410	2 410	0
1978	887	886	-1	2006	978	978	0
1979	1 093	1 081	-12	2007	490	489	-1
1980	1 112	1 112	0	2008	367	367	0
1981	593	593	0	2009	306	306	0
1982	332	332	0	2010	237	237	0
1983	273	273	0	2011	550	550	0
1984	1 071	1 071	0	2012	333	333	0
1985	395	395	0	2013	485	485	0
1986	76	76	0	2014	727	768	41
1987	18	18	0	2015	508	856	348
1988	4	4	0	2016	159	516	357
1989	2	2	0	2017	127	375	248
1991	1	1	0	2018	–	306	–
1992	1	1	0	2019	–	79	–
1994	40	40	0				
1995	73	73	0				
1996	515	515	0				
1997	2 579	2 579	0				

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	Proportion recaptured
CRA 1	16 454	2 163	0.131
CRA 2	23 509	4 522	0.192
CRA 3	36 241	5 637	0.156
CRA 4	38 194	3 121	0.082
CRA 5	35 438	7 354	0.208
CRA 6	4 724	181	0.038
CRA 7	9 793	823	0.084
CRA 8	21 378	10 764	0.504
CRA 9	6 452	126	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	947	1216	2 163
CRA 2	2 358	2 164	4 522
CRA 3	4 273	1 364	5 637
CRA 4	2 411	710	3 121
CRA 5	5 163	2 191	7 354
CRA 6	21	160	181
CRA 7	383	440	823
CRA 8	5 884	4 880	10 764
CRA 9	32	94	126
Total	21 472	13 219	34 691

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.

QMA	CRA1	CRA2	CRA3	CRA4	CRA5	CRA6	CRA7	CRA8	CRA9
CRA1	1 841	9	30	–	-	–	–	–	–
CRA2	–	3 759	2	–	-	–	–	–	–
CRA3	–	16	5 136	–	3	–	–	56	–
CRA4	–	–	–	2 580	32	–	-	–	–
CRA5	–	–	–	3	5 854	–	6	–	–
CRA6	–	–	–	–	–	177	-	–	–
CRA7	–	–	6	–	–	–	800	17	–
CRA8	–	1	127	–	–	–	–	8 475	3
CRA9	–	–	–	–	–	–	–	–	73

Table 19: Number of tag recaptures by calendar year of release and sex for the two CRA 1 tagging regions. Tags classified to tag region on the basis of release statistical area. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Release	All tag recaptures									Tags at liberty for >365 days								
	901–904, 939			905, 906			Total			901–904, 939			905, 906			Total		
Year	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
1975	38	35	73	0	0	0	38	35	73	4	5	9	0	0	0	4	5	9
1976	166	139	305	0	0	0	166	139	305	21	13	34	0	0	0	21	13	34
1977	57	24	81	0	0	0	57	24	81	3	8	11	0	0	0	3	8	11
1978	19	39	58	0	0	0	19	39	58	7	18	25	0	0	0	7	18	25
1979	32	24	56	0	0	0	32	24	56	10	9	19	0	0	0	10	9	19
1983	0	0	0	78	112	190	78	112	190	0	0	0	16	58	74	16	58	74
1984	0	0	0	24	36	60	24	36	60	0	0	0	3	9	12	3	9	12
1985	0	0	0	10	8	18	10	8	18									
1996	0	0	0	423	362	785	423	362	785	0	0	0	144	214	358	144	214	358
1997	0	0	0	331	67	398	331	67	398	0	0	0	68	25	93	68	25	93
1998	0	0	0	210	60	270	210	60	270	0	0	0	29	27	56	29	27	56
1999	0	0	0	25	20	45	25	20	45	0	0	0	8	7	15	8	7	15
2000	175	302	477	0	2	2	175	304	479	64	169	233	0	2	2	64	171	235
2001	54	58	112	2	8	10	56	66	122	4	22	26	1	5	6	5	27	32
2002	41	154	195	71	171	242	112	325	437	18	101	119	26	109	135	44	210	254
2003	138	156	294	219	308	527	357	464	821	41	76	117	40	138	178	81	214	295
2004	42	20	62	54	45	99	96	65	161	1	9	10	2	4	6	3	13	16
2005	5	15	20	12	25	37	17	40	57	1	5	6	1	0	1	2	5	7
2006	1	7	8	0	1	1	1	8	9	0	1	1	0	1	1	0	2	2
2007	1	3	4	0	0	0	1	3	4	1	2	3	0	0	0	1	2	3
2008	0	0	0	17	49	66	17	49	66	0	0	0	6	28	34	6	28	34
2009	11	41	52	9	5	14	20	46	66	3	20	23	1	1	2	4	21	25
2010	24	50	74	2	9	11	26	59	85	9	34	43	0	2	2	9	36	45
2011	5	11	16	0	1	1	5	12	17	0	2	2	0	0	0	0	2	2
2012	72	47	119	0	0	0	72	47	119	35	35	70	0	0	0	35	35	70
2013	25	59	84	0	0	0	25	59	84	17	51	68	0	0	0	17	51	68
2014	3	0	3	24	44	68	27	44	71	0	0	0	5	14	19	5	14	19
2016	0	0	0	8	15	23	8	15	23	0	0	0	1	7	8	1	7	8
2017	13	18	31	2	0	2	15	18	33	1	1	2	0	0	0	1	1	2
Total	922	1 202	2 124	1 521	1 348	2 869	2 443	2 550	4 993	240	581	821	351	651	1 002	591	1 232	1 823

Table 20: Number of tag recaptures by calendar year of recovery and sex for the two CRA 1 tagging regions. Tags classified to tag region on the basis of release statistical area. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Recovery	All tag recaptures									Tags at liberty for >365 days								
	901–904, 939			905, 906			Total			901–904, 939			905, 906			Total		
Year	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
1975	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
1976	147	139	286	0	0	0	147	139	286	0	0	0	0	0	0	0	0	0
1977	92	35	127	0	0	0	92	35	127	17	14	31	0	0	0	17	14	31
1978	28	27	55	0	0	0	28	27	55	8	3	11	0	0	0	8	3	11
1979	25	31	56	0	0	0	25	31	56	5	9	14	0	0	0	5	9	14
1980	11	12	23	0	0	0	11	12	23	6	11	17	0	0	0	6	11	17
1981	5	15	20	0	0	0	5	15	20	5	15	20	0	0	0	5	15	20
1982	3	1	4	0	0	0	3	1	4	3	1	4	0	0	0	3	1	4
1983	1	0	1	2	1	3	3	1	4	1	0	1	0	0	0	1	0	1
1984	0	0	0	79	101	180	79	101	180	0	0	0	6	32	38	6	32	38
1985	0	0	0	30	47	77	30	47	77	0	0	0	12	29	41	12	29	41
1986	0	0	0	1	7	8	1	7	8	0	0	0	1	6	7	1	6	7
1997	0	0	0	463	191	654	463	191	654	0	0	0	2	16	18	2	16	18
1998	0	0	0	407	160	567	407	160	567	0	0	0	169	118	287	169	118	287
1999	0	0	0	103	108	211	103	108	211	0	0	0	62	89	151	62	89	151
2000	0	2	2	1	2	3	1	4	5	0	0	0	1	2	3	1	2	3
2001	176	223	399	10	31	41	186	254	440	26	60	86	9	30	39	35	90	125
2002	52	93	145	22	44	66	74	137	211	29	64	93	3	14	17	32	78	110
2003	49	182	231	152	202	354	201	384	585	23	106	129	11	45	56	34	151	185
2004	111	80	191	149	187	336	260	267	527	9	39	48	43	114	157	52	153	205
2005	57	72	129	36	110	146	93	182	275	34	64	98	16	74	90	50	138	188
2006	8	31	39	2	21	23	10	52	62	6	24	30	1	17	18	7	41	48
2007	3	16	19	1	4	5	4	20	24	2	12	14	1	4	5	3	16	19
2008	0	5	5	10	24	34	10	29	39	0	5	5	1	5	6	1	10	11
2009	1	5	6	14	19	33	15	24	39	1	5	6	4	15	19	5	20	25
2010	13	28	41	4	22	26	17	50	67	0	4	4	2	14	16	2	18	20
2011	25	47	72	1	8	9	26	55	81	10	26	36	1	6	7	11	32	43
2012	10	27	37	0	0	0	10	27	37	2	19	21	0	0	0	2	19	21
2013	41	23	64	0	0	0	41	23	64	9	17	26	0	0	0	9	17	26
2014	36	26	62	17	30	47	53	56	109	28	19	47	0	0	0	28	19	47
2015	15	43	58	5	9	14	20	52	72	15	43	58	3	9	12	18	52	70
2016	0	15	15	5	10	15	5	25	30	0	15	15	2	5	7	2	20	22
2017	0	3	3	6	5	11	6	8	14	0	3	3	0	2	2	0	5	5
2018	13	20	33	1	5	6	14	25	39	1	3	4	1	5	6	2	8	10
Total	922	1 202	2 124	1 521	1 348	2 869	2 443	2 550	4 993	240	581	821	351	651	1 002	591	1 232	1 823

Table 21: Number of tag recaptures by recovery statistical area for the two CRA 1 tagging regions. Tags classified to tag region on the basis of release statistical area. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Recovery	All tag recaptures			Tags at liberty for >365 days		
stat_area	901–904, 939	905, 906	Total	901–904, 939	905, 906	Total
901	269	0	269	168	0	168
902	7	0	7	6	0	6
903	21	0	21	16	0	16
904	1	0	1	0	0	0
905	9	136	145	9	74	83
906	0	2 635	2 635	0	890	890
910	1	0	1	0	0	0
911	29	0	29	0	0	0
939	1 543	0	1 543	472	0	472
Unknown	244	98	342	150	38	188
Total	2 124	2 869	4 993	821	1 002	1 823

Table 22: Statistics for days-at-liberty for recaptures from the two CRA 1 tagging regions. Tags classified to tag region on the basis of release statistical area. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Tag region	Sex	N	Min(days)	p5%(days)	Median(days)	p95%(days)	Max(days)
901–904, 939	Males	922	1	17	278	719	1 855
	Females	1 202	1	30	357	1 353	3 634
905, 906	Males	1 521	1	7	246	685	2 171
	Females	1 348	1	21	356	1 132	3 350
Total	Males	2 443	1	8	263	707	2 171
	Females	2 550	1	24	356	1 229	3 634

Table 23: Number of tag re-releases by sex and the two CRA 1 tagging regions. Tags classified to tag region on the basis of release statistical area. Re-release event code=0 means the first release-recapture event.

	901–904, 939				905, 906				Total			
Re-release event	Male	Female	Proportion male	Proportion female	Male	Female	Proportion male	Proportion female	Male	Female	Proportion male	Proportion female
0	756	994	0.820	0.827	868	1 026	0.571	0.761	1 624	2 020	0.665	0.792
1	120	145	0.950	0.948	332	212	0.789	0.918	452	357	0.850	0.932
2	37	41	0.990	0.982	166	71	0.898	0.971	203	112	0.933	0.976
3	8	12	0.999	0.992	86	28	0.955	0.992	94	40	0.971	0.992
4	1	5	1.000	0.996	38	9	0.980	0.999	39	14	0.987	0.997
5	0	2	1.000	0.998	15	2	0.989	1.000	15	4	0.993	0.999
6	0	2	1.000	0.999	8	0	0.995	1.000	8	2	0.997	1.000
7	0	1	1.000	1.000	3	0	0.997	1.000	3	1	0.998	1.000
8	0	0	1.000	1.000	2	0	0.998	1.000	2	0	0.999	1.000
9	0	0	1.000	1.000	1	0	0.999	1.000	1	0	0.999	1.000
10	0	0	1.000	1.000	1	0	0.999	1.000	1	0	1.000	1.000
11	0	0	1.000	1.000	1	0	1.000	1.000	1	0	1.000	1.000

Table 24: Statistics for tail width growth increments (mm) for recaptures from the two CRA 1 tagging regions. Tags classified to tag region on the basis of release statistical area. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Tag region	Sex	N	Min(incr)	p5%(incr)	Median(incr)	p95%(incr)	Max(incr)
901–904, 939	males	922	-25.8	-0.2	4.8	16.1	37.5
	females	1 202	-29.7	-1.0	3.0	14.1	35.2
905, 906	males	1 521	-37.0	-1.0	3.0	13.0	27.7
	females	1 348	-19.3	-1.3	2.0	10.5	20.7
Total	males	2 443	-37.0	-1.0	3.7	14.7	37.5
	females	2 550	-29.7	-1.2	2.7	12.2	35.2

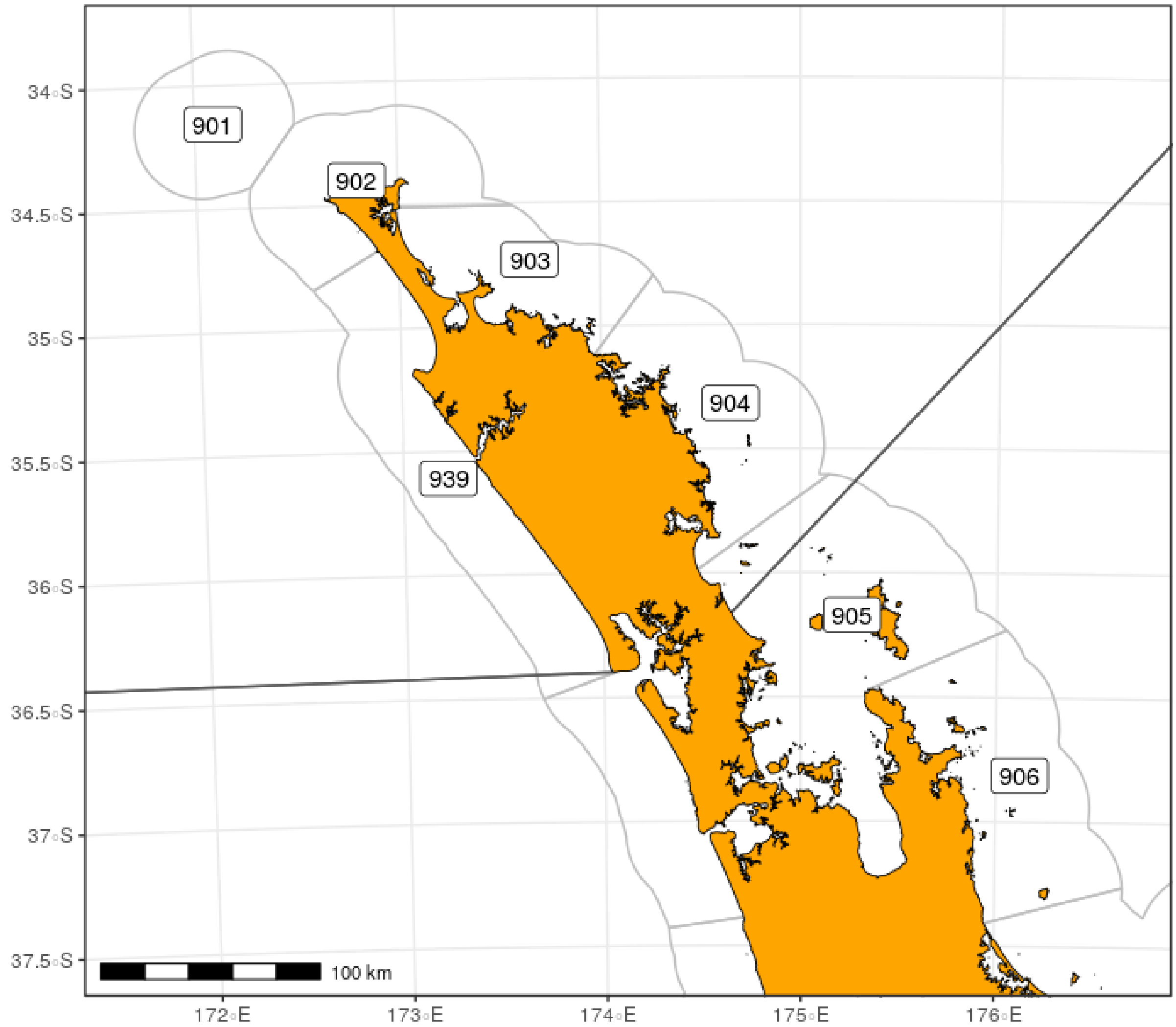


Figure 1: The CRA 1 stock area on the northern coasts of the North Island (including part of CRA 2), and its statistical areas. The QMA boundaries are shown by black lines; the statistical area boundaries are defined by grey lines.

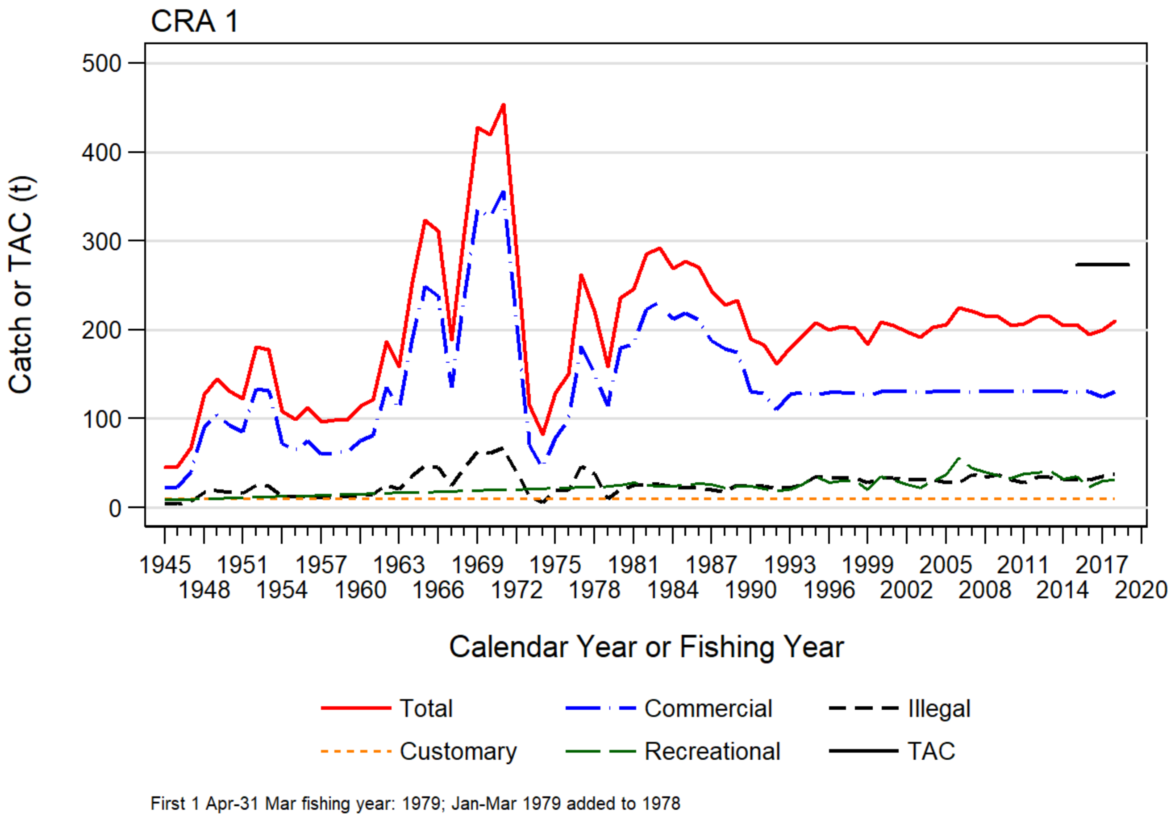


Figure 2: **CRA 1 annual catches (tonnes) by fishery (commercial, illegal [20% of 1981–2018 commercial], recreational, and customary), using the three RLFAWG agreed non-commercial catch series (see Sections 2.2, 2.3, and 2.4).**

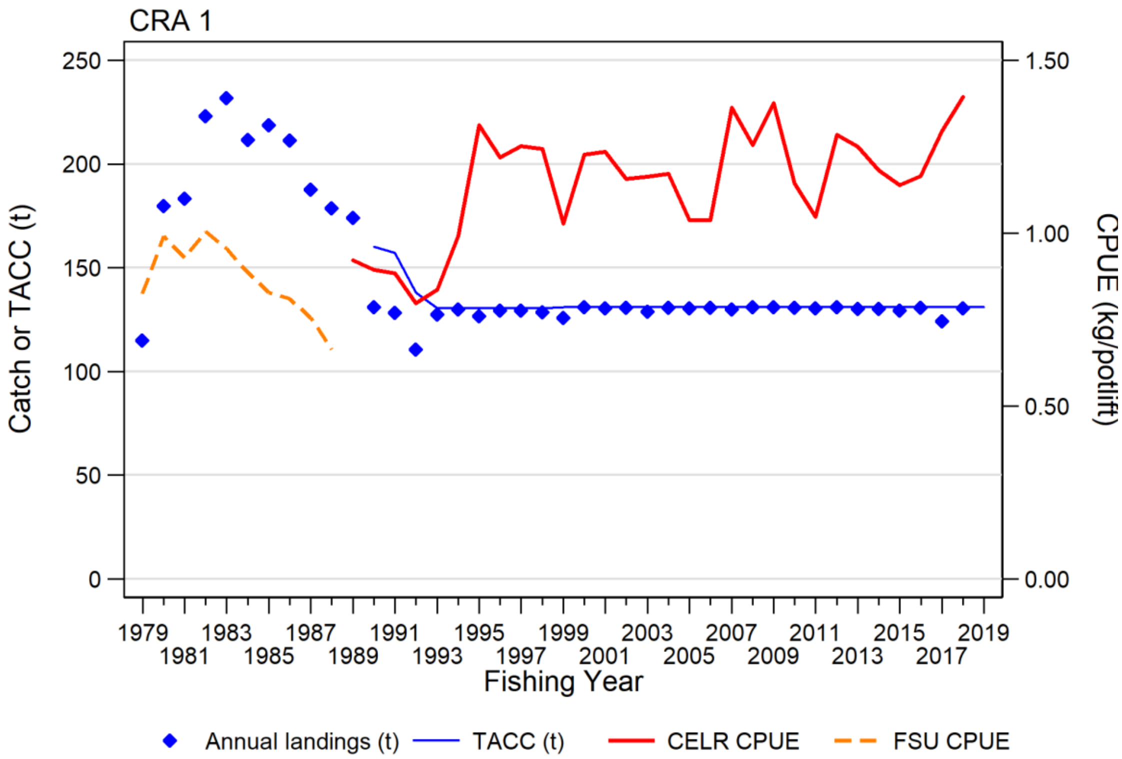


Figure 3: **CRA 1 annual commercial landings (tonnes), the TACC (tonnes), and the annual standardised CPUE index by fishing year, 1979–2018.**

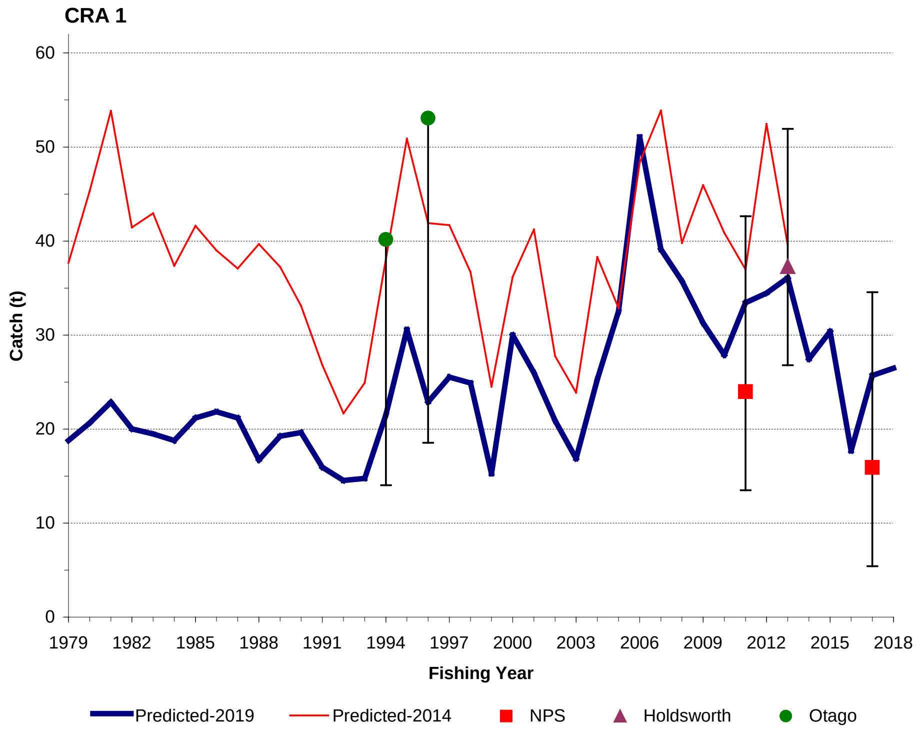


Figure 4: CRA 1 recreational catch trajectory (tonnes) (Eq. 2) based on the unstandardised (geometric mean) SS seasonal CPUE series for Statistical Areas 903 and 904 fitted to five recreational catch surveys (Eq. 1 and Table 1). Error bars are ±2 SE, assuming a lognormal distribution, with the upper error bars for the two Otago estimates suppressed. Also shown is the equivalent recreational catch series used in the 2014 CRA 1 stock assessment.

