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Tini a Tangaroa

Data for the 2017 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2

New Zealand Fisheries Assessment Report 2018/31

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EXECUTIVE SUMMARY

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This document describes the data used in the 2017 CRA 2 stock assessment and to condition a set of operating models for management procedure evaluations. Data sets described in this report include catch estimates for all sectors of the CRA 2 fisheries, seasonal standardised CPUE indices, length frequency distributions, and tag-recapture data.

Catch estimates are provided for the commercial, recreational, customary and illegal fisheries, collated by year to 1978 and then by six-month season (spring-summer [SS] and autumn-winter [AW]), and by size-limited and non-size-limited fisheries. Recreational catch estimates were available from older telephone/diary surveys and from a recent large scale multi-species survey conducted using a population-based survey methodology. The survey catch estimates were fitted, assuming a log-normal distribution, to the SS CPUE for 1994, 1996, 2010 and two 2011 estimates. The estimated scaling coefficient was then used to estimate a recreational catch series from 1979. Recreational catches before 1979 were interpolated from a low value in 1945 to the 1979 value.

CPUE was standardised for the SS and AW seasons. The F2 algorithm, which uses a truncated distribution of “vessel correction factors” to adjust estimated catches to final catch, was used to prepare the catch and effort data. The destination codes “X” (discarded at sea) and “F” (Section 111 recreational catches) were added to the destination code “L” (landed to an LFR) to obtain the final catch total for scaling the estimated catches. The CPUE standardisation procedure was updated in 2017 by the inclusion of a vessel explanatory variable for data beginning in 1989. Earlier data were excluded because vessel codes were not consistent before 1989, effectively splitting the CPUE series.

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

1. INTRODUCTION

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

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

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

The most recent stock assessment of CRA 2 was current to the 2011–12 fishing year (Starr et al. 2014b). The data used in that stock assessment are documented in Starr et al. (2014a). An earlier stock assessment, conducted in 2002, was current to the 2000–01 fishing year (Starr et al. 2003).

CRA 2 (Figure 1) entered the QMS in 1990 with a TACC of 250 tonnes, which was reduced in three steps to 215 tonnes by 1993. The TACC was raised to 236 tonnes in 1997–98 in response to the high CPUEs observed at the time. A TAC of 453 tonnes was established for the first time in the same year, with allowances of 16.5 tonnes for customary fisheries, 140 tonnes for recreational catch, and 60 tonnes for other mortalities. The TACC was dropped to 200 tonnes in 2014–15, based on the operation of a newly adopted management procedure (Rule 4) developed during the 2013 stock assessment. The TAC dropped to 417 tonnes with the 36 tonne drop in TACC, but the non-commercial allowances remained unchanged. The CRA 2 industry voluntarily shelved 49 tonnes in 2016–17 and this amount of shelving has been carried forward into 2017–18 (Daryl Sykes, NZ RLIC, pers. comm.).

The CRA 2 rock lobster industry made a strong commitment to the voluntary logbook programme when it was first introduced in 1993 and has continued to use this design as the primary source of stock monitoring information in this fishery. CRA 2 was identified in the mid-1990s as an important region for tagging experiments, which resulted in considerable tagging effort expended in this QMA. There is also an auxiliary observer catch sampling programme in CRA 2. Approximately twelve sampling days have been assigned annually to this programme in recent years, with the primary purpose of this additional sampling to serve as corroboration to the voluntary logbook programme. Both sets of data were used in this stock assessment.

Decisions on data and modelling choices were discussed and approved by the Rock Lobster Fishery Assessment Working Group (RLFAWG). For definitions of technical terms used here see the Glossary in the 2017 CRA 2 stock assessment report (Webber et al. 2018).

2. CRA 2 CATCH DATA

2.1 Commercial catch

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

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

CRA 2 extends from Te Arai Point, south of Whangarei, to East Cape at the easternmost end of the Bay of Plenty (Figure 1). This QMA includes the Hauraki Gulf, both sides of the Coromandel and all of the Bay of Plenty. Commercial fishing is primarily confined to the Bay of Plenty, extending from the eastern side of the Coromandel Peninsula to East Cape. There were 33 vessels operating in CRA 2 in 2015–16, a total that has been relatively constant since the mid-1990s (Starr 2017a). This fishery supports processing and export operations primarily in Tauranga, Whitianga, and Auckland.

Commercial catches in CRA 2 averaged 196 tonnes/year before 1979, with a short period in the late 1960s when catches exceeded 300 tonnes/year (Figure 2). CRA 2 commercial catches were higher in the period leading up to the introduction of rock lobster into the QMS (1979–1988), with catches peaking at 445 tonnes in 1980–81 and averaging just over 300 tonnes/year during that decade. Commercial catches in CRA 2 have generally closely matched the TACC since the introduction of rock lobster into the QMS in 1990–91 (Figure 3), except from 2015–16, when the commercial catch was reduced due to voluntary shelving of quota (see third paragraph in Section 1). Annual CPUE was low (less than 0.5 kg/potlift) during the entire period of high catches in the 1980s (Figure 3). CPUE began to rise from about 1994 and had more than doubled (to more than 1.0 kg/potlift) by 1997 and 1998. This increase in CPUE mirrored similar increases in CPUE over the same period in CRA 3, CRA 4, and CRA 5 (Starr 2017a). CPUE dropped to below 0.5 kg/potlift by 2002 and has remained at that level to the present (Figure 3). The CRA 2 CPUE is the lowest of the all the CRA QMAs, with the remaining QMAs approaching or exceeding 1.0 kg/potlift (Starr 2017a).

There has been increased use of intermediate destination codes (see Table A.1) in many of the CRA QMAs, a practice which allows operators to wait for favourable market conditions for selling their catch. However, this practice has also affected the analysis of commercial catch and effort data by breaking the link between the effort used to take the lobsters and the validated landing information (see MPI 2016 for a discussion of this problem). The landing information was examined to see the extent of this practice in CRA 2, which was found to be relatively small (see Figure A.1) compared to some other QMAs. There is no evidence of high levels of legal discarding in CRA 2 and consequently little use is made of Destination “X” (Figure A.1).

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

2.2 Recreational catch

Seven annual recreational survey catch estimates are available for CRA 2 (Table 1). Estimates from the two Kingett Mitchell National Surveys (Boyd et al. 2004; Boyd & Reilly 2004) were not accepted by the RLFAWG for the 2013 CRA 2 stock assessment (Starr et al. 2014a) because these survey estimates were considered implausibly high for CRA 2. The earlier 1994 and 1996 surveys, conducted by researchers at the University of Otago, were considered biased in a review of the available recreational surveys (unpublished minutes: Recreational Technical Working Group [Auckland NIWA, 10–11 June 2004]) because the interview questions possibly underestimated fisher participation rates by allowing for an easy exit from the interview (“soft refusal” bias). These two early surveys continue to be used by the RLFAWG 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.

A large-scale population-based diary/interview survey was conducted under contract for MPI from 1 October 2011–30 September 2012 (National Panel Survey or NPS), with the intention of estimating FMA- and QMA-specific annual catches for all major finfish and non-finfish species (Heinemann et al. 2015). This survey was based on a design that resembled the NZ 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 2, with 69 fishers providing 168 interviews over the survey period (see table 60 in Wynne-Jones et al. 2014) with a relatively low CV (0.24; Table 2). This survey made estimates of the distribution of fishing platforms used to take lobsters in CRA 2, with motor boats accounting for about three quarters of the effort and only 13% coming from land (Table 2). The primary capture method used to take rock lobster in CRA 2 is diving (83%) followed by potting (16%) (Table 2). NPS survey results from the CATI logbook participants were in terms of number of fish. Mean recreational catch weight for the most important finfish and non-finfish species QMAs was estimated in a parallel project (Hartill & Davey 2015).

The Holdsworth catch estimates (Table 1) were based on data collected by a stratified on-site ramp survey conducted in the western Bay of Plenty from Port Charles to Maketu over the period 1 October 2010 to 30 September 2012 (Holdsworth 2016). Catch estimates for 2010 and 2011 were generated for all of CRA 2 using scaling factors derived from the 2011 NPS survey. Mean weights were derived from length frequencies collected by the survey during the sampling period.

A recreational catch vector was developed by assuming that recreational catch has been proportional to the CRA 2 SS abundance, as reflected by SS CPUE. By agreement in the RLFAWG, the recreational catch vector was based on five of the seven survey estimates (in tonnes – see Table 1) from the 1994 (Otago), 1996 (Otago), 2010 (Holdsworth), 2011 (Holdsworth) and the 2011 NPS surveys. The 2011 NPS survey was assumed to be the least biased and most precise so the estimated CV for this survey (0.24) was assumed. The CVs for the remaining surveys were assumed to be 50% higher than that of the NPS survey. A scalar quantity q (Eq. 1) was estimated by obtaining the best fit to these survey estimates when minimising a log-normal distribution using the CVs indicated in Table 1:

Eq. 1

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

where:

t subscripts five recreational survey estimates in Table 1:

1=1994 Otago; 2=1996 Otago; 3=2010 Holdsworth; 4=2011 Holdsworth; 5=2011 NPS.

$w_t =$ mean spring/summer weight >= MLS for sampled lobster in year/survey t for CRA2

$N_t =$ mean number lobsters in year/survey t for CRA2

$CPUE_t =$ CRA2 spring/summer standardised CPUE in year t

$\hat{W}_t =$ CRA2 estimated recreational catch (tonnes) for year t

The estimated recreational catch trajectory (Eq. 2) based on the q estimated in Eq. 1 closely matches the 2011 NPS and the 2010 Holdsworth observations while missing the 2011 Holdsworth observation and both Otago observations (Figure 4). This pattern is consistent with the CV assumptions. The *q* parameter is estimated to be 96 tonnes/CPUE-unit and the recreational catch vector accounts for about 2050 tonnes of historical catch from 1979 to 2016.

Eq. 2

$$
\begin{aligned}
&\hat{W}_y = \hat{q}\ \ CPUE_y \ \text{ if } y >= 1979 \\
&\hat{W}_{1945} = 0.2 *\ \hat{W}_{1979} \\
&\hat{W}_y = \ \hat{W}_{y-1} + \frac{(\ \hat{W}_{1979} -\ \hat{W}_{1945})}{(1979-1945)} \ \text{ if } y > 1945\ \&\ y < 1979
\end{aligned}
$$

For assessments conducted since 2006, the RLFAWG has included recreational landings made by commercial vessels under Section 111 of the Fisheries Act. Greenweight landings with destination code “F” were extracted from the CRACE database (Bentley et al. 2005), which showed a maximum annual value of 2036 kg for CRA 2, occurring in 2014–15. The RLFAWG has agreed to add the maximum catch estimate to the estimated recreational catch in each year since 1979 (Figure 4), increasing the total 1979 to 2016 recreational catch in the model to 2130 t.

MPI were asked to provide estimates of recreational catches to use in the CRA 2 stock assessment and an appreciation of their uncertainty (see Appendix B). As the request letter was submitted at a late date, we have only received an informal reply (A. McKinnon, pers. comm.):

> *For recreational harvest estimates, in May 2013, the MPI Marine Amateur Fisheries Working Group provided the following advice:*
>
> *Advice to RLWG on CRA 2 harvest estimates*
>
> kkk) recommended the CRA WG use the following information in its upcoming CRA 2 stock assessment:
>
> i. for 2010-11 the harvest estimate from the western Bay of Plenty survey scaled to the QMA using the LSMS panel survey data;
>
> ii. for 2011-12 the LSMS panel survey harvest estimate for the QMA;
>
> iii. commercial CPUE to impute harvest estimates for a time series of catch history in years where an absolute estimate is not available;
>
> iv. length frequencies and average weights of recreationally caught fish to be taken from the 2010-11 and 2011-12 MAF-2010/02 survey data;
>
> lll) noted that the imputed CPUE data should only be used in years where a harvest estimate is not available – in those years the estimated value should be used (e.g. 2010-11 and 2011-12);
>
> mmm) noted that the 2011-12 harvest estimate from the western Bay of Plenty survey provided important information on trends between years (c.f. the same estimate from 2010-11);
>
> nnn) noted that the outcomes of the calibration research (MAF-2011/04) were important to the interpretation of the onsite and offsite harvest estimates for CRA;
>
> *Given that there has been no new survey or reporting information, I think it’s safe to say this advice still stands. Have you also thought about doing the mean of ratios approach to calculating recreational estimates (as per CRA 4 last year)?*

2.3 Customary catch

CRA 2 customary catches were included in the 2013 stock assessment using a constant catch of 10 tonnes/year over the entire reconstruction period of 1945 to 2012 (Starr et al 2014a). When the RLFAWG discussed the data to be used in the 2017 CRA 2 stock assessment, there was consensus to lower the constant value used for this catch category to 5 tonnes/year in recognition that some customary catch is included in the recreational catch estimate and advice that 10 tonnes/year was probably too high.

MPI were asked to provide estimates of customary catches to use in the CRA 2 stock assessment and an appreciation of their uncertainty (see Appendix B). As the request letter was submitted at a late date, we have only received an informal reply (A. McKinnon, pers. comm.):

> *MPI's information on customary harvest is incomplete (for various reasons), but the information we do have suggests the harvest is low. I am open to discussing whether a 5 tonne constant level is more appropriate.*

2.4 Illegal catch

CRA 2 illegal catches from 1990 to 2001 were included in the 2013 stock assessment by using the values provided by MPI Compliance given in Starr et al. (2014a). A constant illegal catch of 88 tonnes/year was used to fill in the missing years from 2002 to 2012. Years before 2001 without estimated illegal catches were interpolated. When the RLFAWG discussed the data to be used in the 2017 CRA 2 stock assessment, it was generally agreed that a constant illegal catch of 88 tonnes/year beginning in 1996 was likely to be too large. The RLFAWG also agreed that the value of 88 tonnes (=83+5 tonnes, Table 3) for 1996 was potentially real because of the high CPUE in that year but that illegal catches had been dropping since then. Consequently, the RLFAWG agreed to linearly decrease the illegal catch trajectory from 88 tonnes in 1996 to an assumed value of 40 tonnes in 2016. The MPI 2001 estimate of 88 tonnes for CRA 2 illegal catch was discarded under this assumption.

In the past, Ministry Compliance estimates for illegal catch have frequently been provided in two categories ("reported" or "R" and "not reported" or "NR"). The category of "commercial illegal reported" or "reported" (equals "R" in Table 3) was assumed to represent illegal commercial catch that was eventually reported to the QMS as legitimate catch. Therefore this catch was subtracted from the reported commercial catch to avoid double-counting. Missing categories were treated as zeroes and the available values were used to estimate the overall proportion of R/NR for each QMA, which is then applied to all years (including interpolated years). MPI Compliance has stated that it no longer includes the "R" category in its estimates because it takes into account the possibility of eventual reporting to the MHR, so the step of moving the estimated "R" catches from "commercial" to "illegal" has now been discontinued for all CRA QMAs, beginning in 2012.

MPI were asked to provide estimates of illegal catches to use in the CRA 2 stock assessment and an appreciation of their uncertainty (see Appendix B). As the request letter was submitted at a late date, we only received informal replies:

<u>Reply #1 (A. McKinnon, pers. comm.)</u>:

1. CRA 2 illegal catch estimates

Historical estimates of CRA 2 illegal catches have been supplied to the RLFAWG on several occasions from 1990 to 2001. Some of these estimates include a breakdown of the proportion of estimated illegal catches that were reported to the QMS or not. The historical estimates of CRA 2 illegal catch are provided in the November 2012 Rock Lobster Fishery Assessment Plenary Report and are subject to high levels of uncertainty.

The last illegal catch estimate that MPI supplied for CRA 2 was for 88 tonnes in 2001. MPI acknowledges that it has been some time since this estimate was updated. However, there is currently no robust and defensible methodology that MPI can use to accurately estimate illegal catches from the CRA 2 fishery.

Anecdotal information from MPI's Compliance and Response team suggests there are moderate levels of illegal activity in parts of the CRA 2 fishery at this time. The extent of this illegal activity is difficult to quantify with available information, and it is unknown if 88 tonnes is an accurate reflection of current CRA 2 illegal catch.

Given this uncertainty, MPI suggests that the 88 tonne estimate of illegal catch is used in the upcoming CRA 2 stock assessment and sensitivity analyses are carried out with half of the illegal catch estimate (i.e. 44 tonnes).

Reply #2 (A. McKinnon, pers. comm.):

I'm not necessarily saying that we should continue to use 88 tonnes to represent illegal take. MPI Compliance have acknowledged that there is considerable uncertainty in the historical estimates that were provided by MFish at the time. However, in the absence of any other reliable estimates or information to say it is anything else, do we keep on using the historical estimates or do we test an alternative approach that could be more plausible? My personal view is that when you consider that commercial is currently harvesting 150 tonnes per year from CRA2 (people who are very skilled at fishing), 88 tonnes seems a lot for poaching and unreported removals particularly given lower stock abundance. Local compliance suggests that non-commercial illegal take and poaching in CRA2 is at reasonable levels, but what does this mean in weight terms?

2.5 Size-limited and non-size-limited catch

The size-limited (SL) catch is catch taken under the MLS regulations and the restriction on landing berried females; it is the sum of the commercial and recreational catches minus the reported illegal catches (Figure 5). The non-size-limited (NSL) catch is taken without regard to those restrictions; it is the sum of reported and unreported illegal catches and the customary catches. Annual commercial catches were divided into seasons from 1979 onwards based on the seasonal proportions in the FSU and QMR/MHR data (Table 4).

2.6 Seasonal proportion of catch

Annual commercial catches were divided into seasons (Figure 6) beginning in 1979, using proportions based on the monthly returns to the FSU or QMR/MHR data systems. Illegal catches were divided using these same commercial proportions. The CRA 2 recreational catch was split between seasons using 79% assumed taken in the SS and the remainder in AW. The 79%/21% split between seasons was the mean of the seasonal splits observed from the 2011 CRA 2 NPS survey and the 2010/2011 values from the two surveys of the western Bay of Plenty (J. Holdsworth, pers. comm.). It was assumed that 90% of the customary catch was taken in SS.

3. CATCH RATE INFORMATION

3.1 Seasonal standardised CPUE indices

3.1.1 Introduction

Catch and effort data from the FSU and CELR systems were obtained from MPI in September 2017 (Replog 11340), loaded into the CRACE database and processed using standard error checks (Bentley et al. 2005). Data spanned the period from 1 April 1979 through to 31 March 2017.

Data preparation used the F2_LFX procedure (Starr 2017a). The F2 algorithm scales the monthly estimated catch taken by a vessel in a statistical area using a "vessel correction factor" (*vcf*: the ratio of landed catch to estimated catch for one vessel in one year) (Starr 2017a), and discards from the analysis those vessels with *vcf* less than 0.8 or greater than 1.2. The F2_LFX procedure scales the estimated catches to the combined "L" (LFR), "X" (discarded to sea) and "F" (Section 111 recreational catch) destination codes. Although there is an attenuation in recent years with the number of records in this analysis, there remains an adequate number in each of the statistical areas for both seasons (Table 5).

The CPUE standardisation procedure used sequential six-month periods as a forced explanatory variable (see section 2.5 in Starr (2017a) for a description of this procedure). A vessel explanatory variable was added to this model, only accepting vessels with at least five years experience in the fishery. Unlike the series used in previous stock assessments, this series excludes the FSU data because the vessel codes in the earlier data base are not consistent with those used in the current MPI Warehou data base. Consequently, the series used in the 2017 stock assessment began with the 1 April 1989–30 September 1989 autumn-winter season. This initial period included some FSU data because the Warehou data base does not begin until 1 July 1989 (Bentley et al. 2005). It is possible that this overlap with the FSU data base may have caused some of the data scarcity seen in the first analysis year (compare 1989–90 in Table 5 with the same year in Table C.1) because the FSU vessels would have been dropped under the criteria used for selecting vessels.

A second CPUE series covering the period 1979–80 to 1988–89 was generated from a seasonal analysis spanning the entire period from 1979–80 to 2016–17 which did not include a vessel explanatory variable, thus allowing the FSU and MPI Warehou data to be analysed simultaneously. Documentation for this series is provided in Appendix C and the FSU indices extracted from this analysis for use in the 2017 stock assessment are provided in Table C.3.

Three explanatory variables were available for this analysis in addition to the sequential [`period`] variable: [`vessel`] (filtered for vessels with at least five years experience in the fishery), [`month`] of capture and [`statistical_area`] of capture. The seasonal analysis estimates separate relative [`month`] effects in each half-year period by using, as the reference [`month`], the [`month`] in each period with the lowest standard error.

3.1.2 CRA 2 seasonal; standardised series

The total deviance explained by the CRA 2 seasonal standardised model was 50%, with both the [`vessel`] and [`period`] variables having similar strong explanatory power, followed by the [`month`] variable; [`statistical_area`] had almost no explanatory power (Table 6). Residual patterns showed some deviation from the lognormal assumption at both tails of the residual distribution as well as being more peaked in the centre of the residual distribution (Figure 7). The [`vessel`], [`month`] and [`statistical_area`] effects are shown in Figure 8. Note that the pattern of estimated vessel coefficients shown in Figure 8 (top left panel) strongly resembles the vessel coefficient pattern presented in Figure D.2, which is unsurprising given that the annual and seasonal analyses were performed on exactly the same data sets (compare the annual number of records in Table 5 with the equivalent totals in Table D.1). Figure D.2 shows that there is a trend in the distribution of vessels over time, with vessels having the lower CPUE coefficients dropping out of the fishery while those with the higher coefficients remain in the fishery. The relative catch rate patterns within each season are consistent with the equivalent monthly catch rates from the annual analysis based on the same data (compare Figure 8, top right panel, with the month coefficients in Figure D.3). However, the somewhat higher monthly catch rate in the summer months seen in Figure D.3 has been transferred to the seasonal indices. There is very little contrast in the estimated catch rates by statistical area (Figure 8, lower left panel).

CPUE peaked in the late 1990s at more than double the current catch rates (Figure 9, Table 7). There is not much difference between the AW and SS catch rates, unlike in most other QMAs. There is an overall declining trend in the both the AW and SS series from a minor peak in 2007–08. This trend has been uninterrupted in the SS season (Figure 9, right panel) but there have been a couple of small reversals in the overall trend in the AW season, after which the apparent decline continued (Figure 9, left panel).

Figure 10 shows the effect on the AW [left panel] and SS [right panel] standardised seasonal indices under different vessel filtering assumptions, with the three index series which included a vessel explanatory variable having very similar trends regardless of whether the included vessels were constrained by three, five or ten year experience assumptions. All three series using the vessel explanatory variable lie below the series without this variable, starting around 2001–2002.

3.2 Annual standardised CPUE indices

Annual standardised indices for CRA 2 are documented in Appendix D. Although these indices are not used in the CRA 2 stock assessment, they are indicators of annual relative stock status and are plotted in Figure 3. As well, this analysis provides "coefficient-distribution-influence (CDI) plots" (Bentley et al. 2012) for the vessel explanatory variable (Figure D.2), for the month variable (Figure D.3) and for the statistical area variable (Figure D.4) which are also applicable to the seasonal CPUE analysis because the two data sets use the same data set.

3.3 Historical catch rate (CR) data

Monthly catch and effort (days fishing) data from 1963–1973 were summarised by Annala & King (1983) and used to calculate unstandardised catch per day for each calendar year from 1963 to 1973 (Figure 11).

4. LENGTH FREQUENCY DISTRIBUTIONS (LFs)

Data were extracted for CRA 2 in September 2017, comprising both observer and voluntary logbook catch sampling from the 1986–87 to 2016–17 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 logbook catch sampling requires participating fishers to measure every lobster in each of 3–5 marked pots each day. This design results in good spatial and temporal representation of the catch if the participating fishers are representative of the wider fishing population. This goal is likely to have been achieved in CRA 2, with a high rate of participation in the voluntary logbook programme from its very beginning in 1993 (Table 8). Approximately 12–13 days/year of dedicated observer catch sampling have been added since 1999 to corroborate the voluntary logbook programme (Table 8). This sampling project measures and sexes all lobsters in as many pots as feasible during a day's fishing for the vessel being observed.

Record fields included the following information:

- 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), …, [86, 88), [88, ∞)} mm tail width (TW)
- 31 fields for immature female numbers measured
- 31 fields for mature female numbers measured.

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

Eq. 3
$$p_{g,m,a,s} = \frac{N_{g,m,a,s}}{\sum_{s} N_{g,m,a,s}}$$

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. 4

$$P_{g,s} = \frac{\sum_m \sum_a \left(C_{m,a} p_{g,m,a,s} \right)}{\sum_m \sum_a \sum_s \left(C_{m,a} p_{g,m,a,s} \right)}$$

where P_s^g was the relative proportion-at-length for each sex in the record. The model re-normalised these to sum to 1 across each sex.

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. 5

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

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

The CRA 2 LF data comprised 86 records from 1986–2016, with 48 being logbook samples and the remaining 38 being observer samples. The logbook records ranged from 200 to 12 860 lobsters measured across both seasons while the observer samples ranged from 140 to 3073 lobsters measured, across both seasons (Table 9). Consequently, none of the samples were discarded based on a lower limit of 100 measured lobsters, a practice adopted by the RLFAWG in previous stock assessments. The logbook sampling record weights by sex (Eq. 5) ranged from 0.001 to 24.2 while the observer catch sampling record weights ranged from 0.004 to 2.74 (Table 10). All the very low weights corresponded to samples with very few observed immature females, giving an appropriate low weight to the poorly represented sex category.

Sex proportions were calculated from normalised data records (Figure 12; Table 11). There were very few immature females, with females in this QMA usually reaching maturity well below the MLS of 60 mm TW. The sex ratios of males and mature females showed little systematic pattern over time in either the logbook data or the catch sampling data, although there may be a slight declining trend in the proportion of mature females in recent years. The sex proportions estimated by both sampling programmes show the same general trends.

Mean length was also calculated from the data records (Figure 13, Table 12). There was no trend in male or mature female mean length in either the AW or SS for either sampling programme. The logbook data showed a strong increase in the SS mean size over two years in the late 1990s for both males and mature females, followed by a sharp drop to the previous mean size. This strong increase is coincident with the strong increase in CPUE observed in the same years (Figure 3, Figure 9).

Although the model contains size bins in the range 30–92 mm TW, few fish as small as 30 mm were measured and very few large fish were measured, especially for immature females, leading to many cells with zero observations (Figure 14). For sex/size bins with few observations, the model would be comparing many zero observations with zero or very small predictions, resulting in a large number of very small residuals that would distort the diagnostics and waste computing time. Bins at both ends of the range for each sex were therefore combined into accumulator “plus” and “minus” bins. Table 13 shows the number of year, season, sampling category records for each 2 mm TW bin by sex category. This table also shows the number of these records where the year, season, sampling category proportion within a sex category is less than 0.001 (an arbitrary threshold) and the calculated proportion of records greater than 0.001 in the bin. This information is useful to select appropriate accumulator bins for each sex category. Past experience has shown that model results were not very sensitive to the chosen threshold value.

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

5. TAG DATA

This section describes tag-recapture data that are used to inform growth in the stock assessment of rock lobster stocks (Haist et al. 2009). These data will also be useful for informing decisions about stock structure and movement. Tag data for all CRA areas were extracted in early September 2017.

5.1 Data processing

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

The tag processing software does the following:

- removes duplicate records
- removes records with no date
- removes records that are missing both tail width and carapace length
- removes releases with no corresponding recapture
- iteratively matches captures with recaptures
- if sex is missing at capture but not recapture, then infer sex and vice versa
- remove matched records that change sex
- remove matched records that do not have a sex code of 1 or 2
- if statistical area is not 901 to 943 then set to NA
- if the **option** qma_method = "area" then determine the quota management area (i.e. CRA 1,..., CRA 9) from the statistical area, unless the statistical area is NA then set the QMA using the project ID (this option is used). Otherwise, determine the quota management area from the project ID, unless the project ID is NA then set the QMA using the statistical area
- if the calendar year > 1992 and the source=2 (catch sampling) then add 0.5 to the tail width measurement (this step is required because of the measurement instructions provided to the observers doing the catch sampling)

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

Data are then rearranged into the format used by the model:
- sex (1 for males and 2 for females)
- year of release, extracted from release date
- year of recovery, extracted from recovery date
- days at liberty, obtained by subtracting release from recovery dates
- TW at release
- TW at recovery
- number of re-releases
- statistical areas of release and recovery

5.2 Tag data summaries: all QMAs

5.2.1 Comparison with previous extract

A comparison is done to ensure that new data extracts are not missing records that were available in previous years and to see how many new data records are available (Table 14 and Table 15). There was a substantial increase in the number of release-recovery pairs in CRA 2 (in anticipation of this CRA 2 stock assessment) and a reasonable increase in CRA 7 (Table 14); there were also decreases in the number of reported release/recovery pairs in CRA 3, CRA 4 and CRA 5 tagging programmes (Table 14). The reasons for these decreases are not known.

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

There are a total of 32 860 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 16). The CRA QMA with the majority of recovered tags has been CRA 8, while the fewest recaptured tags have come from CRA 9 (Table 16).

Tagged lobsters are generally recaptured in the QMA or statistical area of release, but there are a number of cases where it appears that tagged individuals have moved much greater distances (Table 17, Table 18, and Table 19). 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 17) may be due to data errors, which will be investigated in the future.

5.2.3 Summary for QMAs: growth patterns

The observed growth increment (mm) by tail width (mm) at release was generally greater in smaller individuals, but this relationship is very messy (Figure 15 and Figure 16). Growth rates differ among QMAs, with CRA 2 showing fewer smaller individuals compared to most of the other QMAs (Figure 16). The relationship between observed growth increment (mm) and time at liberty (years) appears to be less variable (Figure 17 and Figure 18). This observation holds true for all of the QMAs with an adequate amount of data (Figure 18).

5.3 CRA 2: tag data summaries

The screened data extract for CRA 2 comprised 4468 records: 2341 males and 2127 females (Table 21). The distributions of sizes at release and recapture by sex are shown in Figure 19.

There are only 269 release/recovery pairs from the 1980s, with the large majority of tag recovery data (greater than 4000 observations) dating from the mid-1990s when the modern tagging project was initiated (Table 21 and Table 22). All of the 1983–1986 releases used western rock lobster tags, with size recorded in carapace length, and all of the post-1996 releases used Hallprint tags, with size recorded in tail width.

