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Data for the 2016 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 4

New Zealand Fisheries Assessment Report 2017/28

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

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***New Zealand Fisheries Assessment Report 2017/28.* 48 p.**

This document presents data for use in the 2016 stock assessment and management procedure evaluations for rock lobsters in CRA 4. Data sets described in this report include catch estimates for all sectors of these fisheries, seasonal standardised CPUE indices, length frequency distributions, tag-recapture data and puerulus settlement 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, beginning in 1979, were scaled relative to the mean SS CPUE over the years 1994, 1996 and 2011. 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.

Length frequency data were available from both observer catch sampling and voluntary logbook programmes. These were collated by data source and by season, and the document describes how the individual records were weighted. Tag-recapture data provide information on growth rates for each sex and the document describes the data set. The time series of puerulus settlement data were standardised for two locations, Napier and Castlepoint, which were averaged across years for use in the stock assessment model.

The authors were part of a stock assessment team contracted by the New Zealand Rock Lobster Industry Council Ltd.

1. INTRODUCTION

This work addressed parts of Objectives 3 and 4 of the Ministry for Primary Industries (MPI) contract CRA2015-01A. This three-year contract began in April 2016 and was awarded to New Zealand Rock Lobster Industry Council Ltd. (NZ RLIC Ltd.), who sub-contracted Objectives 3 and 4 to the authors of this report and other contractors. The report deals with red rock lobsters (*Jasus edwardsii*).

Specific objectives addressed by this report:

> *Objective 3 - CPUE and decision rules: To update the standardised CPUE analysis from all lobster QMAs and report on the operation of current decision rules.*
>
> *Objective 4 - Stock assessment: To estimate biomass and sustainable yields for rock lobster stocks.*

The National Rock Lobster Management Group (NRLMG) determined that CRA 4 should be assessed in 2016. Data were compiled for this stock by the authors of this report. Two approaches were adopted for the assessment of CRA 4 in 2016. The first was an assessment which treated the Quota Management Area (QMA) as a single homogeneous stock, an approach that was consistent with previous assessments of CRA 4 and other New Zealand rock lobster QMAs. This assessment was conducted by Paul Breen, Paul Starr and Charles Edwards, with input from D'Arcy Webber and Vivian Haist (Breen et al. 2017). A second approach, which treated each CRA 4 statistical area as an independent entity, with joint estimation of some parameters such as M, was conducted by D'Arcy Webber and Vivian Haist. This latter assessment was considered exploratory and will be reported in a separate document. This document describes catches – including commercial, recreational, customary and illegal – CPUE, length (tail width) frequency data, retention patterns, tag-recapture data and puerulus settlement data for all of CRA 4.

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 CRA 4 stock assessment report (Breen et al. 2017).

1.1 CRA 4

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

The previous stock assessment of CRA 4 was in 2011, with Starr et al. (2012) describing the data and Breen et al. (2012) describing the stock assessment and management procedure evaluations. Both the 2011 and the 2017 stock assessments used the Bayesian multi-stock length-based model (MSLM, Haist et al. 2009). The model was fit to puerulus settlement data, tag-recapture data, standardised CPUE from 1979–2016, historical catch rate data from 1963–1973 and length frequency data from voluntary logbooks and observer catch sampling. Changes in minimum legal size (MLS) and selectivity caused by escape gap regulations were taken into account.

The CRA 4 TAC and TACC were last changed in April 2016, when the management procedure operation indicated that the TACC should be dropped by 4.5% to 446 t from 467 t. However, the CRA 4 industry requested a greater reduction to 397 t, which was granted. The TAC resulting from this lower TACC was 592 t after allowances of 35 t for customary catches, 85 t for recreational catches and 75 t for other mortalities were added. The fishery is open to recreational fishing all year with a MLS of 54 mm tail width (TW) for males and 60 mm TW for females.