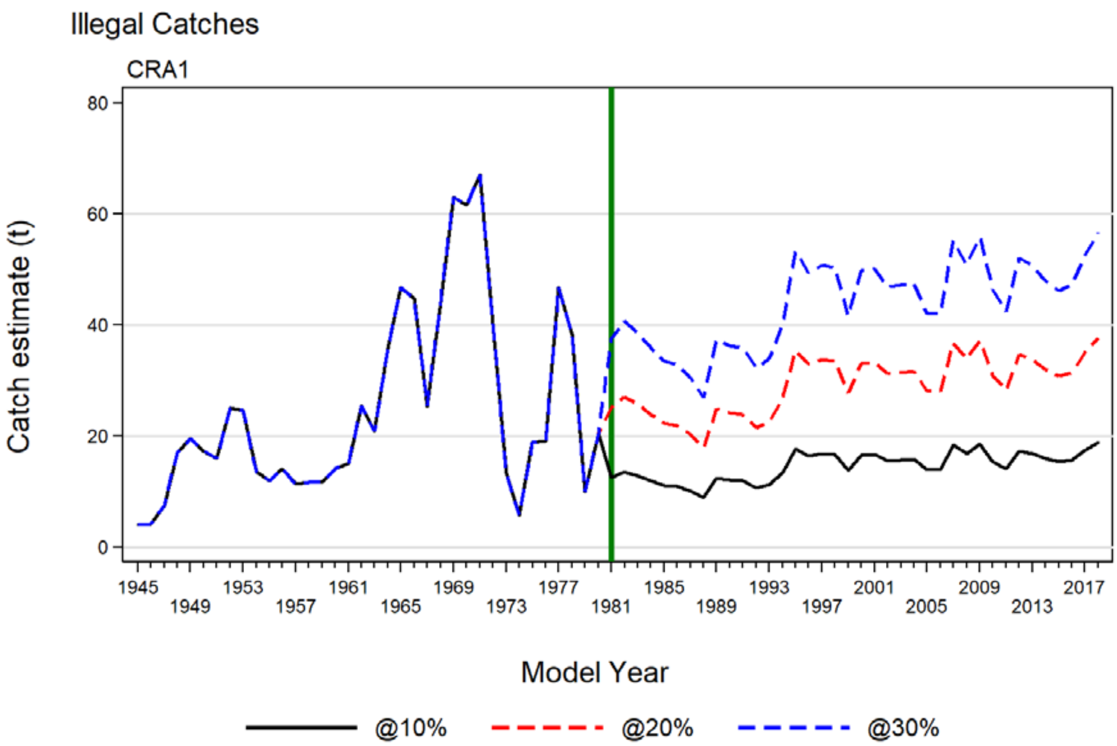


Figure 5: CRA 1 illegal catch trajectories under three assumptions discussed at the RLFAWG meeting held 19 September 2019: post-1980 illegal catches sum to 10%, 20%, or 30% of the total 1981–2018 CRA 1 commercial catch. Each of these post-1980 trajectories follow the standardised CPUE trend with a vessel explanatory variable. All trajectories use the McKoy 'export discrepancy' procedure to set illegal catches from 1945–1980. There were no `illegal reported' estimates for CRA 1.

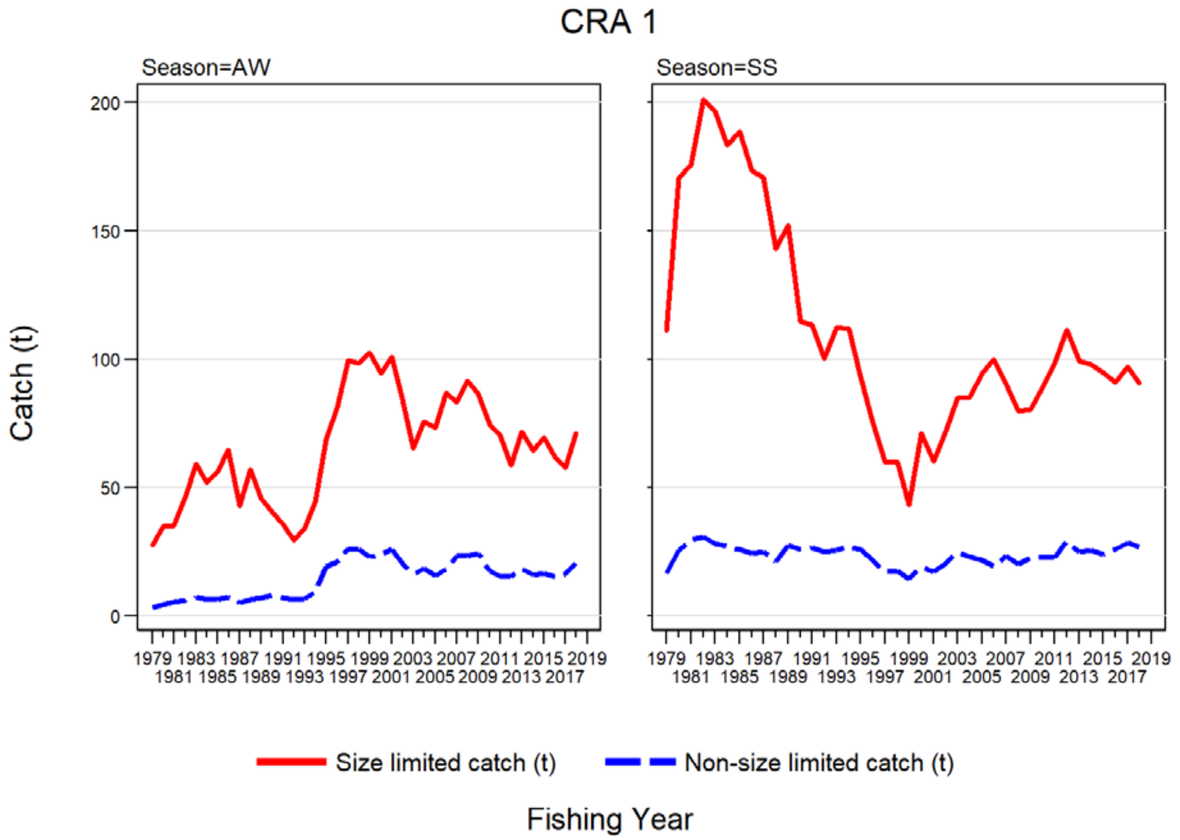


Figure 6: CRA 1 seasonal SL and NSL catches (tonnes) plotted by fishing year, beginning in 1979 using RLFAWG agreed non-commercial catches, including illegal at 20% of 1981–2018 commercial (see Sections 2.2, 2.3, and 2.4).

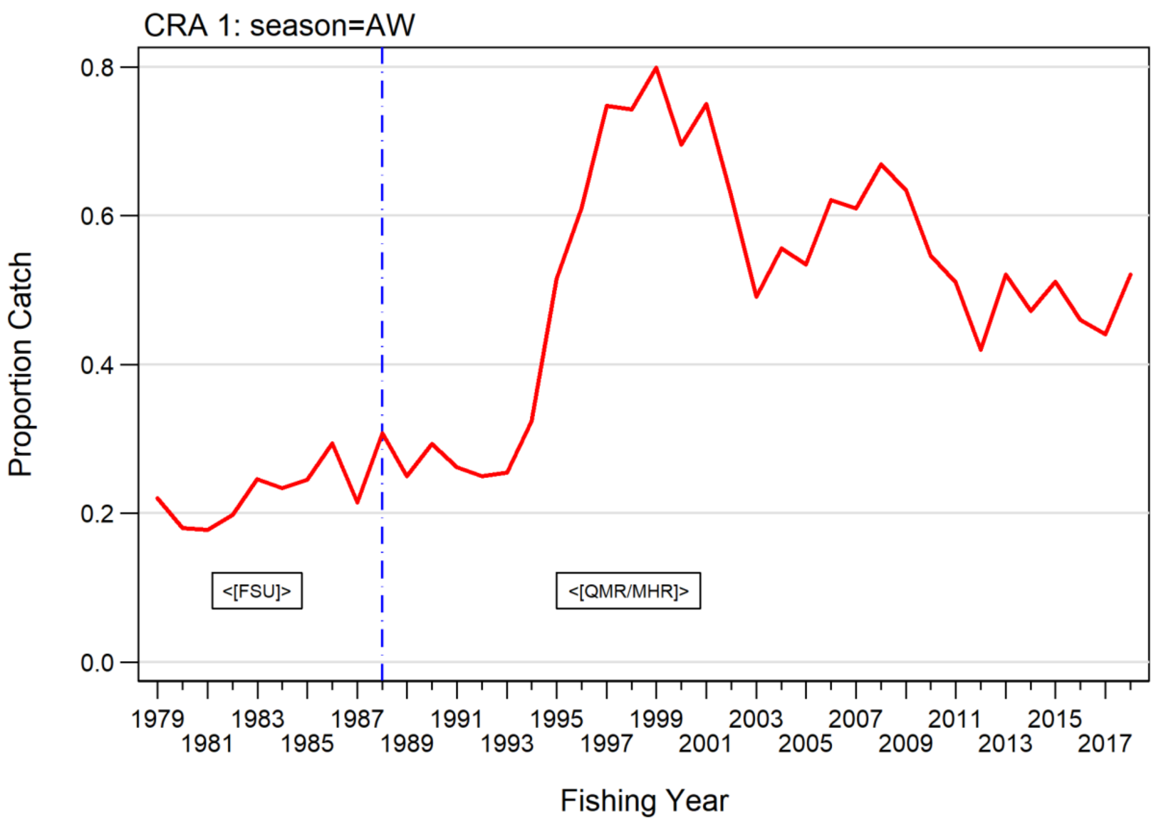


Figure 7: Proportion of the AW commercial catch by fishing year for CRA 1.

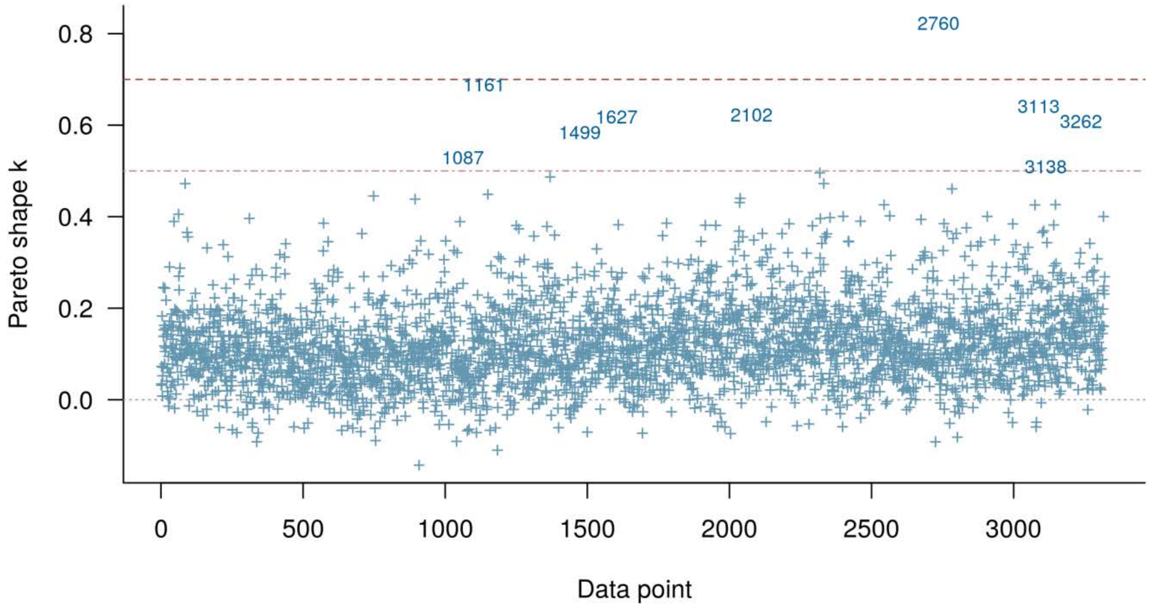


Figure 8: Interaction model: tail shape (Pareto shape parameter *k*) estimates for each point's contribution to the leave-one-out information criteria (LOOIC). Almost all points fall below the preferred threshold *k* < 0.7, with the majority of estimates below *k* < 0.5 (where the distribution of raw importance ratios has a finite variance and the central limit theorem holds) which is considered ideal (Vehtari et al. 2017).

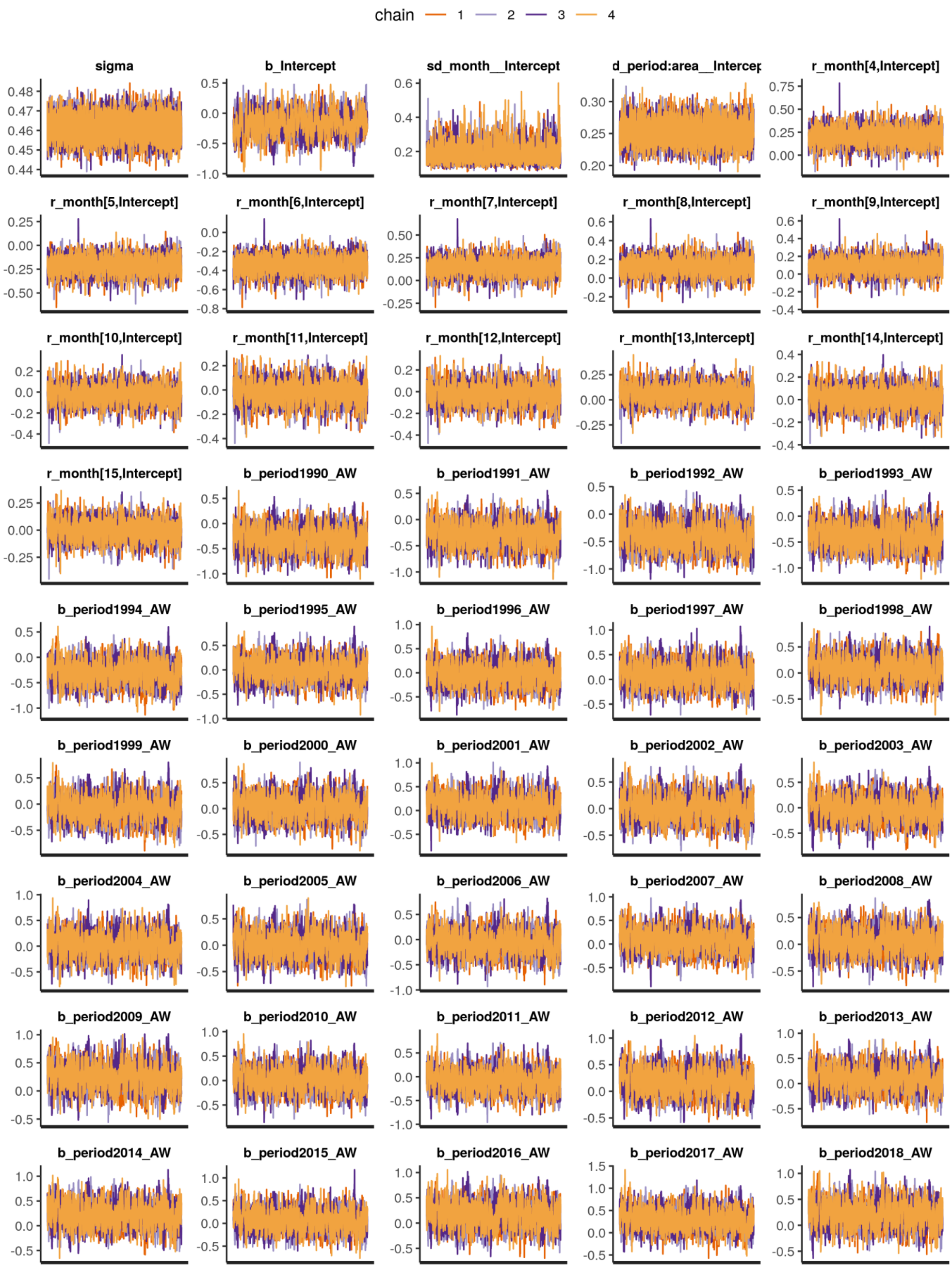


Figure 9: Trace plots of the MCMC posterior samples for parameters and coefficients of the interaction model.

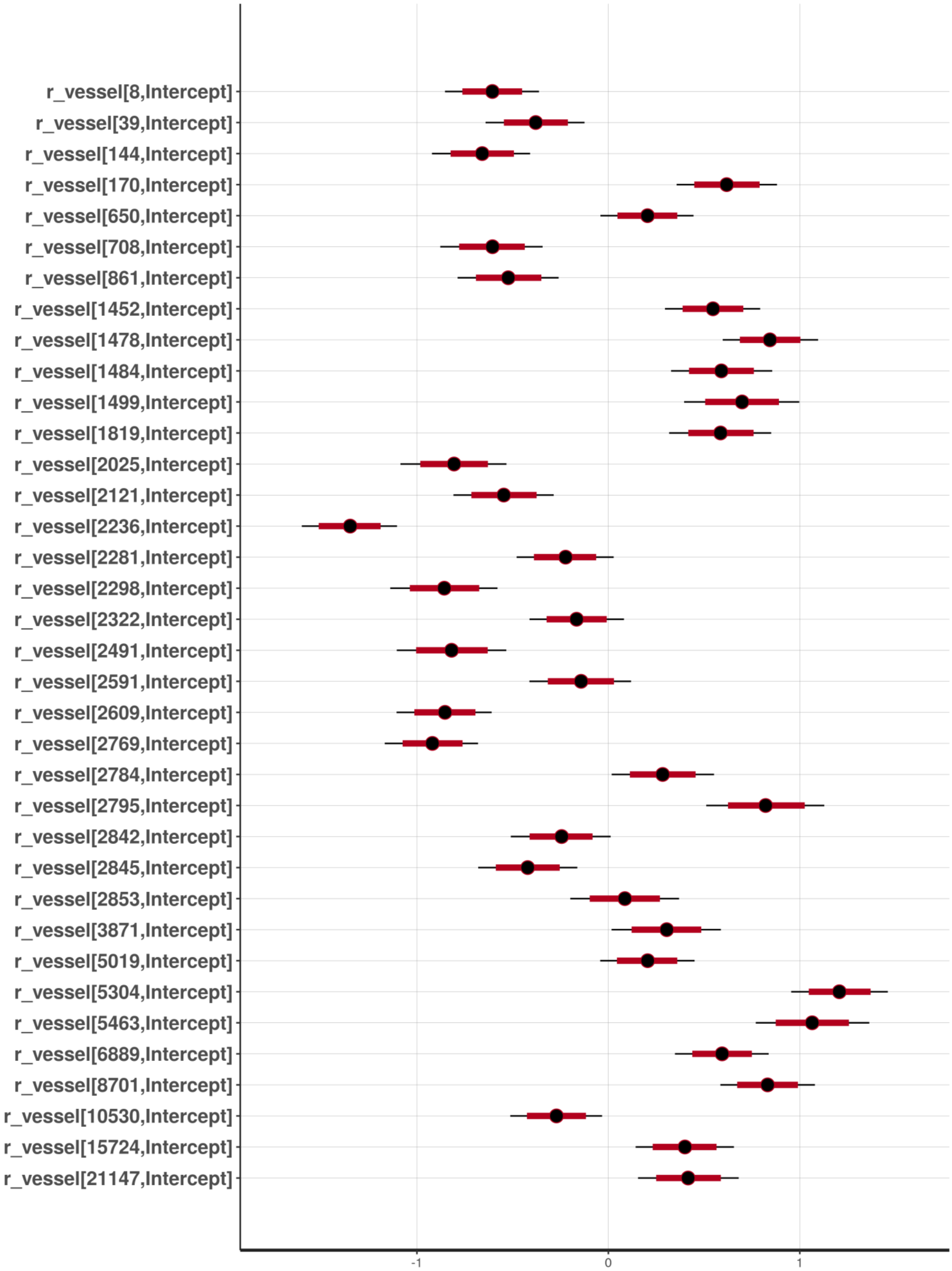


Figure 10: Coefficients for vessels with at least five years data in the fishery from the CRA 1 seasonal CPUE standardisation (interaction model). Vessel coefficients are estimated as group-level effects. MCMC median (black dots), MCMC 95% credible interval (red bars), MCMC marginal posterior distribution range (black bars).

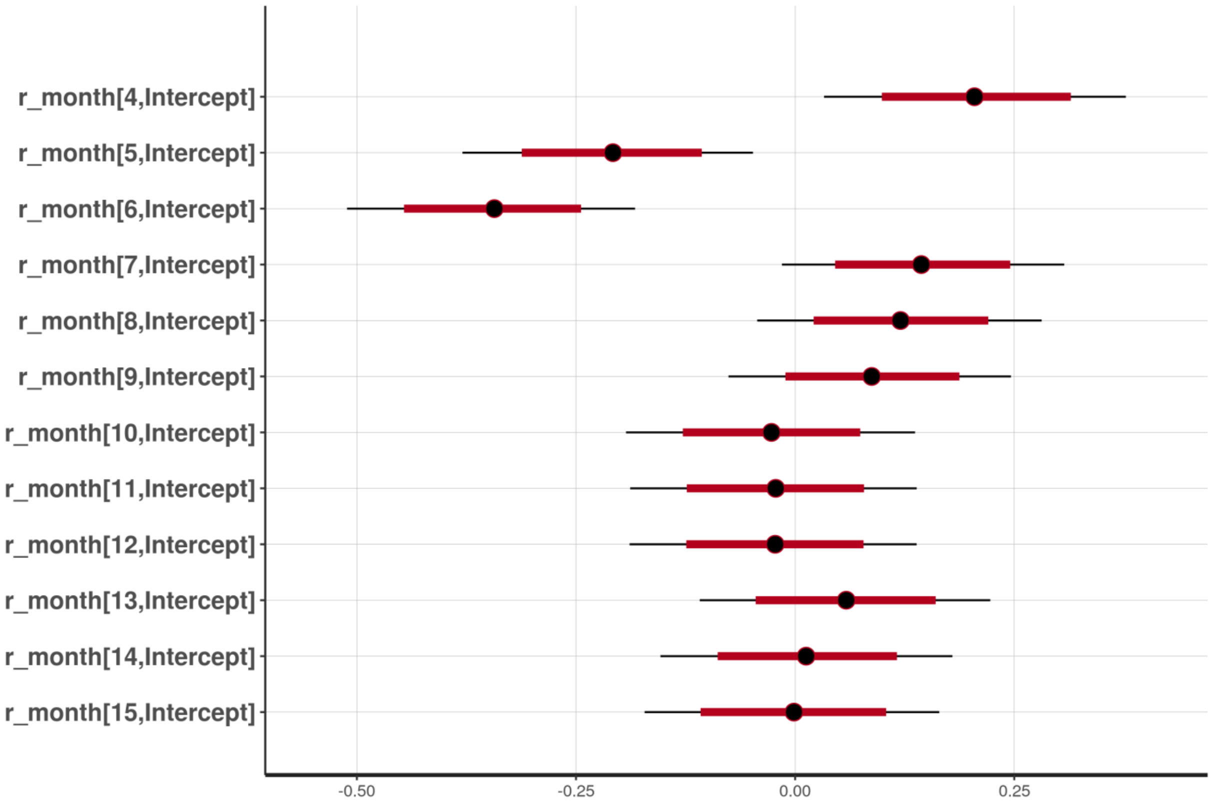


Figure 11: Coefficients for month from the CRA 1 seasonal CPUE standardisation (interaction model). Month coefficients are estimated as group-level effects. MCMC median (black dots), MCMC 95% credible interval (red bars), MCMC marginal posterior distribution range (black bars).