The majority of tag recoveries occurred in the year of release, although there were a considerable number of recoveries one and two years after release in the late 1990s when biomass levels were higher and presumably exploitation rates were lower (Table 23). Area 906 was the most prevalent area of release and recovery (Table 24).

Table 25 and Table 26 show that the high proportion of releases and recoveries in Area 906 has occurred because during the early stages of the modern programme tagging was opportunistic and the majority of fishing was in Area 906. These same tables show that recent (from 2014) tagging has been more evenly distributed among the four statistical areas. There are very few release/recovery pairs in Area 905. The sex ratio of release/recovery pairs favour males slightly, mainly in Area 906 (Table 27).

5.4 CRA 2: times at liberty

Times at liberty in the final CRA 2 tag data set varied from 1 day to 3350 days (9 years), but the median was 299 days, with 66% of recaptures at liberty for less than one year, and 88% less than 2 years. The number of times an individual is re-released is also monitored and one individual was re-released 11 times (Table 28), but 67% of records were from fish that were not re-released. Condition codes were nearly all zero or missing.

5.5 CRA 2: growth increments

Growth increments ranged from -37.0 to 27.7 mm with 5% and 95% quantiles between -1.0 and 12.0 mm (Figure 20 and Figure 21). As with the overall QMA summaries, the observed growth increment (mm) in CRA 2 by tail width (mm) at release is generally greater in smaller individuals (Figure 20). The relationship between observed growth increment (mm) and time at liberty (years) is somewhat tighter (Figure 21). Equivalent plots by statistical area are provided: observed growth increment by tail width at release (Figure 22) and observed growth increment by time at liberty (Figure 23).

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Table 1: Information used to estimate recreational catch for CRA 2. The Holdsworth (2016) survey estimates are described in Starr (2017b).

Survey	Numbers	Mean weight (kg)	Catch Weight (t)	assumed CV
1994 (Otago: Bradford 1997)	142 000	0.672[1]	95.42	1.5×0.24
1996 (Otago: Bradford 1998)	223 000	0.672[1]	149.86	1.5×0.24
2000 (Boyd & Reilly 2004)	324 000	–	235.9[2]	not used
2001 (Boyd et al. 2004)	331 000	–	241.4[2]	not used
2010 (Holdsworth 2016)	55 260	0.741	40.9	1.5×0.24
2011 (Holdsworth 2016)	31 602	0.700	22.1	1.5×0.24
2011 (NPS: Wynne-Jones et al. 2014)	58 413	0.701[3]	40.86	0.24[4]
Section 111 reported landings				
Maximum reported landings (t) (in 2014–15)			2.036	

[1] SS mean weight (kg) calculated from commercial sampling data from 1994 to 1996 assuming recreational minimum legal sizes (Starr et al. 2003)
[2] as reported by Boyd & Reilly (2004) and Boyd et al. (2004)
[3] Hartill & Davey (2015)
[4] estimate provided in Wynne-Jones et al. (2014)

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

Category	Numbers	CV	Catch (t)	CV	Distribution %
Platform (appendix 27.3 in Wynne-Jones et al. 2014)					
Trailer motor boat	36 489	0.27	25.49	0.27	62%
Larger motor boat or launch	8 231	0.46	5.76	0.46	14%
Trailer yacht	0		0		0%
Larger yacht or keeler	3 891	0.75	2.73	0.75	7%
Kayak canoe or rowboat	1 771	0.69	1.24	0.69	3%
Off land including beach rocks or jetty	7 855	0.28	5.49	0.28	13%
Something else	218	1.01	0.15	1.01	0%
Capture method (appendix 27.4 in Wynne-Jones 2014)					
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)	9 106	0.6	6.38	0.6	16%
Dredge grapple or rake	0		0		0%
Hand gather or floundering from shore	635	0.94	0.44	0.94	1%
Hand gather by diving	48 714	0.37	34.03	0.37	83%
Spearfishing	0		0		0%
Some other method	0		0		0%
Total	58 455	0.24	40.86[1]	0.24	100%

[1] uses mean weight estimate of 701 grams (Hartill & Davey 2015)

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

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

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

Table 4: Estimated CRA 2 catches (tonnes) (commercial, recreational including S.111, customary and illegal), provided annually before 1979 and seasonally (AW and SS) from 1979 to 2016. The non-commercial catches in this table reflect the RLFAWG agreements described in Sections 2.2, 2.3 and 2.4.

Calendar Year	Commercial Annual	Recreational Annual	Customary Annual	Illegal Annual	Fishing Year	Commercial AW	Commercial SS	Recreational AW	Recreational SS	Customary AW	Customary SS	Illegal AW	Illegal SS
1945	136.8	13.1	5	22.9	1979	86.4	206.6	5.7	51.7	0.5	4.5	7.5	17.9
1946	116.9	14.4	5	19.6	1980	168.2	277.8	6.1	54.9	0.5	4.5	19.2	31.7
1947	129.7	15.7	5	21.7	1981	120.5	270.5	5.9	52.7	0.5	4.5	20.2	45.3
1948	212.3	17.0	5	35.5	1982	109.5	217.1	4.6	41.3	0.5	4.5	18.3	36.3
1949	198.2	18.3	5	33.2	1983	84.0	190.6	3.9	35.5	0.5	4.5	14.1	31.9
1950	209.1	19.6	5	35.0	1984	92.1	178.1	3.6	32.1	0.5	4.5	15.4	29.8
1951	191.2	20.9	5	32.0	1985	88.5	249.1	4.4	39.9	0.5	4.5	14.8	41.7
1952	178.9	22.2	5	29.9	1986	82.4	192.5	3.8	34.4	0.5	4.5	13.8	32.2
1953	190.9	23.6	5	31.9	1987	81.1	173.3	3.6	32.3	0.5	4.5	13.6	29.0
1954	149.9	24.9	5	25.1	1988	79.4	142.8	3.7	33.4	0.5	4.5	13.3	23.9
1955	155.2	26.2	5	26.0	1989	72.9	179.8	5.5	49.7	0.5	4.5	12.2	30.1
1956	159.9	27.5	5	26.8	1990	96.7	140.9	5.3	47.3	0.5	4.5	28.5	41.5
1957	126.0	28.8	5	21.1	1991	94.5	135.1	4.7	42.3	0.5	4.5	22.0	31.5
1958	155.0	30.1	5	25.9	1992	72.7	117.5	4.3	38.3	0.5	4.5	14.1	22.9
1959	192.3	31.4	5	32.2	1993	101.8	113.1	4.6	41.7	0.5	4.5	25.3	28.2
1960	167.0	32.7	5	27.9	1994	126.3	86.5	5.6	50.1	0.5	4.5	41.5	28.5
1961	198.9	34.0	5	33.3	1995	162.3	50.2	7.4	67.0	0.5	4.5	45.8	14.2
1962	203.2	35.3	5	34.0	1996	189.7	23.4	11.2	101.0	0.5	4.5	78.3	9.7
1963	217.3	36.6	5	36.3	1997	208.6	25.8	10.2	91.9	0.5	4.5	76.2	9.4
1964	260.5	37.9	5	43.6	1998	202.3	30.0	10.5	94.3	0.5	4.5	72.4	10.8
1965	252.2	39.2	5	42.2	1999	178.0	57.1	11.2	100.4	0.5	4.5	61.2	19.6
1966	300.5	40.5	5	50.3	2000	133.7	101.7	8.4	75.2	0.5	4.5	44.5	33.9
1967	330.2	41.8	5	55.2	2001	119.2	105.7	6.1	55.0	0.5	4.5	40.3	35.7
1968	307.8	43.1	5	51.5	2002	72.9	132.8	5.4	48.8	0.5	4.5	26.1	47.5
1969	297.3	44.4	5	49.7	2003	68.8	127.2	4.8	43.1	0.5	4.5	25.0	46.2
1970	201.5	45.7	5	33.7	2004	77.0	120.4	5.7	50.9	0.5	4.5	26.8	42.0
1971	178.0	47.0	5	29.8	2005	82.4	142.8	5.4	48.4	0.5	4.5	24.3	42.1
1972	202.7	48.3	5	33.9	2006	90.6	135.9	6.5	58.2	0.5	4.5	25.6	38.4
1973	185.4	49.6	5	31.0	2007	88.7	141.0	6.1	54.7	0.5	4.5	23.8	37.8
1974	155.0	50.9	5	19.8	2008	87.9	144.4	5.6	50.7	0.5	4.5	22.4	36.8
1975	138.0	52.2	5	33.4	2009	85.8	149.3	4.9	44.2	0.5	4.5	20.7	36.1
1976	144.0	53.5	5	28.0	2010	74.0	150.8	4.5	40.5	0.5	4.5	17.9	36.5
1977	199.0	54.8	5	51.1	2011	62.1	166.9	4.6	41.2	0.5	4.5	14.1	37.9
1978	239.9	56.2	5	61.5	2012	88.1	146.2	4.3	39.1	0.5	4.5	18.6	31.0
					2013	83.2	152.5	4.1	37.2	0.5	4.5	16.7	30.5
					2014	63.0	135.6	3.8	34.5	0.5	4.5	14.2	30.6
					2015	51.4	123.3	3.4	30.8	0.5	4.5	12.5	29.9
					2016	38.2	104.1	3.4	30.9	0.5	4.5	10.7	29.3

Table 5: Number of vessel/statistical area/month records in the dataset used to calculate the CRA 2 seasonal CPUE time series after excluding vessels with less than five years experience in the fishery. Cells with <10 observations are highlighted in grey; '–': no data.

Fishing	Autumn-winter season					Spring-summer season				
Year	905	906	907	908	Total	905	906	907	908	Total
89/90	7	–	–	–	7	12	2	–	–	14
90/91	14	34	19	4	71	16	63	19	9	107
91/92	23	46	23	7	99	21	63	27	14	125
92/93	23	51	19	13	106	27	83	19	22	151
93/94	29	61	12	26	128	22	75	14	30	141
94/95	29	75	8	26	138	16	46	15	24	101
95/96	21	74	15	33	143	8	29	2	15	54
96/97	24	69	12	22	127	1	16	1	5	23
97/98	29	76	20	23	148	5	22	1	4	32
98/99	34	62	15	26	137	16	26	3	6	51
99/00	27	61	21	22	131	9	21	7	6	43
00/01	22	69	17	26	134	19	42	11	12	84
01/02	28	62	22	24	136	33	54	17	16	120
02/03	20	62	17	24	123	36	64	17	29	146
03/04	33	49	17	25	124	31	60	27	45	163
04/05	20	54	13	23	110	21	55	19	41	136
05/06	32	45	18	26	121	46	58	21	40	165

Fishing Year	Autumn-winter season 905	906	907	908	Total	Spring-summer season 905	906	907	908	Total
06/07	35	54	17	21	127	42	65	17	37	161
07/08	30	50	11	23	114	45	64	16	38	163
08/09	29	45	15	21	110	41	57	13	29	140
09/10	40	47	17	23	127	49	70	16	34	169
10/11	30	37	15	24	106	48	63	18	42	171
11/12	24	40	15	22	101	43	74	17	39	173
12/13	28	43	16	26	113	42	69	16	37	164
13/14	27	40	17	28	112	35	62	15	40	152
14/15	15	38	15	26	94	21	59	15	33	128
15/16	21	36	14	19	90	26	56	20	27	129
16/17	19	29	15	9	72	38	40	20	24	122
Total	713	1409	435	592	3149	769	1458	403	698	3328

Table 6: Total deviance (R^2) explained by each variable in the CRA 2 standardised seasonal CPUE model. The number of categories in each explanatory variable is given in parentheses.

Variable	1	2	3	4
Period (56)	0.2217			
Vessel (79)	0.2357	0.4247		
Month (12)	0.0661	0.2930	0.4941	
Statistical Area (4)	0.0132	0.2389	0.4260	**0.4953**
Additional deviance explained	0	0.2029	0.0695	0.0012

Table 7: Seasonal CPUE indices calculated from the analysis of CRA 2 catch and potlift data including a vessel explanatory variable based on vessels with at least five years experience in the fishery. Arithmetic index: sum(annual catch)/sum(potlifts); Unstandardised index: geometric mean of the CPUE observations by year; Standardised index: annual index.

Fishing Year	Autumn-winter season Arithmetic Index	Unstandard-ised Index	Standard-ised Index	Standard Error	Spring-summer season Arithmetic Index	Unstandard-ised Index	Standard-ised Index	Standard Error
89/90	0.5037	0.5325	0.5997	0.1873	0.4895	0.6256	0.7394	0.1355
90/91	0.4688	0.4331	0.4798	0.0618	0.5859	0.5860	0.6464	0.0526
91/92	0.3854	0.3822	0.4425	0.0536	0.4909	0.4933	0.5735	0.0492
92/93	0.3594	0.3598	0.4226	0.0518	0.3947	0.4201	0.4875	0.0449
93/94	0.4008	0.4069	0.4798	0.0474	0.4532	0.4651	0.5478	0.0458
94/95	0.4461	0.4591	0.5514	0.0455	0.6502	0.5898	0.6968	0.0522
95/96	0.6166	0.6437	0.7764	0.0445	0.8333	0.7432	0.8323	0.0687
96/97	0.7548	0.7638	0.8955	0.0470	1.0930	1.1734	1.1704	0.1040
97/98	0.8397	0.9547	1.0422	0.0433	1.1548	1.0215	1.0550	0.0879
98/99	0.9006	0.9939	1.0831	0.0444	0.9614	1.0324	1.1291	0.0702
99/00	0.6387	0.7060	0.7476	0.0453	1.0432	1.1948	1.1187	0.0751
00/01	0.6003	0.6422	0.6448	0.0446	0.8534	0.8461	0.8538	0.0547
01/02	0.4997	0.4812	0.4598	0.0444	0.6224	0.6170	0.5896	0.0468
02/03	0.3628	0.3283	0.2983	0.0463	0.4923	0.5366	0.5030	0.0432
03/04	0.3678	0.3971	0.3610	0.0464	0.4661	0.4618	0.4305	0.0412
04/05	0.3894	0.4398	0.4121	0.0491	0.4730	0.5369	0.5275	0.0450
05/06	0.3968	0.4190	0.3740	0.0469	0.5166	0.5285	0.4991	0.0413
06/07	0.4646	0.4775	0.4418	0.0460	0.5907	0.6243	0.5939	0.0416
07/08	0.4652	0.4728	0.4538	0.0481	0.5666	0.5614	0.5335	0.0414
08/09	0.5125	0.4524	0.4207	0.0490	0.5702	0.5475	0.5067	0.0443
09/10	0.4388	0.4223	0.3864	0.0458	0.5301	0.5018	0.4606	0.0407
10/11	0.4058	0.3687	0.3378	0.0497	0.4770	0.4425	0.4157	0.0407
11/12	0.3519	0.3067	0.2712	0.0506	0.4868	0.4432	0.4171	0.0405
12/13	0.4092	0.3883	0.3477	0.0482	0.4349	0.4205	0.3868	0.0417
13/14	0.3403	0.3155	0.2939	0.0490	0.4168	0.3905	0.3684	0.0432
14/15	0.3048	0.2887	0.2614	0.0530	0.3980	0.3645	0.3355	0.0465
15/16	0.2378	0.2156	0.1959	0.0544	0.3410	0.3270	0.2943	0.0467
16/17	0.2485	0.2626	0.2204	0.0597	0.3370	0.3225	0.2922	0.0477

Table 8: Sampling intensity by fishing year in CRA 2 by the logbook and observer catch sampling programme from 1993. "Lobsters" are the number of individuals measured. Number of active vessels in CRA 2 is included to show the level of participation in the logbook programme.

Fishing				Logbooks		Observer catch sampling	
Year	N vessels[1]	Fishermen	Potlifts	Lobsters	Days	Potlifts	Lobsters
1993	46	23	7 071	18 172	–	–	–
1994	47	25	6 245	18 134	–	–	–
1995	44	21	3 934	11 658	–	–	–
1996	40	19	3 492	12 522	–	–	–
1997	42	16	2 953	9 225	–	–	–
1998	35	17	3 051	9 172	–	–	–
1999	34	17	3 684	10 324	12	NA	3 073
2000	39	16	3 787	9 186	13	NA	3 022
2001	36	13	2 910	5 895	11	NA	3 014
2002	37	18	5 014	8 272	14	NA	2 274
2003	34	13	3 810	7 454	12	NA	1 898
2004	31	14	4 677	8 544	12	NA	1 353
2005	36	18	5 874	10 758	12	NA	2 303
2006	35	17	4 170	8 845	12	NA	1 964
2007	32	13	4 274	9 016	12	NA	2 237
2008	32	15	5 074	10 419	12	NA	2 568
2009	32	14	4 696	8 679	14	NA	2 769
2010	34	16	5 204	12 010	13	NA	1 926
2011	35	20	5 088	8 832	17	NA	2 175
2012	40	17	5 761	11 636	13	NA	2 465
2013	36	18	5 987	11 977	12	NA	2 868
2014	33	19	5 603	8 817	12	NA	2 666
2015	33	17	5 288	6 320	13	NA	1 450
2016	29	16	3 319	3 658	13	NA	2 005
Total	–	–	110 966	239 525	229	NA	42 030

[1] from Starr (2017a)

Table 9: Number of lobsters measured by the observer and logbook catch sampling programmes by fishing year, sex and season. '–': no data.

Fishing year	Logbooks Male	Logbooks Immature female	Logbooks Mature female	Logbooks Total	Observer catch sampling Male	Observer catch sampling Immature female	Observer catch sampling Mature female	Observer catch sampling Total
Season=AW								
1993	5 191	1 378	3 932	10 501	–	–	–	–
1994	6 773	1 155	4 932	12 860	–	–	–	–
1995	5 901	500	3 500	9 901	–	–	–	–
1996	6 944	373	4 507	11 824	–	–	–	–
1997	5 285	67	3 672	9 024	–	–	–	–
1998	4 579	45	4 095	8 719	–	–	–	–
1999	3 937	41	4 685	8 663	1 200	24	1 849	3 073
2000	3 010	104	3 487	6 601	1 051	15	1 214	2 280
2001	1 667	51	1 285	3 003	826	36	624	1 486
2002	2 322	99	2 291	4 712	872	19	954	1 845
2003	1 216	212	1 080	2 508	748	131	879	1 758
2004	2 269	261	1 443	3 973	237	53	219	509
2005	2 111	447	1 487	4 045	696	48	397	1 141
2006	2 902	545	1 433	4 880	274	35	160	469
2007	1 798	215	1 273	3 286	666	56	355	1 077
2008	2 790	285	1 586	4 661	403	22	424	849
2009	1 622	82	1 060	2 764	429	55	425	909
2010	1 928	145	1 202	3 275	296	7	261	564
2011	1 450	245	1 375	3 070	233	4	133	370
2012	2 510	312	1 497	4 319	73	1	103	177
2013	2 791	292	1 626	4 709	133	8	164	305
2014	1 603	112	1 360	3 075	498	7	330	835
2015	1 409	189	1 195	2 793	80	2	120	202
2016	596	109	316	1 021	137	19	88	244
Total	72 604	7 264	54 319	134 187	8 852	542	8 699	18 093
Season=SS								
1986	–	–	–	–	287	49	226	562
1990	–	–	–	–	131	14	219	364
1991	–	–	–	–	516	113	289	918
1993	3 489	814	3 288	7 591	–	–	–	–
1994	2 177	470	2 626	5 273	–	–	–	–
1995	775	142	839	1 756	–	–	–	–
1996	374	10	314	698	–	–	–	–
1997	56	–	144	200	–	–	–	–
1998	233	1	219	453	–	–	–	–
1999	330	8	1 322	1 660	–	–	–	–
2000	777	33	1 775	2 585	180	15	547	742
2001	1 052	67	1 771	2 890	446	57	1 025	1 528
2002	1 160	109	2 288	3 557	89	17	323	429
2003	2 421	376	2 140	4 937	42	2	96	140
2004	2 416	315	1 828	4 559	381	101	362	844
2005	3 153	717	2 833	6 703	614	123	425	1 162
2006	1 927	360	1 669	3 956	689	108	698	1 495
2007	2 690	435	2 597	5 722	532	51	577	1 160
2008	2 631	258	2 865	5 754	878	142	699	1 719
2009	2 365	314	3 219	5 898	689	82	1 089	1 860
2010	4 203	477	4 048	8 728	476	55	831	1 362
2011	2 559	476	2 726	5 761	738	79	988	1 805
2012	3 838	752	2 727	7 317	1 013	231	1 044	2 288
2013	3 347	589	3 331	7 267	1 045	156	1 362	2 563
2014	2 237	310	3 191	5 738	584	46	1 201	1 831
2015	1 495	203	1 824	3 522	526	60	662	1 248
2016	1 149	220	1 268	2 637	991	135	635	1 761
Total	46 854	7 456	50 852	105 162	10 847	1 636	13 298	25 781

Table 10: Sample weight (Eq. 5) calculated for each LF sampling record described in Table 9. '–': no data.

	Logbooks				Observer catch sampling			
Fishing year	Male	Immature female	Mature female	Total	Male	Immature female	Mature female	Total
Season=AW								
1993	22.275	5.786	17.369	45.430	–	–	–	–
1994	24.225	3.528	18.224	45.977	–	–	–	–
1995	23.376	1.944	13.971	39.291	–	–	–	–
1996	23.276	1.141	15.248	39.665	–	–	–	–
1997	19.728	0.249	13.365	33.342	–	–	–	–
1998	15.026	0.154	14.936	30.116	–	–	–	–
1999	15.053	0.155	18.268	33.476	1.682	0.034	2.745	4.461
2000	12.949	0.442	15.396	28.786	1.435	0.018	1.566	3.019
2001	8.414	0.326	6.870	15.610	0.911	0.036	0.645	1.592
2002	12.368	0.562	12.874	25.805	1.722	0.034	1.810	3.566
2003	8.381	1.349	7.328	17.057	1.543	0.279	1.848	3.670
2004	12.665	1.354	8.349	22.367	0.868	0.131	0.657	1.656
2005	12.313	2.282	8.783	23.379	0.936	0.139	0.504	1.579
2006	16.264	3.113	8.285	27.662	0.915	0.143	0.560	1.618
2007	12.329	1.343	8.221	21.894	1.182	0.083	0.629	1.893
2008	14.172	1.349	8.787	24.307	0.996	0.058	1.088	2.143
2009	10.583	0.470	6.960	18.013	0.734	0.090	0.729	1.552
2010	12.070	0.926	7.726	20.722	0.756	0.016	0.686	1.458
2011	10.345	1.449	10.349	22.144	0.866	0.024	0.534	1.425
2012	13.936	1.777	9.056	24.769	0.274	0.004	0.387	0.665
2013	15.351	1.579	8.911	25.841	0.353	0.021	0.435	0.809
2014	11.389	0.744	9.965	22.098	0.573	0.005	0.411	0.989
2015	11.159	1.358	9.059	21.576	0.313	0.008	0.470	0.791
2016	8.060	1.484	4.116	13.661	0.238	0.033	0.153	0.424
Total	345.708	34.863	262.419	642.989	16.298	1.157	15.856	33.311
Season=SS								
1986	–	–	–	–	0.265	0.025	0.182	0.472
1990	–	–	–	–	0.345	0.038	0.587	0.969
1991	–	–	–	–	0.606	0.133	0.339	1.077
1993	17.158	3.718	17.336	38.213	–	–	–	–
1994	12.218	2.428	16.684	31.330	–	–	–	–
1995	11.457	2.183	12.076	25.716	–	–	–	–
1996	5.082	0.139	4.427	9.648	–	–	–	–
1997	1.233	–	2.994	4.227	–	–	–	–
1998	0.815	0.001	1.853	2.669	–	–	–	–
1999	4.777	0.088	17.514	22.378	–	–	–	–
2000	6.259	0.275	14.568	21.103	0.803	0.066	2.303	3.172
2001	7.067	0.453	12.144	19.663	1.106	0.141	2.542	3.789
2002	6.232	0.576	12.766	19.574	0.272	0.053	1.007	1.332
2003	9.476	1.582	9.390	20.448	0.163	0.008	0.371	0.542
2004	9.566	1.394	8.316	19.276	0.869	0.220	0.901	1.989
2005	12.156	2.725	11.160	26.042	1.145	0.229	0.924	2.297
2006	9.231	1.576	8.028	18.836	0.914	0.145	0.902	1.961
2007	10.114	1.579	10.430	22.122	1.075	0.096	1.163	2.334
2008	11.488	1.104	13.545	26.137	0.966	0.119	1.199	2.284
2009	9.633	1.203	14.542	25.378	0.992	0.113	1.619	2.723
2010	11.263	1.420	15.111	27.795	0.695	0.091	1.507	2.292
2011	10.899	1.989	12.449	25.337	1.287	0.082	1.838	3.207
2012	15.103	3.098	12.504	30.705	1.675	0.291	1.492	3.459
2013	13.283	2.374	14.505	30.162	1.439	0.189	1.842	3.470
2014	11.047	1.508	16.118	28.673	0.964	0.074	1.981	3.020
2015	8.925	1.210	11.096	21.232	0.955	0.119	1.159	2.233
2016	8.021	1.455	8.418	17.894	1.177	0.152	1.349	2.678
Total	222.504	34.081	277.973	534.558	17.712	2.382	25.207	45.301

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

	Autumn-Winter			Spring-Summer		
Statistic	**Male**	**Immature Female**	**Mature Female**	**Male**	**Immature Female**	**Mature Female**
Maximum	0.595	0.127	0.554	0.562	0.123	0.783
Minimum	0.441	0.005	0.302	0.213	0.000	0.315
Mean	0.535	0.053	0.411	0.414	0.063	0.523

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

	Autumn-Winter			Spring-Summer		
Statistic	**Male**	**Immature Female**	**Mature Female**	**Male**	**Immature Female**	**Mature Female**
Maximum mean TW	61.6	57.5	65.8	65.6	56.3	70.3
Minimum mean TW	55.9	52.3	61.2	49.1	49.3	55.5
Mean TW	58.1	54.7	63.0	56.6	54.6	62.1

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

	Males			Immature Females			Mature Females		
Bin	**N records**	**N records <0.001**	**Prop >0.001**	**N records**	**N records <0.001**	**Prop >0.001**	**N records**	**N records <0.001**	**Prop >0.001**
[30,32)	8	8	0	2	0	1	4	4	0
[32,34)	5	5	0	3	0	1	3	3	0
[34,36)	8	5	0.38	5	0	1	7	7	0
[36,38)	**16**	**9**	**0.44**	**6**	**0**	**1**	4	4	0
[38,40)	31	17	0.45	14	2	0.86	5	5	0
[40,42)	47	14	0.70	29	0	1.00	**13**	**12**	**0.08**
[42,44)	56	15	0.73	38	0	1.00	22	17	0.23
[44,46)	70	5	0.93	52	0	1.00	37	20	0.46
[46,48)	81	0	1.00	61	0	1.00	47	18	0.62
[48,50)	84	0	1.00	67	0	1.00	66	11	0.83
[50,52)	84	0	1	76	0	1.00	79	2	0.97
[52,54)	86	0	1	80	0	1.00	84	0	1.00
[54,56)	86	0	1	82	0	1.00	86	0	1
[56,58)	86	0	1	78	0	1.00	86	0	1
[58,60)	85	0	1	79	0	1.00	86	0	1
[60,62)	85	0	1	73	0	1.00	86	0	1
[62,64)	84	0	1	65	0	1.00	86	0	1
[64,66)	84	0	1	56	0	1.00	86	0	1
[66,68)	84	0	1	31	2	0.94	86	0	1
[68,70)	81	0	1	**19**	**1**	**0.95**	85	0	1
[70,72)	81	0	1.00	4	0	1	85	0	1
[72,74)	78	0	1.00	6	2	0.67	81	0	1
[74,76)	78	1	0.99	2	0	1	84	0	1
[76,78)	71	1	0.99	2	0	1	82	0	1
[78,80)	72	3	0.96	2	0	1	79	1	0.99
[80,82)	65	2	0.97	1	0	1	77	1	0.99
[82,84)	58	6	0.90	–	–	–	70	4	0.94
[84,86)	57	14	0.75	1	0	1	66	7	0.89
[86,88)	50	13	0.74	1	0	1	56	22	0.61
[88,90)	37	14	0.62	–	–	–	41	26	0.37
[90,∞)	**45**	**14**	**0.69**	3	1	0.67	**36**	**17**	**0.53**

Table 14: Comparison of the number of records by Project ID in the new tag data extract with the number of records in the extract made for the 2016 CRA 4 stock assessment (Starr et al. 2017).

Project_ID	Previous	Current	Difference
CRA_Akaroa	227	227	0
CRA_CCampb	44	44	0
CRA_Gis70s	2 243	2 243	0
CRA_Gisb	48	48	0
CRA_ReefPt	573	573	0
CRA_StewIs	1 615	1 614	-1
CRA01Gisb	1 191	1 191	0
CRA1_TAG	1 306	1 475	169
CRA2_EBOP	5	5	0
CRA2_TAG	3 536	4 309	773
CRA2_WBOP	268	268	0
CRA3_TAG	1 679	1 547	-132
CRA4_TAG	2 612	2 511	-101
CRA4_Wair	10	10	0
CRA5_Kaik	1 176	1 176	0
CRA5_TAG	5 622	5 590	-32
CRA6_TAG	181	183	2
CRA7_TAG	299	513	214
CRA7rs	199	199	0
CRA8_Fiord	1 714	1 714	0
CRA8_TAG	7 289	7 295	6
CRA8rs	236	236	0
CRA9_TAG	71	64	-7

Table 15: Comparison of the number of records by recapture year in the new tag data extract with the number of records in the extract made for the 2016 CRA 4 stock assessment (Starr et al. 2017).