2. CATCH DATA

2.1 Commercial catch

The fishing year and calendar year were the same before 1979. From 1979 onwards, the fishing year changed to an April to March year (Breen et al. 2001). Reported annual commercial catches from 1945 through to 1978, summarised by **calendar year**, are held in the CRACE database, with sources documented 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 documented and held in CRACE (Bentley et al. 2005). The three months of catch from January to March 1979 were added to the 1978 annual total to ensure that no catch was lost when switching from calendar year to fishing year collation. Year references in this document after 1978 apply to 1 April–31 March fishing years, with the year identified with the first year of the pair (e.g., 1979 refers to the 1979–1980 fishing year).

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

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

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

2.2 Recreational catch

Five annual recreational catch estimates are available for CRA 4 (Table 1). The estimates from the Kingett Mitchell National Surveys (Boyd & Reilly 2004; Boyd et al. 2004) were not accepted by the Rock Lobster Fishery Assessment Working Group (RLFAWG) for the 2005 (Breen et al. 2006) or 2011 (Breen et al. 2012) CRA 4 stock assessments because they appeared to be substantially higher than the estimates from the earlier surveys and lacked credibility in the lobster component of the survey. The earlier two surveys, conducted by researchers at the University of Otago, were deemed to be biased by a review of the available recreational surveys (unpublished minutes: Recreational Technical Working Group [Auckland NIWA, 10-11 June 2004]). The most recent survey, done in

2011–12, was a large scale survey based on residence interviews that covered all of New Zealand, with 69 diary participants in CRA 4 reporting on a range of finfish and shellfish species (Heinemann et al. 2015).

MPI, in its response to the Rock Lobster Stock Assessment team's request for its estimate, recommended the following for the CRA 4 recreational fishery (Alicia McKinnon, pers. comm.):

> "*All available estimates of recreational rock lobster harvest by Quota Management Area are presented in the November 2015 Fisheries Assessment Plenary. The harvest estimates provided by the historical telephone diary surveys (1992, 1993, 1994, 1996, 2000 and 2001) are no longer considered reliable by the MPI Marine Amateur Fisheries Working Group.*
>
> *A recreational harvest estimate is available for CRA 4 from the 2011-12 National Panel Survey (NPS), which includes any charter fishing activity*
>
> *MPI recommends that the 2011/12 NPS estimate for CRA 4 is used in the upcoming stock assessment. Given that there were a number of panellists making quite a few trips and the CV is relatively low, the NPS estimate for CRA 4 is considered reasonably robust. However, this is said in recognising that the NPS is unlikely to be reaching a high proportion of rock lobster fishers as finfish fishers, which could mean there is a negative bias in the catch estimates, but this has not been tested or quantified.*"

The RLFAWG agreed that, because there were a number of panellists making quite a few trips and the CV is relatively low, the NPS estimate for CRA 4 would be considered reasonably robust. However, it was also recognised that the NPS was unlikely to be monitoring as high a proportion of rock lobster fishers as finfish fishers, which would imply a negative bias in the rock lobster catch estimates, but this has not been tested or quantified. Apart from the NPS, recreational catches of rock lobster are poorly known throughout New Zealand. It seems unlikely that recreational catch in CRA 4 would have been constant, given its proximity to Wellington and Hawke's Bay. The RLFAWG agreed for the 2003 CRA 4 stock assessment (Kim et al. 2004) to use a catch trajectory that reflected the changing abundance of lobster in this QMA seen in SS CPUE. This stock assessment calculated the ratios of the CPUE relative to the recreational survey catch weight, took the mean of these ratios and applied it to the observed SS CPUE in all other years from 1979 (Eq.1). When this method was implemented for the 2016 CRA 4 stock assessment using the 1994, 1996 and 2011 survey estimates in Table 1, the estimated recreational catches were consistent with the 2011 NPS survey and the values used in the 2011 CRA 4 stock assessment.

