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Tini a Tangaroa

# Data for the 2018 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 6

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## EXECUTIVE SUMMARY

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This document describes the data used in the 2018 CRA 6 stock assessment. Data sets described in this report include catch estimates for all sectors of the CRA 6 fishery, standardised CPUE indices, length frequency distributions, sex ratios, and tag-recapture data.

Catch estimates are provided for the commercial, recreational, customary and illegal fisheries by six-month season (spring-summer [SS] and autumn-winter [AW]), and by size-limited and non-size-limited fisheries, beginning at the start of the CRA 6 fishery in 1965. Recreational catch estimates were available from a 2008–09 Chatham Island recreational survey. Fixed estimates of 6 t/year for recreational catch and 4 t/year for customary catch were used. Illegal catch estimates using procedures (primarily fixed proportions applied to reported commercial catches) implemented for other CRA QMAs were problematic and seemed exceptionally large. Agreement in the Rock Lobster Working Group maintained the large illegal estimates but assumed that they were eventually exported from the Chathams as legal catch. Consequently, the large, early catch totals were not additionally inflated.

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 collected since 1989. The destination codes “X” (discarded at sea) and “F” (Section 111 recreational catches) were added to the destination code “L” (landed to an LFR) to obtain the final catch total for scaling the estimated catches. The CPUE standardisation procedure included a vessel explanatory variable for data beginning in 1989. Earlier data (1979–1988) were estimated separately and did not use a vessel explanatory variable. A new Bayesian procedure was used to estimate the post-1989 seasonal CPUE indices where the median series estimates were similar to the frequentist procedure applied in previous assessments but which estimated wider uncertainty for the series.

Length frequency data were available from both observer catch sampling and voluntary logbook programmes. A 1966 length frequency distribution was estimated from a published plot because the original contributing data could not be located. Length frequency data were collated by data source and by season, and the document describes how the individual records were weighted. A CRA 6-specific length-weight relationship was estimated from data collected in the mid-1990s.

There was only a small amount of available CRA 6 tag-recapture data which were inadequate to provide reliable growth rate estimates by sex. Tagging data from other CRA QMAs were investigated, resulting in the selection of Fiordland (CRA 8 statistical areas 926, 927 and 928) tagging data to augment the tagging data set. The Fiordland statistical areas were selected because they had similar size structure to that observed for CRA 6, and the growth increments were similar to those from the sparse CRA 6 tag-recapture data.

# 1. INTRODUCTION

This document describes work conducted to address Objectives 3 and 4 of the Ministry for Primary Industries (MPI) contract CRA2015-01C. This three-year contract, which began in April 2016, was awarded to New Zealand Rock Lobster Industry Council Ltd. (NZ RLIC Ltd.), who sub-contracted Objectives 3 and 4 to a stock assessment team.

*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.* (in part)

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

This document describes the data used in the 2018 CRA 6 stock assessment. CRA 6 comprises all of the Chatham Islands, including the two main islands (Chatham and Pitt) and most of the marine environment up to the 200 m depth contour (Figure 1). There are four rock lobster statistical areas (940, 941, 942 and 943) which roughly divide the Chatham Islands rock lobster habitat into four quadrants. Data sets described in this report include catch estimates for all sectors of the CRA 6 fishery, standardised CPUE indices, length frequency distributions, sex ratios, and tag-recapture data (Figure 2).

CRA 6 entered the QMS in 1990–91 with a TACC of 518 tonnes, which was reduced in three steps to 360 tonnes by 1998–99, where it remains. A TAC of 480 tonnes was established for the first time in 1997–98, but was promptly dropped to 370 t in the following year (1998–99) when the TACC was also dropped. The only allowance in the current TAC is 10 t for illegal fishing. There is no allowance in the current TAC for customary or recreational catches.

There has been little systematic rock lobster research in CRA 6. A handful of tags have been recovered from which to estimate growth, observer catch sampling was done in the early and mid-1990s, and a voluntary logbook programme has operated in this fishery since 2001 with variable participation by the commercial fleet.

# 2. CRA 6 CATCH DATA

## 2.1 Commercial catch

The number of vessels operating in CRA 6 has remained relatively constant (between 32–42) since the late 1990s, with 36 vessels counted in 2016–17 and 40 in 2017–18 (Starr 2018). CRA 6 catches are landed to Licensed Fish Receivers (LFRs) on Chatham Island. They are then transhipped by air to Christchurch, Wellington or Auckland, with the bulk of the lobsters ending up in the North Island.

The CRA 6 stock assessment model uses the rock lobster April-March statutory fishing year (Fisheries New Zealand 2018), spanning the years 1965–66 to 2017–18. Reported annual commercial catches from January 1965 to December 1973 are available on a monthly basis from data collected and summarised by Annala & King (1983). From 1 January 1979 through to 31 March 1986, catches were taken from monthly data collected by the Fisheries Statistics Unit (FSU: see Bentley et al. 2005), a version of which is now held by Fisheries New Zealand. Data from 1974 to 1978 are only available by calendar year (Annala & Esterman 1986). These data were converted to the April-March fishing year by dividing the catches from 1972 and 1973 (the last two complete years in the Annala & King data) and 1979 and 1980 (first two complete years in the FSU data) into three-month quarterly periods and applying the four-year average quarterly proportions to the Annala & Esterman catches. Once the Annala & Esterman catches were divided into quarterly periods using these average proportions, the first quarter in each year was added to the final three quarters of the preceding year to become the fishing year catch.

From 1 April 1986 through to 30 March 1988, monthly reported catch totals from all of New Zealand were obtained from Quota Management Returns (QMRs), without the corresponding separation into QMAs. 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 the FSU forms for the same periods. From 1 April 1988 through to 30 September 2001, catches by QMA were summarised from monthly QMRs. The QMRs were replaced by Monthly Harvest Returns (MHRs) on 1 October 2001, but the same information is available from these new forms.

Commercial catches in CRA 6 were characterised by very large catches during the early phases of the fishery, with several hundred vessels participating in these early years and with a catch of 17 000 tonnes reported to have been taken in the five year period from 1966 to 1970 (Figure 3). The first two years of this fishery were contemporaneously documented in an early publication by Kensler (1969), who reported:

> *In the first year of fishing 2,177,923 lb of spiny lobsters were caught, and in the second 7,129,658 lb — a 227% increase. Fishing effort also increased substantially: average number of boats fishing each month rose by 174% in the second year, and the total number of boat-fishing days by 152%. Most specimens of J.edwardsii caught are large and mature, typical of a virgin stock.*

The existence of this early publication, along with interviews with fishers who participated in this early fishery, gave confidence to the stock assessment team that the timing and extent of this early fishery were adequately documented. Catches have averaged around 340 t/year since CRA 6 entered the QMS in 1990, ranging from a low of 290 t in 2003 to a high of 388 t in 1991 (Figure 4). Commercial catches in CRA 6 have generally closely matched the TACC since the mid-2000s.

There has been increased use of destination codes that report intermediate holding of catch in many of the CRA QMAs (see Table A.1), 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 2018 for a discussion of this problem). The landing information was examined to see the extent of this practice in CRA 6, which appears to rely heavily on intermediate holding pots (destination code “P”, see Figure A.1). However, little use is made of Destination “X” (discarding of legal lobsters) in CRA 6 (Figure A.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.

Whilst 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. However, the early catch history of CRA 6 documented in the work of Annala & King (1983), was corroborated by interviews with participants in the early fishery by the stock assessment team and a literature search.

## 2.2 Recreational catch

Davey et al. (2011) conducted a Chatham Islands recreational harvest survey in the late 2000s. This survey included 79 diarists, representing local residents and tourists, who recorded their recreational catches from 1 October 2008 to 30 September 2009. The primary species taken by both sectors were blue cod, hapuku, rock lobster and paua, with blue cod having the greatest estimated catch of around 15 t, followed by 9 t of hapuku, 4 t of paua, and 3 t of rock lobster. The latter two species were mainly taken by local residents while the two finfish species were targeted by both tourists and local residents.

There were no CRA 6 recreational fishery catch estimates from the large scale population-based diary/interview survey conducted under contract for MPI from 1 October 2011–30 September 2012 (Wynne-Jones et al. 2014) because the Chatham Islands were not included in the survey design.

The RLFAWG agreed to include a constant 5 t/year of recreational catch in the catch history. An additional 1.03 t of recreational catch was added to represent the Section111 catches in this QMA.

## 2.3 Customary catch

The RLFAWG agreed to use a constant 4 t/year which is the value currently used by Fisheries New Zealand to represent this fishery in CRA 6.

## 2.4 Illegal catch

CRA 6 illegal catches from 1990 to 2001 (Figure 5) were based on estimates provided by the compliance sections within the New Zealand fisheries ministry operative at the time (e.g., Ministry of Agriculture and Fisheries, Ministry of Fisheries) with values of 85 t in 1990, dropping to 70 t in 1992 and ending at 10 t in 2001 (Table 1). Illegal catch was set at a constant 10 t/year from 2001, where it remains. Years before 2001 without estimated illegal catches were filled by interpolation.

CRA 6 illegal catch estimates before 1990 (Figure 5) were derived from unpublished estimates of discrepancies between reported catch totals and total exported weight that were developed for the period 1974 to 1980 (McKoy, pers. comm.). For years before 1972–73 and from 1981–82 to 1989–90, illegal catch was estimated by multiplying the average 1974–1980 discrepancy ratio by QMA with the reported catch in each QMA.

Compliance estimates of illegal catch are often provided in two categories ("reported" or "R" and "not reported" or "NR"). Previously, the RLFAWG agreed to treat CRA 6 illegal estimates, beginning in 1990, as if they were in the "R" category. This implied that these catches were eventually landed legally and had to be subtracted from the legal landings to avoid double counting. The reasoning behind this decision was that it would be difficult to export large amounts of illegal lobsters from a small community with limited transport options without others being aware. When this decision was reviewed for the 2018 CRA 6 stock assessment, it was agreed that the original reasoning was sound, but that it was incongruous to simultaneously treat the pre-1990 catches as "unreported" (or "NR"), which would then be added to the overall catch history. By agreement, the CRA 6 illegal catches were treated in the following manner:

1. From 2001 onwards, the estimate for CRA 6 illegal catch has been 10 t/year (Table 1). This implies a nominal amount of 250 kg of "unreported" illegal catch per operating vessel in a year, given that there were 40 vessels operating in CRA 6 in 2017–18 (Starr 2018). Estimates of vessel numbers are available in the FSU and CELR data from 1979 to 2017 as well as from 1965 to 1974 (the latter estimates are undocumented). The estimated "unreported illegal" (NR) catches for every year were determined by multiplying the annual number of vessels by the nominal value of 250 kg per vessel-year. Vessel numbers for 1975–1978, which have no estimates, were obtained by interpolating between the 1974 and 1979 values.
2. The "reported illegal" (R) catches by year were obtained by subtracting the "unreported illegal" (NR) catches, calculated from vessel numbers, from the total annual illegal catch estimates.

## 2.5 Size-limited and non-size-limited catch

The size-limited (SL) catch is catch taken under the MLS regulations and the restriction on landing berried females; it is the sum of the commercial and recreational catches minus the reported illegal catches (Figure 6). 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 based on the seasonal proportions in the Annala & King, FSU and QMR/MHR data (Table 2).

## 2.6 Seasonal proportion of catch

Annual commercial catches were divided into two seasons in each fishing year, with the AW season comprising the months April–September and the SS season including October–March (Figure 7). This level of summarisation is easily achieved for the Annala & King, FSU and the QMR/MHR catches which are all available on a monthly basis. The estimated quarterly division of the Annala & Esterman catches described above (see Section 2.1) were made into seasonal catch by adding the first quarter to the previous fourth quarter to form the SS season for the previous fishing year and combining the second and third quarters to form the AW season for each fishing year. Illegal catches were divided using the commercial proportions, including using the estimated quarterly proportions from 1974 to 1978. The CRA 6 recreational and customary catches were split by assuming that 90% of each catch category was taken in SS with the remaining 10% taken in the AW.

## 3. CATCH RATE INFORMATION

### 3.1 Seasonal standardised CPUE indices

#### 3.1.1 Introduction and Methods

Catch and effort data from the CELR systems were obtained from Fisheries New Zealand in September 2018 (Replog 11984) and processed using standard error checks (Bentley et al. 2005). Data spanned the period from 1 July 1989 through to 31 March 2018. 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 2018). The F2 algorithm scales the monthly estimated catch taken by a vessel in a statistical area using a "vessel correction factor" (*vcf*: the ratio of landed catch to estimated catch for one vessel in one year) (Starr 2018), and discards from the analysis those vessels with *vcf* less than 0.8 or greater than 1.2. 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 defined in Appendix A; number of records in the CPUE data set provided in Table 3).

The 2018 stock assessment included two standardised CPUE series calculated from generalised linear model (GLM) analyses that used sequential six-month periods as forced explanatory variables (see section 2.5 in Starr (2018) 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. Two explanatory variables were available for both analyses in addition to the sequential [`period`] variable: [`month`] of capture and [`statistical_area`] of capture. The CELR model additionally used a [`vessel`] explanatory variable, filtered for vessels with at least five years' experience in the fishery. The FSU seasonal analysis estimated 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. The CELR GLM model estimated [`month`] as a nested variable within each seasonal [`period`]. The variable [`vessel`] is not used in the FSU analysis because the vessel codes in the earlier data base are not consistent with those used in the current Fisheries New Zealand Warehou database and the FSU series is part of a longer analysis which also included the CELR data (see Appendix B: the FSU indices extracted from this analysis for use in the 2018 stock assessment are provided in Table B.3). There is a discontinuity between the two series, with the FSU series ending with the 1 October 1988–31 March 1989 sequential period while the 1 April 1989–30 September 1989 series can only start on 1 July 1989 when the CELR Warehou data begin (Bentley et al. 2005).

Bayesian inference, coded using the Stan language, was used to estimate parameter uncertainty in the CELR GLM. Stan uses gradient-based Markov chain Monte Carlo (MCMC), specifically the Hamiltonian Monte Carlo (HMC) algorithm, for Bayesian inference. A total of 1000 samples from the posterior distribution were obtained by combining samples across two chains, with each chain consisting of a burn-in period of 1000 discarded samples and then extracting 500 samples from the remaining 1000 samples by discarding every second sample.

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

**Eq. 1**

$$\log\left(\frac{C_i}{E_i}\right) = \mathrm{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon_i}$$
$$= \boldsymbol{\beta_0} + \mathbf{T}\boldsymbol{\beta_t} + \boldsymbol{\varepsilon_i}$$
$$\boldsymbol{\varepsilon}_\mathbf{i} \sim \boldsymbol{N}(\mathbf{0}, \boldsymbol{\sigma}^\mathbf{2})$$
$$\boldsymbol{\sigma} \sim \mathbf{Cauchy}(\mathbf{0}, \mathbf{25})$$
$$\boldsymbol{\beta_t} \sim \mathbf{N}(\mathbf{0}, \mathbf{10})$$

and where $C_i$ is catch (tonnes) for record *i*, $E_i$ is effort (potlifts) 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 ***t*** = (1, 2, 3, …, n), then ***t*** = (AW, SS, AW, …, SS), where SS = October to March.

The status quo model is the same as that used in previous CPUE analyses for New Zealand rock lobster fisheries (Starr 2018) and included main effects for time period *t*, month *m*, statistical area *a*, and vessel *v*,

**Eq. 2**

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

where,

$$\sum_t \beta_t = 0, \quad \sum_{m \in t=\mathrm{AW}} \beta_m = 0, \quad \sum_{m \in t=\mathrm{SS}} \beta_m = 0, \quad \sum_a \beta_a = 0, \quad \sum_v \beta_v = 0$$
$$\boldsymbol{\varepsilon}_\mathbf{i} \sim \boldsymbol{N}(\mathbf{0}, \boldsymbol{\sigma}^\mathbf{2})$$
$$\boldsymbol{\sigma} \sim \mathbf{Cauchy}(\mathbf{0}, \mathbf{25})$$
$$\boldsymbol{\beta_t} \sim \mathbf{N}(\mathbf{0}, \mathbf{10})$$
$$\boldsymbol{\beta_m} \sim \mathbf{N}(\mathbf{0}, \mathbf{10})$$
$$\boldsymbol{\beta_a} \sim \mathbf{N}(\mathbf{0}, \mathbf{10})$$
$$\boldsymbol{\beta_v} \sim \mathbf{N}(\mathbf{0}, \mathbf{10})$$

The interaction model includes main effects for time period *t*, month *m*, and vessel *v*, and a time period+statistical area interaction term *a*,*t* as a random effect,

**Eq. 3**

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

where,

$$\sum_t \beta_t = 0, \quad \sum_{m \in t=\mathrm{AW}} \beta_m = 0, \quad \sum_{m \in t=\mathrm{SS}} \beta_m = 0, \quad \sum_v \beta_v = 0, \quad \sum_{a,t} \beta_{a,t} = 0$$

$$\boldsymbol{\varepsilon}_\mathbf{i} \sim \boldsymbol{N}(\mathbf{0}, \boldsymbol{\sigma}^\mathbf{2})$$
$$\boldsymbol{\sigma} \sim \mathbf{Cauchy}(\mathbf{0}, \mathbf{25})$$
$$\boldsymbol{\beta_t} \sim \mathbf{N}(\mathbf{0}, \mathbf{10})$$
$$\boldsymbol{\beta_m} \sim \mathbf{N}(\mathbf{0}, \mathbf{10})$$
$$\boldsymbol{\beta_a} \sim \mathbf{N}(\mathbf{0}, \mathbf{10})$$
$$\boldsymbol{\beta_{a,t}} \sim \mathbf{N}\left(\mathbf{0}, \boldsymbol{\sigma}^\mathbf{2}_{\boldsymbol{\beta}_{a,t}}\right)$$
$$\boldsymbol{\sigma}_{\boldsymbol{\beta}_{a,t}} \sim \mathbf{N}(\mathbf{0}, \mathbf{1})$$

### 3.1.2 CRA 6 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 for each MCMC sample between models. The calculated leave-one-out information criterion (LOOIC) indicates the best fit (lowest LOOIC value) for the interaction model at 13 009 compared to 13 367 for the status quo model and 15 880 for the null model (Table 4). 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 marginal posterior samples 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 are all less than 0, except for the first month (April) (Figure 11). The CRA 6 commercial fishery is closed in April and the small amount of data in that month is likely to be due to contamination from adjacent months.

There is an overall increasing trend from the mid-1990s in both the AW and SS series (Table 5, Figure 12). Catch rates are generally higher in the SS series compared to those in the AW, an observation made in all CRA QMAs because ovigerous females cannot be taken legally during the AW months. The 2017 AW CPUE is the highest catch rate in the AW series while the 2018 SS CPUE is the highest in the SS series.

Comparing the median values from the Bayesian CPUE model, including interaction effects, with a comparable frequentist GLM (including a [`vessel`] explanatory variable), using the same data set but having no interaction term or random effects, shows little difference in the overall estimated series trend in either season (Figure 13). The greater difference between the two models comes with estimated standard error, with the Bayesian model estimating nearly twice the error in the AW season (Figure 14 [left panel]). The SS season standard error estimates by the two models were similar, with the Bayesian estimates being slightly greater than those from the frequentist model (Figure 14 [right panel]).

### 3.1.3 CRA 6 FSU/CELR seasonal standardised series

The frequentist seasonal model (Appendix B) fitted to the FSU/CELR data set without using a [`vessel`] explanatory variable (see Eq. 3 in Starr 2018) explains 27% of the model deviance (Table B.2). Standardised model residuals show good conformity with the underlying lognormal distribution assumption (Figure B.1). There is little contrast in the [`month`] coefficients and the contrast in the [`statistical_area`] coefficients, while greater than for [`month`], is still relatively small (Figure B.2). Only the first ten seasonal indices were included in the CRA 6 stock assessment (coloured cells: Table B.3).

## 3.2 Historical Annala & King seasonal catch rates

Monthly catch and effort (days fishing) data from 1963–1973 were summarised by Annala & King (1983) and can be used to calculate unstandardised catch per day for each season within a fishing year from 1964 (SS only) to 1973 (SS catch rate is only for October-December 1973) (Figure 15).

## 4. LENGTH FREQUENCY DISTRIBUTIONS (LFs)

### 4.1 Methods

Data were extracted for CRA 6 in August and September 2018, comprising observer catch sampling (CS) from 1982–83 to 1996–97 (`rlcs` database: replog 11951) and voluntary logbook (LB) catch sampling from the 2001–02 to 2017–18 fishing years (John Olver, Fishserve). 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 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 has been achieved sporadically in CRA 6, with a high rate of participation in the voluntary logbook programme in a few years in the mid-2000s (Table 6). Observer catch sampling in CRA 6 has been minimal, with only a few target programmes executed during summer months in the early and mid-1990s (Table 6). Observer sampling measures and sexes all lobsters in as many pots as feasible during a day's fishing for the vessel being observed.

Record fields included the following information. Note that the "plus" length bin has been extended to 120 mm tail width (from 90 mm) due to the comparatively large size of CRA 6 lobsters:

- 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,
- 46 fields, representing the relative proportion (see below) of males measured by sex class within the size classes {[30, 32), [32, 34), …, [118, 120), [120, ∞)} mm tail width (TW),
- 46 fields for immature female numbers measured, and
- 46 fields for mature female numbers measured.

### 4.2 Weighting

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

**Eq. 4** $$\boldsymbol{p_{g,ma,s} = \frac{N_{g,m,a,s}}{\sum_s N_{g,m,as}}}$$

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. 5** $$\boldsymbol{P_{g,s} = \frac{\sum_m \sum_a (C_{m,a} p_{g,m,a,s})}{\sum_m \sum_a \sum_s (C_{m,a} p_{g,m,a,s})}}$$

where $P_s^g$ was the relative proportion-at-length for each sex in the record. The model re-normalised these to sum to 1 across each sex. A relative weight, or effective sample size, for each sex ($w_s$) was assigned to each data record within the LF 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. 6** $$w_s = \sum_m \sum_a \frac{c_{m,a} \sqrt[3]{N_{m,a,s}} \sqrt[3]{D_{m,a}}}{\sum_m \sum_a c_{m,a}}$$

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 receive the same weight (across all three sex categories) and the size class with few or no measured individuals would be up-weighted, thus placing more emphasis on that multivariate distribution.

### 4.3 Data

The CRA 6 LF data comprised 38 seasonal records from 1989–2017, with 31 from logbooks and seven from observer catch sampling. The individual logbook records comprised from 50 to 1 167 measured lobsters in the AW season and 122 to 2 085 measured lobsters in the SS season while the observer records comprised from 462 to 4 373 measured lobsters in AW season and 648 to 3 178 measured lobsters in the SS season (Table 7). All samples were included in the stock assessments, regardless of measured sample size. The logbook sampling record weights by sex category (Eq. 6) ranged from 0.004 to 6.024 while the observer catch sampling record weights ranged from 0.023 to 4.854 (Table 8). Most of the low weights corresponded to samples with few observed immature females, giving an appropriate low weight to the poorly represented sex category.

### 4.4 Sex ratios and mean length

Sex proportions were calculated from normalised data records (Figure 16; Table 9). There were very few immature females, 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 are reasonably consistent, although the sampling periods do not overlap.

Mean length was also calculated from the data records (Figure 17, Table 10). Figure 17 suggests that there may be a declining trend in mean length for males and mature females in both seasons.

Although the model contains size bins in the range 30–120 mm TW, few fish as small as 30 mm were measured and very few large fish were measured, especially for immature females, leading to many cells with zero observations (Figure 18). For sex/size bins with few observations, the model would be comparing many zero observations with 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, a practice known as tail compression. Table 11 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 **C**.1), SS logbook sampling (Figure **C**.2), AW observer catch sampling (Figure **C**.3) and SS observer catch sampling (Figure **C**.4).

## 4.5 1966 length frequency sample

Kensler (1969) described a sample distribution of rock lobster taken by potting in the Chatham Islands during October 1966; however, the contributing data for this sample were not available in the rock lobster data base. According to Kensler (1969), the sample comprised 1339 females with carapace lengths (CL) ranging from 8.0 to 18.0 cm and 1152 males ranging from 8.5 cm to 22.5 cm. Unfortunately, further details about this sample were not available, including sampling location, number of contributing pots and number of contributing vessels.

A LF distribution was constructed from the Kensler (1969) plot by estimating the number of lobsters in each 5 mm CL bin (Figure 19). This was done by measuring the height of each bin and calculating the number of individuals per mm on the graph based on the total numbers in the sample. The numbers per 5 mm CL bin are given in Table 12. Conversion of CL to TW was based on the formula given by Breen & Kendrick (table 5, 1995):

**Eq. 7** males: TW = 11.08 + 0.45825 (CL) for males

females: TW = 1.37 + 0.63738 (CL) for females

Length frequencies by TW bin were generated by converting the mid-points of the CL bins (e.g. 8.0, 8.5, etc.) to TW (Eq. 7) (Table 12) and then accumulating the TW observations into the 2 mm bins used in the stock assessment. This resulted in a substantial number of "0" observations (Table 13, Figure 20) which could potentially misinform the stock assessment model.

Two additional approaches were investigated to smooth the binned TW observations. In one approach, additional CL length bins were created mid-way between those presented in the Kensler document (e.g. 8.25, 8.75). These bins then received 25% of the individuals from each of their neighbouring bins, and the numbers in the original bins were reduced by 50%. These 2.5 mm CL bins were then converted to 2 mm TW bins as described for the original approach. Although much smoother than the original 2 mm TW bin length frequencies, there is still considerable jaggedness in these binned TW observations (Table 13, Figure 20).

The final approach for generating binned TW length frequencies was to smooth the original binned data that were generated from the 5 mm CL bins. This "smoothed" frequency distribution was achieved by taking for each bin 50% of the original numbers plus 25% from each of its neighbouring bins. This approach resulted in somewhat smoother binned length frequency data for use in the stock assessment (Table 13, Figure 20).

## 4.6 CRA 6 length-weight function

Breen & Kendrick (1997) provide parameters for a CRA 6 length-weight model based on catch sample data collected in 1996 and 1997 from on-board catch sampling. Although the figures and tables associated with this work were not available, we were able to obtain the paired length-weight data from the `rlcs` database. When we fitted the same model to these data (351 male and 161 female lobsters), the parameter estimates were nearly the same (Table 14), with good model fit to the data and no discernible pattern to the residuals (Figure 21). Details of the sampling procedure followed were not available, so it was not possible to judge how many pot lift samples contributed to the 512 total lobsters nor how representative was the sampling.

The length-weight model in Breen & Kendrick (1997) was adopted in the base case CRA 6 stock assessment model. A comparison of the estimated Chatham Islands length-weight relationship with the alternative South Island length-weight relationship shows a mixed response, with CRA 6 males generally heavier for the same length while the females are lighter at length (Figure 22).

## 5. TAG DATA

This section describes tag-recapture data that were used to inform growth in the stock assessment of rock lobster stocks (Haist et al. 2009). These data will also be useful for informing decisions about stock structure and movement. Tag data for all CRA areas were extracted in September 2018 (replog 11952).

### 5.1 Data processing

Before the tag data were summarised to inform growth in stock assessments, they were pre-processed (i.e., correcting obvious errors and removing records that cannot be used). 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 does the following:

- removes duplicate records
- removes records with no date
- removes records that are missing both tail width and carapace length
- removes releases with no corresponding recapture
- iteratively matches 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 for this assessment). 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 in 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

We conducted a comparison 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 15 and Table 16). There were no decreases in the data made available for this assessment compared to the data available for the 2017 stock assessment.

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

There were a total of 33 330 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).

Tagged lobsters are generally recaptured in the QMA or statistical area of release, but there are a number of cases where it appears that tagged individuals have apparently moved much greater distances (Table 18). 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 highly variable (Figure 23). Growth rates differ among QMAs, with CRA 6 showing fewer smaller individuals compared to most of the other QMAs (Figure 23). The relationship between observed growth increment (mm) and time at liberty (years) is less variable (Figure 24). This observation holds true for all of the QMAs with an adequate amount of data (Figure 24).

## 5.3 CRA 6

### 5.3.1 CRA 6: tag data summaries

The screened data extract for CRA 6 comprised 183 records: 21 males and 162 females (Table 19). The distributions of sizes at release and recapture by sex are shown in Figure 25.

The available release/recovery pairs all date from the mid-1990s, when there was a research initiative which also included a considerable quantity of on-board observer sampling (Table 19). All of the releases used Hallprint tags, with size recorded in tail width. Tags were mainly released in 1996 and 1997 with recoveries occurring in the same years and extending into 1998. Three recoveries were recorded in 2005. Areas 940 and 941 were the most prevalent areas of release and of recovery as well (Table 20 and Table 21). Area 943 was poorly represented in the release of tags (Table 22) while Area

942, which had a reasonable number of tags released, had low numbers of recoveries (Table 21). In contrast, Area 940 had fewer releases than Area 942 but considerably more recoveries were recorded from 940. Table 22 also shows that males were severely under-represented in the original tagging effort and consequently only 11% of the recoveries are male (Table 19), all of which were quite small (Figure 25).

### 5.3.2 CRA 6: times at liberty

Times at liberty in the CRA 6 tag data set varied from 1 day to 3462 days (9.5 years), but the median was 147 days, with 77% of recaptures at liberty for less than one year and 95% less than two years. The number of times an individual is re-released is also monitored, but only 15 of the 183 recoveries were multiple recoveries (8%; Table 23). Condition codes were nearly all zero (85%).

### 5.3.3 CRA 6: growth increments

Growth increments ranged from -17.8 to 24.5 mm with 5% and 95% quantiles between -1.0 and 8.1 mm (Figure 26 and Figure 27). The observed growth increment (mm) in CRA 6 by tail width (mm) at release and time at liberty (years) is poorly determined given the small amount of available data (Figure 26 and Figure 27). Equivalent plots by statistical area are provided: observed growth increment by tail width at release (Figure 28) and observed growth increment by time at liberty (Figure 29).

## 5.4 Areas 926, 927 and 928

Tagging data from Areas 926, 927 and 928 were added to the model to supplement limited CRA 6 tag recoveries. These three statistical areas were selected because they comprise the closest available data set which appears to be slow-growing but which grow to a relatively large size. Stewart Island (Area 924) was excluded because this population does not share these characteristics.