Year	Previous	Current	Difference
1966	53	53	0
1967	29	29	0
1968	7	7	0
1969	2	2	0
1971	1	1	0
1975	115	115	0
1976	1 268	1 268	0
1977	2 094	2 093	-1
1978	887	887	0
1979	1 093	1 093	0
1980	1 112	1 112	0
1981	593	593	0
1982	332	332	0
1983	273	273	0
1984	1 071	1 071	0
1985	395	395	0
1986	76	76	0
1987	18	18	0
1988	4	4	0
1989	2	2	0
1991	1	1	0
1992	1	1	0
1994	40	40	0
1995	73	73	0
1996	514	515	1
1997	2 575	2 579	4
1998	2 949	2 949	0
1999	2 493	2 494	1
2000	1 587	1 593	6
2001	1 378	1 378	0
2002	1 576	1 576	0
2003	1 122	1 122	0
2004	2 083	2 083	0
2005	2 410	2 410	0
2006	975	978	3
2007	483	490	7
2008	367	367	0
2009	284	306	22
2010	213	236	23
2011	503	549	46
2012	183	207	24
2013	314	466	152
2014	340	481	141
2015	239	490	251
2016	16	139	123
2017	–	88	88

Table 16: Number of complete tagging release/recovery records by sex and QMA. Note that the row totals are not always consistent with other tables as some records could not be assigned to a sex.

QMA	Male	Female	Total
CRA 1	918	1 128	2 046
CRA 2	2 341	2 127	4 468
CRA 3	3 811	1 316	5 127
CRA 4	1 887	622	2 509
CRA 5	4 936	2 067	7 003
CRA 6	21	162	183
CRA 7	328	376	704
CRA 8	5 878	4 878	10 756
CRA 9	27	37	64
Total	20 147	12 713	32 860

Table 17: Number of tags released by QMA (rows) and recaptured by QMA (columns). Note that the row totals are not always the same as in previous tables as some records could not be assigned to a QMA.

QMA	CRA 1	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8	CRA 9
CRA 1	1 828	9	30						
CRA 2		3 744	2						
CRA 3		15	4 921		3			52	
CRA 4				2 477	32				
CRA 5				3	5 818		6		
CRA 6						179			
CRA 7			6				681	17	
CRA 8		1	121					8 473	3
CRA 9									64

Table 18: Number of tags released by statistical area (rows) in the North Island (excluding CRA 9: see Table 20 for CRA 9 statistical area recoveries) and recaptured by statistical area (columns).

CRA	Area	901	902	903	904	939	905	906	907	908	909	910	911	912	913	914	915	934	916	924	Unknown
1	901	265	5	1		2															
1	902		2																		
1	903			20																	
1	904				1		9														
1	939	4				1528						1	29								150
2	905						105	2													27
2	906						29	2622													65
2	907						1	6	508	3											143
2	908							4	7	457	2										215
3	909									15	582		1								73
3	910										4	3139	1						3	51	45
3	911										1	5	1188							1	
4	912													379		8					
4	913														722	6					
4	914													9	3	1011	2				
4	915															9	326	2	32		

Table 19: Number of tags released by statistical area (rows) in the South Island (including Stewart Island and the Chatham Islands, excluding CRA 9: see Table 20 for CRA 9 statistical area recoveries) and recaptured by statistical area (columns).

CRA	Area	916	917	918	919	933	920	921	922	923	924	925	926	927	928	906	910	911	915	929	Unknown
5	916	3013	145			7													3		
5	917		1522			1															994
5	918			220	1		5	1													
5	933	2	3			904															
6	940																				83
6	941																				85
6	942																				13
6	943																				1
7	920						362	40	1		9						4	2			
7	921						15	264	2		3			1	1						
8	922								5	9	15				1						
8	923									86	83		13	5	1						
8	924									4	2432		18	5	1		111	10			1
8	925										3	15	4								
8	926									7	5	5	1157	263	53					1	1
8	927										1		19	3820	25	1				1	1279
8	928										1		2	21	394					1	55

Table 20: Number of tags released by statistical area (rows) in CRA 9 and recaptured by statistical area (columns).

CRA	Area	931	935	936
9	931	10		
9	935		47	
9	936			7

Table 21: CRA 2: number of tag recaptures by release year and sex.

Release year	Females	Males	Total
1983	112	78	190
1984	36	25	61
1985	8	10	18
1996	539	686	1225
1997	116	463	579
1998	71	237	308
1999	31	36	67
2000	2	0	2
2001	8	2	10
2002	202	77	279
2003	423	244	667
2004	63	60	123
2005	35	13	48
2006	4	0	4
2007	4	1	5
2008	100	52	152
2009	17	26	43
2010	17	3	20
2011	2	1	3
2012	1	0	1
2014	199	229	428
2015	67	63	130
2016	70	35	105
Total	2127	2341	4468

Table 22: CRA 2: number of tag recaptures by recapture year and sex.

Recapture year	Females	Males	Total
1983	1	2	3
1984	101	79	180
1985	47	31	78
1986	7	1	8
1996	0	2	2
1997	278	728	1006
1998	219	514	733
1999	174	152	326
2000	4	4	8
2001	52	16	68
2002	66	27	93
2003	225	158	383
2004	257	165	422
2005	148	48	196
2006	36	2	38
2007	21	1	22
2008	39	15	54
2009	49	55	104
2010	45	9	54
2011	16	5	21
2012	4	0	4
2013	2	0	2
2014	126	170	296
2015	79	90	169
2016	131	67	198
Total	2127	2341	4468

Table 23: Number of CRA 2 tag recaptures by release year (rows) and recapture year (columns). Note that tags recaptured before 1997 have been omitted from this table so that it fits on the page.

Recovery																				Recapture year
year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
1996	720	311	140	1	39	6	2	2	2											
1997	286	223	53	3	5	6	2		1											
1998		199	89	1	10	5	4													
1999			44	3	12	4	3		1											
2000						2														
2001					2	4	1	2						1						
2002						66	117	60	24	8	1	3								
2003							254	278	91	20	12	5	2	3	2					
2004								80	40		3									
2005									37	8	2	1								
2006										2		2								
2007											4	1								
2008												42	72	26	9	2	1			
2009													30	9	3	1				
2010														15	4		1			
2011															3					
2012																1				
2014																		296	110	22
2015																			59	71
2016																				105

Table 24: CRA 2: number of tags released (rows) and recaptured (columns) by area.

Release	Recapture statistical area						
statistical area	**905**	**906**	**907**	**908**	**909**	**Unknown**	**Total**
905	105	2	0	0	0	27	134
906	29	2622	0	0	0	65	2716
907	1	6	508	3	0	143	661
908	0	4	7	457	2	215	685
Unknown	0	3	0	1	0	268	272
Total	135	2637	515	461	2	718	4468

Table 25: Number of CRA 2 tag recaptures by release year and statistical area of release.

Release	Release statistical area				
year	**905**	**906**	**907**	**908**	**Unknown**	**Total**
1983	0	190	0	0	0	190
1984	0	60	0	0	1	61
1985	0	18	0	0	0	18
1996	7	778	251	189	0	1225
1997	0	398	68	113	0	579
1998	6	264	21	17	0	308
1999	1	44	17	5	0	67
2000	0	2	0	0	0	2
2001	0	10	0	0	0	10
2002	16	226	12	25	0	279
2003	67	460	102	38	0	667
2004	5	94	23	1	0	123
2005	2	35	5	6	0	48
2006	0	1	3	0	0	4
2007	0	0	3	2	0	5
2008	0	66	20	66	0	152
2009	1	13	2	24	3	43
2010	0	11	0	2	7	20
2011	0	1	0	0	2	3
2012	0	0	0	0	1	1
2014	26	40	75	142	145	428
2015	0	0	18	48	64	130
2016	3	5	41	7	49	105
Total	134	2716	661	685	272	4468

Table 26: Number of CRA 2 tag recaptures by recapture year and release area.

Recapture	Release statistical area					
year	905	906	907	908	Unknown	Total
1983	0	3	0	0	0	3
1984	0	180	0	0	0	180
1985	0	77	0	0	1	78
1986	0	8	0	0	0	8
1996	0	0	2	0	0	2
1997	4	650	158	194	0	1006
1998	4	563	86	80	0	733
1999	2	209	79	36	0	326
2000	0	3	0	5	0	8
2001	4	37	27	0	0	68
2002	2	64	2	25	0	93
2003	44	310	21	8	0	383
2004	33	303	77	9	0	422
2005	9	137	26	24	0	196
2006	2	21	12	3	0	38
2007	0	5	10	7	0	22
2008	0	34	8	12	0	54
2009	1	32	5	66	0	104
2010	0	26	8	11	9	54
2011	0	9	5	5	2	21
2012	0	0	0	3	1	4
2013	0	0	1	0	1	2
2014	13	34	32	109	108	296
2015	8	6	31	36	88	169
2016	8	5	71	52	62	198
Total	134	2716	661	685	272	4468

Table 27: CRA 2: number of tag releases by area and sex.

Release statistical	Sex		
area	Females	Males	Total
905	113	21	134
906	1223	1493	2716
907	359	302	661
908	328	357	685
Unknown	104	168	272
Total	2127	2341	4468

Table 28: Number of CRA 2 tag re-releases by sex. Re-release event code=0 means the first release-recapture event.

Re-release	**Sex**			**%**
event	**Females**	**Males**	**Total**	**by event**
0	1606	1383	2989	67%
1	359	511	870	19%
2	106	231	337	7.5%
3	38	119	157	3.5%
4	14	54	68	1.5%
5	4	21	25	0.6%
6	0	12	12	0.3%
7	0	5	5	0.1%
8	0	2	2	0.04%
9	0	1	1	0.02%
10	0	1	1	0.02%
11	0	1	1	0.02%
Total	2127	2341	4468	

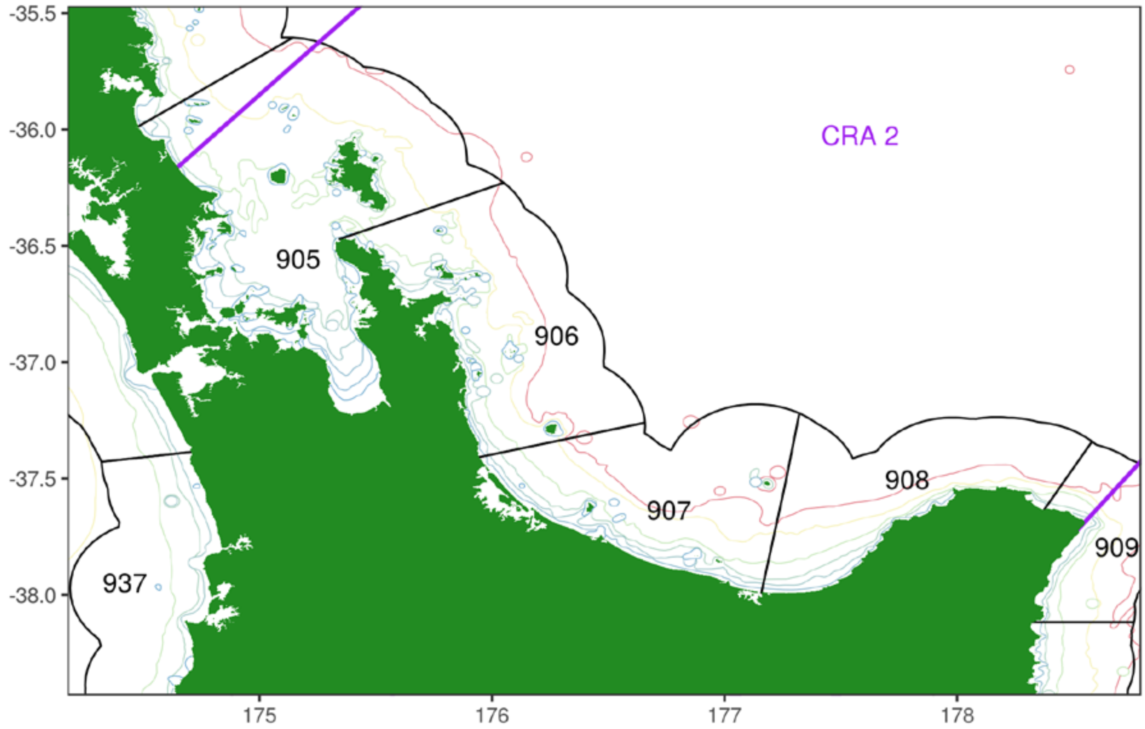

Figure 1: Map of the upper North Island, showing location of CRA 2 and its statistical areas.

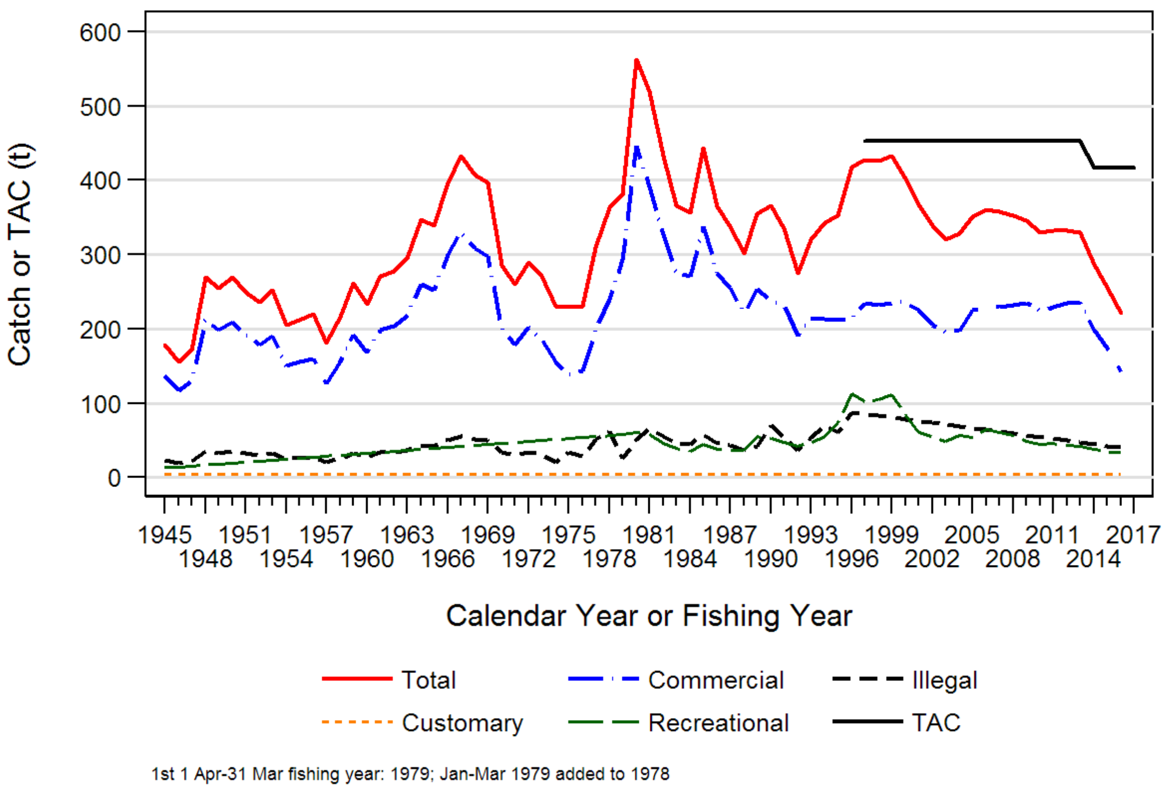

Figure 2: Annual catches (tonnes) by fishery (commercial, illegal, recreational and customary), using the three RLFAWG agreed non-commercial catch series (see Sections 2.2, 2.3 and 2.4).

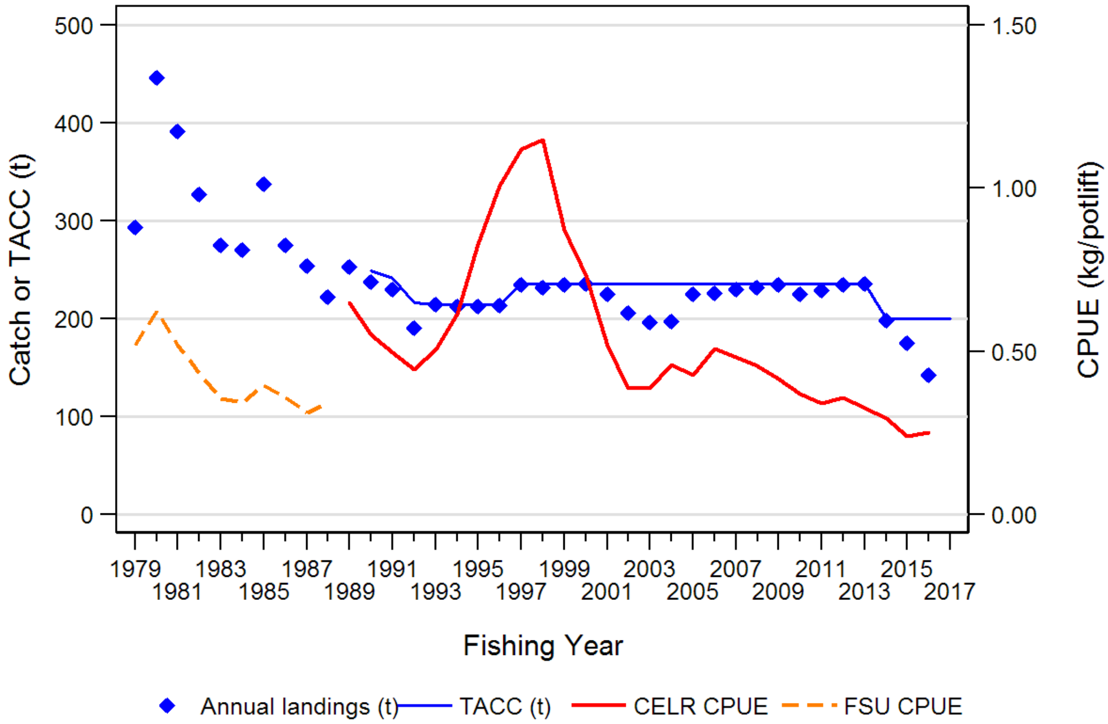

Figure 3: Plot of annual commercial landings (tonnes), the TACC (tonnes) and the annual standardised CPUE index by fishing year, 1979–2016. Note that the 1989–2016 indices have been estimated including a vessel explanatory variable while the 1979–1988 have been estimated separately without the vessel explanatory variable.

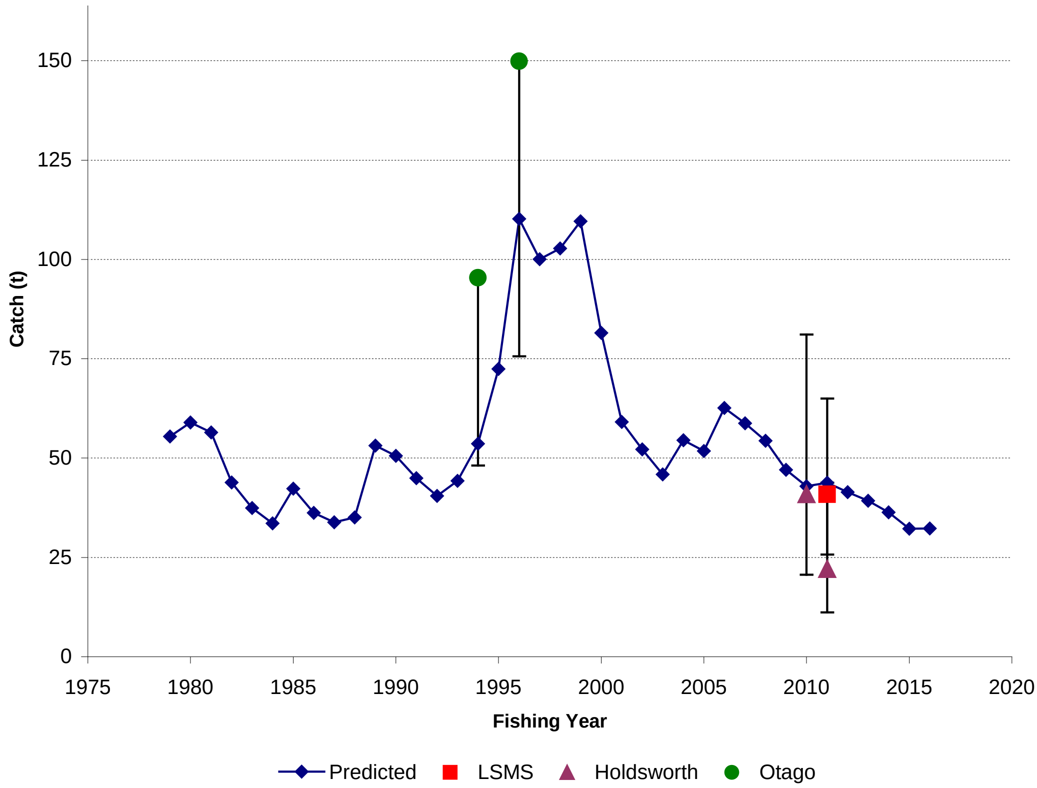

Figure 4: CRA 2 recreational catch trajectory (tonnes) (Eq. 2) based on the SS seasonal CPUE series fitted to five recreational catch surveys (Eq. 1 and Table 1). Error bars are ±2 s.e., assuming a log-normal distribution, with the upper error bars for the two Otago estimates suppressed.

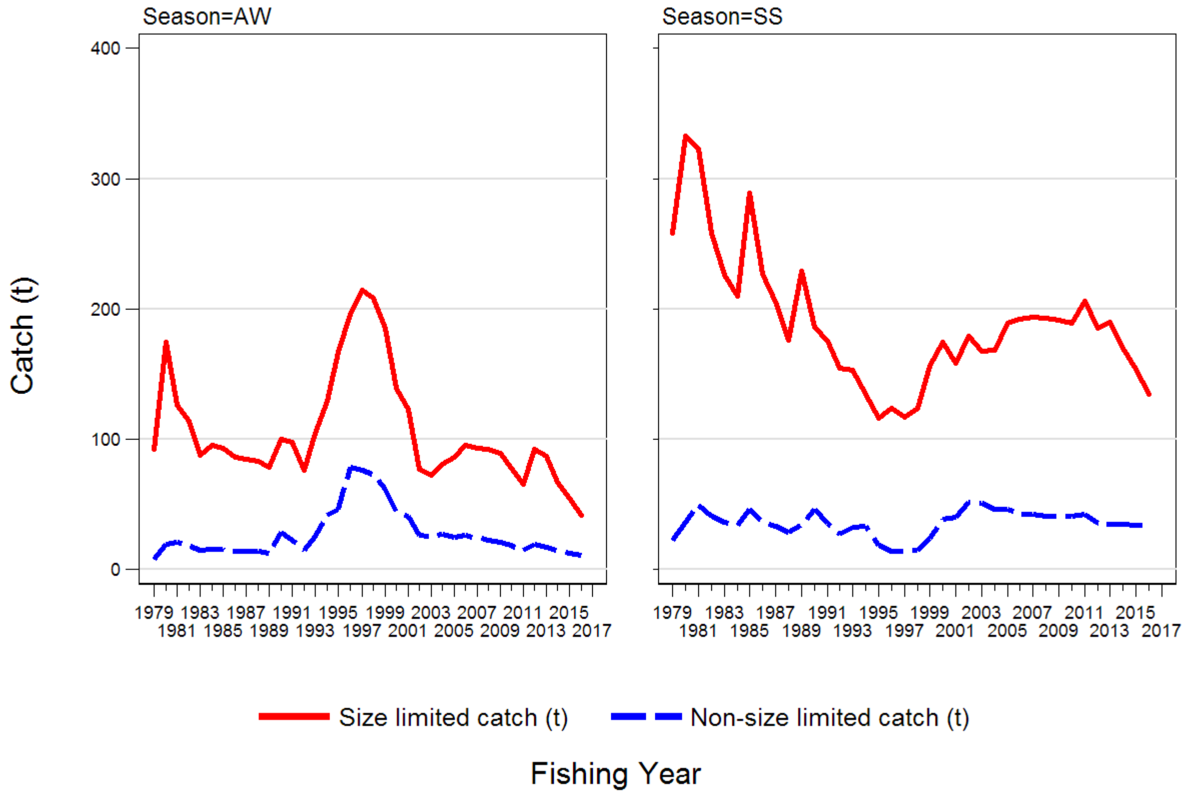

Figure 5: The seasonal SL and NSL catches (tonnes) plotted by fishing year, beginning in 1979 using RLFAWG agreed non-commercial catches (see Sections 2.2, 2.3 and 2.4).

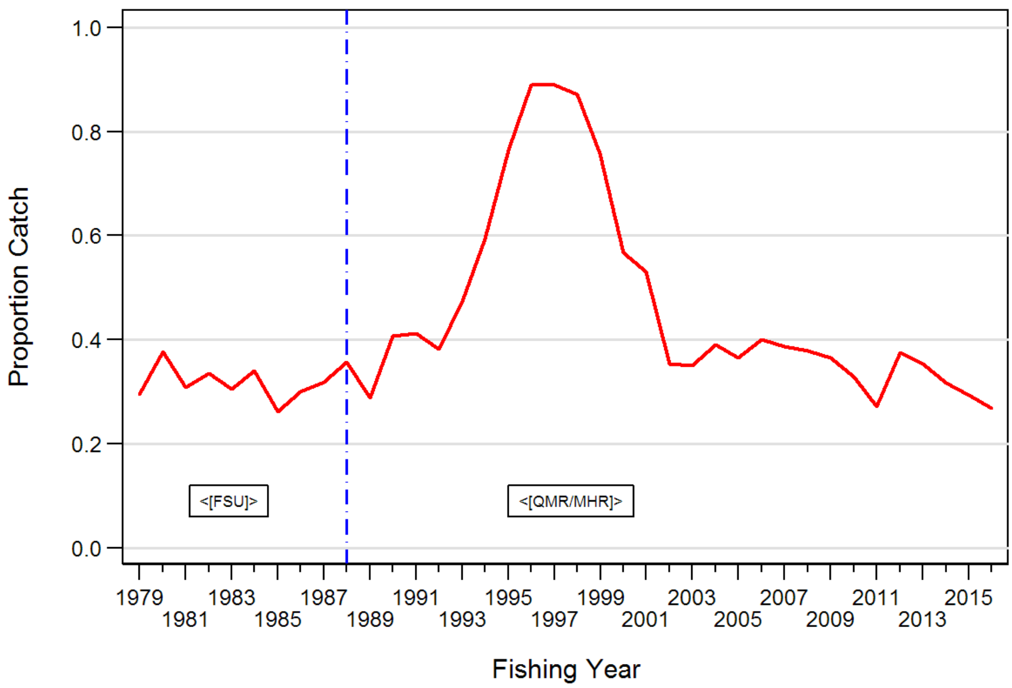

Figure 6: Proportion of the AW commercial catch by fishing year for CRA 2.

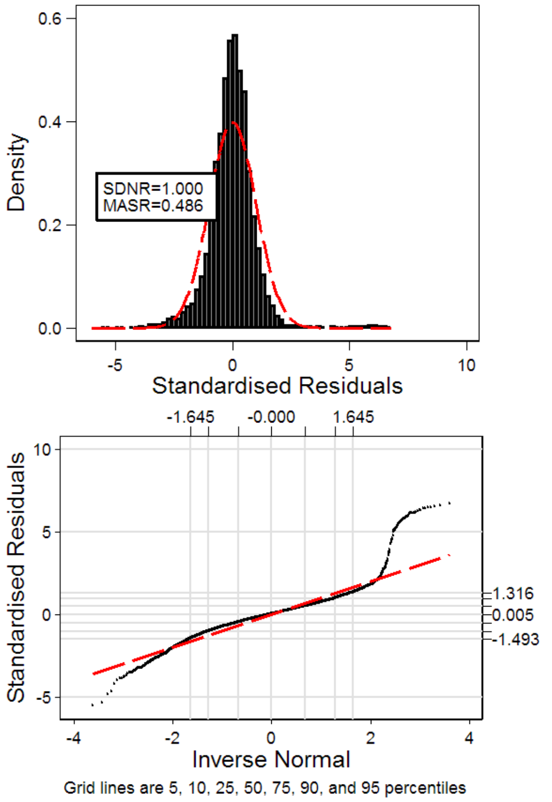

Figure 7: Standardised residuals for the CRA 2 seasonal CPUE GLM analysis which included a vessel variable filtered for vessels with at least five years experience in the fishery.

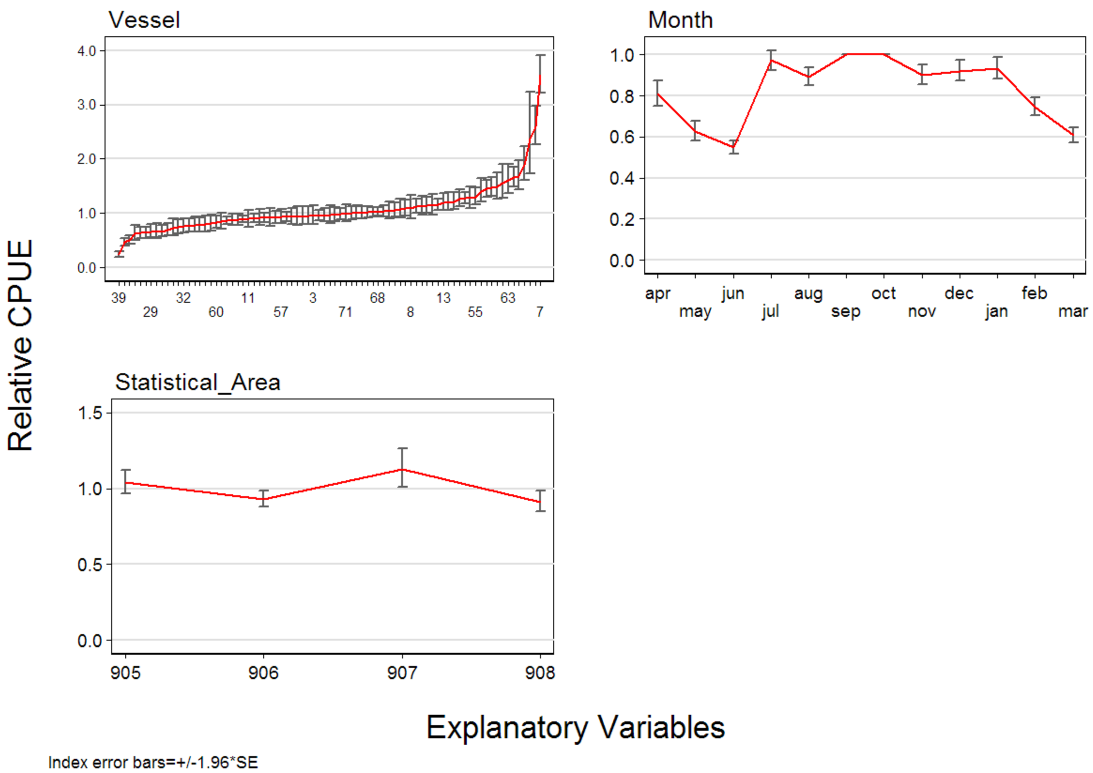

Figure 8: Coefficients for vessels with at least five years experience in the fishery, month and statistical area from the CRA 2 seasonal CPUE standardisation. Month coefficients are not in canonical form, with each of the two reference months (August and October) set to 1.0 and the associated SE set to zero.

