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Data for the 2020 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 4

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This document describes the data used in the 2020 CRA 4 stock assessment. Data sets described in this report include catch estimates for all sectors of the CRA 4 fisheries, seasonal standardised catch-per-unit-effort (CPUE) indices, length frequency distributions, and tag-recapture data.

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

CPUE was standardised for the AW and SS seasons, except for the 2019 SS season, which was dropped because the Rock Lobster Working Group had concerns about the comparability of the new electronic data with the previous paper form data. The F2 algorithm, which uses a truncated distribution of “vessel correction factors” to adjust estimated catches to final catch, was used to prepare the catch and effort data. The destination codes “X” (discarded at sea) and “F” (section 111 recreational catches) were added to the destination code “L” (landed to a Licensed Fish Receiver [LFR]) to obtain the final catch total for scaling the estimated catches. The CPUE standardisation procedure was updated by the inclusion of a vessel explanatory variable in both the Fisheries Statistics Unit and Catch Effort Landing Return data series and Bayesian inference was used to better represent the uncertainty in both series.

Length frequency data were available from both observer catch sampling and voluntary logbook programmes. These were collated by data source and by season, and this document describes how the individual records were weighted. Tag-recapture data provide information on sex-specific growth rates, and this document also describes this data set.

1. INTRODUCTION

This work addressed parts of Objectives 3 and 4 of the Fisheries New Zealand contract CRA2019-01. This one-year contract, which began in April 2020, was awarded to New Zealand Rock Lobster Industry Council Ltd., who sub-contract Objectives 3 and 4 to the authors of this report:

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

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

The National Rock Lobster Management Group decided that CRA 4 and CRA 5 should be assessed in 2020. Data were compiled for both stocks by a team comprising D'Arcy Webber, Merrill Rudd, Jim Roberts, Maite Pons, and Paul Starr. This document is limited to the data for CRA 4 and describes catches (including commercial, recreational, customary, and illegal catches), catch per unit effort (CPUE), length frequencies (LFs), and tag-recapture data. Appendix A documents a formal data requests to Fisheries New Zealand for non-commercial catch information and the associated Fisheries New Zealand response is provided in Appendix B.

Decisions on data and modelling choices were discussed and approved by the Rock Lobster Fishery Assessment Working Group (RLFAWG, renamed the Rock Lobster Working Group in 2021[1]).

The CRA 4 (Figure 1) fishery extends south from the Wairoa River, in northern Hawke's Bay, along the lower east coast of the North Island, then around the southern end of the North Island and past Wellington, to finally end at the Manawatu River in the South Taranaki Bight (Figure 1). There are five statistical areas in CRA 4, which have had consistent spatial reporting of catches since 1979.

The previous stock assessment of CRA 4 was in 2016, with Starr et al. (2017) describing the data and Breen et al. (2017) documenting the stock assessment and management procedure (MP) evaluations. The 2016 stock assessment used the Bayesian multi-stock length-based model (MSLM, Haist et al. 2009), but a CRA 4 stock assessment using an earlier version of the current Stan model (Webber et al. 2018) was run in parallel and produced equivalent results. These models were fit to puerulus settlement indices, tag-recapture observations, standardised CPUE from 1979–2015, historical catch rate data from 1963–1973, and length frequency data from voluntary logbooks and observer catch sampling. The stock assessment model takes into account changes in the minimum legal size (MLS- see table 1 of Rudd et al. (in press) for the years when these changes were made) and in selectivity caused by revised escape gap regulations adopted in 1992 for the 1993–94 fishing year.

The available LF and CPUE data were examined for evidence of differences among the CRA 4 statistical areas (Appendix C). This evaluation concluded that the abundance (CPUE) trends were similar among the four primary areas and there was agreement among the length frequency distributions along the east coast of the Wairarapa. Although the LFs for the south coast appeared to be larger than on the east coast, the Rock Lobster Working Group (RLWG) agreed that assessing this region separately would not result in appreciably different advice, given that the south coast represented around 15% of the total catch.

The CRA 4 Total Allowable Commercial Catch (TACC) was set at 397 t in 2016–17, lower than was specified by the MP. Allowances of 35 t were made for customary fishing, 85 t for recreational fishing, and 75 t for illegal removals. The CRA 4 TACC was dropped to 289 t for the 2017–18 fishing year through the operation of a CRA 4 MP resulting from the 2016 stock assessment, while the operation of the same MP in 2017 resulted in an increase in the TACC to 319 t for the 2018–19 fishing year. The MP recommended an increase to 380 t for 2019–20 and 378 t for 2020–21; the

[1] Note that from here on in this report the Rock Lobster Fishery Assessment Working Group is referred to as the Rock Lobster Working Group (RLWG), including for text reporting on past methods and meetings. The use of RLFAWG is retained in the appendices.

Minister instead chose to keep the TACC at 319 t for both years. The fishery is open to recreational fishing all year with a MLS of 54 mm tail width (TW) for males and 60 mm TW for females.

2. CATCH DATA

2.1 CRA 4 Commercial catch

The fishing year and calendar year were the same before 1979. Since 1979, the fishing year changed to 1 April through 31 March. Reported annual commercial catches from 1945 through to 1978, summarised by **calendar year**, are held in the CRACE database, with sources documented by Bentley et al. (2005). From 1 January 1979 to 31 March 1986, catches were taken from monthly data summarised by **fishing year** from data collected by the Fisheries Statistics Unit (FSU), a version of which is documented and held in CRACE (Bentley et al. 2005). The three months of catch from January to March 1979 were added to the 1978 annual total to ensure that no catch was lost when switching from calendar year to fishing year collation. Year references in this document after 1978 apply to 1 April–31 March fishing years, with the year identified with the first year of the pair (e.g., 1979 refers to the 1979–1980 fishing year).

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

There is some uncertainty in the quality of the catch estimates in the years before the FSU system began in 1979, but there is confidence in the quality of the catch estimates from the 1980s when the FSU system was operating. Catch estimates generated from the FSU data available to the stock assessment team are consistent with published historical catch estimates from the FSU system.

Commercial catches in CRA 4 did not exceed 700 t/year until the early 1980s and exceeded 600 t/year only for a few years in the early 1950s and once in the 1960s (Figure 2). Commercial catches generally varied between 400 and 600 t/year until the early 1980s when they rose to above 900 t/year in 1983, 1986, and 1987. Catches dropped when this QMA entered the QMS in 1990 to levels near to or above 500 t/year as the TACC dropped from its initial value of 576 t to 496 t in 1993. The TACC was raised to 577 t in 1999 as a belated response to high CPUE levels, but catches then dropped to below 250 t by 2008 (Figure 3). A voluntary shelving programme, based on the operation of an MP, was implemented in 2007 and 2008 (Breen 2009) and was then replaced by a large decrease in the TACC to 266 t in 2009 (Figure 3). Management procedures were used to manage CRA 4 catch levels from 2007 (Webber & Starr 2020). Catch and TACC began to rise in 2010, peaking in 2013 at just below 500 t. Annual CPUE declined to a nadir of 0.6 kg/potlift in 2007 after peaking in 1998 at 1.6 kg/potlift. In 2012, CPUE rose to another peak (1.4 kg/potlift) and then dropped sharply to 0.75 kg/potlift in 2015 and 0.65 in 2016 (Figure 3). The TACC was reduced by 15% for 2016 which was greater than the drop of 4.5% required by the MP because stakeholders were concerned with the state of the fishery and opted instead to request that the Minister set a 2016 TACC of 397 t. The drop in CPUE in the following year resulted in another drop in the TACC to 289 t for the 2017–18 fishing year. The CPUE then rose in 2017 to 0.83 and again in 2018 to 0.90 kg/potlift. These increases resulted in MP recommendations for TACC increases which were not supported by stakeholders and the Minister (Webber & Starr 2020).

2.2 CRA 4 Recreational catch

Six annual recreational survey catch estimates are available for CRA 4 (Table 1). Estimates from the two Kingett Mitchell National Surveys (Boyd et al. 2004, Boyd & Reilly 2004) were not accepted by the RLWG for the 2016 CRA 4 stock assessment (Breen et al. 2017) because these survey estimates were considered implausibly high for CRA 4. The earlier 1994 and 1996 surveys, conducted by researchers at the University of Otago, were considered biased by a review of the available recreational surveys (unpublished minutes: Recreational Technical Working Group [Auckland NIWA, 10–11 June 2004]) because the interview questions possibly underestimated fisher participation rates by allowing for an easy exit from the interview ("soft refusal" bias). These two early surveys continue to be used by the RLWG in spite of this advice because the estimates are plausible and no other recreational information is available for these years. Both the Boyd and the Otago surveys were potentially biased high because recreational logbook participants were not closely supervised and may not have accurately recorded their fishing activity. The much higher harvest estimates in the Boyd surveys were a result of higher claimed participation in saltwater fishing over the previous 12 months in the initial screening survey.

Two large-scale population-based diary/interview surveys (National Panel Survey or NPS) were conducted under contract for the Ministry for Primary Industries (MPI) for 1 October 2011–30 September 2012 (Wynne-Jones et al. 2014) and for 1 October 2017–30 September 2018 (Wynne-Jones et al. 2019), with the intention of estimating specific Fishery Management Area and QMA annual catches for all major finfish and non-finfish species (Heinemann et al. 2015). This survey was based on a design that resembled the New Zealand national census, making use of the census population strata ("mesh blocks" of dwellings as the basis for identifying recreational fishers). A door-to-door survey of households in randomly selected strata was used to select participants who would report their catch for an entire year. A structured and carefully-designed Computer Assisted Telephone Interview (CATI) method was used to record harvest in detail from those who had fished. The survey results were thought to be plausible for CRA 4, with 69 (2011–12) and 72 (2017–18) fishers providing 206 and 195 interviews for each survey year (see table 60 of Wynne-Jones et al. 2014 and table 51 of Wynne-Jones et al. 2019). These estimates have reasonable CVs (0.17 in 2011–12 and 0.23 in 2017–18, Table 1). Both the 2011–12 and 2017–18 surveys provided estimates of the distribution of fishing platforms used to take lobsters in CRA 4, with large and small motor boats accounting for about 60% of the catch in each survey, with the balance taken from the shore for both surveys (Table 2, Figure 4). The capture methods were also consistent between surveys, with catches using diving taking up to three-quarters of the catch for both surveys and the balance taken by potting (Table 2, Figure 4). The NPS results from logbook participants were in numbers of fish. Mean recreational catch weight for the most important finfish and non-finfish species QMAs was estimated in parallel projects (Hartill & Davey 2015, Davey et al. 2019).

A recreational catch vector was developed by assuming that recreational catch has been proportional to the CRA 4 SS abundance, as reflected in the standardised SS CPUE for all of CRA 4. By agreement in the RLWG, the recreational catch vector was based on four of the six survey estimates (in tonnes – see Table 1) from the 1994 (Otago), 1996 (Otago), and the 2011–12 and 2017–18 NPS surveys. The two NPSs were assumed to be less biased, so the estimated survey CVs were used. The CVs for the two Otago surveys were assumed to be 50% higher than that of the mean of the two NPSs, as was done for previous rock lobster stock assessments (e.g., CRA 1, CRA 3: see Starr et al. 2020a, 2020b). A parameter ϕ (Eq. 1) was estimated by obtaining the best fit to these survey estimates when minimising a lognormal distribution using the CVs indicated in Table 1:

Eq. 1 $$\boldsymbol{W_t = w_t N_t}$$

$$\boldsymbol{\widehat{W}_t = \phi I_t = \sum_{t=1}^{4}\left[\frac{\left(\log(W_t) - \log(\widehat{W}_t)\right)}{2\sigma_t^2}\right]}$$

where t subscripts the four recreational survey years in Table 1 (1=1994 Otago, 2=1996 Otago, 3=2011 NPS, 4=2017 NPS), w_t is the mean SS weight of sampled lobsters greater than or equal to the MLS in survey year t, N_t is the mean number of lobsters in survey year t, I_t is the SS standardised CPUE during survey year t, and W_t is the estimated recreational catch (tonnes) for survey year t.

The estimated recreational catch trajectory (Eq. 2), based on Eq. 1, matches the 2011 and 2017 NPSs as well as the two Otago observations well within the assumed error bounds (Figure 5). The ϕ parameter was estimated to be 35.45 tonnes/CPUE-unit. The mean of the 2016–2018 CPUE was used for the 2019 estimate because there was no accepted CPUE estimate for 2019 due to the changeover to electronic reporting in the 2019–20 fishing year and the apparent shifts in reporting estimated lobster catches. Recreational catch in 1945 was assumed to be 20% of the 1979 estimated recreational catch, with recreational catch following an increasing linear trajectory from 1945 to 1979 (Eq. 2):

Eq. 2 $\boldsymbol{\widehat{W}_y = \phi I_y}$ **if** $\boldsymbol{y \geq 1979}$

$$\boldsymbol{\widehat{W}_{1945} = 0.2\widehat{W}_{1979}}$$

$$\widehat{W}_y = \widehat{W}_{y-1} + \frac{\widehat{W}_{1979} - \widehat{W}_{1945}}{1979 - 1945} \quad \text{if} \quad 1979 > y > 1979$$

The estimated recreational catch vector accounted for 2177 t of historical catch from 1945 to 2019. For assessments since 2006, the RLWG has included recreational landings made by commercial vessels under section 111 of the Fisheries Act. Greenweight landings with destination code “F” were extracted from the CRACE database (Bentley et al. 2005), which showed a maximum annual value of 5863 kg for CRA 4, occurring in 2012–13. The RLWG agreed to add the maximum catch estimate to the estimated recreational catch in each year since 1945, increasing the total 1945 to 2019 recreational catch in the model to 2615 t.

2.3 CRA 4 Customary catch

Fisheries New Zealand was asked to provide estimates of current and historical customary catches, and an appreciation of their uncertainty (see Appendix A and Appendix B). Fisheries New Zealand advised that a constant customary catch of 20 t should be assumed, a value consistent with what was assumed in past CRA 4 stock assessments.

2.4 CRA 4 Illegal catch

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

When illegal catches for 2020 were initially discussed in the RLWG, the meeting agreed to reject the Fisheries New Zealand compliance estimates of illegal catch because these had not been adequately documented, as was done for CRA 1 and CRA 3 in the 2019 stock assessments (see Starr et al. 2020a, 2020b). The meeting also rejected using the early estimates generated using the ‘export-discrepancy’ methodology (described by Starr et al. 2020a, 2020b) up to 1980. Instead, the meeting agreed to use 10% of the total commercial catch summed over the period 1945–1989, followed by 5% of the summed commercial catch from 1990 to 2019. The lower percentage was used for the post-1989 illegal catches on the assumption that illegal activity would be lower once rock lobster entered the QMS. These fixed catches were then scaled by the annual standardised CRA 4 CPUE, beginning in 1979. Before 1979, the illegal catches were assumed to be constant.

In the past, MPI Compliance Services estimates for illegal catch have been provided in two categories (“reported” or “R” and “not reported” or “NR”) for some QMAs. The category of “commercial illegal reported” or “reported” or “R” was assumed to represent illegal catch that was eventually reported to the QMS as legitimate commercial catch. Therefore, previous stock assessments subtracted these estimates from the reported commercial catch to avoid double-counting. For the 2020 stock assessment, the RLWG agreed to discontinue this practice, given the lack of confidence in the Fishery Officer estimates of illegal catch, a consensus that this category was unlikely to be large, and that the solution applied was highly speculative.

The illegal catch estimates are shown in Table 3 and Figure 6.

2.5 Size-limited and non-size-limited catch by season

The size-limited (SL) catch is taken under the MLS regulations and the restriction on landing berried females. The commercial and recreational catches are summed to create this catch category. The non-size-limited (NSL) catch is taken without regard to those restrictions; it consists of the illegal catches and the customary catches. Annual commercial catches were divided into seasons (autumn-winter [AW] and spring-summer [SS]) beginning in 1979 based on the seasonal distribution of the FSU and QMR/MHR data. Illegal catches were divided between seasons in the same proportions as commercial. It was assumed that 90% of the customary and recreational catches were taken in SS. These catches are shown as summed totals in Figure 7 and Table 3. The proportion of the commercial catch taken in the AW season increased to near 80% in the late 1990s and early 2000s, and then dropped to around 50–60% (Figure 8). The SL and NSL catches are modelled separately in the stock assessment model.

3. CATCH RATE INFORMATION

3.1 Seasonal standardised CPUE indices

3.1.1 Introduction and methods

Catch and effort data from the Catch Effort Landing Return (CELR) forms were obtained from Fisheries New Zealand in May 2020 (replog 12983) and processed using standard error checks (Bentley et al. 2005). Data spanned the period from 1 July 1989 to 30 September 2019. Data for the period 1 April 1979 to 30 June 1989 came from the FSU database, a static copy of which is held by the rock lobster stock assessment team.

Preparation of the CELR data used the F2_LFX procedure (see appendix D of Starr 2021). The F2 algorithm scales the monthly estimated catch taken by a vessel in a statistical area using a "vessel correction factor" (*vcf*) which is the ratio of landed catch to estimated catch for one vessel in one year (eq. D.6 in appendix D of Starr 2021). Vessels with a *vcf* less than 0.8 or greater than 1.2 were discarded from the analysis. The F2_LFX procedure scales the estimated catches to the combined "L" (landed to a Licensed Fish Receiver [LFR]), "X" (discarded to sea), and "F" (section 111 recreational catch) destination codes (destination codes are defined in table B.1 in appendix B of Starr 2021); number of records in the CPUE data set are provided in Table 4.

The 2019–20 fishing year marked the transition of the collection of rock lobster catch and effort data from a paper-based (CELR) system to an electronic reporting (ER) system dependent on a user interface operated from tablets or smart phones. There are three different ER reporting "platforms", each with different user interfaces and slightly different underlying software. Preliminary analyses of the 2019–20 data indicated that the estimated catches returned using the new ER system differed from the equivalent estimates generated by the previous CELR forms (see appendix B of Starr 2021). Therefore, the RLWG agreed to temporarily suspend updating CPUE indices beginning with the 2019–20 spring/summer season (the RLWG concluded that, with the exception of CRA 7, there remained sufficient CELR data in the QMAs that there was comparability with previous indices for the AW 2019–20 data). This meant that the 2020 CRA 4 and CRA 5 stock assessments did not include SS CPUE estimates for 2019–20.

The 2020 CRA 4 stock assessment included two standardised CPUE series calculated from generalised linear models (GLMs) that used sequential six-month periods as explanatory variables.

One CPUE series was based on the early FSU data and the second series used the more recent CELR data. Three explanatory variables were used for both analyses in addition to the sequential [`period`] variable: [`month`] of capture, statistical [`area`] of capture, and an identification code for each fishing [`vessel`].

Both GLMs included the variable [`vessel`] as an explanatory variable. The only difference between the FSU and CELR analyses was that all vessels were included in the FSU analysis while the CELR analysis was filtered for vessels with at least five years of data. Bayesian inference was used to estimate parameter uncertainty. This was done using the R package *brms*, which is a wrapper for doing GLMs coded using the Stan language. Stan uses gradient-based Markov chain Monte Carlo (MCMC), specifically the Hamiltonian Monte Carlo (HMC) algorithm, for Bayesian inference. Four thousand samples from the posterior distribution were obtained by combining samples across four chains, with each chain consisting of a warm-up period of 2000 discarded iterations followed by sampling the next 1000 iterations.

Both GLMs include population-level effects for period (*t*), and group-level effects for month (*m*), vessel (*v*), and a time period × statistical area interaction term (*a*):

Eq. 3 $$\log\left(\frac{C_i}{E_i}\right) = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} = \boldsymbol{\beta_0} + \boldsymbol{T\beta_t} + \boldsymbol{AT\beta_{a,t}} + \boldsymbol{M\beta_m} + \boldsymbol{V\beta_v} + \boldsymbol{\varepsilon}$$

with priors and hyperpriors

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

and distribution

$$\varepsilon_i \sim N(0, \sigma^2)$$

where C_i is the catch (tonnes) for record i, E_i is the effort (number of pot lifts) for record i, β_0 is the intercept, β_t are the period coefficients, $\beta_{a,t}$ are the time period × statistical area coefficients, β_m are the month coefficients, and β_v are the vessel coefficients. 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.

3.1.2 CRA 4 CELR Seasonal standardised series

Trace plots of the samples from the posterior distribution from the Bayesian GLM 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 month coefficients in April, August, October, and March are below the average while September and February have even lower coefficients, suggesting lower catch rates during these months (Figure 11). Vessel coefficients from the FSU analysis show large amounts of inter-vessel variability (Figure 12). Unsurprisingly, the month coefficients estimated by the FSU analysis are very similar to those estimated by the CELR analysis, except that the April catch rate is above the average while it was below average in the CELR analysis (compare Figure 13 with Figure 11).

There is a gradual declining trend in the FSU series from 1982 SS after an initial period of relative stability (Table 5, Figure 14). The FSU series also begins to show the strong annual variation between the AW and SS seasons that is apparent in the CELR series during the latter part of the series. The CELR series, apart from the annual variation between the two seasons, starts from a low level in the early 1990s, shows two periods of high CPUE in the late 1990s and early 2010s, but is presently at a level nearly as low as the initial indices in the 1990s (Table 5, Figure 15). The SS indices are always greater than the AW indices in the same fishing year but both seasons show the same overall trend.

3.2 Historical catch rate (CR) data

Monthly catch and effort (days fishing) data from 1963 to 1973 were summarised by Annala & King (1983) and used to calculate unstandardised catch per day for each calendar year from 1963 to 1973 (Figure 16).

4. LENGTH FREQUENCY DISTRIBUTIONS

Catch sampling data were extracted for CRA 4 in August/September 2020, comprising both observer and voluntary logbook catch sampling from the 1986–87 to 2019–20 fishing years. 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 voluntary logbook catch sampling requires participating fishers to measure every lobster (up to 25 individuals) in each of 3–5 marked pots each day. This design results in good spatial and temporal representation of the catch if the participating fishers are representative of the wider fishing population. This goal is not likely to have been achieved in CRA 4 until 2010, with low levels of participation in the voluntary logbook programme from 1997 to 2009 (Table 6). The primary catch sampling method in CRA 4 has been observer sampling, whereby dedicated observers are placed on vessels, assigned according to availability, and distributed on the basis of the previous year's fishery catches. This sampling procedure measures and sexes all lobsters from as many pots as is feasible during a day's fishing for the vessel being observed. Sampling effort in CRA 4 has exceeded 40 days per year since the mid-2000s, with many years having at least 30 days of sampling before then (Table 6).

Record fields in the data set included the following information:

- fishing year
- season (coded 1 for AW, 2 for SS)
- source (coded 1 for logbooks, 2 for observers)
- a relative weight field for the record (w), described below
- the total number of lobsters measured
- 31 fields, representing the relative proportion (see below) of males measured by sex class within the sizes classes {[30, 32), [32, 34), …, [88, 90), [90, ∞)} mm tail width (TW)
- 31 fields for immature female numbers measured
- 31 fields for mature female numbers measured

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

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

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

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

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

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

Note that catches based on the F0_LFX algorithm (see appendix D of Starr 2021) were used to calculate the relative weights in Eq. 5. Appendix D documents an analysis that compared the 2019–20 LF distributions across all QMAs generated when using the F0_LFX or the F2_LFX algorithms, given that there was concern that the changes in catch reporting attributed to the transition from CELR to ER may have affected this procedure. Although the analysis presented in Appendix D suggests that there is not much sensitivity to the chosen catch algorithm, it is not possible to know if the shift to ER reporting has affected the weighting procedure. The RLWG elected to continue to use the F0_LFX algorithm in Eq. 5 for consistency with past practice and because this algorithm retains all catch data.

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

Eq. 6 $$\boldsymbol{w_s} = \sum_m \sum_a \frac{\boldsymbol{C_{m,a}} \sqrt[3]{\boldsymbol{N_{m,a,s}}} \sqrt[3]{\boldsymbol{D_{m,a}}}}{\sum_m \sum_a \boldsymbol{C_{m,a}}}$$

The approach of applying the relative weight by sex has been implemented in rock lobster stock assessments since 2017. Previous stock assessments used a single weight for the total record, after truncating weights to a maximum value of 10 while raising weights less than 1.0 to 1.0. This was done so that single records did not have exceptional influence (see Starr et al. 2015, for instance). Because of the change to using weights by sex category, the stock assessment team agreed 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. Under the previous methodology, these records would have received the same weight (across all three sex categories) and the size class with few or no measured individuals would have been inappropriately up-weighted, given the small amount of data.

The CRA 4 LF data set comprised 103 records from 1986 to 2019, spanning two seasons: 41 were logbook samples and the remaining 62 were observer samples. The RLWG agreed that all logbook samples before 2010 were unlikely to be representative of the entire fishery, given the low level of participation, and consequently agreed to drop these 21 records, leaving 20 records for use in the stock assessment (Table 6). All 62 observer catch sampling records were used for a total of 82 records available for use in the stock assessment. The logbook records ranged from 1690 to 9852 lobsters measured in both seasons and the observer samples ranged from 276 to 34 001 lobsters measured in both seasons (Table 7). The logbook sampling record weights by sex (Eq. 6) ranged from 0.001 to 8.960 for the accepted samples (after downweighting – see below) whereas the observer catch sampling record weights ranged from 0.001 to 11.01 (Table 8). All the very low weights corresponded to samples with very few observed immature females, giving an appropriate low weight to the poorly represented sex category.

The very high weights assigned to the post-2009 logbook samples compared with the observer samples are a consequence of Eq. 6, which includes the number of sampling days as part of the weight. Table 6 shows that the logbook programme, although it samples about half the potlifts compared with the observer samples, the number of days involved is more than an order of magnitude greater than the observer programme. This disparity has not been previously noted in a rock lobster stock assessment because usually one or the other sampling programme predominates. CRA 4 is the first rock lobster stock assessment where the two sampling procedures have returned similar amounts of data (in terms of numbers of measured lobsters). This disparity will be solved once a more objective weighting procedure is developed. In the meantime, the logbook weights were truncated, starting in 2010, to sum to a maximum of 10.0 to keep the logbook and observer weights on a similar scale. The weights used in the stock assessment are documented in Table 8.

Sex proportions were calculated from normalised data records from the logbook and catch sampling programmes (Table 9, Figure 17). There were relatively few immature females (mean just over 1% in both AW and SS), while the mean percentage of mature females comprised 29% of the AW samples and 39% of the SS samples, averaged across both sampling programmes. The sex ratios of males and mature females showed an increasing trend for the proportion of males in the catch in both seasons, with both sampling programmes showing similar trends (Figure 17).

Mean length was also calculated from the data records (Table 10). There was no apparent trend in male or mature female mean length in either the AW or SS for either sampling programme (Figure 18).

Although the model contains size bins in the range 30–90+ mm TW, few fish as small as 30 mm were measured, leading to many cells with zero observations (Figure 19, Table 11). 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 residuals that would distort the diagnostics and waste computing time. Bins at both ends of the range for each sex were therefore combined into accumulator “plus” and “minus” bins. Table 11 shows the number of year, season, and 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, and sampling category proportion within a sex category is less than 0.001 (an arbitrary threshold) and the calculated proportion of records is 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 observed distributions of the LF data 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) (Figure E.1 to Figure E.9). Figure 20, which plots the weighted LFs in a single plot, shows the progression of increasing size distribution over the period of sampling for males and mature females.

5. TAG DATA

This section describes tag-recapture data that are used to inform growth in the stock assessment of rock lobster stocks (Haist et al. 2009). These data will also be useful for informing decisions about stock structure and movement. Tag data for all CRA areas were extracted in August 2020.

5.1 Data processing

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

The tag processing software implemented the following rules:

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

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

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

5.2 Tag data summaries: all QMAs

5.2.1 Comparison with previous extract

A comparison was done to ensure that new data extracts were not missing records that were available in previous years and to see how many new data records are available (Table 12 and Table 13). This comparison shows small decreases in the overall number of recoveries for a number of tagging programmes (Table 12) and only a small increase of 15 recoveries in 2019 (Table 13). The reasons for the differences with the numbers available in 2019 will be investigated before the next stock assessment.

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

Recovery rates (tags turned in relative to number released) vary by QMA, with the highest rate occurring in CRA 8 (0.460) and the lowest rate in CRA 9 (0.020) (Table 14). There are 34 695 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 15). The CRA QMA with most recovered tags has been CRA 8, and the fewest recaptured tags have come from CRA 6 and CRA 9, where each has had fewer than 200 recoveries (Table 15).

Tagged lobsters are generally recaptured in the QMA or statistical area of release, but there are a number of recaptures where it appears that tagged individuals have moved much greater distances (Table 16). However, it seems more likely that many of these large-scale movements (e.g., from CRA 8 to CRA 3 and from CRA 3 to CRA 8 – see Table 16) 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 21, Figure 22). Growth rates differ among QMAs, with CRA 4 showing fewer large individuals compared with most of the other QMAs (Figure 22). The relationship between observed growth increment (mm) and time at liberty (years) appears to be less variable than for tail width, but it is still highly variable (Figure 23, Figure 24). This observation holds true for all the QMAs with an adequate amount of data (Figure 24).

5.3 CRA 4: tag data summaries

The total number of CRA 4 tag recoveries consisted of just under 3100 events, with almost all recoveries occurring from releases after 1998 (Table 17, Table 18). Unlike CRA 3 (Starr et al. 2020b), there were no recoveries based on tagging from the late 1970s or early 1980s. Tag recoveries were well distributed spatially, with all five statistical areas having reasonable representation. Statistical area 913 had the most recoveries; closely followed by 914. Areas 912, 915, and 934 each had more than 300 recoveries (Table 17, Table 18). Females were not well represented in the recovery data set, with nearly 80% of the recoveries being male. Releases were reasonably well distributed across the entire year with most every month showing several hundred releases (Table 19). Most recaptures were made in the statistical area of release, with little evidence of large-scale movement (Table 20).

The distributions of sizes at release and recapture by sex are shown in Figure 25, with most of the tagged males just below the 54 mm TW whereas the females show a broader distribution of tagged individuals. Note that the recapture polygons for both sexes in this plot are only shifted slightly to the right of the release polygons, indicating relatively small amounts of growth during the period at liberty.

5.3.1 CRA 4: times at liberty

Times at liberty varied from 1 day to 2610 days (7.2 years) for males and from 1 day to 2141 days (5.9 years) for females (Table 21). The medians were 185 days for males and 235 days for females (Table 21). The number of times an individual is re-released is also monitored with a few males re-released five to eight times and three to seven times for females (Table 22). Twenty-nine percent of the male recoveries came from re-releases; the equivalent percentage for females was 13%.

5.3.2 CRA 4: growth increments

Growth increments ranged from -9.9 to 17.9 mm (males) and -18.7 to 22.3 mm (females) (Table 23). As with the overall QMA summaries, the observed growth increment (mm) in CRA 4 by tail width at release is generally greater in smaller individuals, even when viewed by statistical area (Figure 26, Figure 27). Similarly, the relationship between observed growth increment (mm) and time at liberty (years) is somewhat tighter, even when viewed by statistical area (Figure 28, Figure 29).

6. PUERULUS SETTLEMENT DATA

The puerulus settlement programme, conducted by NIWA, is described in annual reports (e.g., Forman et al. 2021). There are two sites available for CRA 4: Napier and Castlepoint. Index series by fishing year were calculated for each site using year, month, and collector group as explanatory variables and assuming a negative binomial likelihood (Forman et al. 2021).
A comparison of the Napier and Castlepoint datasets indicated that they were reasonably similar (Figure 30). The RLWG agreed for the previous CRA 4 stock assessment (Breen et al. 2017) to average the two series to create a single puerulus series for model fitting. The procedure used for this stock assessment averaged the two indices and the logarithm of the standard deviations (after standardising each series to a geometric mean of 1.0) in those years when both were present, and used the available index and its standard deviation in the years where there was only a single index (Table 24).

Although the previous CRA 4 stock assessment incorporated this combined series into the base case assessment, the puerulus series was only used in a sensitivity run for this assessment. This was because the RLWG agreed that model behaviour was less satisfactory than for the selected base case when this data series was included. Given the small differences in fits to the data and model parameter estimates, it was agreed that the base case run should not include the combined puerulus settlement index series.

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8. REFERENCES

Annala, J H; King, M R (1983) The 1963−73 New Zealand rock lobster landings by statistical area. *Fisheries Research Division Occasional Publication, Data Series 11*. 20 p.

Bentley, N.; Kendrick, T.H.; Starr, P.J.; Breen, P.A. (2012). Influence plots and metrics: tools for better understanding fisheries catch-per-unit-effort standardisations. *ICES Journal of Marine Science 69(1)*: 84–88. https://doi.org/10.1093/icesjms/fsr174

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.

Bradford, E. (1997). Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993–94. (Unpublished New Zealand Fisheries Assessment Research Document 97/7 held by NIWA library, Wellington.) 16 p.

Bradford, E. (1998). Harvest estimates from the 1996 national marine recreational fishing surveys. (Unpublished New Zealand Fisheries Assessment Research Document 98/16 held by NIWA library, Wellington.) 27 p.

Boyd, R.O.; Gowing; L.; Reilly, J.L. (2004). 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. (Unpublished draft New Zealand Fisheries Assessment Report for the Ministry of Fisheries project REC2000-03, held by Fisheries New Zealand.) 92 p.

Boyd, R.O.; Reilly, J.L. (2004). 1999–2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished draft New Zealand Fisheries Assessment Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand.) 28 p.

Breen, P.A. (2009). A voluntary harvest control rule for a New Zealand rock lobster (*Jasus edwardsii*) stock. *New Zealand Journal of Marine and Freshwater Research 43(3)*: 941–951.

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

Breen, P.A.; Starr, P.J.; Haist, V.; Edwards, C.T.T.; Webber, D.N. (2017). The 2016 stock assessment and management procedure review for rock lobsters (*Jasus edwardsii*) in CRA 4. *New Zealand Fisheries Assessment Report 2017/29*. 88 p.

Davey, N.; Hartill, B.; Carter, M. (2019) Mean weight estimates for recreational fisheries in 2017–18. *New Zealand Fisheries Assessment Report 2019/25*. 32 p.

Forman, J.S; McKenzie, A.; Stotter, D.R. (2021). Red rock lobster (*Jasus edwardsii*) settlement indices for the 2019 fishing year. *New Zealand Fisheries Assessment Report 2021/42*. 67 p.

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

Hartill, B.; Davey, N. (2015). Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25*. 37 p.

Heinemann, A.; Wynne-Jones, J.; Gray, A.; Hill, L. (2015). National Panel Survey of Marine Recreational Fishers 2011–12 Rationale and Methods. *New Zealand Fisheries Assessment Report 2015/48*. 94 p.

Rudd, M.B.; Pons, M.; Roberts, J.; Webber, D.N.; Starr, P.J. (in press). The 2020 stock assessment of rock lobsters (*Jasus edwardsii*) in CRA 4. (New Zealand Fisheries Assessment Report held by Fisheries New Zealand.)

Starr, P.J. (2021). Rock lobster catch and effort data: 1979–80 to 2019–20. *New Zealand Fisheries Assessment Report 2021/55.* 126 p.