### 5.4.1 Areas 926, 927 and 928: tag data summaries

The screened data extract for these three areas comprised 7112 records: 4183 males and 2929 females, when working from the release information (Table 24). Fewer release/recovery pairs are specified if the recovery information is used, probably because this population is not closed and demonstrates some movement. The majority of recoveries were in the statistical area of release, but there was movement and some possible data errors (Table 25). Some release/recovery pairs date from the late 1970s and early 1980s, while the majority of the recovery information comes from tagging undertaken from the mid-1990s (Table 26). There has been a tendency to tag more males than females in these three areas, and the majority of the tagging effort has been in Areas 926 and 927 (Table 27).

### 5.4.2 Areas 926, 927 and 928: times at liberty

Time at liberty in the Areas 926, 927 and 928 tag data set varied from 1 day to 3473 days (9.5 years), with the median at 294 days. 65% of recaptures were at liberty for less than one year and 88% less than two years. The number of times an individual lobster is re-released is also monitored, with 34% of the 7112 recovery pairs being re-recoveries (Table 28). It was decided to use only the first-time recovery events (4726 observations) to avoid any potential bias stemming from the possibility that lobsters with multiple recoveries were slower growing individuals.

### 5.4.3 Areas 926, 927 and 928: growth increments

Growth increments ranged from -21.1 to 35.0 mm with 5% and 95% quantiles between -0.5 and 12.4 mm. Plots by tail width (mm) at release (Figure 30) and time at liberty (years) (Figure 31) are provided for each of the three statistical areas.

## 6. REFERENCES


Annala, J.H.; Esterman, D.B. (1986). Yield Estimates for the New Zealand rock lobster fishery. In: Jamieson, G. and Bourne, N. (eds.) North Pacific Workshop on Stock Assessment and Management of Invertebrates. *Canadian Special Publication Fisheries &Aquatic Sciences* 92: 347–358.

Annala, J.H.; King, M.R. (1983). The 1963–73 New Zealand rock lobster landings by statistical area. *Fisheries Research Division Occasional Publication, Data Series 11*. 20 p. (Unpublished report held in NIWA library, Wellington.)

Breen, P.A., Booth, J.D.; Tyson, P.J. (1988). Feasibility of a minimum size limit based on tail width for the New Zealand red rock lobster, *Jasus edwardsii*. *New Zealand Fisheries Technical Report No. 6*. 16 p.

Bentley, N.; Starr, P.J.; Walker, N.; Breen, P.A. (2005). Catch and effort data for New Zealand rock lobster stock fisheries. *New Zealand Fisheries Assessment Report* 2005/49. 49 p.

Breen, P.A.; Kendrick, T.K. (1995). The 1994 stock assessment for the red rock lobster (*Jasus edwardsii*) fishery. New Zealand Fisheries Assessment Research Document 95/23. 59 p. (Unpublished report held in NIWA library, Wellington.)

Breen, P.A.; Kendrick, T.K. (1997). Report on biological research for the Chatham Islands (CRA 6) red rock lobster (*Jasus edwardsii*) fishery. 17 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Davey, N.K.; Hartill, B.; Carter, M. (2011). Characterisation of marine non–commercial fishing around the Chatham Islands during the 2008–09 fishing year, including catch estimates for selected species. *New Zealand Fisheries Assessment Report* 2011/49.

Fisheries New Zealand (2018). Fisheries Assessment Plenary, November 2018: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 526 p. (https://www.fisheries.govt.nz/dmsdocument/32410-fisheries-assessment-plenary-stock-assessment-and-stock-status-november-2018-albacore-to-yellowfin-tuna)

Haist, V.; Breen, P.A.; Starr, P.J. (2009). A new multi-stock length-based assessment model for New Zealand rock lobsters (*Jasus edwardsii*). *New Zealand Journal of Marine and Freshwater Research 43 (1):* 355–371.

Kensler, C.B. (1969). Commercial landings of the spiny lobster *Jasus edwardsii* (Hutton) at Chatham Islands, New Zealand (Crustacea: Decapoda: Palinuridae). *New Zealand Journal of Marine and Freshwater Research. 3:*506–517.

Starr, P.J. (2018). Rock lobster catch and effort data: summaries and CPUE standardisations, 1979–80 to 2016–17. *New Zealand Fisheries Assessment Report* 2018/27. 141 p.

Starr, P.J.; Haist, V.; Breen, P.A.; Edwards, C.T.T. (2014). The 2013 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2 and development of management procedures. *New Zealand Fisheries Assessment Report 2014/19*. 75 p. (http://fs.fish.govt.nz/Page.aspx?pk=113&dk=23653)

Starr, P.J.; Webber, D.N. (2018). Data for the 2017 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2. *New Zealand Fisheries Assessment Report 2018/31*. 75 p.

Vehtari, A.; Gelman, A.; Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and Computing. 27(5)*, 1413–1432. :10.1007/s11222-016-9696-4

Wynne-Jones, J.; Gray, A.; Hill, L.; Heinemann, A. (2014). National Panel Survey Of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p. (http://fs.fish.govt.nz/Doc/23718/FAR_2014_67_2847_MAF2010-01.pdf.ashx)

**Table 1: Available estimates of illegal catches (tonnes) by CRA QMA from 1990, as provided by Compliance 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 of the catch/effort system. Cells without data or missing rows have been deliberately left blank or filled with dashes. Years without any Compliance 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] | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

[1] this value discarded by RLFAWG agreement

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

**Table 2: Estimated CRA 6 seasonal (AW and SS) catches (tonnes) (commercial, recreational including S.111, customary and illegal), from 1965 to 2017. The non-commercial catches in this table reflect the RLFAWG agreements described in Sections 2.2, 2.3 and 2.4.**

| Fishing | Commercial | | Recreational | | Customary | | Illegal | |
|---|---|---|---|---|---|---|---|---|
| Year | AW | SS | AW | SS | AW | SS | AW | SS |
| 1965 | 0.00 | 229.21 | 0.60 | 5.42 | 0.40 | 3.60 | 0.00 | 0.96 |
| 1966 | 545.76 | 1 284.09 | 0.60 | 5.42 | 0.40 | 3.60 | 77.38 | 182.07 |
| 1967 | 1 277.11 | 2 618.68 | 0.60 | 5.42 | 0.40 | 3.60 | 179.04 | 367.11 |
| 1968 | 2 038.26 | 3 031.85 | 0.60 | 5.42 | 0.40 | 3.60 | 451.78 | 672.01 |
| 1969 | 956.93 | 1 502.69 | 0.60 | 5.42 | 0.40 | 3.60 | 295.61 | 464.21 |
| 1970 | 302.63 | 676.81 | 0.60 | 5.42 | 0.40 | 3.60 | 94.61 | 211.58 |
| 1971 | 248.61 | 609.45 | 0.60 | 5.42 | 0.40 | 3.60 | 57.71 | 141.46 |
| 1972 | 187.91 | 548.28 | 0.60 | 5.42 | 0.40 | 3.60 | 42.37 | 123.62 |
| 1973 | 163.35 | 533.22 | 0.60 | 5.42 | 0.40 | 3.60 | 39.22 | 128.04 |
| 1974 | 114.06 | 295.30 | 0.60 | 5.42 | 0.40 | 3.60 | 18.48 | 47.83 |
| 1975 | 66.53 | 217.09 | 0.60 | 5.42 | 0.40 | 3.60 | 18.79 | 61.32 |
| 1976 | 80.15 | 221.07 | 0.60 | 5.42 | 0.40 | 3.60 | 20.21 | 55.73 |
| 1977 | 58.64 | 175.73 | 0.60 | 5.42 | 0.40 | 3.60 | 19.47 | 58.34 |
| 1978 | 51.14 | 165.47 | 0.60 | 5.42 | 0.40 | 3.60 | 24.08 | 77.92 |
| 1979 | 106.77 | 268.55 | 0.60 | 5.42 | 0.40 | 3.60 | 9.89 | 24.86 |
| 1980 | 76.97 | 248.83 | 0.60 | 5.42 | 0.40 | 3.60 | 9.59 | 31.00 |
| 1981 | 89.40 | 304.81 | 0.60 | 5.42 | 0.40 | 3.60 | 18.69 | 63.71 |
| 1982 | 115.95 | 285.70 | 0.60 | 5.42 | 0.40 | 3.60 | 24.11 | 59.40 |
| 1983 | 117.59 | 345.63 | 0.60 | 5.42 | 0.40 | 3.60 | 24.62 | 72.36 |
| 1984 | 80.73 | 337.38 | 0.60 | 5.42 | 0.40 | 3.60 | 16.82 | 70.29 |
| 1985 | 110.39 | 400.62 | 0.60 | 5.42 | 0.40 | 3.60 | 23.09 | 83.79 |
| 1986 | 74.75 | 414.81 | 0.60 | 5.42 | 0.40 | 3.60 | 15.69 | 87.06 |
| 1987 | 62.12 | 318.71 | 0.60 | 5.42 | 0.40 | 3.60 | 12.95 | 66.46 |
| 1988 | 63.55 | 317.40 | 0.60 | 5.42 | 0.40 | 3.60 | 13.30 | 66.41 |
| 1989 | 59.95 | 215.79 | 0.60 | 5.42 | 0.40 | 3.60 | 12.25 | 44.11 |
| 1990 | 43.83 | 250.86 | 0.60 | 5.42 | 0.40 | 3.60 | 12.64 | 72.36 |
| 1991 | 51.63 | 270.40 | 0.60 | 5.42 | 0.40 | 3.60 | 12.43 | 65.07 |
| 1992 | 64.67 | 207.25 | 0.60 | 5.42 | 0.40 | 3.60 | 16.65 | 53.35 |
| 1993 | 66.21 | 218.83 | 0.60 | 5.42 | 0.40 | 3.60 | 16.26 | 53.74 |
| 1994 | 54.84 | 202.45 | 0.60 | 5.42 | 0.40 | 3.60 | 14.92 | 55.08 |
| 1995 | 60.36 | 197.73 | 0.60 | 5.42 | 0.40 | 3.60 | 16.37 | 53.63 |
| 1996 | 89.94 | 230.84 | 0.60 | 5.42 | 0.40 | 3.60 | 19.63 | 50.37 |
| 1997 | 101.62 | 191.55 | 0.60 | 5.42 | 0.40 | 3.60 | 20.10 | 37.90 |
| 1998 | 85.95 | 212.79 | 0.60 | 5.42 | 0.40 | 3.60 | 13.23 | 32.77 |
| 1999 | 90.57 | 206.29 | 0.60 | 5.42 | 0.40 | 3.60 | 10.37 | 23.63 |
| 2000 | 108.94 | 220.01 | 0.60 | 5.42 | 0.40 | 3.60 | 7.29 | 14.71 |
| 2001 | 89.40 | 237.26 | 0.60 | 5.42 | 0.40 | 3.60 | 2.74 | 7.26 |
| 2002 | 94.13 | 240.19 | 0.60 | 5.42 | 0.40 | 3.60 | 2.82 | 7.18 |
| 2003 | 77.65 | 211.50 | 0.60 | 5.42 | 0.40 | 3.60 | 2.69 | 7.31 |
| 2004 | 95.86 | 225.60 | 0.60 | 5.42 | 0.40 | 3.60 | 2.98 | 7.02 |
| 2005 | 100.37 | 250.09 | 0.60 | 5.42 | 0.40 | 3.60 | 2.86 | 7.14 |
| 2006 | 117.13 | 233.97 | 0.60 | 5.42 | 0.40 | 3.60 | 3.34 | 6.66 |
| 2007 | 111.25 | 243.51 | 0.60 | 5.42 | 0.40 | 3.60 | 3.14 | 6.86 |
| 2008 | 96.42 | 257.65 | 0.60 | 5.42 | 0.40 | 3.60 | 2.72 | 7.28 |
| 2009 | 73.16 | 270.76 | 0.60 | 5.42 | 0.40 | 3.60 | 2.13 | 7.87 |
| 2010 | 99.91 | 256.50 | 0.60 | 5.42 | 0.40 | 3.60 | 2.80 | 7.20 |
| 2011 | 82.98 | 275.42 | 0.60 | 5.42 | 0.40 | 3.60 | 2.32 | 7.68 |
| 2012 | 64.37 | 290.80 | 0.60 | 5.42 | 0.40 | 3.60 | 1.81 | 8.19 |
| 2013 | 77.24 | 264.81 | 0.60 | 5.42 | 0.40 | 3.60 | 2.26 | 7.74 |
| 2014 | 77.76 | 255.49 | 0.60 | 5.42 | 0.40 | 3.60 | 2.33 | 7.67 |
| 2015 | 79.44 | 272.59 | 0.60 | 5.42 | 0.40 | 3.60 | 2.26 | 7.74 |
| 2016 | 108.48 | 250.03 | 0.60 | 5.42 | 0.40 | 3.60 | 3.03 | 6.97 |
| 2017 | 117.08 | 241.99 | 0.60 | 5.42 | 0.40 | 3.60 | 3.26 | 6.74 |

**Table 3: Number of vessel/statistical area/month records in the dataset used to calculate the CRA 6 seasonal CPUE time series after excluding vessels with less than five years' experience in the fishery.**

| Fishing | Autumn-winter season | | | | | Spring-summer season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 940 | 941 | 942 | 943 | Total | 940 | 941 | 942 | 943 | Total |
| 89/90 | 6 | 10 | 11 | 6 | 33 | 45 | 41 | 56 | 18 | 160 |
| 90/91 | 27 | 33 | 33 | 15 | 108 | 40 | 38 | 61 | 16 | 155 |
| 91/92 | 24 | 37 | 46 | 10 | 117 | 46 | 57 | 92 | 16 | 211 |
| 92/93 | 27 | 25 | 65 | 11 | 128 | 45 | 47 | 114 | 14 | 220 |
| 93/94 | 48 | 39 | 82 | 19 | 188 | 43 | 51 | 100 | 29 | 223 |
| 94/95 | 48 | 44 | 83 | 35 | 210 | 58 | 53 | 92 | 40 | 243 |
| 95/96 | 52 | 41 | 81 | 41 | 215 | 47 | 36 | 95 | 39 | 217 |
| 96/97 | 62 | 28 | 80 | 19 | 189 | 60 | 31 | 83 | 25 | 199 |
| 97/98 | 69 | 31 | 84 | 32 | 216 | 53 | 31 | 77 | 27 | 188 |
| 98/99 | 45 | 26 | 52 | 16 | 139 | 40 | 23 | 45 | 18 | 126 |
| 99/00 | 29 | 29 | 51 | 14 | 123 | 28 | 34 | 57 | 15 | 134 |
| 00/01 | 45 | 31 | 61 | 16 | 153 | 45 | 30 | 56 | 14 | 145 |
| 01/02 | 43 | 33 | 45 | 12 | 133 | 39 | 31 | 47 | 16 | 133 |
| 02/03 | 30 | 33 | 34 | 14 | 111 | 38 | 36 | 44 | 15 | 133 |
| 03/04 | 33 | 30 | 42 | 21 | 126 | 42 | 35 | 49 | 23 | 149 |
| 04/05 | 40 | 30 | 52 | 13 | 135 | 40 | 36 | 55 | 15 | 146 |
| 05/06 | 37 | 45 | 65 | 20 | 167 | 43 | 45 | 68 | 21 | 177 |
| 06/07 | 36 | 33 | 54 | 22 | 145 | 37 | 40 | 53 | 22 | 152 |
| 07/08 | 35 | 37 | 45 | 17 | 134 | 35 | 50 | 53 | 23 | 161 |
| 08/09 | 39 | 34 | 55 | 19 | 147 | 39 | 42 | 67 | 19 | 167 |
| 09/10 | 28 | 21 | 54 | 18 | 121 | 34 | 35 | 65 | 28 | 162 |
| 10/11 | 29 | 24 | 53 | 25 | 131 | 32 | 30 | 53 | 25 | 140 |
| 11/12 | 32 | 28 | 52 | 20 | 132 | 37 | 33 | 74 | 27 | 171 |
| 12/13 | 29 | 17 | 62 | 20 | 128 | 31 | 26 | 79 | 25 | 161 |
| 13/14 | 30 | 20 | 58 | 15 | 123 | 36 | 20 | 92 | 27 | 175 |
| 14/15 | 31 | 23 | 65 | 24 | 143 | 42 | 29 | 82 | 27 | 180 |
| 15/16 | 45 | 20 | 50 | 12 | 127 | 44 | 30 | 80 | 26 | 180 |
| 16/17 | 34 | 22 | 55 | 20 | 131 | 29 | 24 | 74 | 26 | 153 |
| 17/18 | 32 | 21 | 45 | 22 | 120 | 34 | 20 | 54 | 24 | 132 |
| Total | 1 065 | 845 | 1 615 | 548 | 4 073 | 1 182 | 1 034 | 2 017 | 660 | 4 893 |

**Table 4: CRA 6 standardised seasonal CPUE models: total number of model parameters (p), estimated effective number of parameters (p_loo), and the leave-one-out information criterion (LOOIC). 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. (se): standard error.**

| Model | p | p_loo (se) | LOOIC (se) |
|---|---|---|---|
| Interaction | 322 | 282.4 (6.7) | 13009 (203) |
| Status-quo | 150 | 151.6 (3.8) | 13367 (203) |
| null | 59 | 60.3 (1.3) | 15880 (178) |

**Table 5: Seasonal CPUE indices calculated from the analysis of CRA 6 catch and potlift data including a vessel explanatory variable based on vessels with at least five years' experience in the fishery. Standardised index for the null model and the interaction model.**

| | Autumn-winter season | | | | Spring-summer season | | | |
|---|---|---|---|---|---|---|---|---|
| | Null Model | | Interaction Model | | Null Model | | Interaction Model | |
| Fishing Year | Standard-ised Index | Standard Error | Standard-ised Index | Standard Error | Standard-ised Index | Standard Error | Standard-ised Index | Standard Error |
| 89/90 | 0.7709 | 0.1015 | 1.0367 | 0.0983 | 1.1832 | 0.0460 | 1.2985 | 0.0447 |
| 90/91 | 0.7651 | 0.0589 | 0.9252 | 0.0669 | 1.4279 | 0.0467 | 1.4312 | 0.0460 |
| 91/92 | 0.7383 | 0.0552 | 0.8862 | 0.0718 | 1.3382 | 0.0410 | 1.4411 | 0.0398 |
| 92/93 | 0.9837 | 0.0528 | 1.0323 | 0.0695 | 1.0848 | 0.0398 | 1.0427 | 0.0414 |
| 93/94 | 0.7013 | 0.0414 | 0.8130 | 0.0622 | 1.1221 | 0.0405 | 1.1400 | 0.0380 |
| 94/95 | 0.6730 | 0.0384 | 0.7789 | 0.0537 | 1.0432 | 0.0371 | 1.0302 | 0.0352 |
| 95/96 | 0.6848 | 0.0395 | 0.7484 | 0.0551 | 1.1296 | 0.0419 | 1.1006 | 0.0377 |
| 96/97 | 0.6979 | 0.0441 | 0.7928 | 0.0594 | 1.1796 | 0.0419 | 1.1857 | 0.0391 |
| 97/98 | 0.6969 | 0.0409 | 0.7994 | 0.0546 | 1.1612 | 0.0437 | 1.1777 | 0.0435 |
| 98/99 | 0.8140 | 0.0500 | 0.9070 | 0.0653 | 1.3654 | 0.0525 | 1.4181 | 0.0456 |
| 99/00 | 0.8222 | 0.0547 | 0.8454 | 0.0626 | 1.4372 | 0.0515 | 1.2877 | 0.0478 |
| 00/01 | 0.7947 | 0.0469 | 0.8398 | 0.0620 | 1.3501 | 0.0507 | 1.2686 | 0.0456 |
| 01/02 | 0.7122 | 0.0514 | 0.7761 | 0.0655 | 1.3908 | 0.0493 | 1.3937 | 0.0457 |
| 02/03 | 0.8784 | 0.0555 | 0.9681 | 0.0655 | 1.3213 | 0.0499 | 1.3008 | 0.0461 |
| 03/04 | 0.8268 | 0.0551 | 0.8845 | 0.0640 | 1.3220 | 0.0489 | 1.2469 | 0.0462 |
| 04/05 | 0.9750 | 0.0496 | 1.0103 | 0.0663 | 1.4905 | 0.0471 | 1.3729 | 0.0465 |
| 05/06 | 1.0185 | 0.0459 | 1.1247 | 0.0604 | 1.5489 | 0.0450 | 1.4866 | 0.0421 |
| 06/07 | 1.1728 | 0.0464 | 1.2316 | 0.0627 | 1.8389 | 0.0455 | 1.7554 | 0.0446 |
| 07/08 | 1.0876 | 0.0526 | 1.1306 | 0.0618 | 1.5464 | 0.0430 | 1.4233 | 0.0434 |
| 08/09 | 1.0844 | 0.0483 | 1.0878 | 0.0622 | 1.8356 | 0.0453 | 1.7336 | 0.0454 |
| 09/10 | 0.9682 | 0.0532 | 1.0146 | 0.0668 | 1.5777 | 0.0464 | 1.4218 | 0.0439 |
| 10/11 | 1.0681 | 0.0508 | 1.1072 | 0.0632 | 1.5833 | 0.0516 | 1.5645 | 0.0448 |
| 11/12 | 0.9193 | 0.0507 | 0.9584 | 0.0631 | 1.7701 | 0.0481 | 1.6688 | 0.0414 |
| 12/13 | 0.9415 | 0.0528 | 0.9820 | 0.0660 | 1.8639 | 0.0470 | 1.8167 | 0.0470 |
| 13/14 | 1.0462 | 0.0533 | 1.1094 | 0.0677 | 1.6669 | 0.0434 | 1.6284 | 0.0462 |
| 14/15 | 1.0153 | 0.0486 | 1.0933 | 0.0638 | 1.5029 | 0.0447 | 1.4233 | 0.0393 |
| 15/16 | 1.0300 | 0.0510 | 1.1136 | 0.0676 | 1.4606 | 0.0430 | 1.3825 | 0.0408 |
| 16/17 | 1.2781 | 0.0516 | 1.3875 | 0.0630 | 1.8696 | 0.0471 | 1.8080 | 0.0447 |
| 18/19 | 1.1682 | 0.0539 | 1.2620 | 0.0653 | 2.0866 | 0.0506 | 1.9794 | 0.0455 |

**Table 6: Sampling by fishing year in CRA 6 by the logbook and observer catch sampling programme from 1989. "Lobsters" are the number of individuals measured. Total number of active vessels in CRA 6 is included to show the level of participation in the logbook programme (on the assumption that one participant is generally equivalent to one vessel). 1982 data have no associated vessels or effort. Fishing years coded with first year of the paired years. '–': no data.**

| Fishing | | | | Logbooks | Observer catch sampling | | |
|---|---|---|---|---|---|---|---|
| Year | N vessels[1] | Fishermen | Potlifts | Lobsters | Days | Potlifts | Lobsters |
| 1982 | – | – | – | – | – | – | 462 |
| 1989 | – | – | – | – | 9 | 1 144 | 1 472 |
| 1993 | – | – | – | – | 9 | 918 | 648 |
| 1994 | – | – | – | – | 11 | 900 | 669 |
| 1995 | – | – | – | – | 22 | 3 446 | 2 557 |
| 1996 | – | – | – | – | 26 | 3 964 | 7 556 |
| 1997 | – | – | – | – | 18 | 2 372 | 2 714 |
| 2001 | 32 | 2 | 142 | 122 | – | – | – |
| 2002 | 32 | 6 | 445 | 599 | – | – | – |
| 2003 | 35 | 8 | 732 | 1 171 | – | – | – |
| 2004 | 34 | 6 | 621 | 941 | – | – | – |
| 2005 | 35 | 17 | 1 243 | 3 256 | – | – | – |
| 2006 | 36 | 11 | 966 | 2 271 | – | – | – |
| 2007 | 35 | 15 | 978 | 2 797 | – | – | – |
| 2008 | 35 | 12 | 865 | 2 347 | – | – | – |
| 2009 | 35 | 3 | 317 | 543 | – | – | – |
| 2010 | 36 | 9 | 495 | 996 | – | – | – |
| 2011 | 35 | 13 | 809 | 1 997 | – | – | – |
| 2012 | 37 | 5 | 390 | 633 | – | – | – |
| 2014 | 35 | 5 | 475 | 1 224 | – | – | – |
| 2015 | 35 | 5 | 324 | 881 | – | – | – |
| 2016 | 36 | 6 | 200 | 478 | – | – | – |
| 2017 | 40 | 8 | 256 | 820 | – | – | – |
| **Total** | – | – | 9 258 | 21 076 | 95 | 12 744 | 15 616 |

[1] from Starr (2018)

**Table 7: Number of lobsters measured by the observer and logbook catch sampling programmes by fishing year, sex and season. '–': no data. Fishing years coded with first year of the paired years.**

| | Logbooks | | | | Observer catch sampling | | | |
|---|---|---|---|---|---|---|---|---|
| Fishing year | Male | Immature female | Mature female | Total | Male | Immature female | Mature female | Total |
| **Season=AW** | | | | | | | | |
| 1982 | – | – | – | – | 259 | 16 | 187 | 462 |
| 1996 | – | – | – | – | 2 107 | 494 | 1 772 | 4 373 |
| 1997 | – | – | – | – | 1 221 | 74 | 1 418 | 2 713 |
| 2002 | 197 | 5 | 39 | 241 | – | – | – | – |
| 2003 | 175 | | 59 | 234 | – | – | – | – |
| 2004 | 211 | 4 | 98 | 313 | – | – | – | – |
| 2005 | 698 | 89 | 380 | 1 167 | – | – | – | – |
| 2006 | 521 | 35 | 207 | 763 | – | – | – | – |
| 2007 | 499 | 26 | 201 | 726 | – | – | – | – |
| 2008 | 381 | | 118 | 499 | – | – | – | – |
| 2009 | 75 | 1 | 89 | 165 | – | – | – | – |
| 2010 | 152 | 1 | 84 | 237 | – | – | – | – |
| 2011 | 318 | 18 | 159 | 495 | – | – | – | – |
| 2012 | 96 | | 33 | 129 | – | – | – | – |
| 2014 | 365 | 35 | 225 | 625 | – | – | – | – |
| 2015 | 209 | 25 | 136 | 370 | – | – | – | – |
| 2016 | 33 | 1 | 16 | 50 | – | – | – | – |
| 2017 | 92 | 3 | 43 | 138 | – | – | – | – |
| Total | 4 022 | 243 | 1 887 | 6 152 | 3 587 | 584 | 3 377 | 7 548 |
| **Season=SS** | | | | | | | | |
| 1989 | – | – | – | – | 536 | 15 | 921 | 1 472 |
| 1993 | – | – | – | – | 315 | 10 | 323 | 648 |
| 1994 | – | – | – | – | 365 | 9 | 295 | 669 |
| 1995 | – | – | – | – | 1 260 | 39 | 1 257 | 2 556 |
| 1996 | – | – | – | – | 1 348 | 101 | 1 729 | 3 178 |
| 2001 | 58 | 15 | 49 | 122 | – | – | – | – |
| 2002 | 126 | | 232 | 358 | – | – | – | – |
| 2003 | 335 | 46 | 555 | 936 | – | – | – | – |
| 2004 | 227 | 4 | 394 | 625 | – | – | – | – |
| 2005 | 965 | 117 | 1 003 | 2 085 | – | – | – | – |
| 2006 | 739 | 66 | 701 | 1 506 | – | – | – | – |
| 2007 | 916 | 53 | 1 098 | 2 067 | – | – | – | – |
| 2008 | 805 | 34 | 1 007 | 1 846 | – | – | – | – |
| 2009 | 112 | 3 | 262 | 377 | – | – | – | – |
| 2010 | 331 | 4 | 421 | 756 | – | – | – | – |
| 2011 | 515 | 19 | 966 | 1 500 | – | – | – | – |
| 2012 | 184 | 10 | 307 | 501 | – | – | – | – |
| 2014 | 214 | 26 | 359 | 599 | – | – | – | – |
| 2015 | 193 | 13 | 305 | 511 | – | – | – | – |
| 2016 | 199 | 12 | 217 | 428 | – | – | – | – |
| 2017 | 322 | 24 | 336 | 682 | – | – | – | – |
| Total | 6 241 | 446 | 8 212 | 14 899 | 3 824 | 174 | 4 525 | 8 523 |

**Table 8: Sample weight (Eq. 6) calculated for each LF sampling record described in Table 7. '–': no data. Fishing years coded with first year of the paired years.**

| | Logbooks | | | | Observer catch sampling | | | |
|---|---|---|---|---|---|---|---|---|
| Fishing year | Male | Immature female | Mature female | Total | Male | Immature female | Mature female | Total |
| **Season=AW** | | | | | | | | |
| 1982 | | | | | 0.319 | 0.022 | 0.247 | 0.587 |
| 1996 | – | – | – | – | 2.901 | 0.594 | 2.618 | 6.113 |
| 1997 | – | – | – | – | 1.735 | 0.106 | 2.235 | 4.076 |
| 2002 | 3.494 | 0.056 | 0.591 | 4.141 | – | – | – | – |
| 2003 | 2.362 | – | 0.937 | 3.299 | – | – | – | – |
| 2004 | 3.253 | 0.030 | 1.552 | 4.835 | – | – | – | – |
| 2005 | 5.721 | 0.632 | 2.992 | 9.345 | – | – | – | – |
| 2006 | 5.212 | 0.194 | 1.976 | 7.382 | – | – | – | – |
| 2007 | 4.330 | 0.155 | 1.681 | 6.166 | – | – | – | – |
| 2008 | 4.363 | – | 1.256 | 5.620 | – | – | – | – |
| 2009 | 1.026 | 0.011 | 1.180 | 2.217 | – | – | – | – |
| 2010 | 1.355 | 0.004 | 0.985 | 2.344 | – | – | – | – |
| 2011 | 3.399 | 0.110 | 1.468 | 4.977 | – | – | – | – |
| 2012 | 1.379 | – | 0.309 | 1.687 | – | – | – | – |
| 2014 | 2.293 | 0.333 | 1.305 | 3.931 | – | – | – | – |
| 2015 | 1.305 | 0.161 | 1.190 | 2.656 | – | – | – | – |
| 2016 | 0.511 | 0.008 | 0.232 | 0.751 | – | – | – | – |
| 2017 | 1.170 | 0.031 | 0.667 | 1.869 | – | – | – | – |
| Total | 41.174 | 1.726 | 18.322 | 61.222 | 4.954 | 0.722 | 5.100 | 10.776 |
| **Season=SS** | | | | | | | | |
| 1989 | – | – | – | – | 1.144 | 0.035 | 2.214 | 3.393 |
| 1993 | – | – | – | – | 0.858 | 0.023 | 0.885 | 1.766 |
| 1994 | – | – | – | – | 1.402 | 0.035 | 1.133 | 2.569 |
| 1995 | – | – | – | – | 1.806 | 0.044 | 1.815 | 3.665 |
| 1996 | – | – | – | – | 2.035 | 0.154 | 2.625 | 4.814 |
| 2001 | 0.673 | 0.229 | 0.566 | 1.468 | – | – | – | – |
| 2002 | 1.114 | | 1.608 | 2.722 | – | – | – | – |
| 2003 | 2.458 | 0.191 | 3.734 | 6.383 | – | – | – | – |
| 2004 | 1.878 | 0.020 | 3.096 | 4.994 | – | – | – | – |
| 2005 | 5.268 | 0.487 | 5.351 | 11.106 | – | – | – | – |
| 2006 | 5.002 | 0.374 | 4.515 | 9.890 | – | – | – | – |
| 2007 | 5.458 | 0.262 | 6.024 | 11.744 | – | – | – | – |
| 2008 | 4.757 | 0.171 | 5.479 | 10.407 | – | – | – | – |
| 2009 | 0.810 | 0.017 | 1.807 | 2.634 | – | – | – | – |
| 2010 | 2.372 | 0.030 | 3.196 | 5.598 | – | – | – | – |
| 2011 | 1.989 | 0.048 | 3.853 | 5.891 | – | – | – | – |
| 2012 | 1.046 | 0.049 | 1.489 | 2.584 | – | – | – | – |
| 2014 | 1.488 | 0.141 | 1.916 | 3.544 | – | – | – | – |
| 2015 | 1.128 | 0.078 | 1.984 | 3.190 | – | – | – | – |
| 2016 | 1.997 | 0.279 | 1.990 | 4.266 | – | – | – | – |
| 2017 | 2.190 | 0.140 | 2.052 | 4.382 | – | – | – | – |
| Total | 39.629 | 2.515 | 48.661 | 90.805 | 7.244 | 0.292 | 8.671 | 16.207 |