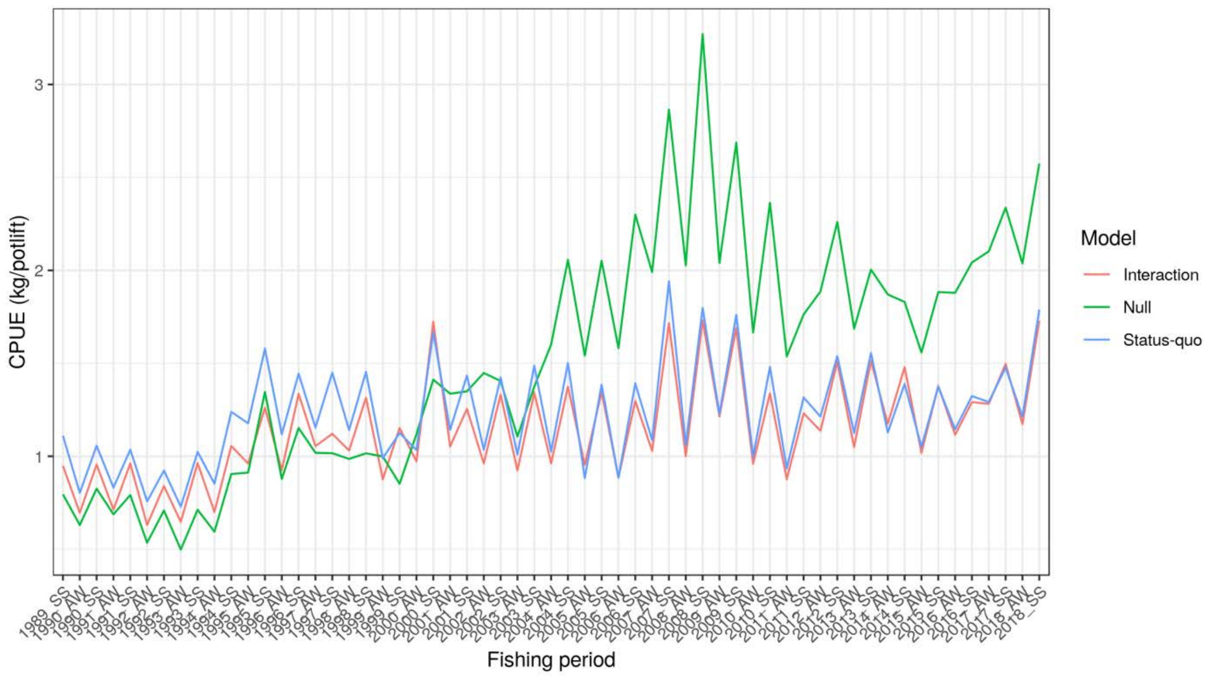


Figure 12: Median CPUE indices (kg/potlift) by season and fishing year from 1989–90 to 2018–19 for the three CRA 1 seasonal CPUE models presented.

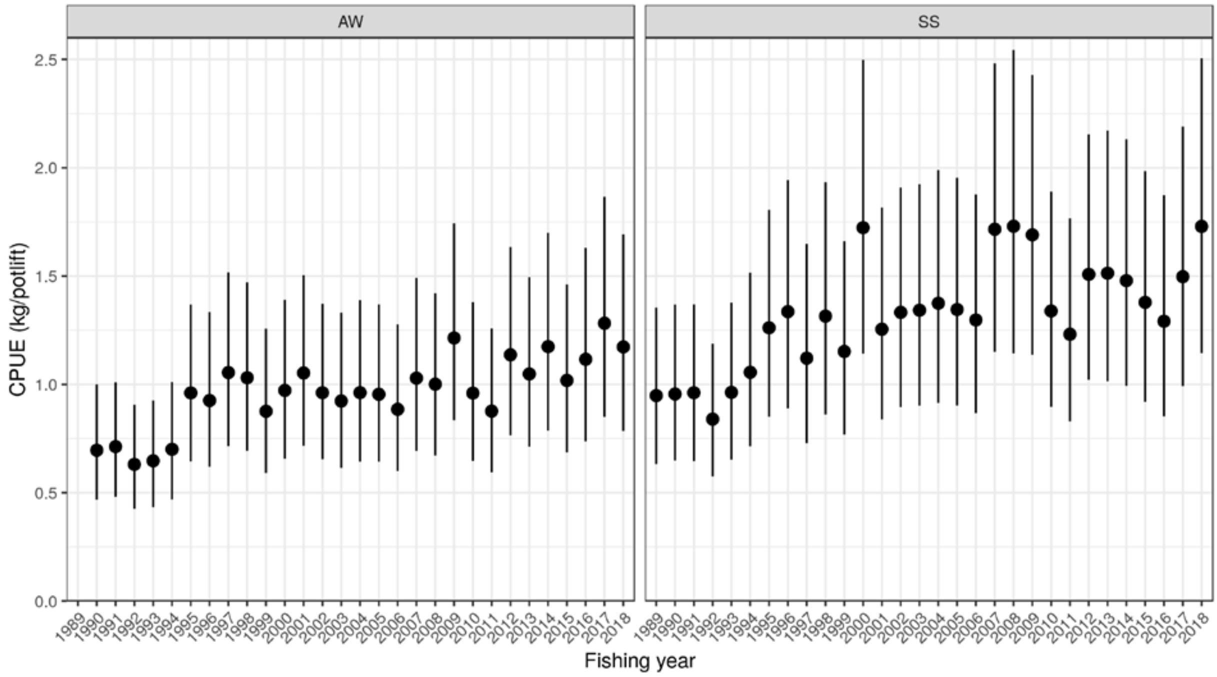


Figure 13: CPUE indices (kg/potlift) by season and fishing year for the CRA 1 seasonal CPUE GLM analysis (interaction model) which included a vessel variable filtered for vessels with at least five years data using the F2 algorithm scaled to "LFX" landings from 1989–90 to 2017–18. Posterior median (points) and 95% credible interval (lines).

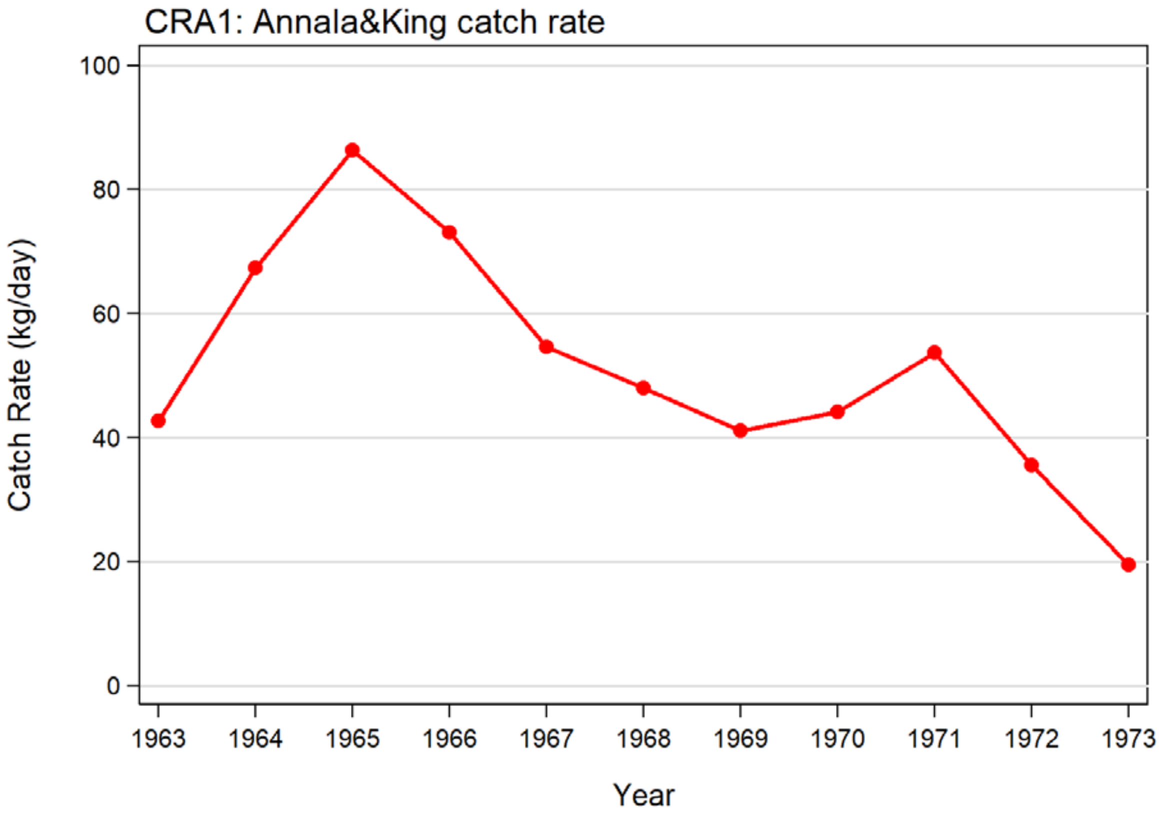


Figure 14: Catch rate (kg/day) by year for CRA 1 from Annala & King (1983).

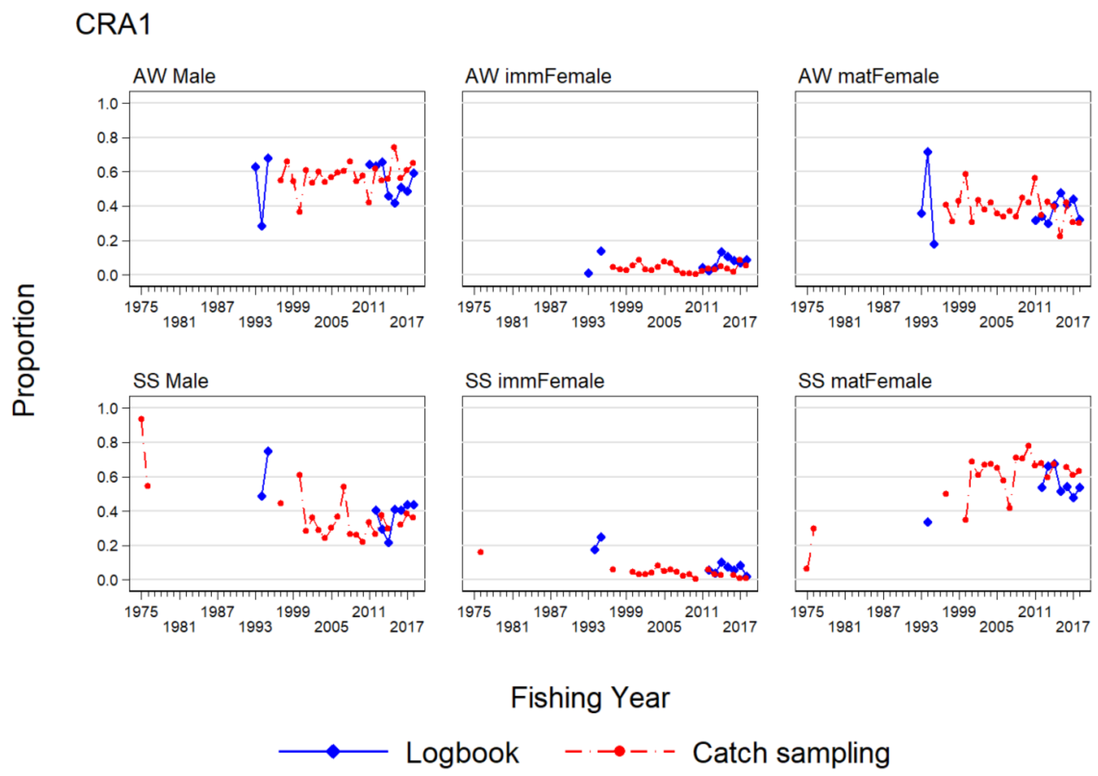


Figure 15: Proportion-at-sex by year, season, and sampling source.

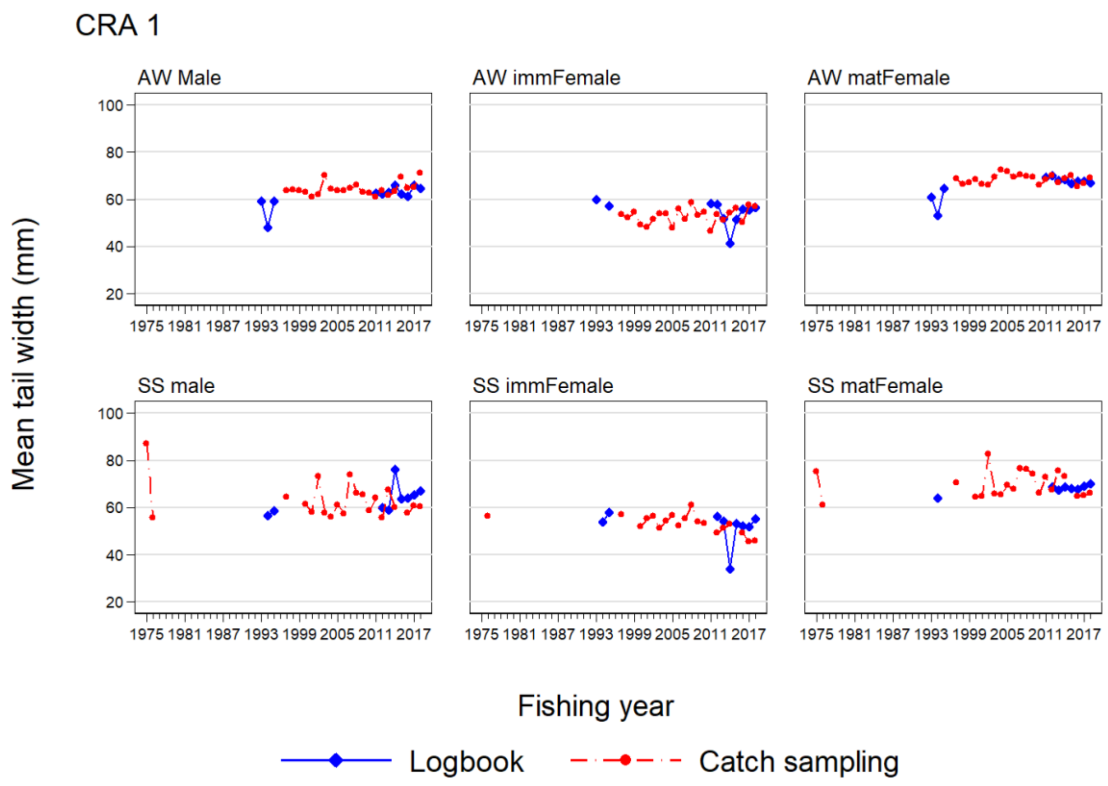


Figure 16: Mean tail width (mm) by year, season, sex, and sampling source.

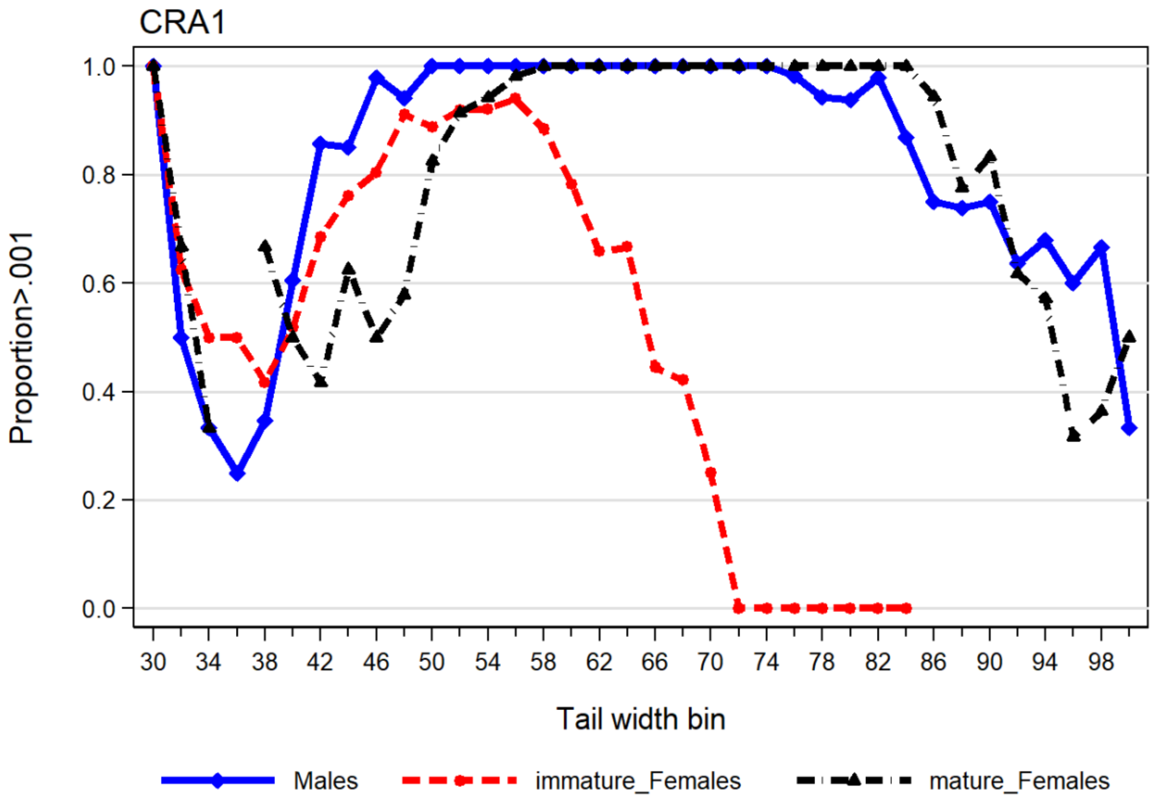


Figure 17: The proportion of size bins (across 86 year/season/sampling source strata) that contain a proportion of 0.001 or higher when the data are normalised by sex.

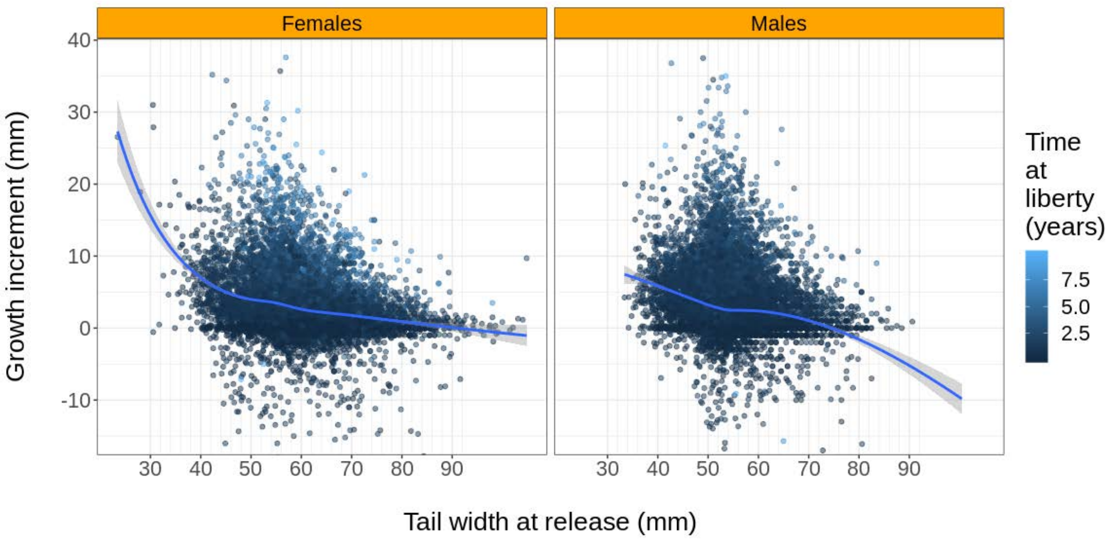


Figure 18: Growth increments (mm) by size at release (mm) and sex. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown.

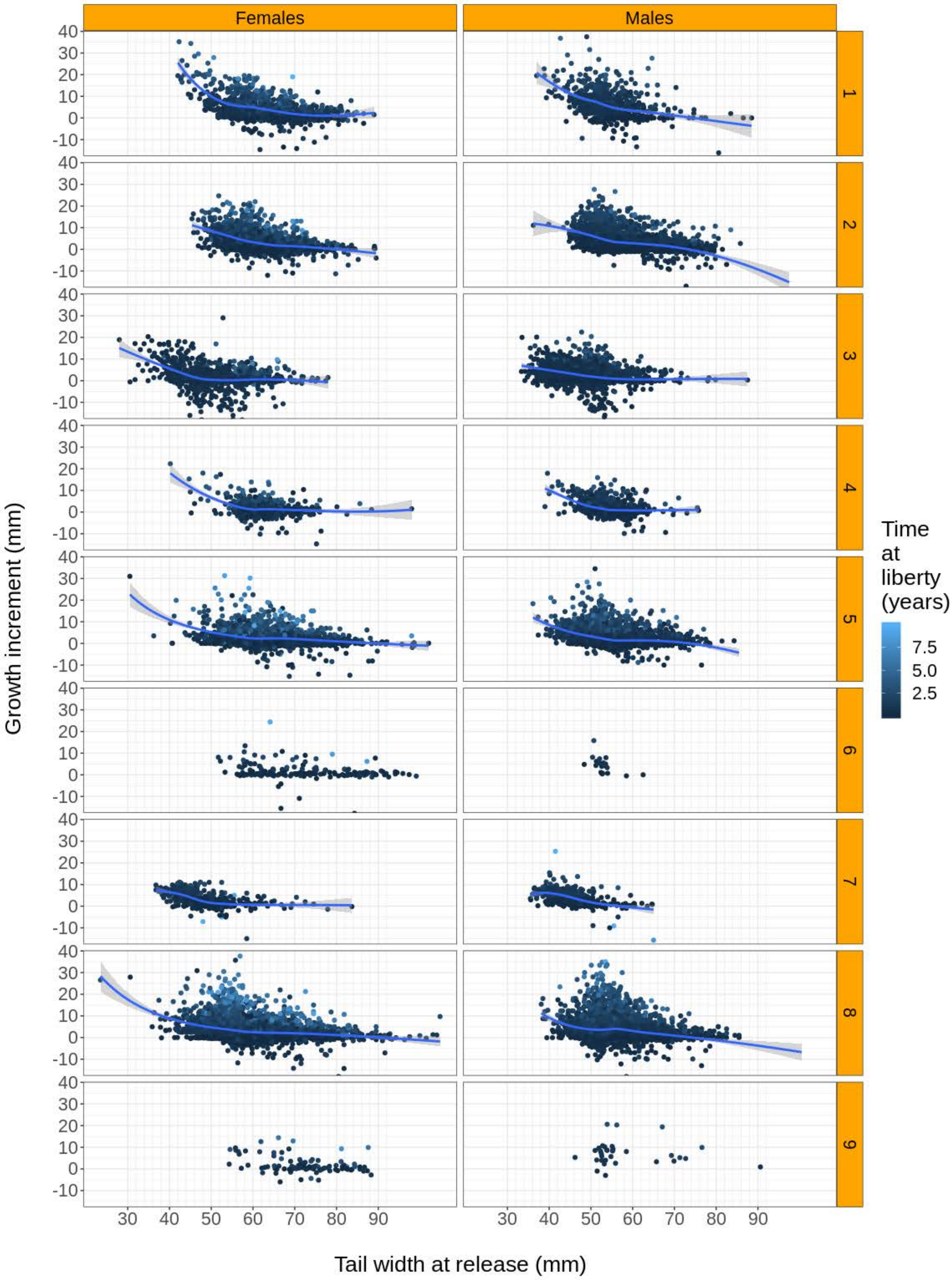


Figure 19: Growth increments (mm) by size at release (mm), sex, and QMA. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown.