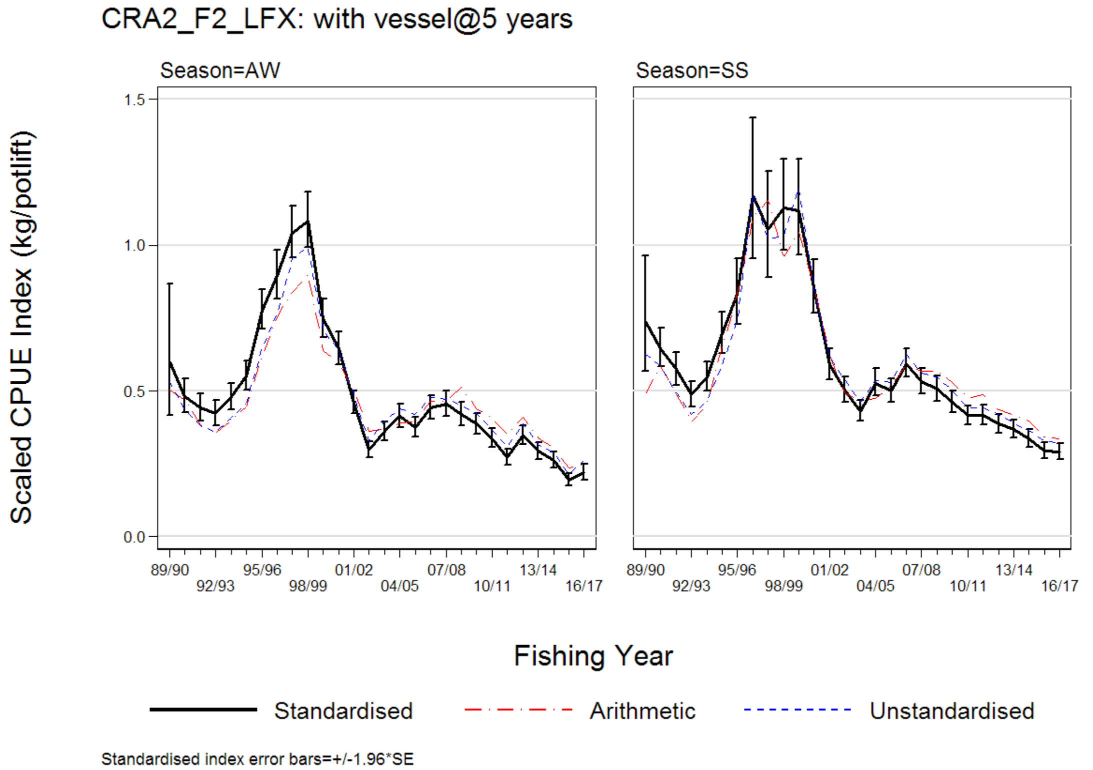

Figure 9: Standardised, unstandardised (geometric mean), and arithmetic mean CPUE indices (kg/potlift) by season and fishing year for the CRA 2 seasonal CPUE GLM analysis which included a vessel variable filtered for vessels with at least five years experience in the fishery using the F2 algorithm scaled to "LFX" landings from 1989–90 to 2016–17: AW ($^{g}\bar{\mu}$ =0.44 kg/potlift) and SS ($^{g}\bar{\mu}$ =0.56 kg/potlift).

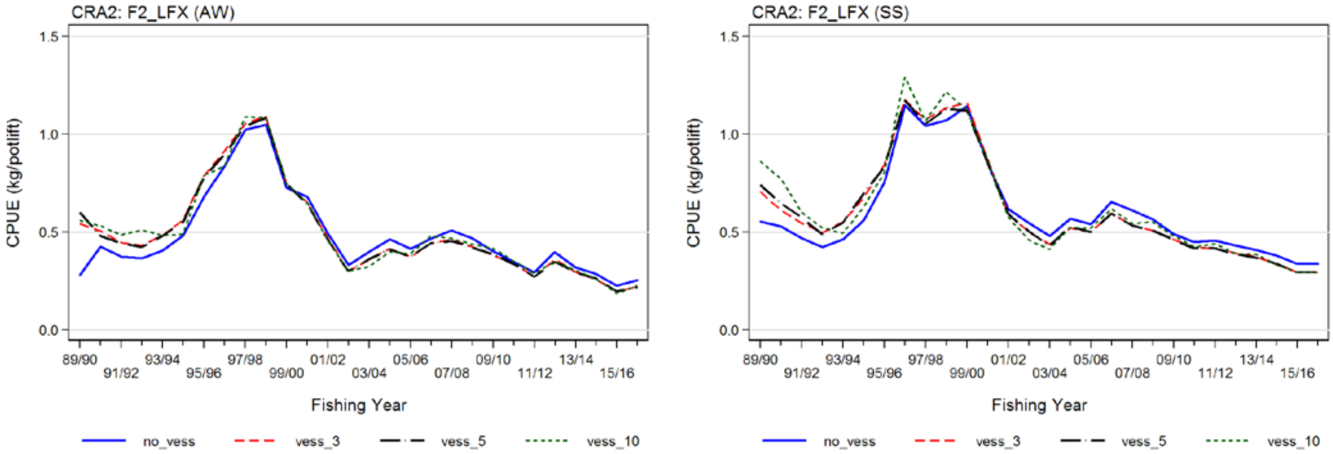

Figure 10: Comparison of the seasonal trajectories [AW: left panel; SS: right panel] after standardising under four vessel experience filtering assumptions: (a) no filter; (b) at least three years experience; (c) at least five years experience; (d) at least ten years experience.

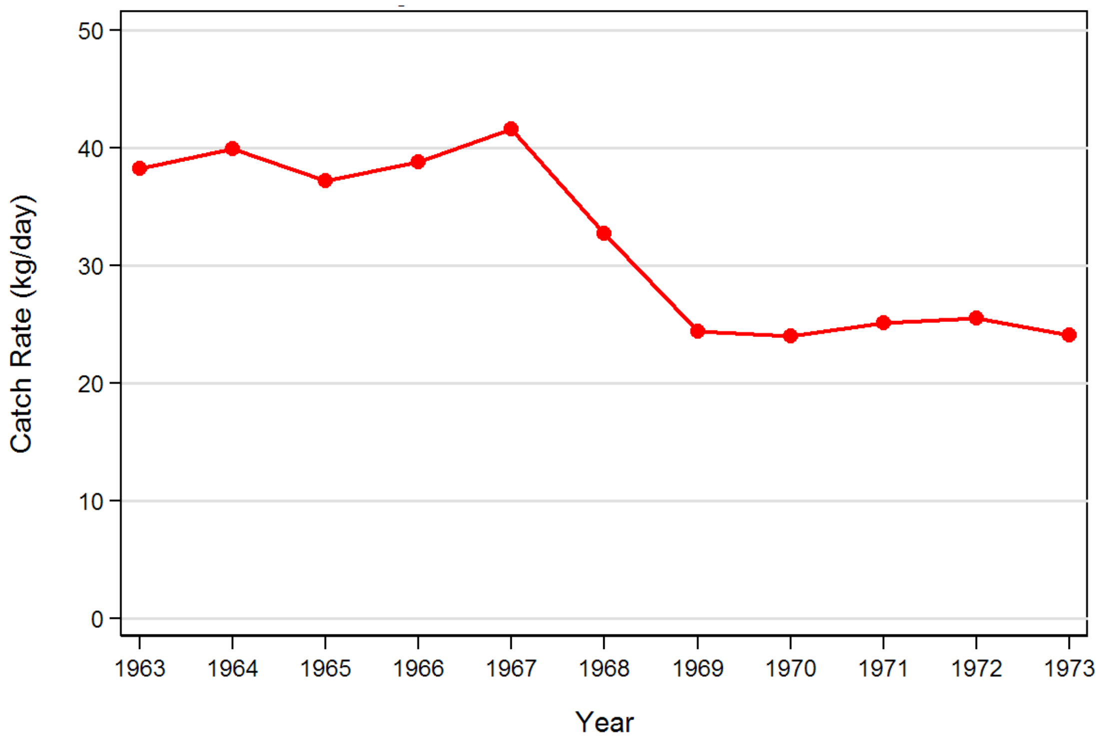

Figure 11: Catch rate (kg/day) by year for CRA 2 from Annala & King (1983).

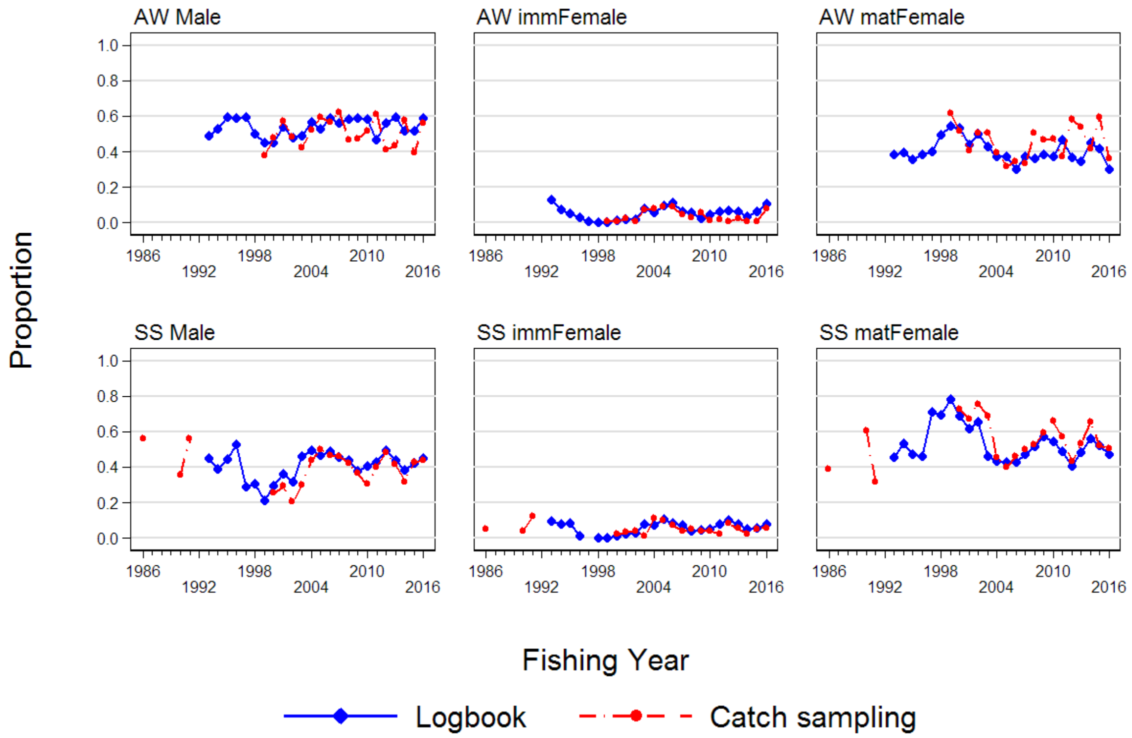

Figure 12: Proportion-at-sex by year, season and sampling source.

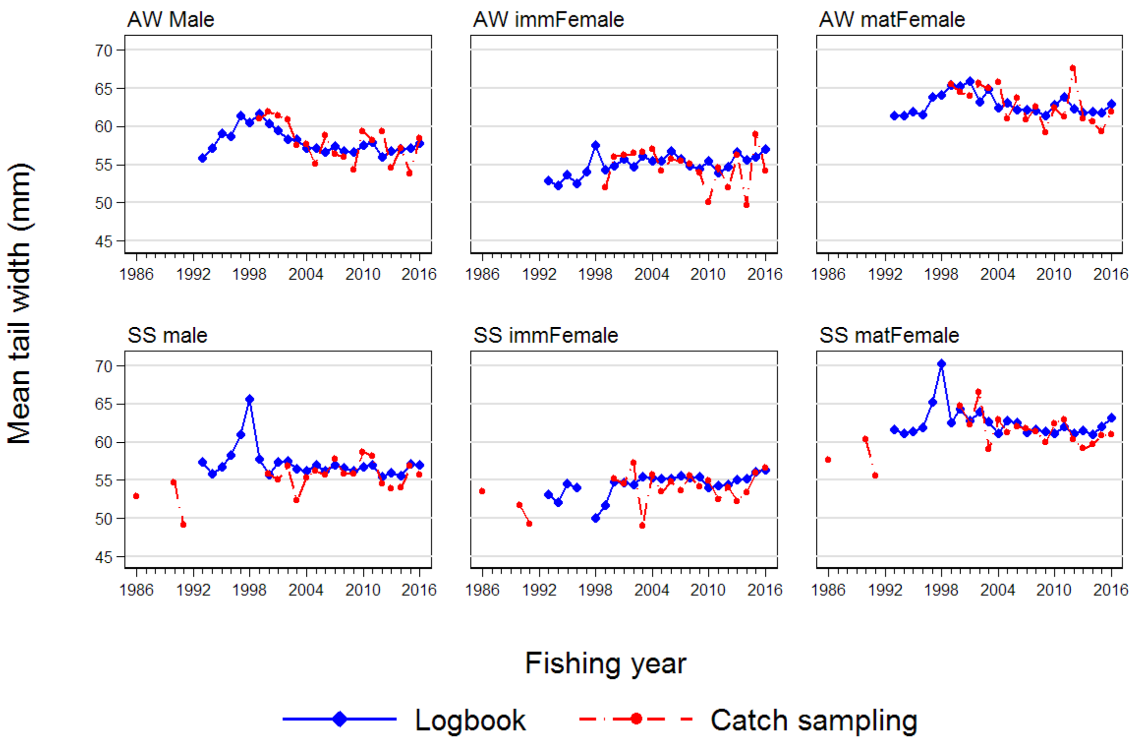

Figure 13: Mean length by year, season, sex and sampling source.

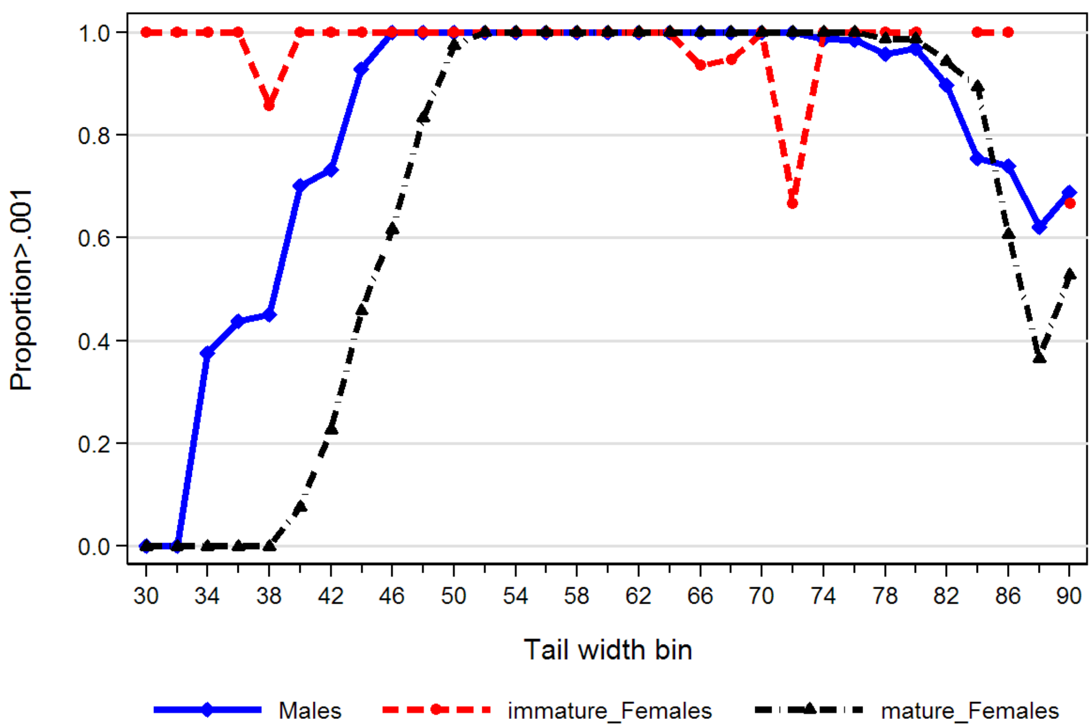

Figure 14: The proportion of size bins (across 86 year/season/sampling source strata) that contain a proportion of 0.001 or higher when the data are normalised by sex.

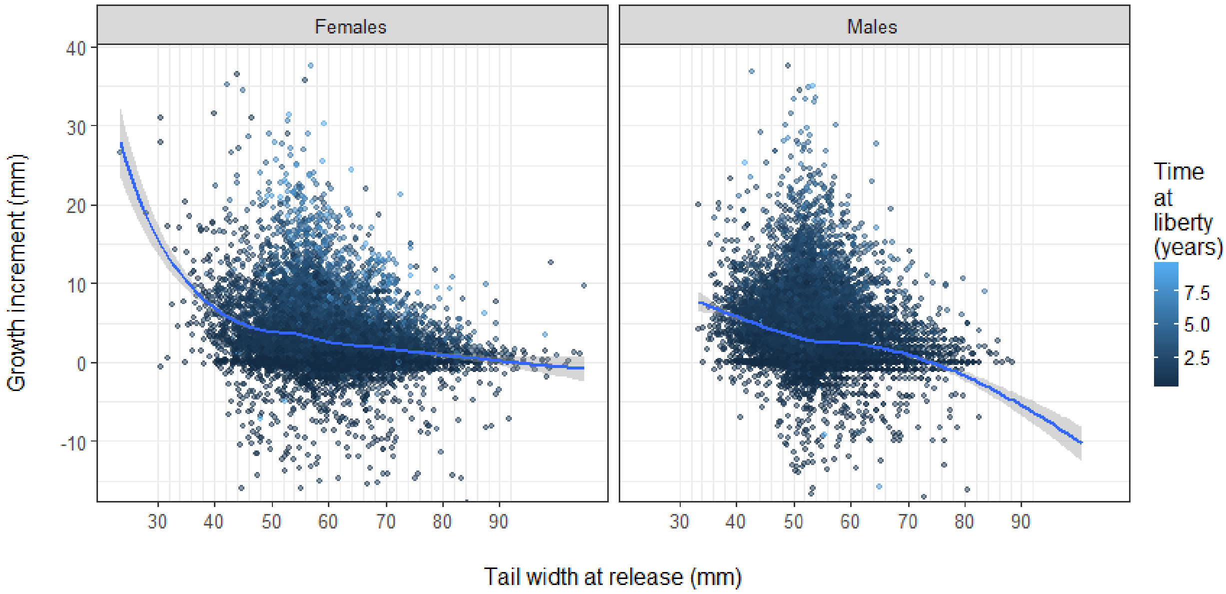

Figure 15: Growth increments (mm) by size at release (mm) and sex. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown.

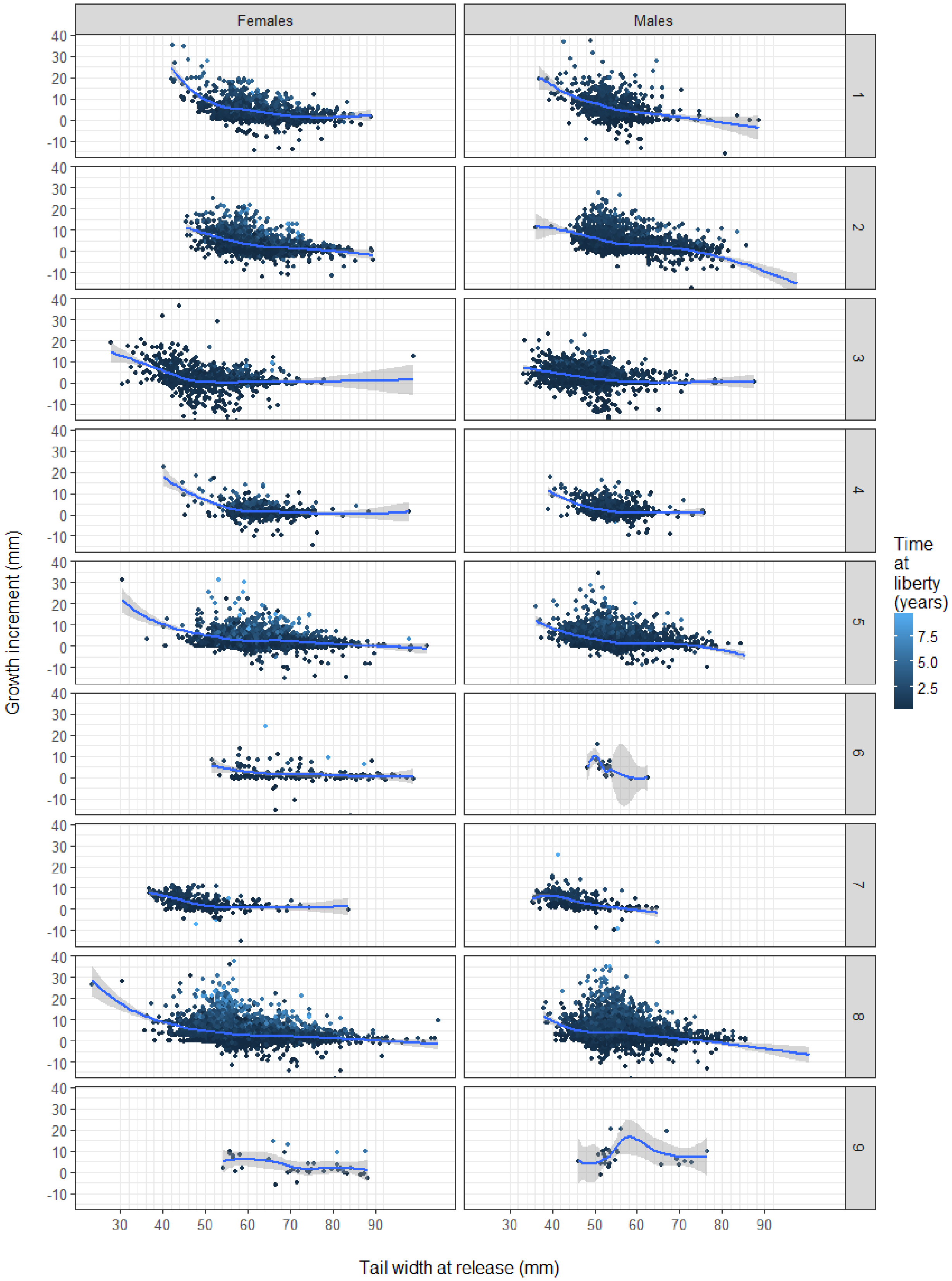

Figure 16: Growth increments (mm) by size at release (mm), sex, and QMA. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown.

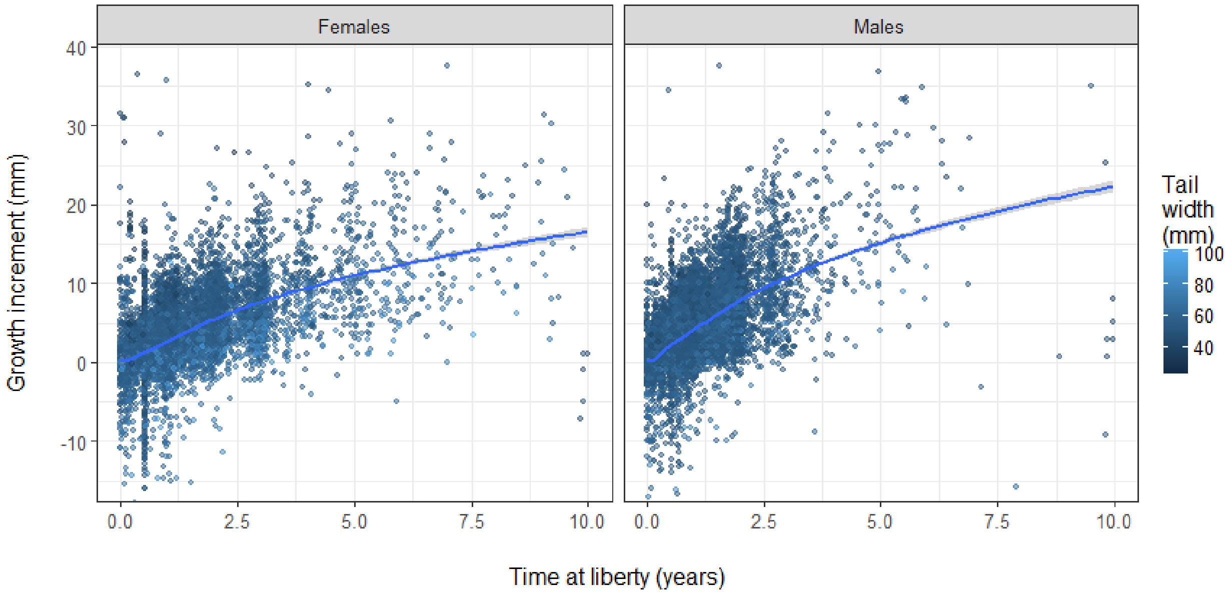

Figure 17: Growth increments (mm) by time at liberty (years) and sex. The colour of each point represents the size at release (mm). A loess smoother and the 95% confidence interval about this smoother is also shown.

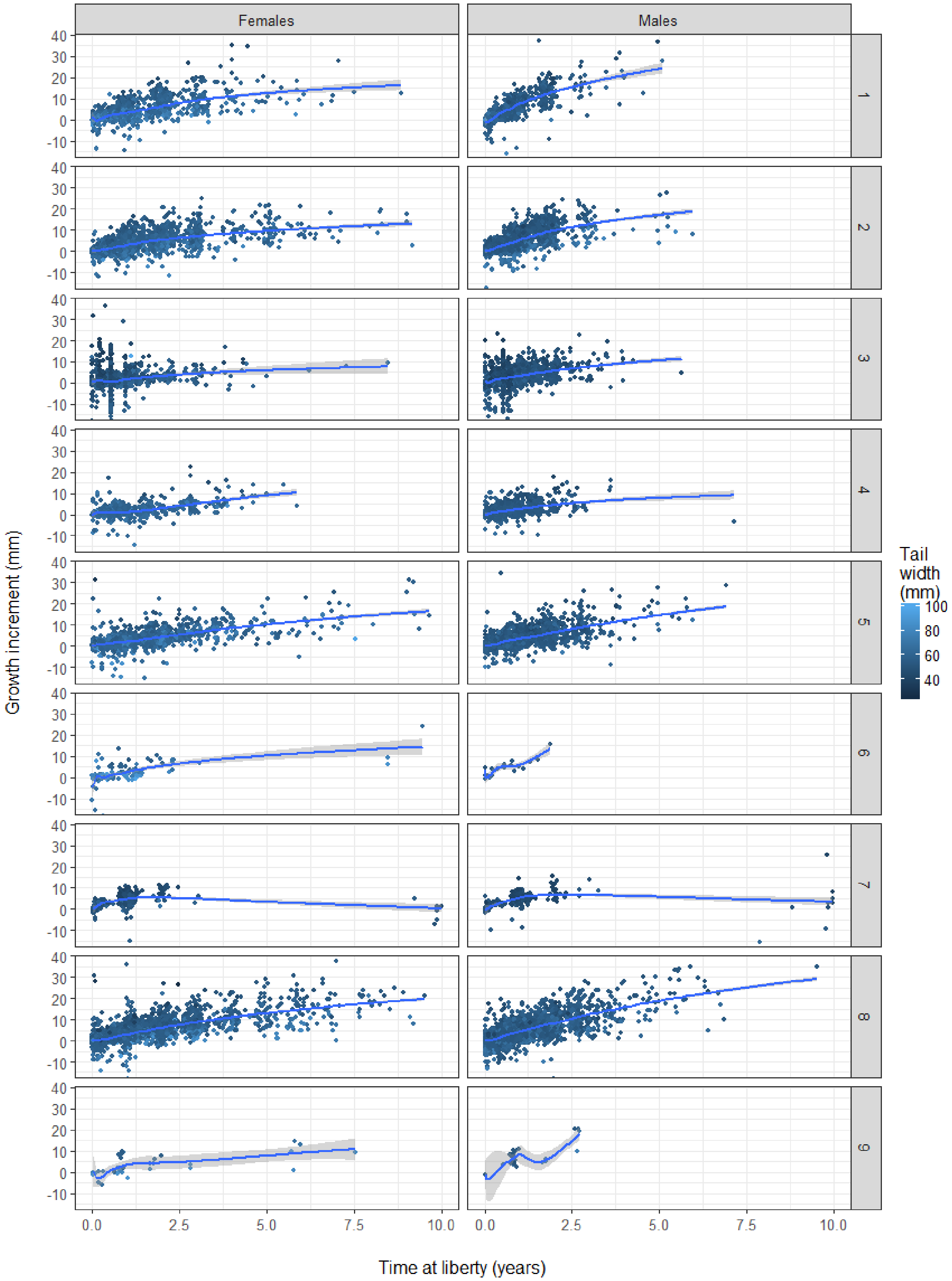

Figure 18: Growth increments (mm) by time at liberty (years), sex, and QMA. The colour of each point represents the size at release (mm). A loess smoother and the 95% confidence interval about this smoother is also shown.