**Table 9: Statistics for the proportion-at-sex for each season, summarised across all records for a season using the weights in Table 8.**

| | Autumn-Winter | | | Spring-Summer | | |
|---|---|---|---|---|---|---|
| **Statistic** | **Male** | **Immature Female** | **Mature Female** | **Male** | **Immature Female** | **Mature Female** |
| Maximum | 0.844 | 0.097 | 0.548 | 0.545 | 0.156 | 0.686 |
| Minimum | 0.426 | 0.002 | 0.143 | 0.308 | 0.004 | 0.386 |
| Mean | 0.641 | 0.034 | 0.325 | 0.438 | 0.026 | 0.536 |

**Table 10: Statistics for mean tail width (mm) by sex for each season, summarised across all records for a season using the weights in Table 8.**

| | Autumn-Winter | | | Spring-Summer | | |
|---|---|---|---|---|---|---|
| **Statistic** | **Male** | **Immature Female** | **Mature Female** | **Male** | **Immature Female** | **Mature Female** |
| Maximum mean TW | 77.8 | 60.5 | 79.0 | 80.8 | 77.3 | 81.0 |
| Minimum mean TW | 58.2 | 46.0 | 63.4 | 61.5 | 45.8 | 68.3 |
| Mean TW | 69.1 | 53.5 | 71.4 | 69.7 | 55.4 | 72.9 |

**Table 11: 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. Coloured cells indicate accumulator bins.**

| | 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) | 3 | 2 | 0.33 | – | – | – | 1 | 1 | 0.00 |
| [32,34) | 1 | 0 | 1.00 | 2 | 1 | 0.50 | – | – | – |
| [34,36) | 1 | 0 | 1.00 | 2 | 1 | 0.50 | – | – | – |
| [36,38) | 2 | 1 | 0.50 | 2 | 2 | 0.00 | – | – | – |
| [38,40) | 6 | 4 | 0.33 | – | – | – | 1 | 1 | 0.00 |
| [40,42) | 6 | 1 | 0.83 | 8 | 4 | 0.50 | 2 | 0 | 1.00 |
| [42,44) | 11 | 8 | 0.27 | 8 | 5 | 0.38 | 3 | 3 | 0.00 |
| [44,46) | 21 | 8 | 0.62 | 14 | 7 | 0.50 | 5 | 4 | 0.20 |
| [46,48) | 21 | 7 | 0.67 | 18 | 8 | 0.56 | 6 | 3 | 0.50 |
| [48,50) | 31 | 1 | 0.97 | 17 | 2 | 0.88 | 13 | 7 | 0.46 |
| [50,52) | 34 | 1 | 0.97 | 26 | 2 | 0.92 | 24 | 4 | 0.83 |
| [52,54) | 36 | 0 | 1.00 | 28 | 3 | 0.89 | 26 | 0 | 1.00 |
| [54,56) | 38 | 0 | 1.00 | 24 | 1 | 0.96 | 33 | 3 | 0.91 |
| [56,58) | 37 | 0 | 1.00 | 25 | 3 | 0.88 | 34 | 0 | 1.00 |
| [58,60) | 37 | 0 | 1.00 | 25 | 3 | 0.88 | 33 | 0 | 1.00 |
| [60,62) | 38 | 0 | 1.00 | 18 | 3 | 0.83 | 38 | 0 | 1.00 |
| [62,64) | 38 | 0 | 1.00 | 11 | 7 | 0.36 | 36 | 0 | 1.00 |
| [64,66) | 38 | 0 | 1.00 | 8 | 7 | 0.13 | 37 | 0 | 1.00 |
| [66,68) | 38 | 0 | 1.00 | 1 | 0 | 1.00 | 35 | 0 | 1.00 |
| [68,70) | 38 | 0 | 1.00 | 3 | 1 | 0.67 | 36 | 0 | 1.00 |
| [70,72) | 37 | 0 | 1.00 | 4 | 3 | 0.25 | 37 | 0 | 1.00 |
| [72,74) | 38 | 0 | 1.00 | 2 | 1 | 0.50 | 35 | 0 | 1.00 |
| [74,76) | 38 | 0 | 1.00 | 1 | 1 | 0.00 | 37 | 0 | 1.00 |
| [76,78) | 38 | 0 | 1.00 | 2 | 0 | 1.00 | 34 | 0 | 1.00 |
| [78,80) | 34 | 1 | 0.97 | 2 | 1 | 0.50 | 34 | 0 | 1.00 |
| [80,82) | 35 | 0 | 1.00 | 3 | 0 | 1.00 | 37 | 0 | 1.00 |
| [82,84) | 36 | 0 | 1.00 | 2 | 1 | 0.50 | 35 | 0 | 1.00 |
| [84,86) | 36 | 0 | 1.00 | 2 | 1 | 0.50 | 36 | 0 | 1.00 |
| [86,88) | 36 | 0 | 1.00 | 1 | 1 | 0.00 | 35 | 1 | 0.97 |
| [88,90) | 33 | 1 | 0.97 | 1 | 1 | 0.00 | 33 | 0 | 1.00 |
| [90,92) | 35 | 1 | 0.97 | – | – | – | 34 | 0 | 1.00 |
| [92,94) | 32 | 0 | 1.00 | 2 | 1 | 0.50 | 35 | 1 | 0.97 |
| [94,96) | 35 | 0 | 1.00 | 1 | 0 | 1.00 | 34 | 1 | 0.97 |
| [96,98) | 33 | 1 | 0.97 | 1 | 0 | 1.00 | 28 | 1 | 0.96 |
| [98,100) | 31 | 2 | 0.94 | – | – | – | 26 | 1 | 0.96 |
| [100,102) | 28 | 2 | 0.93 | – | – | – | 25 | 1 | 0.96 |
| [102,104) | 21 | 3 | 0.86 | – | – | – | 19 | 1 | 0.95 |
| [104,106) | 18 | 2 | 0.89 | – | – | – | 20 | 2 | 0.90 |
| [106,108) | 13 | 4 | 0.69 | – | – | – | 16 | 4 | 0.75 |
| [108,110) | 9 | 2 | 0.78 | – | – | – | 8 | 3 | 0.63 |
| [110,112) | 15 | 5 | 0.67 | – | – | – | 8 | 4 | 0.50 |
| [112,114) | 6 | 2 | 0.67 | – | – | – | 6 | 5 | 0.17 |
| [114,116) | 2 | 0 | 1.00 | – | – | – | 4 | 3 | 0.25 |
| [116,118) | 1 | 0 | 1.00 | – | – | – | 1 | 0 | 1.00 |
| [118,120) | 1 | 1 | 0.00 | – | – | – | 1 | 0 | 1.00 |
| [120,∞) | 2 | 0 | 1.00 | – | – | – | 1 | 0 | 1.00 |

**Table 12: Number of male and female rock lobster, by 5 mm carapace length (CL) bin, from the 1966 potting sample (estimated from Figure 19).**

| | Tail Width | | Number | |
|---|---|---|---|---|
| CL | Female | Male | Female | Male |
| 8.0 | 52.4 | 47.7 | 2 | |
| 8.5 | 55.6 | 50.0 | 4 | 1 |
| 9.0 | 58.8 | 52.3 | 8 | 1 |
| 9.5 | 62.0 | 54.6 | 11 | 2 |
| 10.0 | 65.2 | 56.9 | 19 | 3 |
| 10.5 | 68.3 | 59.2 | 46 | 3 |
| 11.0 | 71.5 | 61.5 | 66 | 17 |
| 11.5 | 74.7 | 63.8 | 106 | 23 |
| 12.0 | 77.9 | 66.1 | 109 | 23 |
| 12.5 | 81.1 | 68.4 | 153 | 43 |
| 13.0 | 84.3 | 70.7 | 180 | 56 |
| 13.5 | 87.5 | 72.9 | 180 | 88 |
| 14.0 | 90.7 | 75.2 | 174 | 68 |
| 14.5 | 93.9 | 77.5 | 114 | 65 |
| 15.0 | 97.0 | 79.8 | 87 | 72 |
| 15.5 | 100.2 | 82.1 | 38 | 74 |
| 16.0 | 103.4 | 84.4 | 26 | 54 |
| 16.5 | 106.6 | 86.7 | 8 | 47 |
| 17.0 | 109.8 | 89.0 | 5 | 59 |
| 17.5 | 113.0 | 91.3 | 1 | 70 |
| 18.0 | 116.2 | 93.6 | 1 | 63 |
| 18.5 | 119.4 | 95.9 | | 52 |
| 19.0 | 122.6 | 98.1 | | 63 |
| 19.5 | 125.7 | 100.4 | | 67 |
| 20.0 | 128.9 | 102.7 | | 41 |
| 20.5 | 132.1 | 105.0 | | 46 |
| 21.0 | 135.3 | 107.3 | | 26 |
| 21.5 | 138.5 | 109.6 | | 11 |
| 22.0 | 141.7 | 111.9 | | 6 |
| 22.5 | 144.9 | 114.2 | | 1 |

**Table 13: Number of individuals per length (TW) bin using a number of methods to convert the original CL bins: 1) mid-point of CL bin converted to TW and then TW binned; 2) the original 5 mm CL bins were modified to 2.5 mm bins and then converted as in 1; 3) the bins created in 1 were smoothed.**

| | Female | | | Male | | |
|---|---|---|---|---|---|---|
| **Min. TW for Bin** | **Original (CL converted to TW)** | **Increase CL Bins** | **Original bins smoothed** | **Original (CL converted to TW)** | **Increase CL Bins** | **Original bins smoothed** |
| 48 | 0 | 0 | 0 | 0 | 0.25 | 0.25 |
| 50 | 0 | 0.5 | 0.5 | 1 | 1 | 0.75 |
| 52 | 2 | 2.5 | 2 | 1 | 1.25 | 1.25 |
| 54 | 4 | 2 | 2.5 | 2 | 2.25 | 2 |
| 56 | 0 | 3 | 3 | 3 | 1.5 | 2.75 |
| 58 | 8 | 4 | 6.75 | 3 | 3 | 6.5 |
| 60 | 11 | 10.25 | 7.5 | 17 | 13.5 | 15 |
| 62 | 0 | 7.5 | 7.5 | 23 | 21.5 | 15.75 |
| 64 | 19 | 9.5 | 9.5 | 0 | 11.5 | 11.5 |
| 66 | 0 | 16.25 | 16.25 | 23 | 28 | 22.25 |
| 68 | 46 | 51 | 39.5 | 43 | 46.25 | 41.25 |
| 70 | 66 | 33 | 44.5 | 56 | 64 | 60.75 |
| 72 | 0 | 43 | 43 | 88 | 44 | 75 |
| 74 | 106 | 53 | 80.25 | 68 | 73 | 72.25 |
| 76 | 109 | 108.25 | 81 | 65 | 65.75 | 67.5 |
| 78 | 0 | 65.5 | 65.5 | 72 | 70.25 | 52.25 |
| 80 | 153 | 76.5 | 76.5 | 0 | 36.5 | 36.5 |
| 82 | 0 | 83.25 | 83.25 | 74 | 69 | 50.5 |
| 84 | 180 | 180 | 135 | 54 | 52.25 | 57.25 |
| 86 | 180 | 90 | 135 | 47 | 50 | 51.75 |
| 88 | 0 | 88.5 | 88.5 | 59 | 29.5 | 58.75 |
| 90 | 174 | 87 | 115.5 | 70 | 67.25 | 65.5 |
| 92 | 114 | 129 | 100.5 | 63 | 64.75 | 62 |
| 94 | 0 | 50.25 | 50.25 | 52 | 54.75 | 41.75 |
| 96 | 87 | 43.5 | 43.5 | 0 | 28.75 | 28.75 |
| 98 | 0 | 31.25 | 31.25 | 63 | 64 | 48.25 |
| 100 | 38 | 35 | 25.5 | 67 | 60.5 | 59.5 |
| 102 | 26 | 13 | 22.5 | 41 | 42.25 | 48.75 |
| 104 | 0 | 8.5 | 8.5 | 46 | 23 | 39.75 |
| 106 | 8 | 4 | 5.25 | 26 | 31 | 27.25 |
| 108 | 5 | 5.75 | 4.5 | 11 | 14.75 | 13.5 |
| 110 | 0 | 1.5 | 1.5 | 6 | 7.25 | 5.75 |
| 112 | 1 | 0.5 | 0.5 | 0 | 1.75 | 1.75 |
| 114 | 0 | 0.5 | 0.5 | 1 | 0.75 | 0.5 |
| 116 | 1 | 0.75 | 0.5 | 0 | 0 | 0.25 |
| 118 | 0 | 0 | 0.25 | 0 | 0 | 0 |

**Table 14: Coefficients for models plotted in Figure 21.**

| | | Coefficient | | Standard error | |
|---|---|---|---|---|---|
| | N | b | a | b | a |
| Re-analysis: | | | | | |
| Male | 351 | 3.3613 | -7.2962 | 0.20370 | 0.88278 |
| Female | 181 | 2.6199 | -4.6165 | 0.35505 | 1.5390 |
| Breen & Kendrick (1997, unpublished): | | | | | |
| Male | | 3.3629 | -7.3187 | | |
| Female | | 2.6025 | -4.5569 | | |

**Table 15: Comparison of the number of records by QMA in the new tag data extract (replog 11952) with the number of records in the extract made for the 2017 CRA 2 stock assessment (Starr & Webber 2018).**

| | 2017 assessment year | 2018 assessment year | Difference |
|---|---|---|---|
| CRA1 | 2 046 | 2 057 | 11 |
| CRA2 | 4 468 | 4 468 | 0 |
| CRA3 | 5 127 | 5 356 | 229 |
| CRA4 | 2 509 | 2 614 | 105 |
| CRA5 | 7 003 | 7 042 | 39 |
| CRA6 | 183 | 183 | 0 |
| CRA7 | 704 | 780 | 76 |
| CRA8 | 10 756 | 10 757 | 1 |
| CRA9 | 64 | 73 | 9 |
| | 32 860 | 33 330 | 470 |

**Table 16: Comparison of the number of records by recapture year in the new tag data extract with the number of records in the extract made for the 2017 CRA 2 stock assessment (Starr & Webber. 2018).**

| Recovery fishing year | 2017 assessment year | 2018 assessment year | Difference | Recovery fishing year | 2017 assessment year | 2018 assessment year | Difference |
|---|---|---|---|---|---|---|---|
| 1966 | 53 | 53 | 0 | 1994 | 41 | 41 | 0 |
| 1967 | 31 | 31 | 0 | 1995 | 190 | 190 | 0 |
| 1968 | 4 | 4 | 0 | 1996 | 470 | 470 | 0 |
| 1969 | 2 | 2 | 0 | 1997 | 2 465 | 2 465 | 0 |
| 1970 | 1 | 1 | 0 | 1998 | 3 064 | 3 064 | 0 |
| 1975 | 204 | 204 | 0 | 1999 | 2 401 | 2 401 | 0 |
| 1976 | 1 513 | 1 513 | 0 | 2000 | 1 560 | 1 560 | 0 |
| 1977 | 1 964 | 1 965 | 1 | 2001 | 1 392 | 1 392 | 0 |
| 1978 | 750 | 750 | 0 | 2002 | 1 554 | 1 554 | 0 |
| 1979 | 1 208 | 1 208 | 0 | 2003 | 1 197 | 1 197 | 0 |
| 1980 | 1 118 | 1 118 | 0 | 2004 | 2 202 | 2 202 | 0 |
| 1981 | 433 | 433 | 0 | 2005 | 2 315 | 2 315 | 0 |
| 1982 | 382 | 382 | 0 | 2006 | 828 | 828 | 0 |
| 1983 | 467 | 467 | 0 | 2007 | 543 | 543 | 0 |
| 1984 | 957 | 957 | 0 | 2008 | 319 | 319 | 0 |
| 1985 | 260 | 260 | 0 | 2009 | 280 | 280 | 0 |
| 1986 | 59 | 59 | 0 | 2010 | 361 | 362 | 1 |
| 1987 | 11 | 11 | 0 | 2011 | 416 | 420 | 4 |
| 1988 | 2 | 2 | 0 | 2012 | 207 | 330 | 123 |
| 1989 | 2 | 2 | 0 | 2013 | 438 | 471 | 33 |
| 1991 | 1 | 1 | 0 | 2014 | 633 | 865 | 232 |
| 1992 | 1 | 1 | 0 | 2015 | 358 | 376 | 18 |
| 1993 | 1 | 1 | 0 | 2016 | 202 | 260 | 58 |
| | | | | Total | 32 860 | 33 330 | 470 |

**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 as some records could not be assigned to a sex.**

| QMA | Male | Female | Total |
|---|---|---|---|
| CRA 1 | 924 | 1 133 | 2 057 |
| CRA 2 | 2 341 | 2 127 | 4 468 |
| CRA 3 | 4 032 | 1 324 | 5 356 |
| CRA 4 | 1 967 | 647 | 2 614 |
| CRA 5 | 4 957 | 2 085 | 7 042 |
| CRA 6 | 21 | 162 | 183 |
| CRA 7 | 352 | 428 | 780 |
| CRA 8 | 5 879 | 4 878 | 10 757 |
| CRA 9 | 27 | 46 | 73 |
| Total | 20 500 | 12 830 | 33 330 |

**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 as some records could not be assigned to a QMA. '–': no data.**

| | | | | | | | | | Recapture QMA |
|---|---|---|---|---|---|---|---|---|---|
| QMA | CRA 1 | CRA 2 | CRA 3 | CRA 4 | CRA 5 | CRA 6 | CRA 7 | CRA 8 | CRA 9 |
| CRA 1 | 1 839 | 9 | 30 | – | – | – | – | – | – |
| CRA 2 | – | 3 744 | 2 | – | – | – | – | – | – |
| CRA 3 | – | 15 | 5 150 | – | 3 | – | – | 52 | – |
| CRA 4 | – | – | – | 2 582 | 32 | – | – | – | – |
| CRA 5 | – | – | – | 3 | 5 857 | – | 6 | – | – |
| CRA 6 | – | – | – | – | – | 179 | – | – | – |
| CRA 7 | – | – | 6 | – | – | – | 757 | 17 | – |
| CRA 8 | – | 1 | 121 | – | – | – | – | 8 474 | 3 |
| CRA 9 | – | – | – | – | – | – | – | – | 73 |

**Table 19: CRA 6: number of tag recaptures by release year, recovery year and sex. '–': no data.**

| Release year | Males | Females | Total | Recovery year | Males | Females | Total |
|---|---|---|---|---|---|---|---|
| 1995 | 1 | 1 | 2 | – | – | – | – |
| 1996 | 19 | 89 | 108 | 1996 | 12 | 63 | 75 |
| 1997 | 1 | 64 | 65 | 1997 | 7 | 59 | 66 |
| 1998 | – | 8 | 8 | 1998 | 2 | 30 | 32 |
| – | – | – | – | 1999 | – | 7 | 7 |
| – | – | – | – | 2005 | – | 3 | 3 |
| Total | 21 | 162 | 183 | Total | 21 | 162 | 183 |

**Table 20: CRA 6: number of tags released (rows) and recaptured (columns) by area. '–': no data.**

| Release | Recapture statistical area | | | | | |
|---|---|---|---|---|---|---|
| statistical area | 940 | 941 | 942 | 943 | Unknown | Total |
| 940 | 81 | – | 1 | 1 | – | 83 |
| 941 | – | 83 | 1 | – | 1 | 85 |
| 942 | – | – | 10 | 1 | 2 | 13 |
| 943 | 1 | – | – | – | – | 1 |
| Unknown | – | – | – | 1 | – | 1 |
| Total | 82 | 83 | 12 | 3 | 3 | 183 |

**Table 21: Number of CRA 6 tag recaptures by release year and statistical area of release and by recovery year and statistical area of recovery. '–': no data; 'Unk': unknown statistical area.**

| Release | Release statistical area | | | | | | Recovery | Recovery statistical area | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| year | 940 | 941 | 942 | 943 | Unk | Total | year | 940 | 941 | 942 | 943 | Unk | Total |
| 1995 | – | 2 | – | – | – | 2 | – | – | – | – | – | – | – |
| 1996 | 13 | 83 | 10 | 1 | 1 | 108 | 1996 | 3 | 60 | 7 | 2 | 3 | 75 |
| 1997 | 62 | – | 3 | – | – | 65 | 1997 | 40 | 23 | 2 | 1 | – | 66 |
| 1998 | 8 | – | – | – | – | 8 | 1998 | 32 | – | – | – | – | 32 |
| – | – | – | – | – | – | – | 1999 | 7 | – | – | – | – | 7 |
| – | – | – | – | – | – | – | 2005 | – | – | 3 | – | – | 3 |
| Total | 83 | 85 | 13 | 1 | 1 | 183 | Total | 82 | 83 | 12 | 3 | 3 | 183 |

**Table 22: CRA 6: number of tag releases by area and sex.**

| Release | Sex | | |
|---|---|---|---|
| statistical area | Males | Females | Total |
| 940 | 80 | 763 | 843 |
| 941 | 520 | 2 270 | 2 790 |
| 942 | 236 | 1 031 | 1 267 |
| 943 | 51 | 162 | 213 |
| Unknown | – | 4 | 4 |
| Total | 887 | 4 230 | 5 117 |

**Table 23: Number of CRA 6 tag re-releases by sex. Re-release event code=0 means the first release-recapture event.**

| Re-release | Sex | | | % |
|---|---|---|---|---|
| event | Males | Females | Total | by event |
| 0 | 20 | 148 | 168 | 92.0% |
| 1 | 1 | 10 | 11 | 6.0% |
| 2 | – | 2 | 2 | 1.1% |
| 3 | – | 1 | 1 | 0.5% |
| 4 | – | 1 | 1 | 0.5% |
| Total | 21 | 162 | 183 | |

**Table 24: Areas 926, 927, 928: number of tag recaptures by release year, recovery year and sex. Left columns are for releases from Areas 926, 927 and 928 while right columns are for recoveries in Areas 926, 927, and 928. '–': no data.**

| Release year | Males | Females | Total | Recovery year | Males | Females | Total |
|---|---|---|---|---|---|---|---|
| – | – | – | – | 1967 | 2 | 2 | 4 |
| – | – | – | – | 1968 | 1 | – | 1 |
| 1978 | 130 | 169 | 299 | – | – | – | – |
| 1979 | 223 | 416 | 639 | 1979 | 1 | – | 1 |
| 1980 | – | 1 | 1 | – | – | – | – |
| 1981 | 96 | 111 | 207 | – | – | – | – |
| 1984 | 27 | 26 | 53 | 1984 | 1 | 1 | 2 |
| – | – | – | – | 1985 | 26 | 22 | 48 |
| – | – | – | – | 1986 | 1 | 1 | 2 |
| – | – | – | – | 1988 | 1 | – | 1 |
| – | – | – | – | 1989 | – | 1 | 1 |
| – | – | – | – | 1991 | – | 1 | 1 |
| 1993 | 31 | 23 | 54 | 1993 | 1 | – | 1 |
| 1994 | 5 | 4 | 9 | 1994 | 15 | 9 | 24 |
| 1995 | 101 | 110 | 211 | 1995 | 23 | 25 | 48 |
| 1996 | 5 | 9 | 14 | 1996 | 20 | 22 | 42 |
| 1997 | 322 | 1 001 | 1 323 | 1997 | 68 | 293 | 361 |
| 1998 | 640 | 518 | 1 158 | 1998 | 434 | 658 | 1 092 |
| 1999 | 257 | 249 | 506 | 1999 | 529 | 498 | 1 027 |
| 2000 | 115 | 132 | 247 | 2000 | 253 | 268 | 521 |
| 2001 | 18 | 38 | 56 | 2001 | 56 | 115 | 171 |
| 2002 | 22 | 40 | 62 | 2002 | 39 | 73 | 112 |
| 2003 | 1 229 | 23 | 1 252 | 2003 | 17 | 39 | 56 |
| 2004 | 534 | 18 | 552 | 2004 | 1 215 | 43 | 1 258 |
| 2005 | 230 | 12 | 242 | 2005 | 508 | 42 | 550 |
| 2006 | 130 | 11 | 141 | 2006 | 290 | 28 | 318 |
| 2007 | 33 | 3 | 36 | 2007 | 81 | 15 | 96 |
| 2008 | 24 | 4 | 28 | 2008 | 59 | 6 | 65 |
| 2009 | 7 | 2 | 9 | 2009 | 25 | 7 | 32 |
| 2010 | 3 | 2 | 5 | 2010 | 16 | 3 | 19 |
| 2011 | 1 | 7 | 8 | 2011 | 4 | 12 | 16 |
| – | – | – | – | 2012 | 1 | 4 | 5 |
| – | – | – | – | 2013 | 1 | – | 1 |
| Total | 4 183 | 2 929 | 7 112 | Total | 3 688 | 2 188 | 5 876 |

**Table 25: Areas 926, 927, 928: number of tags released (rows) and recaptured (columns) by area. '–': no data; 'Unk': unknown recovery area**

| Release statistical area | Recapture statistical area | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 906 | 923 | 924 | 925 | 926 | 927 | 928 | 929 | Unk | Total |
| 926 | – | 7 | 5 | 5 | 1 157 | 263 | 53 | 1 | 1 | 1 492 |
| 927 | 1 | – | 1 | – | 19 | 3 820 | 25 | 1 | 1 279 | 5 146 |
| 928 | – | – | 1 | – | 2 | 21 | 394 | 1 | 55 | 474 |
| Total | 1 | 7 | 7 | 5 | 1 178 | 4 104 | 472 | 3 | 1 335 | 7 112 |

**Table 26: Number of Areas 926, 927, 928 tag recaptures by release year and statistical area of release and by recovery year and statistical area of recovery. Left columns are for releases from Areas 926, 927 and 928 while right columns are for recoveries in Areas 926, 927, and 928. '–': no data.**

| Release | Release statistical area | | | | Recovery | Recovery statistical area | | | |
|---|---|---|---|---|---|---|---|---|---|
| year | 926 | 927 | 928 | Total | year | 926 | 927 | 928 | Total |
| – | – | – | – | – | 1967 | 3 | 1 | – | 4 |
| – | – | – | – | – | 1968 | 1 | – | – | 1 |
| 1978 | – | 299 | – | 299 | – | – | – | – | – |
| 1979 | – | 639 | – | 639 | 1979 | – | 1 | – | 1 |
| 1980 | – | 1 | – | 1 | – | – | – | – | – |
| 1981 | – | 207 | – | 207 | – | – | – | – | – |
| 1984 | 53 | – | – | 53 | 1984 | 1 | 1 | – | 2 |
| – | – | – | – | – | 1985 | 41 | 5 | 2 | 48 |
| – | – | – | – | – | 1986 | 1 | 1 | – | 2 |
| – | – | – | – | – | 1988 | 1 | – | – | 1 |
| – | – | – | – | – | 1989 | – | 1 | – | 1 |
| – | – | – | – | – | 1991 | – | 1 | – | 1 |
| 1993 | 54 | – | – | 54 | 1993 | 1 | – | – | 1 |
| 1994 | 6 | 3 | – | 9 | 1994 | 17 | 5 | 2 | 24 |
| 1995 | 6 | 159 | 46 | 211 | 1995 | 23 | 18 | 7 | 48 |
| 1996 | 2 | – | 12 | 14 | 1996 | 5 | 3 | 34 | 42 |
| 1997 | 208 | 975 | 140 | 1 323 | 1997 | 42 | 241 | 78 | 361 |
| 1998 | 374 | 699 | 85 | 1 158 | 1998 | 161 | 841 | 90 | 1 092 |
| 1999 | 101 | 379 | 26 | 506 | 1999 | 279 | 698 | 50 | 1 027 |
| 2000 | 7 | 235 | 5 | 247 | 2000 | 54 | 441 | 26 | 521 |
| 2001 | 1 | 55 | – | 56 | 2001 | 14 | 140 | 17 | 171 |
| 2002 | 4 | 57 | 1 | 62 | 2002 | 16 | 92 | 4 | 112 |
| 2003 | 547 | 613 | 92 | 1 252 | 2003 | 14 | 40 | 2 | 56 |
| 2004 | 119 | 385 | 48 | 552 | 2004 | 449 | 694 | 115 | 1 258 |
| 2005 | 9 | 222 | 11 | 242 | 2005 | 70 | 434 | 46 | 550 |
| 2006 | – | 135 | 6 | 141 | 2006 | 10 | 276 | 32 | 318 |
| 2007 | 1 | 35 | – | 36 | 2007 | 5 | 90 | 1 | 96 |
| 2008 | – | 27 | 1 | 28 | 2008 | 2 | 60 | 3 | 65 |
| 2009 | – | 9 | – | 9 | 2009 | 3 | 28 | 1 | 32 |
| 2010 | – | 4 | 1 | 5 | 2010 | – | 15 | 4 | 19 |
| 2011 | – | 8 | – | 8 | 2011 | – | 16 | – | 16 |
| – | – | – | – | – | 2012 | – | 5 | – | 5 |
| – | – | – | – | – | 2013 | – | 1 | – | 1 |
| Total | 1 492 | 5 146 | 474 | 7 112 | Total | 1 213 | 4 149 | 514 | 5 876 |