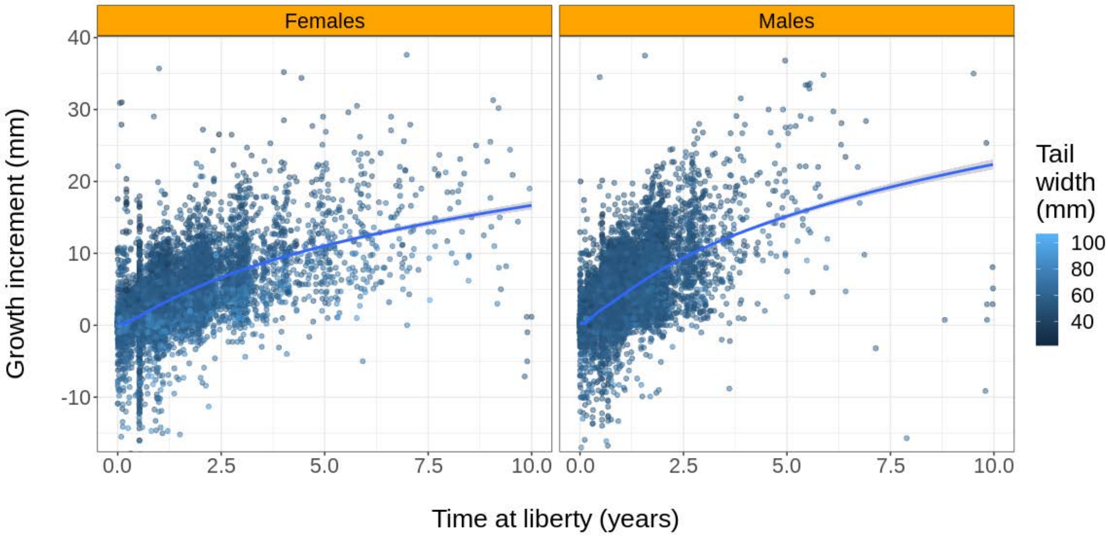


Figure 20: Growth increments (mm) by time at liberty (years) and sex. The colour of each point represents the size at release (mm). A loess smoother and the 95% confidence interval about this smoother is also shown.

Figure 21: 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 and the 95% confidence interval about this smoother is also shown.

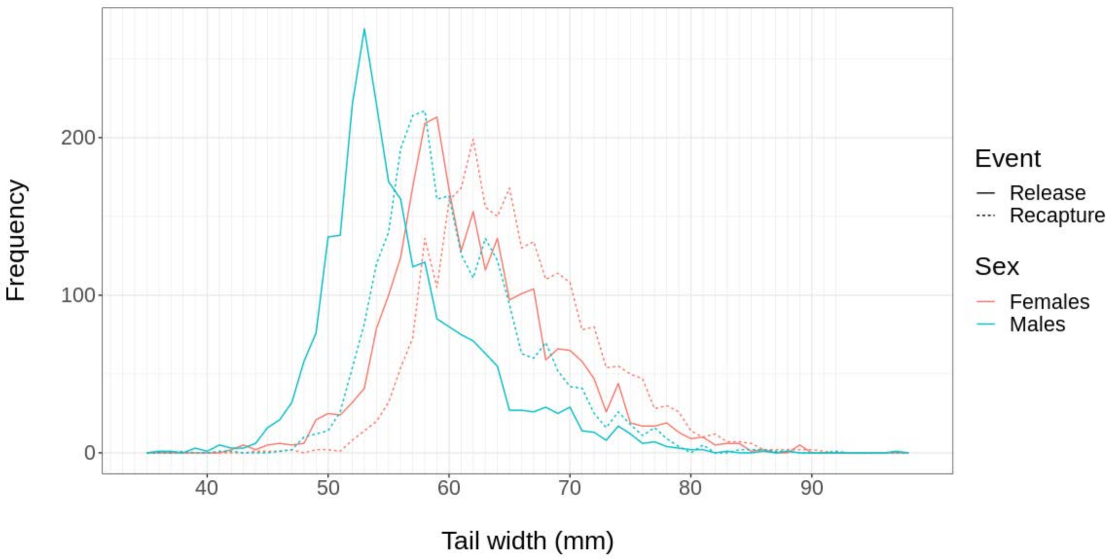


Figure 22: CRA 1 frequency polygons of size at release (solid lines) and recapture (dashed lines) by sex. A bin width of 1 mm was used.

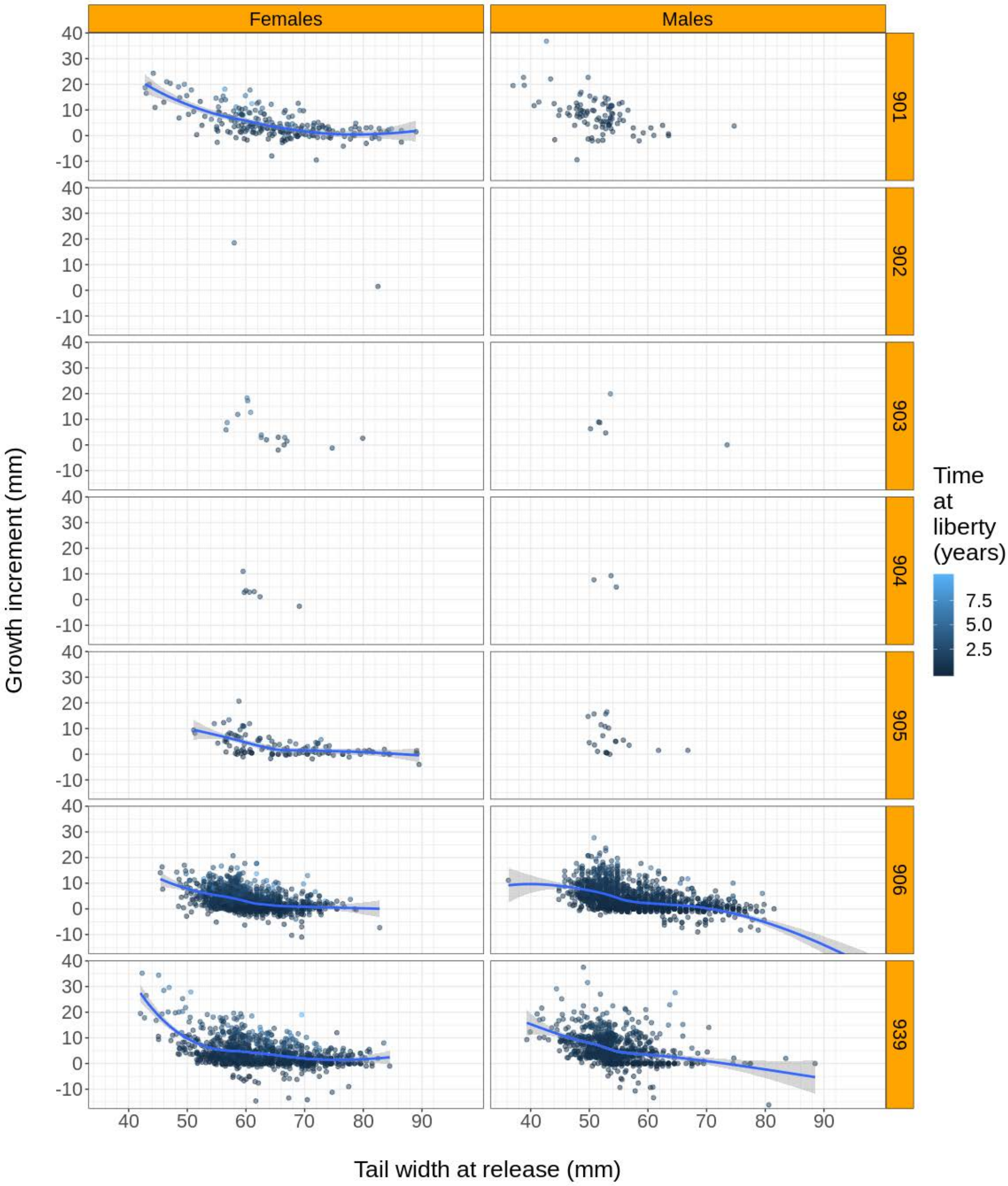


Figure 23: CRA 1 (combined 901–904, 939 and 905, 906 tag regions) growth increments (mm) by size at release (mm) and sex in each statistical area. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.

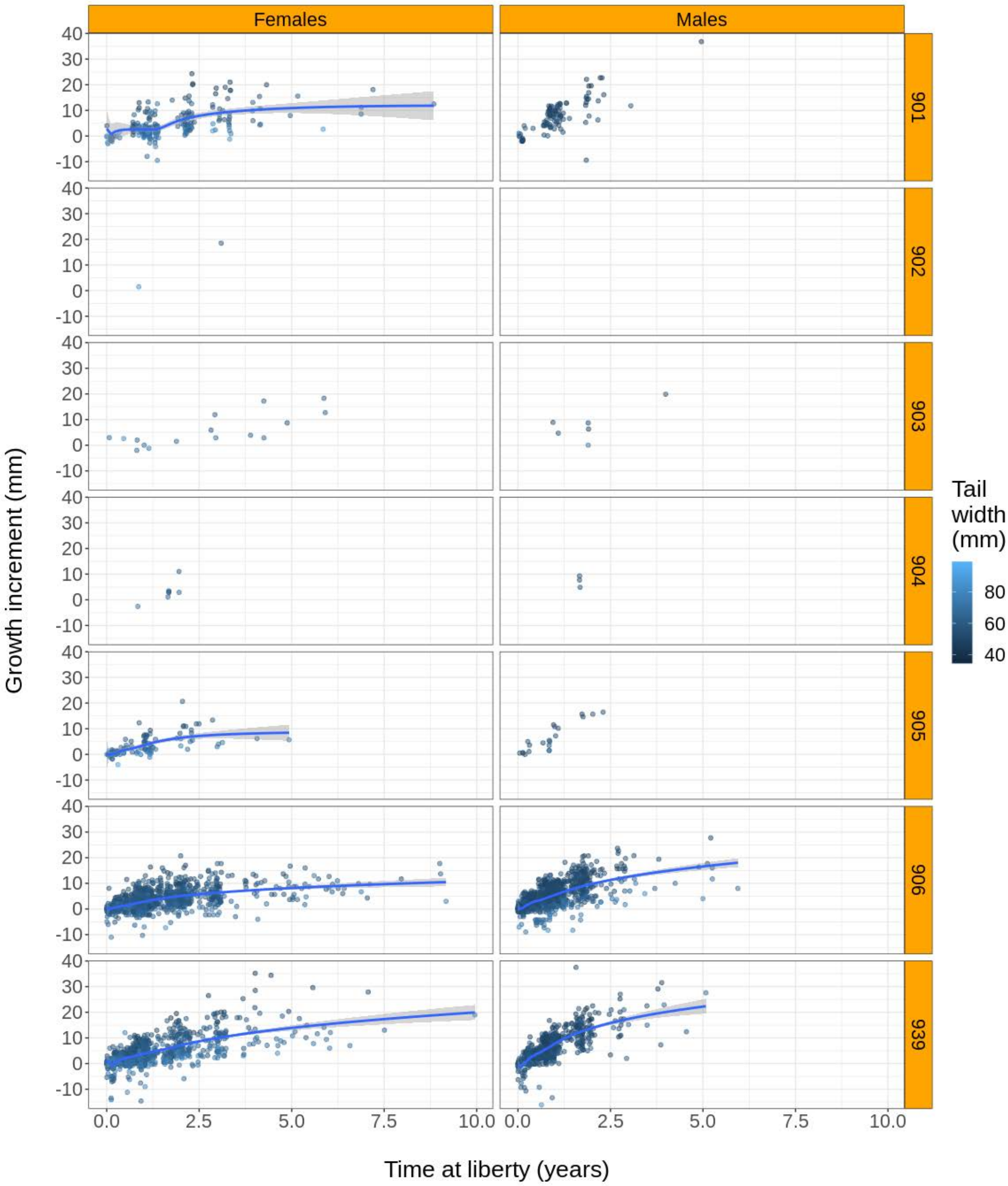


Figure 24: CRA 1 (combined 901–904, 939 and 905, 906 tag regions) growth increments (mm) by time at liberty (years) and sex in each statistical area. The colour of each point represents the tail width (mm). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.

APPENDIX A. LETTER TO FISHERIES NEW ZEALAND REQUESTING NON-COMMERCIAL CATCH INFORMATION

NZ ROCK LOBSTER INDUSTRY COUNCIL

Ka whakapai te kai o te moana

PRIVATE BAG 24-901 WELLINGTON 6142
64 4 385 4005 PHONE
64 4 385 2727 FAX
lobster@seafood.co.nz

June 2019

Alicia McKinnon, Ministry for Primary Industries – Fisheries New Zealand

by email: *Alicia.McKinnon@mpi.govt.nz*

cc Marine Pomarede, Chair, RLFAWG
by email: *Marine.Pomarede@fish.govt.nz cc ECs:*
darcy@quantifish.co.nz
merrillrudd@gmail.com paul@starrfish.net

Dear Alicia

Under the objectives set out in MPI contract CRA 2018/01, in September and October of this year, the stock assessment team will be conducting a CRA 1 stock assessment and a CRA 3 stock assessment and developing the management procedure options.

The stock assessment team has access to data on current and historical commercial catches. However, there are limited data on the non-commercial catch components, which are customary, illegal and recreational catches.

The team has no access to customary or illegal catch information.

The stock assessment cannot ignore the current and historical non-commercial catches: that would cause stock productivity to be greatly underestimated. In the absence of information, only MPI can solve the problem of what to assume for these components; it is up to MPI to specify the non-commercial catch assumptions that MPI wishes to be used in the stock assessment.

It is likely that the RLFAWG will request sensitivity analyses on catch series that are alternatives to the base case non-commercial catch vectors, but the base case non-commercial mortalities must be provided by MPI.

For **illegal catches**, the assessment team needs to know:

- **the MPI estimates of current and recent CRA 1 illegal catch and its historical trend**
- **the MPI estimates of current and recent CRA 3 illegal catch and its historical trend**

To assign illegal catch to the appropriate catch components in the stock assessment model, the stock assessment team needs to know:

- **the proportions by year of the estimated illegal catches that were eventually reported to the QMS**

Otherwise, if commercial fishermen report scrubbed females or other illegal fish that are already part of the illegal catch estimate, then that catch will have been double-counted. The assessment team also request:

- **an appreciation of the uncertainty in the MPI illegal catch estimates.**

For **customary catch**, the requirement is similar: the assessment team requests that MPI provide:

- **estimates of the current customary catch in CRA 1 and its historical trend**
- **estimates of the current customary catch in CRA 3 and its historical trend**

The assessment team also request:

- **an appreciation of the uncertainty in the MPI customary catch estimates.**

For **recreational catch**, the requirements are similar: the assessment team requests that MPI provide:

- **estimates of the current recreational catch in CRA 1 and its historical trend**
- **estimates of the current recreational catch in CRA 3 and its historical trend**

The assessment team also request:

- **an appreciation of the uncertainty in the MPI recreational catch estimates**

Without these estimates from MPI, it will not be possible to produce acceptable stock assessments. The assessment input data, including these estimates, are scheduled to be discussed at a RLFAWG meeting on
19th September 2019. These MPI estimates of non-commercial catches are thus required by:

- **12th September 2019**

Can you please confirm your understanding of this written request and advise likely delivery dates for these catch estimates? To assist the task, I will be happy to answer any questions you may have.

Sincerely,

Daryl R Sykes

Daryl Sykes

Research Programme Manager
NZ Rock Lobster Industry Council Ltd

APPENDIX B. FISHERIES NEW ZEALAND RESPONSE TO NON-COMMERCIAL DATA REQUEST

To: Daryl Sykes <lobster@nzrocklobster.co.nz>, Marine Pomarede <Marine.Pomarede@mpi.govt.nz>
CC: Sonja Hempel <Sonja.Hempel@mpi.govt.nz>, Mark Edwards <Mark.Edwards@nzrocklobster.co.nz>, Darcy Webber <darcy@quantifish.co.nz>, "paul@starrfish.net" <paul@starrfish.net>
Subject: Non-commercial harvest estimates for CRA1 and CRA3

Hi Daryl

Non-commercial catch estimates for the CRA1 and CRA3 stock assessments

Thank you for your request for information to support the upcoming stock assessments in CRA1 and CRA3. We do not have the information to accurately answer a number of the questions you pose as part of your data request. The following response provides guidance on what information should be considered for recreational, customary and illegal take within the stock assessment models.

Recreational harvest estimates

Available estimates of recreational rock lobster harvest for each stock are presented in the November Fisheries Assessment Plenary. This is while acknowledging that the harvest estimates provided by the 2000 and 2001 telephone-diary surveys are no longer considered reliable by the MPI Marine Amateur Fisheries Working Group (they are implausibly high for many species).

Missing from the November 2018 Plenary is the recently released 17/18 National Panel Survey harvest estimates for rock lobster. These estimates can be found in the Fisheries Assessment Report here: https://fs.fish.govt.nz/Page.aspx?pk3D113&dk3D24728. These estimates should be considered as part of the new CRA1 and CRA3 stock assessments.

Customary harvest estimates

A summary of the information Fisheries New Zealand holds on CRA1 and CRA3customary harvest since the 07/08 April fishing year is provided in the attached excel file.This includes information provided under the Fisheries (Kaimoana) Regulations 1998, and the Fisheries (Amateur Fishing) Regulations 13 (previously Regulation 27A of the Fisheries (Amateur Fishing) Regulations 1986).

Based on the customary harvest information available, noting its incompleteness and uncertainty, we consider it appropriate to continue to use a 10 tonne constant customary catch estimate for CRA1 and a 20 tonne constant estimate for CRA3.

Illegal take estimates

Estimating illegal removals is inherently difficult, as by its nature it is hard to detect. We acknowledge that historical illegal take estimates are highly uncertain and that we do not currently have a robust and defensible methodology to accurately estimate illegal take from any New Zealand fishery (be it rock lobster or another species). We are currently working on solutions to this issue, including looking at the metrics compliance collect (i.e. compliance breach rates) and how we can make improvementsto the FOCUS system compliance use to record inspection and enforcement information (i.e. based off the recommendations provided in the 12 MRAG report). Having better quality compliance information, will hopefully allow us to better estimate illegal take in time (a challenge in itself).

Based on our experience and knowledge of the CRA1 and CRA3 fisheries, and compliance monitoring, knowledge and intelligence, we propose that the illegal take estimates for CRA1 and CRA3 are reduced to 40 and 50 tonnes respectively. This recognises that illegal take is unlikely to be at 72 tonnes for CRA1 and 89.5 tonnes for CRA3, but acknowledges that illegal take is still at reasonable levels in these fisheries. We propose that theCRA1 illegal take is ramped down from 72 tonnes in 01 to 40 tonnes in 19, and the CRA3 illegal take estimate is ramped down from 89.5 tonnes in 03 to 50 tonnes in 19.As you suggest in your request, we recommend that sensitivity trials are carried out to test for robustness to uncertainty in the illegal take assumptions.

Happy to discuss ahead of the RLFAWG next week.

See you then.

Cheers

Alicia

Alicia McKinnon | Senior Fisheries AnalystFisheries Management | Fisheries New Zealand - Tini a TangaroaMinistry for Primary Industries | 21 Domett Street, Ahuriri | P O Box 134 | Napier

APPENDIX C. EVIDENCE FOR REGIONAL SEPARATION IN CRA 1

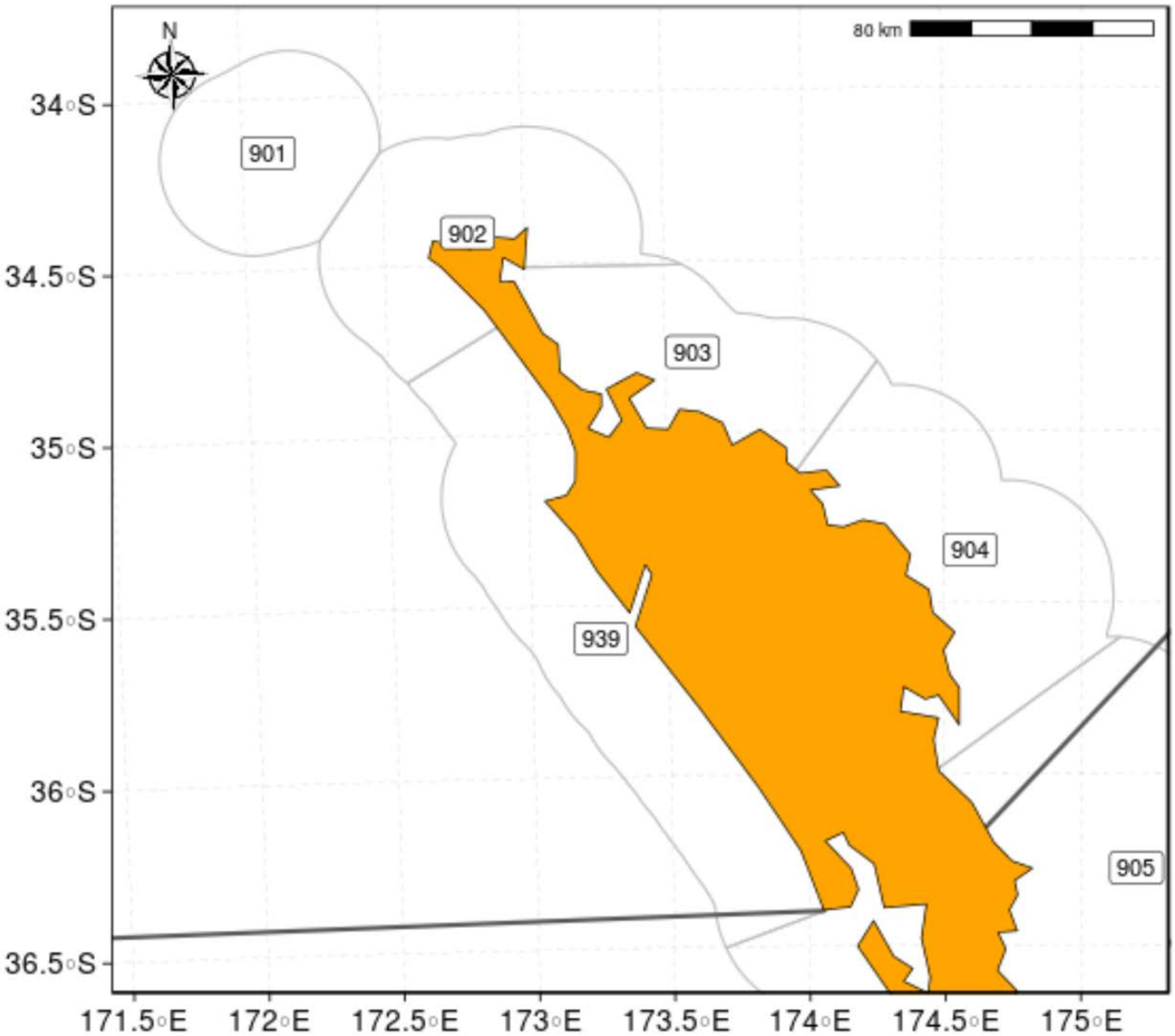


Figure C.1: Map showing location of CRA 1 statistical areas.

The stock assessment team evaluated the evidence for separating CRA 1 into two regions based on observed differences in absolute unstandardised catch rates:

<u>Region 1</u>: combined Statistical Areas 901, 902, and 939 (see Figure C.1: top of North Island including Three Kings and Ninety Mile Beach);

<u>Region 2</u>: combined Statistical Areas 903 and 904 (East Northland).

The stock assessment team recommends that CRA 1 should be treated as a single region, given the equivocal nature of the evidence presented in this document and the lack of adequate biological sampling coverage for Region 2 (Table C.1).

C.1 COMPARISON OF LENGTH FREQUENCY (LF) DISTRIBUTIONS

Length frequency data for CRA 1 organised into the above regions were plotted by fishing year, season and sex as empirical cumulative frequency distributions, using the summed weights for each tail width (TW) measurement after combining the two sources of length frequency data (logbook and catch sampling). The underlying statistics to these plots are provided in Table C.1. This table indicates that the amount of data for

Region 2 (East Northland) in this analysis is low, reducing the reliability of this analysis. The LF comparison plots by fishing year indicate that there is no strong evidence for size differences in the lobster population between Region 2 (East Northland) and Region 1 (top of North Island and Ninety Mile Beach).