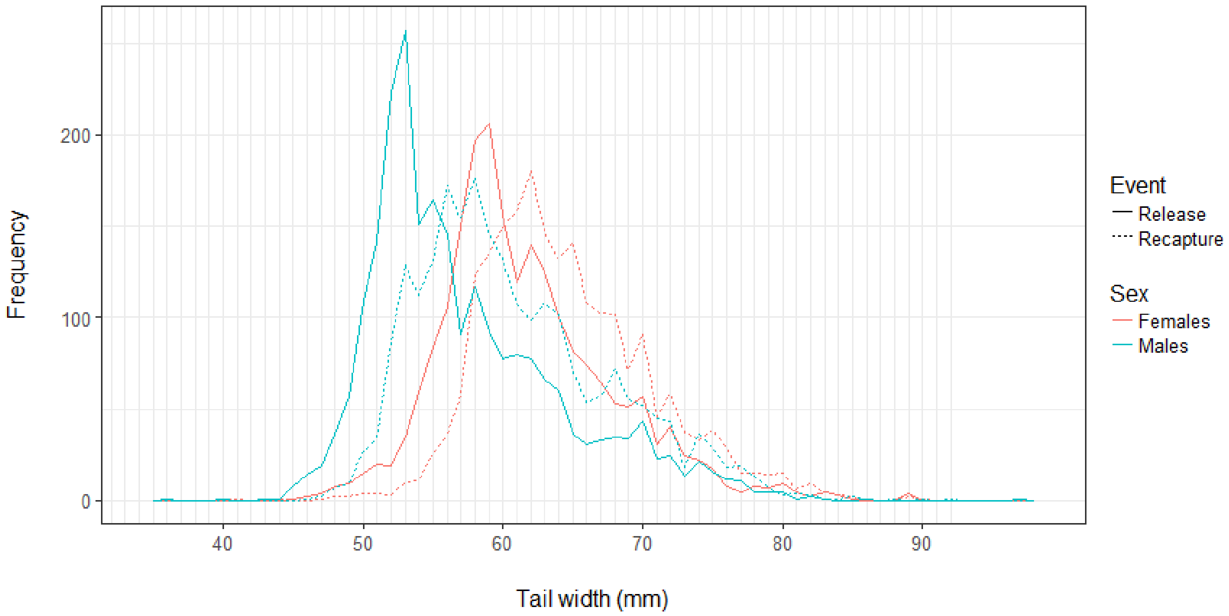

Figure 19: CRA 2: Frequency polygons of size at release (solid lines) and recapture (dashed lines) by sex. A bin width of 1 mm was used.

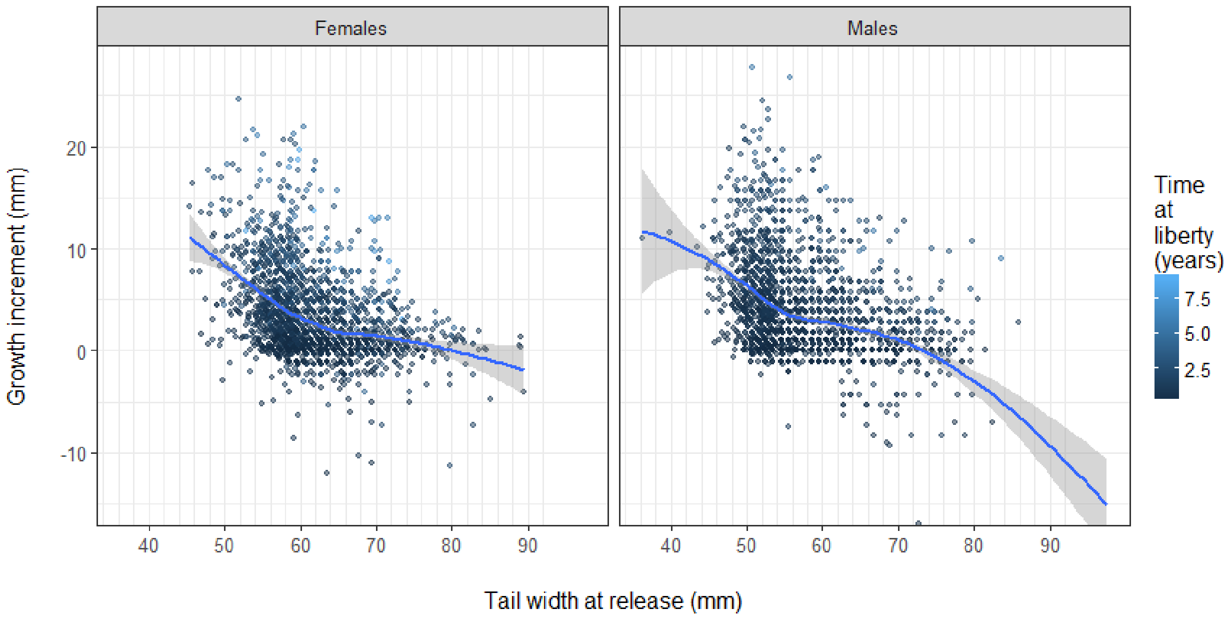

Figure 20: CRA 2 growth increments (mm) by size at release (mm) and sex. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.

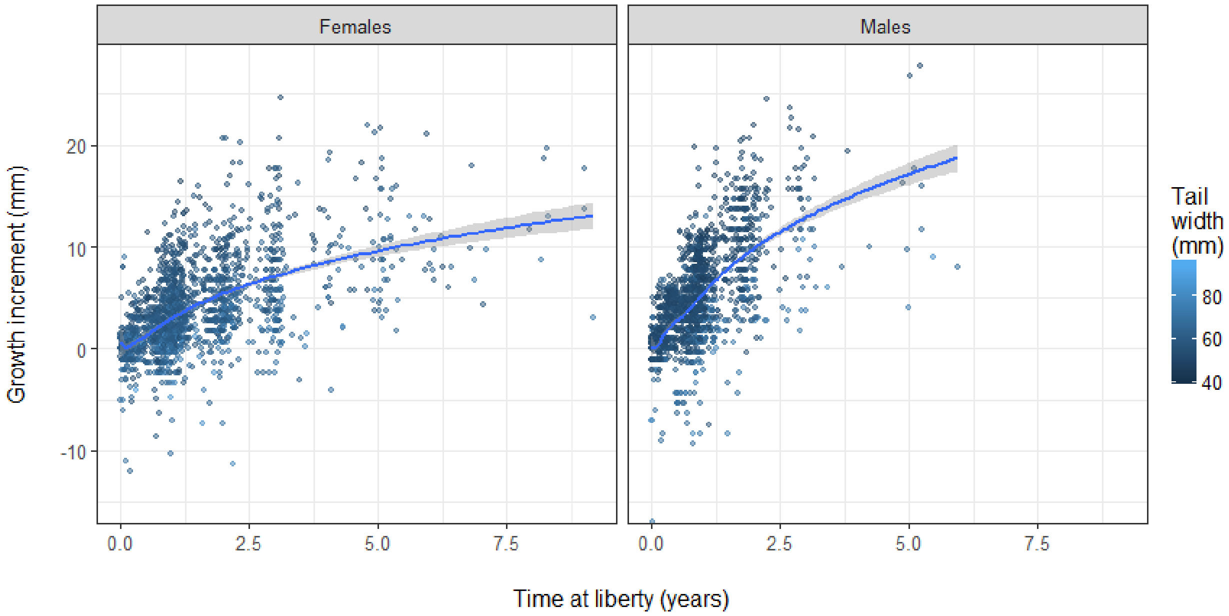

Figure 21: CRA 2 growth increments (mm) by time at liberty (years) and sex. The colour of each point represents the tail width (mm). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.

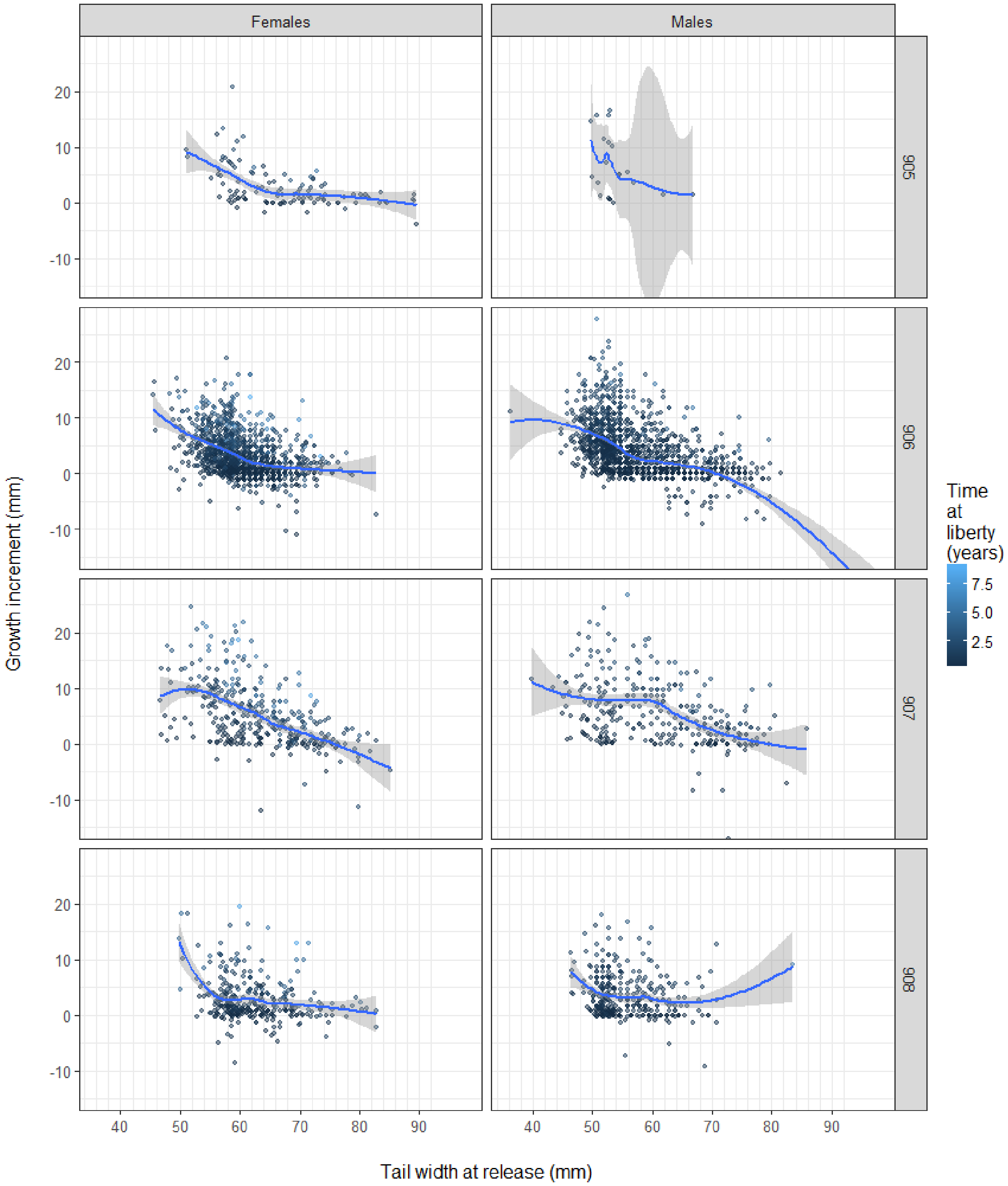

Figure 22: CRA 2 growth increments (mm) by size at release (mm) and sex in each statistical area. The colour of each point represents the time at liberty (years). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.

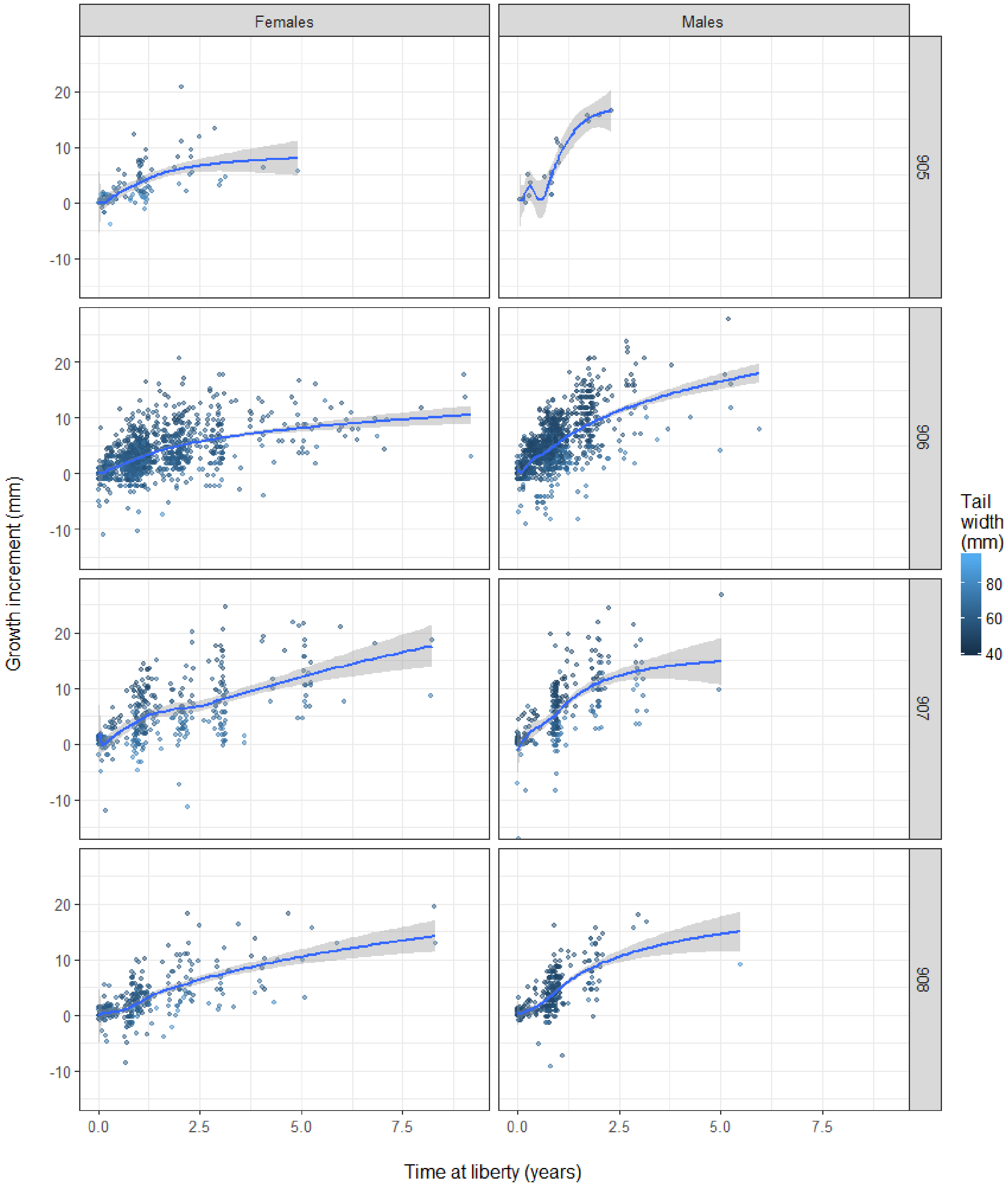

Figure 23: CRA 2 growth increments (mm) by time at liberty (years) and sex in each statistical area. The colour of each point represents the tail width (mm). A loess smoother and the 95% confidence interval about this smoother is also shown for each panel.

APPENDIX A. DISTRIBUTION OF DESTINATION CODES IN CRA 2 LANDING DATA

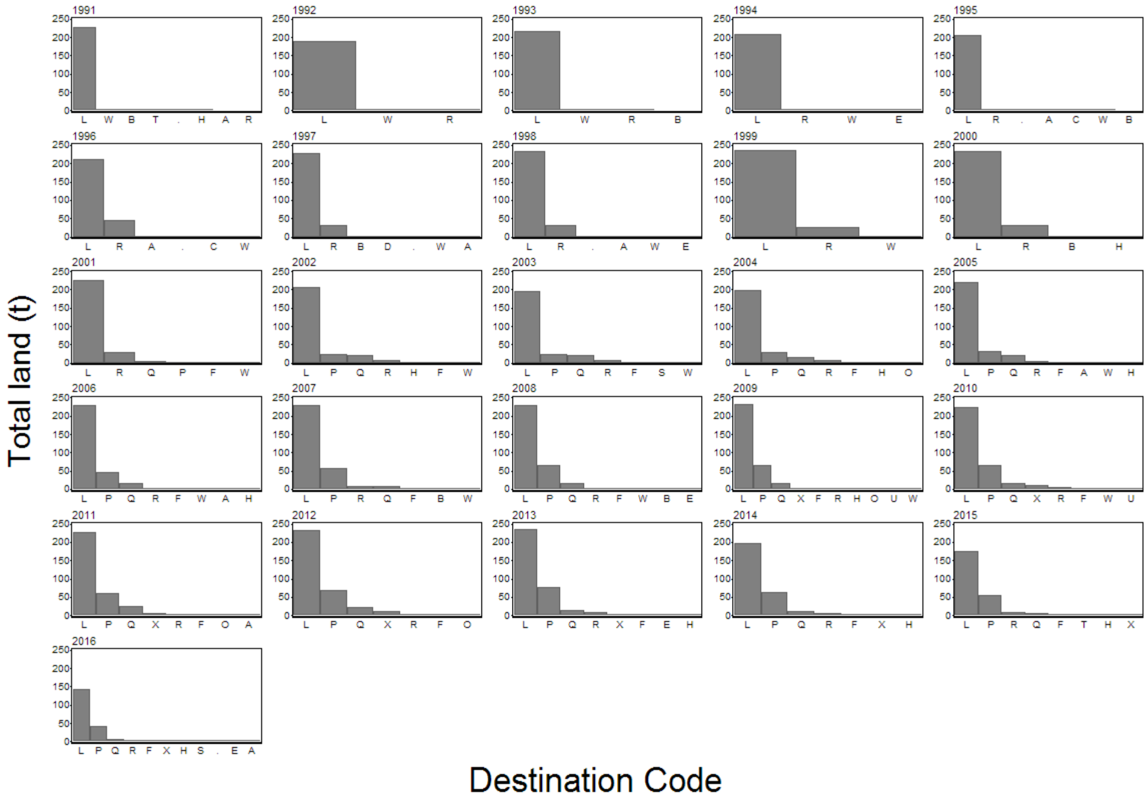

Figure A.1: Plot showing destination codes reported by fishing year in CRA 2. Only the destination codes reported in each year are shown in descending order of total annual landings.

Table A.1: Destination codes used by MPI.

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

APPENDIX B. LETTER TO MPI REQUESTING NON-COMMERCIAL CATCH INFORMATION

NZ ROCK LOBSTER INDUSTRY COUNCIL

Ka whakapai te kai o te moana

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

September 2017

Alicia McKinnon, Ministry for Primary Industries

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

cc Dr. Julie Hills, Chair, RLFAWG
by email: *Julie.Hills@fish.govt.nz*
cc ECs:
charles.edwards@niwa.co.nz
haistv@shaw.ca
paul@starrfish.net
darcy@quantifish.co.nz
merrillrudd@gmail.com

Dear Alicia

Under Objectives 4 and 5 of MPI contract CRA 2012/01C, in September and October of this year, the stock assessment team will be conducting a CRA 2 stock assessment and developing the CRA 2 management procedure options.

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

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

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

Recreational catch has been estimated by the large-scale multi-species national survey (LSMS), which ended in September 2012. Previous estimates of recreational catch are available from various telephone-diary surveys conducted in the 1990s and early 2000s.

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

It is likely that the RLFAWG will request sensitivity analyses on catch series that are alternatives to the base case non-commercial catch vectors, but the base case non-commercial mortalities must be provided by MPI.
For **illegal catches**, the assessment team needs to know:

- **the MPI estimates of current and recent CRA 2 illegal catch and its historical trend**

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

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

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

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

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

- **estimates of the current customary catch in CRA 2 and its historical trend**

The assessment team also request:

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

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

- **estimates of the current recreational catch in CRA 2 and its historical trend**

The assessment team also request:

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

Without these estimates from MPI, it will not be possible to produce acceptable stock assessments. The assessment input data, including these estimates, are scheduled to be discussed at a RLFAWG meeting on 20 September 2016. These MPI estimates of non-commercial catches are thus required by:

- **26th September 2016**

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

Sincerely,

Daryl R Sykes

Daryl Sykes

Research Programme Manager
NZ Rock Lobster Industry Council Ltd

APPENDIX C. DOCUMENTATION FOR CRA 2 SEASONAL CPUE ANALYSIS WITHOUT VESSEL EFFECT

The data used in this analysis are described in the first two paragraphs in Section 3.1.1 and the methods followed are documented in Starr (2017a). A [`vessel`] explanatory variable was not used in this model, with the purpose of the analysis to provide a set of FSU seasonal indices. The FSU data had been excluded from the analysis presented in Section 3.1 with the inclusion of the [`vessel`] explanatory variable.

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

Table C.1: Number of vessel/statistical area/month records in the dataset used to calculate the CRA 2 seasonal CPUE time series without including a vessel explanatory variable. Cells with <10 observations are highlighted in grey; '–': no data.

Fishing	Autumn-winter season					Spring-summer season				
Year	905	906	907	908	Total	905	906	907	908	Total
79/80	65	104	37	69	275	84	182	75	146	487
80/81	51	154	64	98	367	70	193	82	129	474
81/82	75	135	61	91	362	102	206	67	151	526
82/83	79	132	54	91	356	100	187	64	135	486
83/84	80	114	59	81	334	97	187	64	118	466
84/85	67	124	56	85	332	73	194	70	129	466
85/86	61	116	56	73	306	79	180	78	119	456
86/87	48	110	42	61	261	67	175	71	126	439
87/88	41	111	55	75	282	51	172	65	98	386
88/89	47	87	46	35	215	49	151	56	66	322
89/90	38	48	22	17	125	33	3	–	8	44
90/91	42	68	38	44	192	36	114	39	66	255
91/92	31	79	45	36	191	34	101	47	59	241
92/93	23	69	21	25	138	27	104	20	45	196
93/94	29	79	14	36	158	22	92	18	46	178
94/95	31	81	14	31	157	19	47	24	32	122
95/96	25	76	19	41	161	11	29	2	20	62
96/97	30	69	19	26	144	2	16	1	7	26
97/98	31	76	21	23	151	6	22	1	4	33
98/99	36	62	15	26	139	16	26	3	6	51
99/00	33	63	21	26	143	15	21	7	6	49
00/01	26	69	20	33	148	32	42	12	13	99
01/02	32	65	29	26	152	38	57	25	16	136
02/03	26	65	25	28	144	43	70	28	32	173
03/04	33	52	23	25	133	31	66	39	45	181
04/05	21	54	17	27	119	21	55	22	47	145
05/06	32	45	19	26	122	46	58	23	40	167
06/07	35	57	22	24	138	42	69	17	39	167
07/08	30	50	12	26	118	46	64	19	40	169
08/09	29	46	15	21	111	41	57	13	30	141
09/10	46	48	17	23	134	54	76	16	34	180
10/11	34	40	15	24	113	56	69	18	42	185
11/12	32	40	15	22	109	56	74	18	39	187
12/13	38	44	17	26	125	51	72	16	37	176
13/14	37	49	17	28	131	44	78	15	40	177
14/15	19	49	15	26	109	26	74	15	33	148
15/16	27	46	14	27	114	41	73	20	36	170
16/17	25	40	15	16	96	47	57	20	33	157
Total	1485	2816	1086	1518	6905	1708	3513	1198	2148	8479

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

Variable	1	2	3
Period (76)	0.1738		
Month (12)	0.0422	0.2184	
Statistical Area (4)	0.0135	0.1893	**0.2332**
Additional deviance explained	0	0.0446	0.0149

Table C.3: Seasonal CPUE indices calculated from the analysis of CRA 2 catch and potlift data without including a vessel explanatory variable. Arithmetic index: sum(annual catch)/sum(potlifts); Unstandardised index: geometric mean of the CPUE observations by year; Standardised index: annual index. Coloured cells show the FSU indices used in the 2017 CRA 2 stock assessment.

	Autumn-winter season				Spring-summer season			
Fishing Year	Arithmetic Index	Unstandard-ised Index	Standard-ised Index	Standard Error	Arithmetic Index	Unstandard-ised Index	Standard-ised Index	Standard Error
79/80	0.4833	0.4735	0.4613	0.0376	0.5381	0.5694	0.5776	0.0293
80/81	0.6209	0.6449	0.6526	0.0330	0.6029	0.6083	0.6146	0.0297
81/82	0.4674	0.4565	0.4520	0.0332	0.6008	0.5786	0.5888	0.0284
82/83	0.4199	0.4184	0.4149	0.0334	0.4627	0.4518	0.4573	0.0293
83/84	0.3381	0.3247	0.3218	0.0344	0.4126	0.3868	0.3904	0.0299
84/85	0.3598	0.3491	0.3457	0.0346	0.3781	0.3456	0.3503	0.0299
85/86	0.3695	0.3593	0.3553	0.0358	0.4564	0.4388	0.4413	0.0302
86/87	0.3362	0.3615	0.3519	0.0385	0.3913	0.3717	0.3774	0.0307
87/88	0.2965	0.2802	0.2758	0.0372	0.3733	0.3521	0.3525	0.0324
88/89	0.3499	0.3338	0.3214	0.0421	0.3686	0.3615	0.3656	0.0351
89/90	0.2964	0.2695	0.2786	0.0552	0.5965	0.5852	0.5540	0.0912
90/91	0.4492	0.4423	0.4263	0.0444	0.5118	0.5295	0.5269	0.0391
91/92	0.3782	0.3782	0.3733	0.0446	0.4711	0.4704	0.4682	0.0401
92/93	0.3585	0.3643	0.3655	0.0520	0.3900	0.4145	0.4218	0.0442
93/94	0.4020	0.3990	0.4054	0.0488	0.4489	0.4604	0.4612	0.0462
94/95	0.4569	0.4720	0.4813	0.0490	0.6405	0.5853	0.5590	0.0551
95/96	0.6272	0.6594	0.6806	0.0484	0.8180	0.7631	0.7548	0.0766
96/97	0.7992	0.7943	0.8360	0.0511	1.0487	1.1456	1.1487	0.1178
97/98	0.8525	0.9836	1.0210	0.0500	1.1718	1.0703	1.0430	0.1046
98/99	0.9011	1.0113	1.0484	0.0519	0.9614	1.0572	1.0708	0.0844
99/00	0.6347	0.6975	0.7258	0.0513	1.0332	1.2044	1.1420	0.0860
00/01	0.6066	0.6674	0.6789	0.0503	0.8550	0.8663	0.8493	0.0610
01/02	0.4985	0.4880	0.4900	0.0498	0.6305	0.6266	0.6159	0.0524
02/03	0.3611	0.3333	0.3301	0.0511	0.4953	0.5433	0.5438	0.0468
03/04	0.3640	0.3999	0.3991	0.0530	0.4691	0.4773	0.4781	0.0459
04/05	0.3886	0.4541	0.4623	0.0559	0.4690	0.5497	0.5678	0.0510
05/06	0.3958	0.4240	0.4150	0.0553	0.5153	0.5357	0.5397	0.0477
06/07	0.4608	0.4668	0.4665	0.0521	0.5925	0.6464	0.6528	0.0476
07/08	0.4681	0.5022	0.5080	0.0562	0.5679	0.5991	0.6122	0.0474
08/09	0.5126	0.4685	0.4671	0.0579	0.5710	0.5625	0.5663	0.0516
09/10	0.4333	0.4061	0.4026	0.0528	0.5246	0.4895	0.4906	0.0460
10/11	0.4000	0.3538	0.3466	0.0573	0.4740	0.4438	0.4476	0.0454
11/12	0.3475	0.3068	0.2934	0.0583	0.4849	0.4558	0.4564	0.0452
12/13	0.4149	0.4035	0.3958	0.0546	0.4367	0.4355	0.4315	0.0464
13/14	0.3387	0.3198	0.3207	0.0534	0.4170	0.4088	0.4094	0.0463
14/15	0.2990	0.2844	0.2858	0.0583	0.3935	0.3739	0.3786	0.0504
15/16	0.2412	0.2198	0.2260	0.0571	0.3438	0.3336	0.3358	0.0473
16/17	0.2502	0.2621	0.2542	0.0620	0.3425	0.3406	0.3364	0.0490

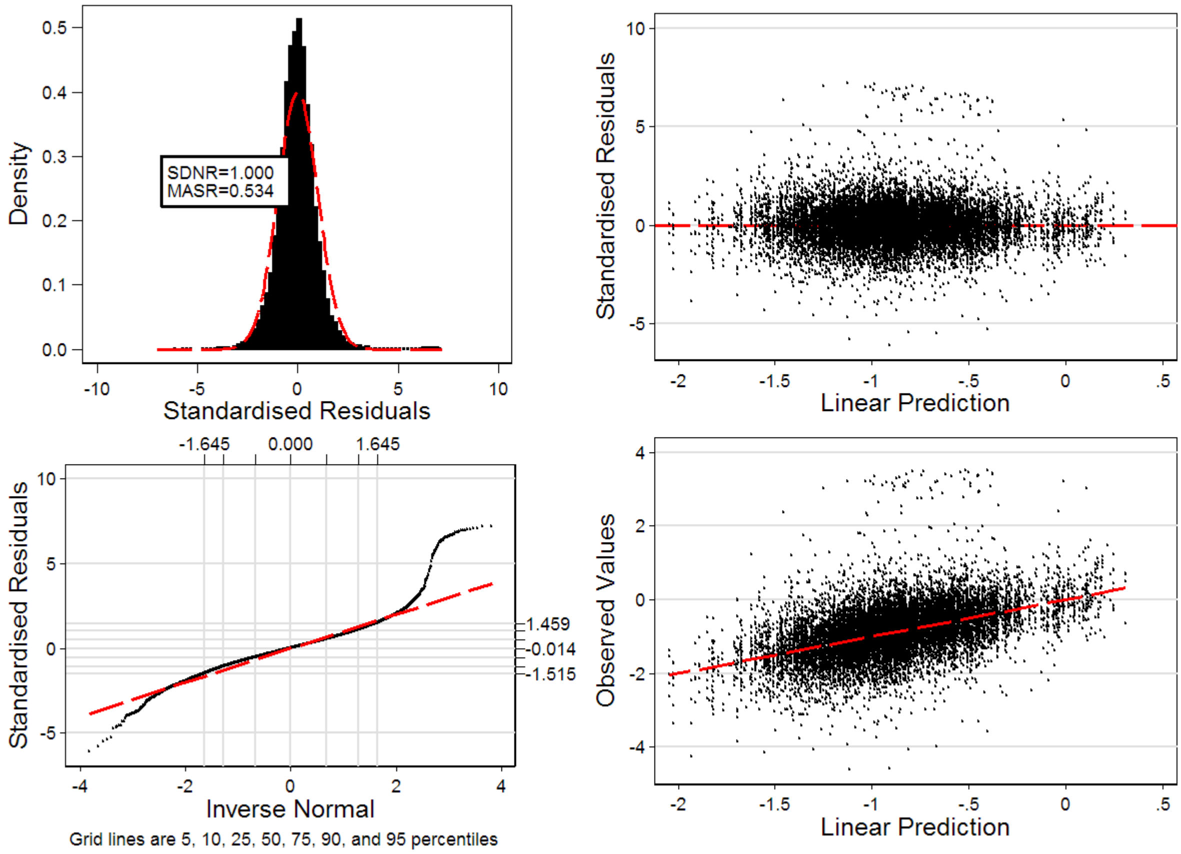

Figure C.1: Standardised residuals for the CRA 2 seasonal CPUE GLM analysis without the inclusion of a vessel explanatory variable.