**Table 27: Areas 926, 927, 928: number of tag releases by area and sex.**

| Release | Sex | | |
|---|---|---|---|
| statistical area | Males | Females | Total |
| 926 | 6 902 | 2 772 | 9 674 |
| 927 | 7 087 | 5 480 | 12 567 |
| 928 | 1 632 | 1 344 | 2 976 |
| Total | 15 621 | 9 596 | 25 217 |

**Table 28: Number of CRA 6 tag re-releases by sex. Re-release event code=0 means the first release-recapture event.**

| Re-release | Sex | | | % |
|---|---|---|---|---|
| event | Males | Females | Total | by event |
| 0 | 2 697 | 2 029 | 4 726 | 66% |
| 1 | 769 | 489 | 1 258 | 18% |
| 2 | 353 | 212 | 565 | 7.9% |
| 3 | 171 | 111 | 282 | 4.0% |
| 4 | 88 | 47 | 135 | 1.9% |
| 5 | 45 | 17 | 62 | 0.9% |
| 6 | 29 | 10 | 39 | 0.5% |
| 7 | 19 | 3 | 22 | 0.3% |
| 8 | 10 | 2 | 12 | 0.2% |
| 9 | 2 | 2 | 4 | 0.1% |
| 10 | – | 3 | 3 | 0.04% |
| 11 | – | 2 | 2 | 0.03% |
| 12 | – | 1 | 1 | 0.01% |
| 13 | – | 1 | 1 | 0.01% |
| Total | 4 183 | 2 929 | 7 112 | |

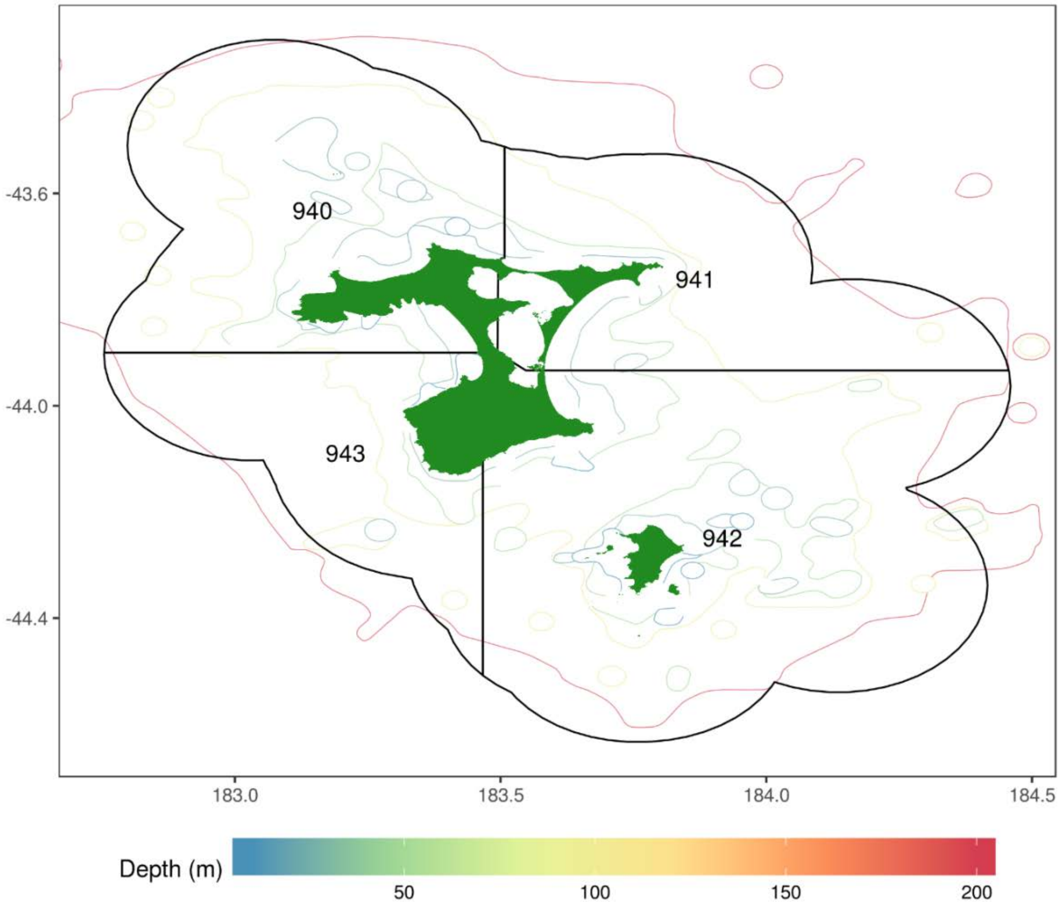


**Figure 1: Map showing location of CRA 6 and its statistical areas.**

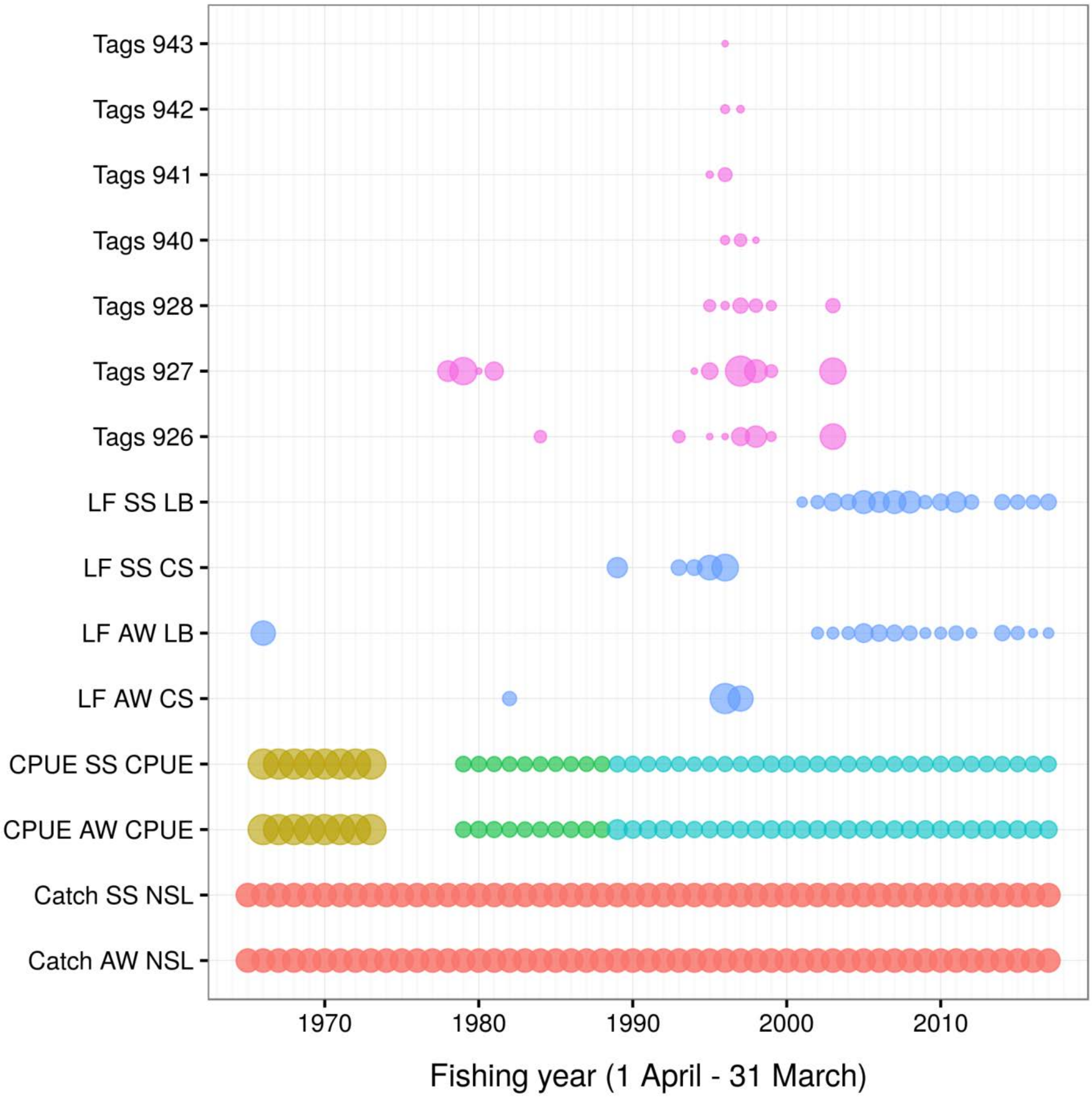


**Figure 2: Extent of data from each fishing year used in the CRA 6 stock assessment. The size of the bubbles respectively represent the relative number of recaptured tags, the effective sample size for length frequency distributions, the standard deviation for CPUE, and a fixed size for catch. The bubble colours represent different data sets (e.g. for CPUE, CR, FSU and CELR series).**

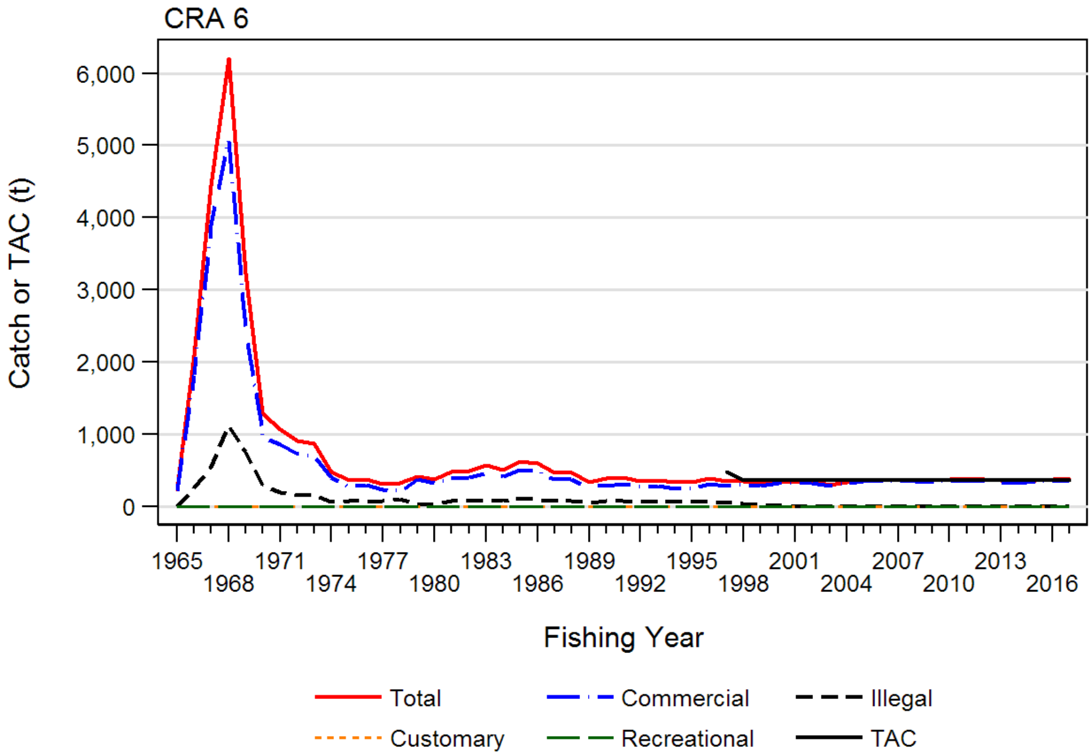


**Figure 3:** **Annual catches (tonnes) by fishery (commercial, illegal, recreational and customary), using the three RLFAWG agreed non-commercial catch series (see Sections 2.2, 2.3 and 2.4).**

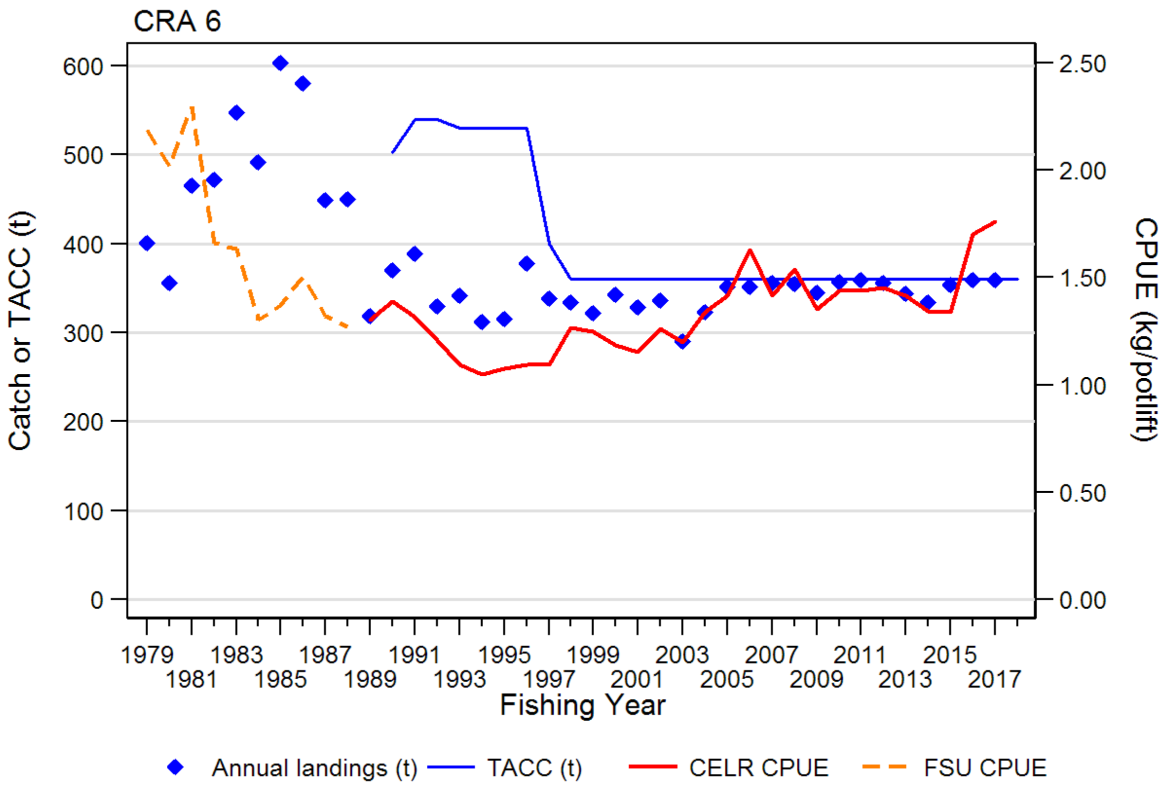


**Figure 4:** **Plot of annual commercial landings (tonnes), the TACC (tonnes) and the annual standardised CPUE index by fishing year, 1979–2017. The 1989–2017 CELR indices have been estimated including a [`vessel`] explanatory variable while the 1979–1988 FSU indices have been estimated separately without the [`vessel`] explanatory variable.**

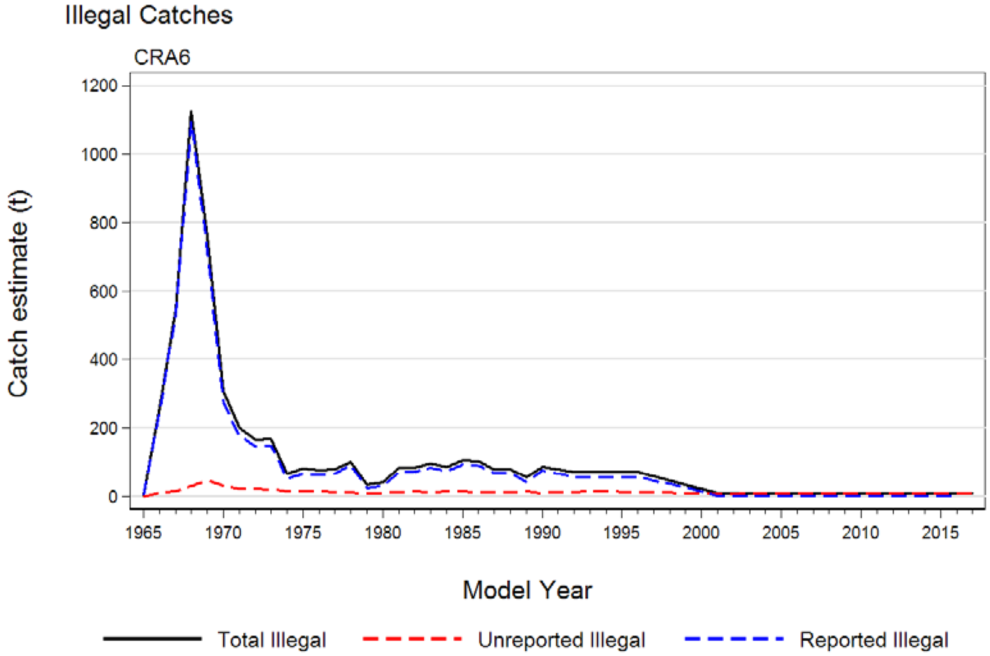


**Figure 5: CRA 6 illegal catch trajectory: 'unreported illegal' catches are added to the catch history while 'reported illegal' catches are subtracted from the commercial catch.**

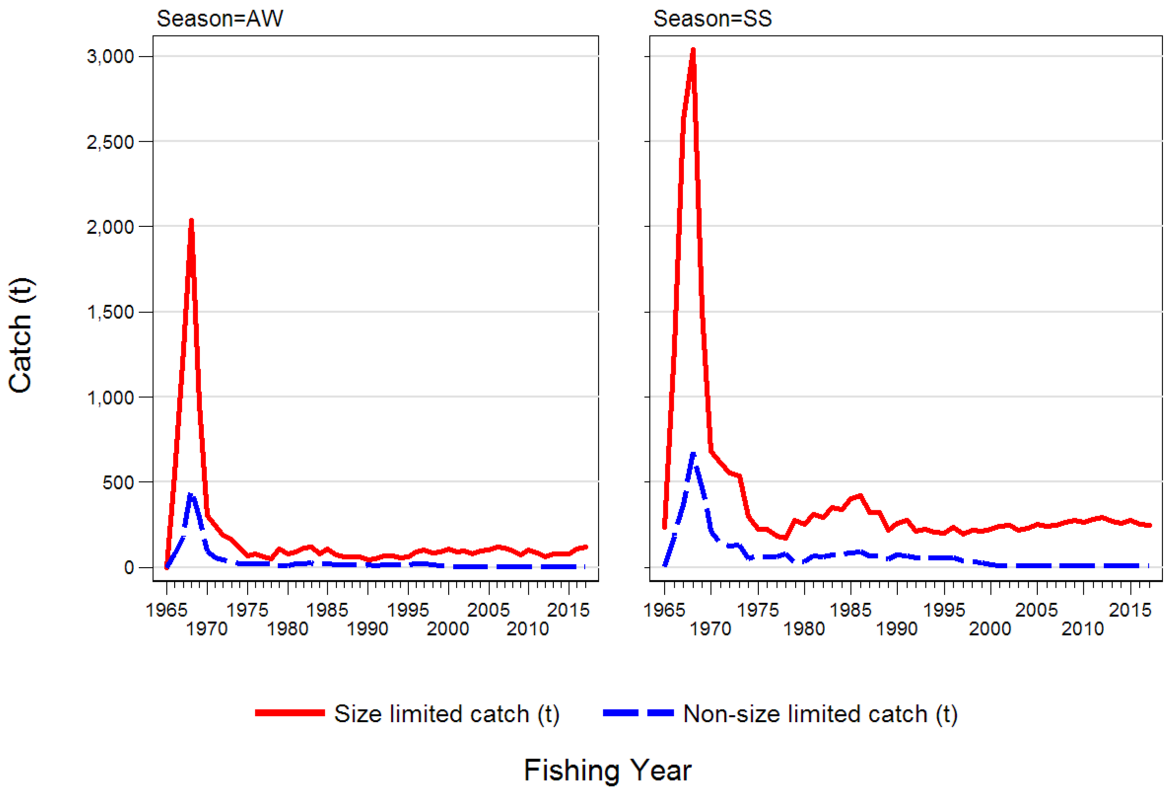


**Figure 6: The seasonal SL and NSL catches (tonnes) plotted by fishing year, beginning in 1965 using RLFAWG agreed non-commercial catches (see Sections 2.2, 2.3 and 2.4).**

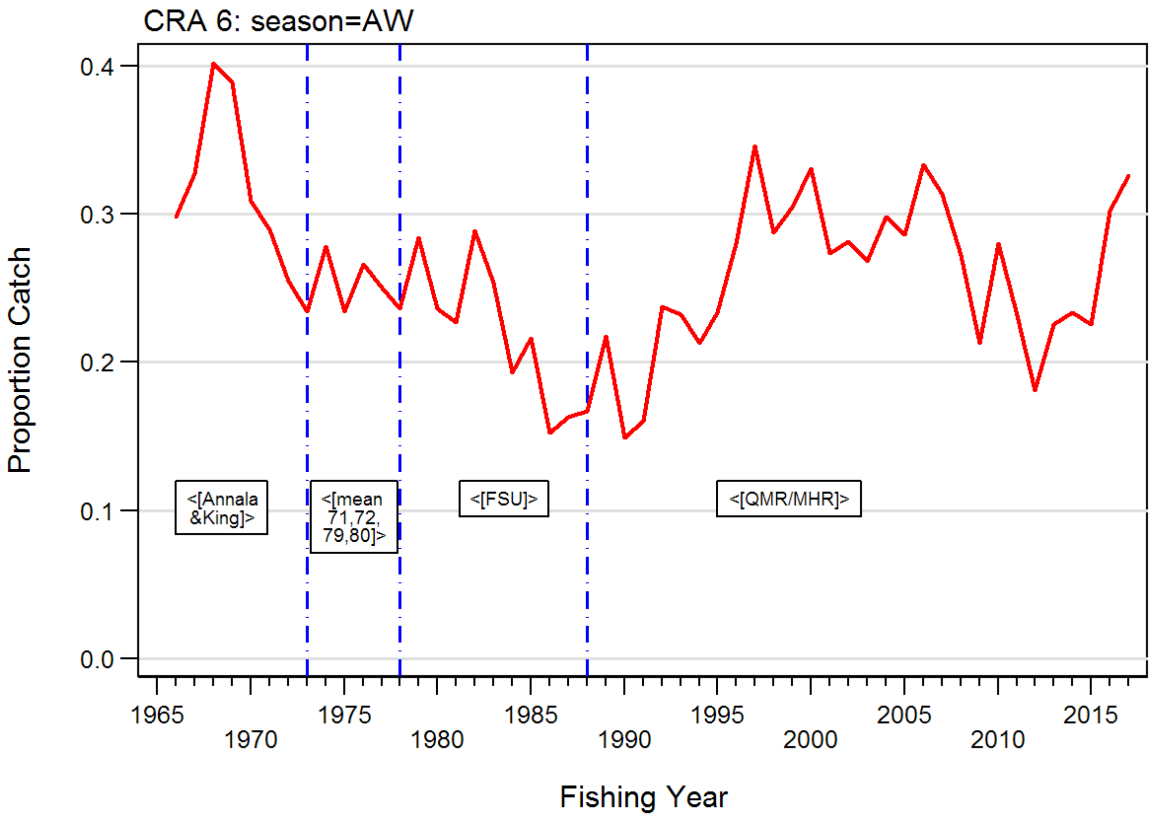


**Figure 7: Proportion of the commercial catch taken in the AW season by fishing year for CRA 6.**

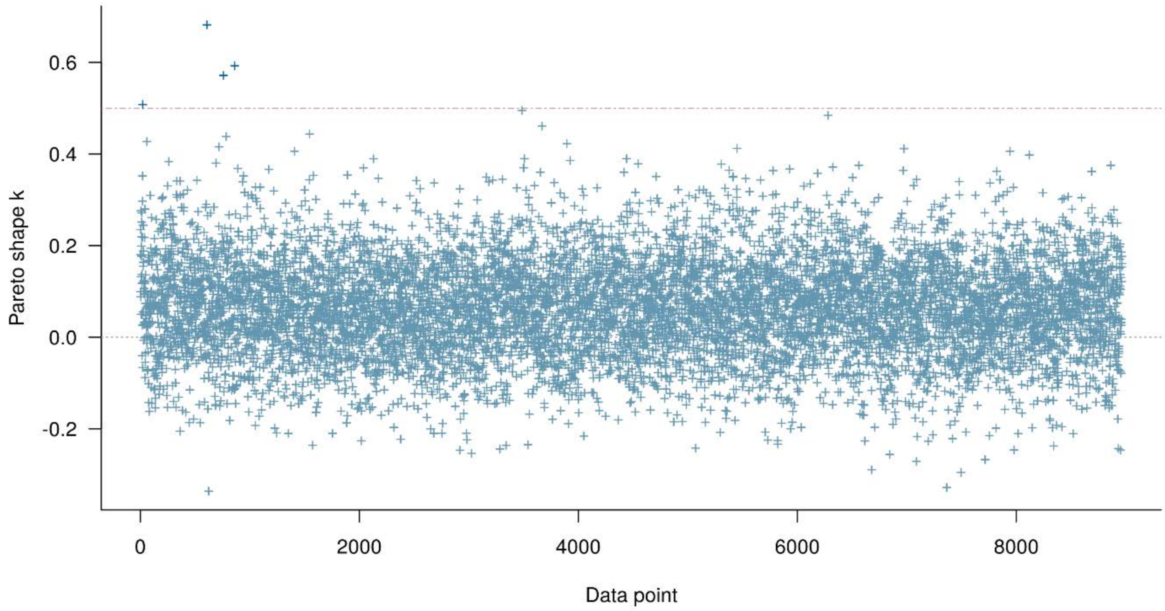


**Figure 8: Interaction Model: Tail shape (Pareto shape parameter k) estimates for each point's contribution to the model comparison leave-one-out information criteria (LOOIC). All points fall below the preferred threshold k < 0.7, with the majority of estimates below k < 0.5 (where the distribution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

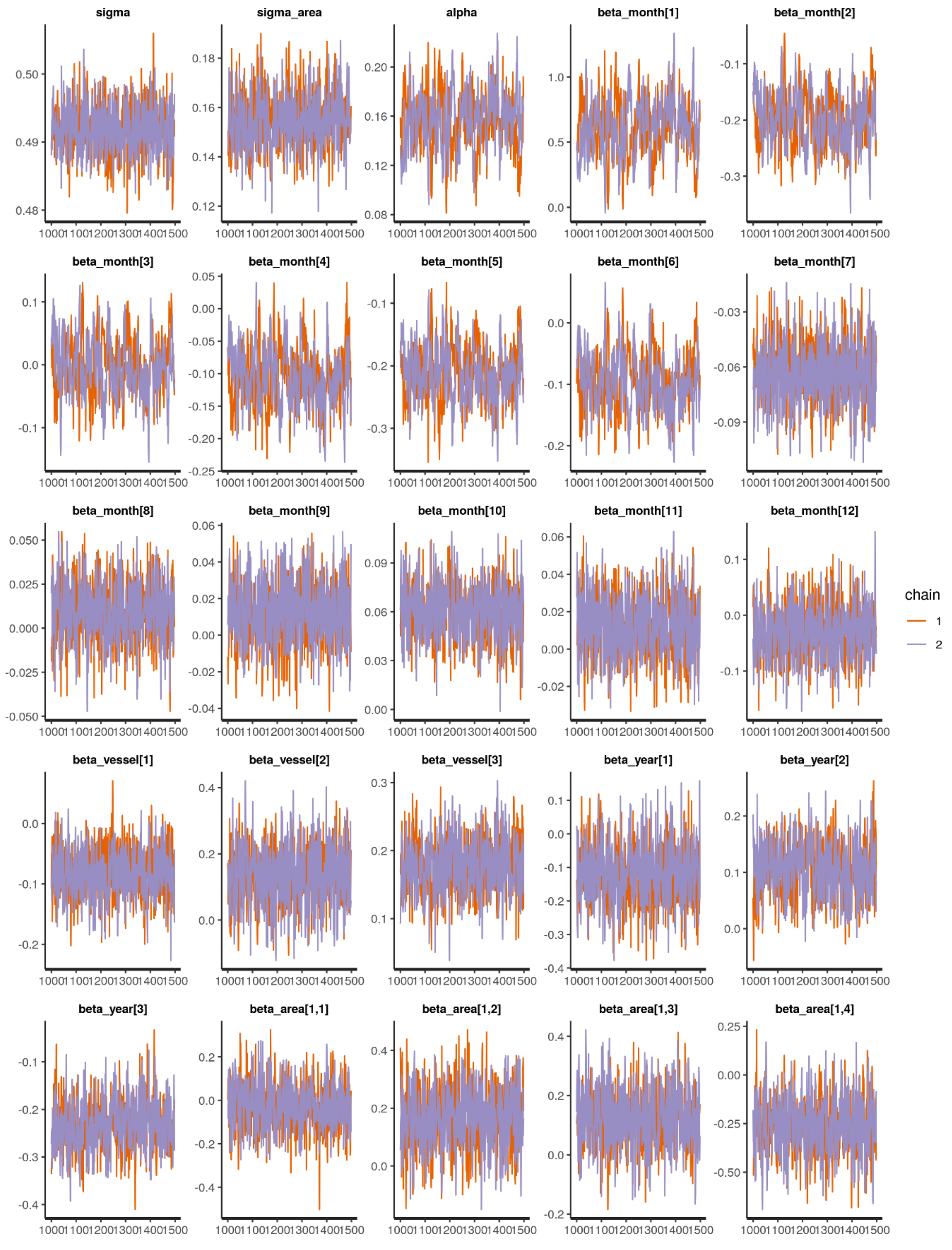


**Figure 9: Trace plots of the posterior samples of the MCMC for parameters and coefficients of the interaction model.**

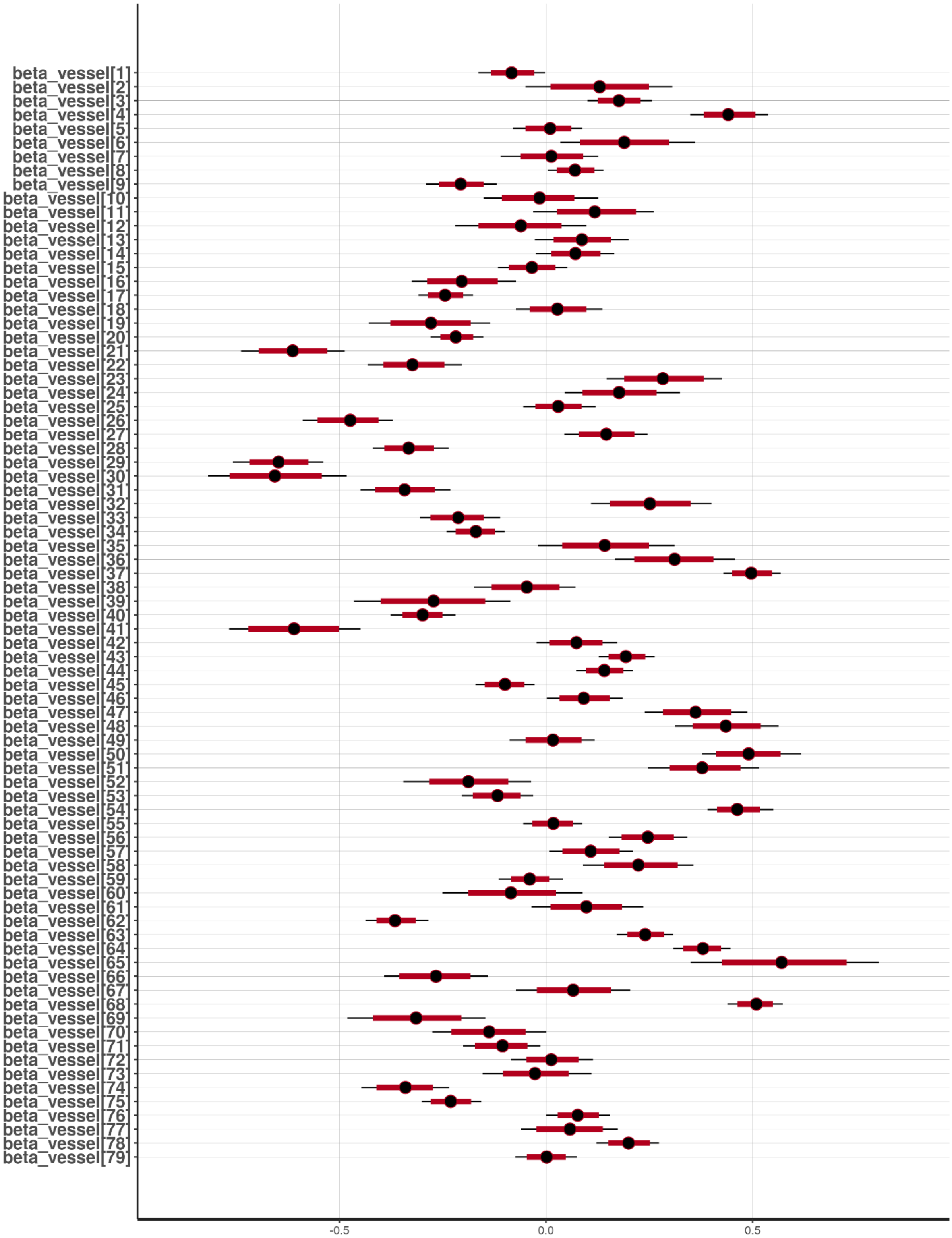


**Figure 10: Coefficients for vessels with at least five years' experience in the fishery from the CRA 6 seasonal CPUE standardisation (Interaction model). MCMC median (black dots), MCMC 95% credible interval (red bars), MCMC marginal posterior distribution range (black bars).**