AW males	Figure C.2	most (12) of the comparisons show similar LFs between the two regions with (4) of the remaining (5) having Region 2 smaller than Region 1 and (1) has Region 2 larger than Region 1
SS males	Figure C.3	(5) of the comparisons are similar between the two regions while (5) have Region 2 being smaller and (2) have Region 2 larger than Region 1
AW mature females	Figure C.4	(8) of the comparisons have Region 2 smaller than Region 1, while (8) of the comparisons are the same
SS mature females	Figure C.5	(8) of the comparisons have Region 2 smaller than Region 1, while (5) of the comparisons are the same

The stock assessment team recognises that this evaluation is weak because the amount of Region 2 data is small compared to Region 1 (Table C.1). However, the patterns of relative size distributions are inconsistent across the two sexes in either season, making it difficult to come to the conclusion that the two regions have consistently different length frequency distributions.

C.2 COMPARISON OF STANDARDISED CPUE SERIES

The catch effort data for each of the defined regions were standardised in the usual way and compared in Figure C.6. Although there is some divergence between the two regions for the standardisation that omits the vessel effect (Figure C.6, left panel), the two series show very similar trends once the vessel effect is added to the analysis (after giving each series the same mean; Figure C.6, right panel). Figure C.7 shows the large disparity in absolute CPUE between the two regions, demonstrating the need to give each series the same mean. The stock assessment team does not find evidence in this CPUE comparison that these two regions should be assessed separately.

C.3 CONCLUSION

The stock assessment team has reviewed this information and concluded that the evidence for separating CRA 1 into these two regions is equivocal. Given the relatively small amount of length frequency data for Region 2 (Table C.1) and the similarity between the two standardised series (Figure C.6, right panel), the stock assessment team has reached the same conclusion as was made in the 2014 CRA 1 stock assessment (Webber & Starr 2015): that CRA 1 is best evaluated as a single region.

Table C.1: Statistics for CRA 1 sub-regional analysis by region, sex, season and fishing year.

	Number lobsters measured				Total weight			
	AW		SS		AW		SS	
	901,902,939	903,904	901,902,939	903,904	901,902,939	903,904	901,902,939	903,904
Male								
1993	214	–	–	–	1.66	–	–	–
1994	–	8	310	98	–	0.05	1.54	0.39
1995	666	–	6	–	4.28	–	0.02	–
1997	1 514	410	680	–	1.49	0.46	1.04	–
1998	3 120	242	–	–	3.74	0.25	–	–
1999	7 348	348	–	–	13.86	0.41	–	–
2000	3 478	298	–	28	3.69	0.78	–	0.21
2001	2 116	334	128	278	3.33	0.42	0.38	0.38
2002	3 452	–	990	20	4.73	–	2.06	0.03
2003	708	436	2 118	102	1.66	0.41	2.08	0.08
2004	3 486	–	416	–	4.71	–	0.93	–
2005	3 668	–	1 002	–	3.82	–	1.51	–
2006	2 628	368	1 570	–	1.50	0.38	3.62	–
2007	2 752	128	520	–	9.67	0.17	0.01	–
2008	2 430	760	474	100	7.36	1.18	0.41	0.07
2009	3 186	1 214	322	176	6.54	0.72	0.44	0.17
2010	1 824	1 152	604	12	3.64	1.56	0.72	0.05
2011	1 940	96	726	396	4.24	0.18	1.88	0.65
2012	4 812	–	1 726	212	5.39	–	2.42	0.07
2013	4 230	–	696	–	5.78	–	1.56	–
2014	3 812	–	536	48	10.61	–	1.76	0.02
2015	3 836	270	1 506	–	15.96	0.14	9.15	–
2016	2 936	28	3 932	50	19.19	0.20	25.70	0.14
2017	1 668	436	2 104	148	17.39	1.19	16.40	0.39
2018	4 820	212	2 146	4	41.00	0.36	25.32	0.01
Matfem								
1993	126	–	–	–	0.95	–	–	–
1994	–	20	254	124	–	0.13	0.92	0.42
1995	172	–	–	–	1.15	–	–	–
1997	896	320	802	–	1.10	0.34	1.17	–
1998	1 650	90	–	–	1.83	0.09	–	–
1999	5 444	168	–	–	11.84	0.12	–	–
2000	4 718	202	–	16	6.33	0.53	–	0.12
2001	1 238	156	374	548	1.69	0.20	1.10	0.76
2002	2 812	–	1 582	128	3.84	–	3.29	0.22
2003	462	534	4 532	294	0.92	0.38	4.97	0.24
2004	2 648	–	1 150	–	3.65	–	2.56	–
2005	2 382	–	2 254	–	2.41	–	3.29	–
2006	1 718	122	2 578	–	0.90	0.15	6.93	–
2007	1 690	108	450	–	6.03	0.14	0.01	–
2008	1 572	380	1 328	194	4.37	0.57	1.16	0.14
2009	2 564	834	722	472	4.99	0.51	1.12	0.53
2010	1 324	910	2 272	30	2.41	1.22	2.73	0.12
2011	2 492	12	1 102	886	3.32	0.02	3.10	1.45
2012	2 700	–	4 312	332	2.97	–	5.81	0.11
2013	3 344	–	1 154	–	3.92	–	2.70	–
2014	2 906	–	904	100	7.71	–	6.41	0.04
2015	2 052	378	1 534	–	13.94	0.20	12.93	–
2016	2 124	20	7 568	126	12.27	0.20	39.69	0.20
2017	1 212	162	2 744	112	9.81	0.44	19.19	0.30
2018	2 104	264	3 060	20	19.07	0.46	31.05	0.04

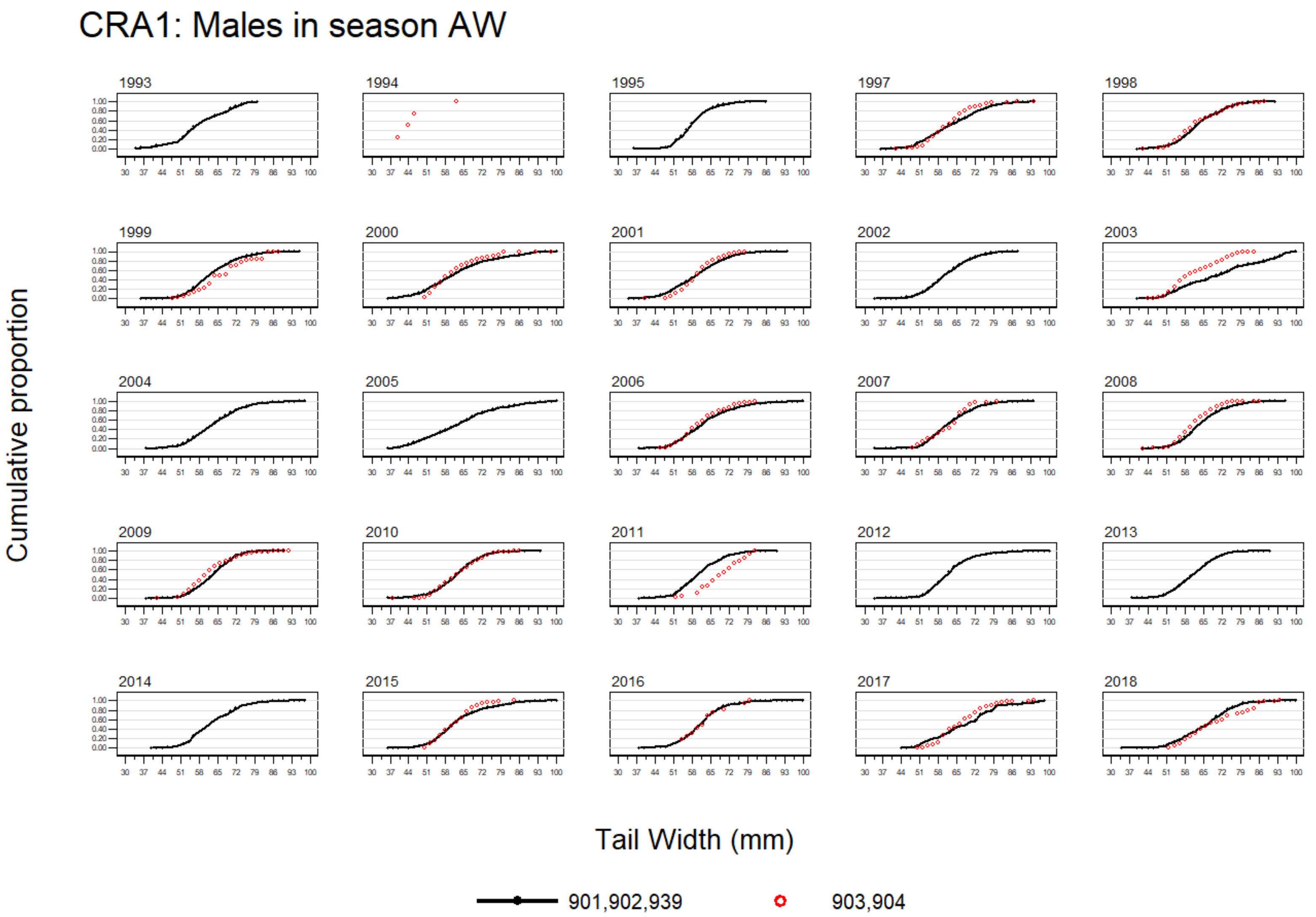


Figure C.2: Plot of cumulative male LFs by AW fishing year for CRA 1 divided into two regions: 1) Statistical Areas 901, 902 plus 939 (black solid line) and 2) Statistical Areas 903 plus 904 (hollow red markers).

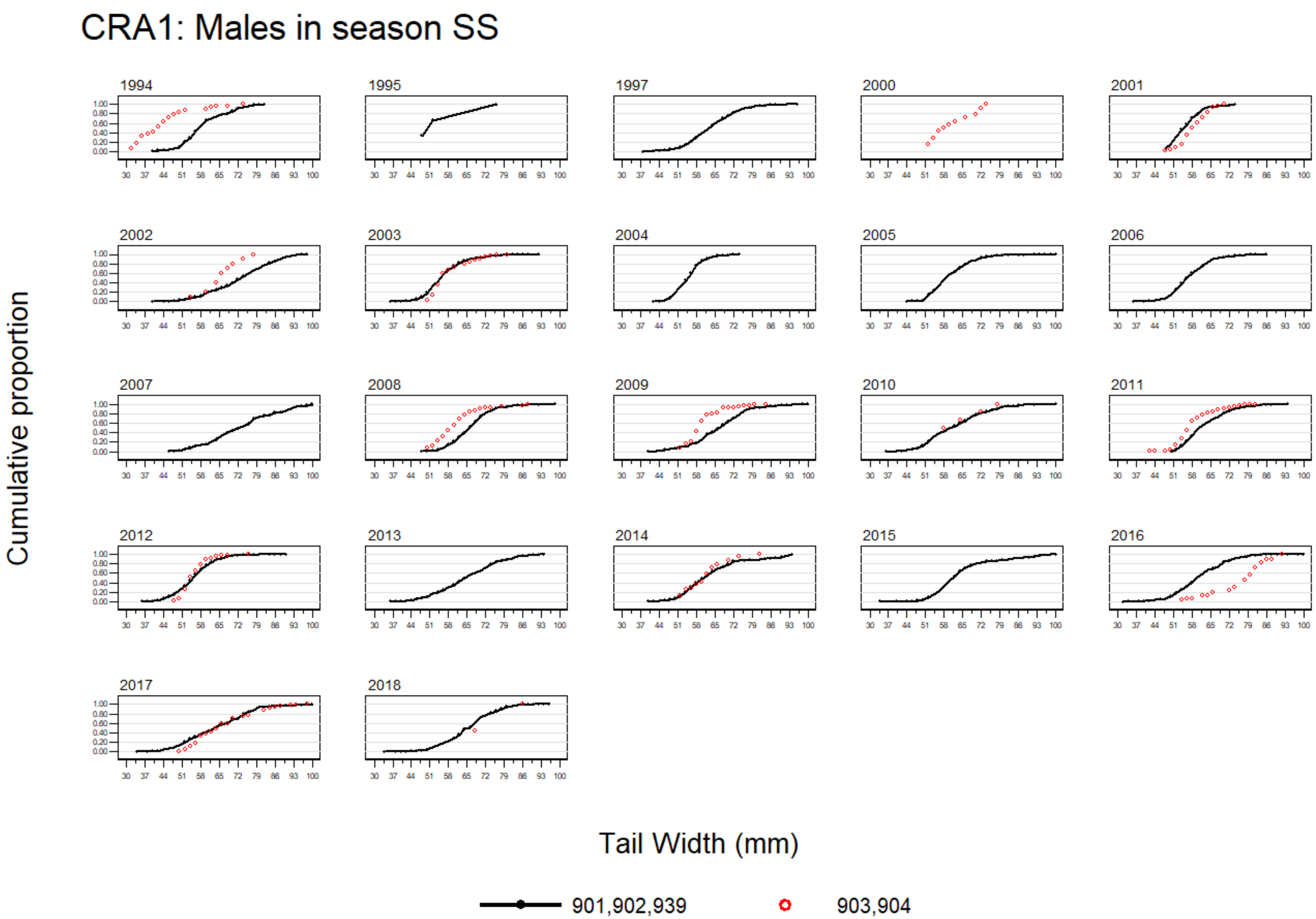


Figure C.3: Plot of cumulative male LFs by SS fishing year for CRA 1 divided into two regions: 1) Statistical Areas 901, 902 plus 939 (black solid line) and 2) Statistical Areas 903 plus 904 (hollow red markers).

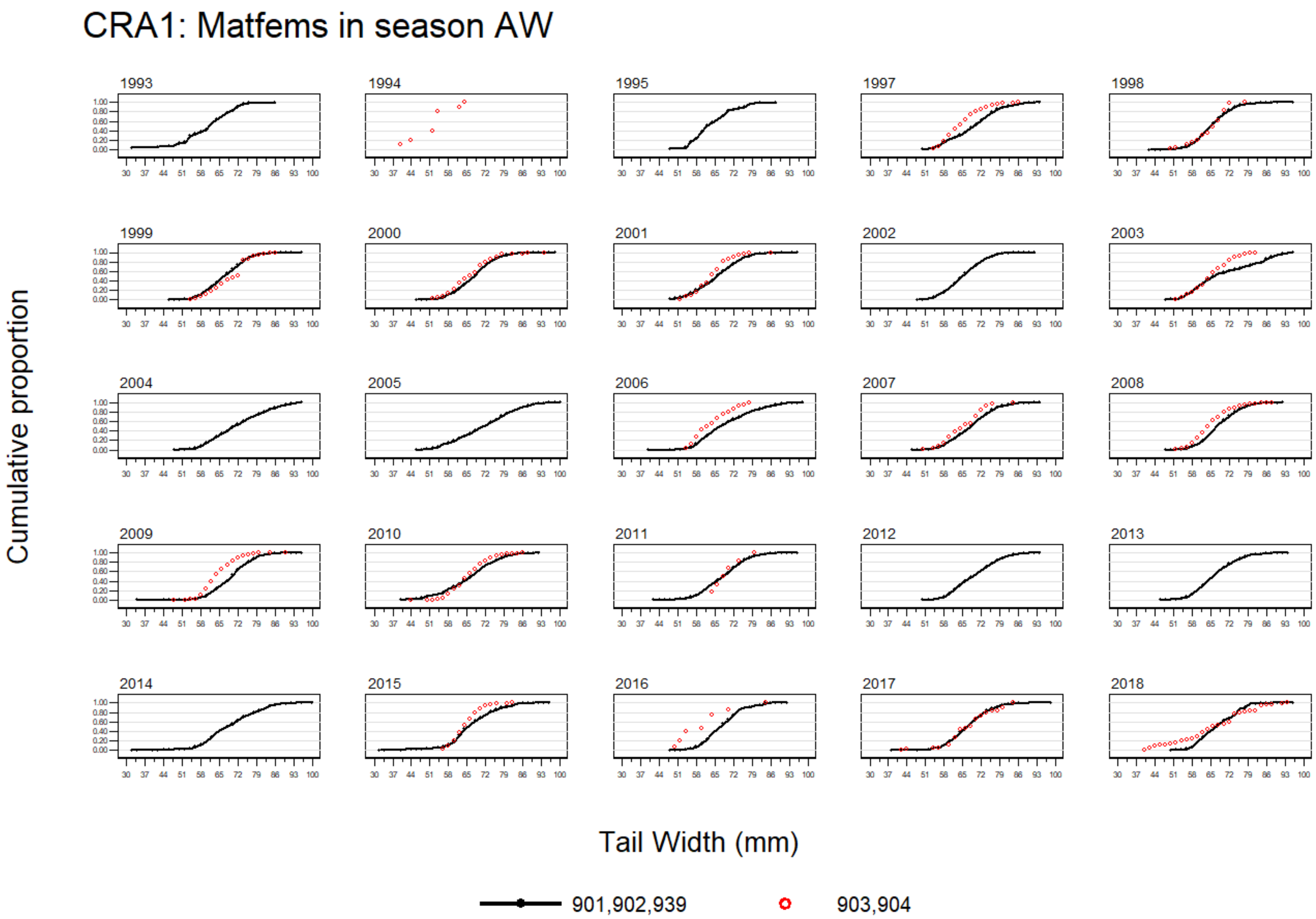


Figure C.4: Plot of cumulative mature female LFs by AW fishing year for CRA 1 divided into two regions: 1) Statistical Areas 901, 902 plus 939 (black solid line) and 2) Statistical Areas 903 plus 904 (hollow red markers).

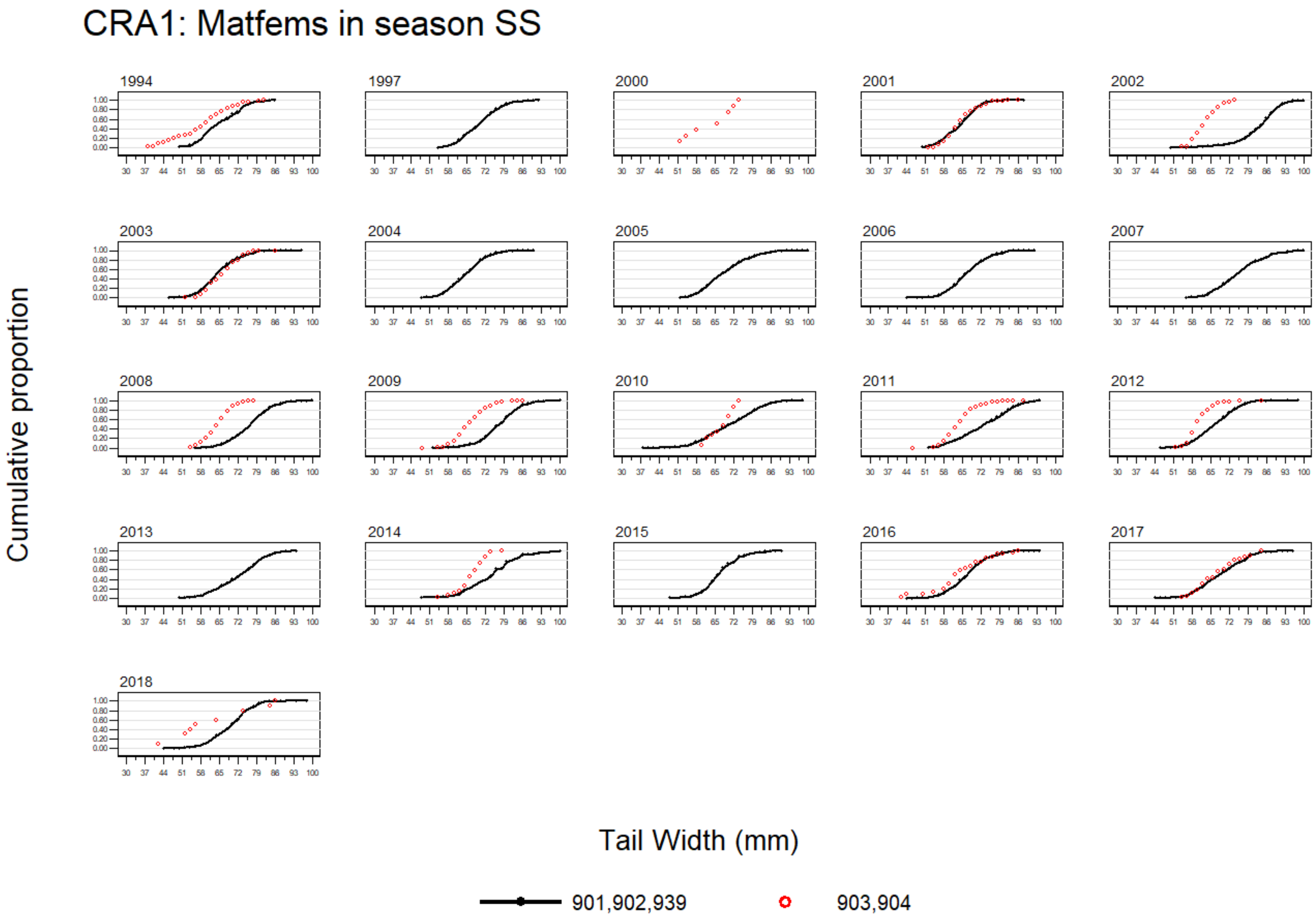


Figure C.5: Plot of cumulative female LFs by SS fishing year for CRA 1 divided into two regions: 1) Statistical Areas 901, 902 plus 939 (black solid line) and 2) Statistical Areas 903 plus 904 (hollow red markers).

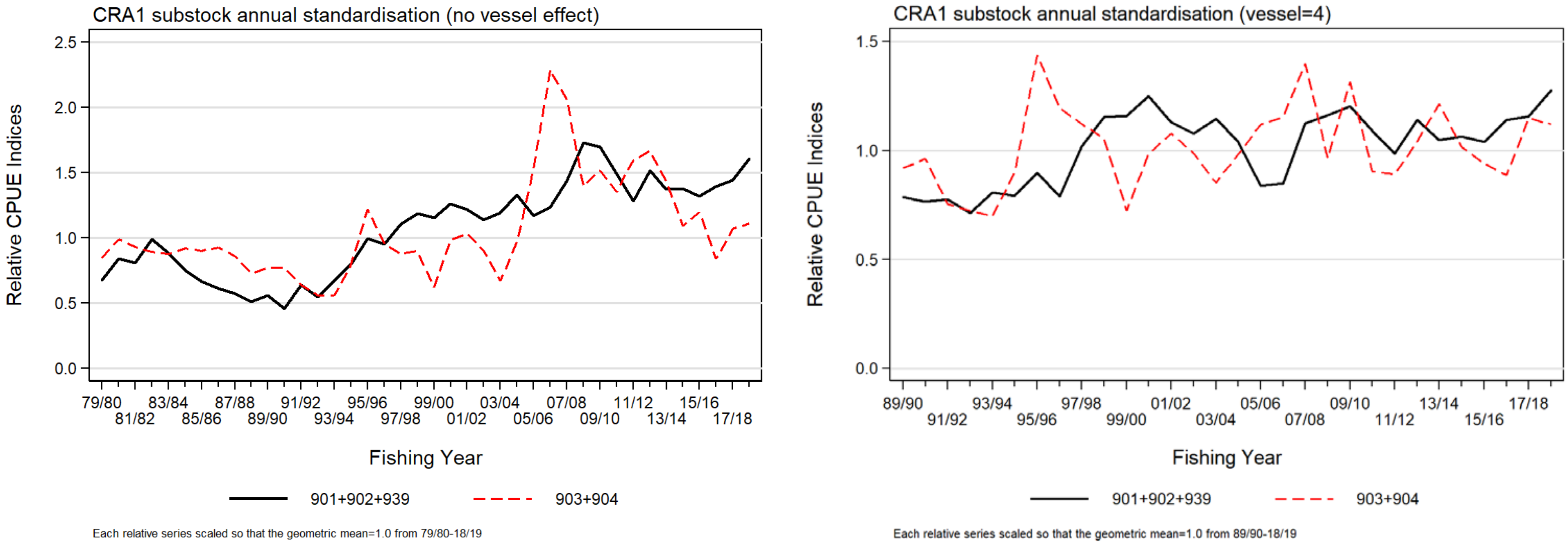


Figure C.6: Comparison of standardised CPUE trends for the two CRA 1 regions (1. Statistical Areas 901, 902 plus 939 (black solid line) and 2. Statistical Areas 903 plus 904 (red dashed line)): [left panel]: standardised without a vessel effect; [right panel]: standardised with a vessel effect using vessels with at least 4 years of data. Each series scaled so that the geometric mean = 1.0.