Starr, P.J.; Breen, P.A.; Webber, D.N. (2015). Data for the 2014 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1. *New Zealand Fisheries Assessment Report 2015/37*. 39 p.

Starr, P.J.; Webber, D.N.; Breen, P.A. (2017). Data for the 2016 stock assessments of red rock lobsters (*Jasus edwardsii*) in CRA 4. *New Zealand Fisheries Assessment Report 2017/28.* 48 p.

Starr, P.J.; Webber, D.N.; Rudd, M.B.; Large, K.; Roberts, J. (2020a). Data for the 2019 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1. *New Zealand Fisheries Assessment Report 2020/44*. 78 p.

Starr, P.J.; Webber, D.N.; Rudd, M.B.; Large, K.; Roberts, J. (2020b). Data for the 2019 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 3. *New Zealand Fisheries Assessment Report 2020/41*. 102 p.

Webber, D.N.; Haist, V.; Starr, P.J.; Edwards, C.T.T. (2018). A new model for the assessment of New Zealand rock lobster (*Jasus edwardsii*) stocks and an exploratory multi-area CRA 4 assessment. *New Zealand Fisheries Assessment Report 2018/53.* 111 p.

Webber, D.N.; Starr, P.J. (2020). Operational management procedures of New Zealand rock lobster (*Jasus edwardsii*) stocks for 2020–21. *New Zealand Fisheries Assessment Report 2020/46.* 29 p.

Wynne-Jones, J.; Gray, A.; Heinemann, A.; Hill, L; Walton, L. (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

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.

9. TABLES

Table 1: Information used to estimate recreational catch for CRA 4.

Category	Numbers	Mean weight	Weight (kg)	Assumed CV
1994 (Bradford 1997)	65 000	0.510[1]	33 182	1.5*(0.17+0.23)/2
1996 (Bradford 1998)	118 000	0.510[1]	60 237	1.5*(0.17+0.23)/2
2000 (Boyd & Reilly 2004)	371 000	0.513[2]	190 275	not used
2001 (Boyd et al. 2004)	289 000	0.513[2]	148 220	not used
2011 (NPS)	53 847[3]	0.82[3]	44 170	0.17
2017 (NPS)	52 145[4]	0.79[4]	41 370	0.23
Section 111 reported landings				
Maximum reported landings (kg) (in 2012)			5 835	

[1] SS mean weight (kg) calculated from commercial sampling data from 1994 to 1996 assuming recreational minimum legal sizes
[2] SS mean weight (kg) calculated from commercial sampling data from 2000 and 2001 assuming recreational minimum legal sizes
[3] 2011/12 National Panel Survey (NPS) (Wynne-Jones et al. 2014)
[4] 2017/18 National Panel Survey (NPS) (Wynne-Jones et al. 2019)

Table 2: Fishing platform and capture method categories for CRA 4 during 2011–12 and 2017–18 estimated by the NPS recreational survey (Wynne-Jones et al. 2014). The final line shows the 2011–12 and 2017–18 CRA 4 total catch estimates. CV=standard error (SE) of the estimate, which does not include error associated with the estimate of mean weight.

Category	Numbers	CV	Catch (t)[1,2]	CV	% of Total Catch Weight
Survey year: 2011–12					
Fishing platform					
Trailer motor boat	35 009	0.26	27.20	0.27	62
Larger motor boat or launch	599	0.92	0.37	0.87	1
Trailer yacht	0		0		0
Larger yacht or keeler	240	1.01	0.24	1.01	1
Kayak canoe or rowboat	1 413	0.63	0.99	0.86	2
Off land including beach rocks or jetty	16 587	0.40	15.38	0.41	35
Something else	0		0		0
Capture method					
Rod or line (not long line)	0		0		0
Long-line including set line kontiki or kite	0		0		0
Net (not including landing net used if caught on line)	0		0		0
Pot (e.g. for crayfish)	22581	0.38	13.13	0.38	30
Dredge grapple or rake	0		0		0
Hand gather or floundering from shore	844	0.62	0.84	0.62	2
Hand gather by diving	30 422	0.28	30.20	0.28	68
Spearfishing	0		0		0
Some other method	0		0		0
Total (2011–12)	53 813	0.17	44.17	0.17	100
Survey year: 2017–18					
Fishing platform					
Trailer motor boat	31 426	0.32	23.71	0.36	57
Larger motor boat or launch	1 844	0.63	1.30	0.54	3
Trailer yacht	0	0			0
Larger yacht or keeler	0	0			0
Kayak canoe or rowboat	266	0.71	0.13	0.71	0
Off land including beach rocks or jetty	18 483	0.26	16.16	0.25	39
Something else	126	1.00	0.06	1.00	0
Fishing capture method					
Rod or line (not long line)	0	0.00			0
Long-line including set line kontiki or kite	0	0.00			0
Net (not including landing net used if caught on line)	0	0.00			0
Pot (e.g. for crayfish)	20 147	0.30	10.11	0.3	24
Dredge grapple or rake	0	0.00			0
Hand gather or floundering from shore	50	1.00	0.05	1	0.1
Hand gather by diving	31 949	0.29	31.21	0.29	75
Spearfishing	0	0.00			0
Some other method	0	0.00			0
Total (2017–18)	52 146	0.33	41.37	0.21	100

[1] mean weight estimate (Hartill & Davey 2015)
[2] mean weight estimate (Davey et al. 2019)

Table 3: **Estimated CRA 4 catches (commercial, recreational including section 111, customary and illegal) by season in tonnes. Note that the model does not use two seasons until 1979; annual estimates are provided in the AW column before 1979. (Continued on next page)**

	Commercial		Recreational		Customary		Illegal		Total	
Year	AW	SS	AW	SS	AW	SS	AW	SS	AW	SS
1945	247.3	–	11.9	–	20	–	55.4	–	334.6	–
1946	218.0	–	12.6	–	20	–	55.4	–	305.9	–
1947	246.3	–	13.3	–	20	–	55.4	–	335.0	–
1948	245.8	–	14.0	–	20	–	55.4	–	335.2	–
1949	266.5	–	14.7	–	20	–	55.4	–	356.7	–
1950	496.1	–	15.4	–	20	–	55.4	–	586.9	–
1951	666.3	–	16.2	–	20	–	55.4	–	757.8	–
1952	646.5	–	16.9	–	20	–	55.4	–	738.7	–
1953	671.4	–	17.6	–	20	–	55.4	–	764.3	–
1954	659.3	–	18.3	–	20	–	55.4	–	752.9	–
1955	496.4	–	19.0	–	20	–	55.4	–	590.8	–
1956	426.6	–	19.7	–	20	–	55.4	–	521.7	–
1957	320.3	–	20.4	–	20	–	55.4	–	416.1	–
1958	333.2	–	21.1	–	20	–	55.4	–	429.7	–
1959	286.7	–	21.8	–	20	–	55.4	–	383.9	–
1960	354.5	–	22.6	–	20	–	55.4	–	452.5	–
1961	412.5	–	23.3	–	20	–	55.4	–	511.1	–
1962	494.0	–	24.0	–	20	–	55.4	–	593.3	–
1963	302.9	–	24.7	–	20	–	55.4	–	403.0	–
1964	452.5	–	25.4	–	20	–	55.4	–	553.3	–
1965	574.0	–	26.1	–	20	–	55.4	–	675.5	–
1966	656.1	–	26.8	–	20	–	55.4	–	758.3	–
1967	505.3	–	27.5	–	20	–	55.4	–	608.2	–
1968	502.2	–	28.2	–	20	–	55.4	–	605.8	–
1969	599.4	–	29.0	–	20	–	55.4	–	703.7	–
1970	551.6	–	29.7	–	20	–	55.4	–	656.6	–
1971	412.0	–	30.4	–	20	–	55.4	–	517.7	–
1972	418.9	–	31.1	–	20	–	55.4	–	525.4	–
1973	366.4	–	31.8	–	20	–	55.4	–	473.6	–
1974	367.6	–	32.5	–	20	–	55.4	–	475.5	–
1975	396.6	–	33.2	–	20	–	55.4	–	505.2	–
1976	448.6	–	33.9	–	20	–	55.4	–	557.9	–
1977	430.6	–	34.6	–	20	–	55.4	–	540.6	–
1978[1]	489.0	–	35.4	–	20	–	55.4	–	599.7	–
1979–80	157.1	339.9	3.6	32.5	2	18	15.8	34.1	178.5	424.4
1980–81	221.3	379.9	3.4	30.3	2	18	17.8	30.5	244.5	458.7
1981–82	226.5	380.8	3.6	32.5	2	18	19.3	32.5	251.4	463.9
1982–83	303.9	542.2	3.9	34.8	2	18	20.0	35.7	329.8	630.7
1983–84	369.7	563.9	3.5	31.2	2	18	20.0	30.6	395.3	643.7
1984–85	338.8	518.3	3.2	29.2	2	18	18.2	27.8	362.2	593.3
1985–86	269.2	572.9	3.5	31.2	2	18	14.0	29.9	288.7	651.9
1986–87	269.0	672.2	3.6	32.6	2	18	13.3	33.3	287.9	756.1
1987–88	273.9	650.0	3.3	29.9	2	18	12.1	28.7	291.3	726.5
1988–89	233.5	527.2	2.8	25.6	2	18	10.5	23.8	248.9	594.7
1989–90	218.0	536.0	2.9	26.2	2	18	9.8	24.0	232.6	604.2
1990–91	167.9	353.7	2.7	24.3	2	18	3.9	8.2	176.5	404.2
1991–92	175.7	353.2	2.7	24.4	2	18	4.1	8.1	184.5	403.7
1992–93	182.5	311.6	2.6	23.7	2	18	4.3	7.4	191.5	360.7
1993–94	232.9	257.5	2.9	26.2	2	18	6.1	6.7	243.9	308.4
1994–95	270.1	218.1	3.5	31.5	2	18	9.1	7.3	284.6	274.9
1995–96	341.8	142.5	4.7	41.9	2	18	15.2	6.4	363.7	208.8
1996–97	443.0	46.8	6.1	55.2	2	18	26.3	2.8	477.4	122.7
1997–98	456.7	29.2	6.5	58.3	2	18	31.8	2.0	497.0	107.6
1998–99	445.8	42.3	8.4	75.2	2	18	35.2	3.3	491.3	138.8
1999–00	528.2	43.7	7.1	63.9	2	18	32.1	2.7	569.4	128.3
2000–01	500.1	69.4	7.9	70.9	2	18	28.6	4.0	538.6	162.3
2001–02	471.5	98.9	6.2	55.8	2	18	23.0	4.8	502.7	177.5
2002–03	433.4	138.5	6.6	59.0	2	18	21.7	6.9	463.6	222.4
2003–04	363.4	208.4	6.3	56.9	2	18	18.7	10.7	390.4	294.0
2004–05	260.5	306.4	5.0	45.0	2	18	10.3	12.1	277.8	381.5
2005–06	197.1	304.4	3.7	33.0	2	18	7.6	11.7	210.3	367.1
2006–07	115.2	327.3	3.3	29.3	2	18	4.1	11.7	124.6	386.3
2007–08	72.6	240.8	3.0	26.7	2	18	3.2	10.6	80.8	296.0
2008–09	70.3	176.8	3.7	33.2	2	18	5.0	12.5	80.9	240.5
2009–10	119.0	140.0	4.9	44.0	2	18	11.2	13.2	137.1	215.2
2010–11	200.8	210.7	5.0	45.0	2	18	11.9	12.5	219.7	286.2
2011–12	259.0	203.3	5.8	51.9	2	18	16.5	13.0	283.3	286.2
2012–13	238.3	228.0	6.2	55.4	2	18	16.9	16.2	263.3	317.6

Year	Commercial AW	Commercial SS	Recreational AW	Recreational SS	Customary AW	Customary SS	Illegal AW	Illegal SS	Total AW	Total SS
2013–14	249.8	249.6	5.3	48.0	2	18	14.1	14.1	271.2	329.7
2014–15	194.8	270.7	4.6	41.0	2	18	10.3	14.3	211.7	344.0
2015–16	108.8	329.3	3.7	32.9	2	18	4.4	13.3	118.9	393.6
2016–17	79.1	303.8	3.5	31.7	2	18	3.2	12.2	87.8	365.6
2017–18	63.5	225.5	4.1	37.0	2	18	4.3	15.2	73.9	295.7
2018–19	90.3	228.1	4.2	38.2	2	18	6.0	15.2	102.5	299.5
2019–20	82.4	197.8	4.0	35.6	2	18	5.5	13.2	93.9	264.7

[1] includes January-March 1979 catches

Table 4: Number of vessel/statistical area/month records in the dataset used to calculate the CRA 4 seasonal CPUE time series for both the FSU and CELR data sets.

Fishing year	Autumn-Winter 912	913	914	915	934	Total	Spring-Summer 912	913	914	915	934	Total
FSU data												
1979–80	89	80	92	50	1	312	136	113	136	96	1	482
1980–81	101	80	102	61	1	345	149	90	135	110	7	491
1981–82	109	72	103	55	–	339	146	76	122	97	1	442
1982–83	122	66	117	64	1	370	147	98	157	108	3	513
1983–84	109	84	121	74	2	390	137	111	157	101	5	511
1984–85	99	91	137	73	3	403	118	96	149	91	5	459
1985–86	112	77	134	71	1	395	133	79	158	97	8	475
1986–87	102	85	131	67	–	385	127	103	152	85	6	473
1987–88	98	80	125	53	–	356	121	94	160	79	3	457
1988–89	94	71	127	54	2	348	105	92	149	66	–	412
1989–90	56	55	75	22	-	208	–	–	–	–	–	–
Total	1 091	841	1 264	644	11	3 851	1 319	952	1 475	930	39	4 715
CELR data												
1989–90	–	–	–	–	–	–	80	89	123	39	–	331
1990–91		67	81	33	–	248	84	78	94	53	–	309
1991–92	97	76	97	39	1	310	101	77	99	50	4	331
1992–93	97	79	100	38	2	316	115	87	97	43	5	347
1993–94	120	80	112	43	3	358	86	78	68	39	2	273
1994–95	79	78	139	45	1	342	35	69	48	30	–	182
1995–96	73	60	141	30	–	304	38	45	36	15	–	134
1996–97	72	53	115	46	–	286	22	9	15	6	–	52
1997–98	63	38	110	32	–	243	10	4	13	5	–	32
1998–99	77	33	104	40	–	254	16	3	15	12	–	46
1999–00	73	38	94	31	–	236	16	2	19	3	–	40
2000–01	79	29	98	31	–	237	26	10	18	13	–	67
2001–02	70	42	101	43	–	256	24	20	30	9	–	83
2002–03	70	68	113	25	–	276	29	27	46	19	–	121
2003–04	51	75	98	37	–	261	37	41	45	31	–	154
2004–05	52	56	113	34	–	255	52	48	73	23	–	196
2005–06	41	53	81	31	–	206	49	47	92	37	–	225
2006–07	34	46	82	39	6	207	62	51	110	52	11	286
2007–08	30	27	68	31	7	163	57	39	91	42	9	238
2008–09	31	28	48	24	6	137	44	41	52	26	5	168
2009–10	36	40	47	25	5	153	44	35	39	35	5	158
2010–11	51	40	73	43	10	217	47	37	67	44	3	198
2011–12	45	54	81	26	7	213	36	31	61	26	9	163
2012–13	38	41	83	22	7	191	38	39	67	29	8	181
2013–14	34	31	88	19	4	176	39	30	78	22	2	171
2014–15	31	32	88	26	3	180	42	41	93	32	–	208
2015–16	30	32	87	25	5	179	46	47	110	39	5	247
2016–17	37	33	59	24	4	157	39	47	100	39	3	228
2017–18	23	27	48	16	4	118	21	43	63	20	2	149
2018–19	18	24	48	23	4	117	18	37	65	27	2	149
2019–20	7	18	26	13	3	67	–	–	–	–	–	–
Total	1 626	1 398	2 623	934	82	6 663	1 353	1 252	1 927	860	75	5 467

Table 5: Seasonal standardised CPUE Bayesian GLM results used in the CRA 4 stock assessment, showing median estimated standardised indices and standard error derived from separate analyses using the FSU (1979–80 AW to 1989–90 AW) data and the CELR (1989–90 SS to 2019–20 AW) data.

	Autumn-winter		Spring-Summer	
Fishing year	Standardised Index	Standard Error	Standardised Index	Standard Error
FSU data				
1979–80	1.133	0.135	1.216	0.133
1980–81	1.156	0.133	1.103	0.118
1981–82	1.189	0.138	1.206	0.133
1982–83	1.247	0.146	1.290	0.142
1983–84	1.173	0.134	1.129	0.121
1984–85	0.987	0.113	1.020	0.113
1985–86	0.823	0.095	1.069	0.120
1986–87	0.849	0.098	1.125	0.121
1987–88	0.722	0.085	1.018	0.110
1988–89	0.630	0.072	0.840	0.095
1989–90	0.567	0.068	–	–
CELR data				
1989–90	–	–	0.852	0.126
1990–91	0.535	0.080	0.773	0.115
1991–92	0.555	0.082	0.750	0.112
1992–93	0.524	0.078	0.745	0.113
1993–94	0.570	0.085	0.825	0.125
1994–95	0.682	0.104	1.072	0.166
1995–96	0.924	0.137	1.415	0.223
1996–97	1.158	0.172	1.864	0.309
1997–98	1.379	0.209	1.993	0.346
1998–99	1.587	0.242	2.408	0.398
1999–00	1.433	0.214	2.152	0.377
2000–01	1.331	0.203	2.376	0.379
2001–02	1.112	0.168	1.754	0.275
2002–03	1.046	0.158	1.944	0.297
2003–04	1.050	0.155	1.715	0.259
2004–05	0.786	0.118	1.399	0.212
2005–06	0.729	0.111	0.879	0.134
2006–07	0.608	0.091	0.821	0.121
2007–08	0.498	0.076	0.753	0.114
2008–09	0.671	0.103	0.968	0.147
2009–10	0.898	0.135	1.284	0.198
2010–11	0.848	0.126	1.338	0.201
2011–12	0.995	0.147	1.539	0.237
2012–13	1.206	0.184	1.594	0.243
2013–14	1.013	0.152	1.395	0.213
2014–15	0.918	0.139	1.110	0.166
2015–16	0.596	0.089	0.898	0.136
2016–17	0.453	0.069	0.862	0.132
2017–18	0.597	0.092	0.925	0.145
2018–19	0.694	0.107	1.024	0.157
2019–20	0.627	0.101	–	–

Table 6: Sampling intensity by fishing year in CRA 4 by the logbook and observer catch sampling programme from 1986. "Lobsters" are the number of individuals measured. Number of active vessels in CRA 4 is included to show the level of participation in the logbook programme. Cells marked in grey were not used in the stock assessment because the data were considered to be unrepresentative.

Fishing					Logbooks				Observer catch sampling
year	Vessels[1]	Fishers	Days	Potlifts	Lobsters	Vessels	Days	Potlifts	Lobsters
1986	–	–	–	–	–	2	2	177	552
1987	–	–	–	–	–	4	15	1 280	4 005
1988	–	–	–	–	–	7	15	1 280	4 783
1989	–	–	–	–	–	7	25	2 734	8 477
1990	–	–	–	–	–	8	39	4 312	25 484
1991	–	–	–	–	–	4	22	2 394	19 108
1992	–	–	–	–	–	4	20	2 295	18 395
1993	–	–	–	–	–	3	20	2 300	12 179
1994	–	–	–	–	–	4	12	1 379	8 286
1995	–	–	–	–	–	5	16	1 634	9 911
1996	–	–	–	–	–	6	7	711	4 631
1997	72	1	60	213	1 844	13	34	4 220	34 479
1998	65	3	50	174	1 397	11	27	3 123	19 445
1999	70	1	33	119	297	15	39	4 639	25 488
2000	61	1	7	23	331	15	39	4 217	22 887
2001	62	–	–	–	–	18	32	3 980	21 013
2002	65	1	51	200	592	18	35	4 533	21 335
2003	65	1	95	374	1 501	21	35	4 429	18 769
2004	61	1	73	278	1 024	25	36	4 397	23 351
2005	54	2	126	498	2 462	26	46	5 410	26 433
2006	66	2	118	452	1 406	23	46	5 665	22 604
2007	53	1	71	278	1 400	24	47	5 235	20 510
2008	42	1	39	146	522	22	40	3 991	20 496
2009	43	2	37	143	945	21	42	4 318	20 498
2010	51	7	199	715	3 675	25	43	3 968	18 393
2011	51	11	191	711	5 674	23	43	4 143	19 452
2012	49	6	214	753	5 988	24	44	5 292	23 514
2013	47	4	159	548	3 559	24	45	5 620	22 600
2014	49	9	316	1 129	8 618	22	41	4 537	16 871
2015	47	11	548	1 821	10 194	23	41	4 922	15 065
2016	45	14	695	2 253	12 449	27	43	4 337	13 762
2017	39	13	494	1 640	9 498	26	47	4 803	19 976
2018	45	13	624	2 040	12 136	27	45	4 738	14 957
2019	38	13	391	1 351	9 031	22	46	4 369	16 954
Total	–	–	4 591	15 859	94 543	–	1 129	125 382	594 663

[1] from Starr (2021).

Table 7: Number of lobsters measured by the observer and logbook catch sampling programmes by fishing year, sex category, and season. '–': no data. Cells marked in grey were not used in the stock assessment because the data were considered to be unrepresentative. (Continued on next page)

Fishing year	Logbooks				Observer catch sampling			
	Male	Immature female	Mature female	Total	Male	Immature female	Mature female	Total
Season=AW								
1986	–	–	–	–	–	–	––	
1987	–	–	–	–	895	41	258	1 194
1988	–	–	–	–	1 492	80	408	1 980
1989	–	–	–	–	2 259	222	1 180	3 661
1990	–	–	–	–	3 582	597	3 672	7 851
1991	–	–	–	–	1 951	32	1 001	2 984
1992	–	–	–	–	1 026	33	443	1 502
1993	–	–	–	–	595	32	485	1 112
1994	–	–	–	–	2 217	8	315	2 540
1995	–	–	–	–	1 701	76	618	2 395
1996	–	–	–	–	3 687	40	822	4 549
1997	610	–	1 164	1 774	24 163	148	9 690	34 001
1998	99	10	702	811	14 558	61	4 513	19 132
1999	151	2	144	297	18 421	257	6 437	25 115
2000	230	–	101	331	12 913	317	9 294	22 524
2001	–	–	–	–	10 815	211	6 131	17 157
2002	248	20	226	494	11 899	405	5 792	18 096
2003	297	1	954	1 252	9 062	168	5 892	15 122
2004	258	26	651	935	8 833	143	4 261	13 237
2005	840	157	1 164	2 161	5 395	39	4 011	9 445
2006	534	56	709	1 299	5 213	77	3 345	8 635
2007	333	39	366	738	5 181	155	2 083	7 419
2008	364	2	156	522	3 029	138	1 156	4 323
2009	424	18	423	865	4 678	73	1 409	6 160
2010	1 591	22	593	2 206	5 276	67	2 766	8 109
2011	3 312	16	412	3 740	8 710	41	2 878	11 629
2012	2 408	50	347	2 805	9 310	47	3 451	12 808
2013	1 234	14	442	1 690	6 584	56	1 729	8 369
2014	2 123	7	1 044	3 174	6 785	38	2 079	8 902
2015	3 292	18	750	4 060	4 595	17	1 353	5 965
2016	2 126	21	568	2 715	3 200	22	646	3 868
2017	1 701	29	520	2 250	2 409	37	1 014	3 460
2018	1 697	27	557	2 281	4 164	45	1 160	5 369
2019	2 002	37	848	2 887	4 000	135	1 142	5 277
Total	25 874	572	12 841	39 287	208 598	3 858	91 434	303 890
Season=SS								
1986	–	–	–	–	224	5	47	276
1987	–	–	–	–	990	63	511	1 564
1988	–	–	–	–	1 496	58	297	1 851
1989	–	–	–	–	2 256	183	2 174	4 613
1990	–	–	–	–	7 925	538	8 707	17 170
1991	–	–	–	–	9 062	255	6 338	15 655
1992	–	–	–	–	12 350	297	3 899	16 546
1993	–	–	–	–	5 868	149	4 774	10 791
1994	–	–	–	–	3 393	19	2 118	5 530
1995	–	–	–	–	4 772	58	2 543	7 373
1996	–	–	–	–	–	–	–	–
1997	4	–	66	70	–	–	–	–
1998	151	12	423	586	–	–	–	–
1999	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–
2001	–	–	–	–	706	19	2 836	3 561
2002	50	8	40	98	1 276	15	1 590	2 881
2003	36	–	210	246	1 505	66	1 865	3 436

Fishing year	Logbooks				Observer catch sampling			
	Male	Immature female	Mature female	Total	Male	Immature female	Mature female	Total
2004	13	–	75	88	4 431	56	5 362	9 849
2005	136	21	143	300	8 297	114	8 227	16 638
2006	31	–	76	107	6 548	217	6 938	13 703
2007	303	5	354	662	6 753	162	5 972	12 887
2008	–	–	–	–	9 862	658	5 463	15 983
2009	60	1	19	80	7 234	82	6 854	14 170
2010	1 065	10	389	1 464	4 773	87	5 371	10 231
2011	1 546	6	380	1 932	4 476	32	3 150	7 658
2012	2 056	4	1 121	3 181	4 361	64	4 602	9 027
2013	1 204	1	663	1 868	4 041	69	4 390	8 500
2014	3 801	170	1 460	5 431	4 312	112	3 001	7 425
2015	4 139	80	1 890	6 109	4 462	52	4 539	9 053
2016	5 865	91	3 758	9 714	5 689	33	4 141	9 863
2017	4 446	211	2 586	7 243	8 431	91	7 929	16 451
2018	7 350	228	2 274	9 852	5 654	64	3 753	9 471
2019	4 173	32	1 933	6 138	7 197	98	4 341	11 636
Total	36 429	880	17 860	55 169	148 344	3 716	121 732	273 792

Table 8: Sample weight (Eq. 6) calculated for each LF sampling record given in Table 7. '–': no data. Cells marked in grey were not used in the stock assessment because the data were considered to be unrepresentative. Logbook sample weights from 2010 were proportionately reduced to an arbitrary maximum seasonal weight of 10. See text for an explanation. (Continued on next page)

	Logbooks				Observer catch sampling			
Fishing year	Male	Immature female	Mature female	Total	Male	Immature female	Mature female	Total
Season=AW								
1987	–	–	–	–	0.793	0.024	0.203	1.020
1988	–	–	–	–	0.976	0.054	0.290	1.319
1989	–	–	–	–	1.812	0.126	0.941	2.879
1990	–	–	–	–	2.563	0.271	2.774	5.607
1991	–	–	–	–	0.914	0.015	0.469	1.398
1992	–	–	–	–	0.461	0.015	0.199	0.674
1993	–	–	–	–	0.043	0.002	0.035	0.080
1994	–	–	–	–	0.369	0.001	0.052	0.423
1995	–	–	–	–	0.862	0.038	0.313	1.213
1996	–	–	–	–	1.884	0.013	0.351	2.248
1997	2.447	–	4.440	6.887	11.011	0.058	6.250	17.319
1998	0.334	0.029	2.033	2.395	8.407	0.036	3.172	11.615
1999	1.515	0.010	1.302	2.827	8.825	0.113	3.551	12.488
2000	0.135	–	0.059	0.195	7.099	0.134	5.041	12.274
2001	–	–	–	–	4.956	0.056	3.139	8.152
2002	0.510	0.031	0.318	0.858	6.575	0.134	3.240	9.948
2003	0.389	0.001	0.967	1.357	6.661	0.101	4.566	11.327
2004	0.280	0.026	0.637	0.944	7.025	0.093	4.708	11.826
2005	1.277	0.256	1.618	3.151	5.127	0.025	2.173	7.325
2006	1.567	0.131	1.922	3.620	4.401	0.060	2.630	7.091
2007	1.798	0.229	1.889	3.917	4.722	0.175	2.178	7.075
2008	1.541	0.008	0.628	2.177	3.055	0.133	1.041	4.230
2009	1.277	0.056	1.251	2.584	4.106	0.063	1.235	5.404
2010	6.141	0.036	1.394	7.572	3.499	0.032	1.455	4.986
2011	8.960	0.053	0.987	10.000	7.001	0.013	1.591	8.605
2012	8.746	0.192	1.062	10.000	7.426	0.026	2.084	9.536
2013	5.360	0.014	1.824	7.198	6.476	0.053	1.904	8.433
2014	7.157	0.051	2.791	10.000	5.672	0.049	2.316	8.037
2015	8.301	0.061	1.639	10.000	7.704	0.029	2.325	10.057
2016	7.800	0.092	2.108	10.000	4.831	0.013	0.935	5.779
2017	7.737	0.146	2.117	10.000	2.314	0.023	1.191	3.529
2018	7.803	0.092	2.105	10.000	4.209	0.049	1.159	5.416
2019	6.980	0.125	2.896	10.000	2.865	0.100	0.901	3.865
Season=SS								
1986	–	–	–	–	0.091	0.002	0.019	0.112
1987	–	–	–	–	0.762	0.042	0.410	1.214
1988	–	–	–	–	0.628	0.022	0.144	0.794
1989	–	–	–	–	1.629	0.114	1.440	3.183
1990	–	–	–	–	3.905	0.248	4.579	8.732
1991	–	–	–	–	4.969	0.148	3.843	8.961
1992	–	–	–	–	5.392	0.124	1.915	7.431
1993	–	–	–	–	4.359	0.098	3.594	8.052
1994	–	–	–	–	3.468	0.021	2.365	5.854
1995	–	–	–	–	3.899	0.053	2.390	6.342
1996	–	–	–	–	–	–	––	
1997	0.104	–	1.714	1.818	–	–	––	
1998	1.331	0.149	3.702	5.183	–	––	–	
1999	–	–	–	–	–	–	––	
2000	–	–	–	–	–	–	––	
2001	–	–	–	–	0.366	0.007	1.616	1.988
2002	0.094	0.015	0.075	0.185	1.205	0.010	1.305	2.521

	Logbooks				Observer catch sampling			
Fishing year	Male	Immature female	Mature female	Total	Male	Immature female	Mature female	Total
2003	0.078	–	0.454	0.532	1.048	0.057	1.683	2.788
2004	0.019	–	0.107	0.126	3.487	0.052	5.249	8.787
2005	0.299	0.053	0.271	0.622	4.383	0.054	5.069	9.506
2006	0.107	–	0.262	0.370	4.254	0.096	4.617	8.967
2007	0.684	0.014	0.764	1.462	4.504	0.086	4.048	8.638
2008	–	–	–	–	6.453	0.198	2.749	9.400
2009	0.250	0.001	0.126	0.378	6.080	0.068	5.639	11.786
2010	3.735	0.017	1.073	4.825	3.283	0.050	3.311	6.644
2011	8.100	0.038	1.862	10.000	4.016	0.026	3.118	7.160
2012	6.537	0.005	3.457	10.000	3.392	0.018	2.686	6.096
2013	4.323	0.004	3.210	7.537	0.865	0.010	1.041	1.916
2014	7.584	0.647	1.770	10.000	3.961	0.097	2.873	6.932
2015	7.101	0.231	2.668	10.000	2.776	0.045	2.813	5.634
2016	6.164	0.093	3.744	10.000	4.588	0.029	3.353	7.970
2017	6.173	0.284	3.542	10.000	5.077	0.077	5.775	10.928
2018	7.505	0.252	2.243	10.000	3.046	0.040	2.248	5.334
2019	6.492	0.039	3.468	10.000	4.258	0.055	2.981	7.293

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	0.884	0.034	0.392	0.811	0.050	0.619
Minimum	0.577	0.002	0.111	0.379	0.002	0.174
Mean	0.738	0.010	0.252	0.611	0.014	0.375

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	54.8	57.1	64.2	54.6	57.6	60.9
Minimum mean TW	49.0	39.7	51.7	49.8	43.2	52.8
Mean TW	53.7	50.8	60.9	52.9	53.1	58.4

Table 11: Number of year, season, and sampling category records by 2-mm tail width bin for each sex category. Also shown are the number of these records where the year, season, sampling category proportion within a sex category is less than 0.001 and the calculated proportion of records greater than 0.001. Bold grey cells indicate accumulator bins.

	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)	22	22	0.00	**13**	**13**	**0.00**	0		
[32,34)	31	27	0.13	17	16	0.06	2	1	0.50
[34,36)	38	30	0.21	25	23	0.08	8	8	0.00
[36,38)	47	31	0.34	28	23	0.18	15	15	0.00
[38,40)	63	37	0.41	51	40	0.22	25	24	0.04
[40,42)	**79**	**39**	**0.51**	57	41	0.28	40	34	0.15
[42,44)	87	21	0.76	63	42	0.33	**54**	**42**	**0.22**
[44,46)	92	8	0.91	73	45	0.38	69	46	0.33
[46,48)	96	2	0.98	67	40	0.40	83	41	0.51
[48,50)	100	0	1.00	72	45	0.38	91	16	0.82
[50,52)	102	0	1.00	74	45	0.39	98	5	0.95
[52,54)	103	0	1.00	78	49	0.37	99	2	0.98
[54,56)	103	0	1.00	85	43	0.49	101	0	1.00
[56,58)	102	0	1.00	83	39	0.53	103	0	1.00
[58,60)	100	1	0.99	79	41	0.48	103	0	1.00
[60,62)	98	5	0.95	61	41	0.33	103	0	1.00
[62,64)	95	5	0.95	42	31	0.26	102	0	1.00
[64,66)	94	10	0.89	31	23	0.26	101	1	0.99
[66,68)	89	15	0.83	20	17	0.15	100	3	0.97
[68,70)	86	16	0.81	**10**	**9**	**0.10**	96	5	0.95
[70,72)	79	24	0.70	10	7	0.30	95	9	0.91
[72,74)	76	33	0.57	6	6	0.00	87	9	0.90
[74,76)	66	33	0.50	3	3	0.00	83	18	0.78
[76,78)	64	44	0.31	2	2	0.00	76	27	0.64
[78,80)	61	43	0.30	3	3	0.00	75	31	0.59
[80,82)	**57**	**49**	**0.14**	0			68	35	0.49
[82,84)	56	48	0.14	0			63	34	0.46
[84,86)	45	38	0.16	2	2	0.00	**57**	**38**	**0.33**
[86,88)	42	41	0.02	0			53	40	0.25
[88,90)	39	37	0.05	0			42	37	0.12
[90, ∞)	36	30	0.17	1	1	0	48	39	0.19

Table 12: Comparison of the number of records by Project ID in the new tag data extract with the number of records in the extract made for the 2019 CRA 1/CRA 3 stock assessments (Starr et al. 2020a, 2020b).