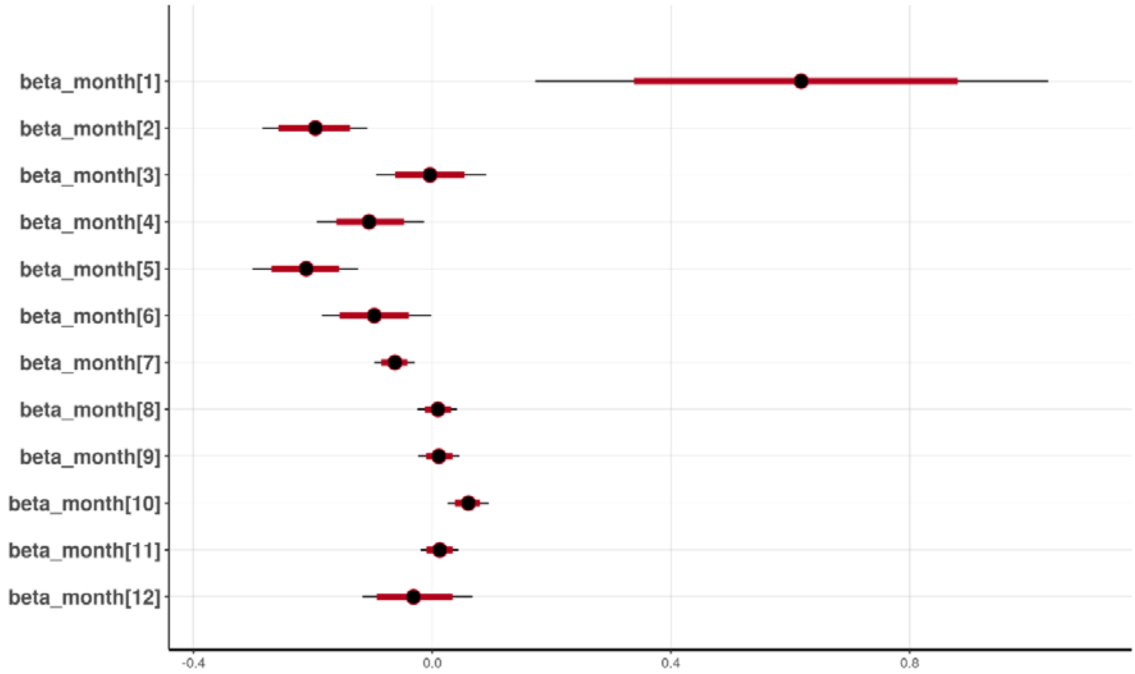


**Figure 11: Coefficients for month from the CRA 6 seasonal CPUE standardisation, Interaction model. Month coefficients are forced to sum to 1. MCMC median (black dots), MCMC 95% credible interval (red bars), MCMC marginal posterior distribution range (black bars).**

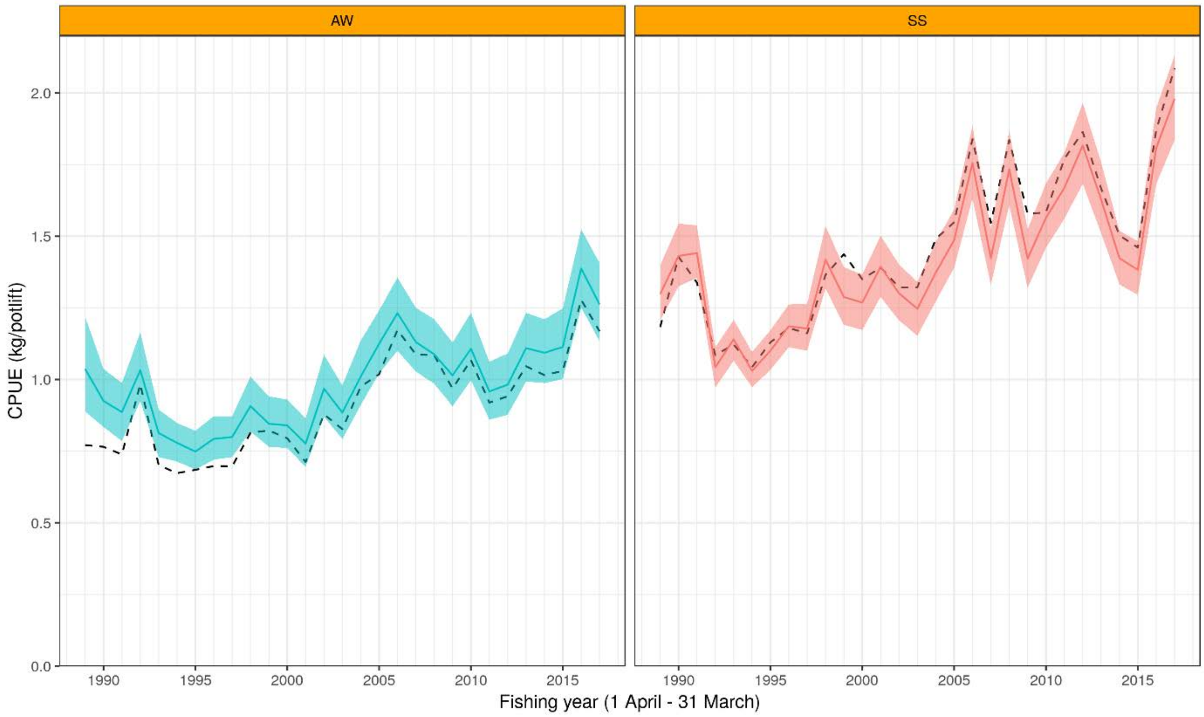


**Figure 12: CPUE indices (kg/potlift) by season and fishing year for the CRA 6 seasonal CPUE GLM analysis which included a vessel variable filtered for vessels with at least five years' experience in the fishery using the F2 algorithm scaled to "LFX" landings from 1989–90 to 2017–18: AW ($^{g}\bar{\mu}$ =0.97 kg/potlift) and SS ($^{g}\bar{\mu}$ =1.39 kg/potlift). MCMC sample median (solid line) and 95% credible interval (shaded area) for the Interaction model, and MCMC sample median (dashed line) for the Null model.**

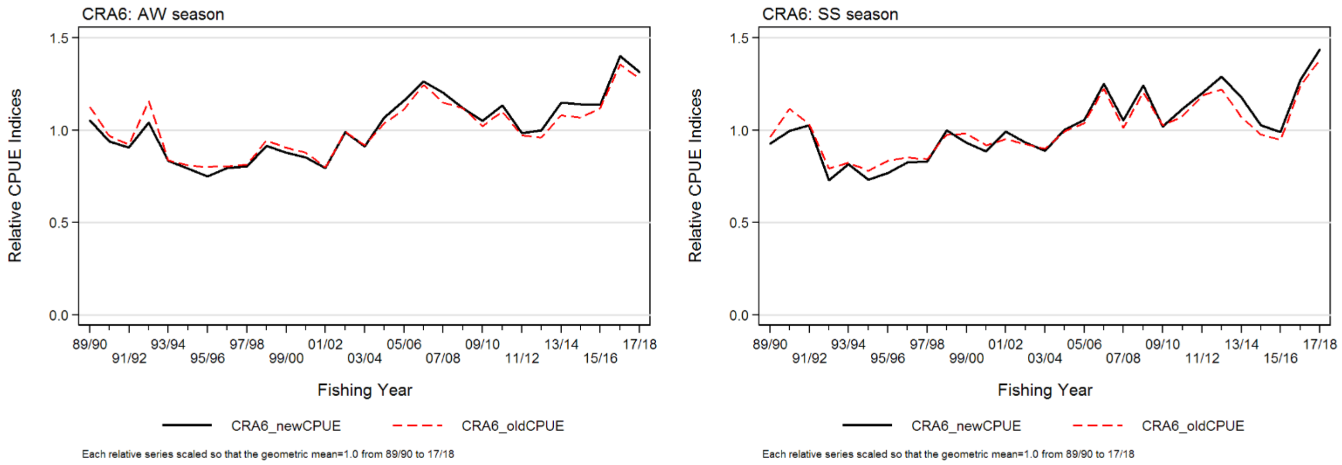


**Figure 13: Comparison of the seasonal trajectories [AW: left panel; SS: right panel] calculated using the previous standardisation procedure with the median trajectory from the new Bayesian standardisation procedure.**

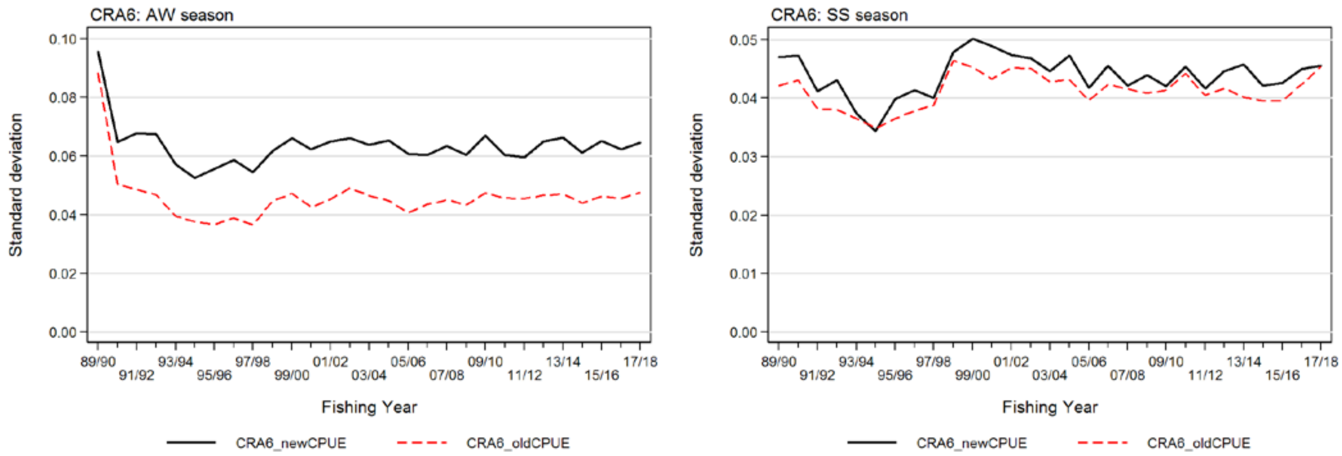


**Figure 14: Comparison of the standard deviation [AW: left panel; SS: right panel] calculated using the previous standardisation procedure with the median standard deviation from the new Bayesian standardisation procedure.**

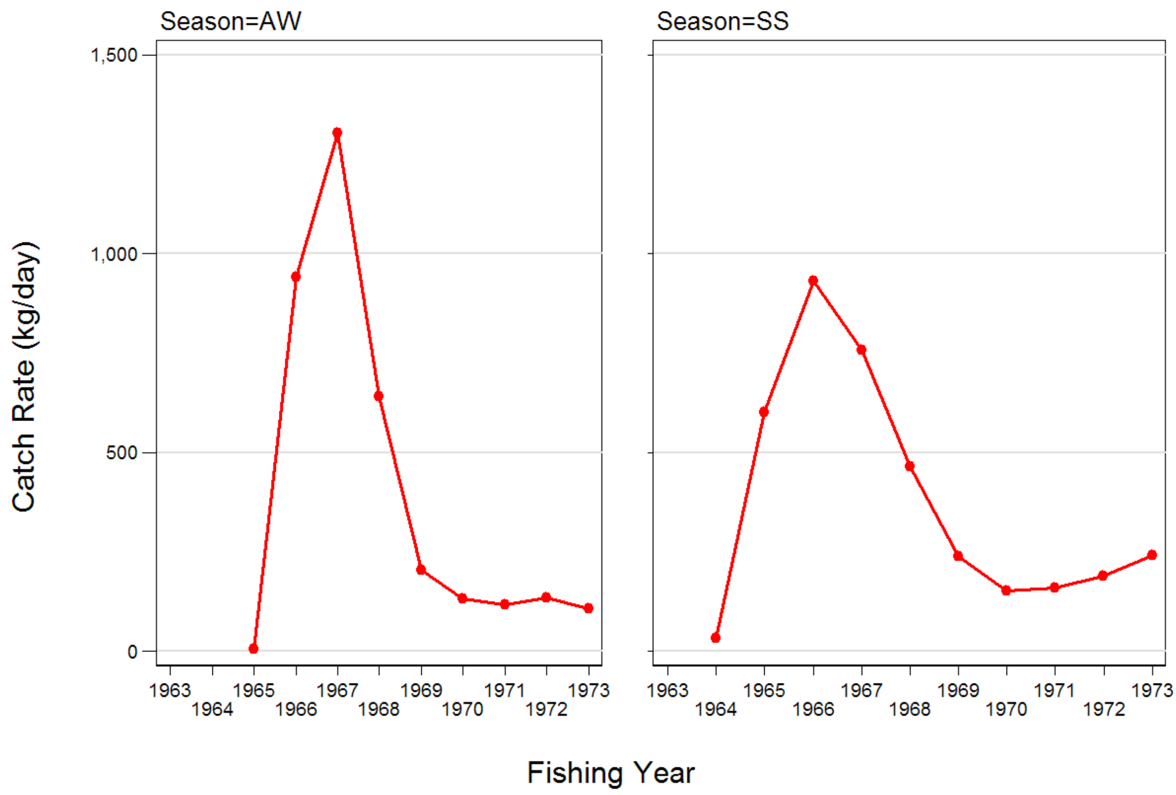


**Figure 15: Annala & King (1983) seasonal catch rate by fishing year for CRA 6.**

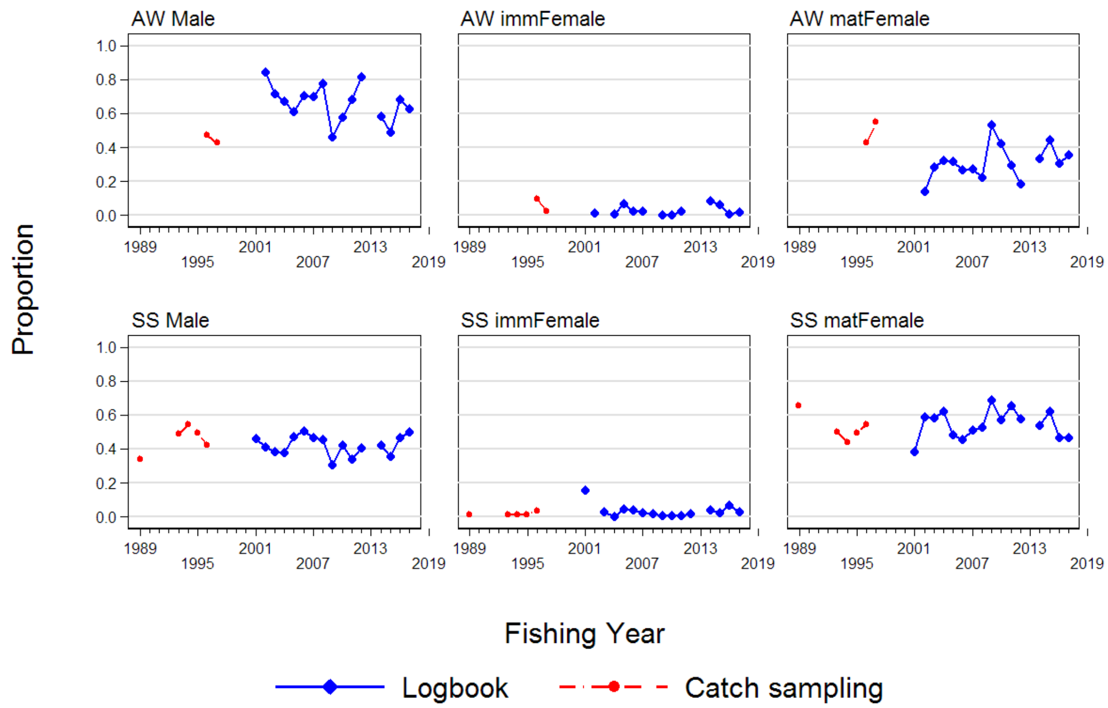


**Figure 16: Proportion-at-sex by year, season and sampling source.**

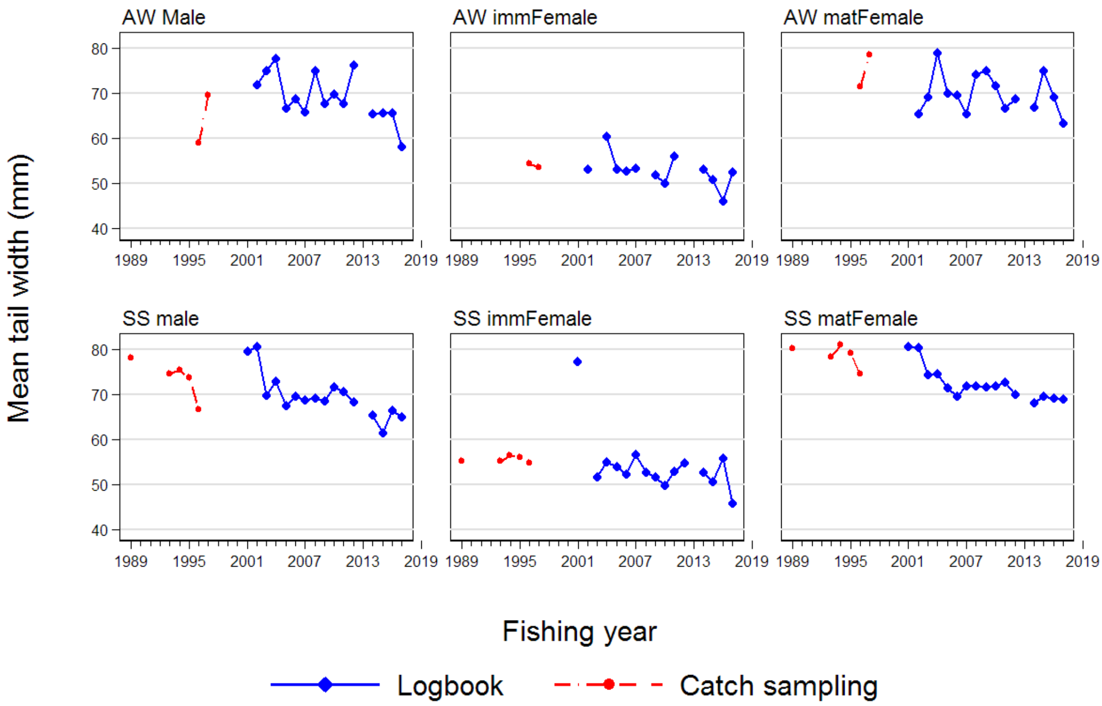


**Figure 17: Mean tail width (mm) by year, season, sex and sampling source.**

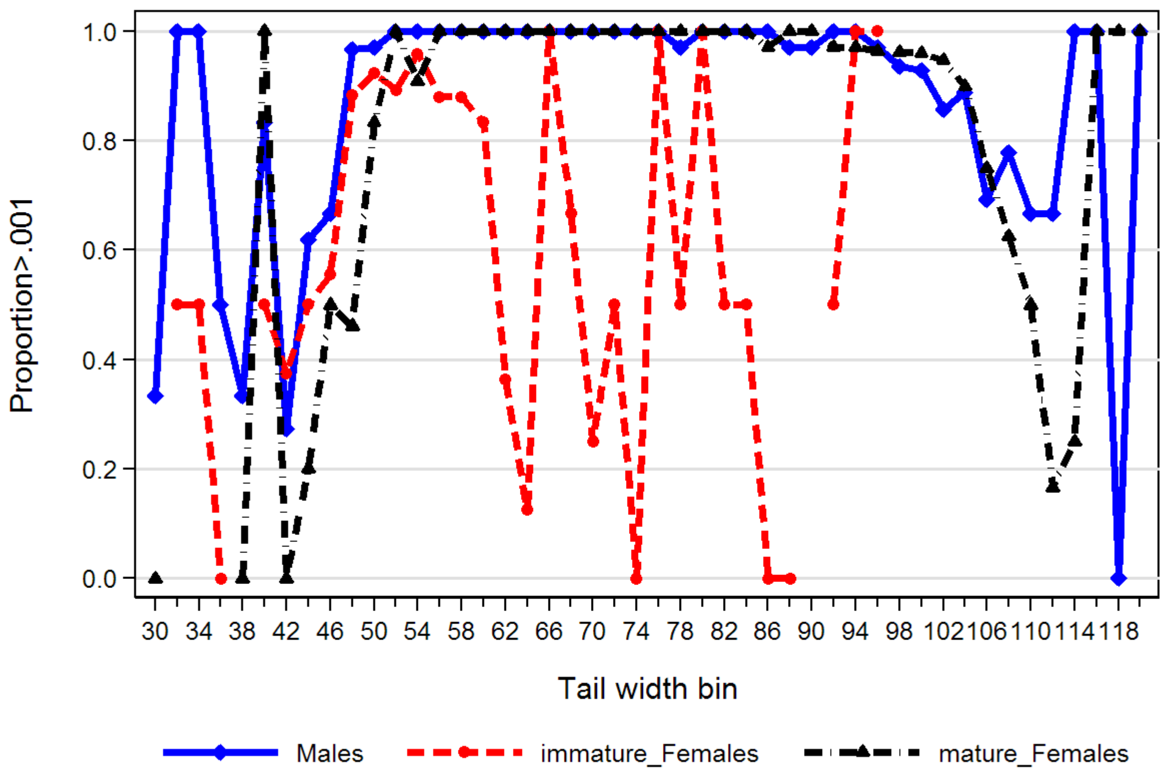


**Figure 18: The proportion of size bins (across 86 year/season/sampling source strata) that contain a proportion of 0.001 or higher when the data are normalised by sex.**

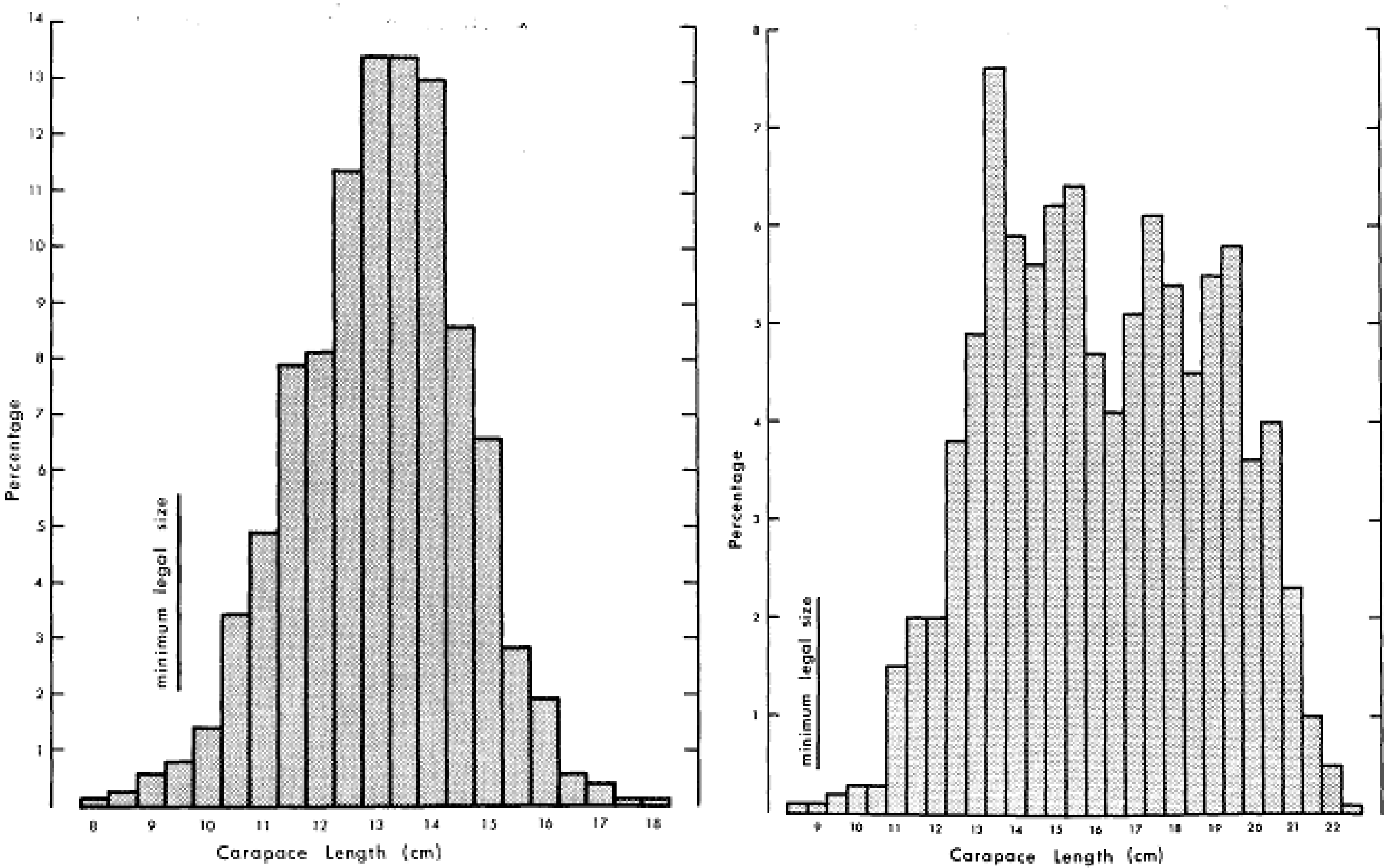


**Figure 19: Percentage at length from a 1966 rock lobster sample from the Chatham Islands (female shown in left panel and males in right panel). The figure is taken from Kensler (1969).**