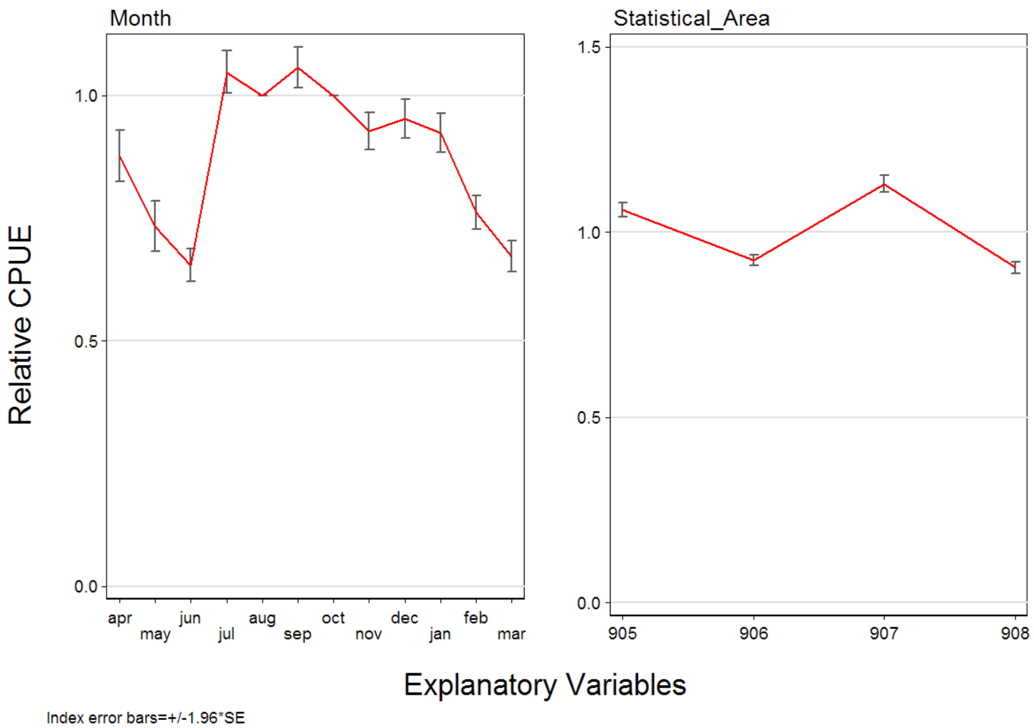

Figure C.2: Coefficients for month and statistical area from the CRA 2 seasonal CPUE standardisation without the inclusion of a vessel explanatory variable. Month coefficients are not in canonical form, with each of the two reference months (August and October) set to 1.0 and the associated SE set to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

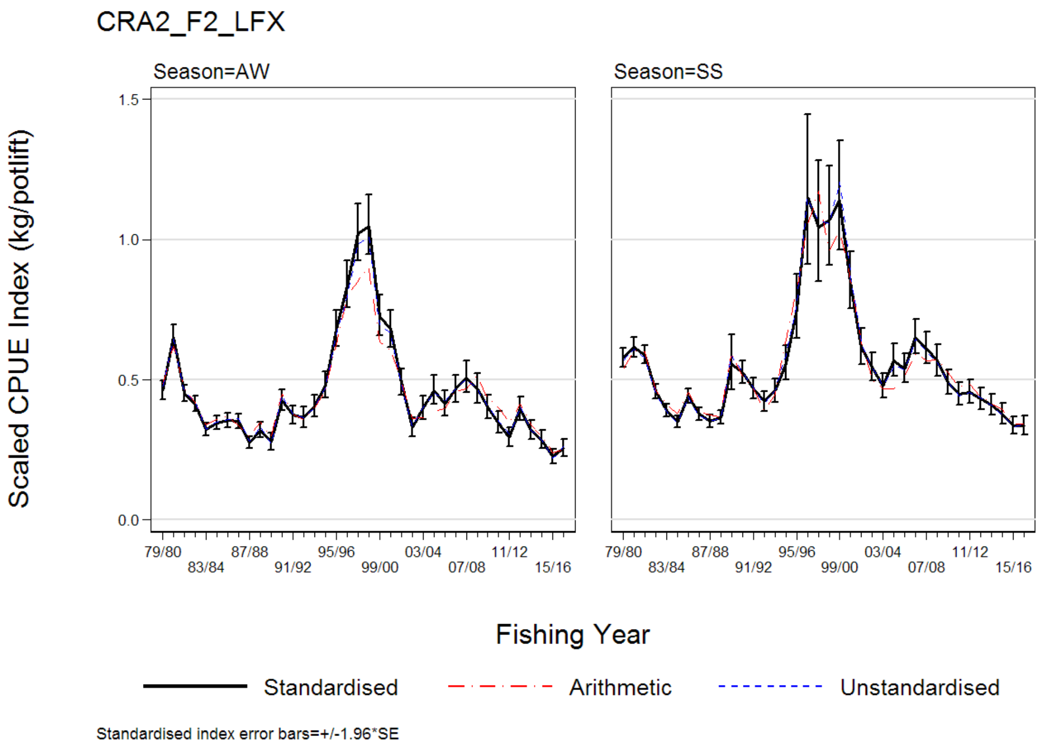

Figure C.3: Standardised, unstandardised (geometric mean), and arithmetic mean CPUE indices (kg/potlift) by season and fishing year for the CRA 2 CPUE analysis without including a vessel explanatory variable and using the F2 algorithm scaled to "LFX" landings from 1979–80 to 2016–17: AW ($^{g}\overline{\mu}$ =0.43 kg/potlift) and SS ($^{g}\overline{\mu}$ =0.53 kg/potlift).

APPENDIX D. DOCUMENTATION FOR CRA 2 ANNUAL (1 APRIL–31 MARCH) CPUE ANALYSIS

The data used are described in the first two paragraphs in Section 3.1.1 and the methods followed are documented in Starr (2017a). A [vessel] explanatory variable was added to this model, selecting only those vessels with at least five years experience in the fishery. Unlike previous series which did not include a vessel explanatory variable, this series excluded the FSU data because the vessel codes in the FSU data base are not consistent with the current MPI Warehou data base. Consequently, this series begins with the 1989–90 fishing year, the first complete rock lobster fishing year in the Warehou data base, with the exception of April–June 1989, which predate the start of the MPI Warehou database on 01 July 1989 (Bentley et al. 2005).

The quantity of vessel/month/statistical area records available to this analysis are provided in Table D.1. The amount of deviance explained by each model variable is given in Table D.2 and the index values with the associated standard errors are provided in Table D.3. Model residuals are shown in Figure D.1. Coefficient-distribution-influence (CDI) plots (Bentley et al. 2012) are provided for the vessel explanatory variable (Figure D.2), for the month variable (Figure D.3) and for the statistical area variable (Figure D.4). A “stepwise” graph, showing the effect on the year index variable with the addition of each model explanatory variable, is given in Figure D.5 and the trajectory of the final year standardised indices is shown in Figure D.6. Figure D.7 shows the effect on the standardised year index under different vessel filtering assumptions, with the three index series which included a vessel explanatory variable having very similar trends regardless of whether the included vessels were constrained by three, five or ten year experience assumptions. All three series using the vessel explanatory variable lie below the series without this variable, starting around 2001–2002.

Table D.1: Number of vessel/statistical area/month records in the dataset used to calculate the CRA 2 annual CPUE time series after removal of vessels with less than five years experience in the fishery. Cells with <10 observations are highlighted in grey; ‘–’: no data.

Fishing	Statistical Area				
Year	905	906	907	908	Total
89/90	19	2	–	–	21
90/91	30	97	38	13	178
91/92	44	109	50	21	224
92/93	50	134	38	35	257
93/94	51	136	26	56	269
94/95	45	121	23	50	239
95/96	29	103	17	48	197
96/97	25	85	13	27	150
97/98	34	98	21	27	180
98/99	50	88	18	32	188
99/00	36	82	28	28	174
00/01	41	111	28	38	218
01/02	61	116	39	40	256
02/03	56	126	34	53	269
03/04	64	109	44	70	287
04/05	41	109	32	64	246
05/06	78	103	39	66	286
06/07	77	119	34	58	288
07/08	75	114	27	61	277
08/09	70	102	28	50	250
09/10	89	117	33	57	296
10/11	78	100	33	66	277
11/12	67	114	32	61	274
12/13	70	112	32	63	277
13/14	62	102	32	68	264
14/15	36	97	30	59	222
15/16	47	92	34	46	219
16/17	57	69	35	33	194
Total	1482	2867	838	1290	6477

Table D.2: Total deviance (R^2) explained by each variable in the CRA 2 standardised annual CPUE model.

Variable	**1**	**2**		**3**
Fishing Year (28)	0.1827			
Vessel (79)	0.2357	0.3796		
Month (12)	0.0719	0.2866	0.4882	
Statistical Area (4)	0.0132	0.1983	0.3809	**0.4892**
Additional deviance explained	0	0.1970	0.1086	0.0011

Table D.3: Annual CPUE indices calculated from the analysis of CRA 2 catch and potlift data which included a vessel explanatory variable using vessels with at least five years experience in the fishery. Arithmetic index: sum(annual catch)/sum(potlifts); Unstandardised index: geometric mean of the CPUE observations by year; Standardised index: annual index, after extracting vessel, month and statistical area effects.

Fishing year	**Arithmetic Index**	**Unstandardised Index**	**Standardised Index**	**Lower Bound**	**Upper Bound**	**Standard Error**
89/90	0.4972	0.5924	0.6492	0.5221	0.8071	0.1111
90/91	0.5285	0.5181	0.5528	0.5099	0.5993	0.0412
91/92	0.4414	0.4391	0.4978	0.4624	0.5358	0.0376
92/93	0.3799	0.3930	0.4445	0.4151	0.4759	0.0349
93/94	0.4248	0.4344	0.5061	0.4737	0.5407	0.0337
94/95	0.5122	0.5067	0.6143	0.5738	0.6576	0.0348
95/96	0.6550	0.6622	0.8283	0.7700	0.8909	0.0372
96/97	0.7791	0.8042	1.0064	0.9268	1.0929	0.0421
97/98	0.8652	0.9532	1.1186	1.0382	1.2052	0.0380
98/99	0.9076	0.9930	1.1478	1.0674	1.2344	0.0371
99/00	0.7071	0.7946	0.8704	0.8076	0.9382	0.0382
00/01	0.6873	0.7084	0.7322	0.6850	0.7826	0.0340
01/02	0.5518	0.5374	0.5156	0.4845	0.5486	0.0317
02/03	0.4354	0.4269	0.3878	0.3649	0.4121	0.0310
03/04	0.4234	0.4312	0.3881	0.3658	0.4118	0.0303
04/05	0.4392	0.4892	0.4607	0.4320	0.4913	0.0329
05/06	0.4649	0.4776	0.4286	0.4037	0.4550	0.0305
06/07	0.5346	0.5526	0.5078	0.4783	0.5390	0.0305
07/08	0.5233	0.5215	0.4831	0.4548	0.5133	0.0309
08/09	0.5460	0.5016	0.4554	0.4272	0.4854	0.0326
09/10	0.4919	0.4644	0.4155	0.3918	0.4407	0.0300
10/11	0.4504	0.4117	0.3696	0.3477	0.3928	0.0311
11/12	0.4378	0.3862	0.3415	0.3212	0.3631	0.0312
12/13	0.4245	0.4059	0.3591	0.3378	0.3817	0.0312
13/14	0.3852	0.3556	0.3259	0.3058	0.3472	0.0324
14/15	0.3608	0.3292	0.2939	0.2744	0.3148	0.0350
15/16	0.3044	0.2747	0.2417	0.2254	0.2591	0.0356
16/17	0.3079	0.2983	0.2529	0.2352	0.2721	0.0372

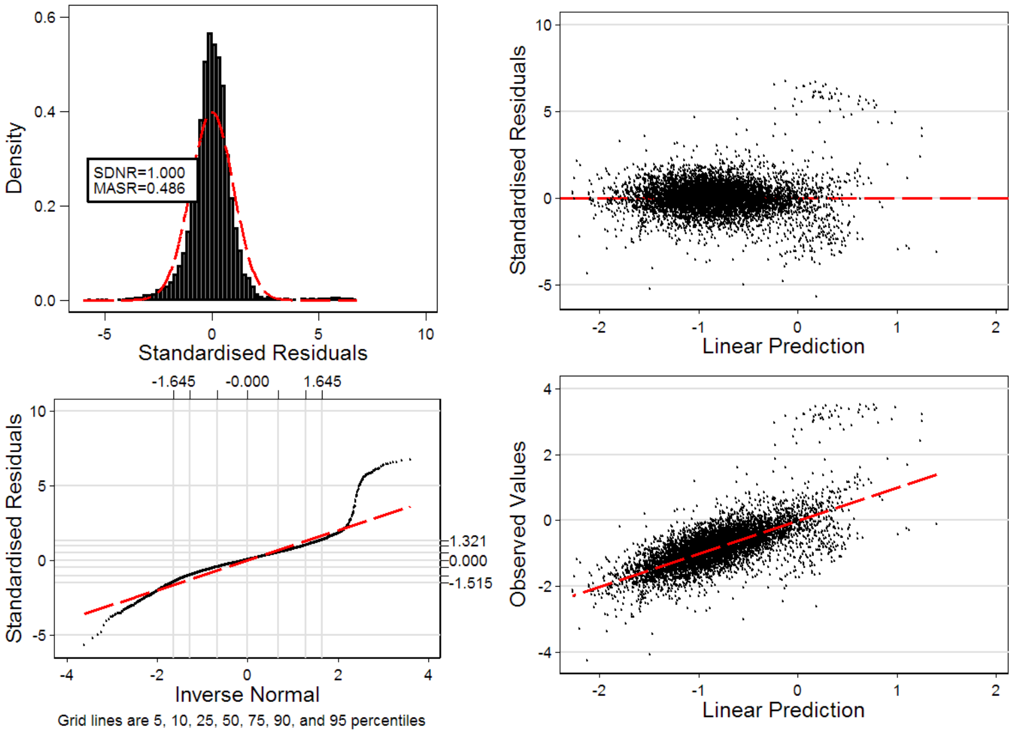

Figure D.1: Standardised residual plots for the CRA 2 standardised annual CPUE analysis which included a vessel explanatory variable using vessels with at least five years experience in the fishery.

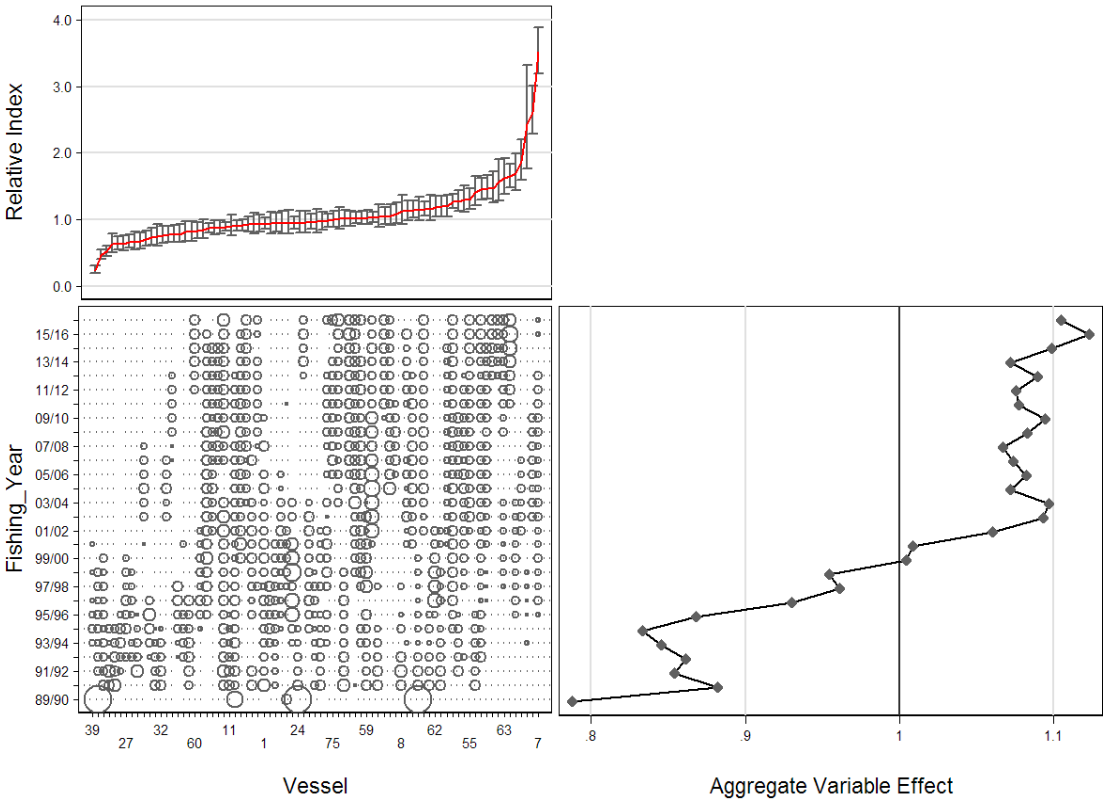

Figure D.2: The effect of the vessel categorical variable (filtered for vessels with at least five years experience in the fishery) in the annual CRA 2 lognormal regression model: top left: effect by level of variable; bottom-left: distribution of variable by year; bottom-right: cumulative effect of variable by year.

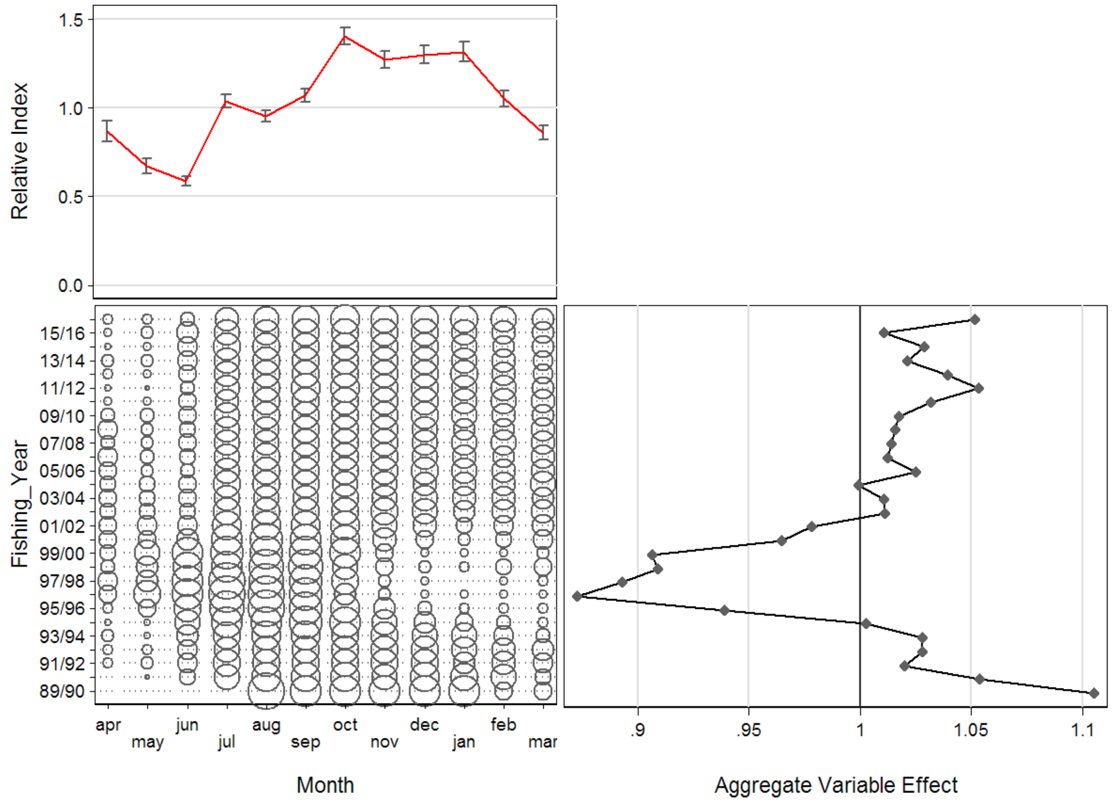

Figure D.3: The effect of the month categorical variable in the annual CRA 2 lognormal regression model: top left: effect by level of variable; bottom-left: distribution of variable by year; bottom-right: cumulative effect of variable by year.

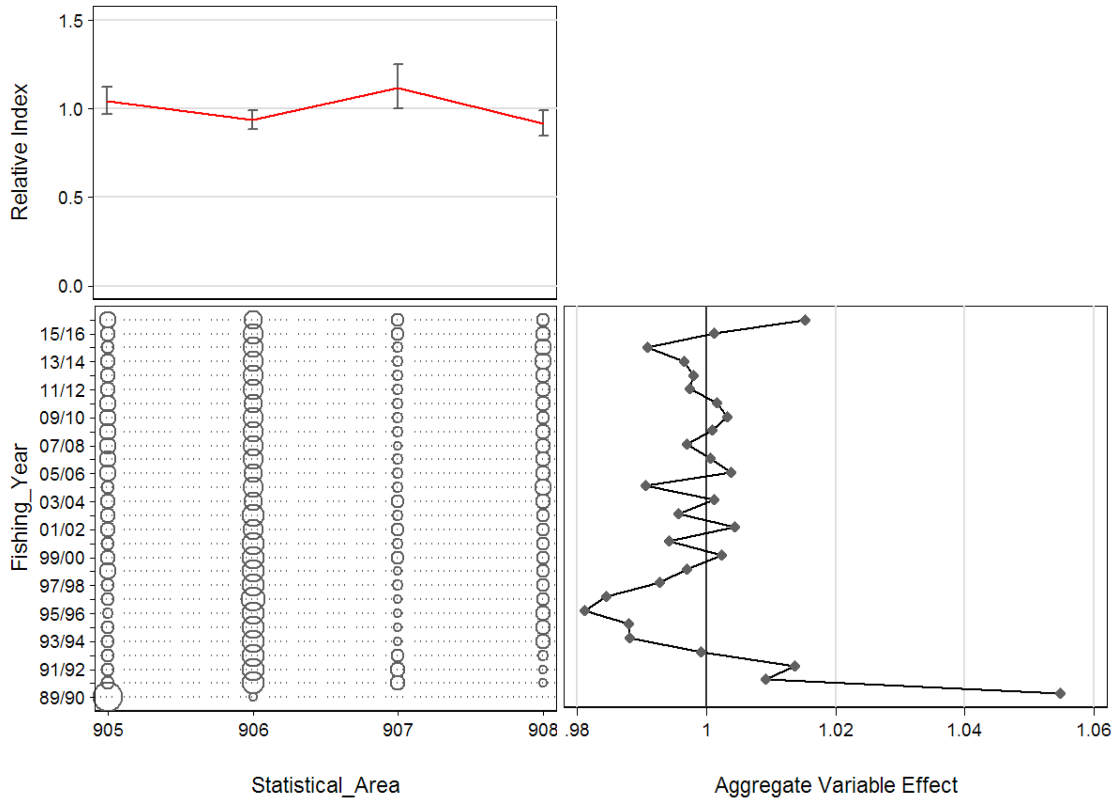

Figure D.4: The effect of the statistical area categorical variable in the annual CRA 2 lognormal regression model: top left: effect by level of variable; bottom-left: distribution of variable by year; bottom-right: cumulative effect of variable by year.

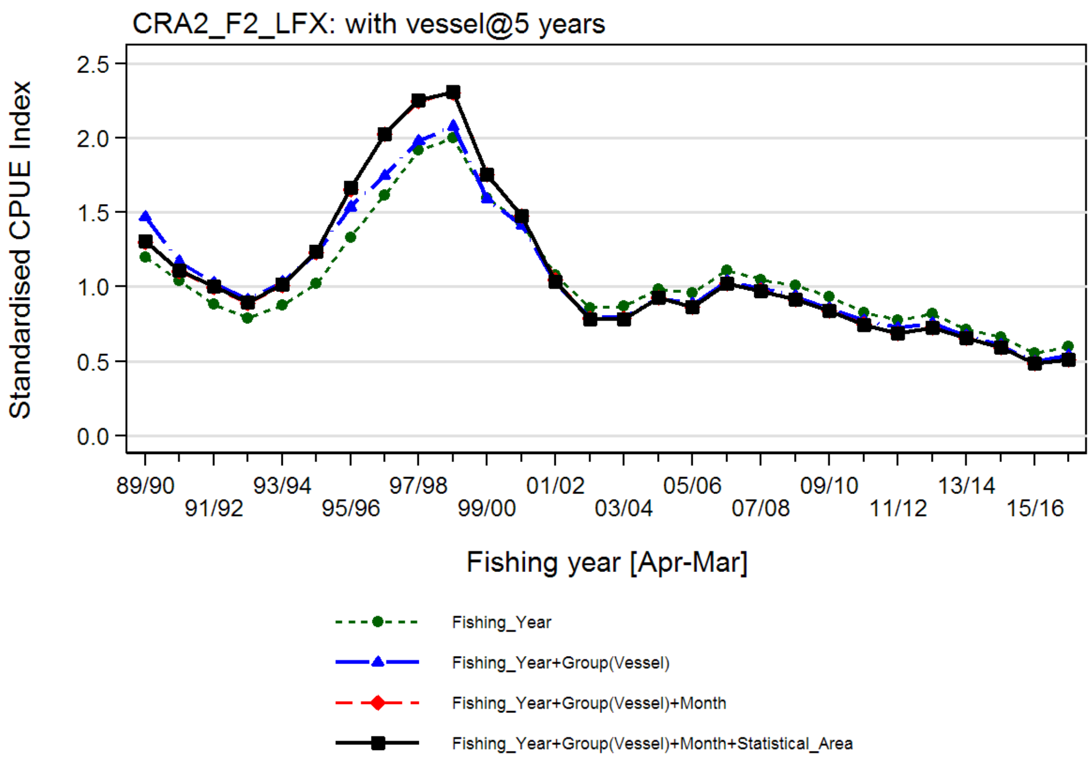

Figure D.5: **Stepwise graph showing the effect on the year coefficients from the successive addition of each categorical variable to the annual CRA 2 lognormal regression model. The final model is shown by a thick heavy line.**

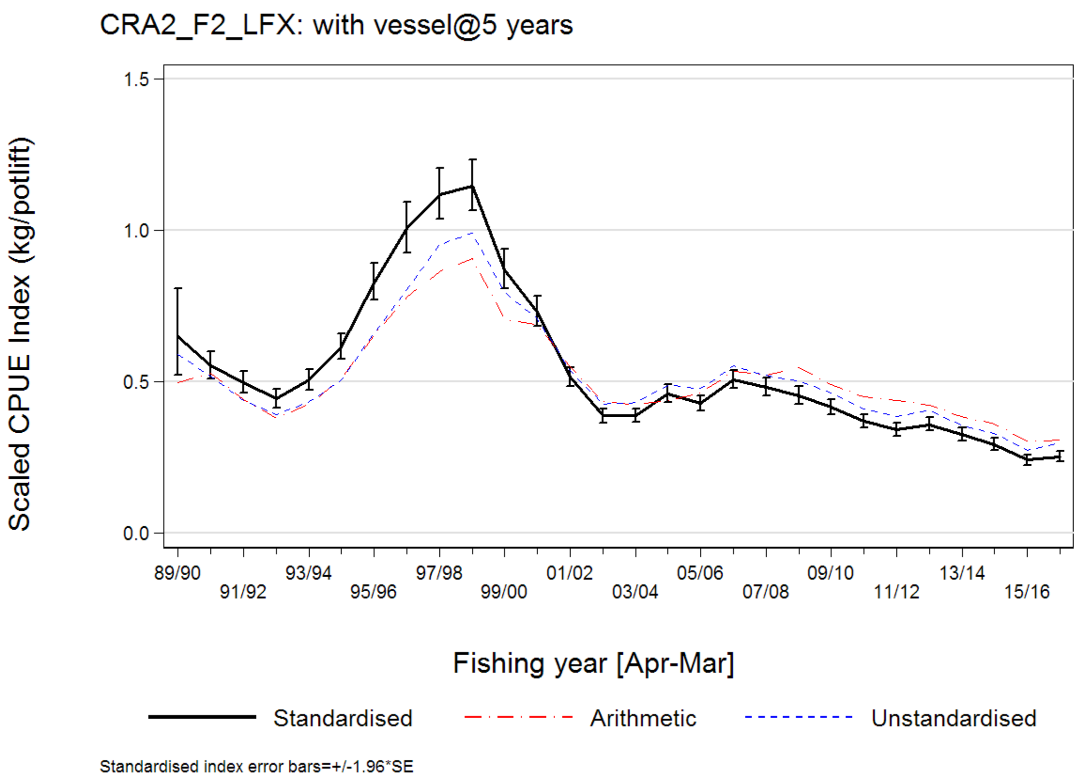

Figure D.6: **Annual CPUE indices for CRA 2: arithmetic (dashed line), unstandardised (dotted line), and standardised (bold line) ± 1.96 s.e. from 1989–90 to 2016–17. The geometric mean for each series = 0.50 kg/potlift.**

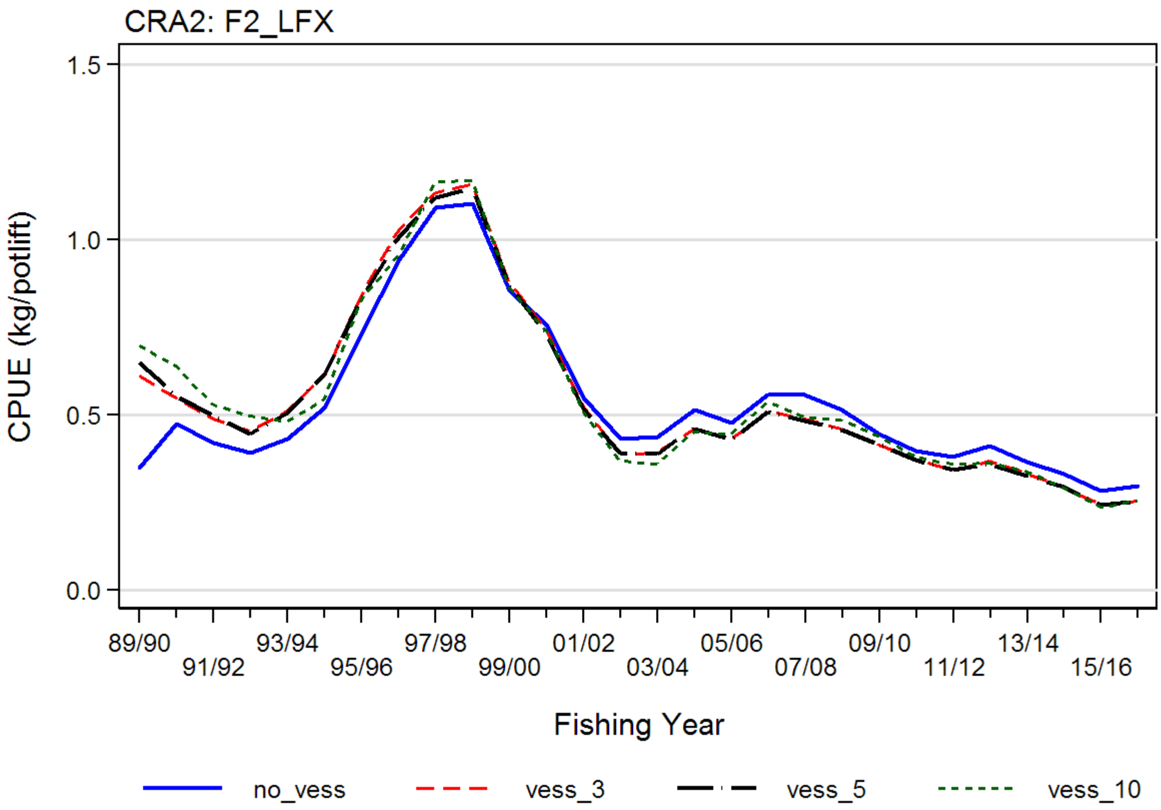

Figure D.7: Comparison of the year effect trajectories after standardising under four vessel experience filtering assumptions: (a) no filter; (b) at least three years experience; (c) at least five years experience; (d) at least ten years experience.