Project_ID	Previous	Current	Difference
CRA_Akaroa	227	227	0
CRA_CCampb	44	44	0
CRA_Gis70s	2244	2240	-4
CRA_Gisb	48	48	0
CRA_ReefPt	573	573	0
CRA_StewIs	1622	1614	-8
CRA01Gisb	1179	1179	0
CRA1_TAG	1592	1591	-1
CRA2_EBOP	5	5	0
CRA2_TAG	4364	4357	-7
CRA2_WBOP	268	268	0
CRA3_TAG	2070	2057	-13
CRA4_TAG	3128	3115	-13
CRA4_Wair	10	10	0
CRA5_Kaik	1176	1176	0
CRA5_TAG	5946	5903	-43
CRA6_TAG	183	181	-2
CRA7_TAG	632	646	14
CRA7rs	199	199	0
CRA8_Fiord	1714	1714	0
CRA8_TAG	7295	7189	-106
CRA8rs	236	233	-3
CRA9_TAG	126	126	0

Table 13: 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 2019 CRA 1/CRA 3 stock assessments (Starr et al. 2020a, 2020b).

Year	Previous	Current	Difference	Year	Previous	Current	Difference
1966	53	53	0	1997	2 579	2 558	- 21
1967	29	28	- 1	1998	2 950	2 944	- 6
1968	7	7	0	1999	2 494	2 486	- 8
1969	2	2	0	2000	1 593	1 587	- 6
1971	1	1	0	2001	1 378	1 377	- 1
1975	115	115	0	2002	1 576	1 571	- 5
1976	1 275	1 268	- 7	2003	1 122	1 121	- 1
1977	2 096	2 091	- 5	2004	2 083	2 079	- 4
1978	886	886	0	2005	2 410	2 386	- 24
1979	1 081	1 081	0	2006	978	978	0
1980	1 112	1 112	0	2007	489	488	- 1
1981	593	593	0	2008	367	366	- 1
1982	332	332	0	2009	306	304	- 2
1983	273	273	0	2010	237	237	0
1984	1 071	1 071	0	2011	550	548	- 2
1985	395	394	- 1	2012	333	333	0
1986	76	76	0	2013	485	484	- 1
1987	18	18	0	2014	768	764	- 4
1988	4	4	0	2015	856	855	- 1
1989	2	2	0	2016	516	514	- 2
1991	1	1	0	2017	375	372	- 3
1992	1	1	0	2018	306	306	0
1994	40	39	- 1	2019	79	94	15
1995	73	72	- 1				
1996	515	423	- 92				

Table 14: Number of tags released, including tags that were never recaptured, compared with the number and proportion recaptured by QMA.

QMA	Number released	Number recaptured	Proportion recaptured
CRA 1	16 892	2 163	0.128
CRA 2	24 358	4 522	0.186
CRA 3	36 255	5 633	0.155
CRA 4	39 594	3 121	0.079
CRA 5	35 439	7 354	0.208
CRA 6	4 724	181	0.038
CRA 7	10 578	838	0.079
CRA 8	23 389	10 757	0.460
CRA 9	6 452	126	0.020

Table 15: Number of complete tagging release/recovery records by sex and QMA. Note that the row totals are not always consistent with other tables because some records could not be assigned to a sex category.

QMA	Male	Female	Total	QMA	Male	Female	Total
CRA 1	947	1 216	2 163	CRA 6	21	160	181
CRA 2	2 358	2 164	4 522	CRA 7	391	447	838
CRA 3	4 269	1 364	5 633	CRA 8	5 879	4 878	10 757
CRA 4	2 411	710	3 121	CRA 9	32	94	126
CRA 5	5 163	2 191	7 354	Total	21 471	13 224	34 695

Table 16: Number of tags released by QMA (rows) and recaptured by QMA (columns). Note that the row totals are not always the same as in previous tables because some records could not be assigned to a QMA.

Release									Recovery QMA
QMA	CRA 1	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8	CRA 9
CRA 1	1 841	9	30	–	–	–	–	–	–
CRA 2	–	3 759	2	–	–	–	–	–	–
CRA 3	–	16	5 136	–	3	–	–	52	–
CRA 4	–	–	–	2 580	32	–	–	–	–
CRA 5	–	–	–	3	5 854	–	6	–	–
CRA 6	–	–	–	–	–	177	–	–	–
CRA 7	–	–	6	–	–	–	815	17	–
CRA 8	–	1	121	–	–	–	–	8 474	3
CRA 9	–	–	–	–	–	–	–	–	73

Table 17: Number of tag recaptures by calendar year of release and sex for each CRA 4 statistical area and for all of CRA 4. Tags classified to statistical area on the basis of release statistical area. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Release	Release statistical area																				
	Unknown			912			913			914			915			934			CRA 4		
year	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
1982	–	–	–	–	–	–	7	3	10	–	–	–	–	–	–	–	–	–	7	3	10
1996	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	–	1	–	1
1998	–	–	–	149	29	178	112	36	148	129	111	240	96	45	141	–	–	–	486	221	707
1999	–	–	–	113	8	121	110	25	135	81	44	125	21	8	29	8	18	26	333	103	436
2000	–	–	–	32	–	32	62	2	64	8	5	13	1	5	6	8	27	35	111	39	150
2001	–	–	–	–	–	–	4	–	4	–	–	–	–	1	1	–	–	–	4	1	5
2002	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	3	3	–	4	4
2003	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6	6	–	6	6
2004	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	2	–	2	2
2005	–	–	–	–	–	–	16	5	21	18	3	21	36	9	45	51	57	108	121	74	195
2006	–	–	–	–	–	–	14	3	17	5	2	7	3	1	4	39	28	67	61	34	95
2007	–	–	–	8	3	11	5	–	5	8	1	9	53	6	59	39	25	64	113	35	148
2008	–	–	–	1	1	2	2	–	2	–	–	–	–	–	–	–	1	1	3	2	5
2009	–	–	–	19	10	29	3	–	3	11	4	15	24	2	26	–	1	1	57	17	74
2010	–	–	–	9	3	12	259	5	264	1	–	1	3	–	3	2	2	4	274	10	284
2011	–	–	–	–	–	–	51	–	51	–	–	–	–	1	1	–	–	–	51	1	52
2012	–	–	–	–	–	–	6	–	6	–	–	–	–	–	–	–	–	–	6	–	6
2014	2	–	2	–	–	–	41	–	41	334	46	380	32	15	47	7	8	15	416	69	485
2015	47	1	48	–	–	–	179	21	200	60	8	68	2	1	3	–	–	–	288	31	319
2016	21	2	23	–	–	–	43	2	45	–	5	5	–	1	1	–	3	3	64	13	77
2017	3	–	3	–	–	–	2	–	2	–	2	2	–	–	–	–	–	–	5	2	7
2018	1	–	1	–	–	–	1	1	2	–	1	1	–	–	–	–	–	–	2	2	4
Total	74	3	77	331	54	385	917	103	1 020	655	233	888	272	95	367	154	181	335	2 403	669	3 072

Table 18: Number of tag recaptures by calendar year of recovery and sex for each CRA 4 statistical area and for all of CRA 4. Tags classified to statistical area on the basis of release statistical area. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Recovery	Release statistical area																				
	Unknown			912			913			914			915			934			CRA 4		
year	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
1983	–	–	–	–	–	–	3	2	5	–	–	–	–	–	–	–	–	–	3	2	5
1984	–	–	–	–	–	–	4	–	4	–	–	–	–	–	–	–	–	–	4	–	4
1985	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	1	1
1996	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	–	1	–	1
1998	–	–	–	–	–	–	–	–	–	10	1	11	13	2	15	–	–	–	23	3	26
1999	–	–	–	147	22	169	101	24	125	143	102	245	80	35	115	–	–	–	471	183	654
2000	–	–	–	144	15	159	168	22	190	44	24	68	17	7	24	5	6	11	378	74	452
2001	–	–	–	3	–	3	17	14	31	16	13	29	8	9	17	9	12	21	53	48	101
2002	–	–	–	–	–	–	1	1	2	2	10	12	–	2	2	1	10	11	4	23	27
2003	–	–	–	–	–	–	–	1	1	3	10	13	–	1	1	1	21	22	4	33	37
2004	–	–	–	–	–	–	–	–	–	–	1	1	–	3	3	–	7	7	–	11	11
2005	–	–	–	–	–	–	3	3	6	10	1	11	15	5	20	24	31	55	52	40	92
2006	–	–	–	–	–	–	14	6	20	10	3	13	23	5	28	27	18	45	74	32	106
2007	–	–	–	–	–	–	7	–	7	6	2	8	44	4	48	56	44	100	113	50	163
2008	–	–	–	6	4	10	9	–	9	5	–	5	7	2	9	18	7	25	45	13	58
2009	–	–	–	1	–	1	7	–	7	1	–	1	2	–	2	3	6	9	14	6	20
2010	–	–	–	19	5	24	124	3	127	8	3	11	18	1	19	2	6	8	171	18	189
2011	–	–	–	6	3	9	167	1	168	3	1	4	9	2	11	1	1	2	186	8	194
2012	–	–	–	5	5	10	26	–	26	–	–	–	1	–	1	–	–	–	32	5	37
2013	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	1	1	–	2	2
2014	2	–	2	–	–	–	21	–	21	231	35	266	16	9	25	–	–	–	270	44	314
2015	31	–	31	–	–	–	118	9	127	154	13	167	15	4	19	7	5	12	325	31	356
2016	31	2	33	–	–	–	115	9	124	8	8	16	3	4	7	–	4	4	157	27	184
2017	5	1	6	–	–	–	6	2	8	1	2	3	–	–	–	–	–	–	12	5	17
2018	5	–	5	–	–	–	6	4	10	–	4	4	–	–	–	–	2	2	11	10	21
Total	74	3	77	331	54	385	917	103	1 020	655	233	888	272	95	367	154	181	335	2,403	669	3,072

Table 19: Number of tag releases by sex and release month for CRA 4 by release statistical area and for all of CRA 4.

Release month	Release statistical area						
	Unknown	912	913	914	915	934	CRA 4
Males							
Jan	10	7	49	72	65	14	217
Feb	6	1	50	79	47	40	223
Mar	–	–	–	–	5	4	9
Apr	–	10	4	–	–	1	15
May	10	9	59	16	–	–	94
Jun	10	30	114	259	31	2	446
Jul	1	12	239	28	3	3	286
Aug	3	5	8	27	77	42	162
Sep	–	1	1	38	16	45	101
Oct	2	7	4	30	–	1	44
Nov	25	1	130	15	3	–	174
Dec	7	248	259	91	25	2	632
CRA 4	74	331	917	655	272	154	2 403
Females							
Jan	–	2	–	38	32	7	79
Feb	–	–	1	64	9	35	109
Mar	–	–	–	–	4	11	15
Apr	–	–	–	1	–	–	1
May	–	–	2	3	1	2	8
Jun	–	1	2	40	11	4	58
Jul	–	–	12	8	1	4	25
Aug	–	–	–	5	12	42	59
Sep	–	–	4	14	6	67	91
Oct	1	5	3	12	1	4	26
Nov	1	–	19	6	3	4	33
Dec	1	46	60	42	15	1	165
CRA 4	3	54	103	233	95	181	669

Table 20: Number of tag recaptures by release and recovery statistical areas for CRA 4 releases. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Release statistical area	Recovery statistical area									
	Unknown	911	912	913	914	915	916	933	934	Total
Unknown	69	–	–	7	1	–	–	–	–	77
912	–	1	384	–	–	–	–	–	–	385
913	102	–	–	913	4	–	–	–	1	1 020
914	11	–	–	1	856	18	–	–	2	888
915	–	–	–	–	83	277	1	–	6	367
934	–	–	–	–	1	9	–	2	323	335
CRA 4	182	1	384	921	945	304	1	2	332	3 072

Table 21: Days-at-liberty statistics for recaptures of CRA 4 releases. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Release statistical area	Sex	N	Min(days)	p5%(days)	Median(days)	p95%(days)	Max(days)
Unknown	Males	74	1	3	38	546	763
	Females	3	13	13	173	331	331
912	Males	331	1	6	195	552	1 047
	Females	54	21	168	295	870	1 071
913	Males	917	1	5	190	562	2 610
	Females	103	10	18	313	1 100	2 141
914	Males	655	1	4	158	550	1 325
	Females	233	1	18	203	1 306	1 683
915	Males	272	1	14	180	578	1 060
	Females	95	9	29	235	1 057	2 007
934	Males	154	2	44	247	675	1 026
	Females	181	1	44	295	1 305	1 821
CRA 4	Males	2 403	1	5	185	557	2 610
	Females	669	1	21	234	1 226	2 141

Table 22: Number of tag re-releases by sex for CRA 4 by release statistical area and for all of CRA 4. Re-release event code = 0 means the first release-recapture event.

	Release statistical area											
Re-	912		913		914		915		934		CRA 4	
release event	N	Cum Prop.	N	Cum Prop.	N	Cum Prop.	N	Cum Prop.	N	Cum Prop.	N	Cum Prop.
Males												
0	261	0.79	650	0.71	425	0.65	235	0.86	139	0.90	1 710	0.71
1	48	0.93	174	0.90	130	0.85	28	0.97	10	0.97	430	0.89
2	16	0.98	61	0.97	52	0.93	7	0.99	3	0.99	162	0.96
3	5	1.00	22	0.99	25	0.96	2	1.00	2	1.00	64	0.98
4	1	1.00	6	1.00	12	0.98	–	1.00	–	1.00	22	0.99
5	–	1.00	2	1.00	6	0.99	–	1.00	–	1.00	8	1.00
6	–	1.00	1	1.00	2	1.00	–	1.00	–	1.00	3	1.00
7	–	1.00	1	1.00	2	1.00	–	1.00	–	1.00	3	1.00
8	–	1.00	–	1.00	1	1.00	–	1.00	–	1.00	1	1.00
Females												
0	51	0.94	96	0.93	186	0.80	87	0.92	162	0.90	582	0.87
1	2	0.98	7	1.00	30	0.93	7	0.99	13	0.97	62	0.96
2	1	1.00	–	1.00	8	0.96	1	1.00	3	0.98	13	0.98
3	–	1.00	–	1.00	3	0.97	–	1.00	2	0.99	5	0.99
4	–	1.00	–	1.00	2	0.98	–	1.00	1	1.00	3	0.99
5	–	1.00	–	1.00	2	0.99	–	1.00	–	1.00	2	1.00
6	–	1.00	–	1.00	1	1.00	–	1.00	–	1.00	1	1.00
7	–	1.00	–	1.00	1	1.00	–	1.00	–	1.00	1	1.00

Table 23: Statistics for tail width growth increments (mm) for recaptures of CRA 4 releases. Recaptures were considered valid if there was a valid growth increment, regardless of the location of recapture.

Release statistical area	Sex	N	Min(increment)	p5%(increment)	Median(increment)	p95%(increment)	Max(increment)
Unknown	Males	74	-3.0	-1.0	0.0	2.0	5.0
	Females	3	-3.0	-3.0	-1.0	0.0	0.0
912	Males	331	-9.9	-1.0	0.4	3.8	8.3
	Females	54	-6.0	-3.9	-0.4	5.5	17.4
913	Males	917	-7.0	-1.0	0.9	4.3	14.0
	Females	103	-9.6	-1.8	0.8	4.0	10.1
914	Males	655	-9.4	-1.0	0.9	4.8	15.9
	Females	233	-18.7	-1.9	1.0	5.2	13.9
915	Males	272	-3.5	-0.4	1.9	6.6	14.8
	Females	95	-3.2	-1.5	1.2	7.0	13.8
934	Males	154	-5.7	0.0	2.9	9.3	17.9
	Females	181	-7.5	-1.3	1.7	10.0	22.3
CRA 4	Males	2 403	-9.9	-1.0	1.0	5.2	17.9
	Females	669	-18.7	-1.9	1.1	6.6	22.3

Table 24: Combined puerulus index series and standard deviation (SD) for CRA 4, based on the Napier and Castlepoint standardised series (Forman et al. 2021).

Fishing	Combined		Fishing	Combined	
year	Index	SD	year	Index	SD
1979	0.820	0.199	2000	0.637	0.117
1980	1.314	0.164	2001	0.993	0.104
1981	2.153	0.155	2002	1.124	0.103
1982	1.791	0.181	2003	1.129	0.108
1983	1.263	0.153	2004	0.787	0.109
1984	0.568	0.178	2005	1.286	0.104
1985	0.399	0.233	2006	0.572	0.120
1986	0.807	0.130	2007	0.990	0.121
1987	1.604	0.118	2008	0.843	0.118
1988	1.191	0.197	2009	0.977	0.114
1989	1.189	0.161	2010	1.066	0.112
1990	1.084	0.157	2011	0.693	0.122
1991	2.321	0.109	2012	0.654	0.132
1992	2.158	0.102	2013	1.335	0.112
1993	1.678	0.103	2014	0.865	0.116
1994	1.232	0.100	2015	1.365	0.109
1995	1.003	0.102	2016	1.274	0.121
1996	1.440	0.093	2017	1.030	0.120
1997	1.396	0.093	2018	0.726	0.134
1998	1.041	0.103	2019	0.895	0.127
1999	0.394	0.119			

10. FIGURES

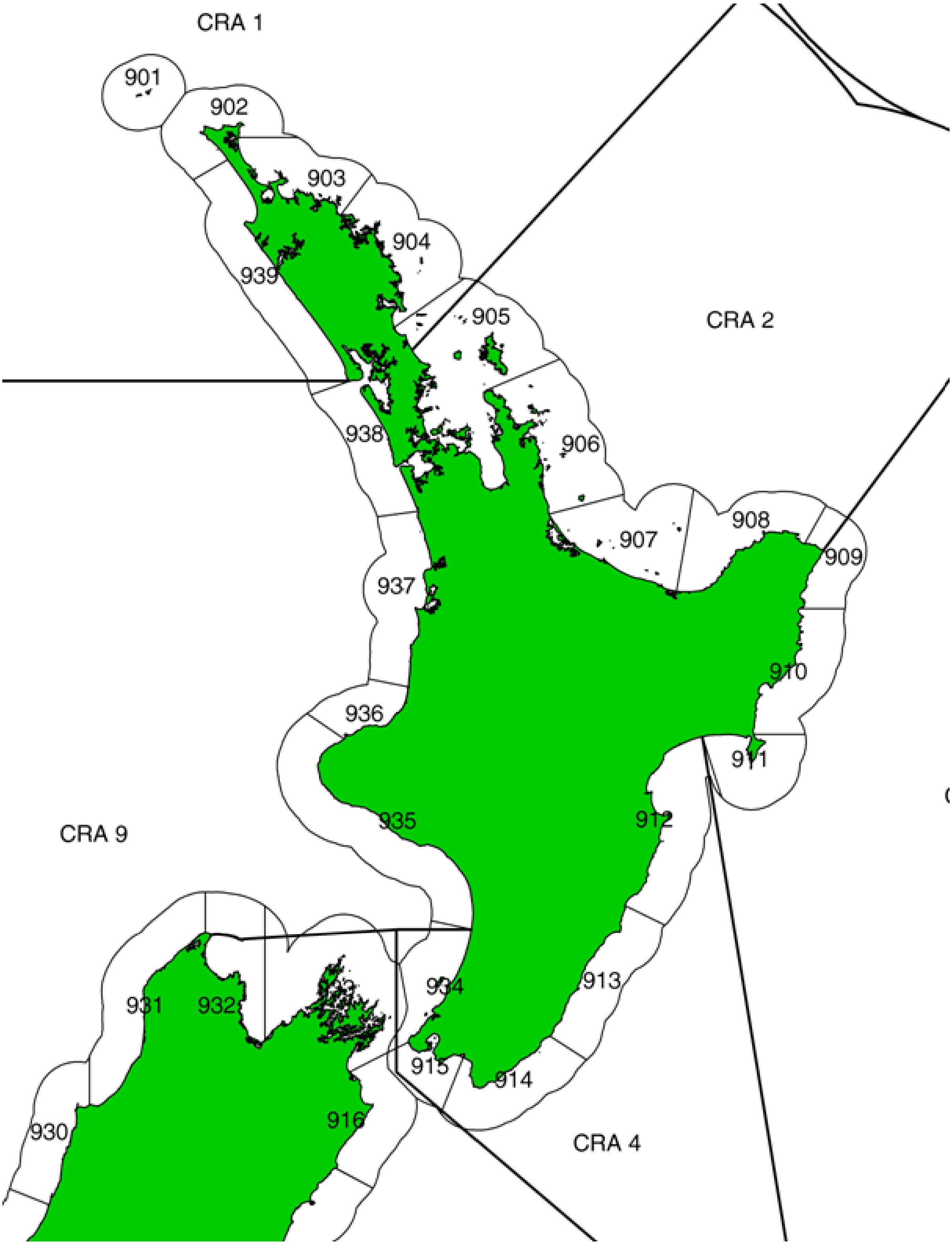

Figure 1: Map of the North Island, showing location of Quota Management Areas (QMAs) and statistical areas, including CRA 4. The QMA boundaries are shown with heavy black lines while the statistical area boundaries have thinner grey lines.

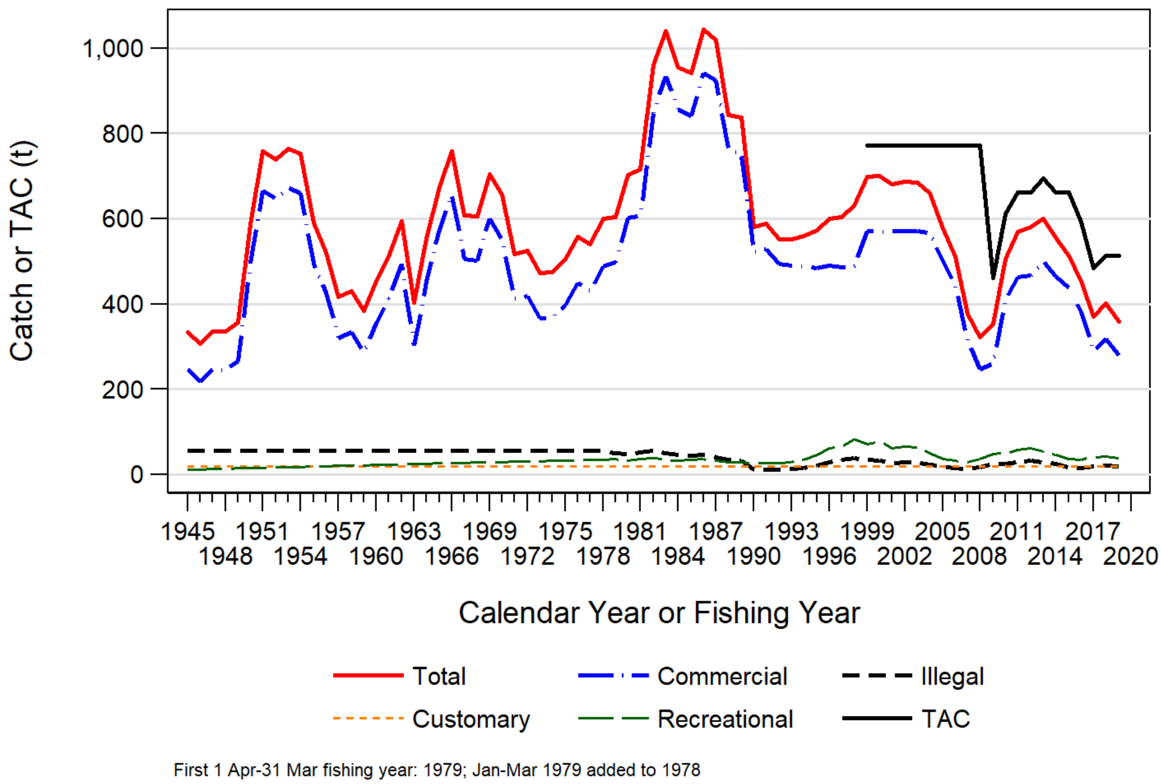

Figure 2: **CRA 4 catches by fishery source, 1945–2019.**

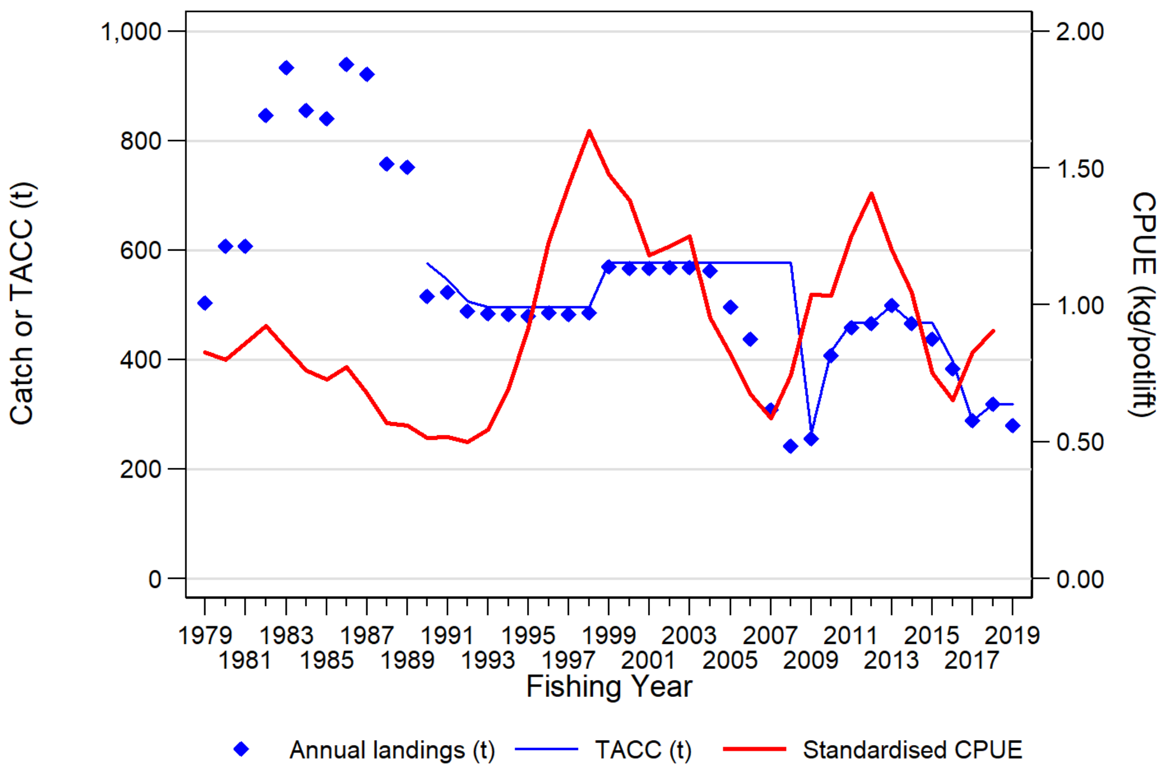

Figure 3: **CRA 4 commercial catch, TACC and standardised CPUE, 1979–2019.**

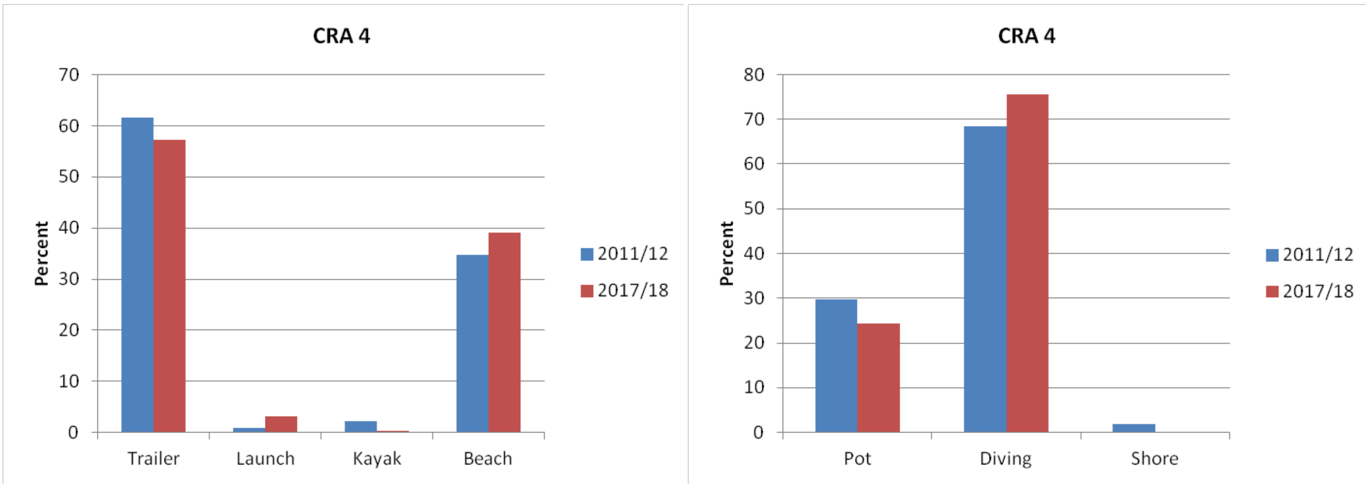

Figure 4: CRA 4 recreational catch information: distribution of fishing platform by survey year [left panel]; distribution of fishing method by survey year [right panel] (2011/12 data from Wynne-Jones et al. 2014; 2017/18 data from Wynne-Jones et al. 2019)

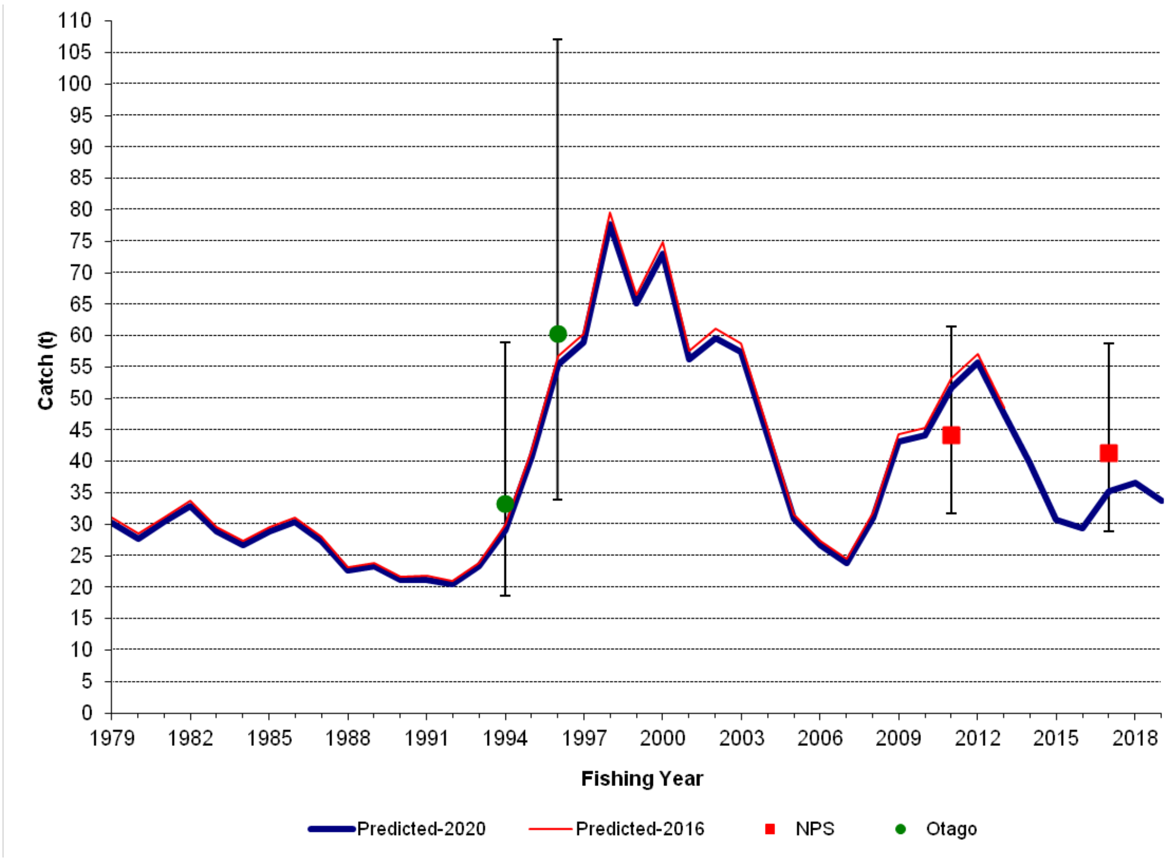

Figure 5: CRA 4 recreational catch trajectory (tonnes) (Eq. 2) based on the CRA 4 SS seasonal CPUE series fitted to four recreational catch surveys (Eq. 1 and Table 1). Error bars are ±2 s.e., assuming a lognormal distribution. Also shown is the equivalent recreational catch series used in the 2016 CRA 4 stock assessment.