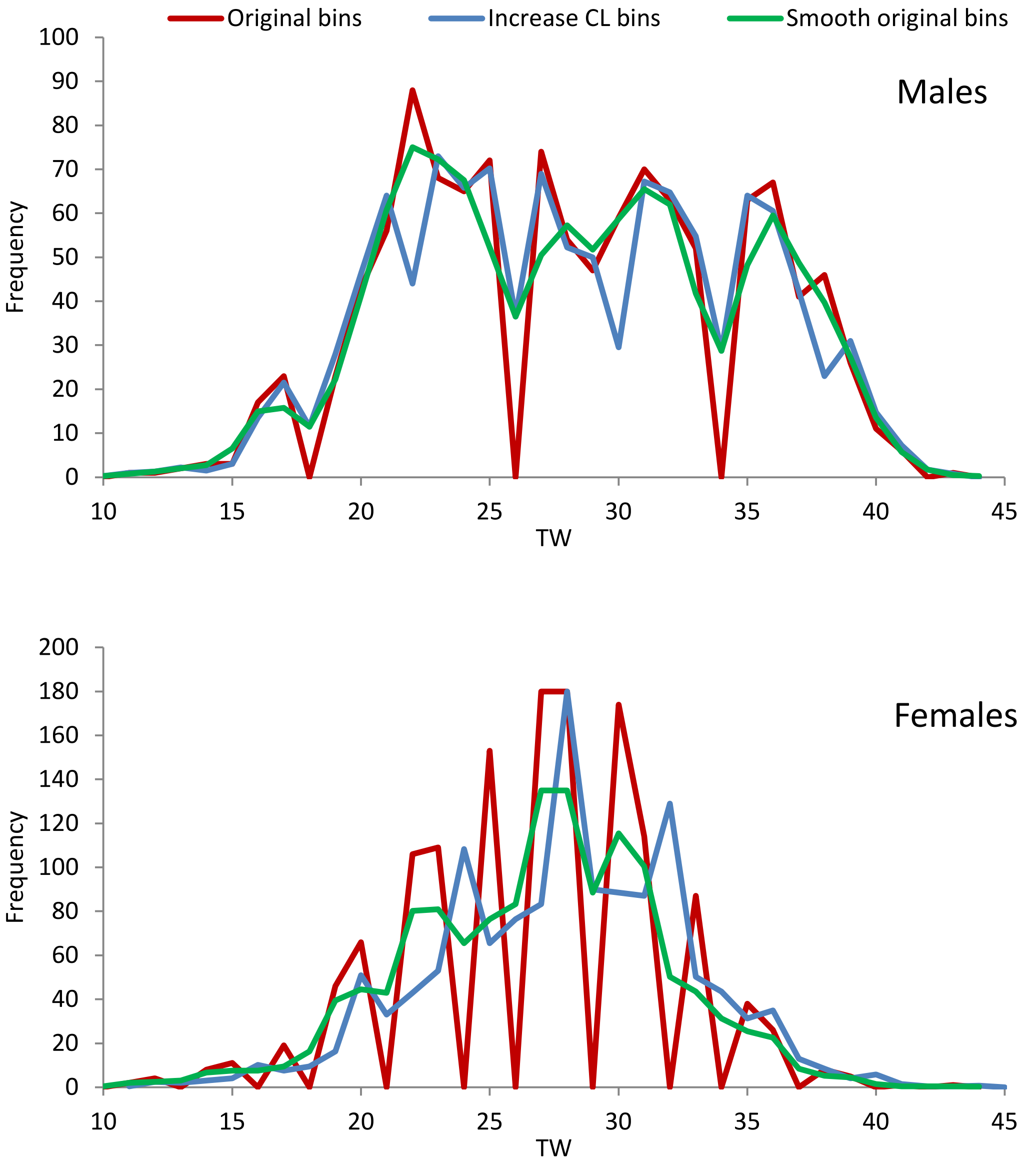


**Figure 20: Length frequency distributions by 2 mm TW bins using 3 methods to generate the observations: 1) Converting the original 5mm bin CLs to TWs and then applying the 2 mm bins; 2) Increasing the original 5mm CL bins to 2.5 mm bins before converting to TW and binning; and 3) smoothing the original bins generated by method 1.**

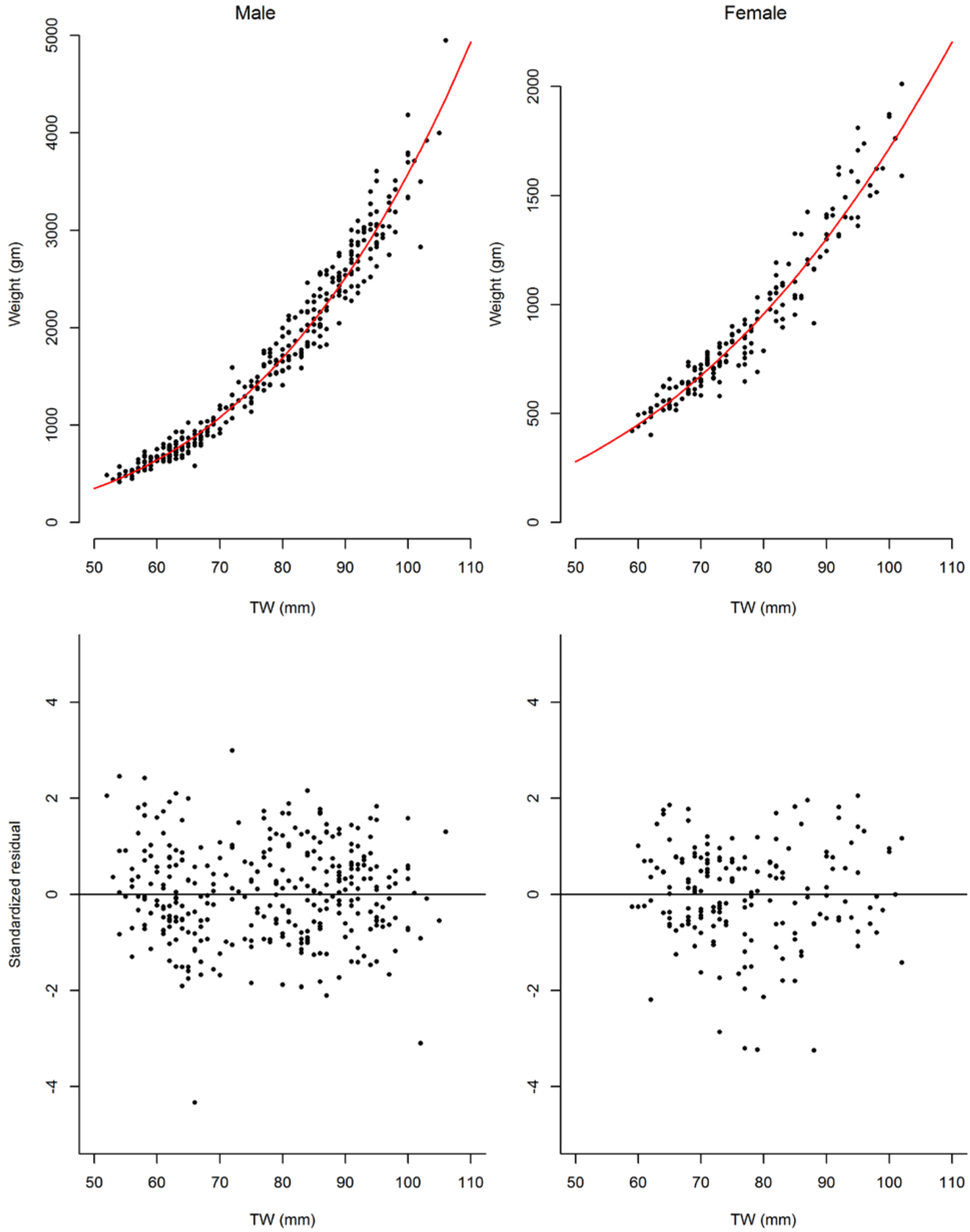


**Figure 21: CRA 6 TW-weight data and the relationship predicted using geometric mean regression for male and female rock lobster (upper panels) and the standardised residuals from the regression fits (bottom panels).**

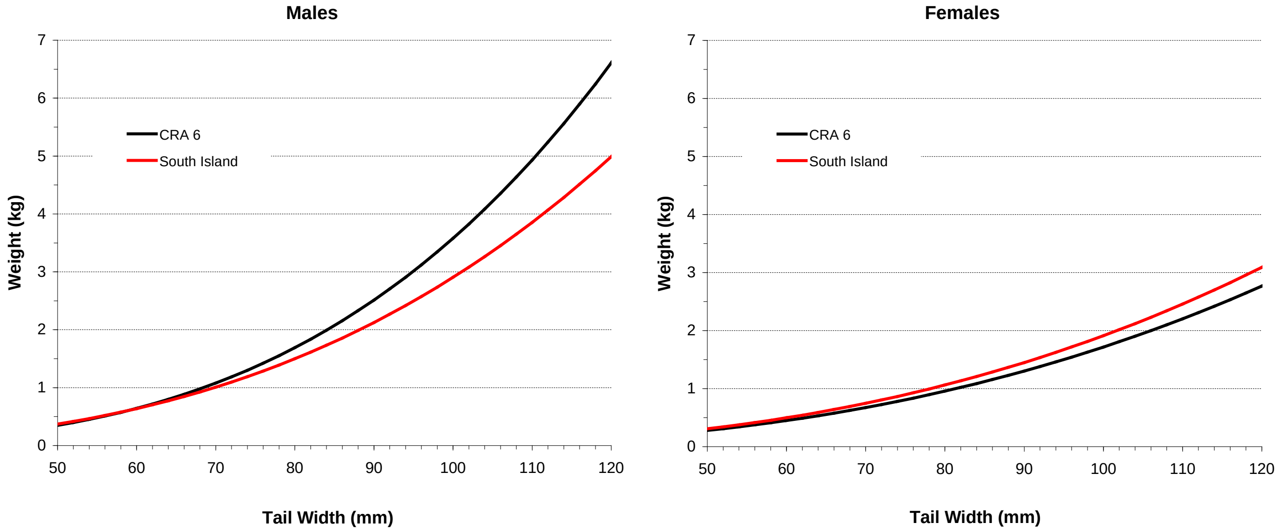


**Figure 22: Comparison of sex-specific growth estimated by the CRA 6 (Chatham Islands) length-weight function (Table 14) with the equivalent South Island (SI) growth estimated by the SI length-weight function.**

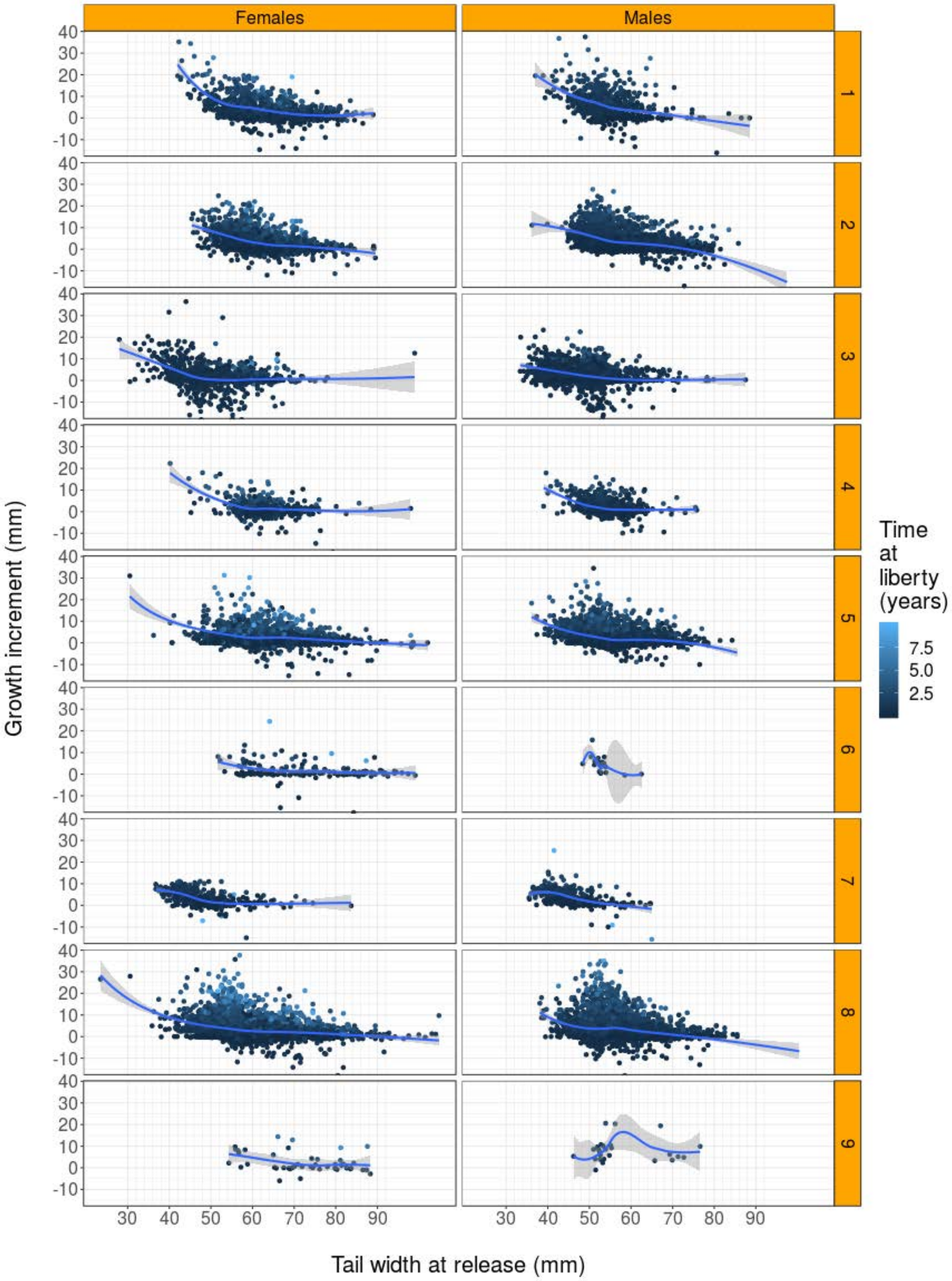


**Figure 23: Growth increments (mm) by size at release (mm), sex, and QMA. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown.**

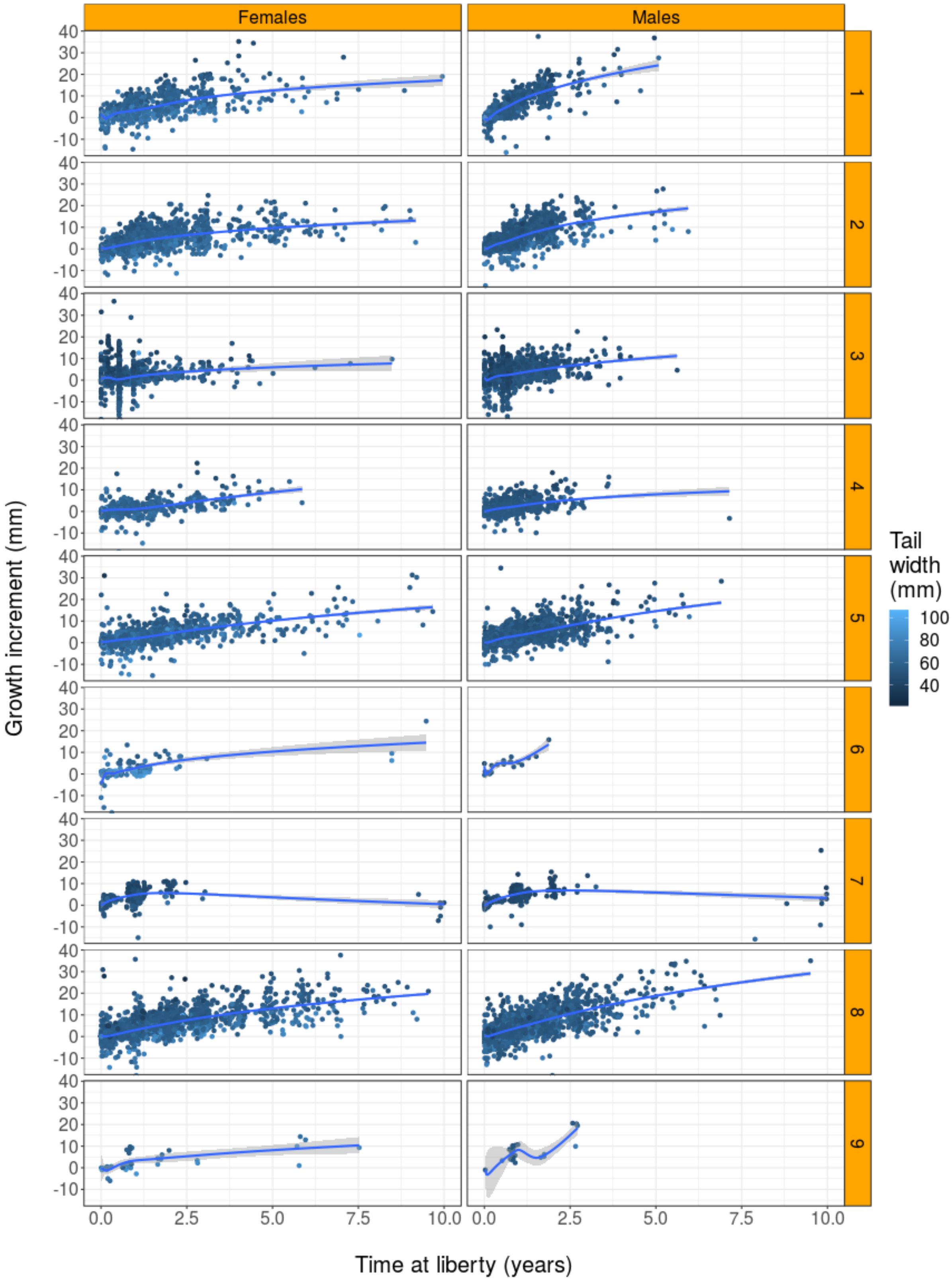


**Figure 24: Growth increments (mm) by time at liberty (years), sex, and QMA. The colour of each point represents the size at release (mm). A loess smoother and the 95% confidence interval about this smoother is also shown.**

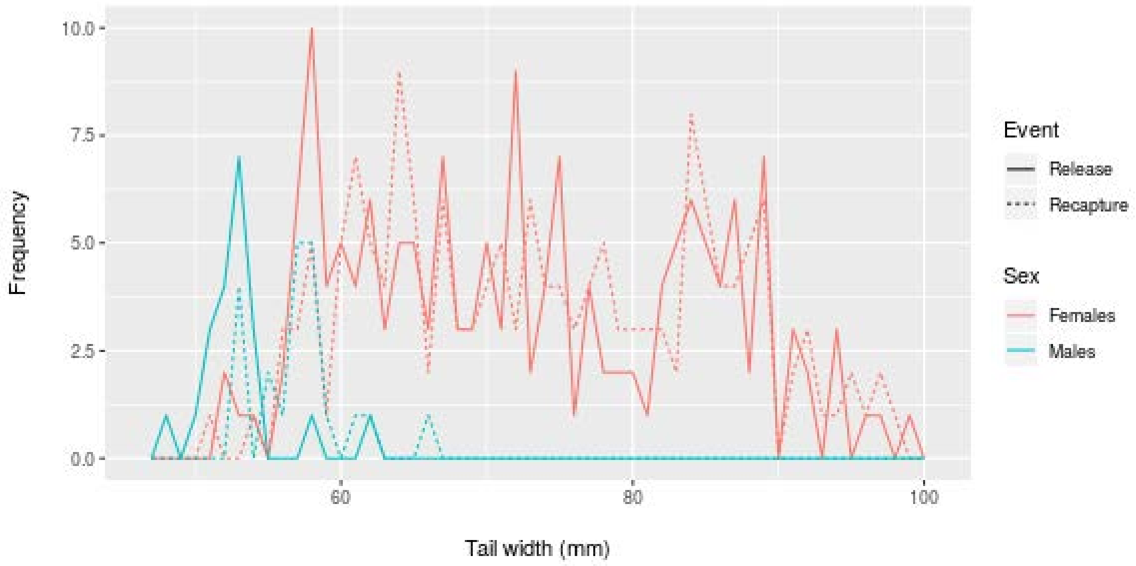


**Figure 25: CRA 6: Frequency polygons of size at release (solid lines) and recapture (dashed lines) by sex. A bin width of 1 mm was used.**

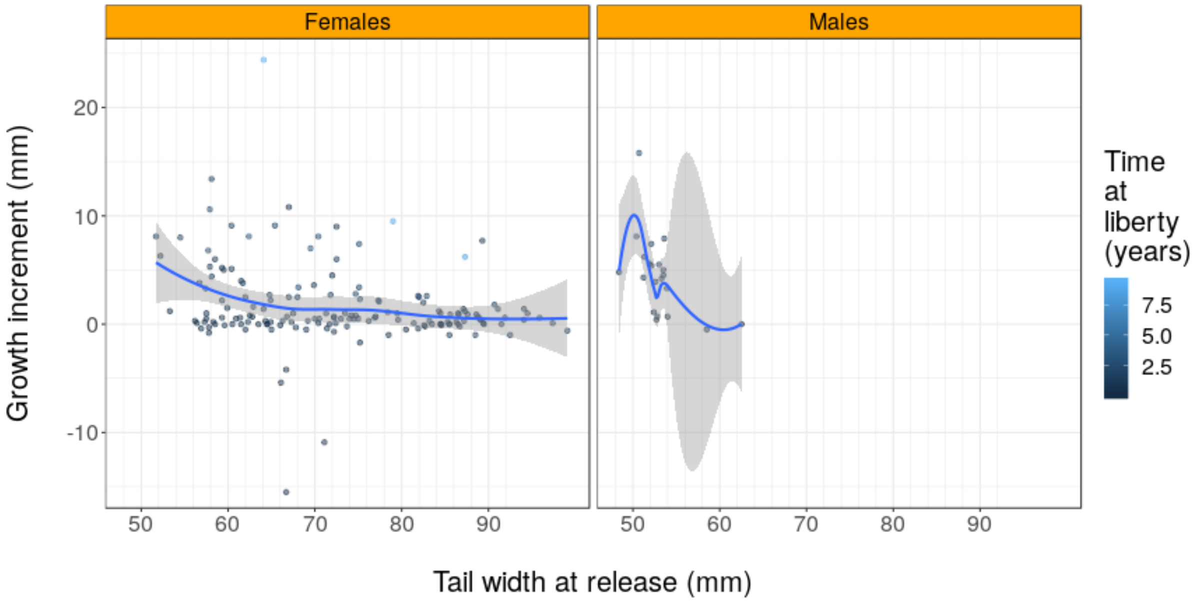


**Figure 26: CRA 6 growth increments (mm) by size at release (mm) and sex. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.**

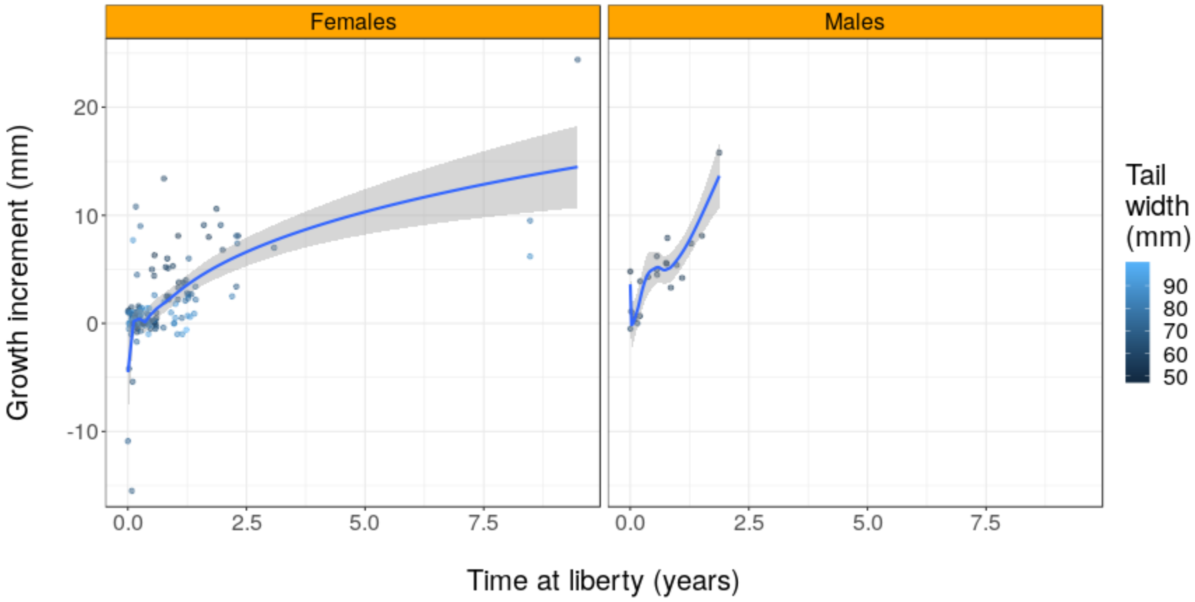


**Figure 27: CRA 6 growth increments (mm) by time at liberty (years) and sex. The colour of each point represents the tail width (mm). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.**

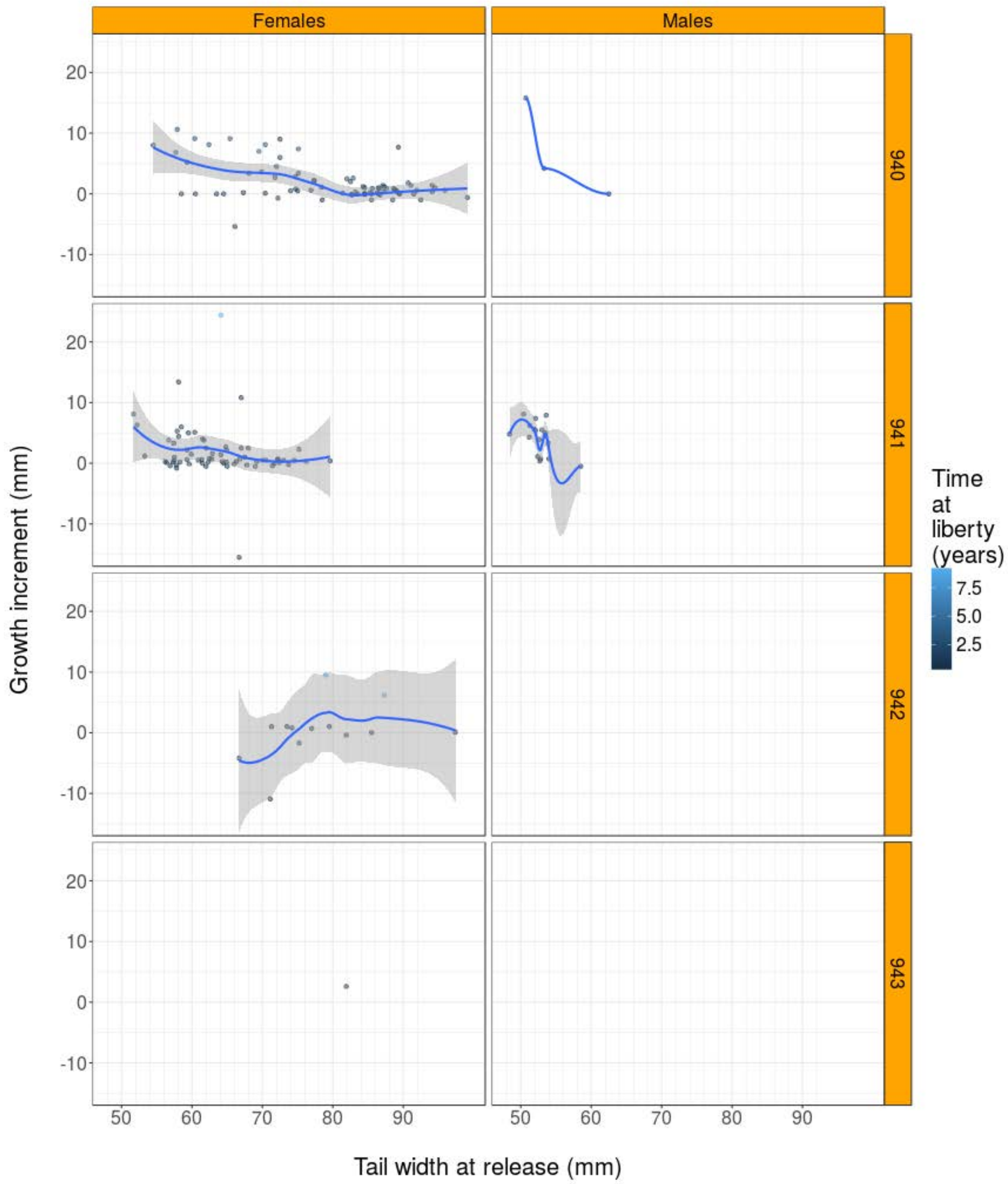


**Figure 28: CRA 6 growth increments (mm) by size at release (mm) and sex in each statistical area. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.**

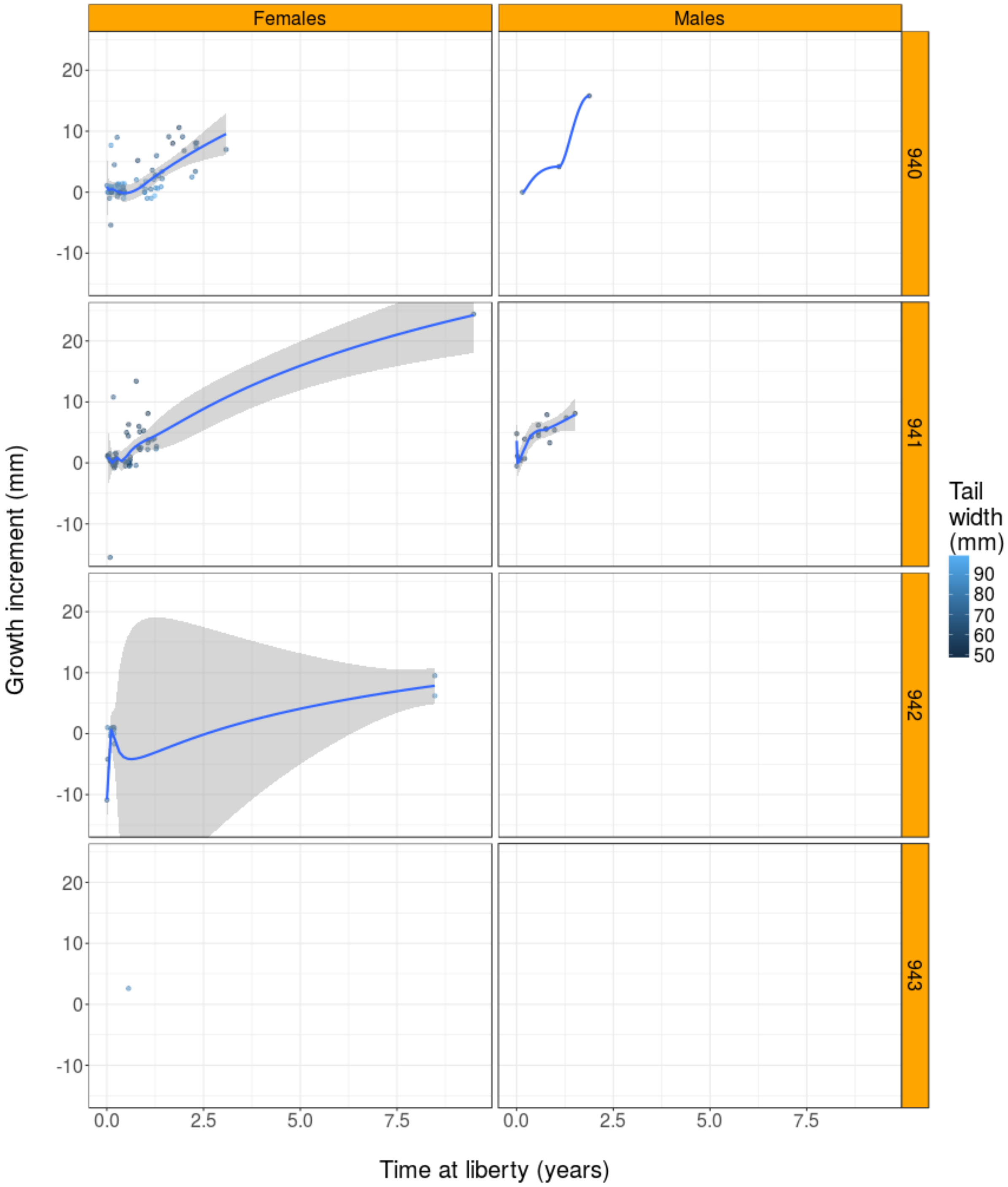


**Figure 29: CRA 6 growth increments (mm) by time at liberty (years) and sex in each statistical area. The colour of each point represents the tail width (mm). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.**