APPENDIX E. LENGTH FREQUENCY DISTRIBUTIONS FROM LOGBOOK AND CATCH SAMPLING

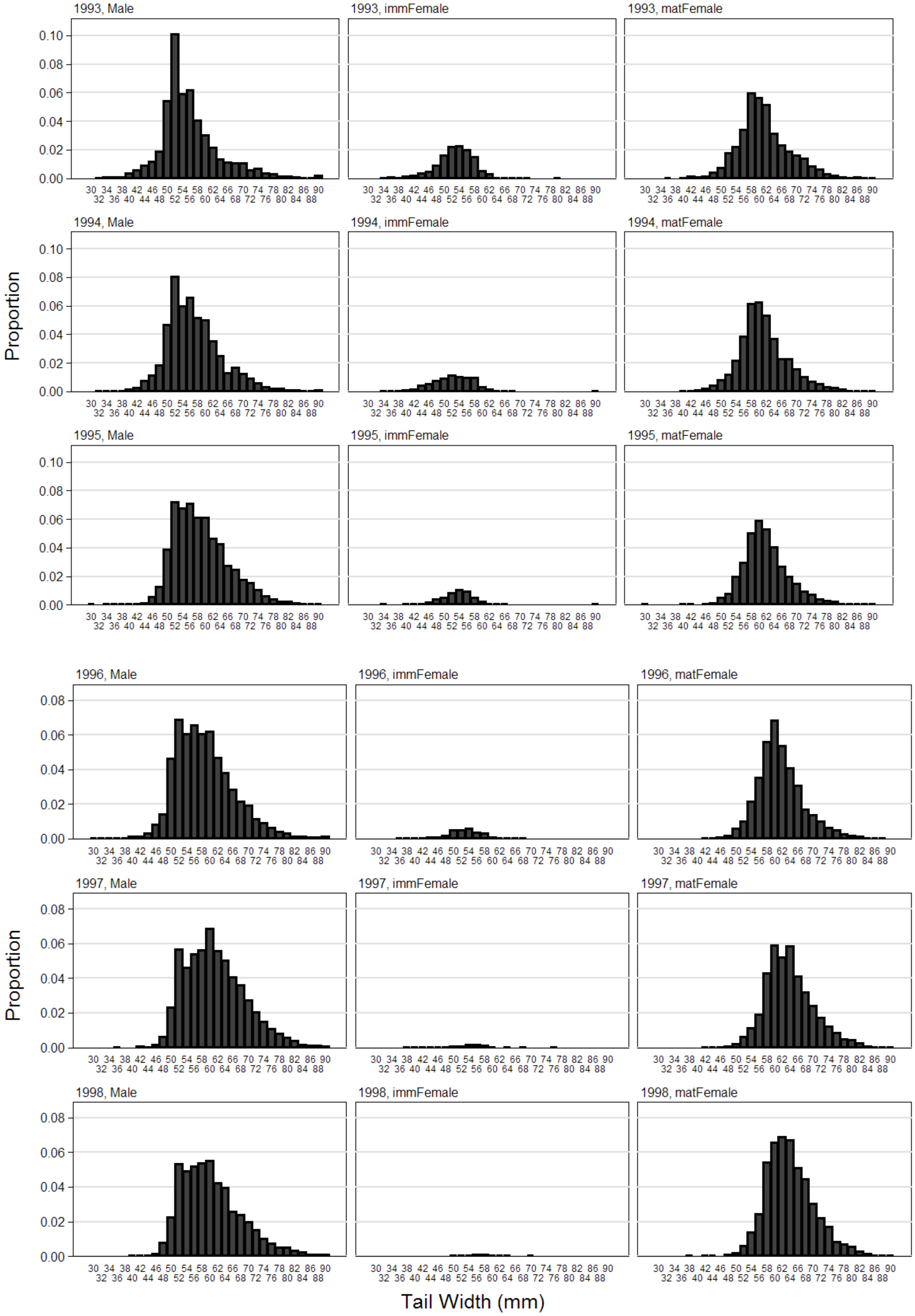

Figure E.1A: Length frequency histograms by sex category for AW logbook sampling, 1993–1998. Each year (row) sums to 1.0.

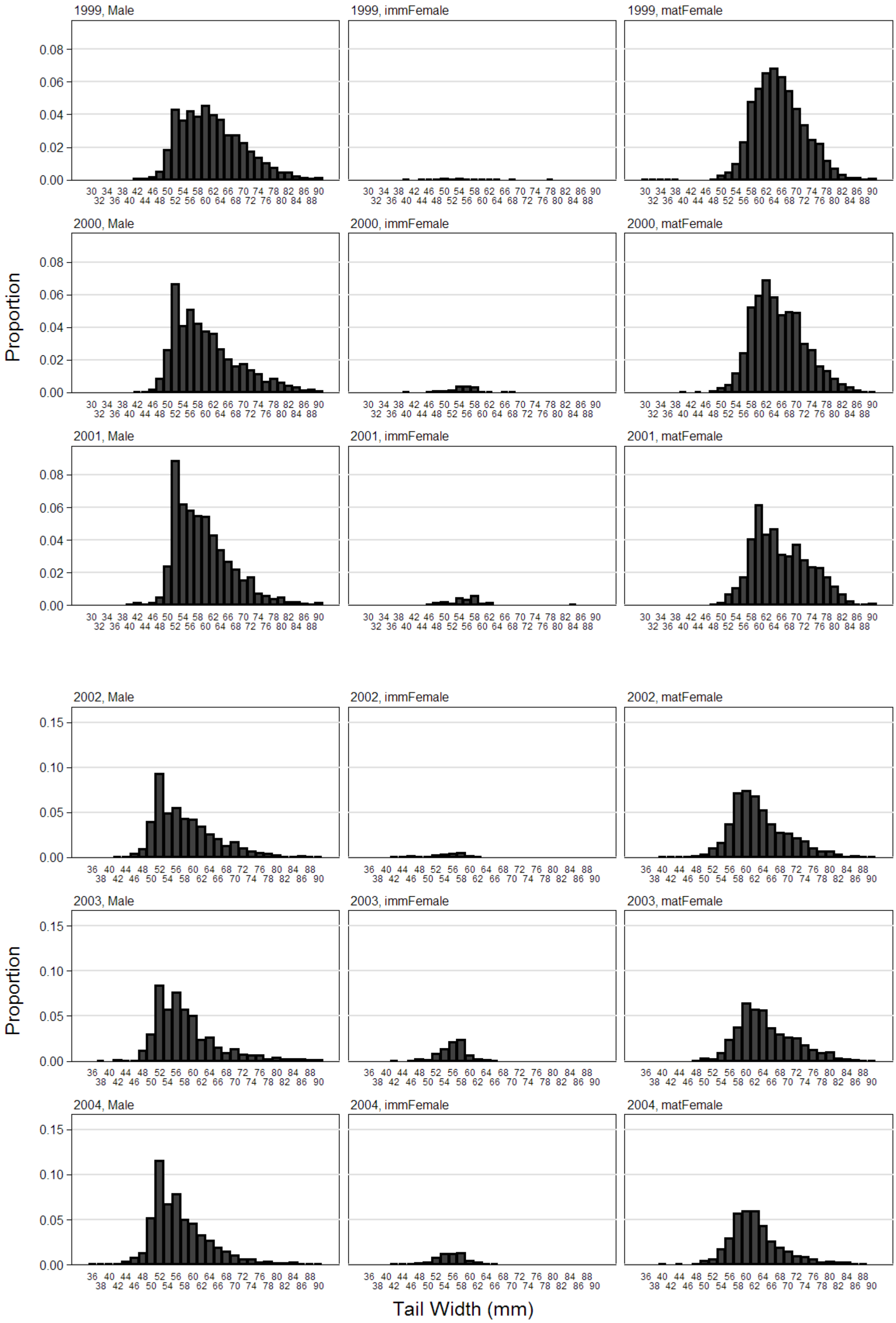

Figure E.1B: Length frequency histograms by sex category for AW logbook sampling, 1998–2004. Each year (row) sums to 1.0.

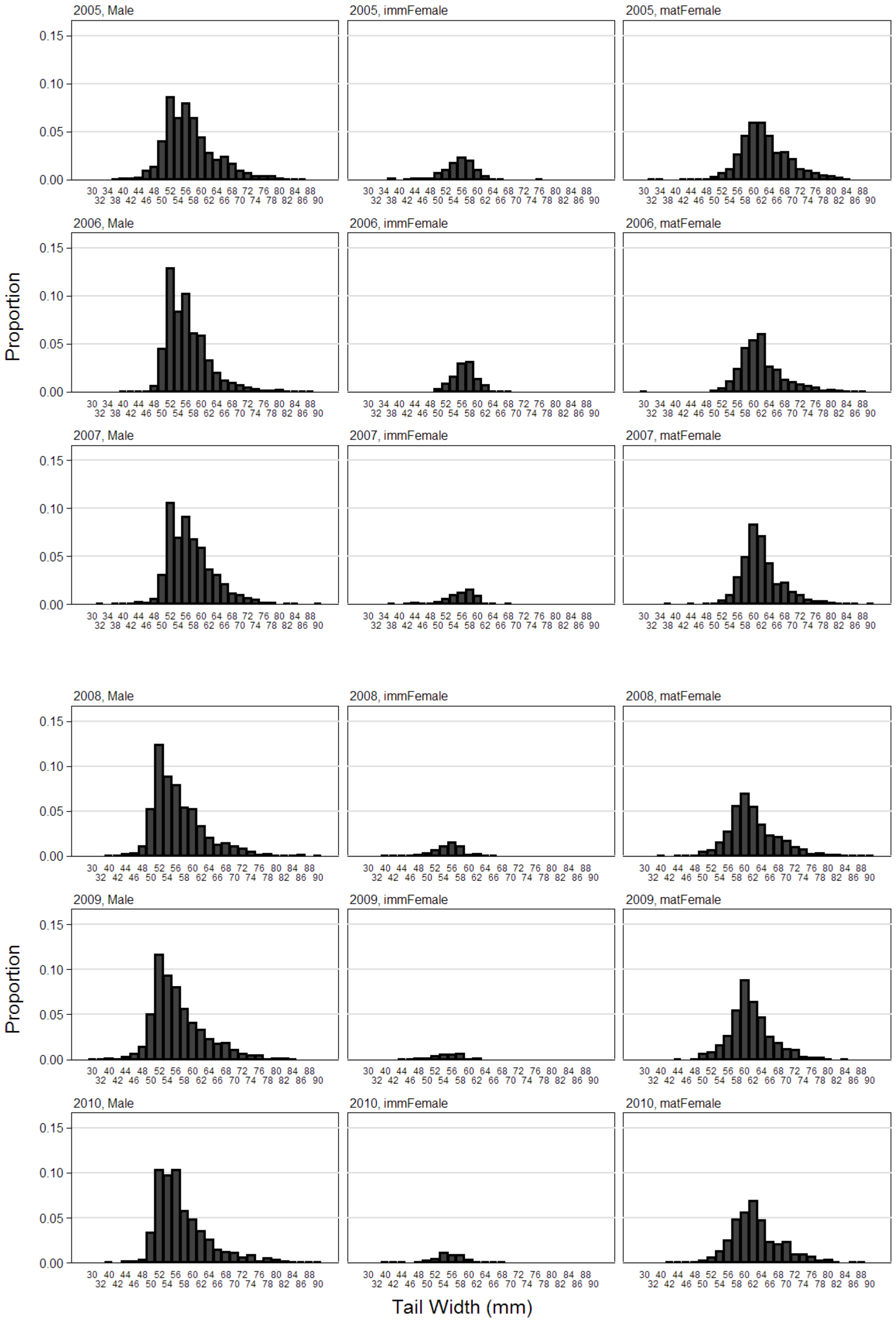

Figure E.1C: Length frequency histograms by sex category for AW logbook sampling, 2005–2010. Each year (row) sums to 1.0.

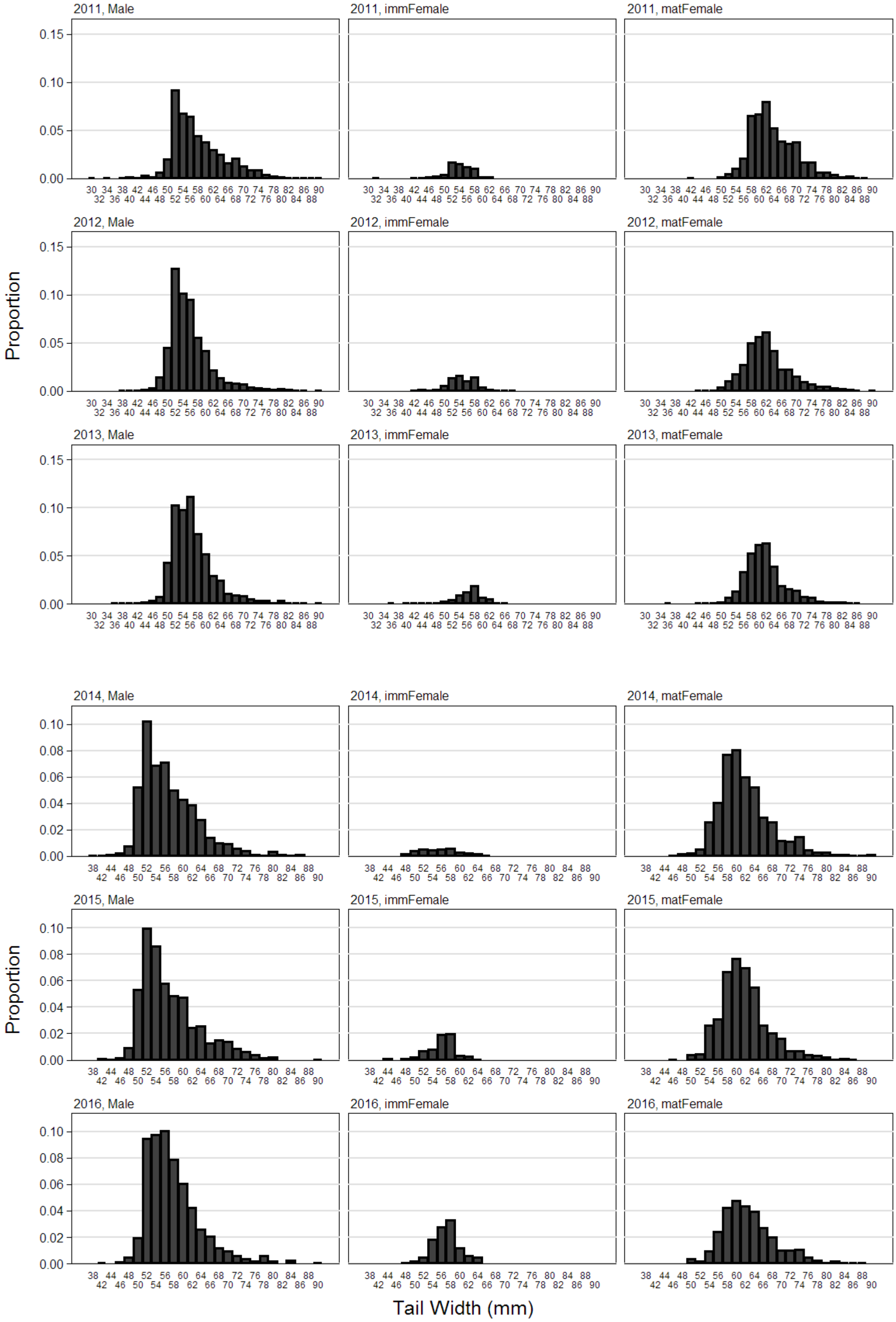

Figure E.1D: Length frequency histograms by sex category for AW logbook sampling, 2011–2016. Each year (row) sums to 1.0.

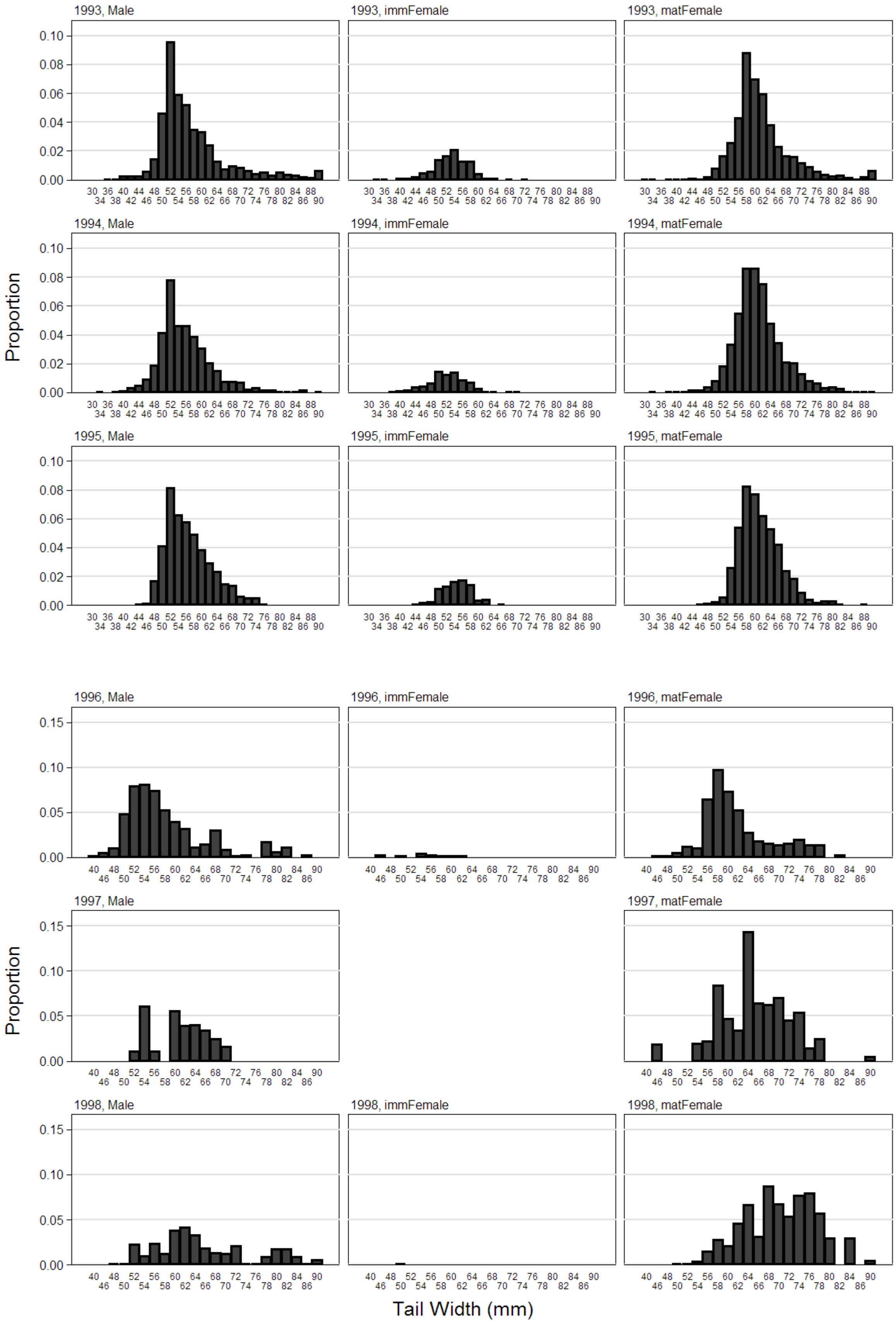

Figure E.2A: Length frequency histograms by sex category for SS logbook sampling, 1993–1998. Each year (row) sums to 1.0.

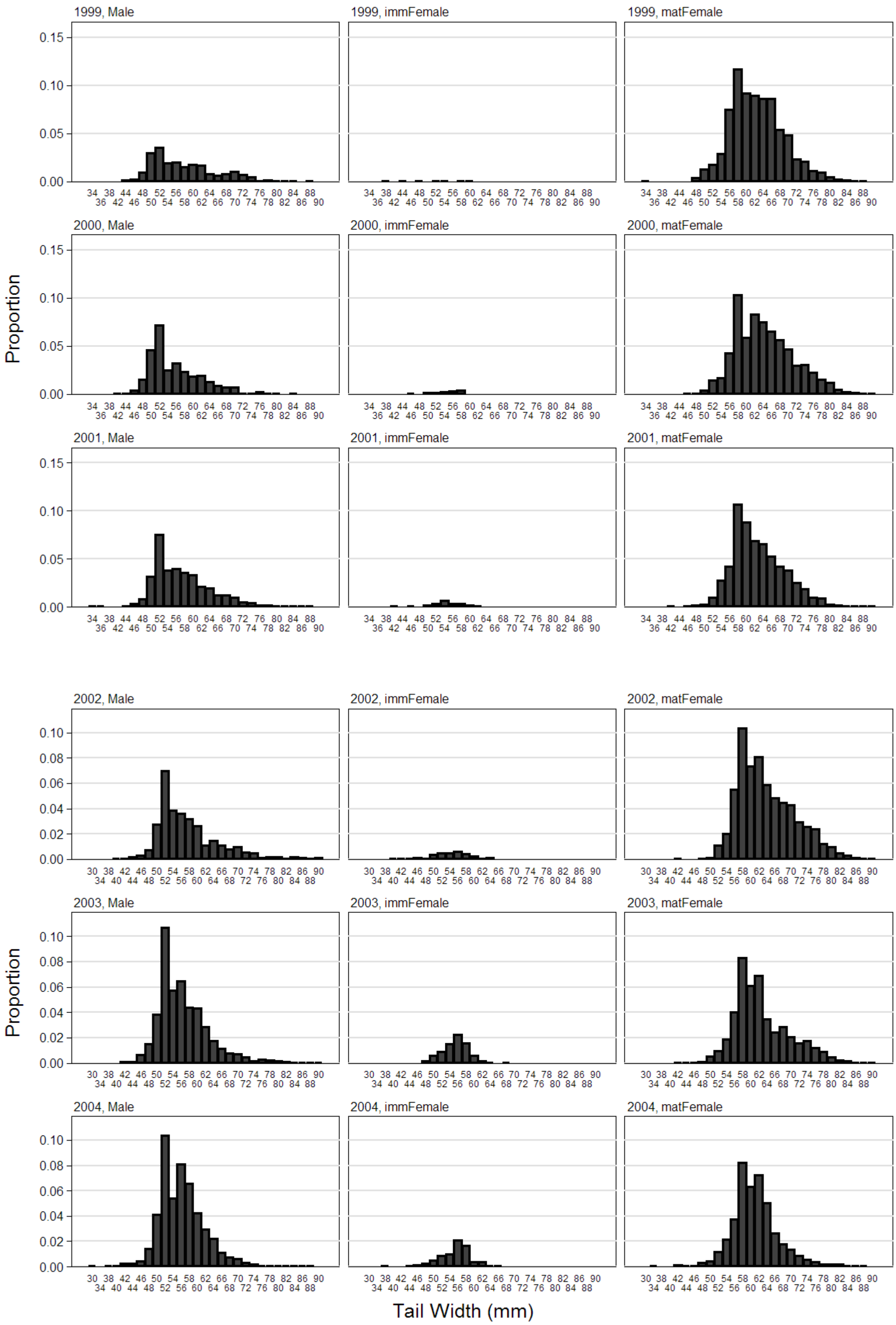

Figure E.2B: Length frequency histograms by sex category for SS logbook sampling, 1999–2004. Each year (row) sums to 1.0.

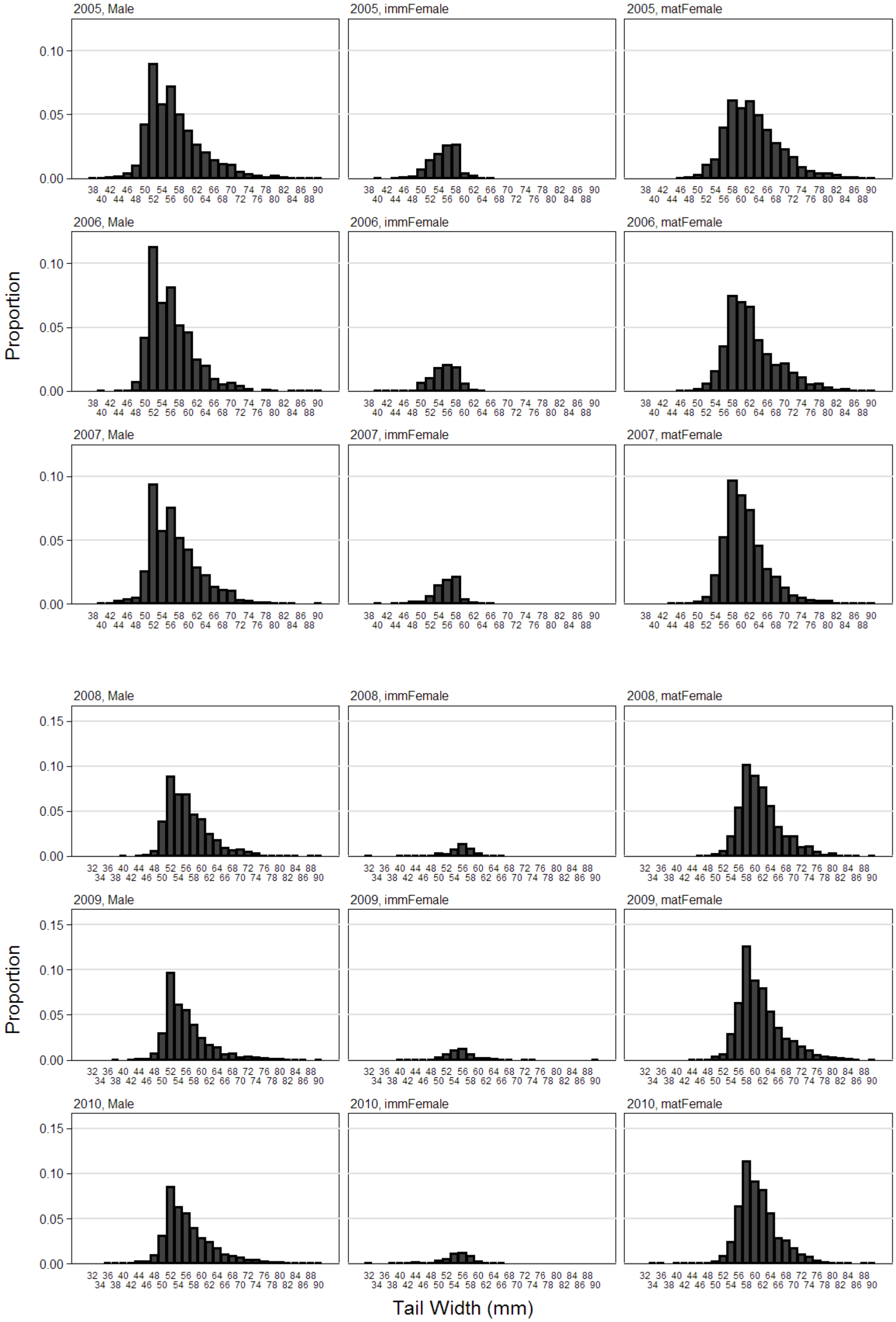

Figure E.2C: Length frequency histograms by sex category for SS logbook sampling, 2005–2010. Each year (row) sums to 1.0.