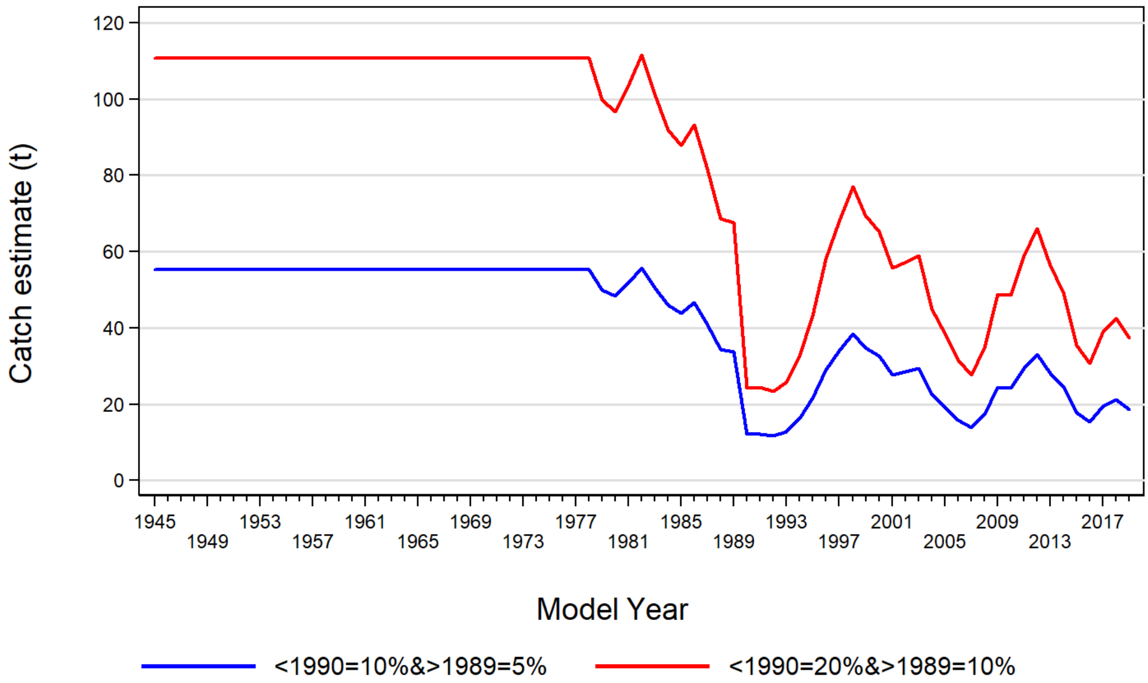

Figure 6: **Illegal catch trajectory options considered for the 2020 stock assessment. Option 10% for 1945–1989 and 5% from 1990 was selected by RLWG for the base run. The remaining option was used as catch sensitivity run.**

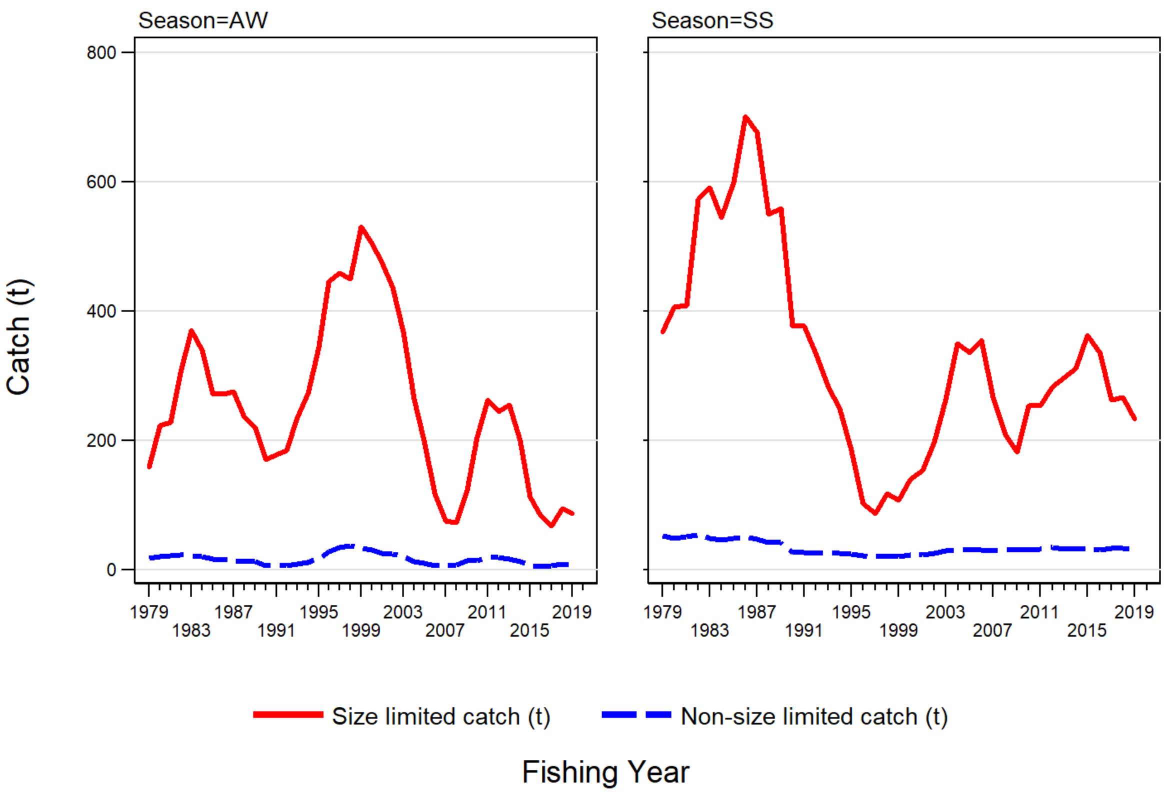

Figure 7: **CRA 4 seasonal size-limited (SL, solid red line) and non-size-limited (NSL, dashed blue line) catches (t).**

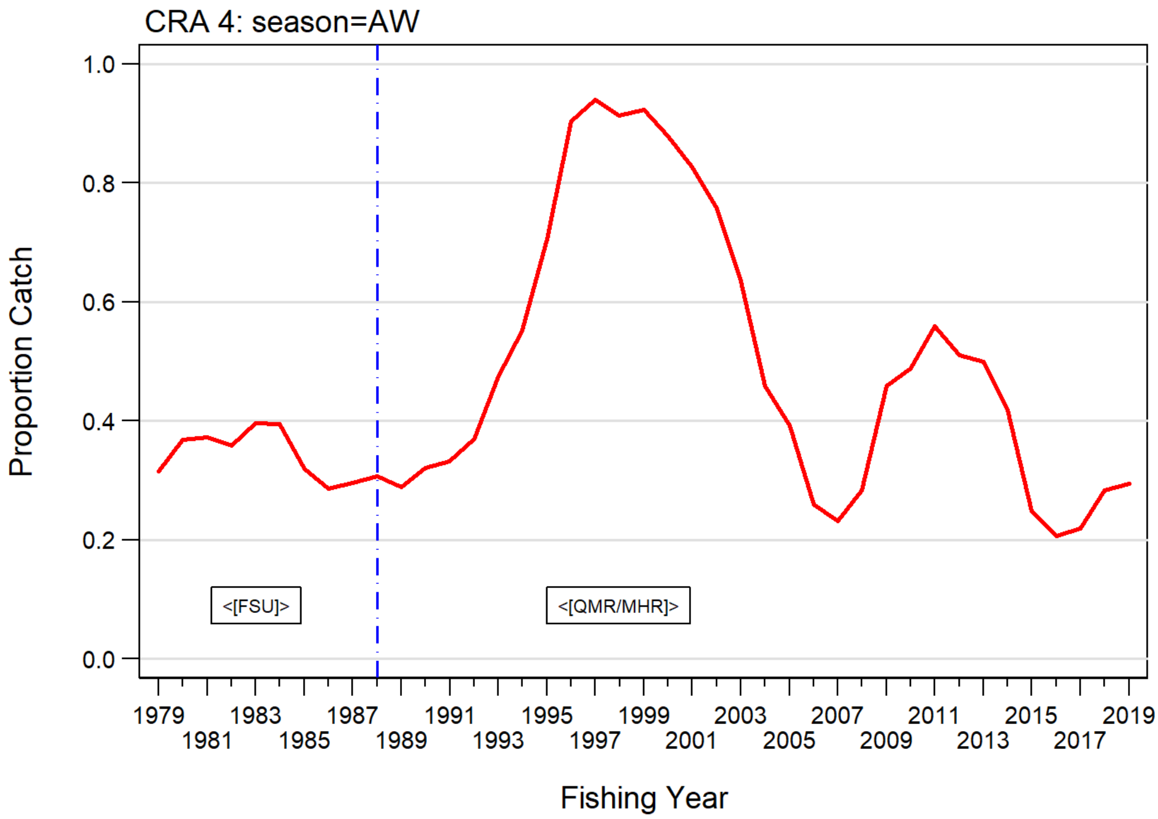

Figure 8: Proportion by fishing year of the commercial catch taken in the AW season in CRA 4.

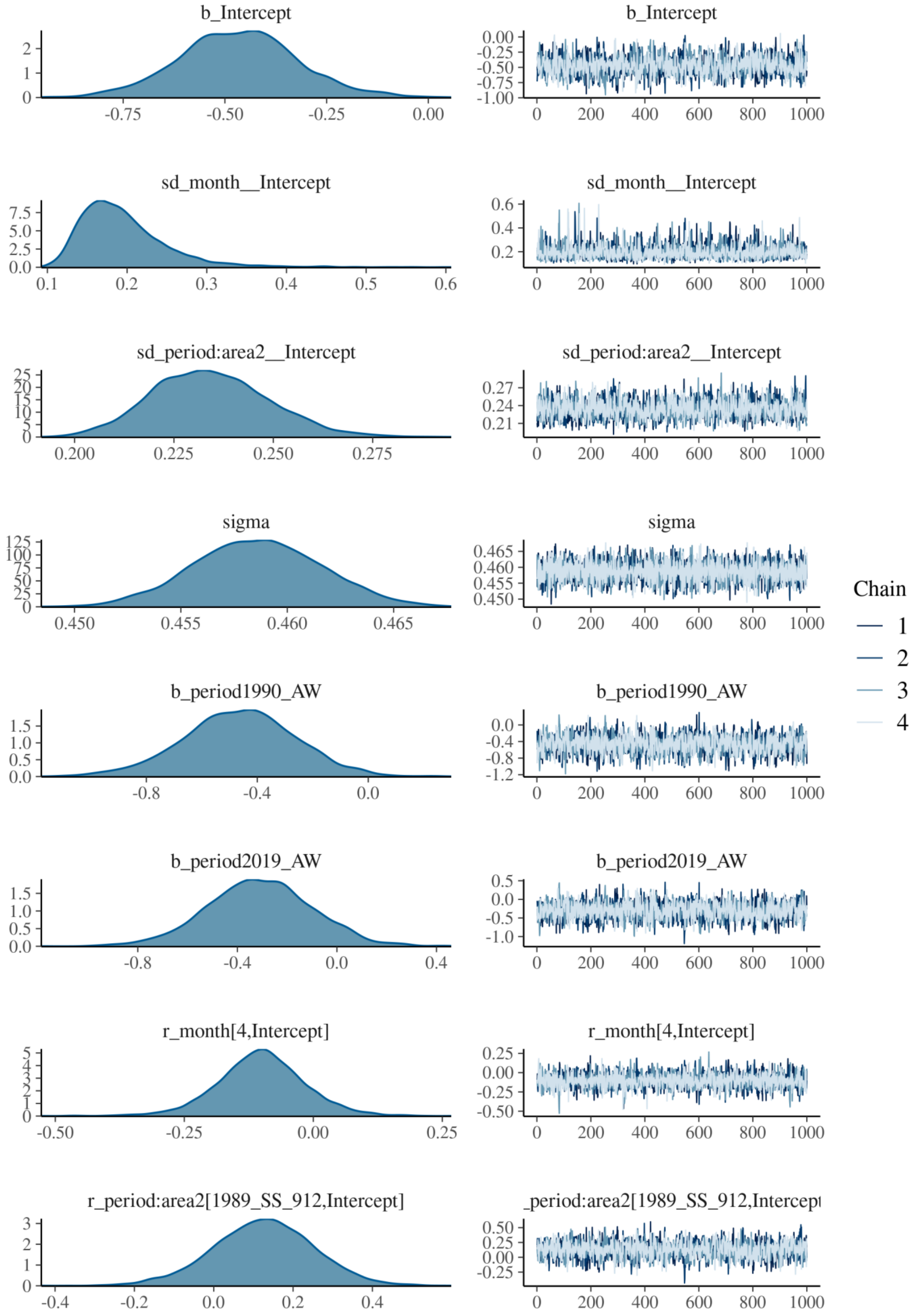

Figure 9: Density and trace plots of the MCMC posterior samples for a subset of model parameters from the analysis based on CELR data.

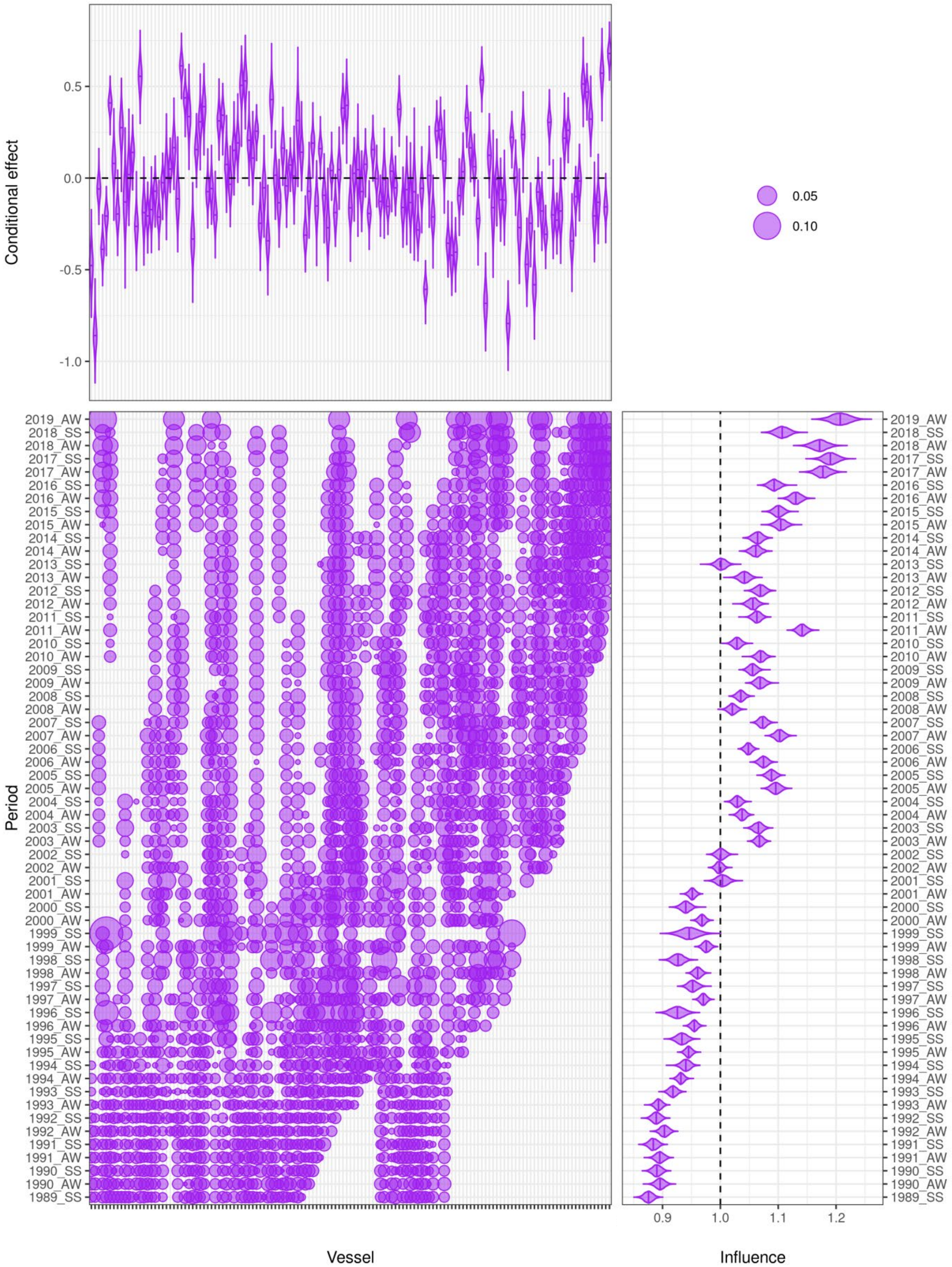

Figure 10: [top panel]: CDI plot (Bentley et al. 2012) showing MCMC posterior distribution of coefficients for vessels with at least five years of data in the CRA 4 fishery from the CELR seasonal CPUE standardisation (interaction model). Vessel coefficients were estimated as group-level effects; [bottom left panel]: relative distribution of records by fishing year/season, with each row summing to one; [bottom right panel]: MCMC posterior distribution of influence (product of coefficients weighted by the data distribution) for core vessels in each fishing year/season.

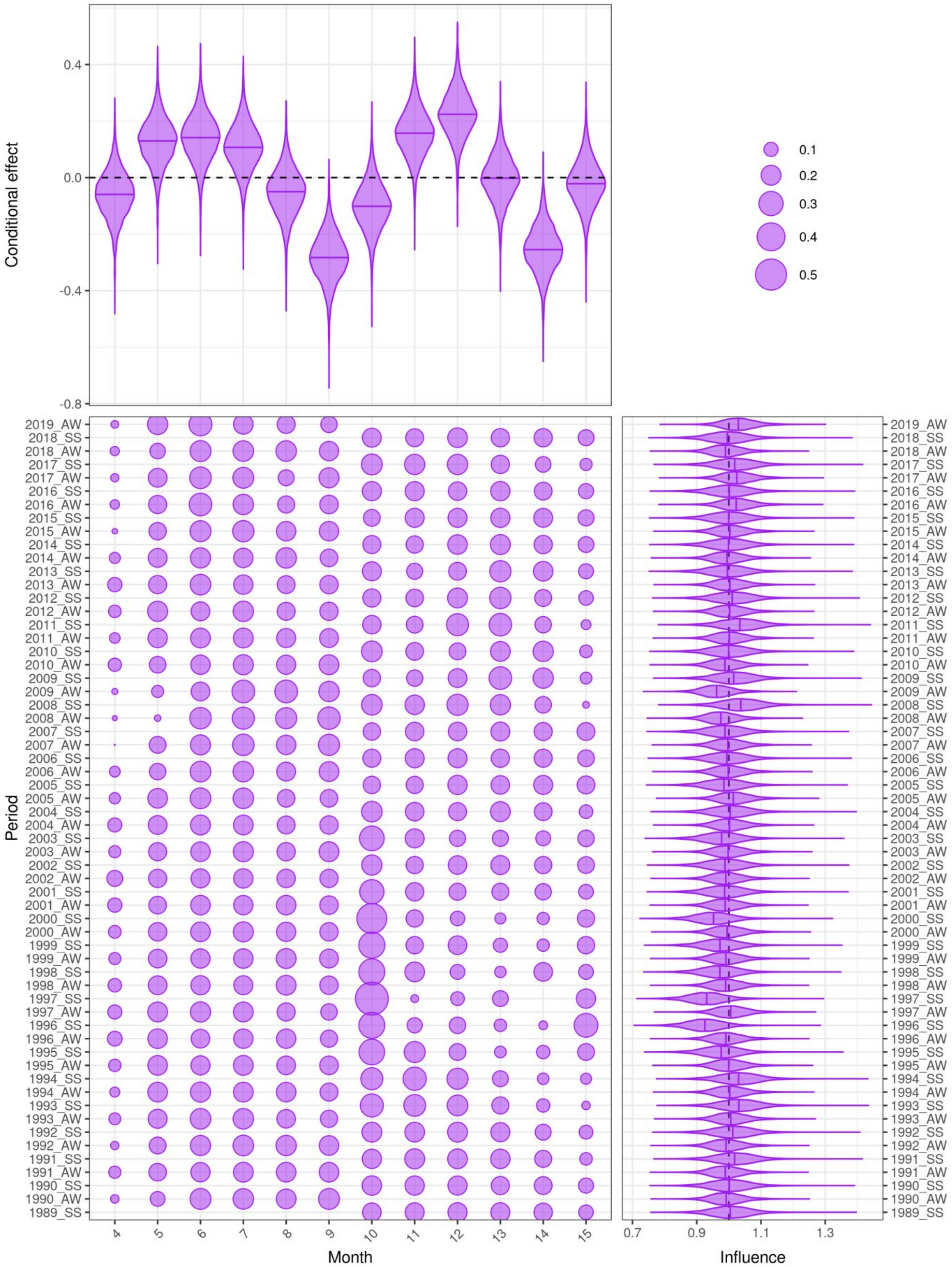

Figure 11: [top panel]: CDI plot (Bentley et al. 2012) showing MCMC posterior distribution of coefficients for in the CRA 4 fishery from the CELR seasonal CPUE standardisation (interaction model). Month coefficients (4=April to 15=March) were estimated as group-level effects; [bottom left panel]: relative distribution of records by fishing year/season, with each row summing to one; [bottom right panel]: MCMC posterior distribution of influence (product of coefficients weighted by the data distribution) for the month variable for each fishing year/season.

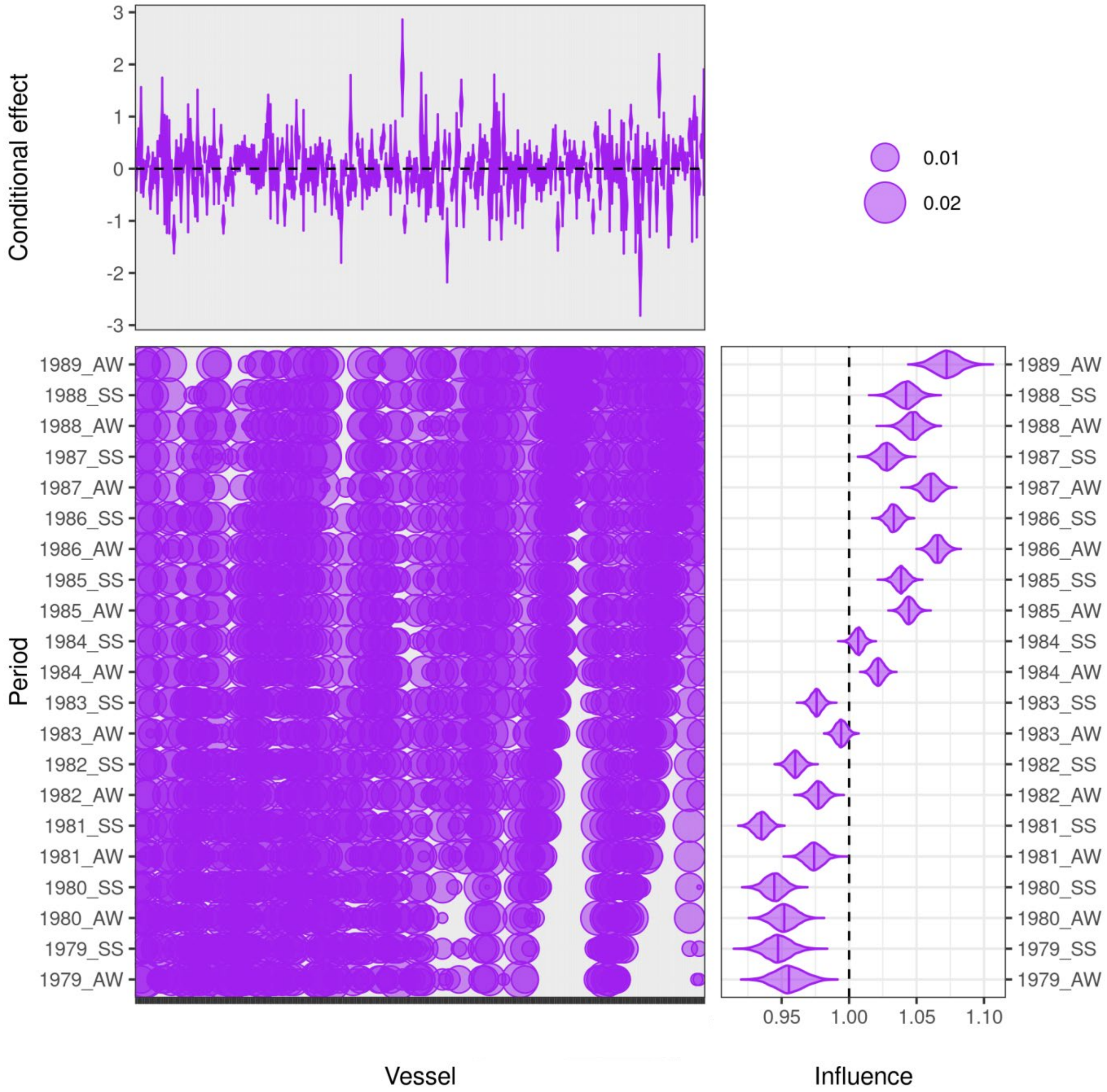

Figure 12: [top panel]: CDI plot (Bentley et al. 2012) showing MCMC posterior distribution of coefficients for vessels with at least five years of data in the CRA 4 fishery from the FSU seasonal CPUE standardisation (interaction model). Vessel coefficients were estimated as group-level effects; [bottom left panel]: relative distribution of records by fishing year/season, with each row summing to one; [bottom right panel]: MCMC posterior distribution of influence (product of coefficients weighted by the data distribution) for vessels in each fishing year/season.

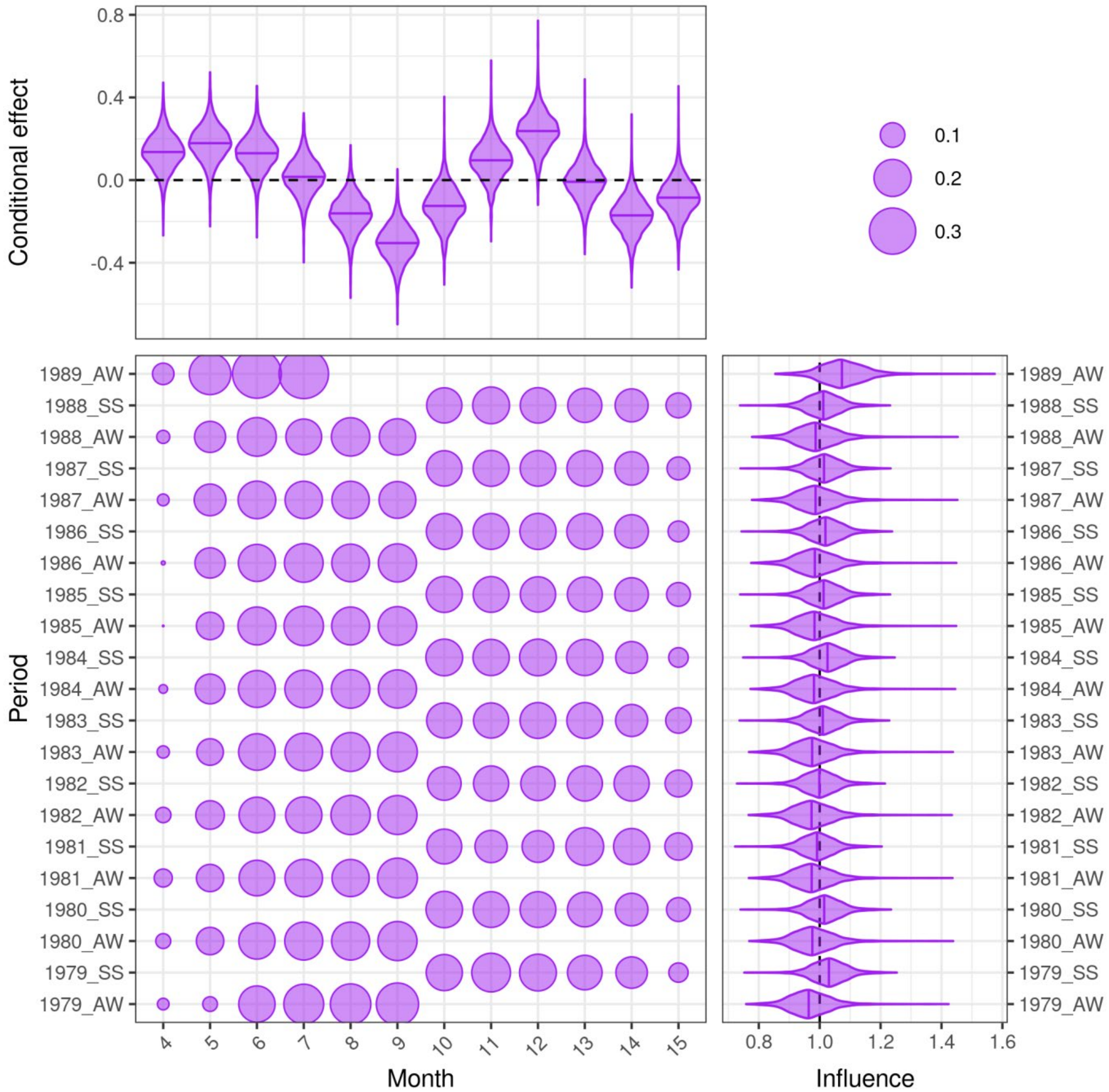

Figure 13: [top panel]: CDI plot (Bentley et al. 2012) showing MCMC posterior distribution of coefficients for in the CRA 4 fishery from the FSU seasonal CPUE standardisation (interaction model). Month coefficients (4=April to 15=March) were estimated as group-level effects; [bottom left panel]: relative distribution of records by fishing year/season, with each row summing to one; [bottom right panel]: MCMC posterior distribution of influence (product of coefficients weighted by the data distribution) for the month variable for each fishing year/season.

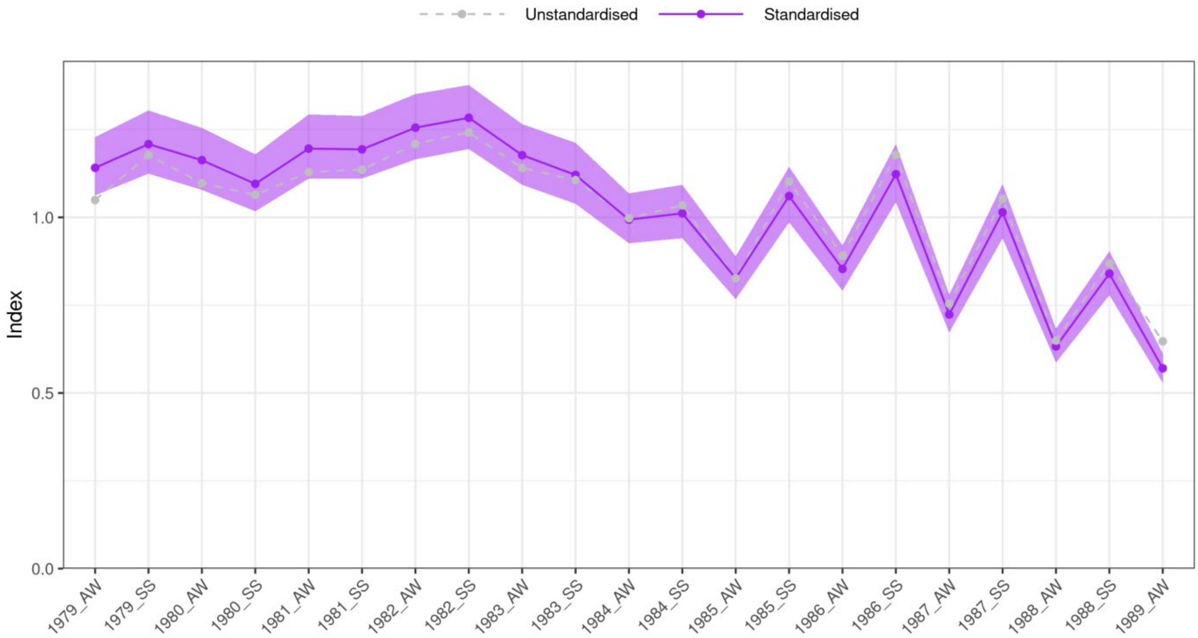

Figure 14: Standardised CPUE indices (kg/potlift) by season and fishing year for the CRA 4 FSU. Plot shows the posterior median (points) connected by lines and the 95% credible interval (shaded region).

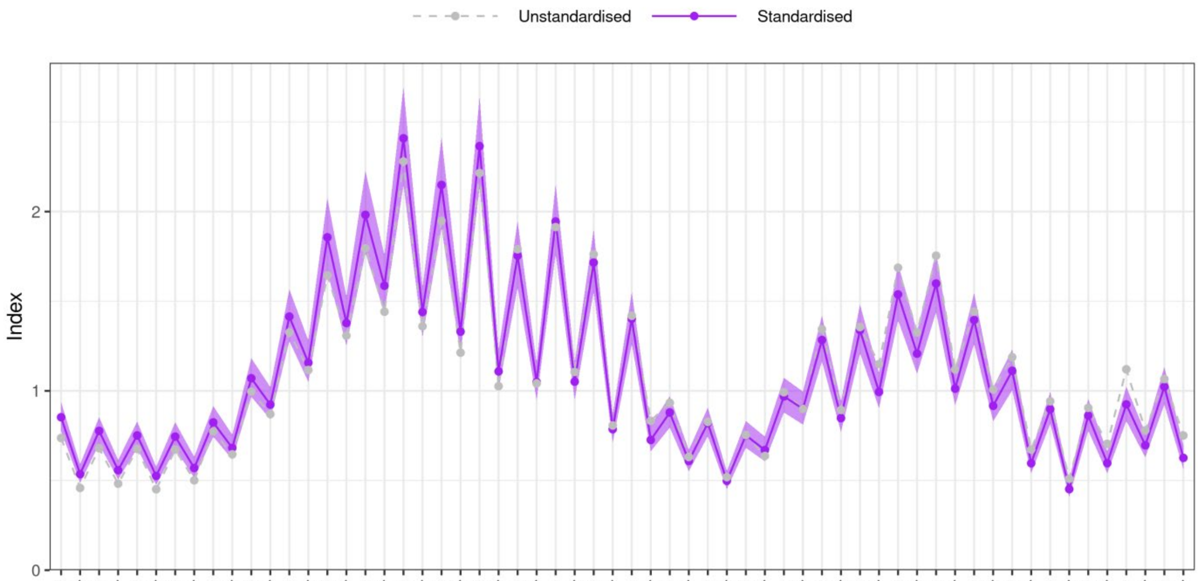

Figure 15: Standardised CPUE indices (kg/potlift) by season and fishing year for the CRA 4 CELR seasonal CPUE GLM analysis (interaction model) which included a vessel variable filtered for vessels with at least five years data using the F2 algorithm scaled to "LFX" landings from SS 1989–90 to AW 2019–20. Plot shows the posterior median (points) connected by lines and the 95% credible interval (shaded region).

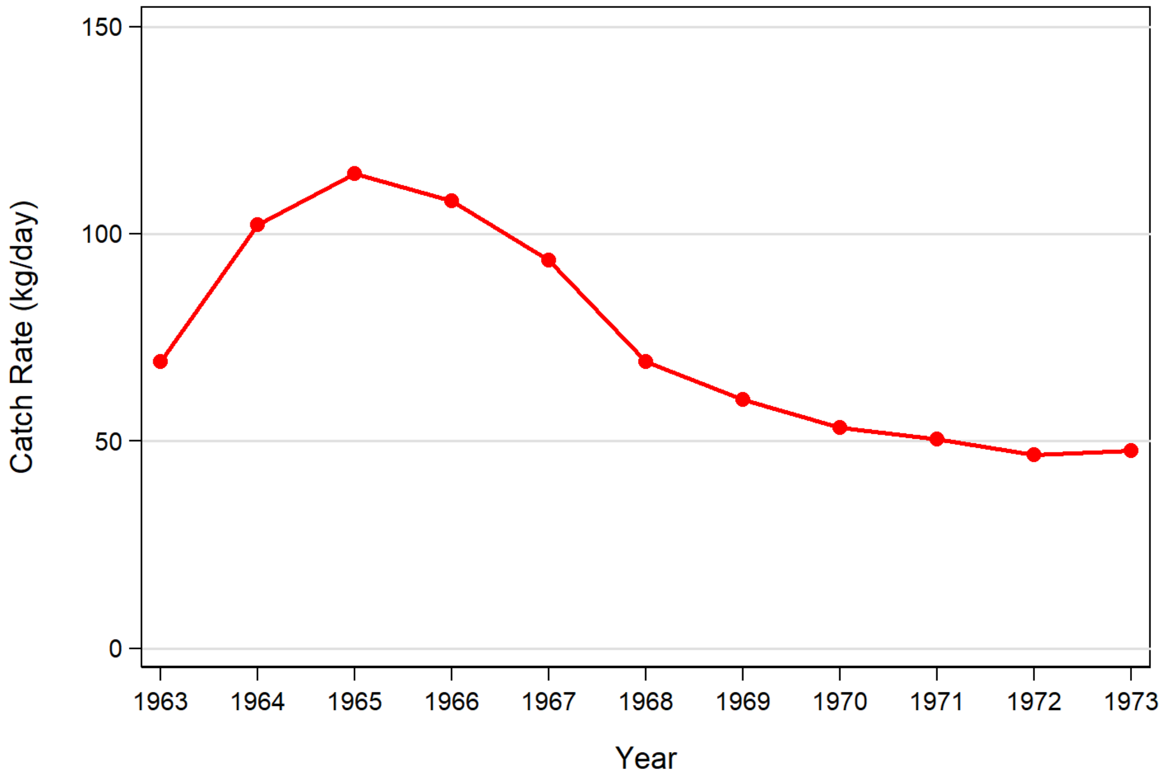

Figure 16: Catch rate (kg/day) by year for CRA 4 from Annala & King (1983).