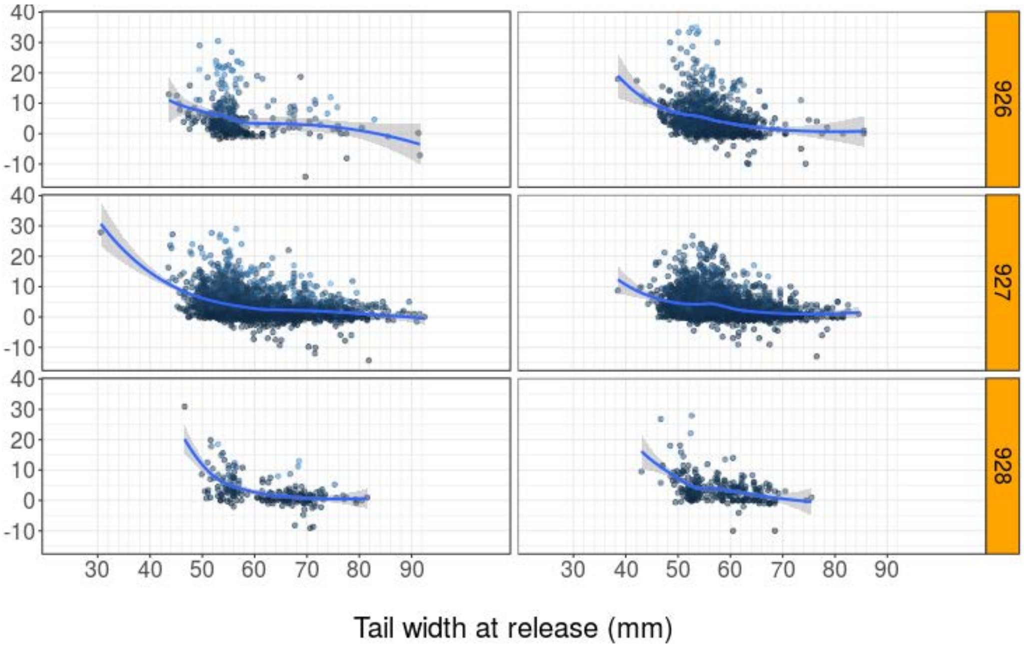


**Figure 30: Growth increments (mm) for Areas 926, 927 and 928 by size at release (mm) and sex in each statistical area. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel. Females are found on the left column and males on the right column. Right (y) axis is the growth increment in mm.**

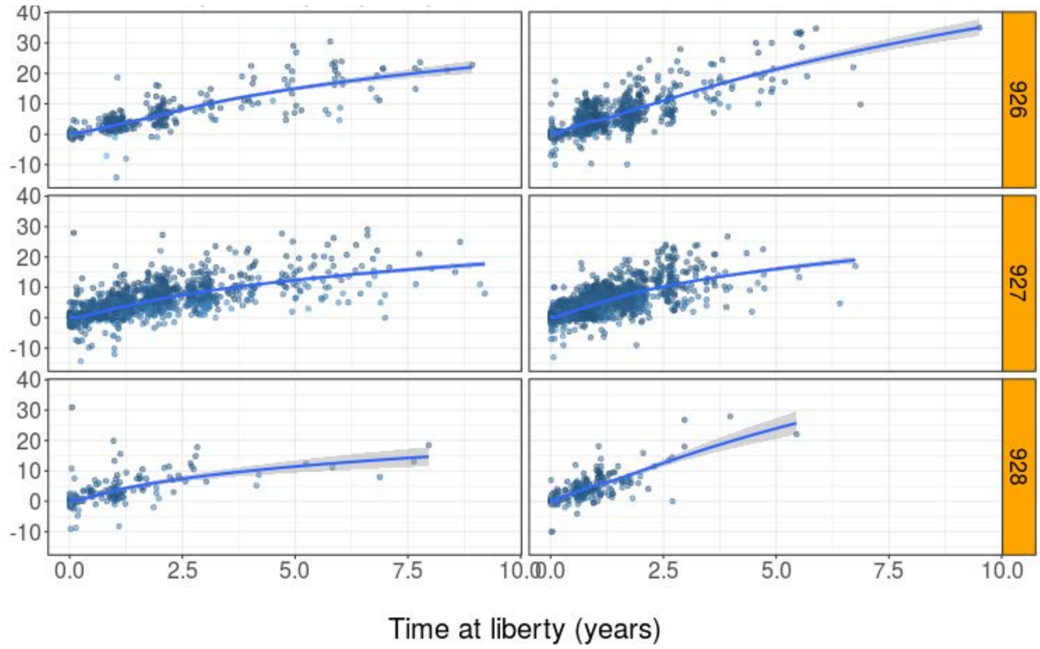


**Figure 31: Growth increments (mm) for Areas 926, 927 and 928 by time at liberty (years) and sex in each statistical area. The colour of each point represents the tail width (mm). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel. Females are found on the left column and males on the right column. Right (y) axis is the growth increment in mm.**

# APPENDIX A. DISTRIBUTION OF DESTINATION CODES IN CRA 6 LANDING DATA

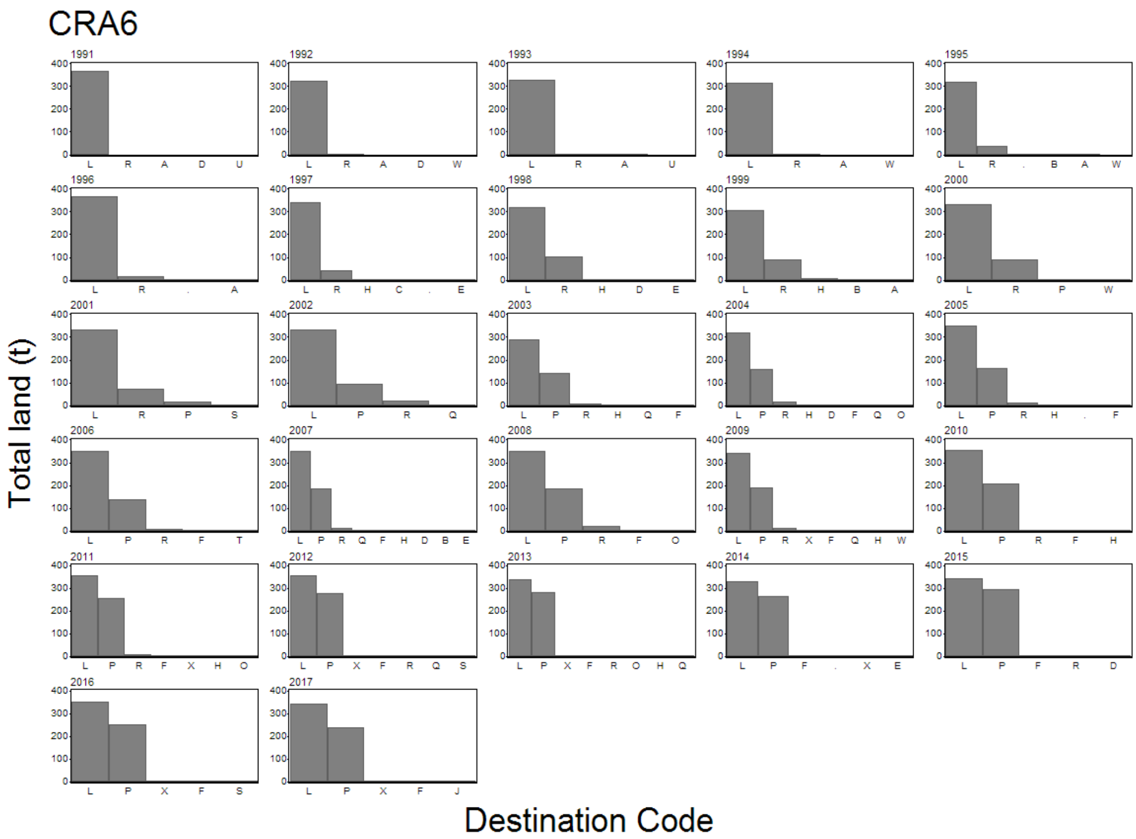


**Figure A.1: Destination codes reported by fishing year in CRA 6. Only the destination codes reported in each year are shown in descending order of total annual landings.**

**Table A.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 B. DOCUMENTATION FOR CRA 6 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 (2018). A [vessel] explanatory variable was not used in this model, with the purpose of the analysis to provide a set of FSU (1979–1988) seasonal indices. The FSU data had been excluded from the analysis presented in Section 3.1 with the inclusion of the [vessel] explanatory variable because the vessel codes in the earlier data base are not consistent with those used in the current Fisheries New Zealand Warehou database and the FSU series is part of this longer analysis which also included the CELR data. Two explanatory variables were available 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 B.1: Number of vessel/statistical area/month records in the dataset used to calculate the CRA 6 seasonal CPUE time series without including a vessel explanatory variable. Cells with <10 observations are highlighted in grey; '–': no data.**

| Fishing | Autumn-winter season | | | | | Spring-summer season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 940 | 941 | 942 | 943 | Total | 940 | 941 | 942 | 943 | Total |
| 79/80 | 34 | 53 | 39 | 29 | 155 | 40 | 39 | 68 | 30 | 177 |
| 80/81 | 27 | 35 | 45 | 9 | 116 | 54 | 46 | 52 | 42 | 194 |
| 81/82 | 25 | 51 | 40 | 23 | 139 | 34 | 59 | 80 | 50 | 223 |
| 82/83 | 23 | 74 | 70 | 36 | 203 | 48 | 57 | 93 | 48 | 246 |
| 83/84 | 28 | 59 | 73 | 32 | 192 | 42 | 61 | 115 | 35 | 253 |
| 84/85 | 34 | 54 | 71 | 34 | 193 | 51 | 65 | 107 | 29 | 252 |
| 85/86 | 42 | 52 | 51 | 37 | 182 | 50 | 59 | 104 | 51 | 264 |
| 86/87 | 45 | 37 | 42 | 29 | 153 | 62 | 42 | 85 | 52 | 241 |
| 87/88 | 30 | 37 | 51 | 19 | 137 | 64 | 56 | 94 | 49 | 263 |
| 88/89 | 41 | 33 | 53 | 19 | 146 | 45 | 38 | 81 | 27 | 191 |
| 89/90 | 24 | 25 | 44 | 18 | 111 | 56 | 56 | 75 | 24 | 211 |
| 90/91 | 30 | 35 | 41 | 20 | 126 | 45 | 46 | 76 | 21 | 188 |
| 91/92 | 26 | 48 | 48 | 18 | 140 | 54 | 78 | 106 | 18 | 256 |
| 92/93 | 31 | 44 | 73 | 15 | 163 | 49 | 61 | 127 | 26 | 263 |
| 93/94 | 49 | 46 | 92 | 26 | 213 | 46 | 67 | 111 | 35 | 259 |
| 94/95 | 51 | 48 | 88 | 38 | 225 | 64 | 53 | 107 | 49 | 273 |
| 95/96 | 56 | 49 | 86 | 45 | 236 | 59 | 48 | 101 | 41 | 249 |
| 96/97 | 67 | 43 | 80 | 24 | 214 | 62 | 45 | 85 | 25 | 217 |
| 97/98 | 69 | 40 | 89 | 32 | 230 | 54 | 41 | 87 | 27 | 209 |
| 98/99 | 47 | 36 | 52 | 16 | 151 | 45 | 33 | 45 | 18 | 141 |
| 99/00 | 29 | 29 | 53 | 14 | 125 | 28 | 34 | 58 | 15 | 135 |
| 00/01 | 45 | 31 | 61 | 17 | 154 | 45 | 30 | 56 | 14 | 145 |
| 01/02 | 43 | 34 | 45 | 12 | 134 | 39 | 31 | 47 | 16 | 133 |
| 02/03 | 30 | 33 | 34 | 14 | 111 | 38 | 37 | 44 | 15 | 134 |
| 03/04 | 33 | 30 | 42 | 21 | 126 | 42 | 35 | 49 | 25 | 151 |
| 04/05 | 43 | 30 | 52 | 13 | 138 | 44 | 36 | 55 | 15 | 150 |
| 05/06 | 37 | 45 | 65 | 20 | 167 | 43 | 45 | 68 | 21 | 177 |
| 06/07 | 36 | 33 | 54 | 22 | 145 | 37 | 40 | 53 | 22 | 152 |
| 07/08 | 35 | 37 | 45 | 20 | 137 | 35 | 50 | 53 | 28 | 166 |
| 08/09 | 40 | 34 | 55 | 19 | 148 | 43 | 42 | 67 | 19 | 171 |
| 09/10 | 33 | 21 | 54 | 18 | 126 | 39 | 35 | 65 | 28 | 167 |
| 10/11 | 34 | 24 | 53 | 25 | 136 | 37 | 30 | 58 | 25 | 150 |
| 11/12 | 37 | 28 | 57 | 20 | 142 | 42 | 33 | 79 | 27 | 181 |
| 12/13 | 29 | 17 | 67 | 20 | 133 | 31 | 26 | 84 | 30 | 171 |
| 13/14 | 30 | 20 | 58 | 17 | 125 | 36 | 20 | 92 | 32 | 180 |
| 14/15 | 31 | 23 | 65 | 28 | 147 | 42 | 29 | 85 | 32 | 188 |
| 15/16 | 45 | 25 | 54 | 14 | 138 | 44 | 35 | 85 | 31 | 195 |
| 16/17 | 34 | 27 | 65 | 23 | 149 | 36 | 31 | 83 | 31 | 181 |
| 17/18 | 37 | 26 | 71 | 22 | 156 | 38 | 30 | 78 | 27 | 173 |
| Total | 1 460 | 1 446 | 2 278 | 878 | 6 062 | 1 763 | 1 699 | 3 058 | 1 150 | 7 670 |

**Table B.2: Total deviance ($R^2$) explained by each variable in the CRA 6 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 (78) | 0.2066 | | |
| Month (12) | 0.0539 | 0.2595 | |
| Statistical Area (4) | 0.0899 | 0.2170 | **0.2698** |
| Additional deviance explained | 0.0000 | 0.0529 | 0.0103 |

**Table B.3: Seasonal CPUE indices calculated from the analysis of CRA 6 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 2018 CRA 6 stock assessment.**

| | Autumn-winter season | | | | Spring-summer season | | | |
|---|---|---|---|---|---|---|---|---|
| Fishing Year | Arithmetic Index | Unstandard-ised Index | Standard-ised Index | Standard Error | Arithmetic Index | Unstandard-ised Index | Standard-ised Index | Standard Error |
| 79/80 | 1.612 | 1.447 | 1.516 | 0.0478 | 2.821 | 2.651 | 2.655 | 0.0448 |
| 80/81 | 1.862 | 1.793 | 1.795 | 0.0548 | 2.297 | 2.008 | 2.060 | 0.0429 |
| 81/82 | 1.729 | 1.877 | 1.963 | 0.0503 | 2.374 | 2.354 | 2.395 | 0.0403 |
| 82/83 | 1.582 | 1.332 | 1.373 | 0.0421 | 1.872 | 1.729 | 1.739 | 0.0385 |
| 83/84 | 1.369 | 1.274 | 1.294 | 0.0432 | 1.897 | 1.791 | 1.774 | 0.0380 |
| 84/85 | 1.074 | 0.998 | 1.005 | 0.0430 | 1.440 | 1.448 | 1.444 | 0.0380 |
| 85/86 | 1.124 | 1.093 | 1.119 | 0.0443 | 1.517 | 1.466 | 1.467 | 0.0373 |
| 86/87 | 1.144 | 1.075 | 1.107 | 0.0481 | 1.800 | 1.722 | 1.719 | 0.0388 |
| 87/88 | 1.202 | 1.083 | 1.095 | 0.0506 | 1.555 | 1.381 | 1.411 | 0.0380 |
| 88/89 | 1.176 | 1.058 | 1.059 | 0.0491 | 1.465 | 1.348 | 1.329 | 0.0432 |
| 89/90 | 1.154 | 0.937 | 0.930 | 0.0559 | 1.341 | 1.201 | 1.211 | 0.0412 |
| 90/91 | 0.915 | 0.794 | 0.805 | 0.0526 | 1.477 | 1.421 | 1.419 | 0.0436 |
| 91/92 | 0.814 | 0.839 | 0.856 | 0.0500 | 1.426 | 1.407 | 1.440 | 0.0383 |
| 92/93 | 1.031 | 1.043 | 1.032 | 0.0466 | 1.265 | 1.121 | 1.120 | 0.0382 |
| 93/94 | 0.805 | 0.780 | 0.768 | 0.0411 | 1.224 | 1.177 | 1.178 | 0.0376 |
| 94/95 | 0.741 | 0.766 | 0.754 | 0.0402 | 1.213 | 1.152 | 1.143 | 0.0366 |
| 95/96 | 0.787 | 0.781 | 0.782 | 0.0392 | 1.215 | 1.203 | 1.198 | 0.0383 |
| 96/97 | 0.779 | 0.801 | 0.790 | 0.0411 | 1.225 | 1.274 | 1.267 | 0.0407 |
| 97/98 | 0.686 | 0.783 | 0.766 | 0.0398 | 1.047 | 1.214 | 1.202 | 0.0415 |
| 98/99 | 0.823 | 0.918 | 0.921 | 0.0484 | 1.405 | 1.484 | 1.512 | 0.0500 |
| 99/00 | 0.899 | 0.922 | 0.907 | 0.0529 | 1.458 | 1.539 | 1.539 | 0.0510 |
| 00/01 | 0.870 | 0.896 | 0.882 | 0.0479 | 1.417 | 1.441 | 1.440 | 0.0493 |
| 01/02 | 0.783 | 0.805 | 0.815 | 0.0512 | 1.417 | 1.490 | 1.505 | 0.0513 |
| 02/03 | 0.932 | 0.984 | 1.008 | 0.0559 | 1.386 | 1.413 | 1.446 | 0.0511 |
| 03/04 | 0.860 | 0.930 | 0.940 | 0.0527 | 1.310 | 1.409 | 1.433 | 0.0483 |
| 04/05 | 1.027 | 1.100 | 1.088 | 0.0504 | 1.454 | 1.619 | 1.629 | 0.0485 |
| 05/06 | 1.045 | 1.149 | 1.154 | 0.0461 | 1.566 | 1.662 | 1.673 | 0.0448 |
| 06/07 | 1.253 | 1.317 | 1.314 | 0.0492 | 1.718 | 1.957 | 1.996 | 0.0482 |
| 07/08 | 1.140 | 1.191 | 1.215 | 0.0506 | 1.722 | 1.632 | 1.686 | 0.0462 |
| 08/09 | 1.142 | 1.218 | 1.221 | 0.0488 | 1.793 | 1.965 | 1.972 | 0.0456 |
| 09/10 | 0.966 | 1.110 | 1.091 | 0.0527 | 1.668 | 1.700 | 1.693 | 0.0461 |
| 10/11 | 1.129 | 1.206 | 1.185 | 0.0508 | 1.592 | 1.739 | 1.736 | 0.0485 |
| 11/12 | 1.030 | 1.052 | 1.043 | 0.0498 | 1.809 | 1.905 | 1.875 | 0.0444 |
| 12/13 | 1.093 | 1.085 | 1.035 | 0.0514 | 1.949 | 1.970 | 1.905 | 0.0456 |
| 13/14 | 1.162 | 1.156 | 1.125 | 0.0529 | 1.753 | 1.767 | 1.692 | 0.0445 |
| 14/15 | 1.147 | 1.131 | 1.102 | 0.0490 | 1.609 | 1.588 | 1.549 | 0.0436 |
| 15/16 | 1.175 | 1.179 | 1.172 | 0.0505 | 1.632 | 1.596 | 1.569 | 0.0428 |
| 16/17 | 1.435 | 1.445 | 1.414 | 0.0487 | 2.128 | 2.178 | 2.129 | 0.0444 |
| 17/18 | 1.456 | 1.431 | 1.399 | 0.0476 | 2.244 | 2.352 | 2.305 | 0.0453 |

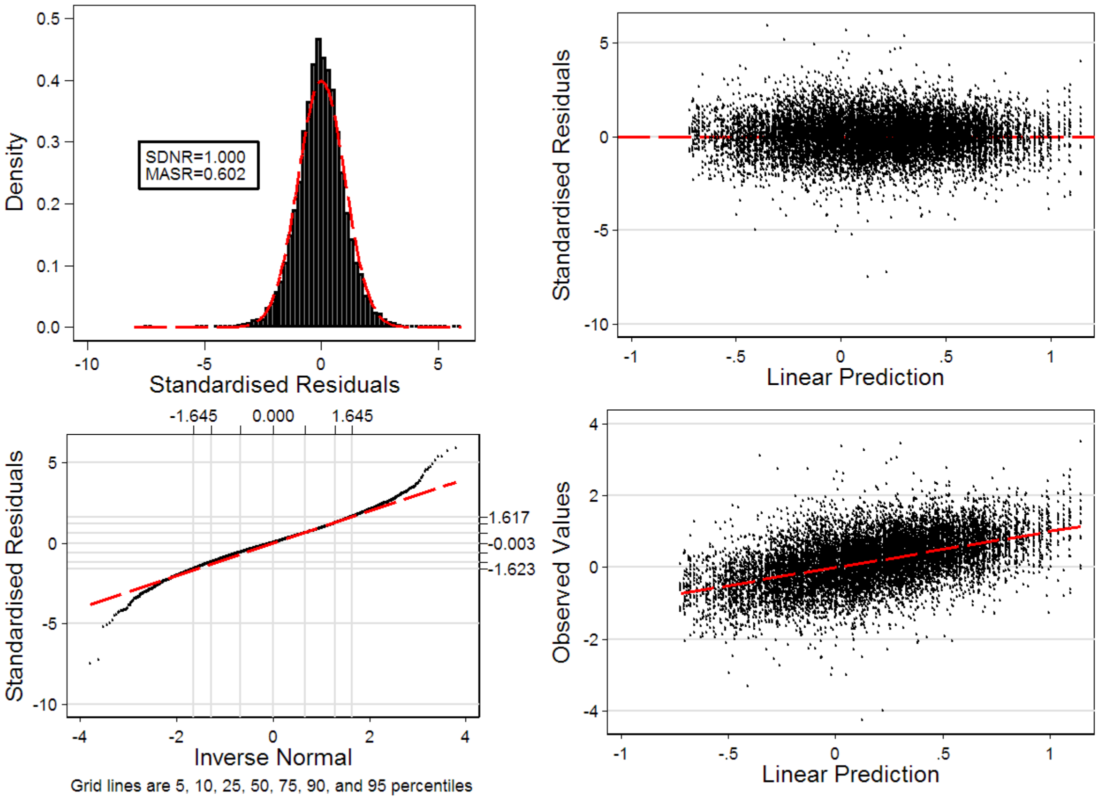


**Figure B.1: Standardised residuals for the CRA 6 seasonal CPUE GLM analysis without the inclusion of a vessel explanatory variable.**

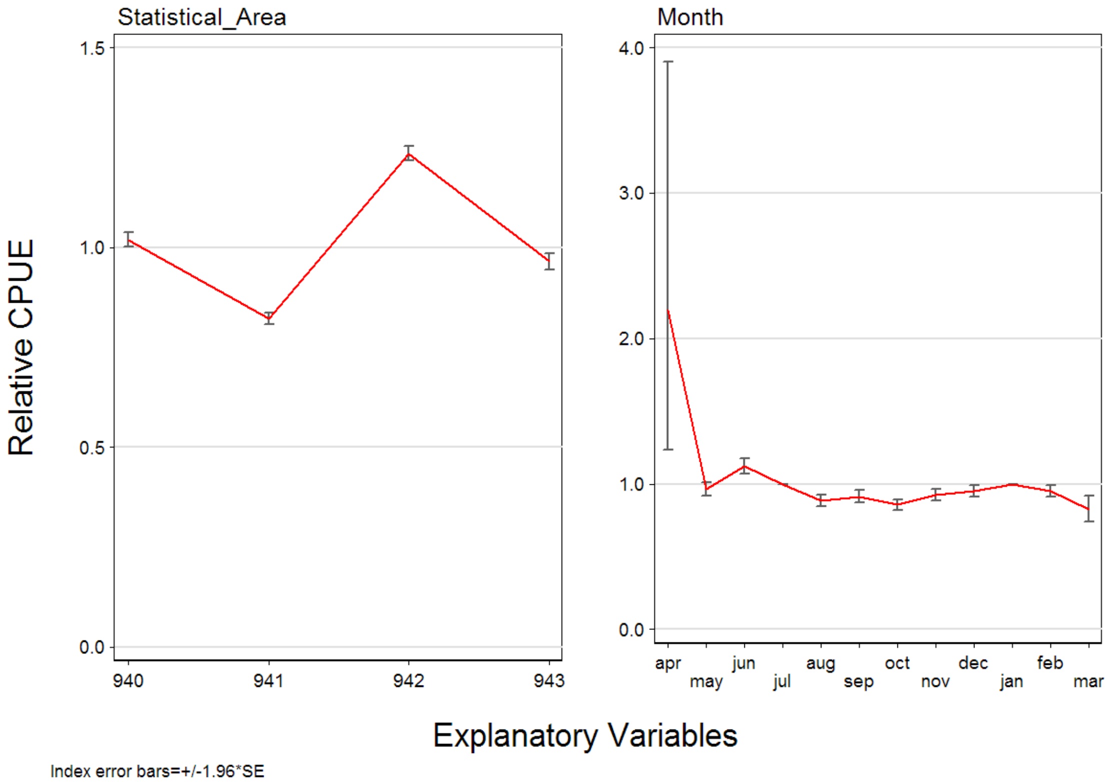


**Figure B.2: Coefficients for month and statistical area from the CRA 6 seasonal CPUE standardisation without the inclusion of a vessel explanatory variable. Month coefficients are not in canonical form, with each of the two reference months (August and October) set to 1.0 and the associated SE set to zero.**

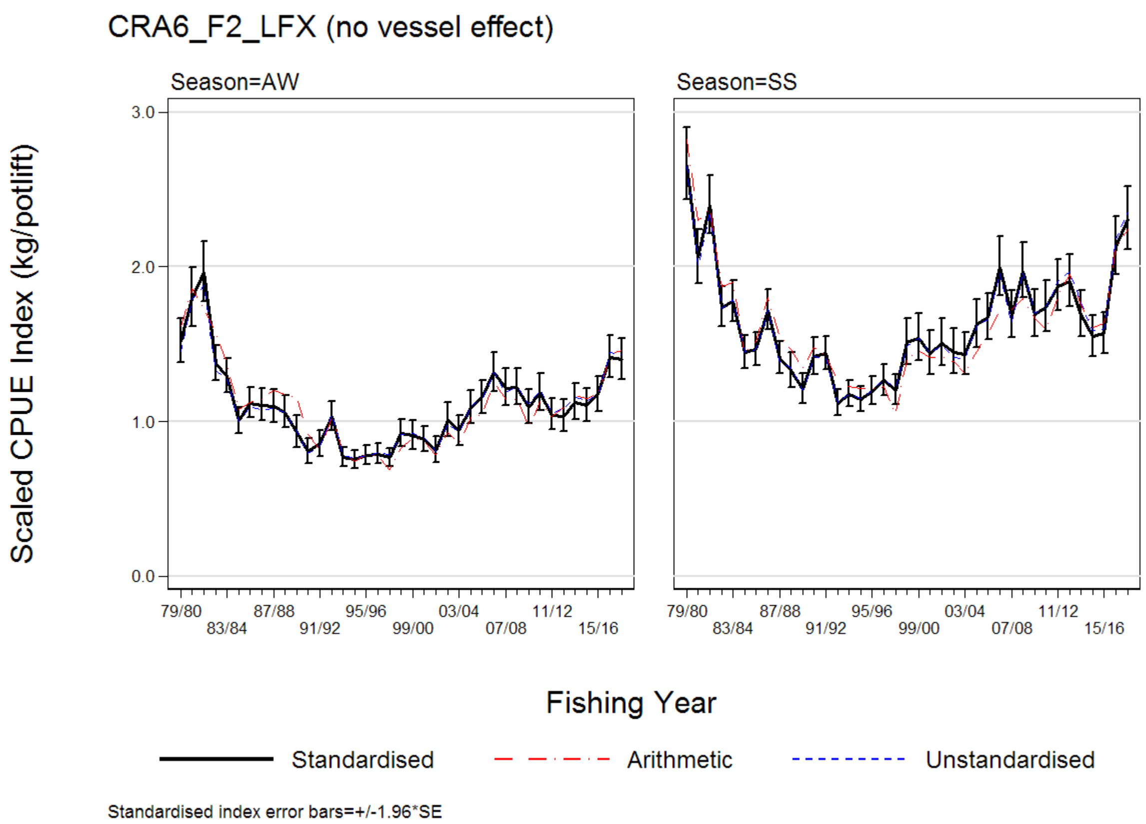


**Figure B.3: Standardised, unstandardised (geometric mean), and arithmetic mean CPUE indices (kg/potlift) by season and fishing year for the CRA 6 CPUE analysis without including a vessel explanatory variable and using the F2 algorithm scaled to "LFX" landings from 1979–80 to 2017–18: AW ($^{g}\overline{\mu}$ =1.07 kg/potlift) and SS ($^{g}\overline{\mu}$ =1.59 kg/potlift).**