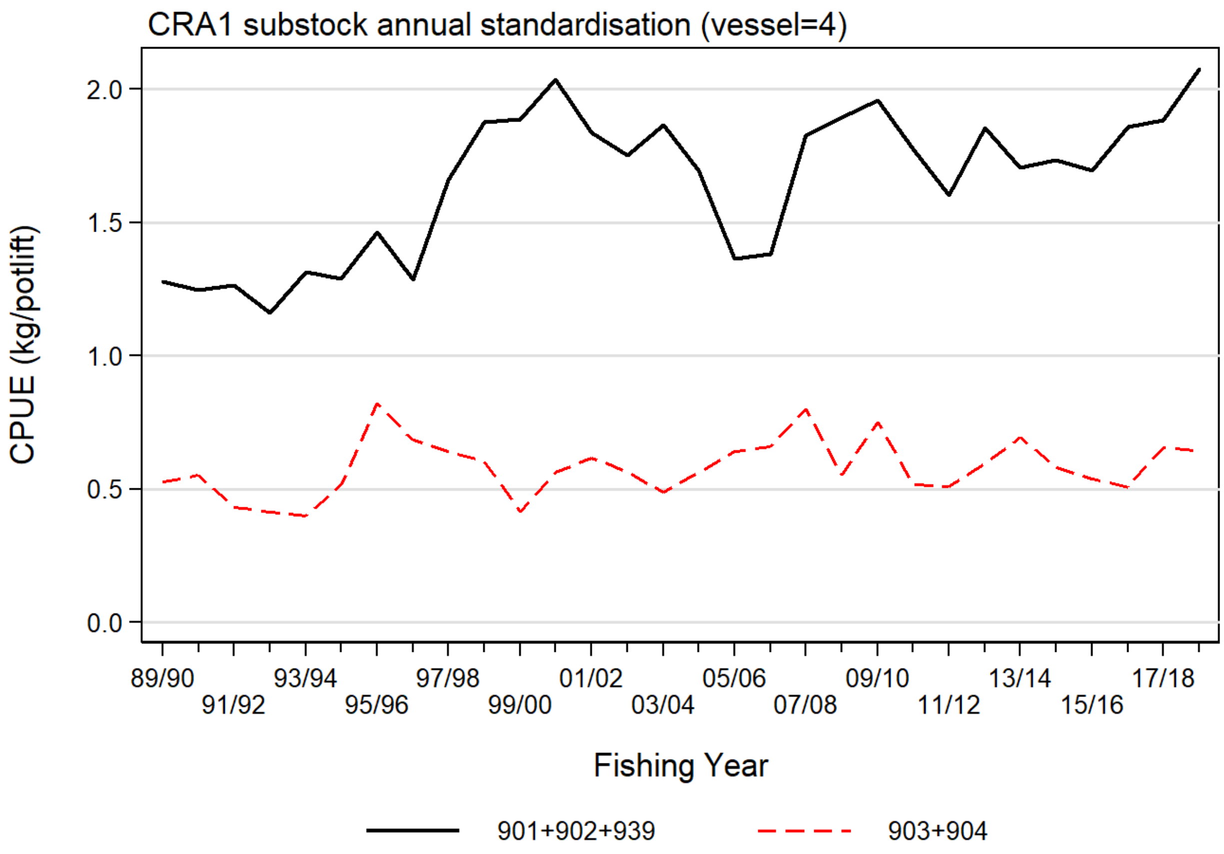


Figure C.7: Same comparison plot as in Figure C.6 (right panel), plotted without standardising to the same geometric mean.

APPENDIX D. DISTRIBUTION OF DESTINATION CODES IN CRA 1 LANDING DATA

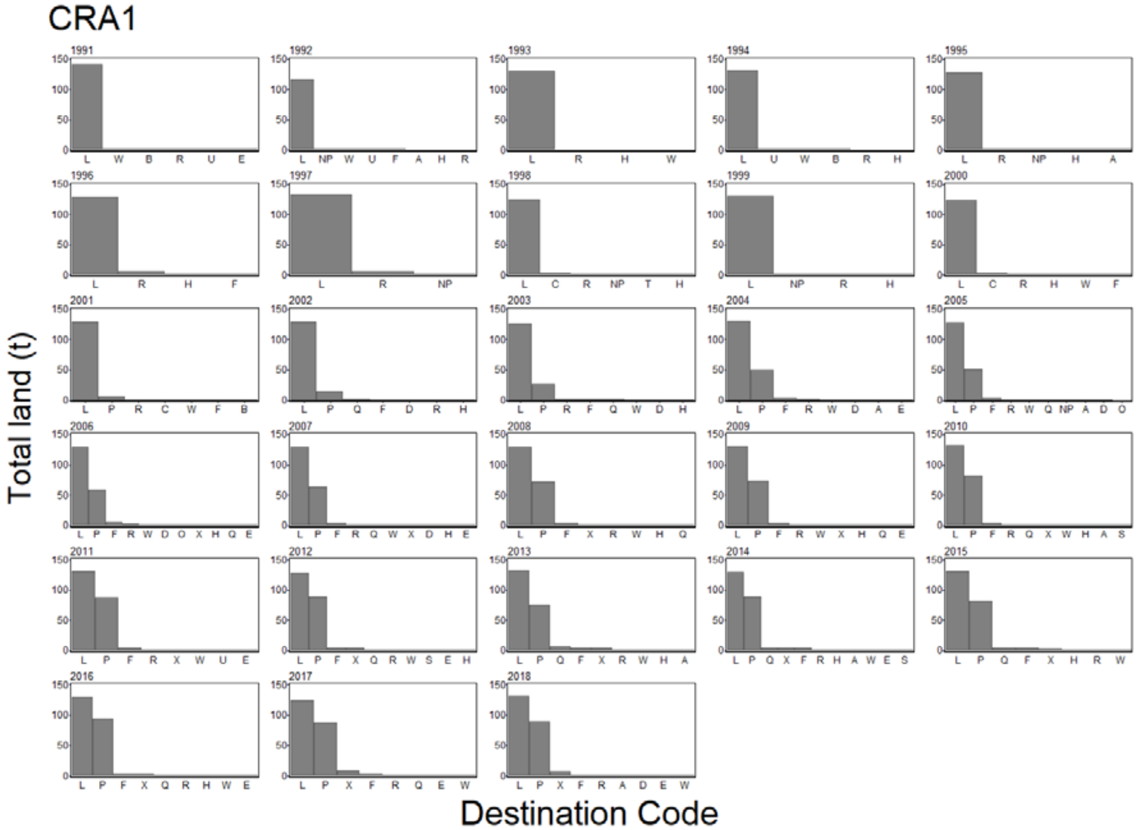


Figure D.1: Plot showing destination codes reported by fishing year in CRA 1. Only the destination codes reported in each year are shown in descending order of total annual landings.

Table D.1: Destination codes used by Fisheries New Zealand.

Destination code	Description	How used in procedure
A	Accidental loss	Keep
C	Disposed to Crown	Keep
E	Eaten	Keep
F	Section 111 Recreational Catch	Keep
H	Loss from holding pot	Keep
L	Landed in NZ (to LFR)	Keep
M	QMS returned to sea (Part 6A)	Keep
O	Conveyed outside NZ	Keep
S	Seized by Crown	Keep
U	Bait used on board	Keep
W	Sold at wharf	Keep
X	QMS returned to sea, except 6A	Keep
B	Bait stored for later use	Drop
D	Discarded (non-ITQ)	Drop
P	Holding receptacle in water	Drop
Q	Holding receptacle on land	Drop
R	Retained on board	Drop
T	Transferred to another vessel	Drop
NULL	Nothing	Drop

APPENDIX E. DOCUMENTATION FOR CRA 1 SEASONAL CPUE ANALYSIS WITHOUT VESSEL EFFECT

The data used in this analysis are described in the first two paragraphs in Section 3.1.1 and the methods followed are documented in Starr (2019). A [vessel] explanatory variable was not used in this model; the purpose of the analysis was to provide a set of FSU seasonal indices. The FSU data had been excluded from the analysis presented in Section 3.1 with the inclusion of the [vessel] explanatory variable.

Two explanatory variables were used for this analysis in addition to the sequential [period] variable: [month] of capture and [statistical_area] of capture. The seasonal analysis estimates separate relative [month] effects in each half-year period by using, as the reference [month], the [month] in each period with the lowest standard error.

Table E.1: Number of vessel/statistical area/month records in the dataset used to calculate the CRA 1 seasonal CPUE time series without including a vessel explanatory variable.

Fishing	Autumn-Winter						Spring-Summer					
Year	901	902	903	904	939	Total	901	902	903	904	939	Total
79/80	8	17	29	33	13	100	16	22	71	62	51	222
80/81	7	6	30	41	13	97	13	31	50	58	41	193
81/82	6	14	30	21	12	83	7	32	52	35	38	164
82/83	3	13	29	30	21	96	9	36	44	41	45	175
83/84	7	16	24	29	16	92	20	52	31	43	41	187
84/85	12	25	17	22	17	93	16	57	30	56	34	193
85/86	14	21	25	37	23	120	25	40	31	53	36	185
86/87	10	22	22	33	20	107	17	38	47	56	46	204
87/88	7	27	27	27	24	112	18	30	50	43	44	185
88/89	9	11	27	16	6	69	20	30	41	29	30	150
89/90	11	15	20	12	13	71	19	26	29	27	26	127
90/91	16	15	14	17	19	81	31	29	20	29	34	143
91/92	9	13	25	22	22	91	8	23	41	44	43	159
92/93	6	8	11	26	25	76	12	22	15	33	38	120
93/94	10	12	16	33	23	94	20	25	19	39	31	134
94/95	12	13	17	31	14	87	24	18	22	38	20	122
95/96	5	12	15	25	23	80	7	10	16	20	14	67
96/97	6	8	15	29	4	62	3	11	22	23	1	60
97/98	8	7	17	23	6	61	1	4	12	22	1	40
98/99	5	7	11	21	23	67	1	4	9	20	5	39
99/00	13	4	6	17	20	60	3	3	8	17	8	39
00/01	17	4	12	19	23	75	8	3	12	22	4	49
01/02	18	8	11	14	27	78	7	1	11	13	12	44
02/03	19	13	10	10	20	72	12	7	8	13	14	54
03/04	6	10	3	15	24	58	6	13	6	16	19	60
04/05	9	13	4	4	15	45	8	12	7	5	11	43
05/06	11	10	8	5	18	52	12	9	6	10	13	50
06/07	14	10	14	10	15	63	13	5	16	8	8	50
07/08	18	13	19	5	11	66	12	15	22	9	3	61
08/09	16	14	12	5	15	62	8	8	9	4	3	32
09/10	16	18	10	8	15	67	14	4	12	9	4	43
10/11	18	9	10	6	14	57	16	12	19	10	5	62
11/12	18	12	19	8	12	69	12	10	23	13	5	63
12/13	15	8	14	15	8	60	21	14	16	17	5	73
13/14	18	5	12	11	14	60	12	12	14	19	7	64
14/15	18	4	6	8	14	50	20	7	7	18	7	59
15/16	20	4	11	10	9	54	21	5	13	12	3	54
16/17	12	3	7	8	8	38	12	7	9	9	3	40
17/18	12	4	8	8	8	40	17	8	8	11	4	48
18/19	11	9	8	6	8	42	10	9	7	12	4	42
Total	470	457	625	720	635	2 907	531	704	885	1 018	761	3 899

Table E.2: Total deviance (R^2) explained by each variable in the CRA 1 standardised seasonal CPUE model without including a vessel explanatory variable. The number of categories in each explanatory variable is given in parentheses.

Variable	1	2	3
Period (76)	0.178		
Statistical Area (5)	0.295	0.419	
Month (12)	0.011	0.190	0.431
Additional deviance explained	0.000	0.241	0.012

Table E.3: Seasonal CPUE indices calculated from the analysis of CRA 1 catch and potlift data without including a vessel explanatory variable. Arithmetic index: sum(annual catch)/sum(potlifts); Unstandardised index: geometric mean of the CPUE observations by year; Standardised index: annual index. Coloured cells show the FSU indices used in the 2019 CRA 1 stock assessment.

	Autumn-Winter				Spring-Summer			
Fishing Year	Arithmetic Index	Unstandard-ised Index	Standard-ised Index	Standard Error	Arithmetic Index	Unstandard-ised Index	Standard-ised Index	Standard Error
79/80	0.667	0.774	0.838	0.0671	0.757	0.751	0.844	0.0473
80/81	0.922	0.804	0.993	0.0683	1.037	0.923	1.013	0.0501
81/82	0.891	0.747	0.790	0.0731	1.143	0.969	1.030	0.0539
82/83	0.805	0.779	0.903	0.0683	1.237	1.024	1.080	0.0524
83/84	0.926	0.822	0.884	0.0697	1.190	1.052	1.015	0.0508
84/85	0.879	0.890	0.857	0.0695	0.989	0.920	0.923	0.0503
85/86	0.776	0.694	0.741	0.0616	0.935	0.898	0.895	0.0511
86/87	0.667	0.711	0.750	0.0649	0.790	0.814	0.859	0.0489
87/88	0.581	0.586	0.613	0.0636	0.803	0.830	0.863	0.0510
88/89	0.569	0.607	0.656	0.0807	0.875	0.705	0.687	0.0562
89/90	0.594	0.558	0.535	0.0789	0.877	0.853	0.822	0.0605
90/91	0.625	0.554	0.518	0.0739	0.754	0.740	0.665	0.0572
91/92	0.511	0.559	0.592	0.0700	0.666	0.681	0.754	0.0547
92/93	0.408	0.459	0.531	0.0765	0.660	0.639	0.656	0.0620
93/94	0.448	0.472	0.526	0.0690	0.864	0.788	0.789	0.0588
94/95	0.618	0.652	0.715	0.0717	0.954	0.974	0.974	0.0614
95/96	0.825	0.873	1.013	0.0747	1.182	1.237	1.336	0.0809
96/97	0.753	0.719	0.904	0.0843	0.920	0.923	1.091	0.0857
97/98	0.862	0.762	0.901	0.0850	0.732	0.749	1.018	0.1040
98/99	0.930	0.816	0.962	0.0813	0.795	0.862	1.127	0.1052
99/00	0.966	0.825	0.851	0.0856	0.892	0.724	0.883	0.1051
00/01	1.172	0.927	0.949	0.0770	1.305	1.224	1.424	0.0940
01/02	1.260	1.108	1.064	0.0756	1.344	1.157	1.280	0.0991
02/03	1.200	1.199	1.042	0.0784	1.290	1.196	1.147	0.0897
03/04	1.035	0.863	0.880	0.0870	1.356	1.208	1.218	0.0854
04/05	1.374	1.324	1.149	0.0984	1.794	1.749	1.498	0.1004
05/06	1.313	1.272	1.136	0.0916	1.663	1.757	1.579	0.0932
06/07	1.204	1.453	1.379	0.0836	1.768	2.276	2.102	0.0933
07/08	1.391	1.654	1.450	0.0818	2.371	2.331	2.127	0.0848
08/09	1.465	1.597	1.368	0.0843	1.894	2.698	2.313	0.1156
09/10	1.623	1.687	1.445	0.0812	2.002	2.287	2.059	0.1002
10/11	1.293	1.396	1.176	0.0877	1.655	2.135	1.888	0.0843
11/12	1.255	1.474	1.328	0.0801	1.580	1.693	1.657	0.0836
12/13	1.409	1.729	1.665	0.0855	1.929	1.946	1.724	0.0779
13/14	1.263	1.368	1.276	0.0856	1.575	1.685	1.671	0.0828
14/15	1.331	1.511	1.297	0.0935	1.288	1.532	1.372	0.0863
15/16	1.263	1.326	1.205	0.0904	1.452	1.711	1.466	0.0902
16/17	1.240	1.273	1.157	0.1067	1.356	1.343	1.199	0.1040
17/18	1.263	1.396	1.309	0.1041	1.647	1.666	1.408	0.0954
18/19	1.732	1.492	1.317	0.1016	1.784	1.729	1.620	0.1015

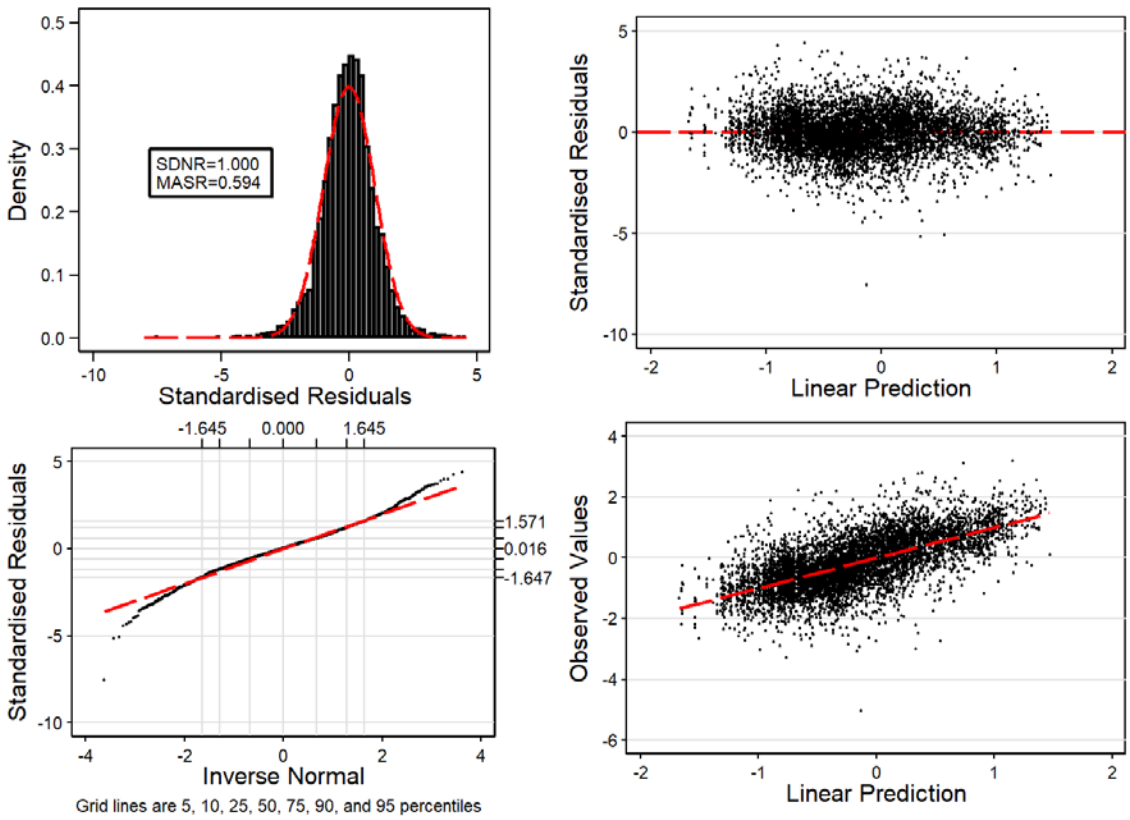


Figure E.1: Standardised residuals for the CRA 1 seasonal CPUE GLM analysis without the inclusion of a vessel explanatory variable.

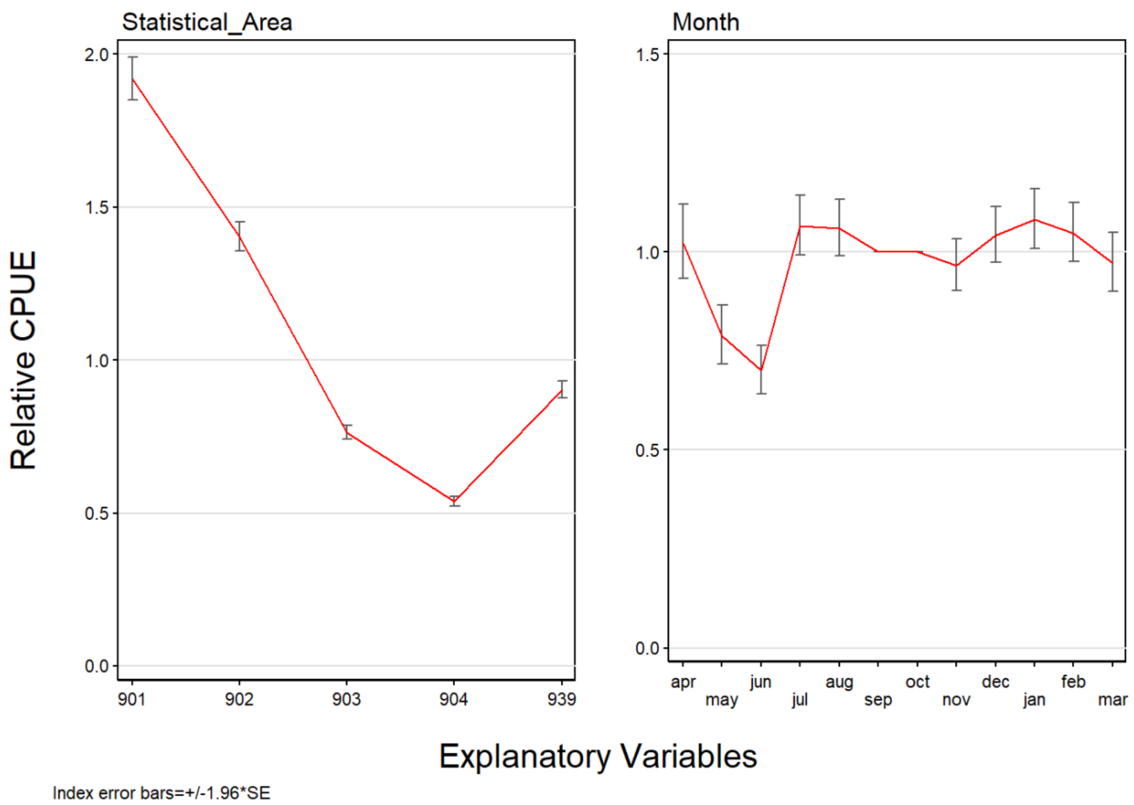


Figure E.2: Coefficients for month and statistical area from the CRA 1 seasonal CPUE standardisation without the inclusion of a vessel explanatory variable. Month coefficients are not in canonical form, with each of the two reference months (August and October) set to 1.0 and the associated SE set to zero.

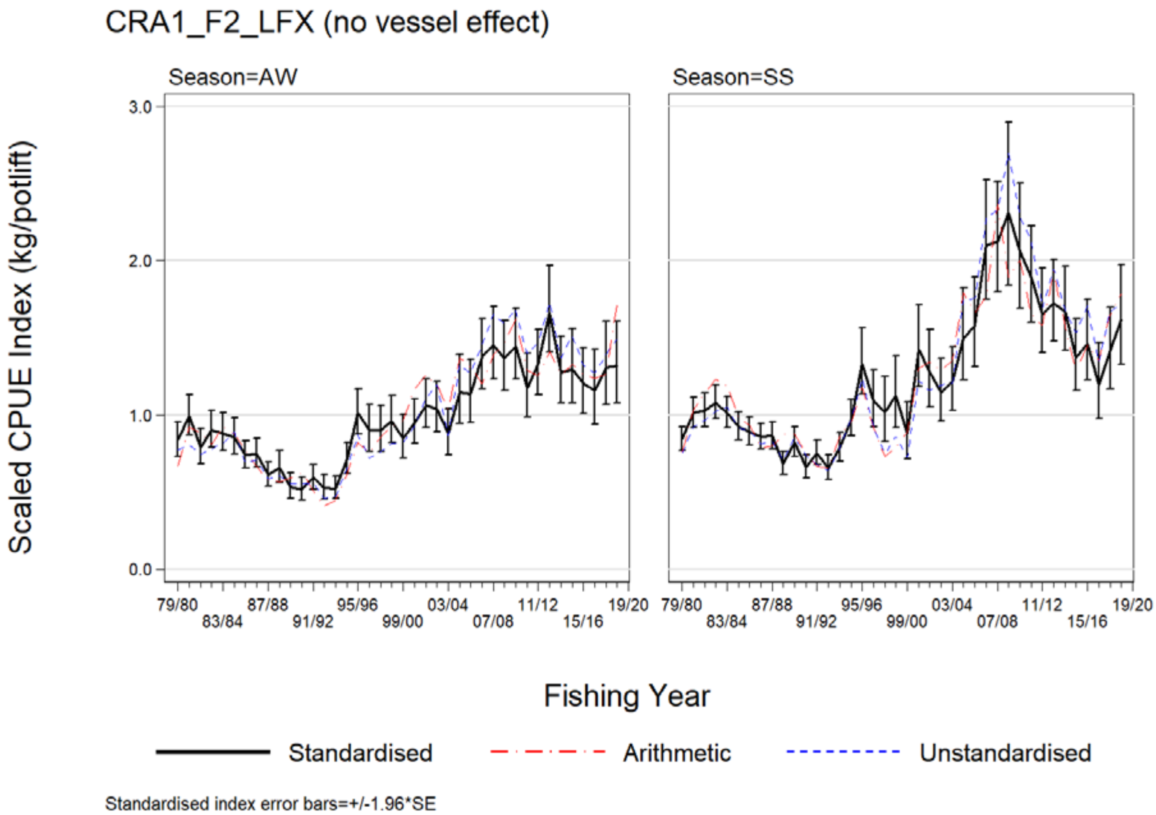


Figure E.3: Standardised, unstandardised (geometric mean), and arithmetic mean CPUE indices (kg/potlift) by season and fishing year for the CRA 1 CPUE analysis without including a vessel explanatory variable and using the F2 algorithm scaled to "LFX" landings from 1979–80 to 2018–19: AW ($^{g}\overline{\mu}$ =0.95 kg/potlift) and SS ($^{g}\overline{\mu}$ =1.18 kg/potlift).