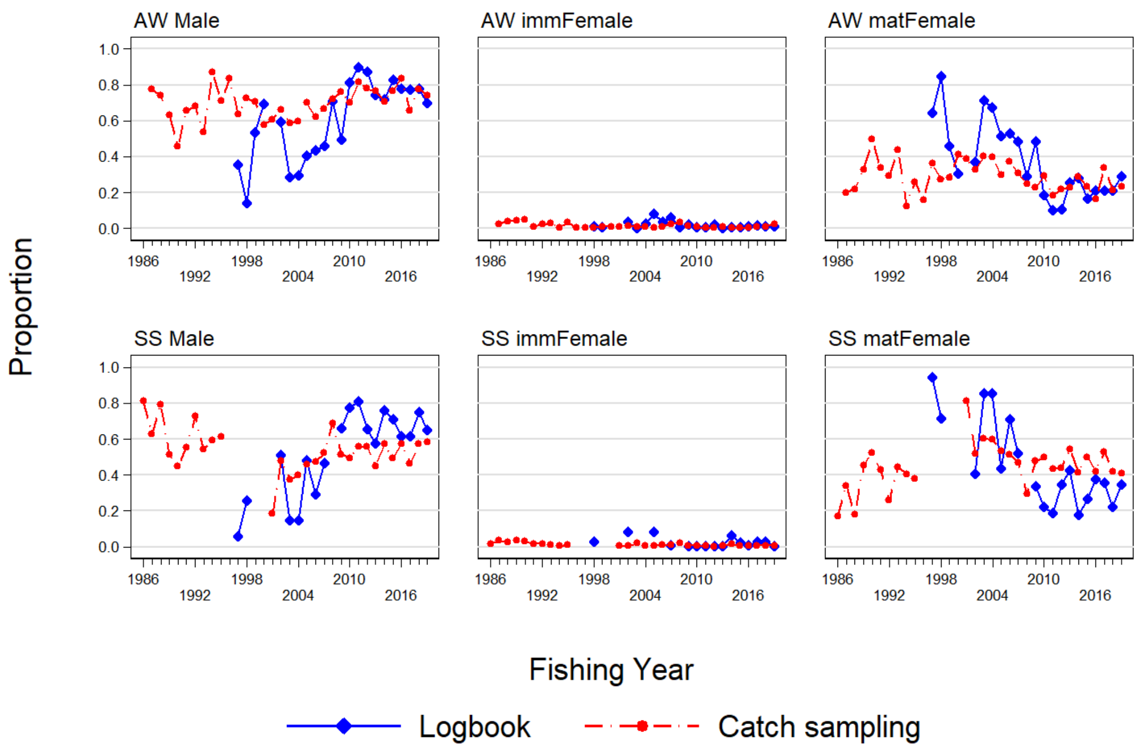

Figure 17: Proportion-at-sex by year, season, sex category, and sampling source.

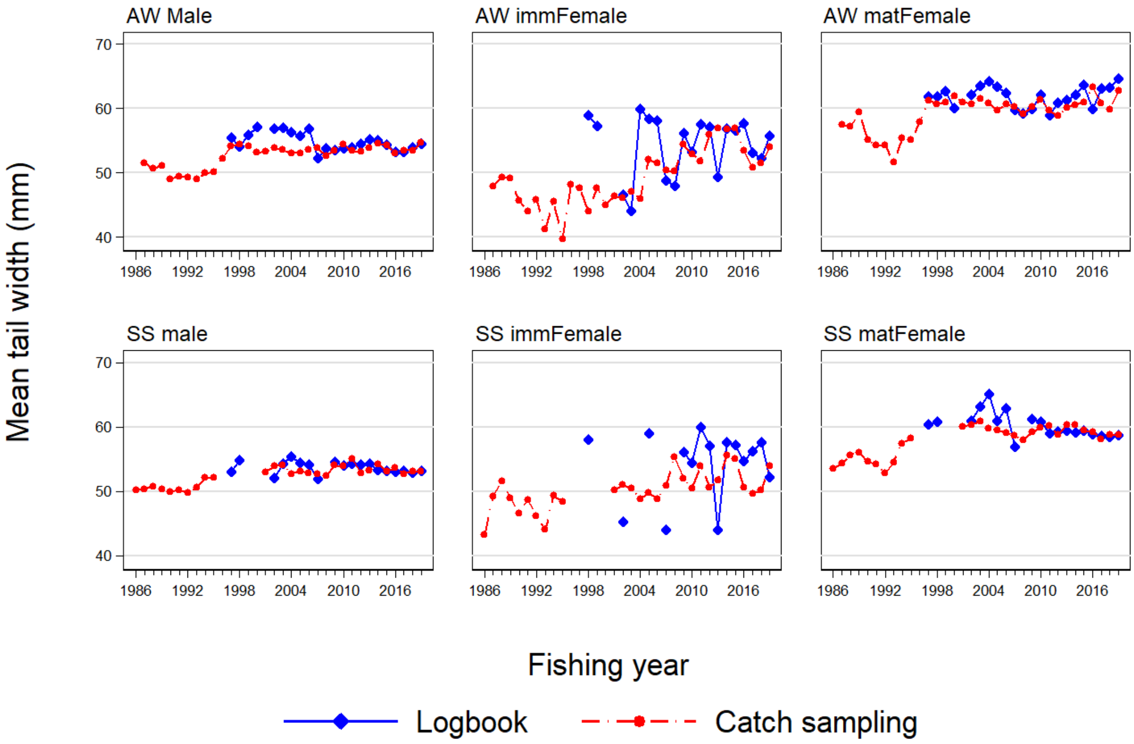

Figure 18: Mean tail width (mm) by year, season, sex, sex category, and sampling source.

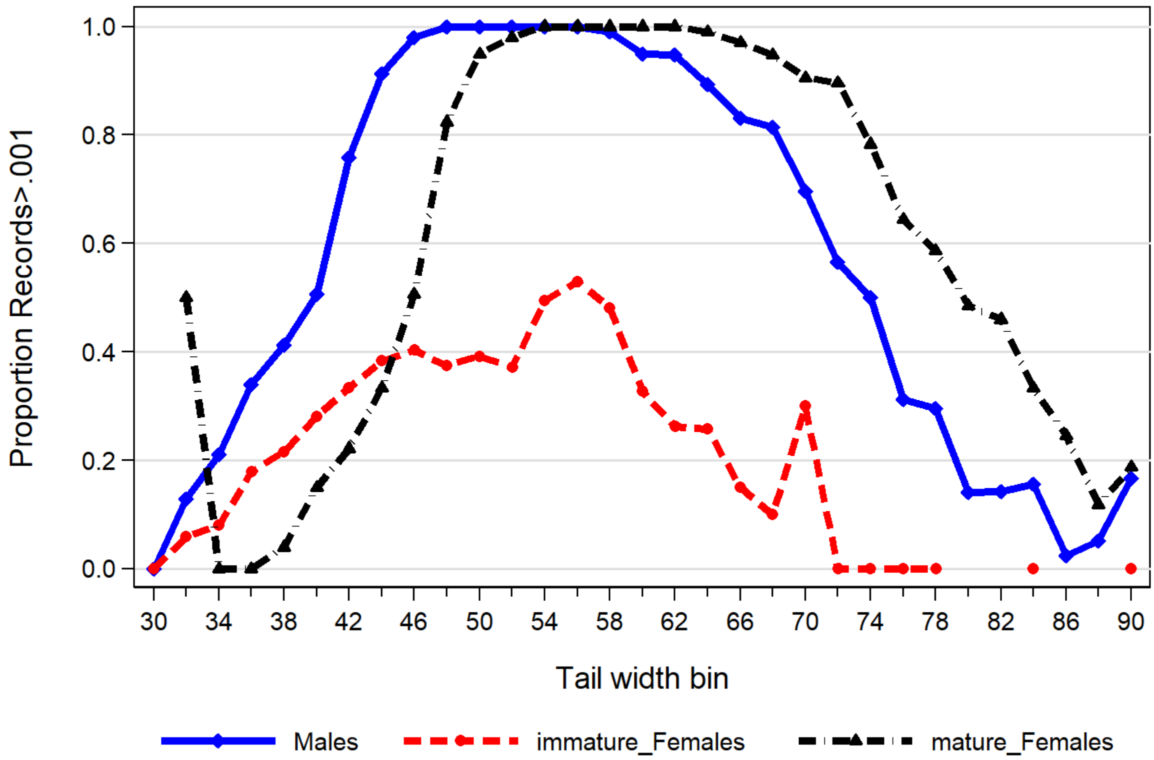

Figure 19: The proportion of size bins (across 88 year/season/sampling source strata) that contain a proportion of 0.001 or higher when the data are normalised by sex.

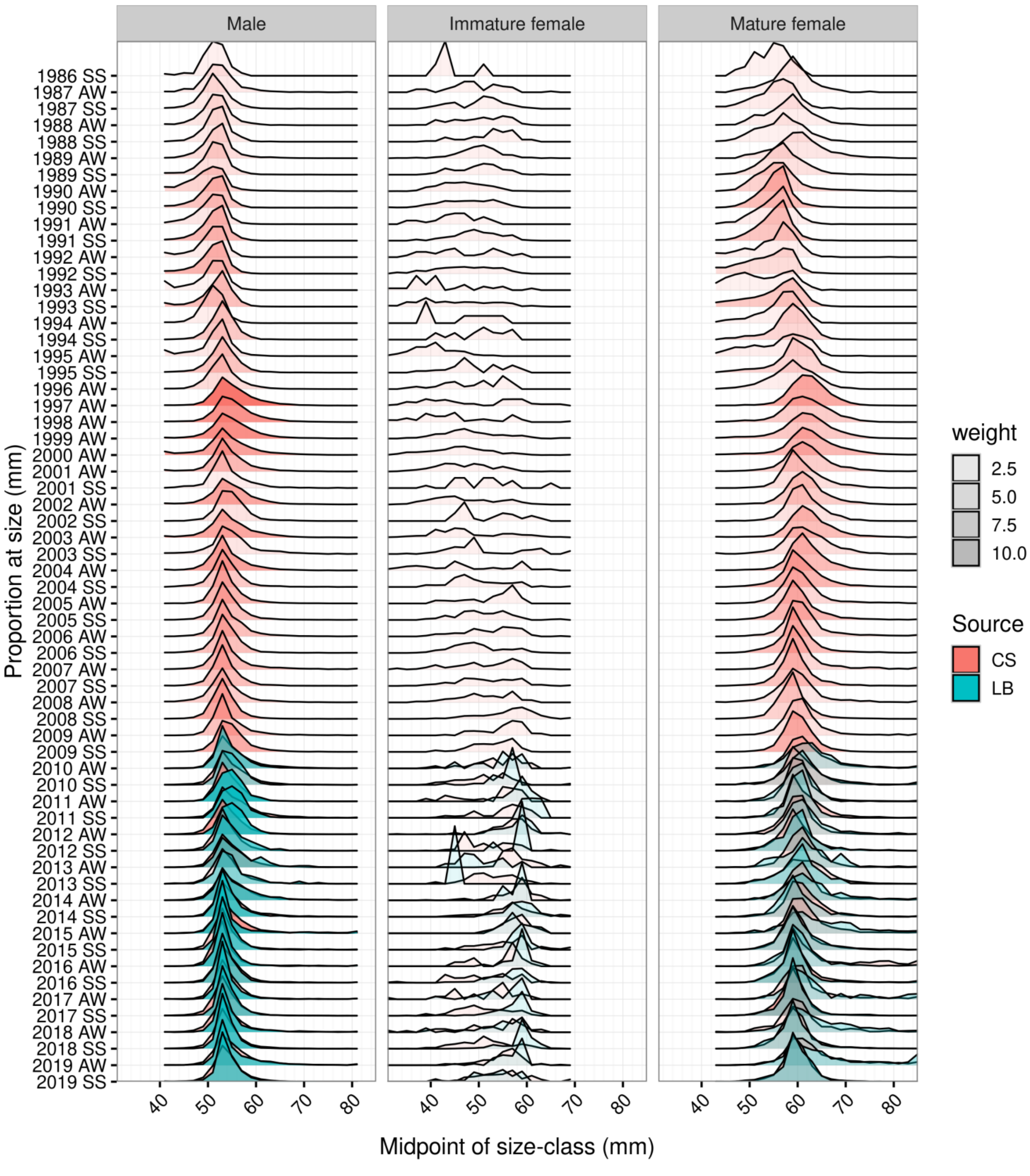

Figure 20: All observed CRA 4 length frequency distributions, by sex category, fishing year, and sample source.

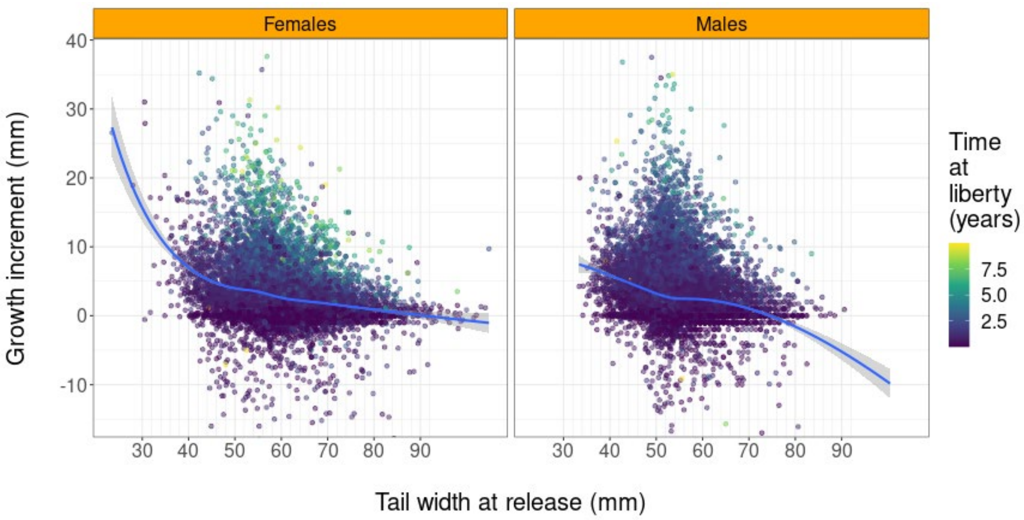

Figure 21: Growth increments (mm) by size at release (mm) and sex for all combined tag recoveries. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

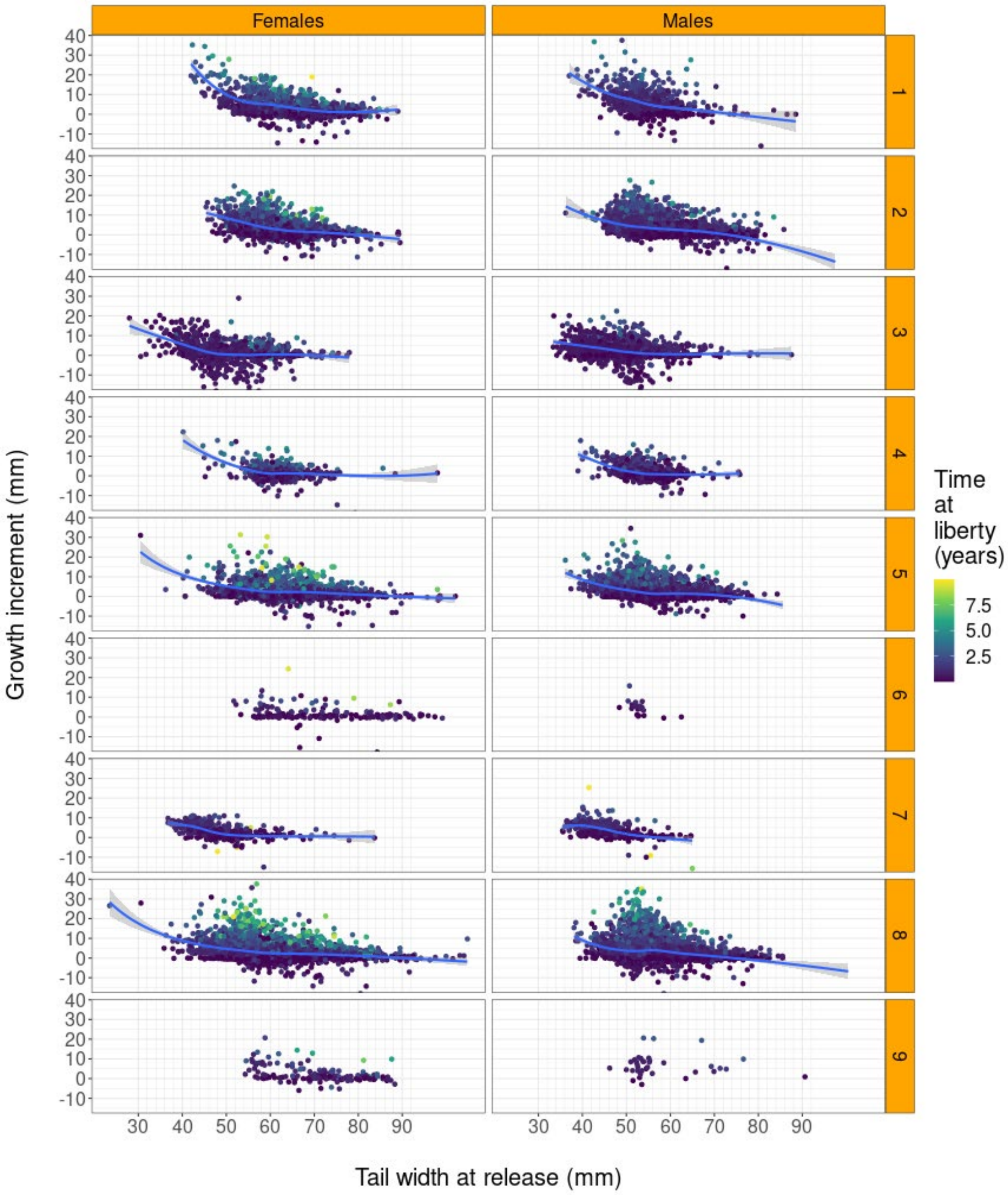

Figure 22: Growth increments (mm) by size at release (mm), sex, and QMA. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

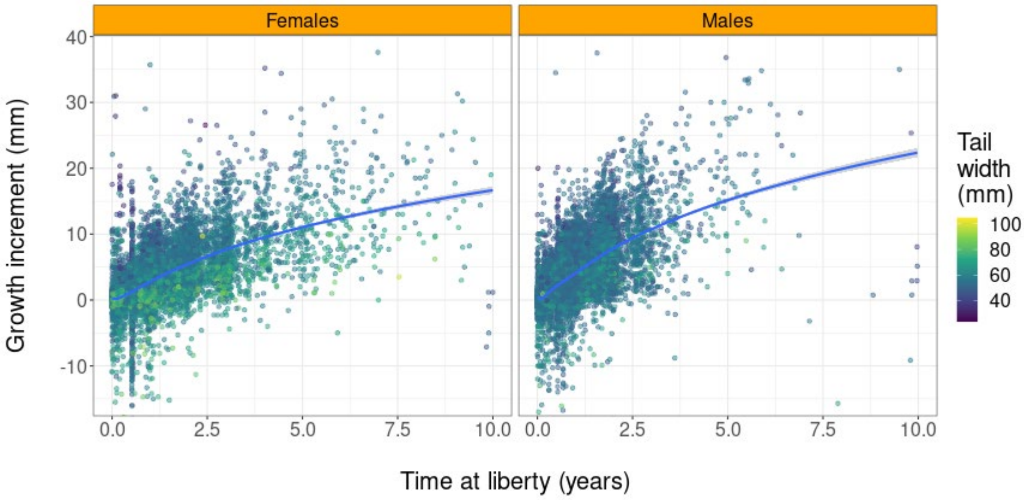

Figure 23: Growth increments (mm) by time at liberty (years) and sex for all combined tag recoveries. The colour of each point represents the size at release (mm). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

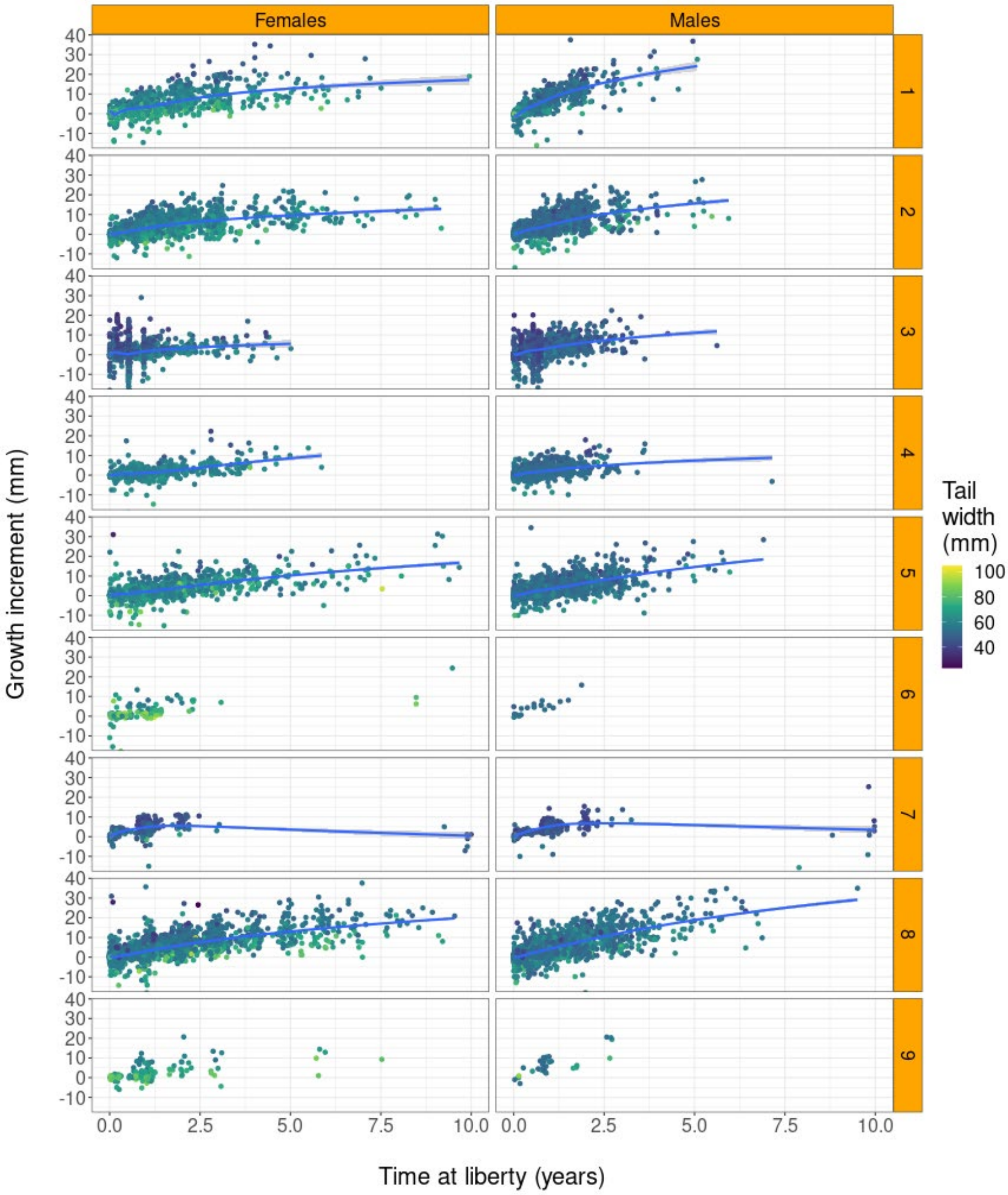

Figure 24: Growth increments (mm) by time at liberty (years), sex, and QMA. The colour of each point represents the size at release (mm). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

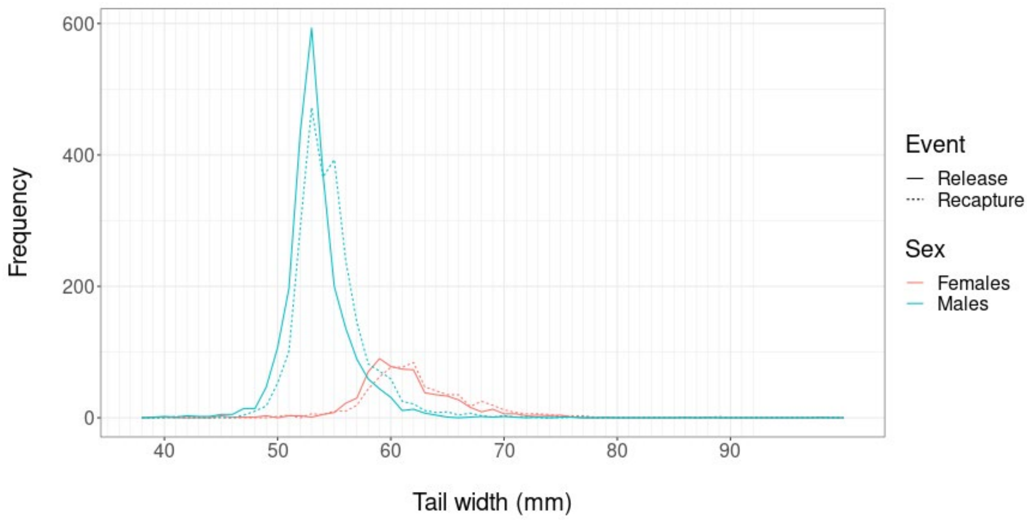

Figure 25: CRA 4 frequency polygons of size at release (solid lines) and recapture (dashed lines) by sex. A bin width of 1 mm was used.

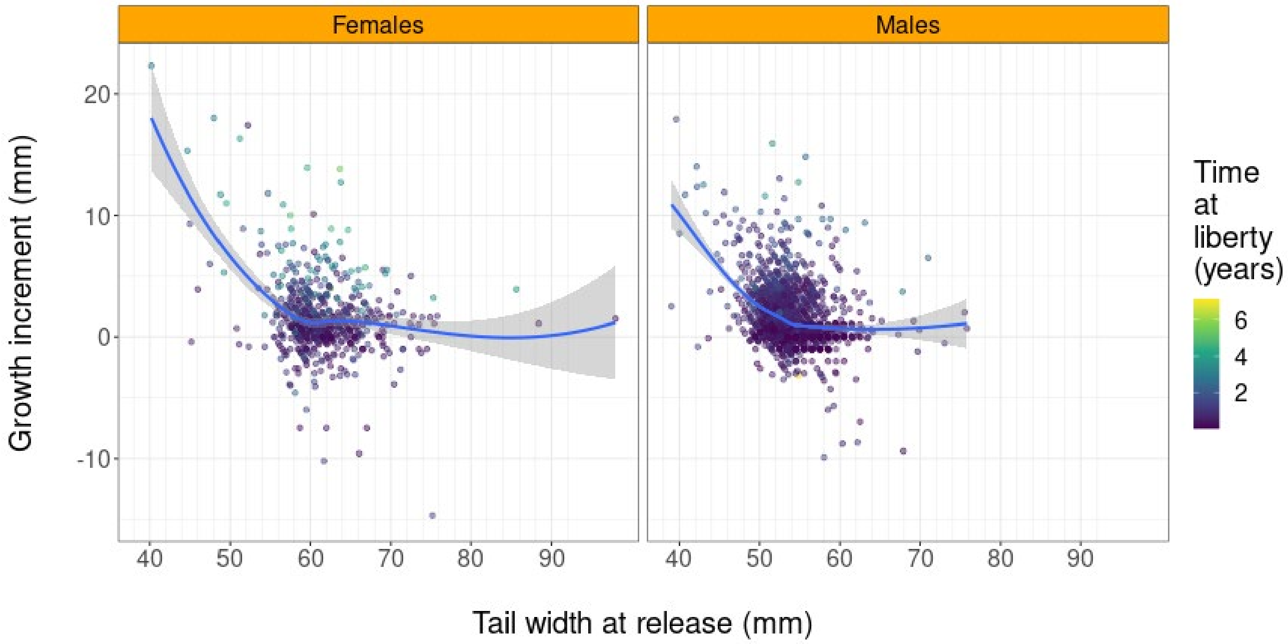

Figure 26: Growth increments (mm) by size at release (mm) and sex for all tags included in the CRA 4 stock assessment. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

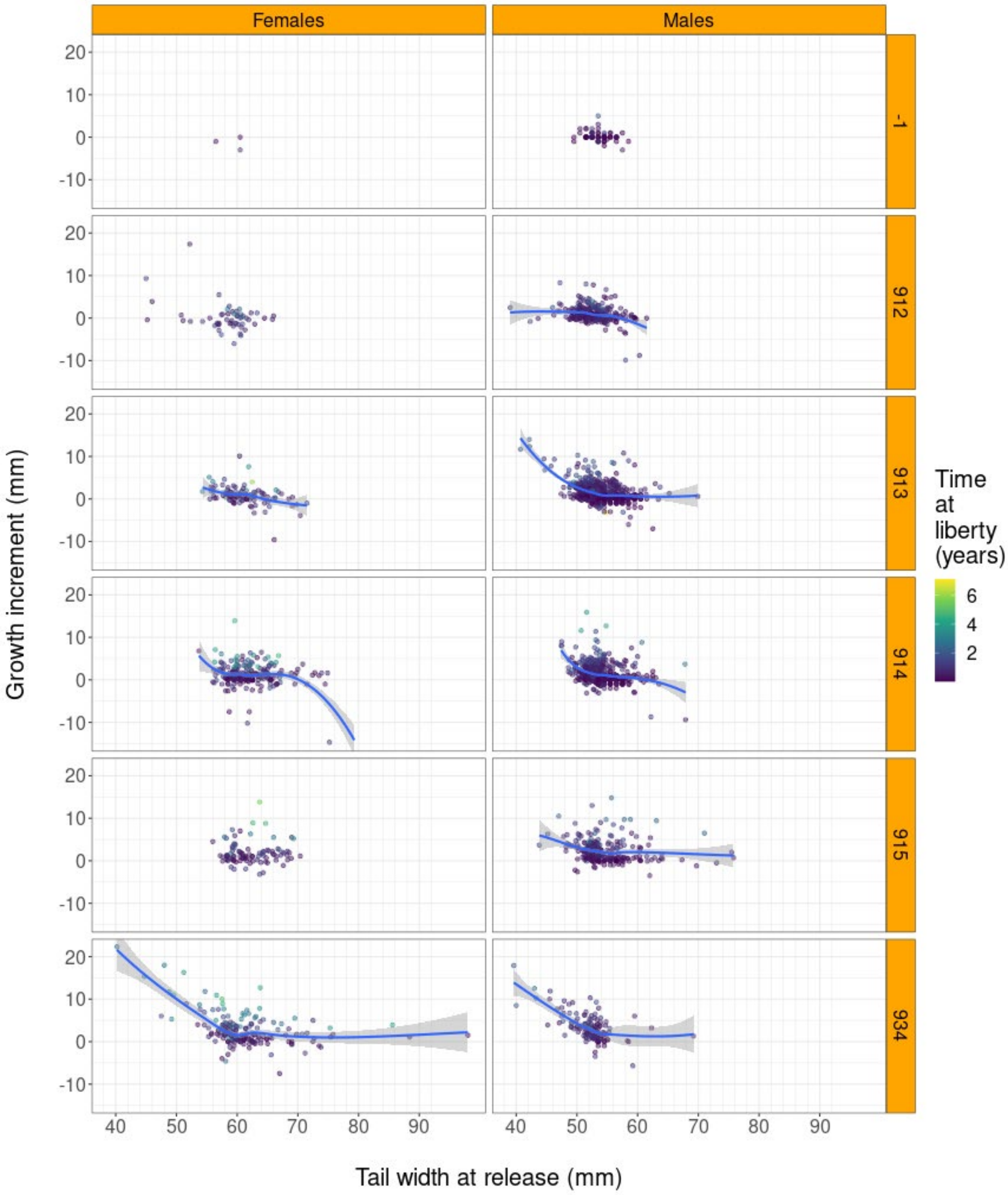

Figure 27: CRA 4 growth increments (mm) by size at release (mm) and sex in each statistical area. The colour of each point represents the time at liberty (years). A loess smoother (blue line) and the 95% confidence interval (grey shading) about this smoother is also shown.

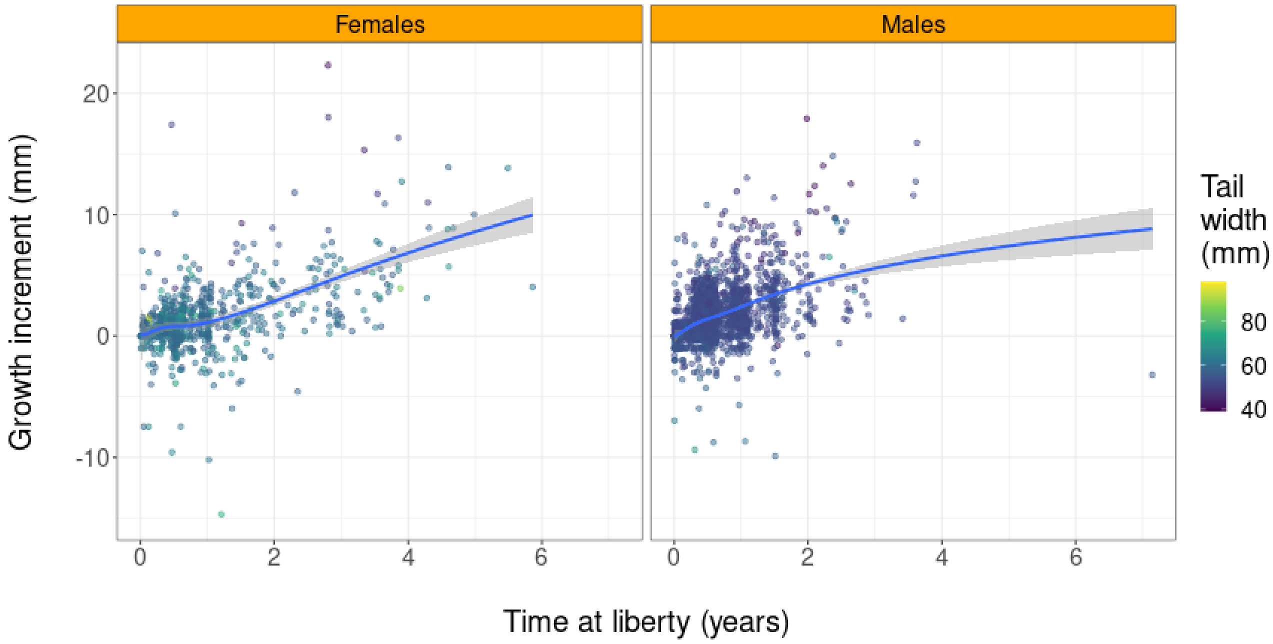

Figure 28: CRA 4 growth increments (mm) by time at liberty (years) and sex for all tags included in the stock assessment. The colour of each point represents the tail width (mm). A loess smoother (blue line) and the 95% confidence interval (grey shading) about this smoother is also shown.