$$W_y = w_y\, N_y$$

$$S = \left(W_{94} / CPUE_{94} + W_{96} / CPUE_{96} + W_{11} / CPUE_{11} \right) / 3$$

$$\hat{W}_i = S * CPUE_i \text{ if } i >= 1979$$

$$\hat{W}_{1945} = 0.2 * \hat{W}_{1979}$$

$$\hat{W}_i = \hat{W}_{i-1} + \frac{(\hat{W}_{1979} - \hat{W}_{1945})}{(1979 - 1945)} \text{ if } i > 1945 \,\&\, i < 1979$$

Eq. 1

where

y: subscripts 1994, 1996 and 2011

w_y = mean spring/summer weight >= MLS for sampled lobster in year y for CRA4

N_y = mean numbers lobster in survey year y for CRA4

$CPUE_i$ = spring/summer standardised CPUE from 1979 to 2015 for CRA4

$\hat{W}_i$ = estimated recreational catch by weight for year i for CRA4

${}^{q}S = 45.833$ t was used when Eq.1 was fitted to the survey estimates in Table 1 and the estimated recreational catch trajectory is plotted in Figure 4. Recreational catch was split between seasons, with 90% assumed taken in the SS and the remainder in AW.

2.2.1 Recreational catches declared under provisions of Section 111

For assessments conducted since 2006, the RLFAWG have 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 5 835 kg for CRA 4, occurring in 2012–13 (Table 1). The RLFAWG agreed to add the maximum catch estimate to the estimated recreational catch in each year since 1945 (Figure 4).

2.3 Customary catch

MPI was asked to provide estimates of current and historical customary catches, and an appreciation of their uncertainty. MPI concluded for CRA 4 (Alicia McKinnon, pers. comm.):

> "*Based on the customary harvest information available for CRA 4, noting its incompleteness and uncertainty, MPI considers it appropriate to continue to use a 20 tonne constant customary catch estimate for CRA 4.*"

This annual estimate of 20 t is the same value used for the 2005 (Breen et al. 2006) and 2011 (Breen et al. 2012) CRA 4 stock assessments. Customary catch was split between seasons with 90% assumed taken in the SS season and the balance in the AW.

2.4 Illegal catch

MPI was asked to provide estimates of current and historical illegal catches, along with an appreciation of their uncertainty. MPI suggested the following (Alicia McKinnon, pers. comm.):

> "*MPI acknowledges that there is currently no robust and defensible methodology that can be used to accurately estimate illegal catches from any rock lobster fishery.*
>
> *MPI has considered available information on detected illegal removals from prosecutions, observed activities, intelligence and intangible anecdotal knowledge, and other information provided by Fishery Officers for the CRA 4 fishery. Based on this assessment, MPI suggests that a 40 tonne illegal catch estimate continues to be used in the upcoming CRA 4 stock assessment. MPI notes that illegal take of rock lobster has likely decreased in the CRA 4 fishery and that the majority of the illegal activity in the area relates to paua. However, there is no robust way to estimate the magnitude of any decrease due to the uncertainty in the available information on illegal take.*"

Given this advice from MPI, 40 t was used as the estimate for illegal catch in CRA 4, which was also the estimate used in the 2005 (Breen et al. 2006) and 2011 (Breen et al. 2012) CRA 4 stock assessments. In the past, MPI 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 2) 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.

Illegal catch estimates before 1990 have been derived from unpublished estimates of discrepancies between reported catch totals and total exported weight that were developed for the period 1974 to 1980 (McKoy pers. comm.). For years before 1973 and from 1981–82 to 1989–90, illegal catch was estimated using the average ratio of annual exports of rock lobster relative to the reported catch in each year from 1974 to 1980, which was 0.183 for CRA 4. This ratio was calculated by assuming that the exports were distributed by QMA in the same proportion as the reported catches. The RLFAWG members have little confidence in the estimates of illegal catch because the estimates cannot be verified.

2.5 Size-limited and non-size-limited catch

The size-limited (SL) catch is the 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. The non-size-limited (NSL) catch is the catch 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 3). Illegal catches were divided in the same seasonal proportions as commercial. It was assumed that 90% of the customary and recreational catches were taken in SS. Catches by season from all four sources are shown in Figure 5 and as SL/NSL catches in Figure 6.