APPENDIX F. LENGTH FREQUENCY DISTRIBUTIONS FROM LOGBOOK AND CATCH SAMPLING

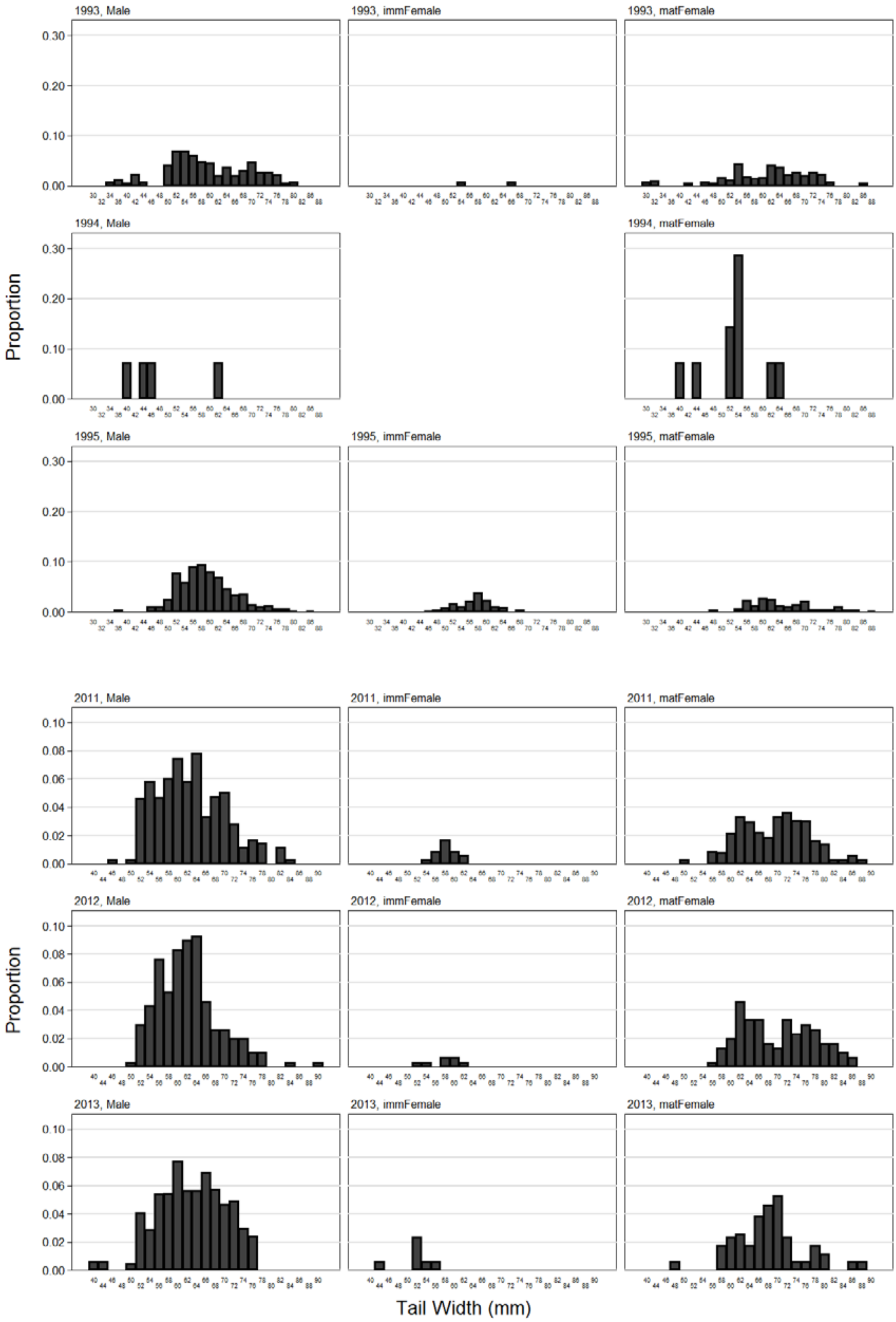


Figure F.1A: Length frequency histograms by sex category for AW logbook sampling for indicated years. Each year (row) sums to 1.0.

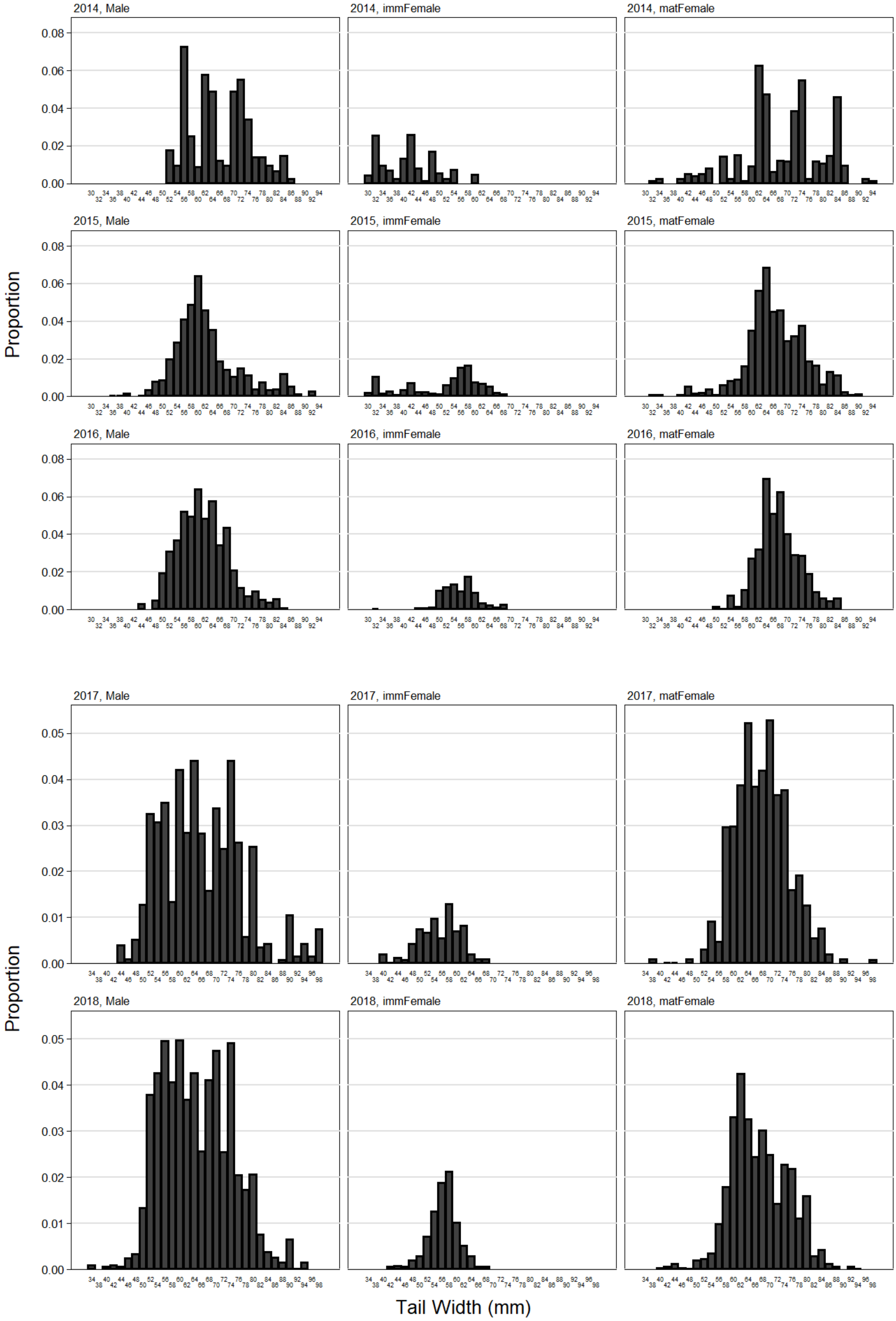


Figure F.1B: Length frequency histograms by sex category for AW logbook sampling for indicated years. Each year (row) sums to 1.0.

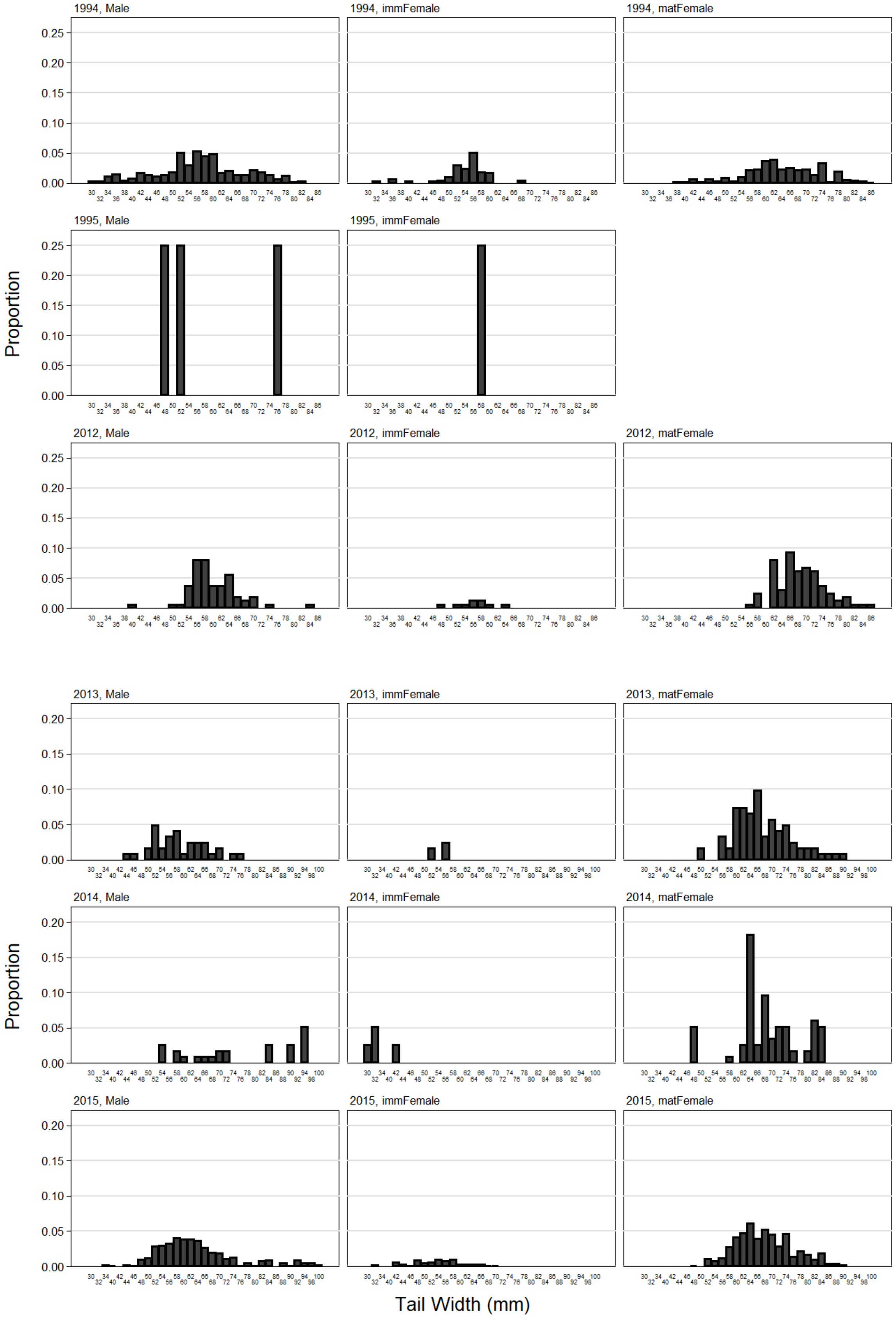


Figure F.2A: Length frequency histograms by sex category for SS logbook sampling for indicated years. Each year (row) sums to 1.0.

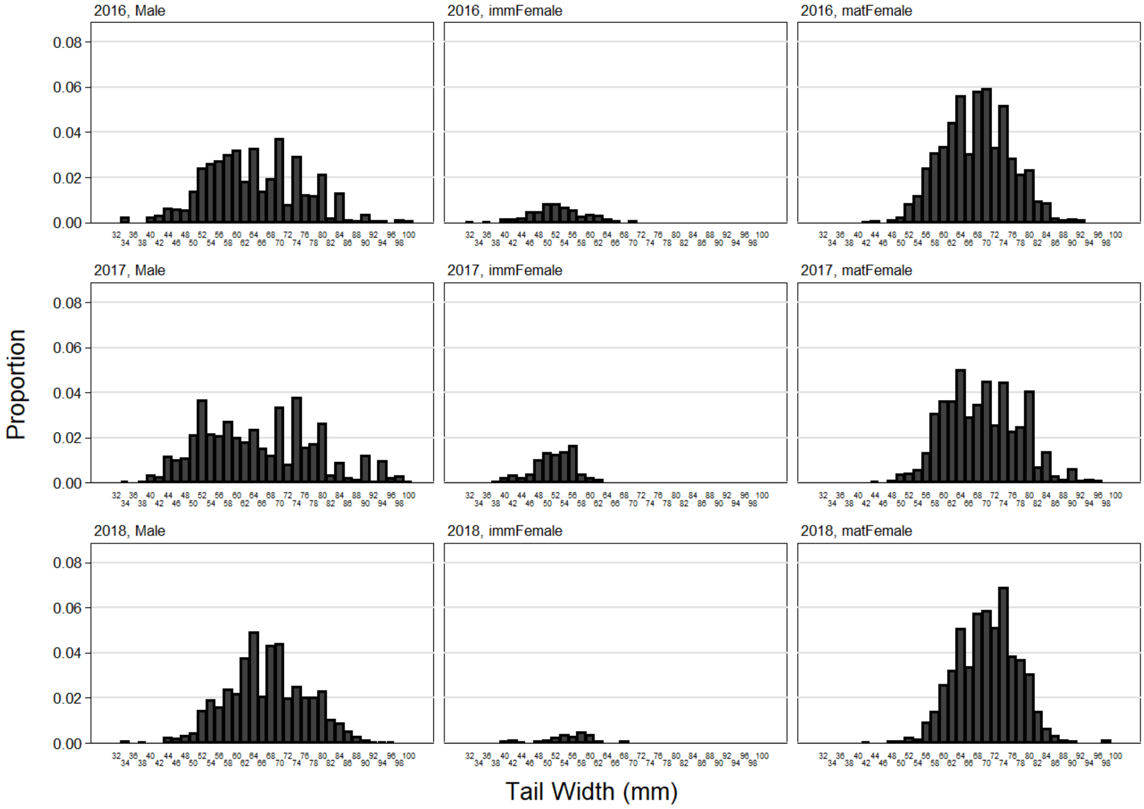


Figure F.2B: Length frequency histograms by sex category for SS logbook sampling for indicated years. Each year (row) sums to 1.0.

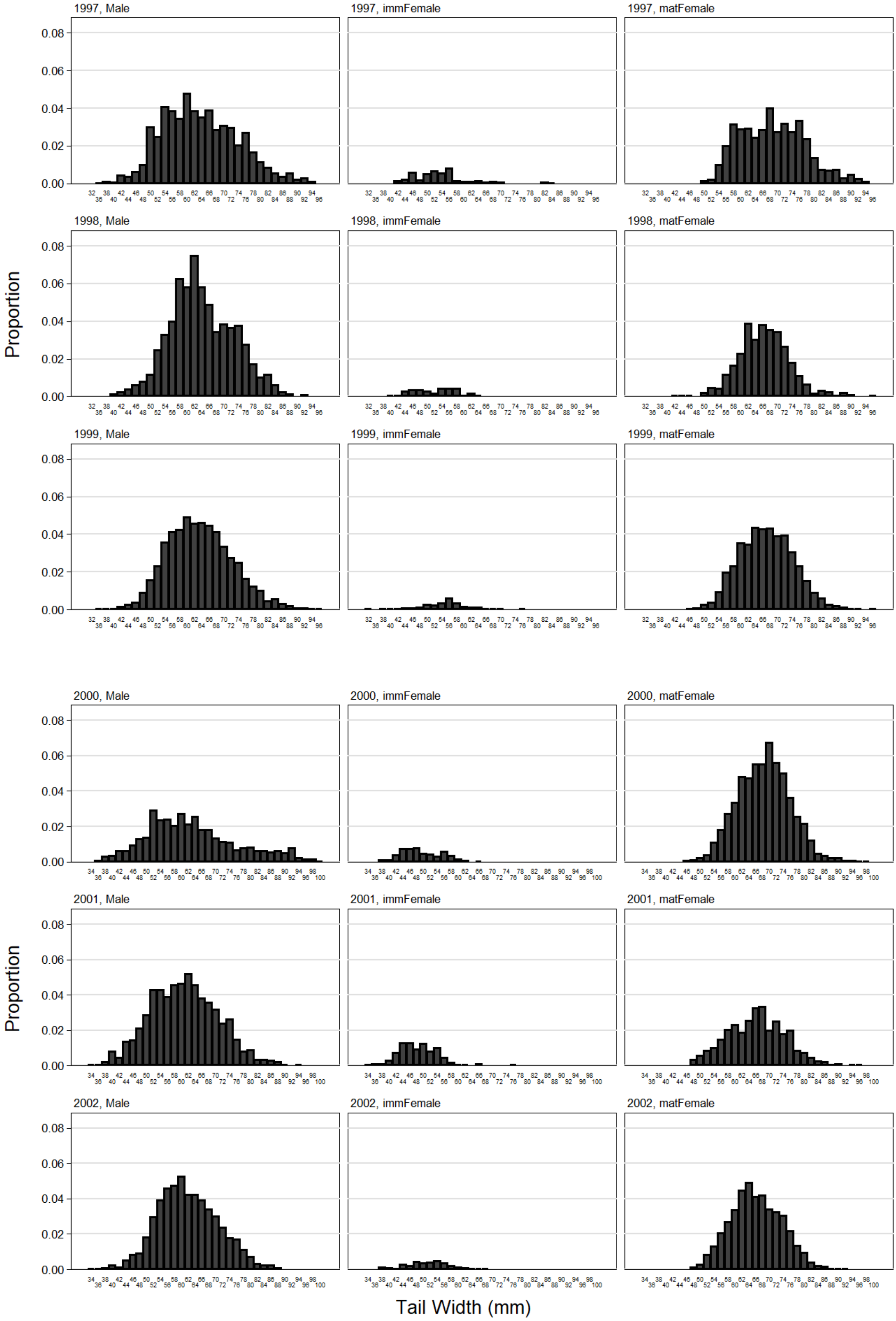


Figure F.3A: Length frequency histograms by sex category for AW observer catch sampling for indicated years. Each year (row) sums to 1.0.

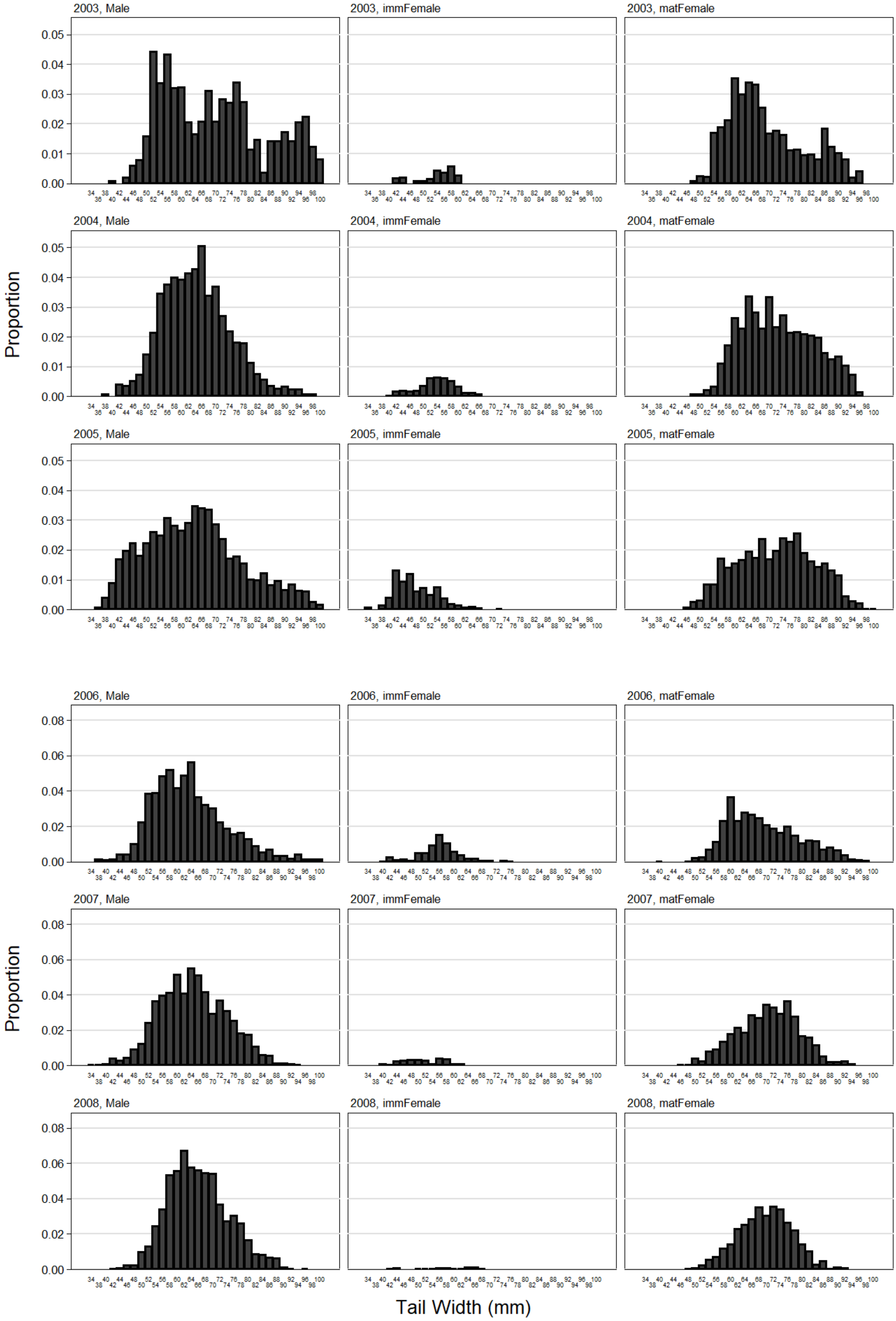
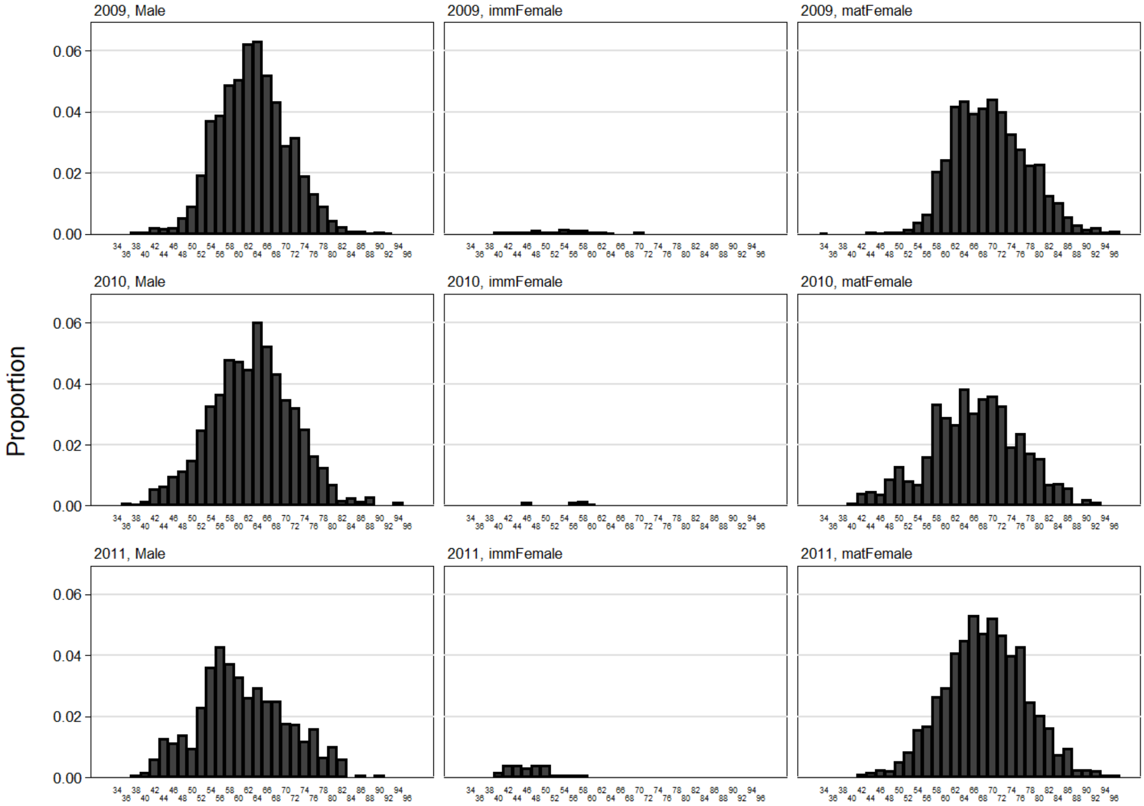


Figure F.3B: Length frequency histograms by sex category for AW observer catch sampling for indicated years. Each year (row) sums to 1.0.