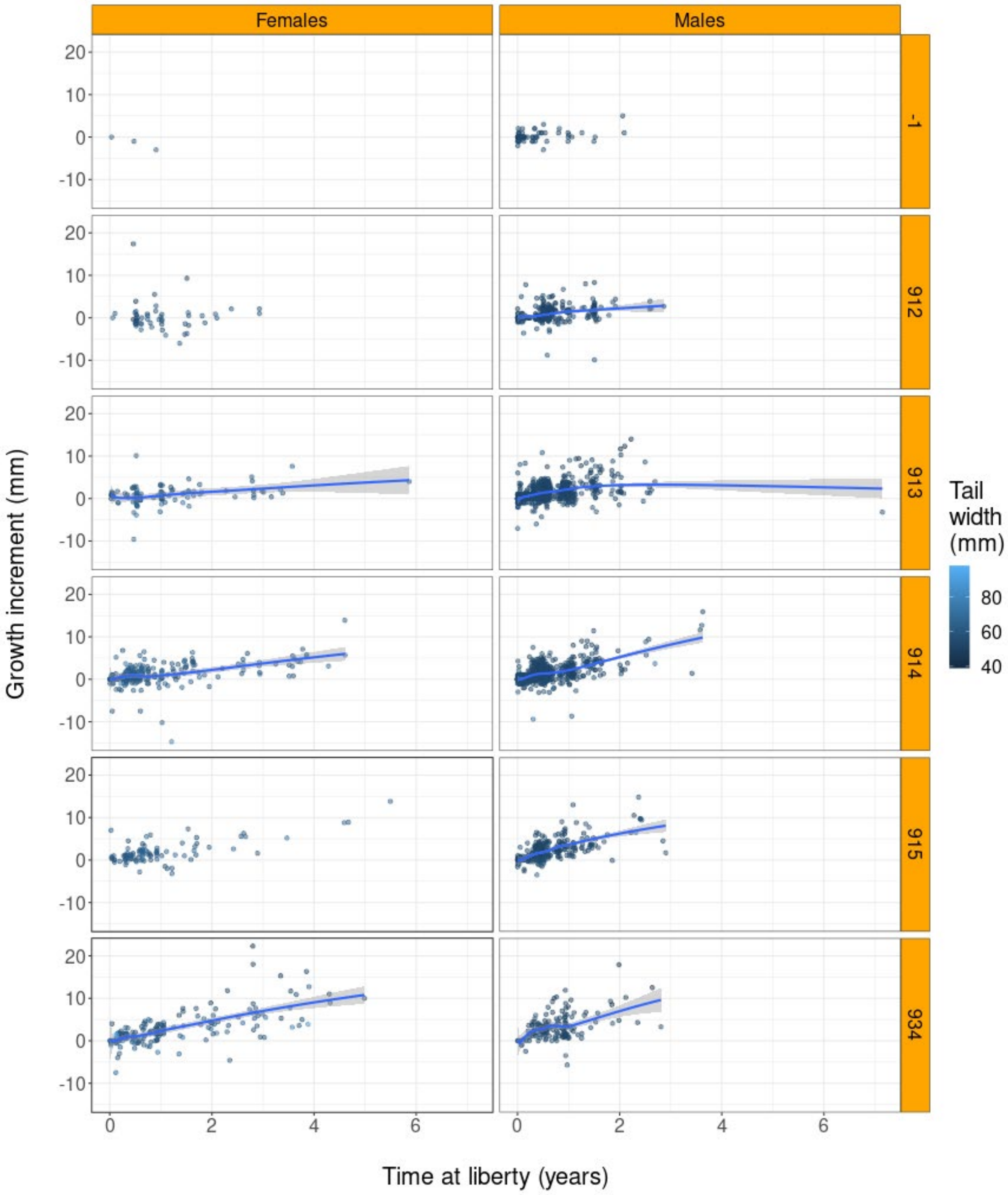

Figure 29: CRA 4 growth increments (mm) by time at liberty (years) and sex in each statistical area. The colour of each point represents the tail width (mm). A loess smoother (blue line) and the 95% confidence interval about this smoother (grey shading) is also shown.

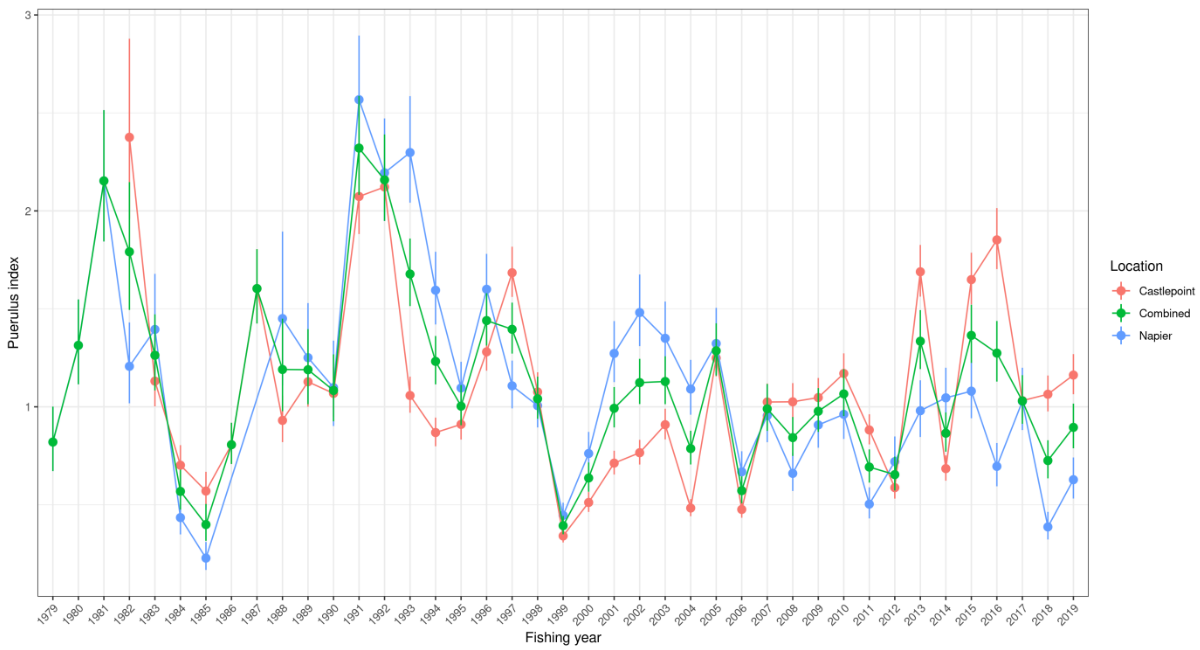

Figure 30: Plot of the two available standardised puerulus series for CRA 4 (Napier and Castlepoint) and the combined series. Error bars are 95% confidence intervals using the combined standard deviation (Table 24).

APPENDIX A: REQUEST TO FISHERIES NEW ZEALAND FOR NON-COMMERCIAL CATCH ESTIMATES

NZ ROCK LOBSTER INDUSTRY COUNCIL

Ka whakapai te kai o te moana

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

20th July 2020

Alicia McKinnon, Ministry for Primary Industries

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

cc
Dr Leyla Knittweis – Chair RLFAWG
By email: *Leyla.Knittweis@mpi.govt.nz>*

Dr. Marine Pomarède, RLFAWG
by email: *Marine.Pomarede@mpi.govt.nz*

cc ECs: *jimoroberts@gmail.com*
paul@starrfish.net
darcy@quantifish.co.nz
merrillrudd@gmail.com
pons.maite@gmail.com

Dear Alicia

Under Objectives 4 and 5 of MPI contract CRA 2018/01, the stock assessment team will be conducting CRA 4 and CRA 5 stock assessments in September and October of this year.

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

In the past, MPI's predecessor (MFish) provided estimates of illegal catches, but these were highly uncertain and, since 2004, only estimates in response to requests for the stock(s) being assessed in each year have been made available.

The stock assessment cannot ignore the current and historical non-commercial catches because doing so would cause stock productivity to be underestimated. In the absence of information, MPI must lead the process for choosing what to assume for these components; it is up to MPI to specify the non-commercial catch assumptions that MPI wishes to be used in the stock assessment.

It is likely that the RLFAWG will request sensitivity analyses on catch series that are alternatives to the base case non-commercial catch vectors, but the responsibility for providing the base case non-commercial mortalities lies with MPI.

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

- **the MPI estimates of current and recent CRA 4 and CRA 5 illegal catches and each historical trend**

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

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

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

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

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

- **estimates of the current customary catch in CRA 4 and CRA 5 and each historical trend**

The assessment team also request:

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

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

- **estimates of the current recreational catch in CRA 4 and CRA 5 and each historical trend**

The assessment team also request:

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

Without these estimates from MPI, it will not be possible to produce acceptable stock assessments. These MPI estimates of non-commercial catches are required by:

- **14th August 2020**

Can you please confirm your understanding of this written request? To assist the task, I will be happy to answer any questions you may have.

Sincerely,

Daryl R Sykes

Daryl Sykes

Research Programme Manager
NZ Rock Lobster Industry Council Ltd

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

Email correspondence from Fisheries New Zealand

From: Alicia McKinnon
Sent: Monday, 20 July 2020
To: Daryl Sykes
Cc: Darcy Webber, Leyla Knittweis, Marine Pomarede, Martin Cryer, Sonja Hempel
Subject: CRA4 and CRA5 non-commercial harvest estimates

Dear Daryl

This email provides guidance on the approach we propose for generating customary, illegal, and recreational take trajectories for the CRA 4 and CRA 5 stock assessments this year.

If you happen to have any questions or have ideas on alternate approaches, we're more than happy to discuss.

Customary harvest estimates
A summary of the information Fisheries New Zealand holds on CRA 4 and CRA 5 customary harvest since the 2007/08 April fishing year is provided in the attached excel file. This includes information provided under the Fisheries (Kaimoana) Regulations 1998, and the Fisheries (Amateur Fishing) Regulations 2013 (previously Regulation 27A of the Fisheries (Amateur Fishing) Regulations 1986).

Based on the customary harvest information available, noting its incompleteness and uncertainty, we consider it appropriate to continue to use a 20 tonne constant customary catch estimate for CRA 4 and a 10 tonne constant estimate for CRA 5.

Illegal take estimates
Because of the lack of robust illegal take estimates, we propose that a similar approach is taken for CRA 4 and CRA 5 this year as per CRA 4 and CRA 3 last year. This includes:

- Not using the historical estimates of illegal take, as provided by Compliance
- Using the 'export-discrepancy' methodology to generate early estimates of illegal take (i.e. up to 1980)
- Using a fixed percentage of the summed total commercial catch from 1981 to 2019 to represent illegal take, and explore scaling the catch total proportionately to annual commercial CPUE. The fixed percentages that we propose exploring for each stock are 5%, 10% and 15%.

Recreational harvest estimates
Available estimates of recreational rock lobster harvest for each stock are presented in the November Fisheries Assessment Plenary. All estimates are presented there, but the harvest estimates provided by the 2000 and 2001 telephone-diary surveys are no longer considered reliable by the MPI Marine Amateur Fisheries Working Group and should not be used (they are implausibly high for many species). The most recent harvest estimates are from the 2017/18 National Panel Survey (NPS) – Table 57 from FAR2019-24 is duplicated below. Harvest is given in numbers of lobsters and tonnes.

For CRA4 and CRA5, we propose that a scaling parameter between the available survey estimates and commercial CPUE is explored to create a recreational catch vector, like has been done recently for CRA1 and CRA3.

For CRA5 this includes the use of the 80 tonne 2011/12 estimate previously specified by Fisheries NZ. We also suggest considering whether it is feasible to use the results from Kaikoura/Motunau ramp-based surveys to index harvest in years between National Panel Surveys.

We also encourage the Rock Lobster Fisheries Assessment Working Group to consider different sensitivities, including double or half recreational catch.

Estimates of the mean weights of lobsters taken by recreational fishers are available – see Table 7 below from FAR2019-25 (noting some of this information for pot-caught lobsters comes from commercial catches). There will also be recreational length frequency data available for CRA 4 and CRA 5 from the mean weights programme. This may be useful for estimating selectivity of recreational divers (which seems different from pots) if the stock assessment team can/decide to separate this out in the models.

Table 57: Lobster/crayfish harvest by fishstock.

QMA.CRA	Fishers (n)	Events (n)	Harvest (n)	CV	Mean Weight (kg)	Harvest (tonnes)	CV
1	34	65	19 350	0.47	0.82	15.91	0.47
2	33	79	19 123	0.35	0.74	14.21	0.36
3	30	90	22 515	0.26	0.54	12.21	0.26
4	72	195	52 145	0.21	0.79	41.38	0.23
5	61	265	51 464	0.21	0.80	40.96	0.21
7	1	1	82	1.00	1.12	0.09	1.00
8	25	62	24 732	0.36	0.65	16.17	0.36
9	22	62	20 034	0.34	0.85	17.07	0.34
TOTAL	261	819	209 446	0.11	0.75	158.00	0.11

Table 7: Mean weight estimates (g) for rock lobster by QMA, by diver and by pot caught fish. Best estimates are boxed.

	Summer			Winter			All year			Seasonal	Best
	Estimate (g)	SE	n	Estimate (g)	SE	n	Estimate (g)	SE	n	difference	estimate
CRA 1 (diver)	851	34.0	162	755	36.2	70	822	26.3	232	–	Annual
CRA 2 (diver)	747	20.3	229	795	35.9	44	754	18.0	273	–	Annual
CRA 3 (diver)	563	13.6	50	597	29.8	12	570	97.5	62	–	Annual ##
CRA 4 (diver)	961	71.9	70	1 169	354.0	6	977	71.3	76	–	Annual
CRA 5 (diver)	945	24.1	344	1 203	66.1	39	971.0	23.0	383	***	Seasonal
CRA 7 (diver)	1125	107.9	25	–	–	–	1 125	107.9	25	–	Annual
CRA 8 (diver)	No creel data available						654	–	6 921	–	Annual #
CRA 9 (diver)	791	55.9	29	1 478	251.1	9	852	–	268	*	Annual #
CRA 1 (pot)	–	–	–	871	–	1	817	–	2 091	–	Annual #
CRA 2 (pot)	704	49.4	18	662	59.8	6	588	–	2 285	–	Annual #
CRA 3 (pot)	553	33.4	18	–	–	–	531	–	2 716	–	Annual #
CRA 4 (pot)	614	34.6	34	1 116	427.7	2	502	–	8 858	–	Annual #
CRA 5 (pot)	595	10.6	241	678	24.8	83	616	10.3	324	**	Seasonal
CRA 7 (pot)	No creel data available			–	–	–	657	–	1 471	–	Annual #
CRA 8 (pot)	No creel data available						654	–	6 921	–	Annual #
CRA 9 (pot)	758	65.8	13	951	34.0	6	852	–	268	*	Annual #

\# based on commercial observer and logbook data - see Appendix 1

\## data from 2016–17 and 2017–18 combined

Kind regards
Alicia

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APPENDIX C: EVIDENCE FOR STATISTICAL AREA SEPARATION IN CRA 4

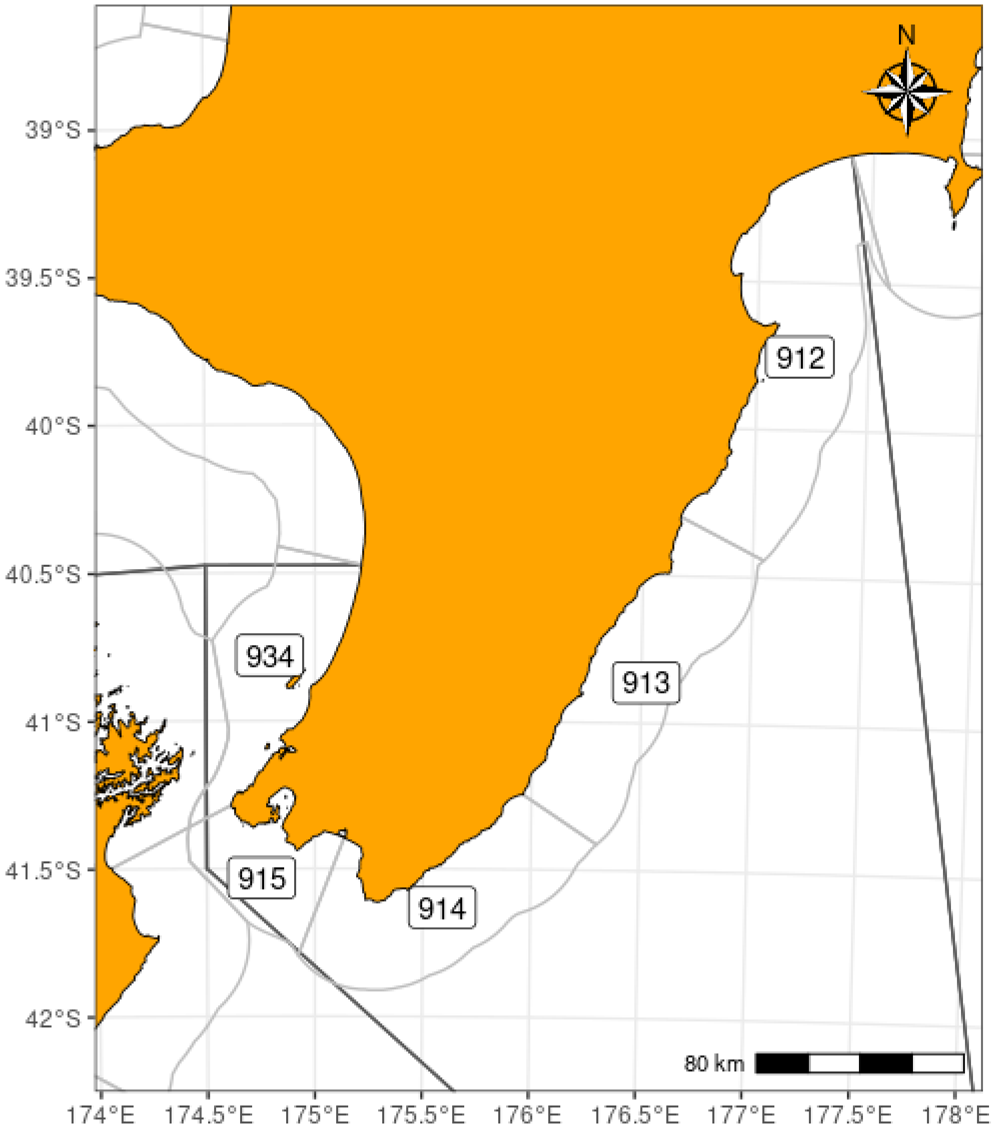


Figure C.1: Map showing location of CRA 4 statistical areas.

The stock assessment team evaluated the available statistical area information for CRA 4 (Figure C.1), with the intent of determining if any of these areas showed differences among the available biological or abundance data. Based on this evaluation, the RLFAWG agreed with the recommendation that CRA 4 should be treated as a single region, given that there appeared to be few differences in the available data by statistical area.

C.1 COMPARISON OF STANDARDISED CPUE SERIES

The standardisation procedure described in section 3.1 evaluates each statistical area using an area × period interaction term. Therefore, each series can be plotted separately (Figure C.2) or superimposed (Figure C.3). Both plots show that CPUE is reasonably synchronous among the four statistical areas, with the main difference being the amplitude of the peaks. Similarly, seasonal catches vary synchronously among the statistical areas over the full forty years of available catch history (Figure C.4).

C.2 COMPARISON OF LENGTH FREQUENCY (LF) DISTRIBUTIONS

Comparison of the empirical cumulative length frequency distributions for each sex category across the five CRA 4 statistical areas and averaged over the period 1997–2019, indicates that the south coast (statistical areas 915 and 934) has consistently larger males and mature females in the AW (Figure C.5) and SS (Figure C.6). However, the other three statistical areas have similar cumulative distributions, particularly 913 and 914, the two most important areas in terms of catch. Statistical area 912 is the smallest in terms of length frequencies among the five statistical areas, but the difference is small.

C.3 COMPARISON OF PROPORTIONS OF MATURE FEMALES

There appears to be a declining trend in the proportion of mature females in the catch, both overall (see Figure 17) and for each of the five CRA 4 statistical areas (Figure C.7). While the proportion of mature females among the four main statistical areas is clearly variable, they all show the overall downward trend.

C.4 CONCLUSION

The RLFAWG reviewed this information and concluded that the evidence for separating CRA 4 into component regions based on apparent differences between statistical areas is weak. CPUE and catches appear to be varying synchronously and the decline in the proportion of mature females in the catch is apparent in all five statistical areas. The only consistent difference that is noteworthy is the somewhat larger lobsters in statistical areas 915 and 934, which constitute the south coast of the North Island. However, as these two statistical areas only represent about 15% of the overall catch, it seems unlikely that separating out these two areas and assessing them separately has the potential to alter the provided advice.

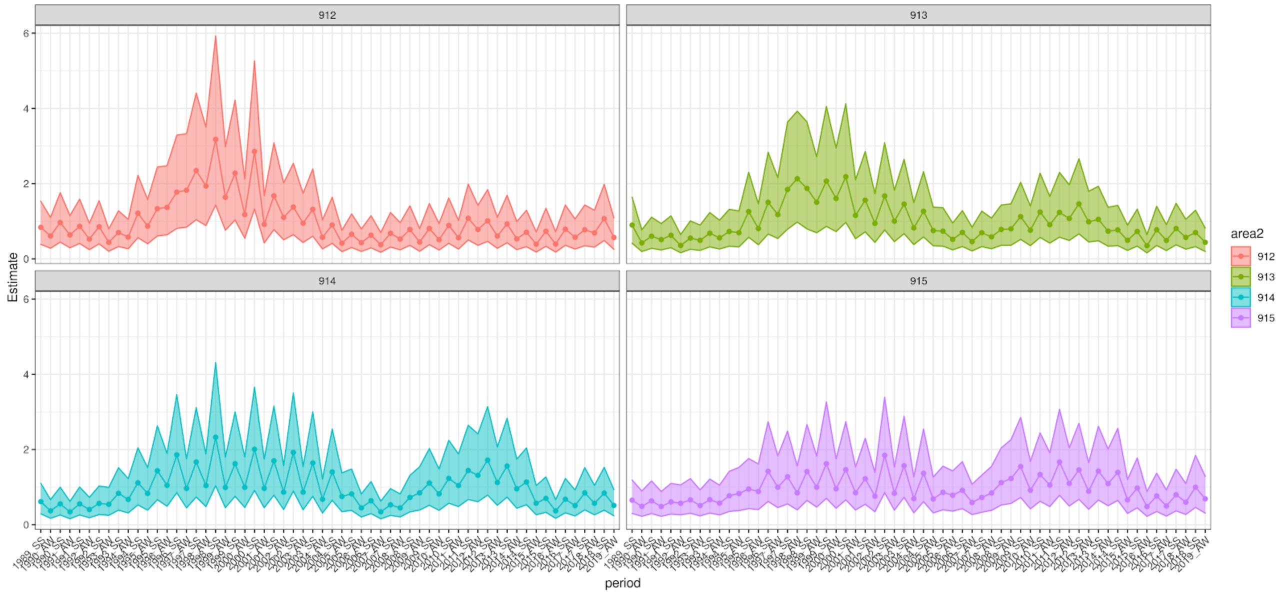


Figure C.2: Seasonal standardised CPUE for each of the four main CRA 4 statistical areas. Median posterior estimates connected with solid lines are shown, along with the associated 90% credibility intervals.

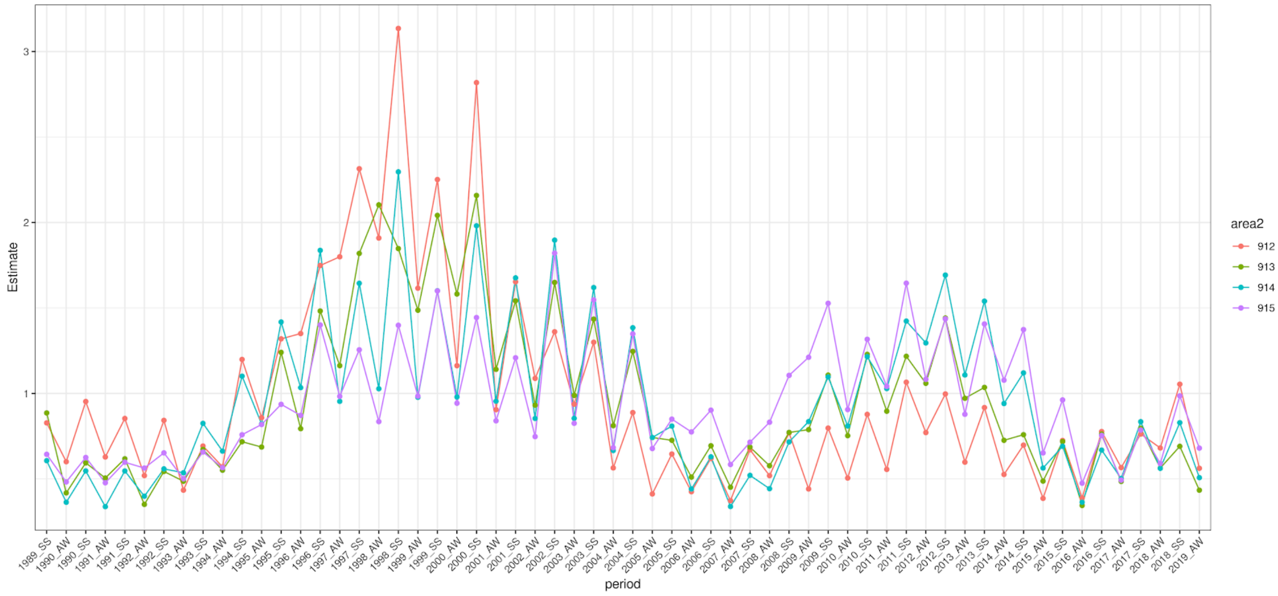


Figure C.3: Median posterior estimates of standardised CPUE for each of the four main CRA 4 statistical areas.

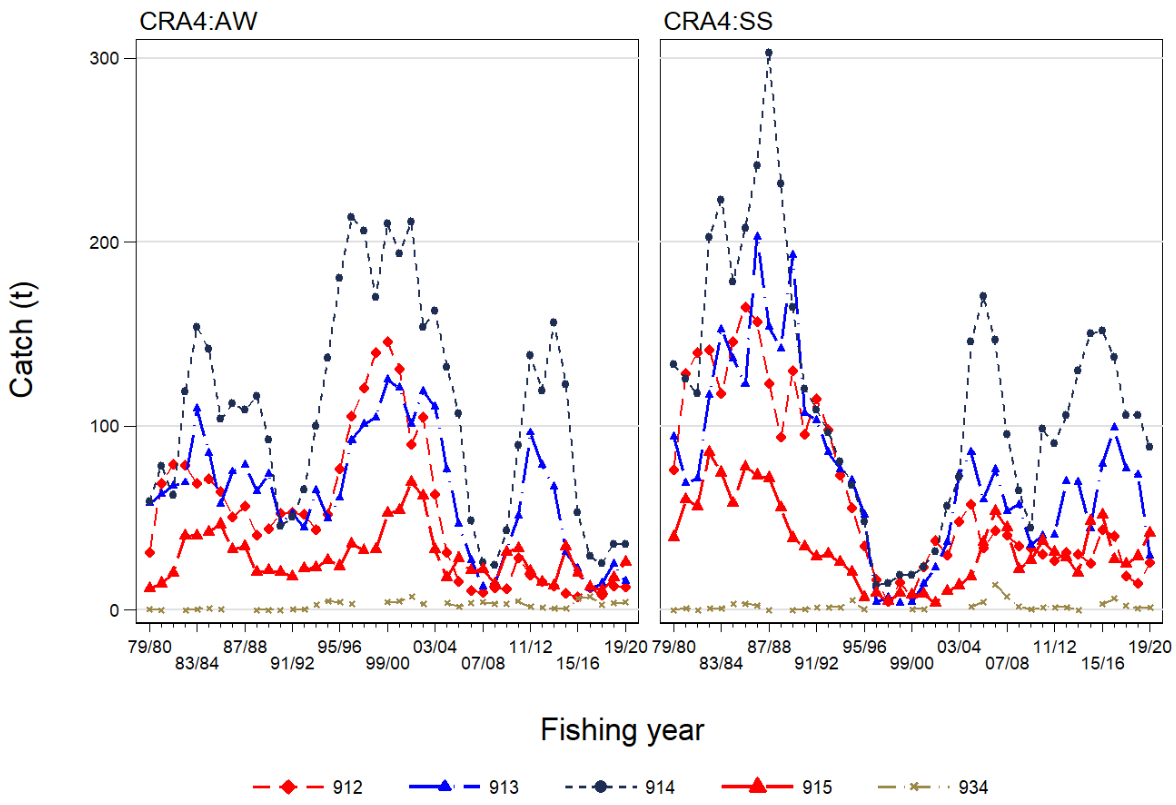


Figure C.4: Seasonal catch trajectories from 1979 to 2019 for each of the five CRA 4 statistical areas.

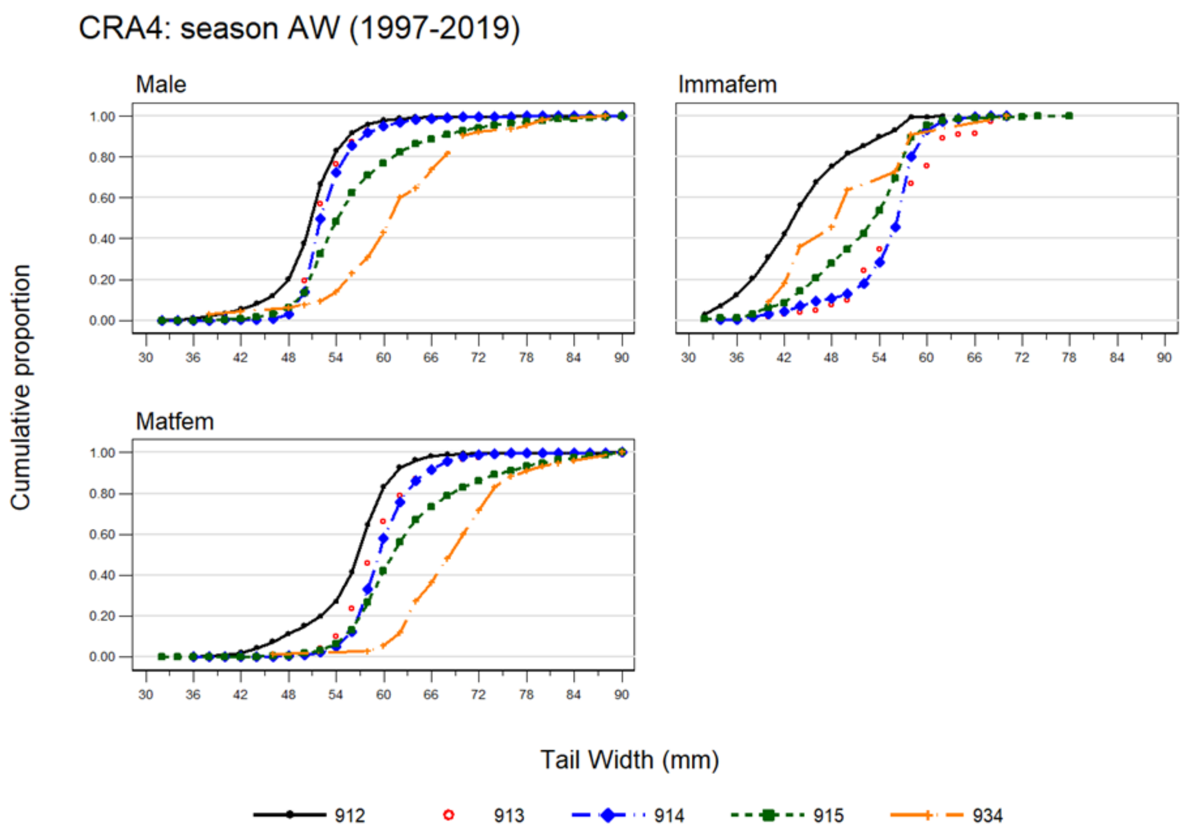


Figure C.5: Mean (1997-2019) empirical cumulative LF distribution by sex category for the four main CRA 4 statistical areas in the AW season.

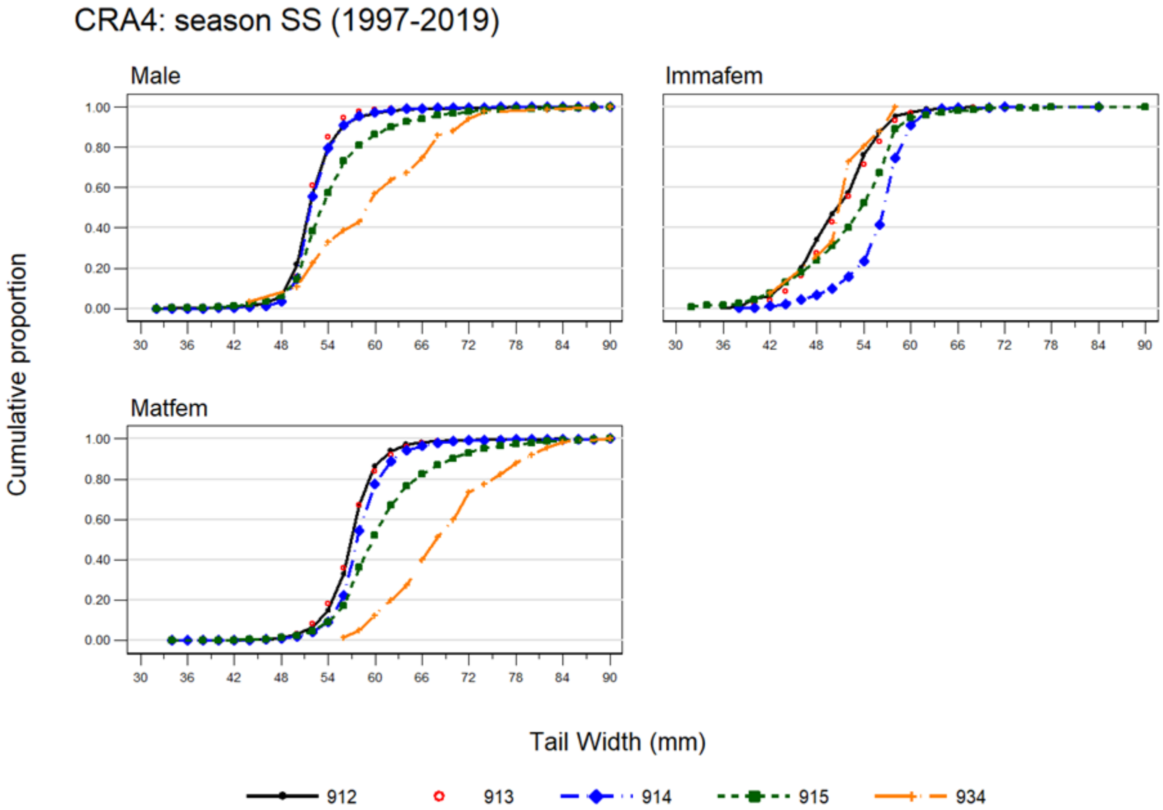


Figure C.6: Mean (1997-2019) empirical cumulative LF distribution by sex category for the four main CRA 4 statistical areas in the SS season.