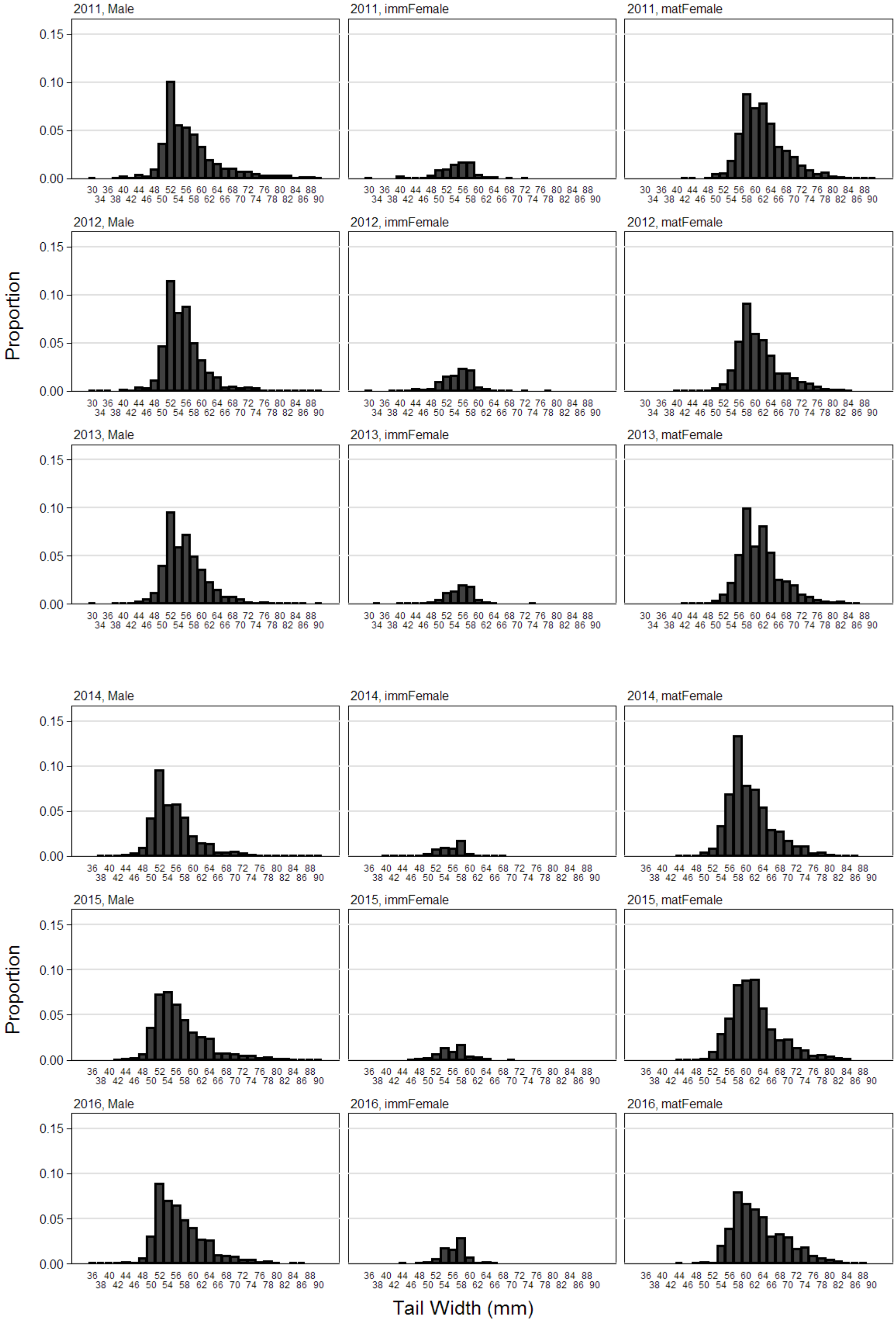

Figure E.2D: Length frequency histograms by sex category for SS logbook sampling, 2011–2016. Each year (row) sums to 1.0.

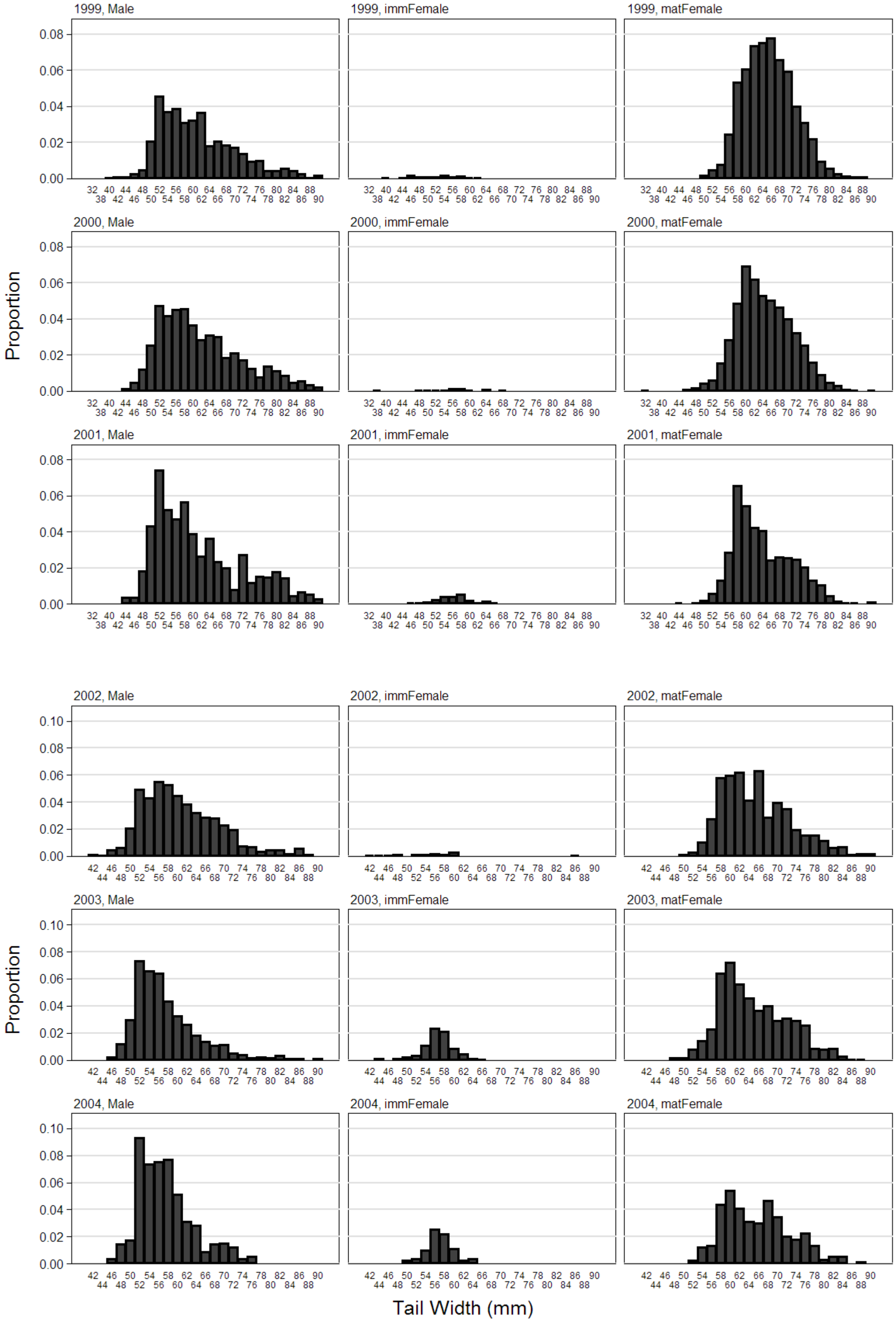

Figure E.3A: Length frequency histograms by sex category for AW observer catch sampling, 1999–2004. Each year (row) sums to 1.0.

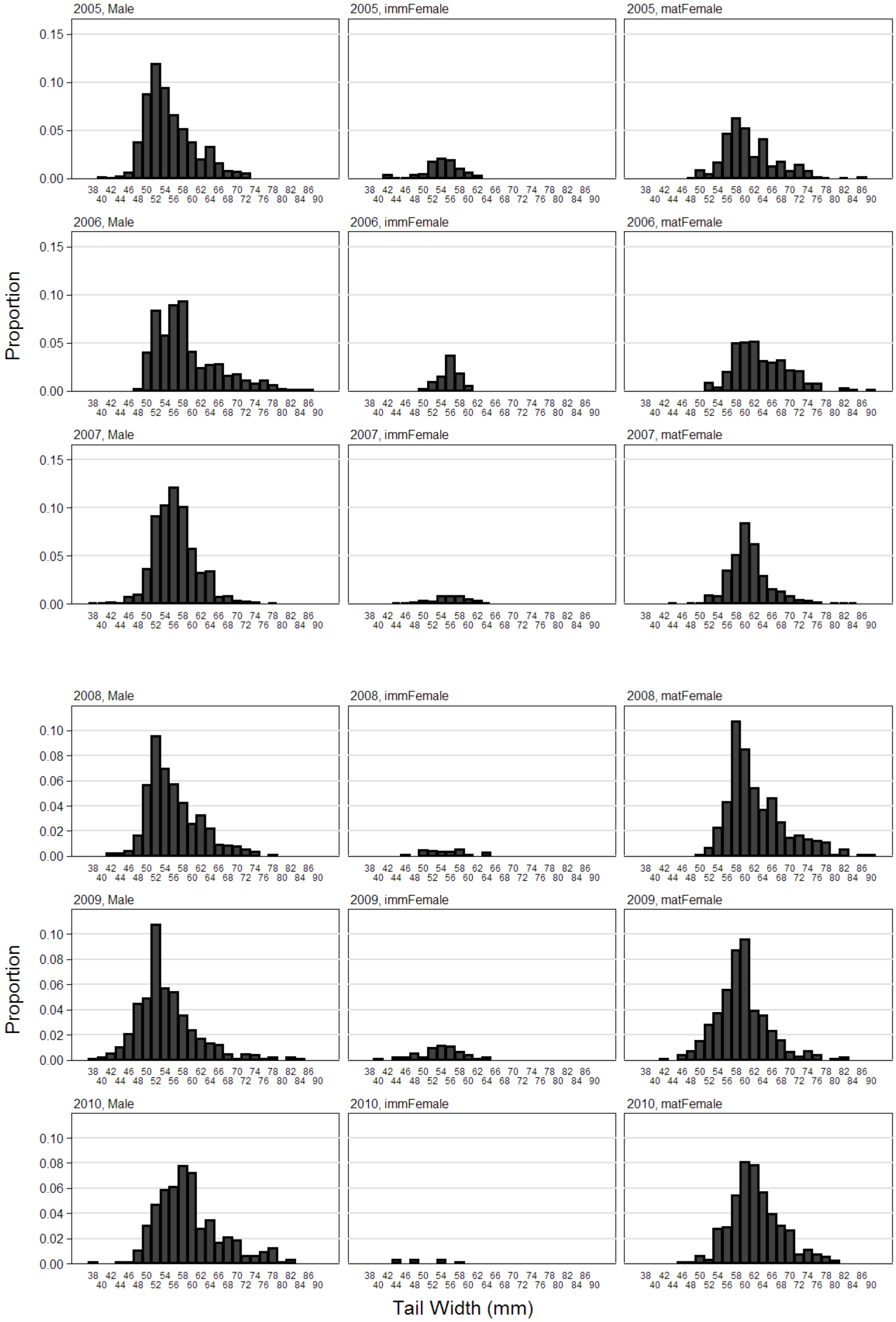

Figure E.3B: Length frequency histograms by sex category for AW observer catch sampling, 2005–2010. Each year (row) sums to 1.0.

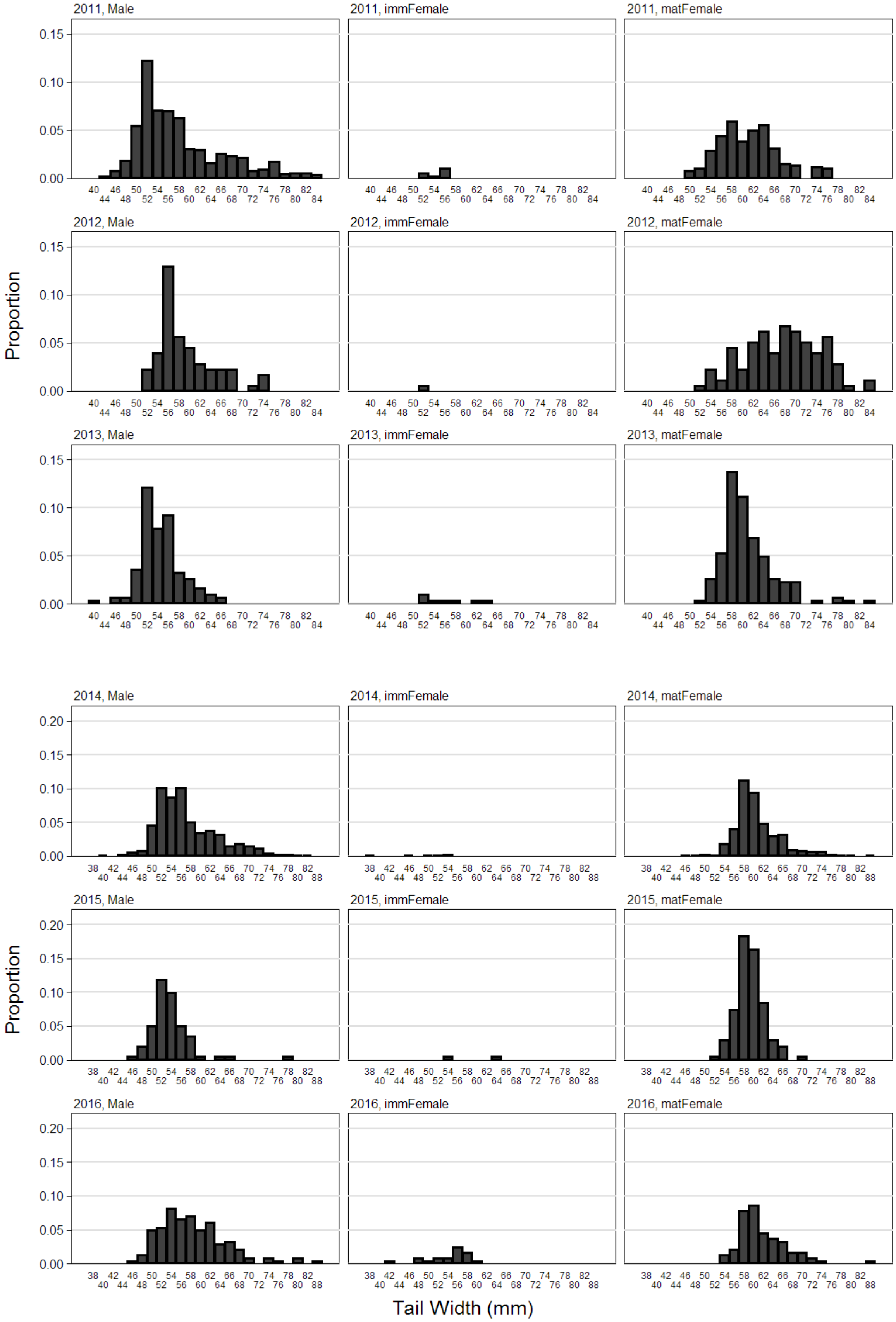

Figure E.3C: Length frequency histograms by sex category for AW observer catch sampling, 2011–2016. Each year (row) sums to 1.0.

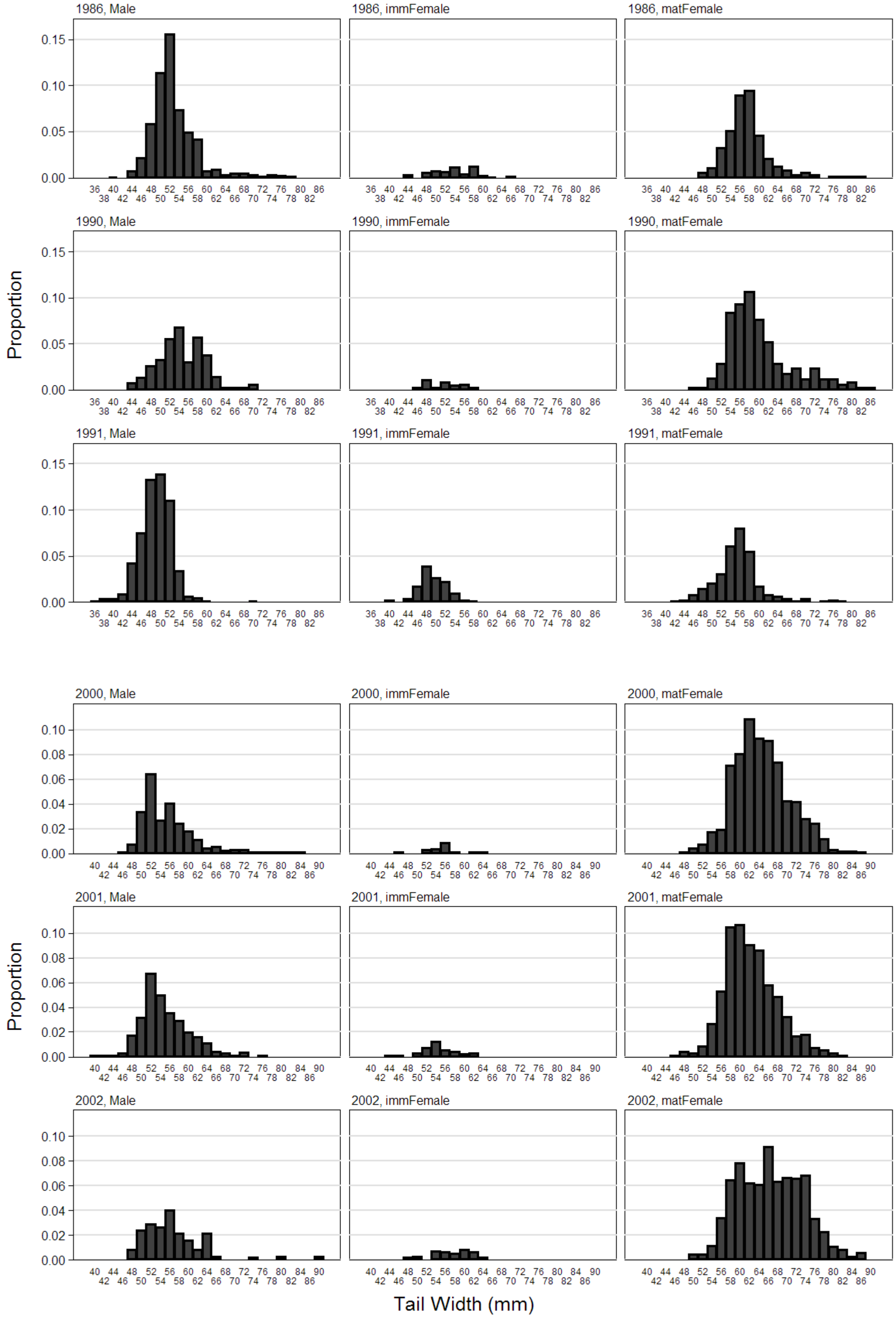

Figure E.4A: Length frequency histograms by sex category for SS observer catch sampling, 1986–2002. Each year (row) sums to 1.0.

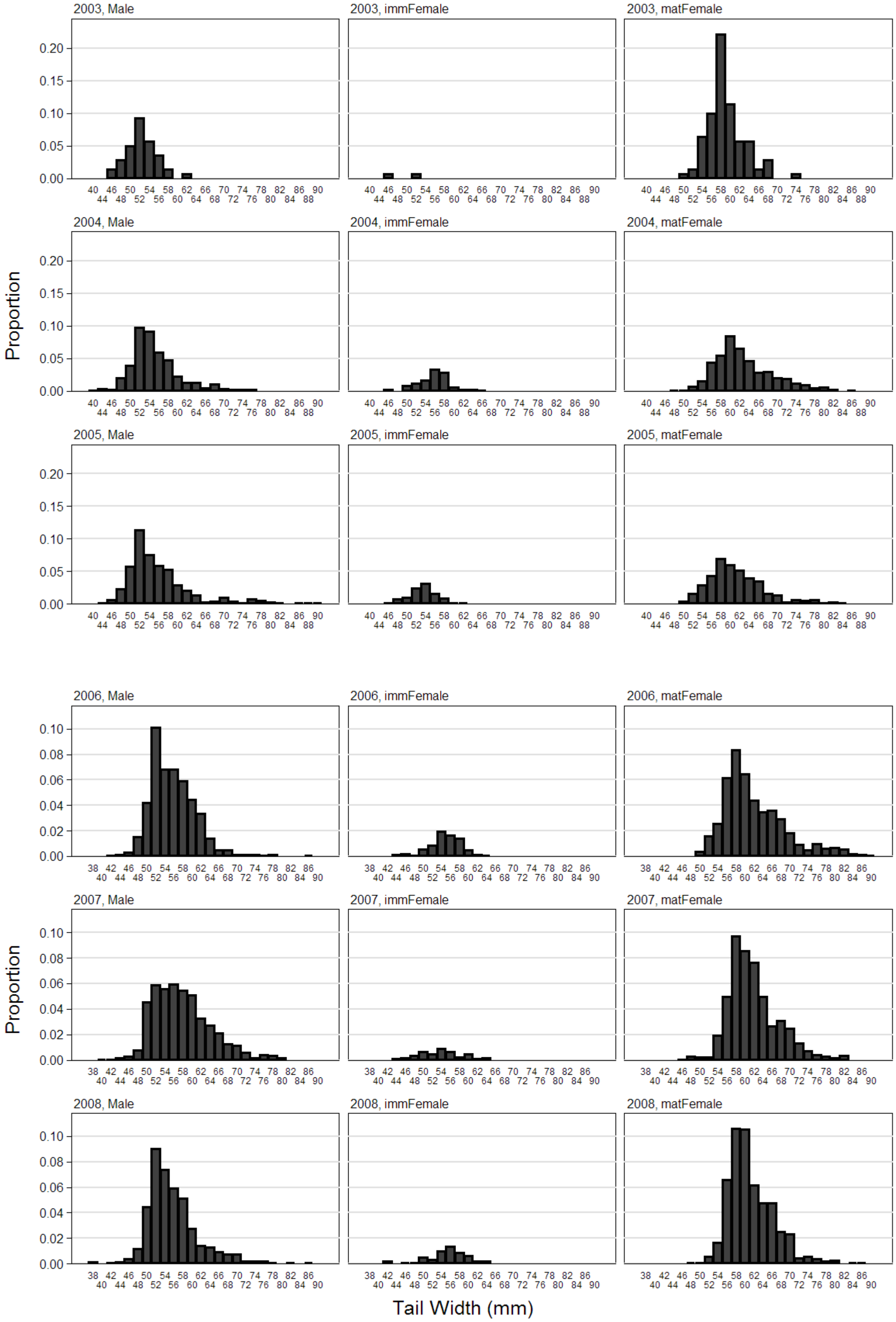

Figure E.4B: Length frequency histograms by sex category for SS observer catch sampling, 2003–2008. Each year (row) sums to 1.0.

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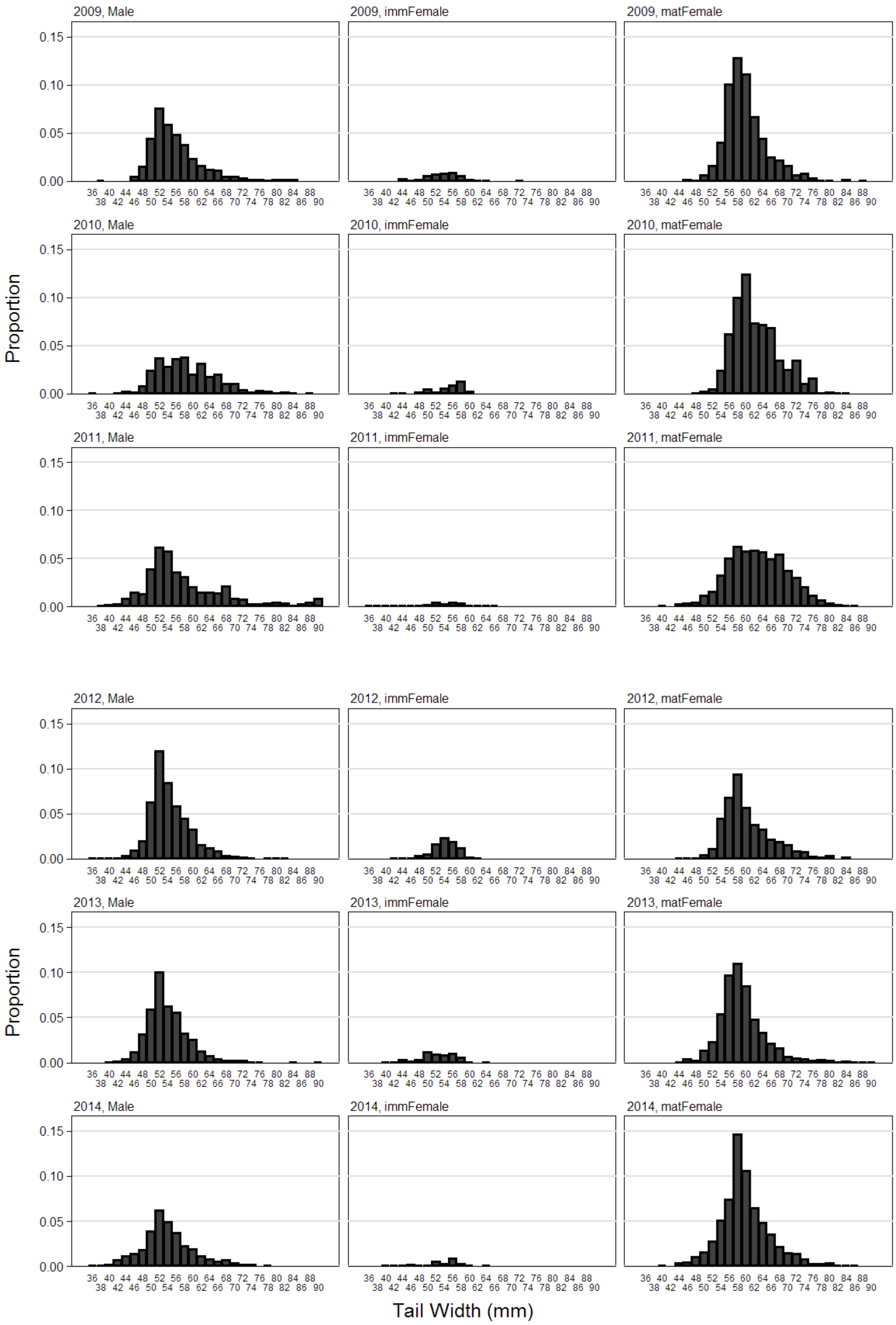

Figure E.4C: Length frequency histograms by sex category for SS observer catch sampling, 2009–2014. Each year (row) sums to 1.0.

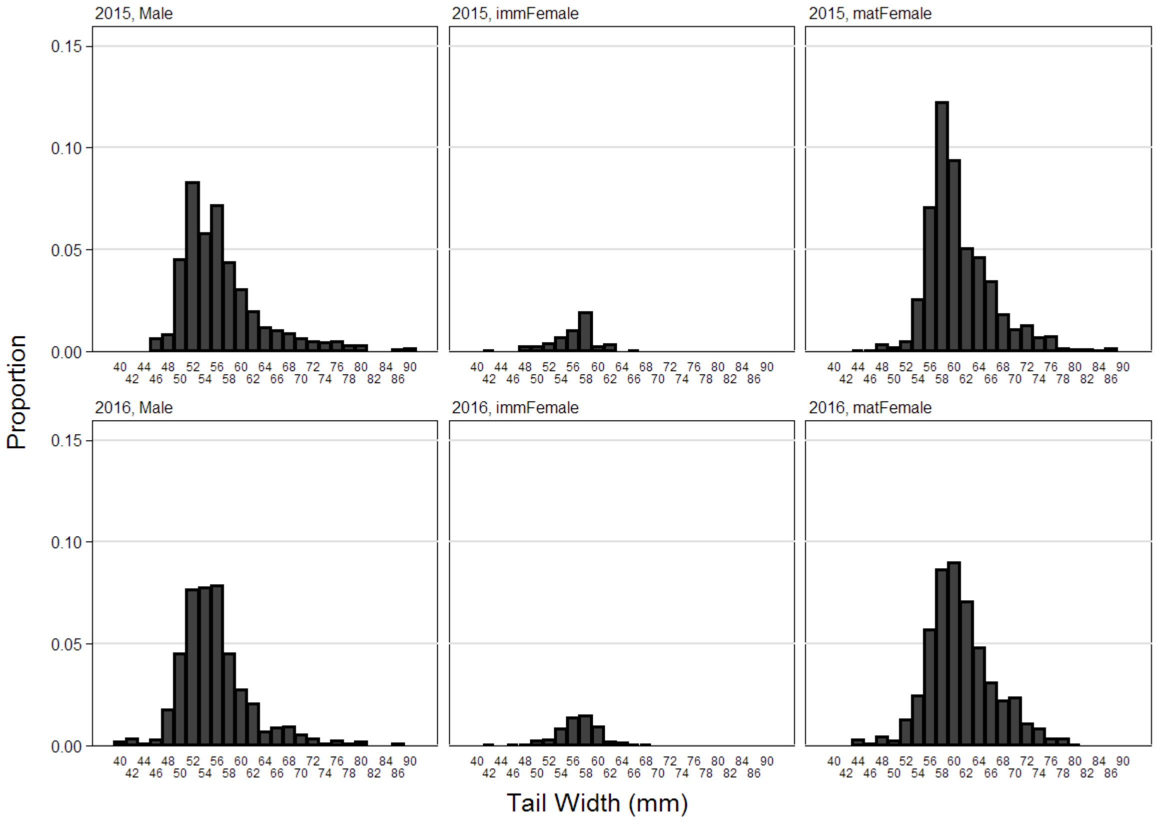

Figure E.4D: Length frequency histograms by sex category for SS observer catch sampling, 2015–2016. Each year (row) sums to 1.0.