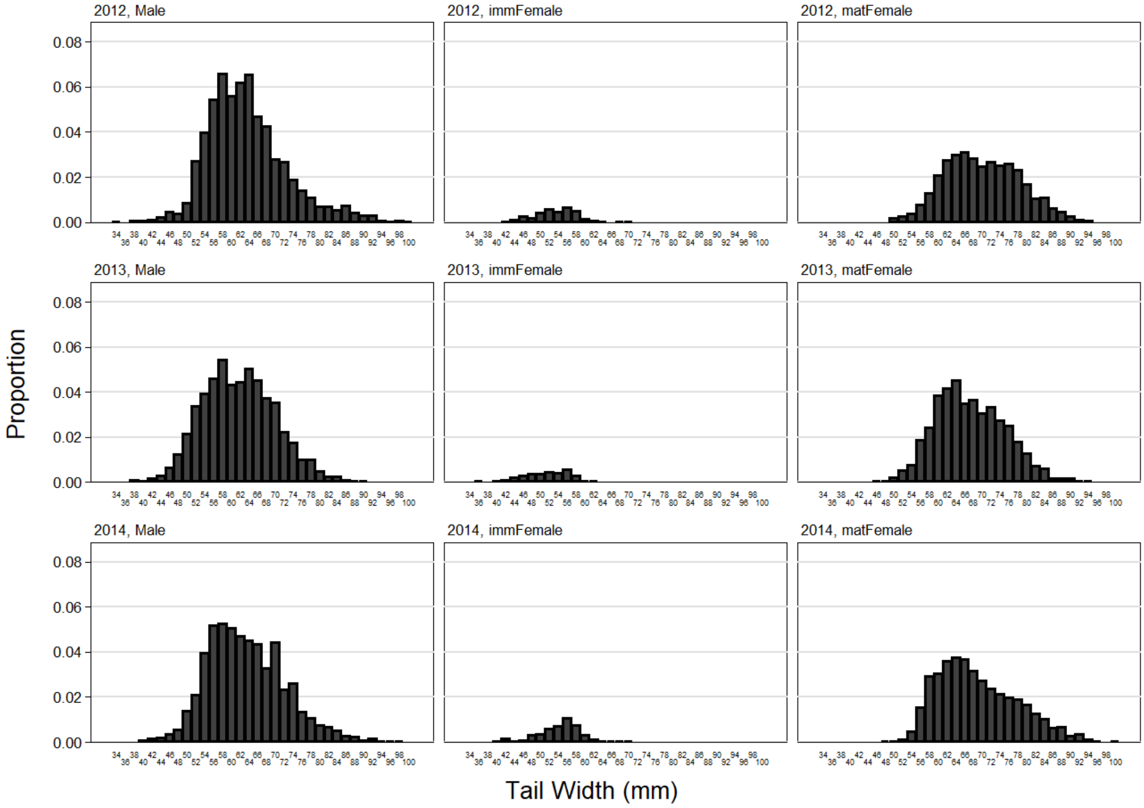


Figure F.3C: Length frequency histograms by sex category for AW observer catch sampling for indicated years. Each year (row) sums to 1.0.

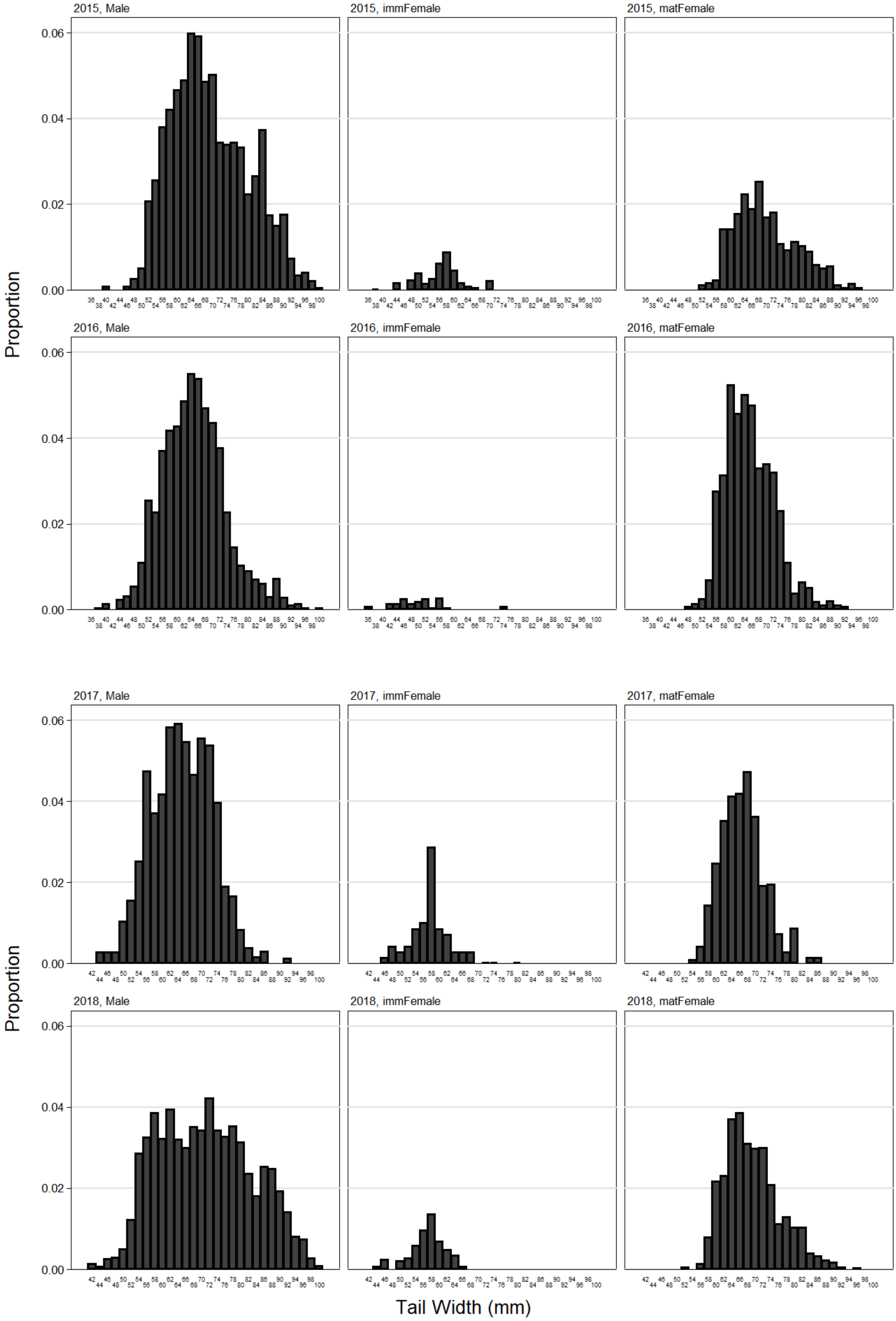


Figure F.3D: Length frequency histograms by sex category for AW observer catch sampling for indicated years. Each year (row) sums to 1.0.

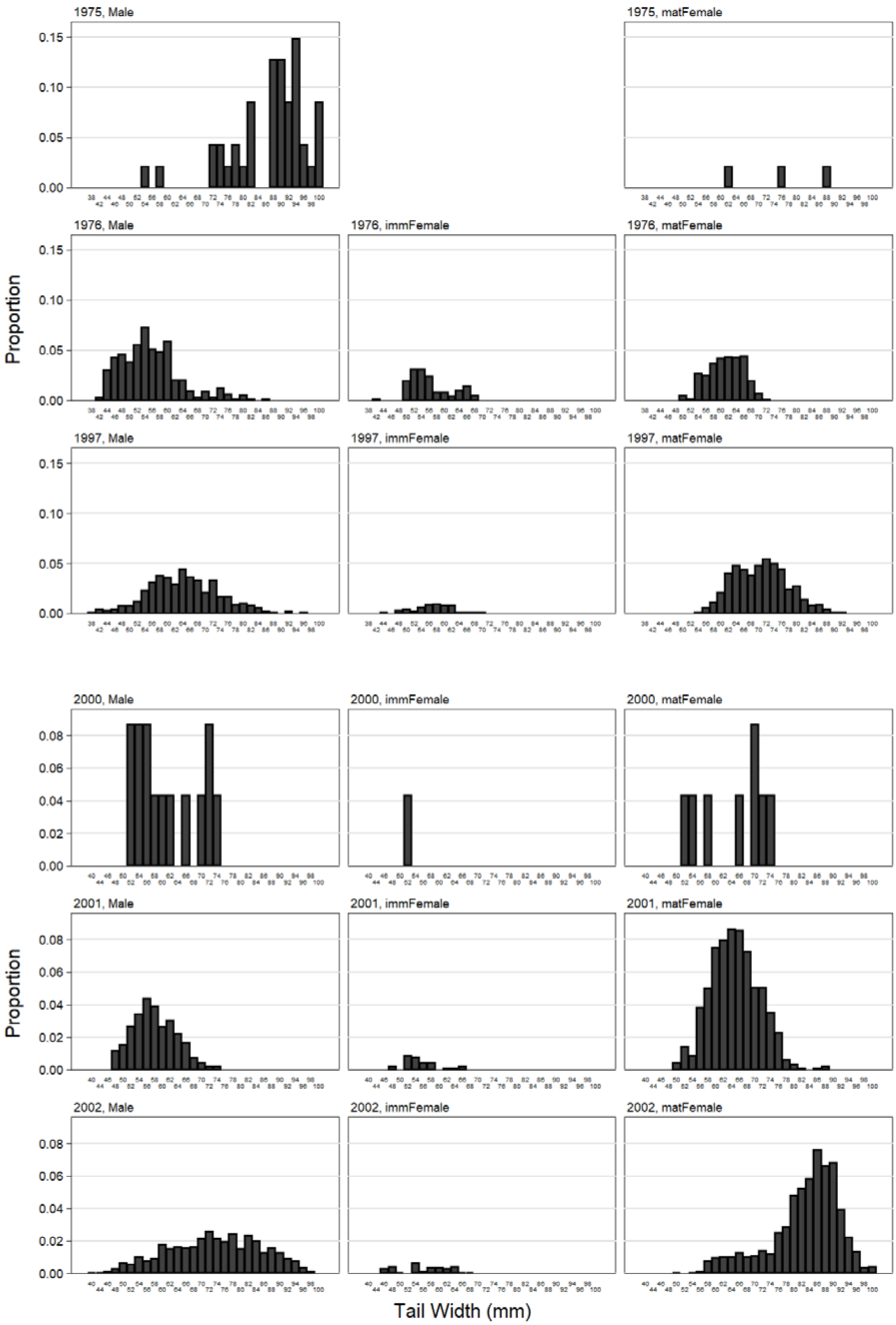


Figure F.4A: Length frequency histograms by sex category for SS observer catch sampling for indicated years. Each year (row) sums to 1.0.

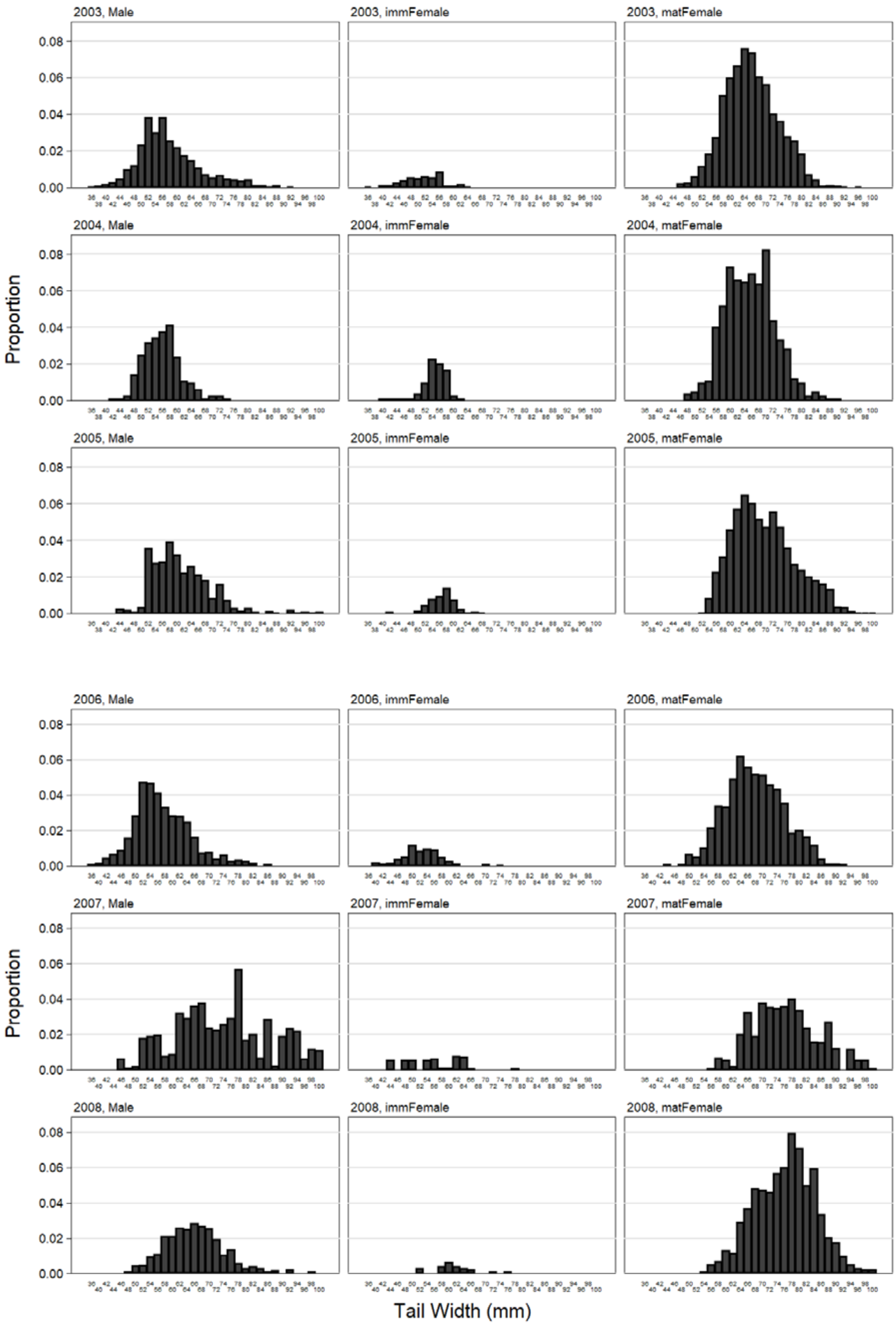


Figure F.4B: Length frequency histograms by sex category for SS observer catch sampling for indicated years. Each year (row) sums to 1.0.

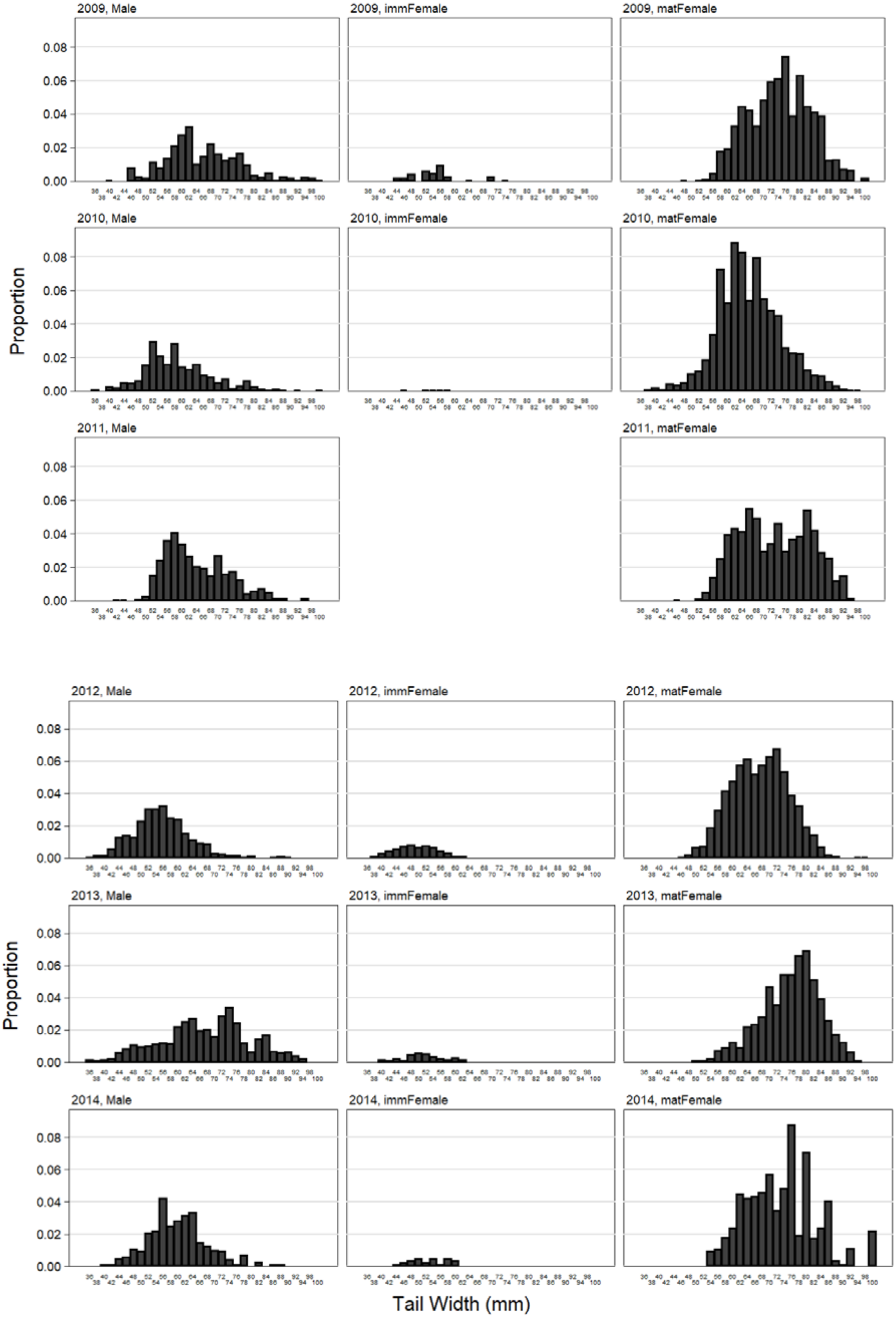


Figure F.4C: Length frequency histograms by sex category for SS observer catch sampling for indicated years. Each year (row) sums to 1.0.

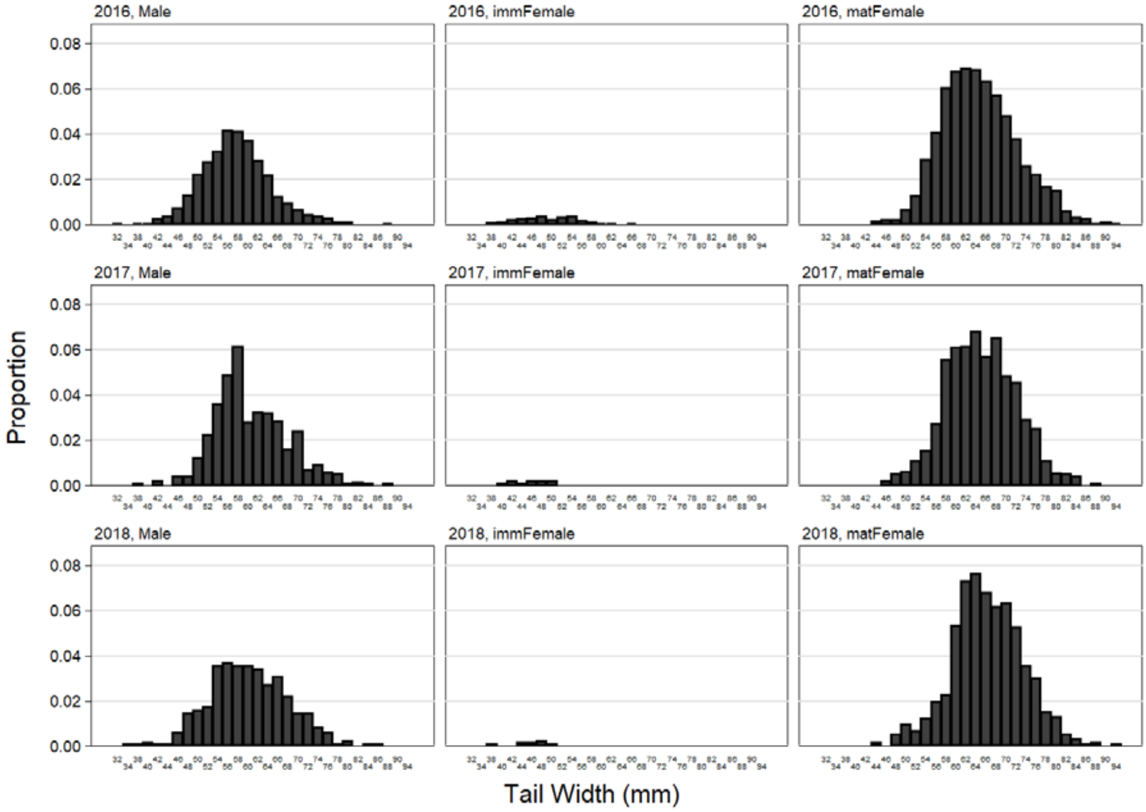


Figure F.4D: Length frequency histograms by sex category for SS observer catch sampling for indicated years. Each year (row) sums to 1.0.