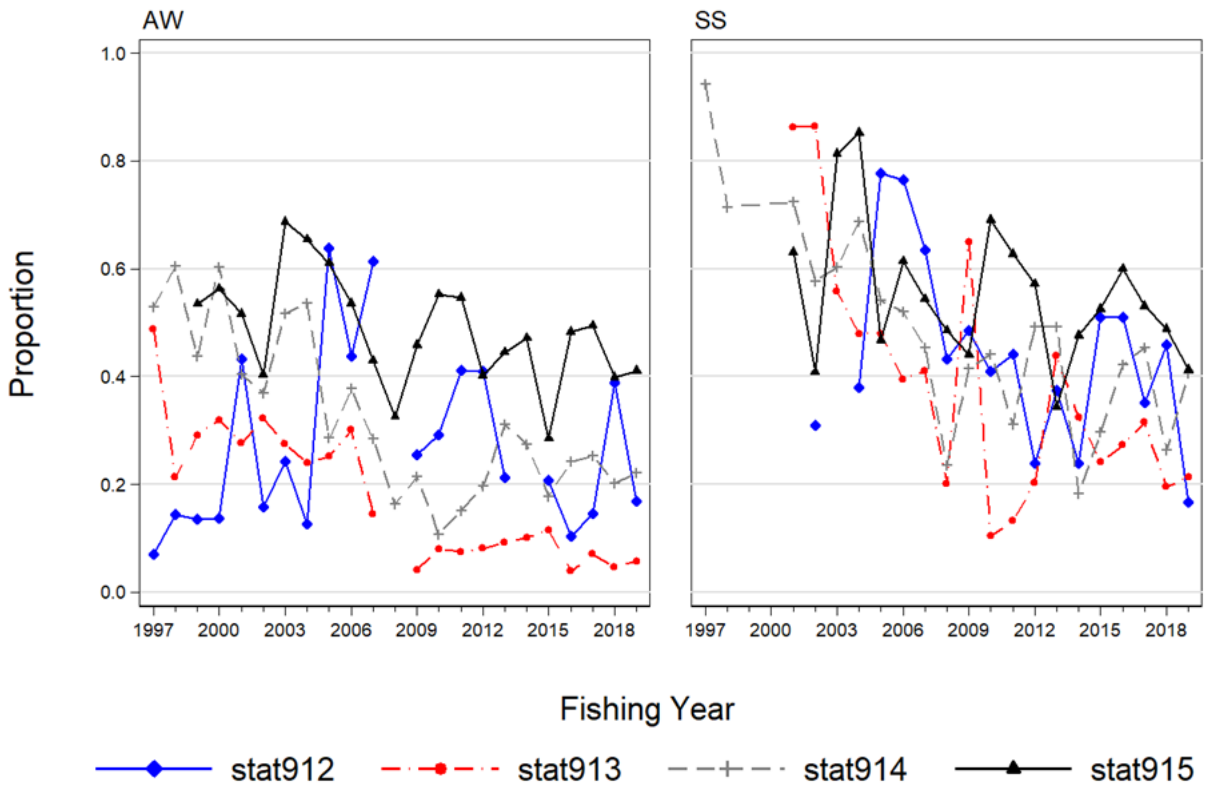


Figure C.7: Plot of proportion mature females in the catch for each of the four main CRA 4 statistical areas, 1997–2019.

APPENDIX D: COMPARISON OF LENGTH FREQUENCY DISTRIBUTIONS USING F0_LFX AND F2_LFX CATCH WEIGHTING

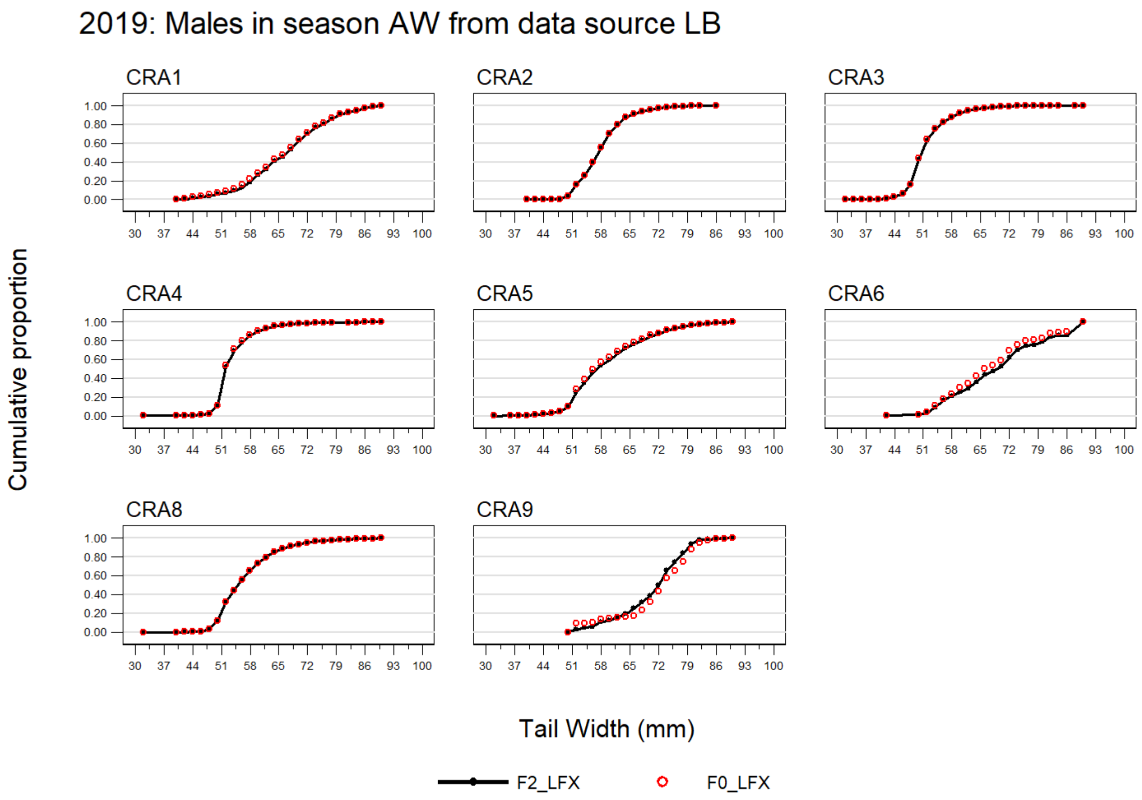
The preparation of the length frequency (LF) data requires weighting by catch between statistical areas and months (see Eq. 5 in section 4). The RLFAWG agreed in 2013 to use catch data based on the F0_LFX catch expansion algorithm (see appendix D of Starr 2021). This decision was based on an unpublished comparison of LFs prepared using three different algorithms, the F0_LFX, F2_LFX, and B4_LFX, which found no appreciable differences among the resulting distributions. The F0_LFX distribution was chosen because, unlike the other two algorithms, no catch data are dropped.

Given the problems described in section 1 with the transition from paper forms to electronic reporting (also see appendix B of Starr 2021), the 2013 comparison was repeated for the 2019–20 fishing year using the F0_LFX and the F2_LFX algorithms. Note that the F0_LFX algorithm retains all data, regardless of the *vcf* value while the F2_LFX algorithm only accepts catch associated with a vessel having a *vcf* between 0.8 and 1.2. As defined in appendix E of Starr (2021), *vcf* is the ratio of the total annual estimated catch divided by the annual landings for that vessel. Because the *vcf* is defined annually, this quantity combined all CELR and ER returns in 2019–20 for a vessel.

Plots comparing the empirical cumulative LF distributions prepared using catch weights derived from the two catch correction algorithms are available by QMA, sex category, season and catch sampling programme:

Sex category	Sampling programme	Figure number
male	logbook	Figure D.1
immature female	logbook	Figure D.2
mature female	logbook	Figure D.3
male	observer catch sampling	Figure D.4
immature female	observer catch sampling	Figure D.5
mature female	observer catch sampling	Figure D.6

These plots show that there is no difference between the resulting LF distributions in the large majority of comparisons (61 of the 71 available pairs). There are some exceptions, particularly in the immature females where there tend to be less data. Only in CRA 3/immature females (Figure D.5) is there a strong difference between the distributions generated by the two catch algorithms while the remaining nine divergent plots are reasonably close. The RLFAWG agreed to proceed with LFs prepared using catch data from the F0_LFX algorithm for this stock assessment.



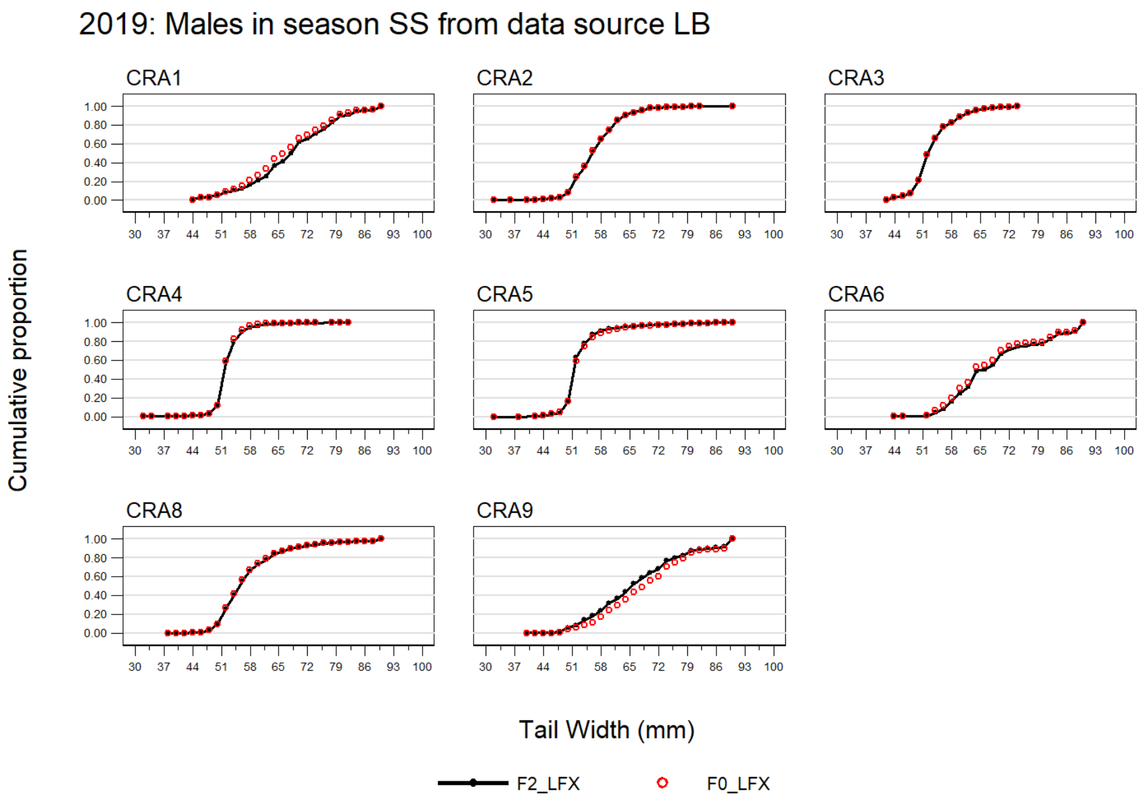


Figure D.1: Comparison of two 2019–20 empirical cumulative length frequency distributions by QMA for males sampled by the respective logbook programmes in the AW (top) and SS (bottom) seasons. The catches used to weight these distributions (Eq. 5) were generated using either F0_LFX or the F2_LFX catch correction algorithms.

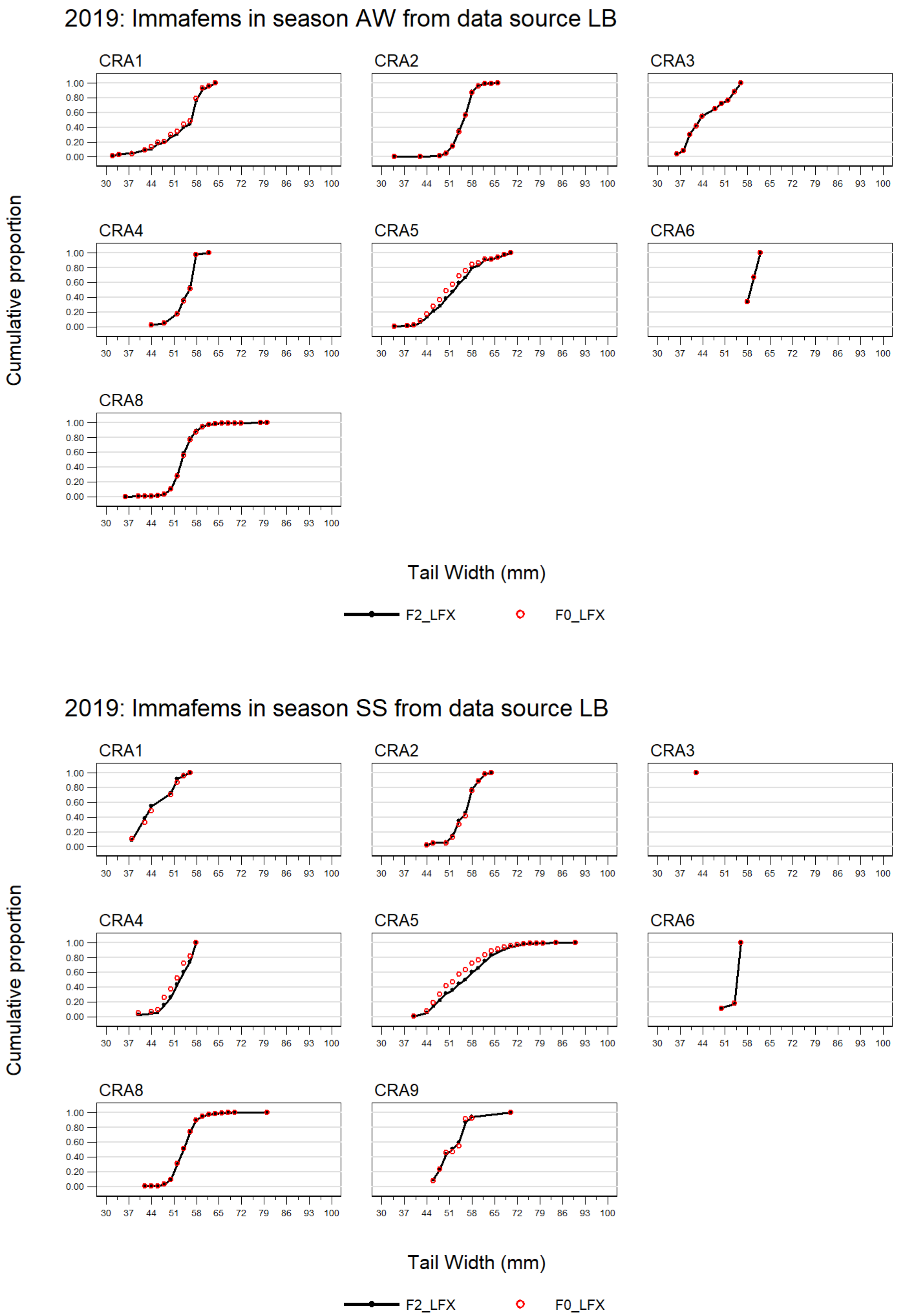


Figure D.2: Comparison of two 2019–20 empirical cumulative length frequency distributions by QMA for immature females sampled by the respective logbook programmes in the AW (top) and SS (bottom) seasons. The catches used to weight these distributions (Eq. 5) were generated using either F0_LFX or the F2_LFX catch correction algorithms.

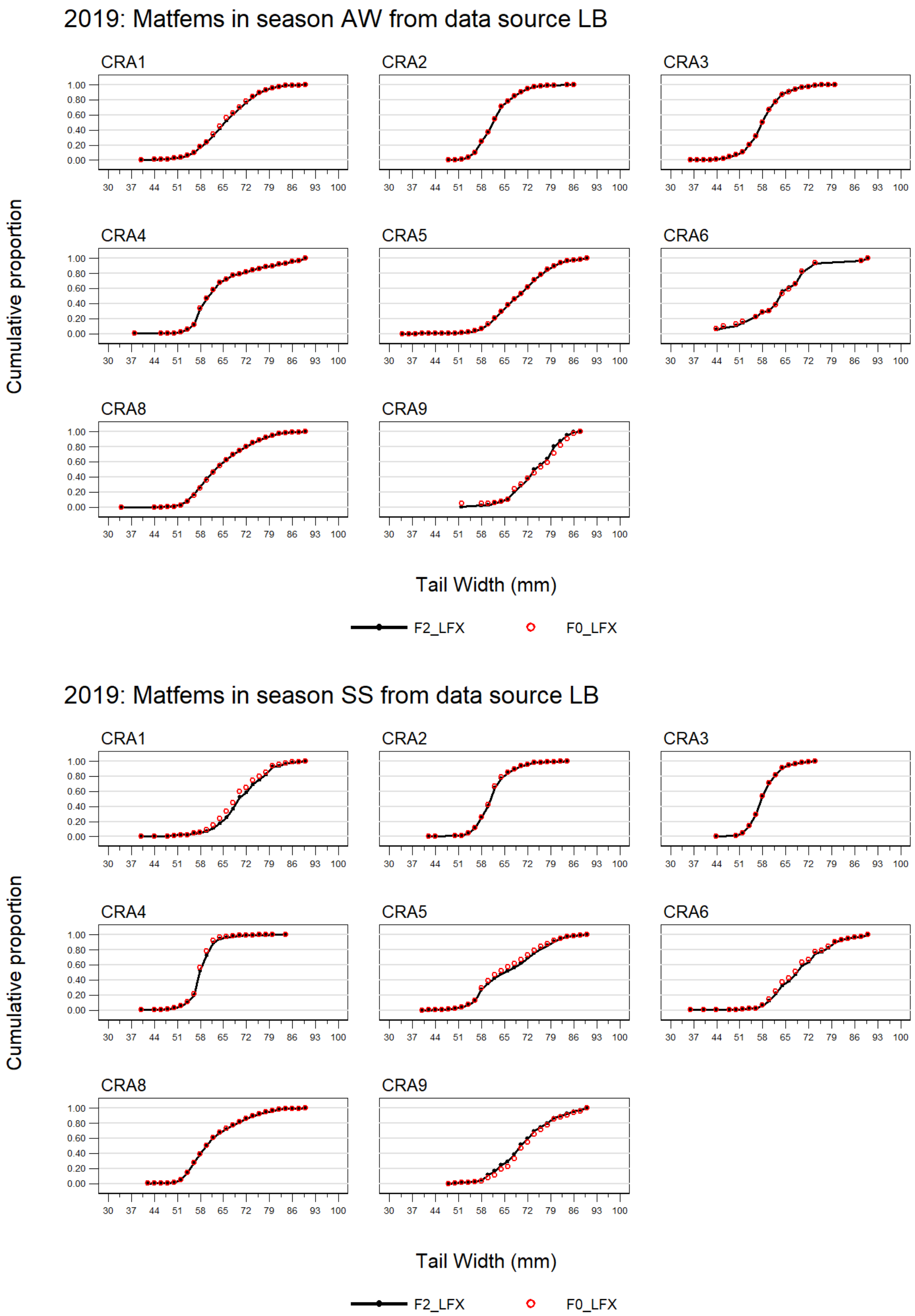
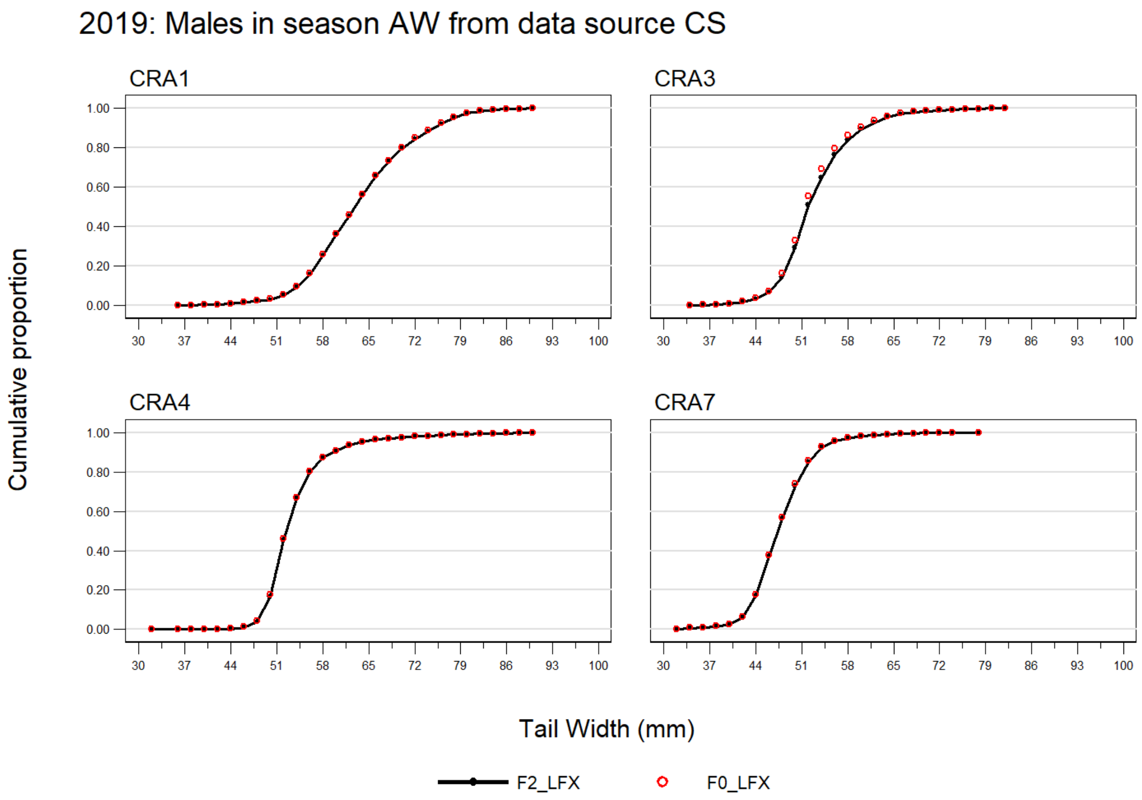


Figure D.3: Comparison of two 2019–20 empirical cumulative length frequency distributions by QMA for mature females sampled by the respective logbook programmes in the AW (top) and SS (bottom) seasons. The catches used to weight these distributions (Eq. 5) were generated using either F0_LFX or the F2_LFX catch correction algorithms.



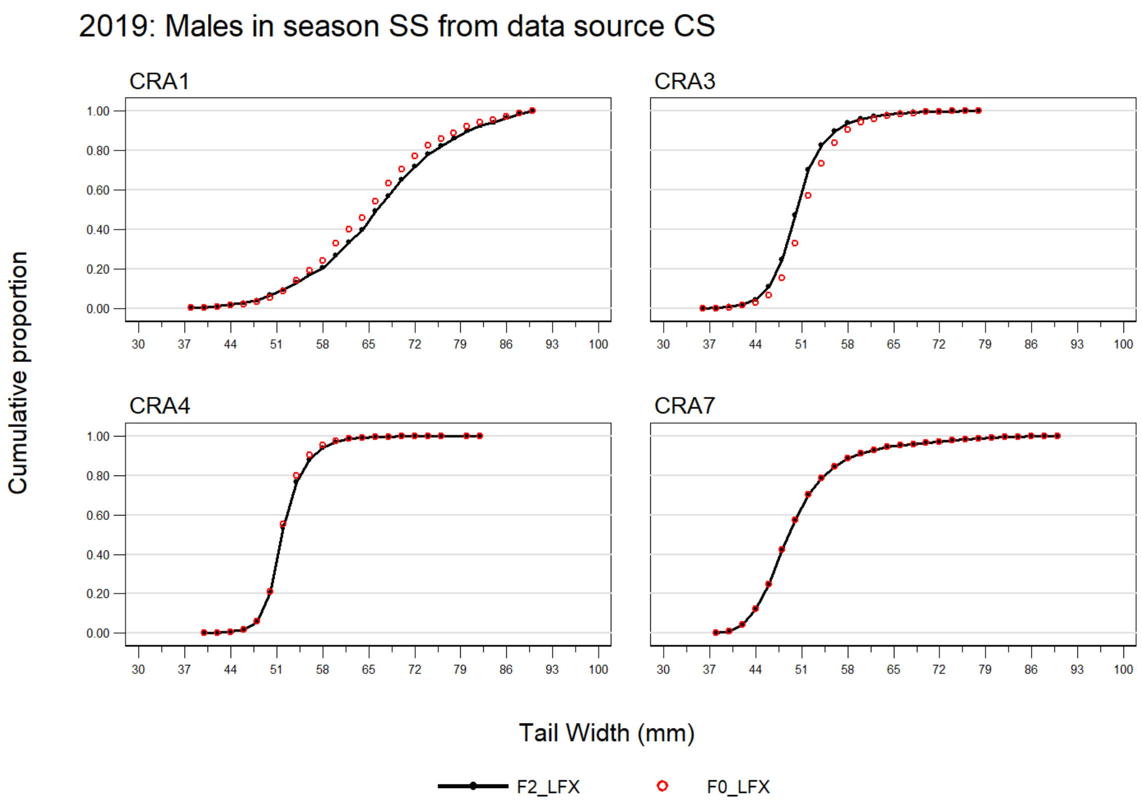


Figure D.4: Comparison of two 2019–20 empirical cumulative length frequency distributions by QMA for males sampled by the respective observer catch sampling programmes in the AW (top) and SS (bottom) seasons. The catches used to weight these distributions (Eq. 5) were generated using either F0_LFX or the F2_LFX catch correction algorithms.

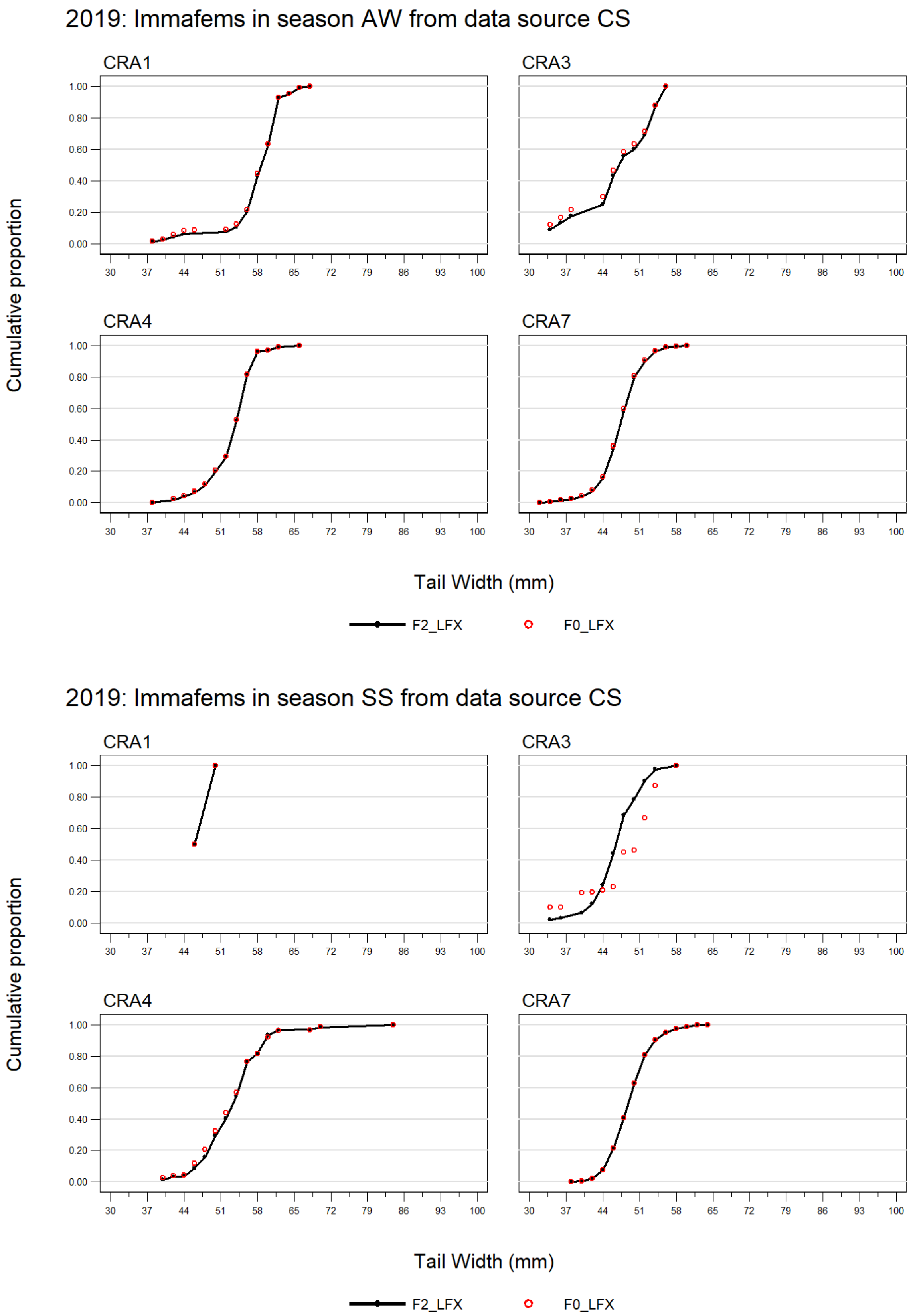


Figure D.5: Comparison of two 2019–20 empirical cumulative length frequency distributions by QMA for immature females sampled by the respective observer catch sampling programmes in the AW (top) and SS (bottom) seasons. The catches used to weight these distributions (Eq. 5) were generated using either F0_LFX or the F2_LFX catch correction algorithms.

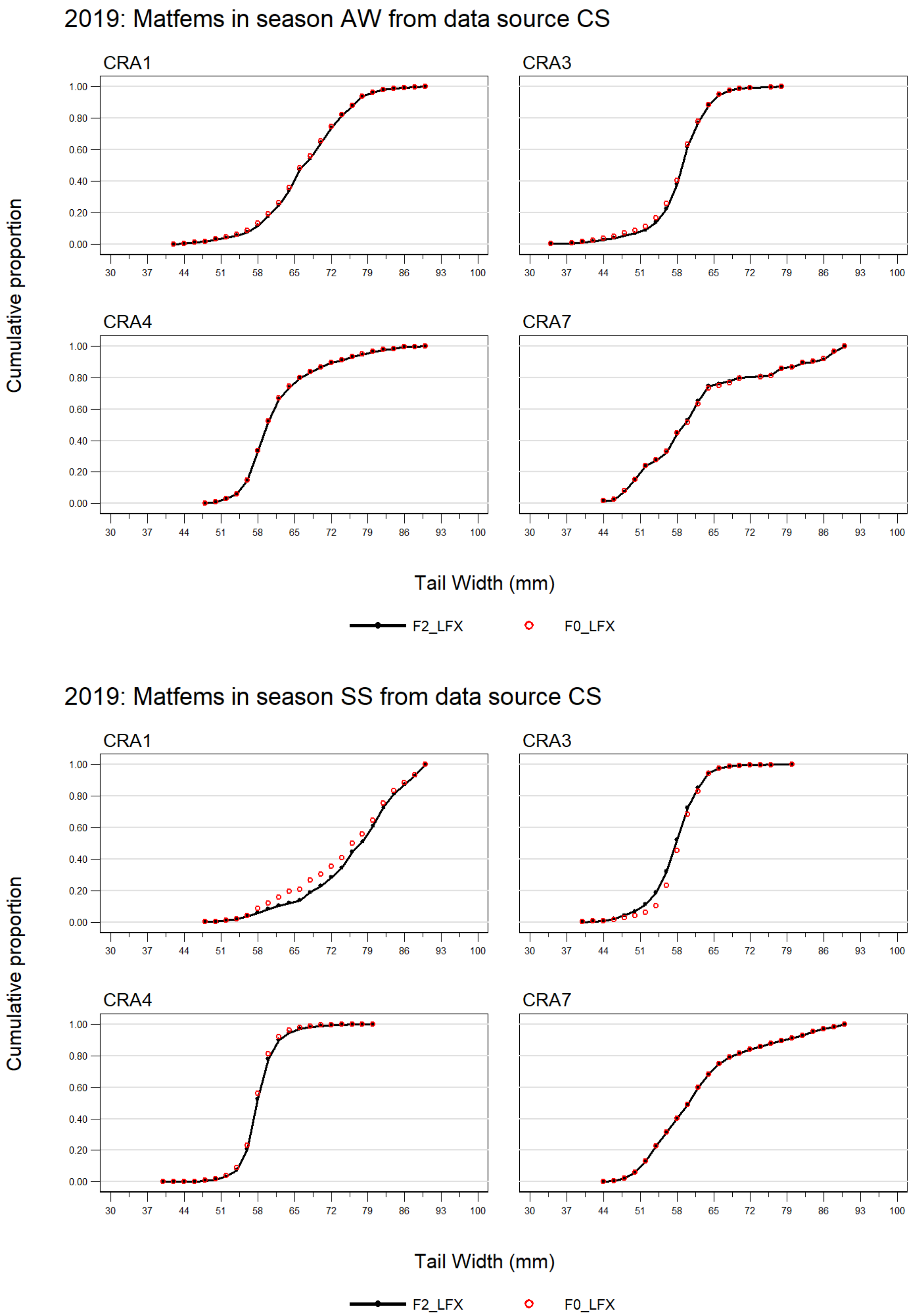


Figure D.6: Comparison of two 2019–20 empirical cumulative length frequency distributions by QMA for mature females sampled by the respective observer catch sampling programmes in the AW (top) and SS (bottom) seasons. The catches used to weight these distributions (Eq. 5) were generated using either F0_LFX or the F2_LFX catch correction algorithms.