3. CATCH RATE INFORMATION

3.1 FSU and CELR CPUE Indices

Catch and effort data from the FSU and CELR systems were obtained from MPI in September 2016 (Replog 10736), 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 2016.

Data preparation used the F2-LFX procedure (Starr 2016). The F2 algorithm corrects 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 2012; Starr et al. 2012), 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.

The CPUE standardisation procedure used sequential six-month periods as a forced explanatory variable (see section 2.6 in Starr (2014) for a description of this procedure). Two other explanatory variables were available for this analysis: [`month`] of capture and [`statistical_area`] of capture. These analyses estimate separate relative [`month`] effects in each half-year period by using, as the reference [`month`], the [`month`] in each period with the lowest standard error. The variable [`vessel`] was not used, although Starr (2012) showed that it was potentially important. Vessel codes are not consistent between the FSU and CELR data systems, so using [`vessel`] would require fitting to separate CPUE series unless the vessel codes could be reconciled.

As in all recent rock lobster stock assessments, the CRA 4 data set shows a diminishing number of records (Table 4). However, all four primary statistical areas (Areas 912, 913, 914 and 915) have an adequate number of records in both the AW and SS seasons throughout the period (Table 4). Only Area 934 is poorly represented, a feature which goes back to the beginning of the data set in both seasons. The total deviance explained by the CRA 4 model was 31% (Table 5), with the greatest explanatory power lying with model period, followed by month. This was consistent with other rock

lobster standardisation analyses. Residual patterns showed some deviation from the lognormal assumption at both tails of the residual distribution (Figure 7).

The month categorical variable in the CRA 4 seasonal CPUE analysis appears to be cyclical, with a winter peak in May and June and an early summer peak in November and December ([left panel] Figure 8). There is not much difference in the expected catch rates among the three major statistical areas along the Wairarapa coast (Areas 912 to 914 – [right panel] Figure 8). The south coast (Wellington – Area 915) has a slightly lower expected catch rate than the other three areas, while the Area 934 catch rate is high, although poorly estimated ([right panel] Figure 8). Both the CRA 4 AW and SS CPUE series showed similar patterns, with the AW series having lower absolute catch rates (Figure 9; Table 6). Both series peak twice, once in 1998–99 and the second time in 2012–13 (Figure 9). The SS series had a larger associated error than the AW series, particularly during the first peak period, reflecting the relatively smaller amount of data in the SS series in those years (Figure 9).

3.2 Historical Catch Rate (CR) Data

Monthly catch and effort (days fishing) data from 1963 through to 1973 were summarised by Annala & King (1983) and used to calculate unstandardised catch per day for each calendar year from 1963 to 1973 (Figure 10).

4. LENGTH FREQUENCY DISTRIBUTIONS (LFs)

Data were extracted for CRA 4 in September 2016, comprising both observer and voluntary logbook catch sampling from 1987 to 2015. 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 standard was unlikely to have been achieved in the early years of this programme in CRA 4 because of the small number of active participants (Table 7). Observer catch sampling measures and sexes all lobsters in as many pots as feasible during a day's fishing. The design of this programme in CRA 4 specifies about 40 sampling days per year, which are allocated based on the spatial/temporal catch pattern in the previous year (Table 7). For CRA 4, this latter series represents a longer data series with more lobster measured than in the logbook programme.

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, where the first size class is 30–31.9 mm tail width (TW), the next is 32–33.9 mm, etc.
- 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 cell, the numbers-at-length were summed for each sex, and the proportion-at-sex was calculated as:

Eq. 2 $$p^{g}_{m,a,s} = \frac{N^{g}_{m,a,s}}{\sum_{s} N^{g}_{m,a,s}}$$

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 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. 3 $$P^{g}_{s} = \frac{\sum_{m}\sum_{a}\left(C_{m,a}\, p^{g}_{m,a,s}\right)}{\sum_{m}\sum_{a}\sum_{s}\left(C_{m,a}\, p^{g}_{m,a,s}\right)}$$