## APPENDIX C. LENGTH FREQUENCY DISTRIBUTIONS FROM LOGBOOK AND CATCH SAMPLING

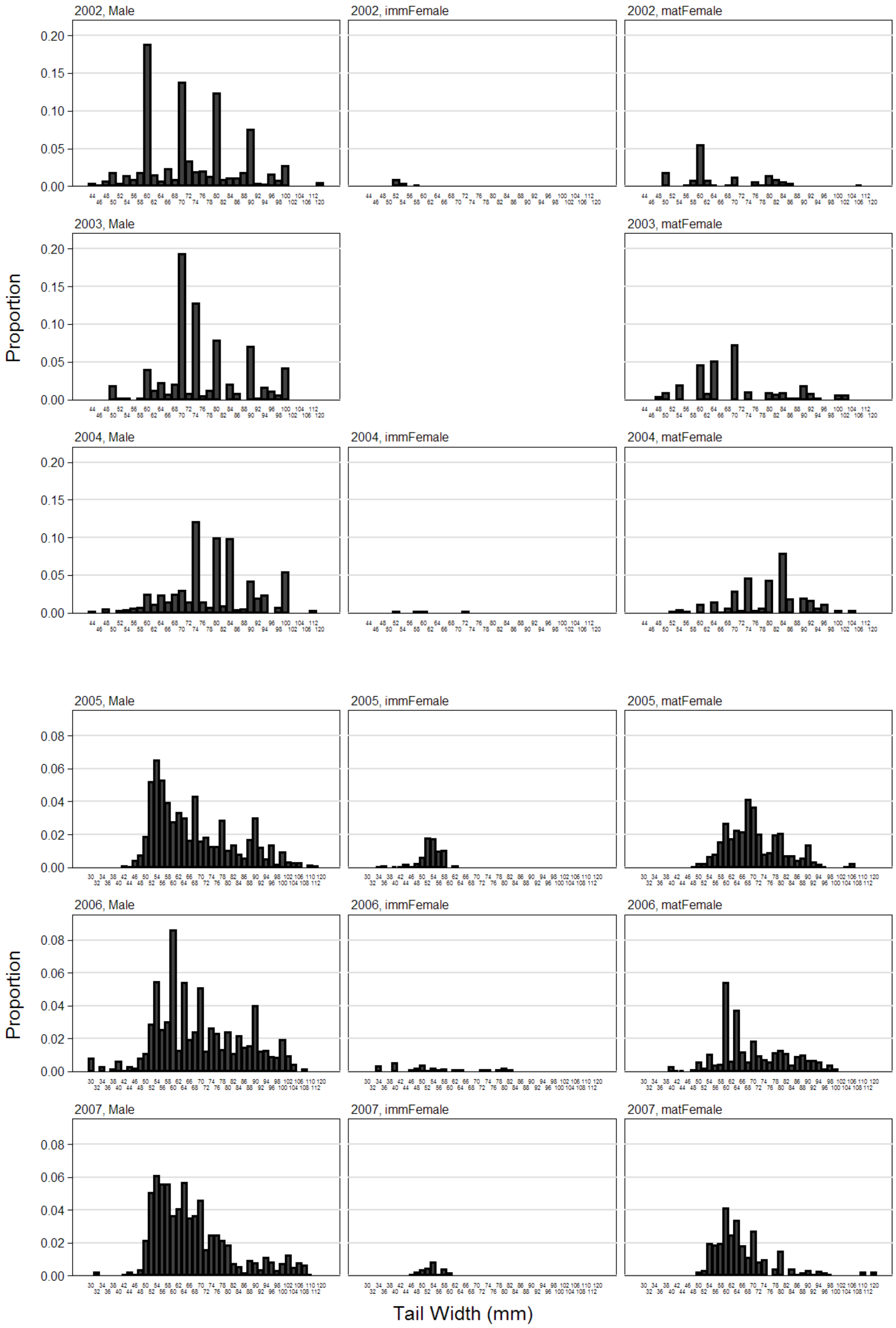


**Figure C.1A: Length frequency histograms by sex category for AW logbook sampling, 2002–2007. Each year (row) sums to 1.0. The number of measured lobsters by sex category can be found in Table 7 and the sample weight by sex category (Eq. 6) is found in Table 8.**

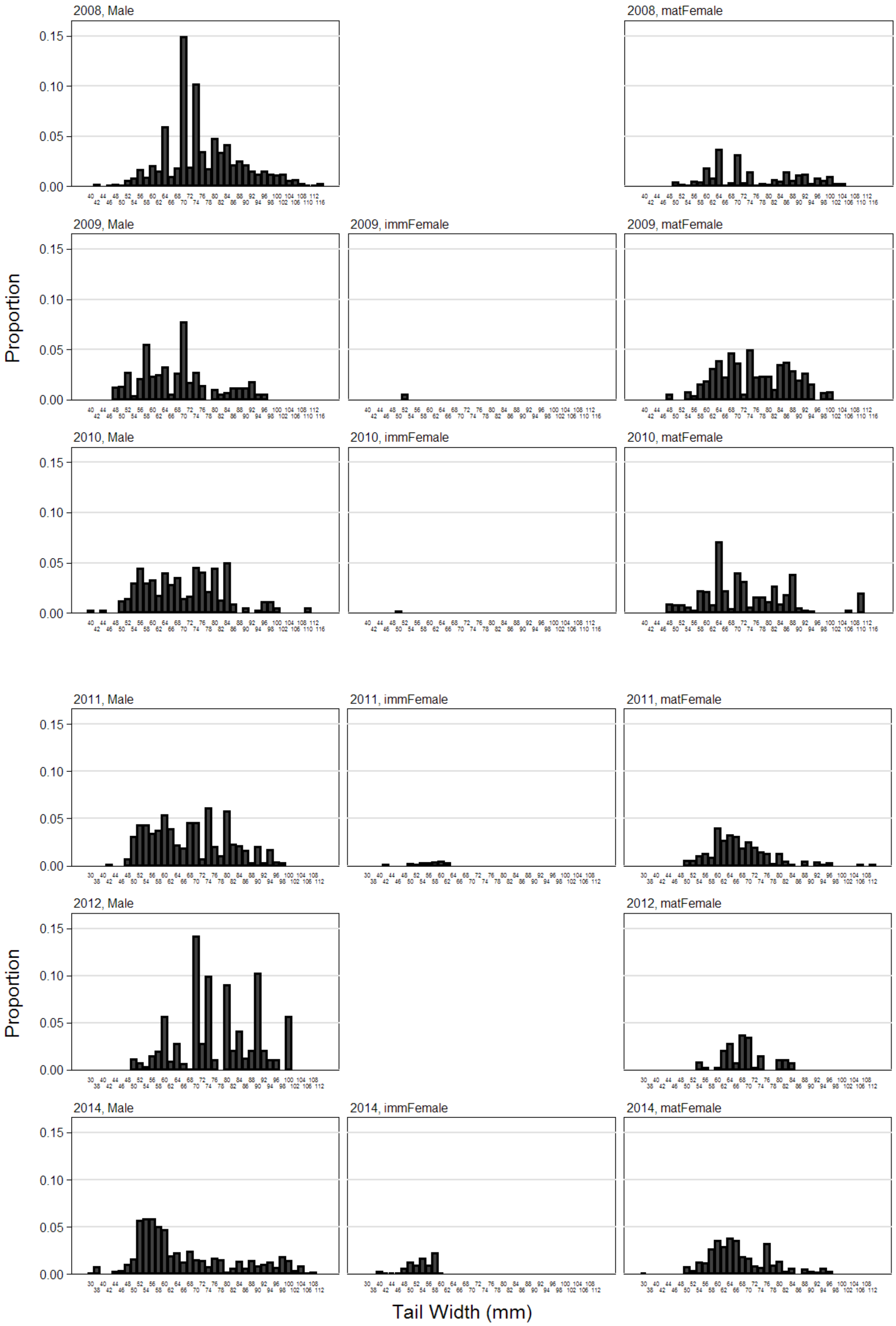


**Figure C.1B: Length frequency histograms by sex category for AW logbook sampling, 2008–2014. Each year (row) sums to 1.0. The number of measured lobsters by sex category can be found in Table 7 and the sample weight by sex category (Eq. 6) is found in Table 8.**

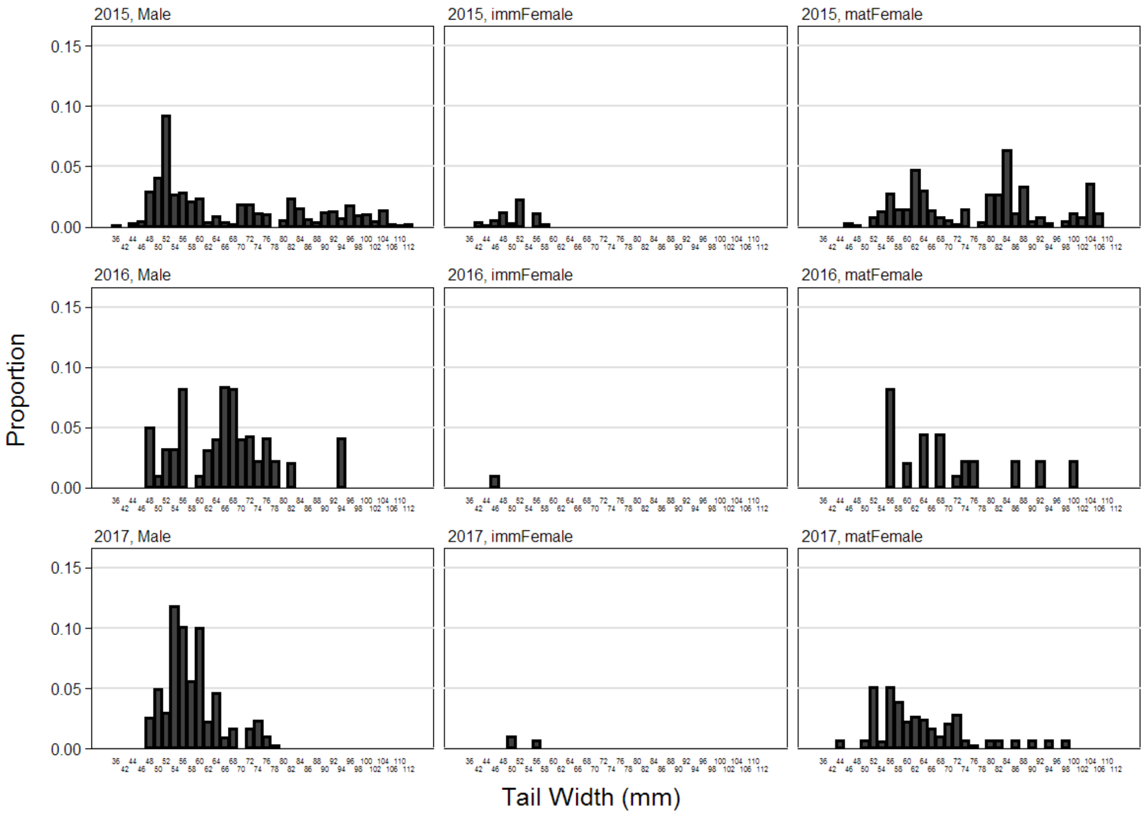


**Figure C.1C: Length frequency histograms by sex category for AW logbook sampling, 2015–2017. Each year (row) sums to 1.0. The number of measured lobsters by sex category can be found in Table 7 and the sample weight by sex category (Eq. 6) is found in Table 8.**

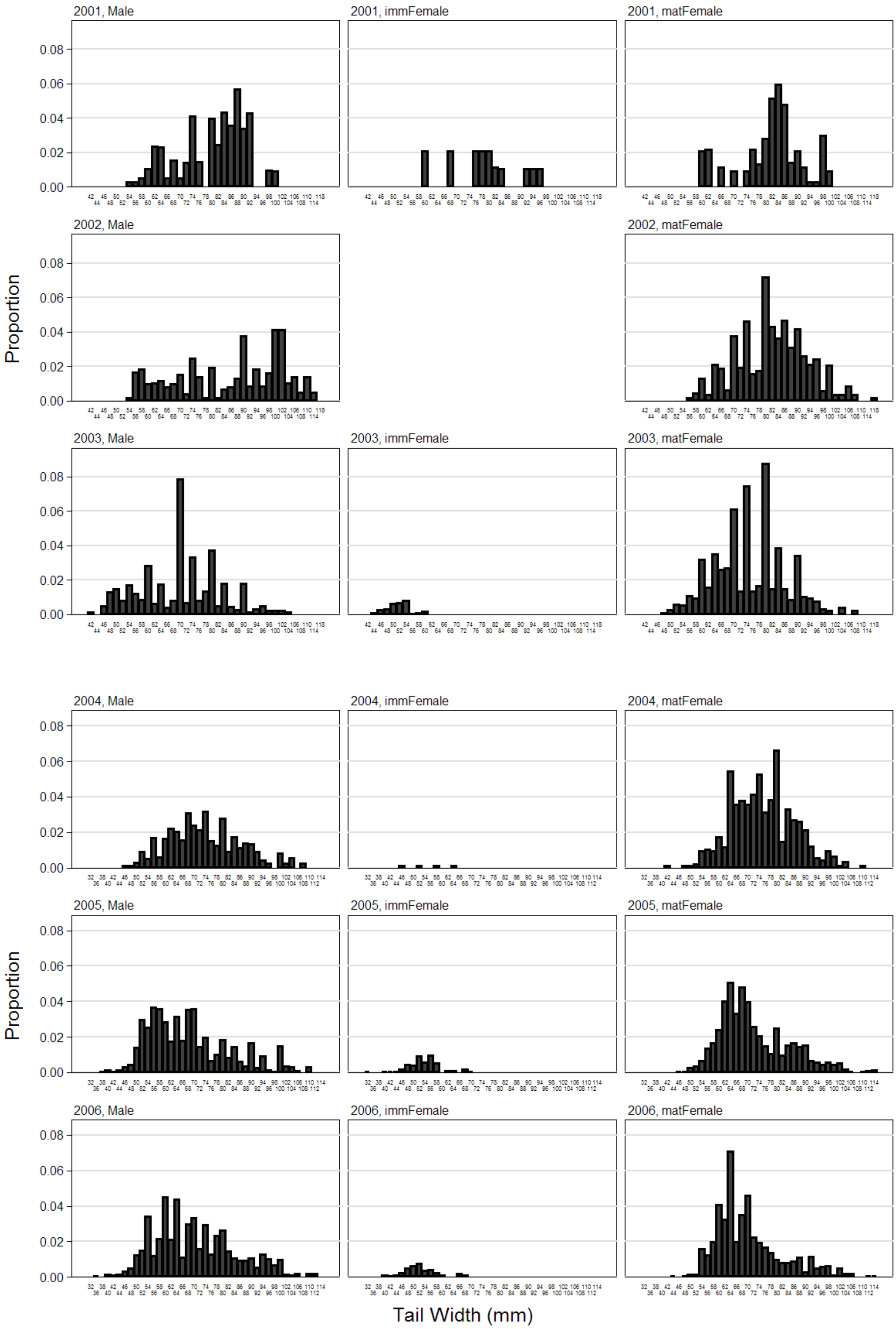


**Figure C.2A: Length frequency histograms by sex category for SS logbook sampling, 2001–2006. Each year (row) sums to 1.0. The number of measured lobsters by sex category can be found in Table 7 and the sample weight by sex category (Eq. 6) is found in Table 8.**

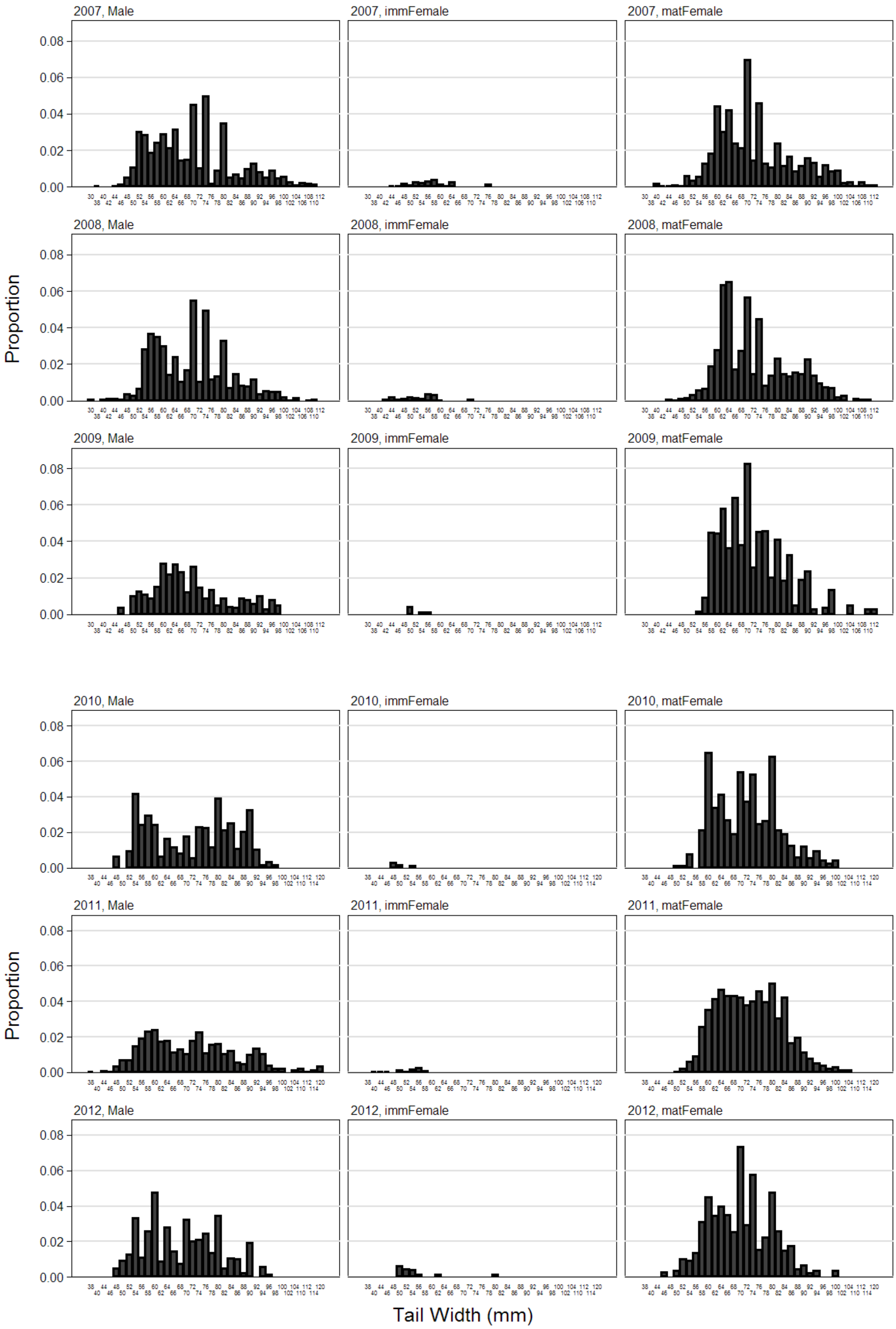


**Figure C.2B: Length frequency histograms by sex category for SS logbook sampling, 2007–2012. Each year (row) sums to 1.0. The number of measured lobsters by sex category can be found in Table 7 and the sample weight by sex category (Eq. 6) is found in Table 8.**

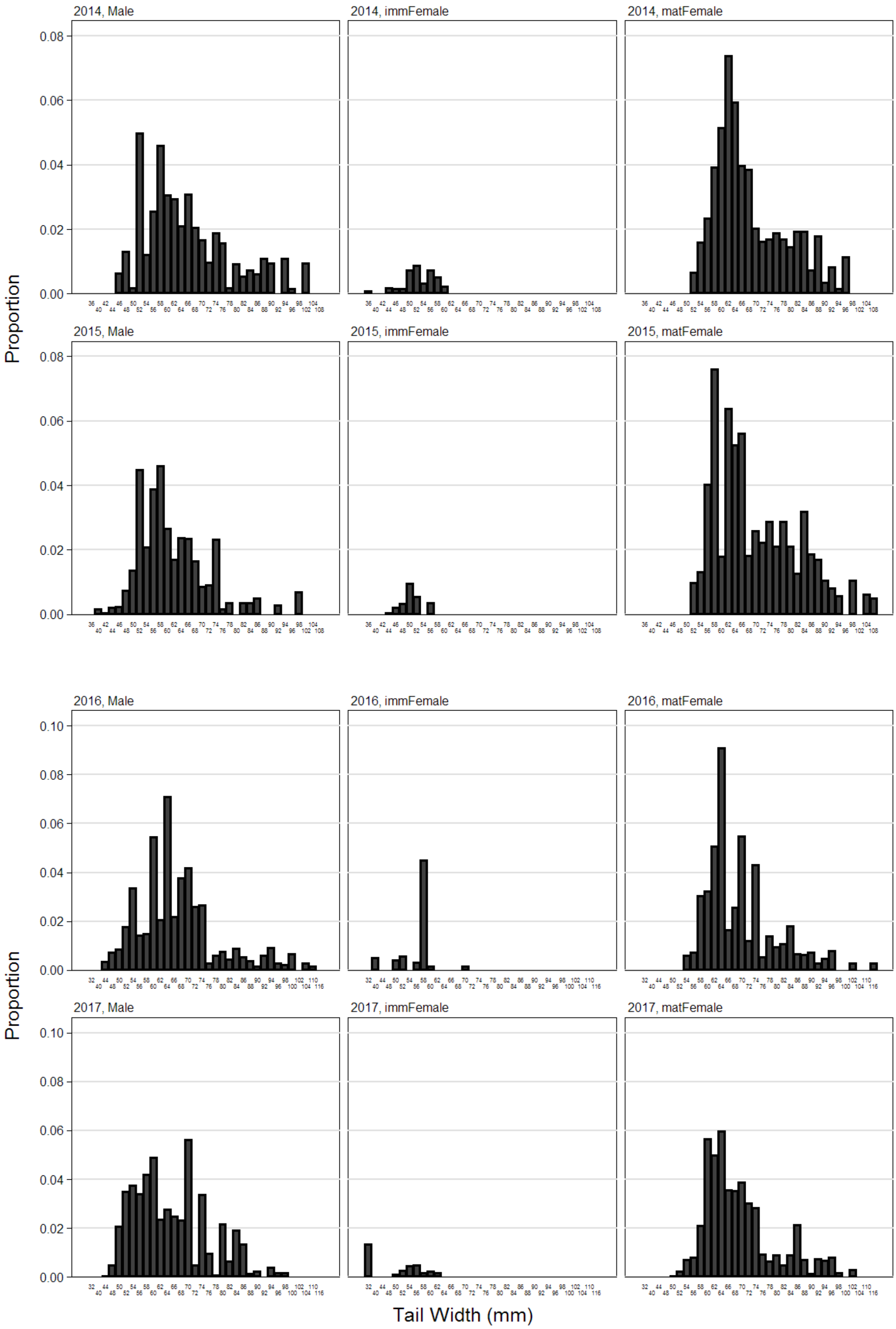


**Figure C.2C: Length frequency histograms by sex category for SS logbook sampling, 2014–2017. Each year (row) sums to 1.0. The number of measured lobsters by sex category can be found in Table 7 and the sample weight by sex category (Eq. 6) is found in Table 8.**

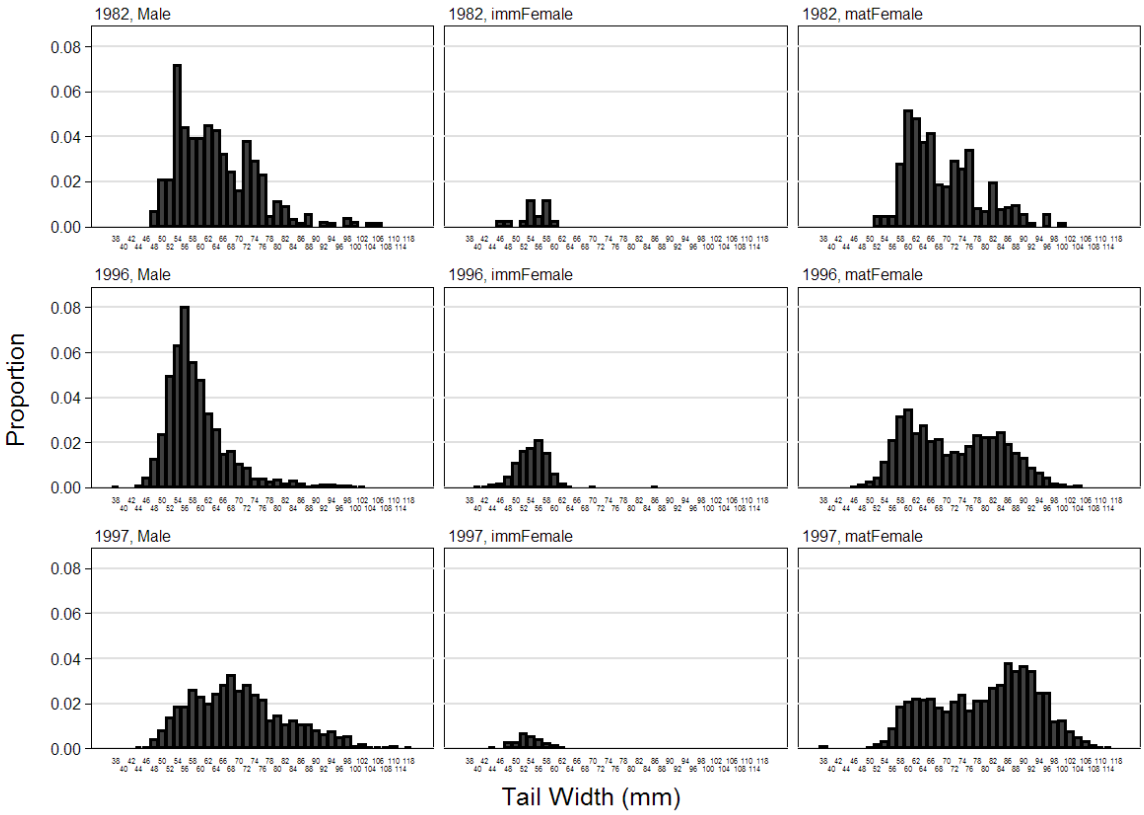


**Figure C.3: Length frequency histograms by sex category for AW observer catch sampling, 1996–1997. Each year (row) sums to 1.0. The number of measured lobsters by sex category can be found in Table 7 and the sample weight by sex category (Eq. 6) is found in Table 8.**

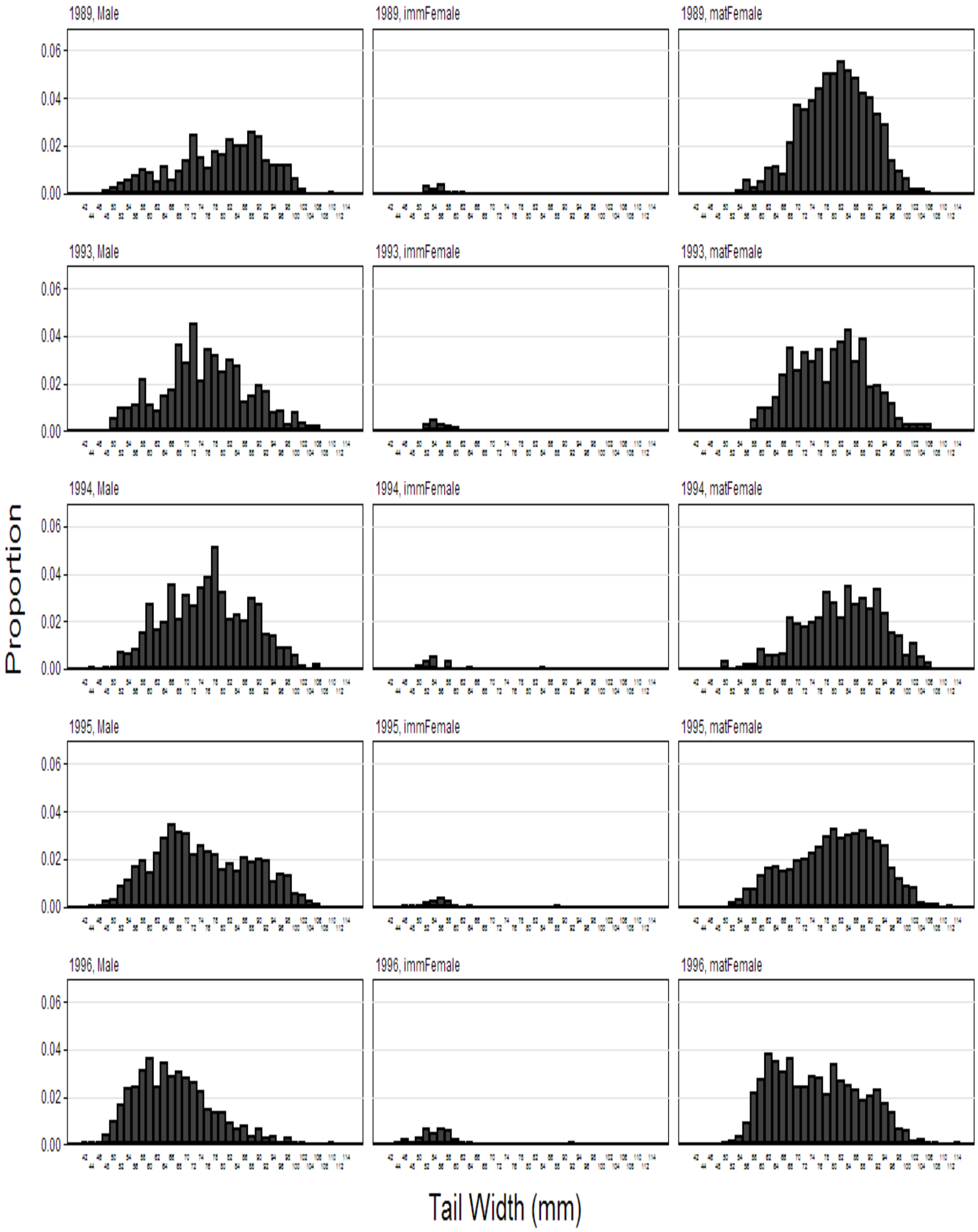


**Figure C.4: Length frequency histograms by sex category for SS observer catch sampling, 1989–1996. Each year (row) sums to 1.0. The number of measured lobsters by sex category can be found in Table 7 and the sample weight by sex category (Eq. 6) is found in Table 8.**