APPENDIX E: LENGTH FREQUENCY DISTRIBUTIONS FROM LOGBOOK AND CATCH SAMPLING

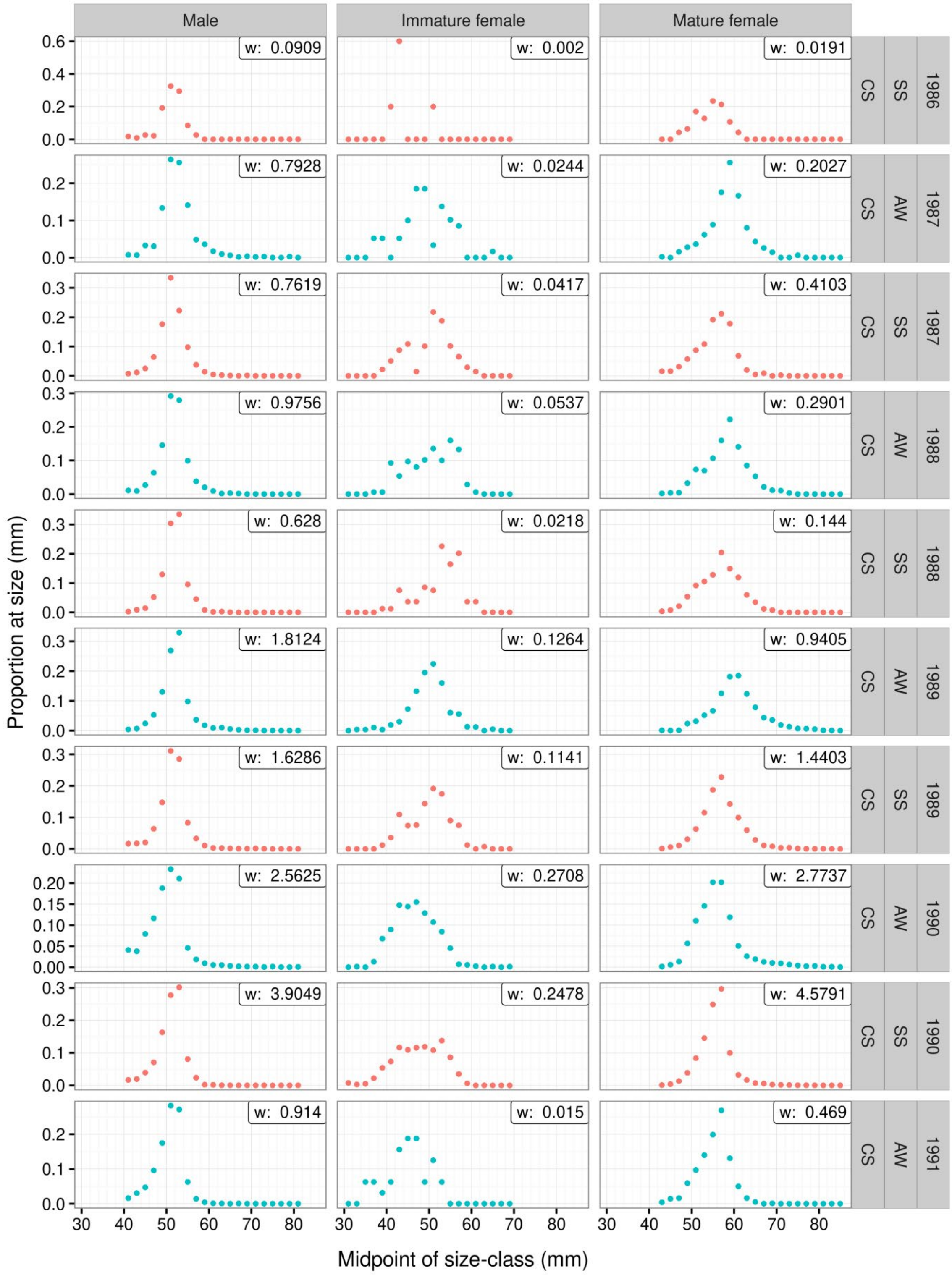


Figure E.1: Observed CRA 4 length frequency distributions by sex category from 1986.SS.CS to 1991.AW.CS. Each cell shows the associated weight from Table 8. CS=observer catch sampling.

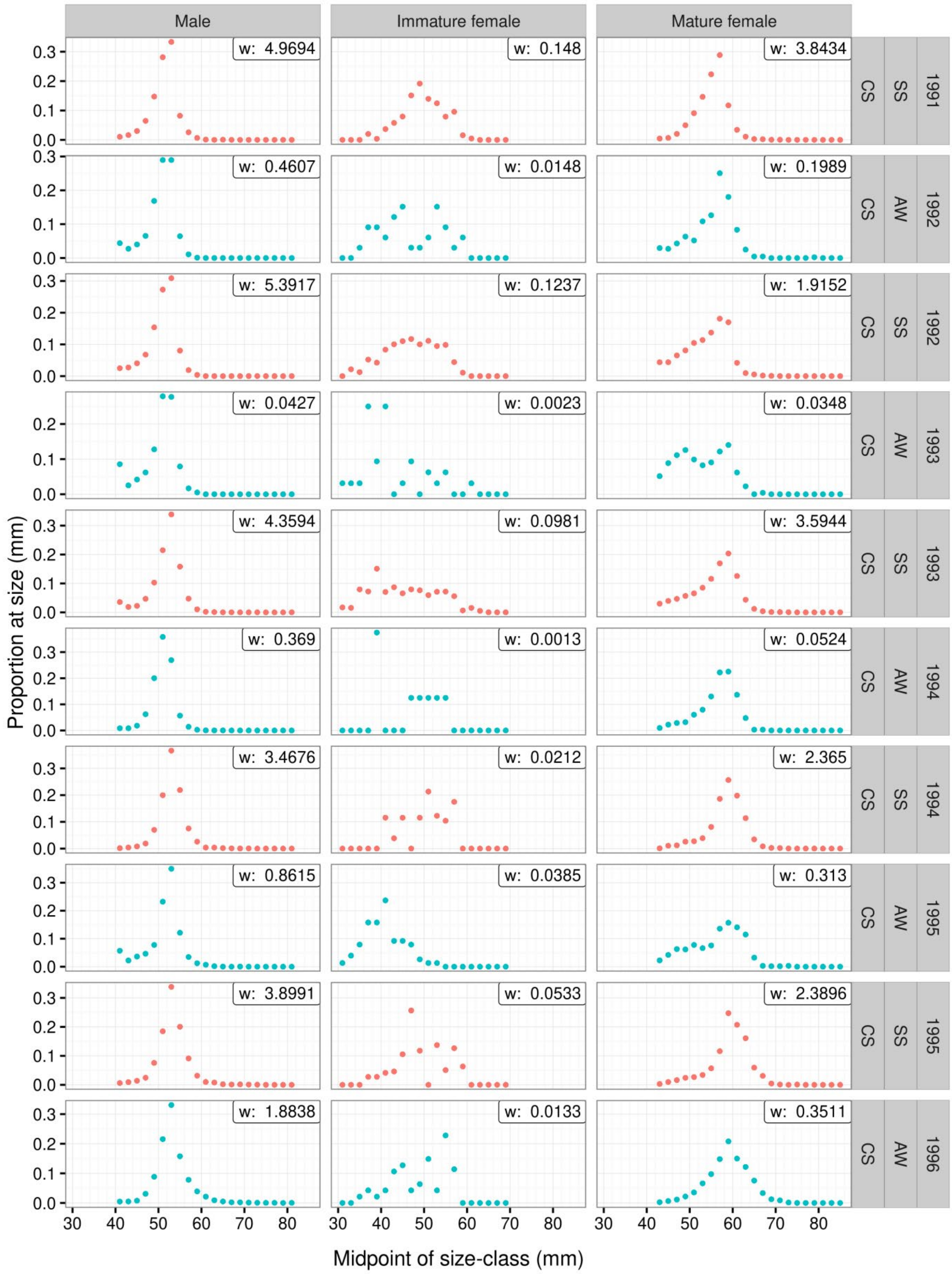


Figure E.2: Observed CRA 4 length frequency distributions by sex category from 1991.SS.CS to 1996.AW.CS. Each cell shows the associated weight from Table 8. CS=observer catch sampling.

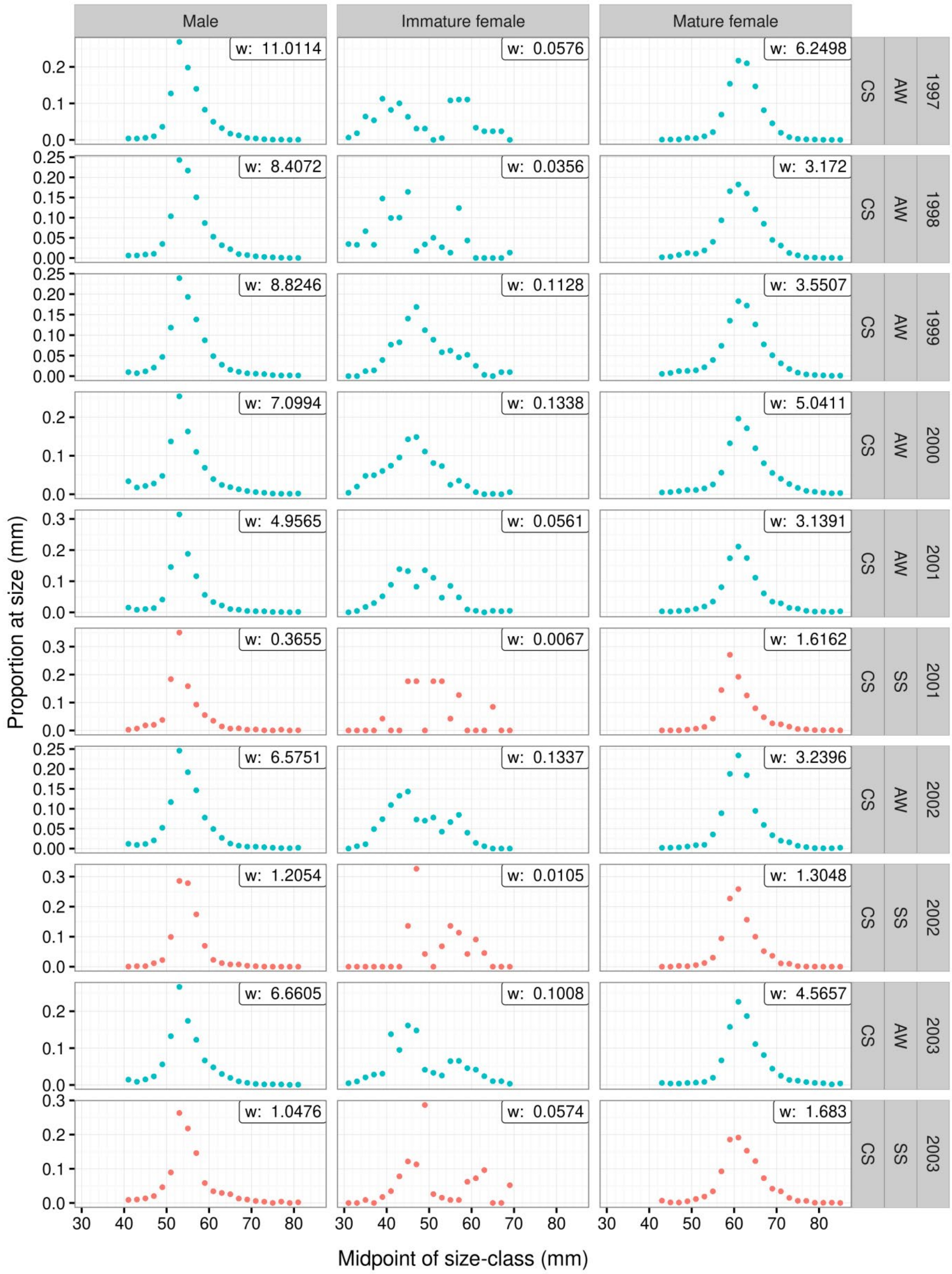


Figure E.3: Observed CRA 4 length frequency distributions by sex category from 1997.AW.CS to 2003.SS.CS. Each cell shows the associated weight from Table 8. CS=observer catch sampling.

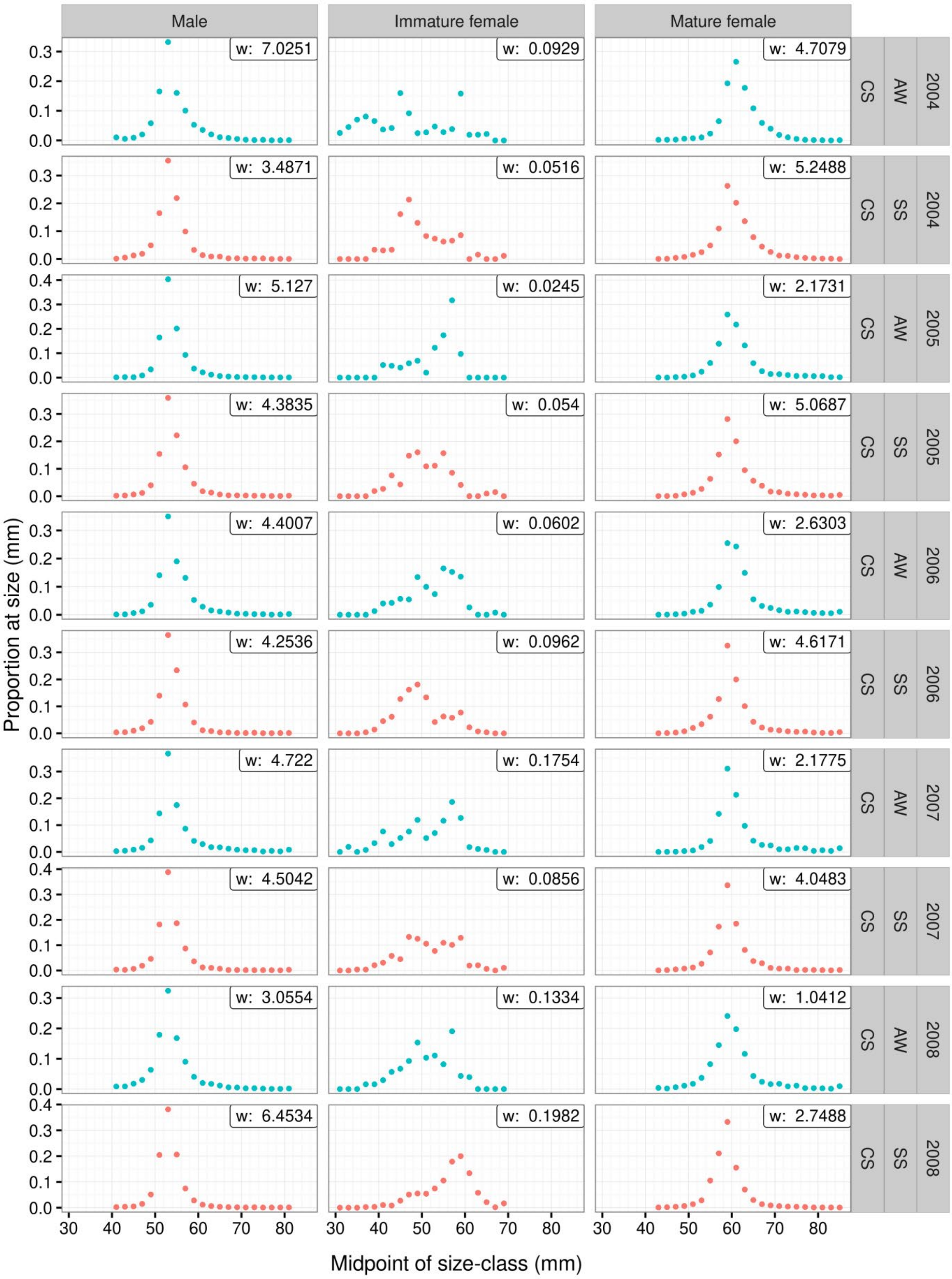


Figure E.4: Observed CRA 4 length frequency distributions by sex category from 2004.AW.CS to 2008.SS.CS. Each cell shows the associated weight from Table 8. CS=observer catch sampling.

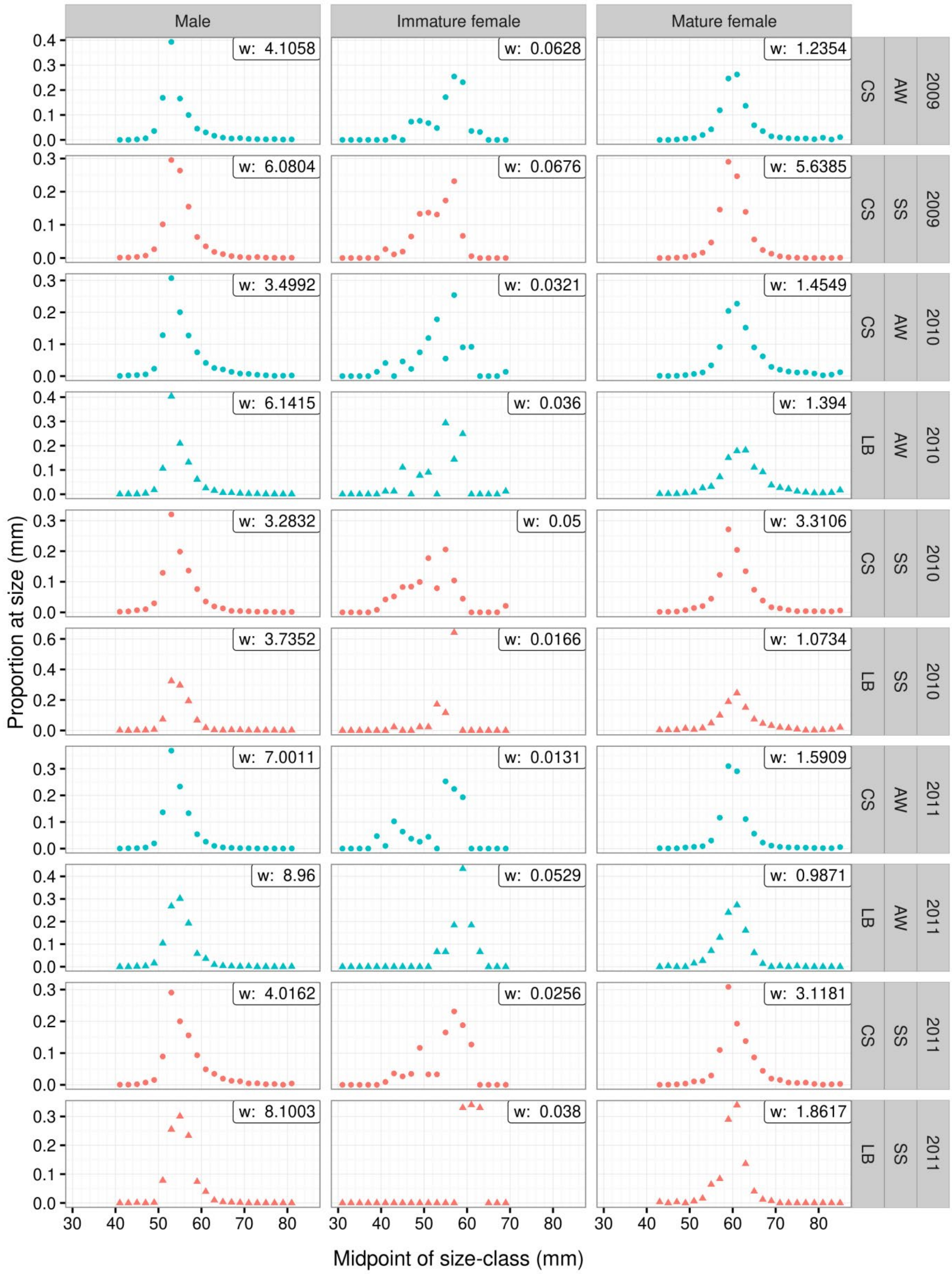


Figure E.5: Observed CRA 4 length frequency distributions by sex category from 2009.AW.CS to 2011.SS.LB. Each cell shows the associated weight from Table 8. CS=observer catch sampling; LB=logbook catch sampling.

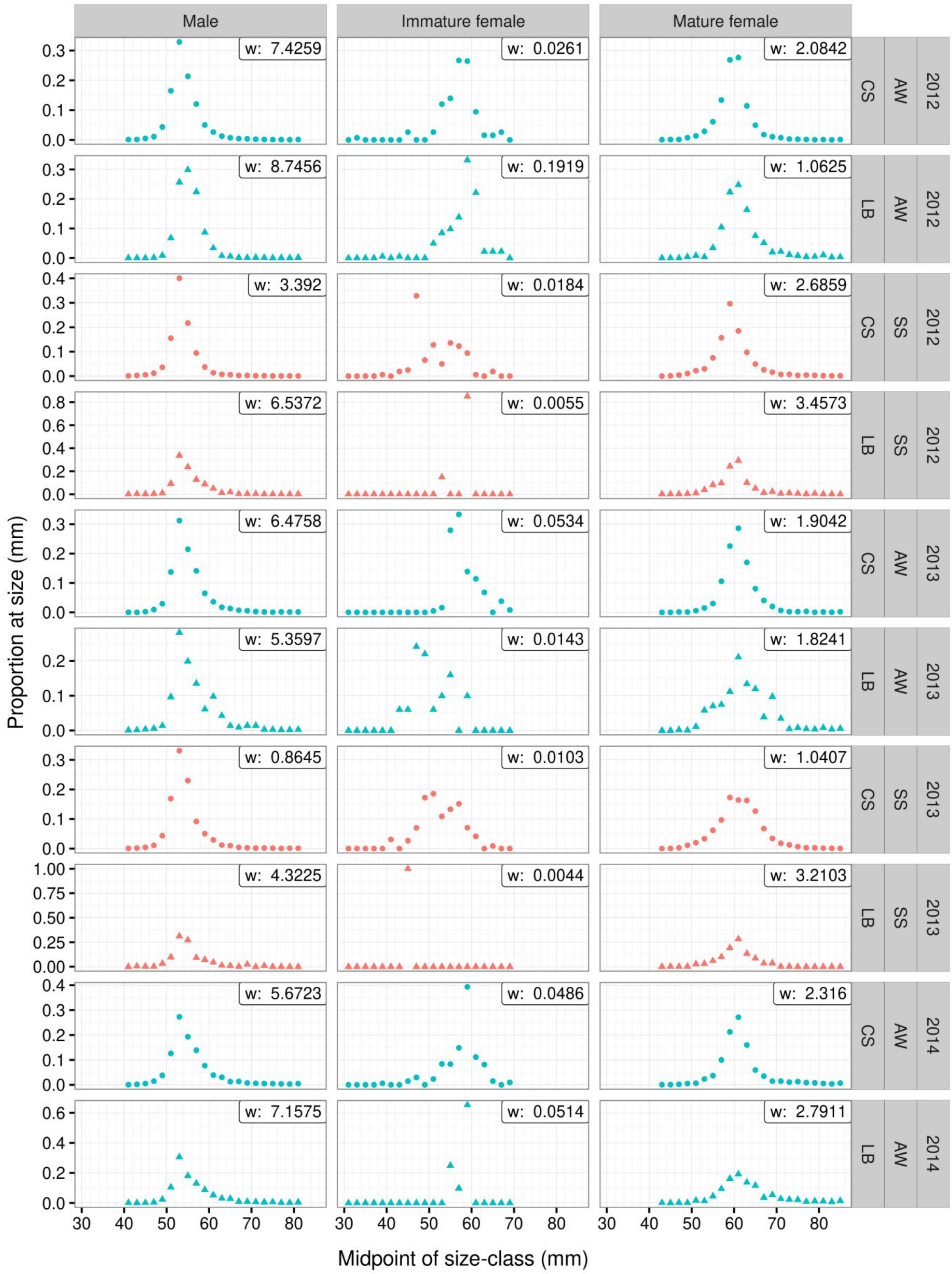


Figure E.6: Observed CRA 4 length frequency distributions by sex category from 2012.AW.CS to 2014.AW.LB. Each cell shows the associated weight from Table 8. CS=observer catch sampling; LB=logbook catch sampling.

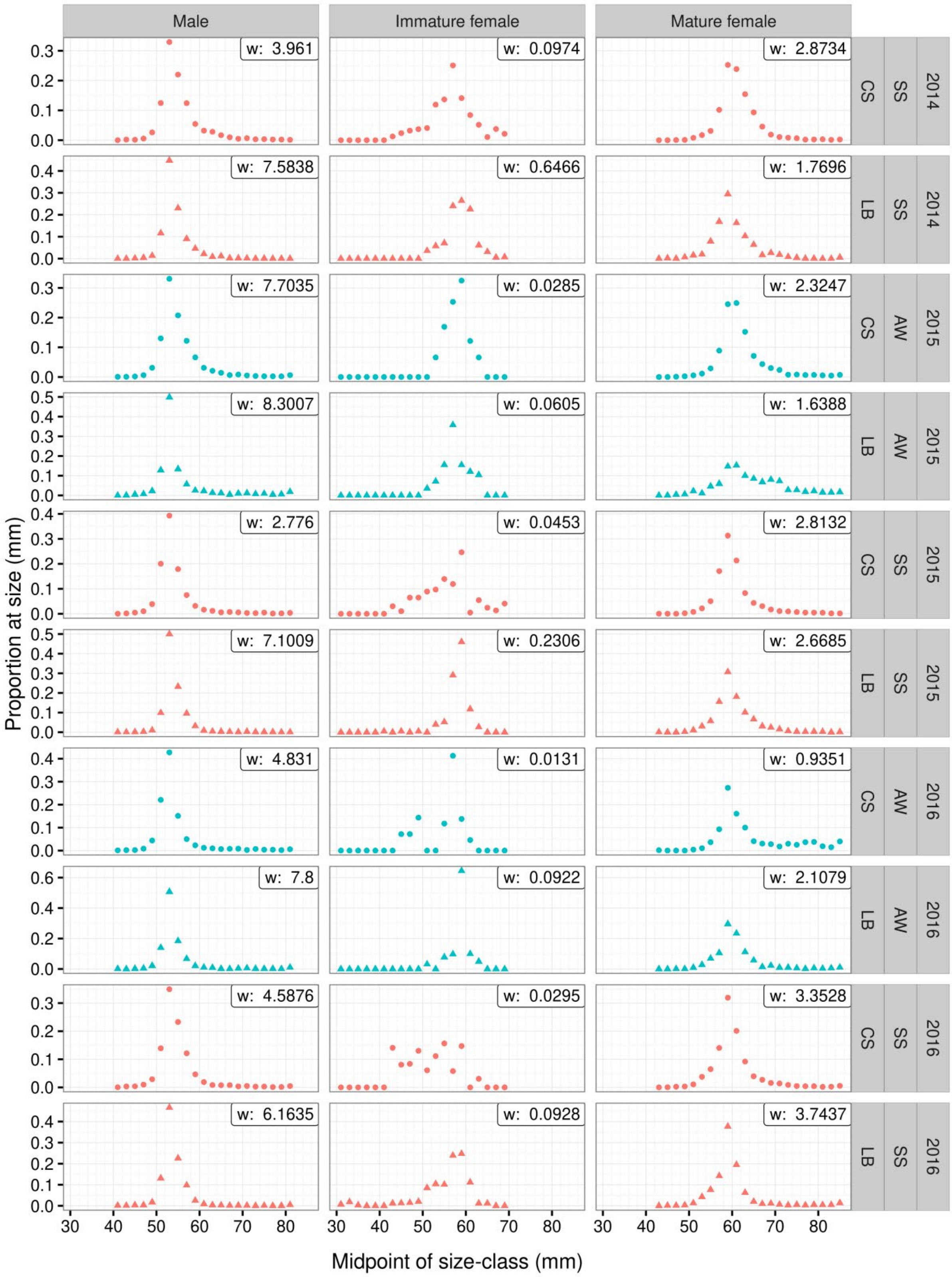


Figure E.7: Observed CRA 4 length frequency distributions by sex category from 2014.SS.CS to 2016.SS.LB. Each cell shows the associated weight from Table 8. CS=observer catch sampling; LB=logbook catch sampling.

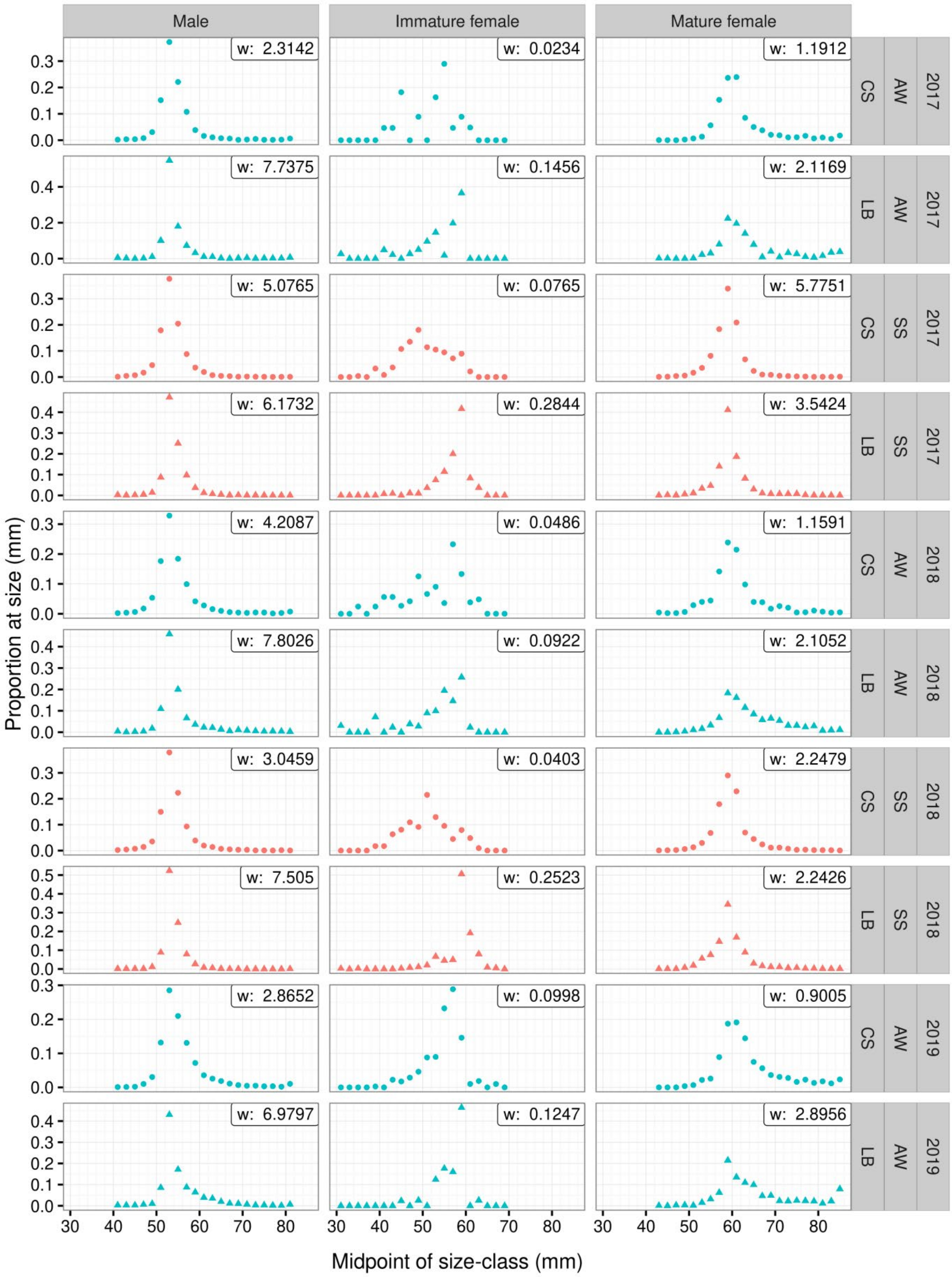


Figure E.8: Observed CRA 4 length frequency distributions by sex category from 2017.AW.CS to 2019.AW.LB. Each cell shows the associated weight from Table 8. CS=observer catch sampling; LB=logbook catch sampling.

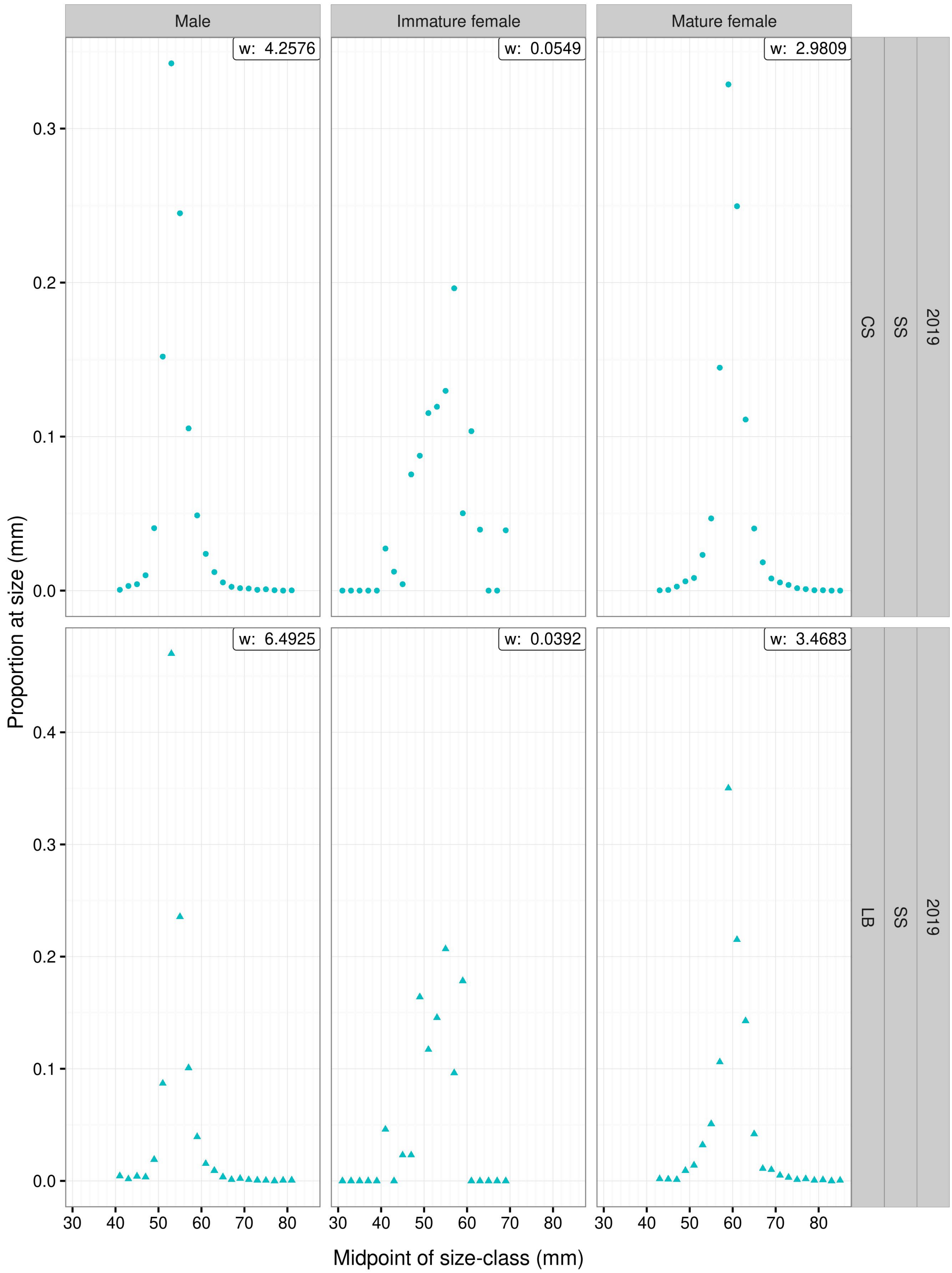


Figure E.9: Observed CRA 4 length frequency distributions by sex category from 2019.SS.CS to 2019.SS.LB. Each cell shows the associated weight from Table 8. CS=observer catch sampling; LB=logbook catch sampling.