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

As well as the relative weight assigned to the overall LF dataset, a relative weight (w) 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 ($N_{m,a}$) and the cube root of the number of days sampled ($D_{m,a}$):

Eq. 4 $$w = \sum_{m}\sum_{a} \frac{C_{m,a}\sqrt[3]{N_{m,a}}\sqrt[3]{D_{m,a}}}{\sum_{m}\sum_{a} C_{m,a}}$$

The CRA 4 LF data comprised 87 records from 1986–2015, with 33 being logbook samples and 54 observer samples. Four of the logbook samples were discarded because they had fewer than 100 measured lobsters (Table 8). The logbook records ranged from 70 to 6 109 lobsters while the observer samples ranged from 276 to 34 001 lobsters measured (Table 8). The logbook record weights (Eq. 4) ranged from 0.126 to 16.5 (the base case model truncated 10 records that were greater than 10 and raised the weights below 1.0 to 1.0).The observer record weights (Eq. 4) ranged from 0.08 to 17.3, with the same truncation rule applied (Table 9). Fourteen observer samples[1] from the SS in 2012, 2013 and 2014 were removed because of apparent misidentification of mature females as immature and the lobsters in these samples have not been included in Table 8 or Table 9.

Sex proportions were calculated from normalised data records (Figure 11; Table 10). 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 some systematic pattern over time in the logbook data. However, this may have been because of the low participation in the CRA 4 programme in the 1990s and early 2000s (see Table 7), rather than reflecting a real trend in the population.

Mean length was also calculated from the data records (Figure 12, Table 10). There was no trend in male or mature female mean length in either the AW or SS. The apparent increasing trend in mean length for immature females may be due to inconsistent staging of this category in the samples.

[1] The following is a list of the 14 excluded samples: 40114, 40214, 40314, 40414, 42114, 42612, 42613, 42712, 42713, 42812, 42813, 42913, 43013, 43113. These sample numbers are unique in the MPI *rlcs* database held by NIWA in Wellington.

Although the model contains size bins in the range 30–92 mm TW, few fish as small as 30 mm are measured and very few large fish are measured, especially for immature females, leading to many cells with zero observations (Figure 13). For sex/size bins with few observations, the model would be comparing many zero observations with zero or very small predictions, resulting in a large population of very small residuals that would distort the diagnostics and wasting computing time. Bins at both ends of the range for each sex were therefore combined into "plus" and "minus" bins. The range of bins for each sex category that contained a reasonable number of observations is provided in Table 11. This range was determined arbitrarily by inspecting the proportion of cells in each sex/size bin that contained a minimum proportion of normalised observations using a threshold of 0.001. Past experience has shown that model results were not very sensitive to the chosen 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). Length frequency distributions by year are shown for AW logbook sampling (Figure 14), SS logbook sampling (Figure 15), AW observer sampling (Figure 16) and SS observer sampling (Figure 17).

5. TAG-RECAPTURE DATA

Tag release and re-capture data for CRA 4 were extracted in September 2016 and processed with purpose-built software (unpublished). This software does the following:

- removes duplicate records
- removes white space from all columns
- formats the date and determines the period, removes records with no date
- assigns a numeric code to tag type and writes the key to file: `TypeKey.dat`
- assigns a numeric code to each release stage
- removes records that are missing both tail width and carapace length
- matches release and recapture data and removes release records that have not been recaptured
- infers sex if sex is missing at release but not recapture or vice versa
- removes records with different sex at release and recapture, or with sex code invalid
- sets statistical area to NA if not 901 to 943
- if the option qma_method = "area", determines QMA from statistical area, or if statistical area is NA then sets QMA using the project ID
- otherwise determines QMA from the project ID, or if project ID is NA then determines the QMA from statistical area
- adds 0.5 mm TW to the recapture measurement if calendar year > 1992 and source = 2 (commercial recapture with measurement rounded down)
- for older records with no TW, calculates TW from carapace length using relationships developed by Breen et al. (1988).
- removes records that are less than or greater than a specified TW, in this study 20 mm and 150 mm
- calculates time at liberty in days
- removes records from fish at liberty for less than or greater than a specified time (in this study, 1 day and 10 years)
- calculates apparent growth increment
- removes records with apparent increments that are less than or greater than specified values (in this work, -40 and 40 mm)

- treats subsequent release and recapture events with the same tag code as sequential independent events.

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

- a unique 5-digit event code
- sex (1 for males and 2 for females)
- month of release, extracted from release date
- fishing year of release, extracted from release date
- month of recovery, extracted from recovery date
- fishing year of recovery, extracted from recovery date
- days at liberty, obtained by subtracting release from recovery dates
- TW at release and recovery
- sequential number of re-releases, if tag code has been used multiple times
- statistical areas of release and recovery
- a condition code
- code showing tag type used (3 for western rock lobster tag and 4 for Hallprint Floy-type tag)

For exploration only (not for use by the model), increments were "annualised" based on days at large:

Eq. 5 $$V_i = 365.25\left(L_i^2 - L_i^1\right)/\delta_i$$

Where V_i is the annualised increment for the ith record, L_i^1 and L_i^2 are the sizes at release and recapture and δ_i is the number of days at liberty.

The screened data extract for CRA 4 comprised 2468 records: 1838 males and 630 females (Table 12). Sizes at release and recapture by sex are shown in Figure 18. Nine releases were made in 1982 using Western rock lobster tags and those from 1998 to 2015 were made using HallPrint tags. The nine early releases had size recorded in carapace length while all the later releases used tail width. The number of tags released by statistical area and sex is shown in Table 12. Generally most tags were recaptured in the area of release (Table 13).

Times at liberty varied from 1 day to 2141 days (about 6 years), but the median was 190 days and 81% were at liberty for less than one year and 95% less than 2 years. One lobster was re-released five times and five lobsters were re-released four times, but 81% of the tag recovery records were from fish that were not re-released (Table 14). Ninety-five percent of the condition codes were zero or missing. Growth increments ranged from –19 mm to 22 mm. Annualised growth increments ranged from -2557 to 1096 and are shown for males and females in Figure 19.

6. PUERULUS SETTLEMENT DATA

The puerulus settlement programme, conducted by NIWA, is described in annual reports (e.g. Forman et al. 2017). There are two sites available for CRA 4: Napier and Castlepoint. Index series by fishing year were calculated for each site using year, month and collector group as explanatory variables and assuming a negative binomial likelihood (Figure 20, Forman et al. 2017).

A comparison of the Napier and Castlepoint datasets indicated that they were reasonably similar (Figure 21), leading the RLFAWG to agree to an averaging procedure to combine the two series to create a single puerulus series for model fitting. The agreed procedure averaged the two indices (after standardising each series to a geometric mean of 1.0) in those years when both were present and used the available index in the years where there was only a single index (Table 15). A combined standard error was calculated using the following equation:

Eq. 6: $$SE_{\text{combined}} = \sqrt{SE^2_{\text{Napier}} + SE^2_{\text{Castlepoint}}}$$

The standard error was arbitrarily doubled in those years when there was only a single index (Table 15).

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Table 1: Recreational catch information for CRA 4.

Category	Numbers	Mean weight	Weight (kg)
1994 (Bradford 1997)	65 000	0.510[1]	33 182
1996 (Bradford 1998)	118 000	0.510[1]	60 237
2000 (Boyd et al. 2004a)	371 000	0.513[2]	190 275
2001 (Boyd et al. 2004b)	289 000	0.513[2]	148 220
2011 (LSMS)	53 847[3]	0.82[3]	44 170
Section 111 reported landings			
Maximum reported landings (kg) (in 2012)			5 835

[1] SS mean weight (kg) calculated from commercial sampling data from 1994 to 1996 assuming recreational minimum legal sizes

[2] SS mean weight (kg) calculated from commercial sampling data from 2000 and 2001 assuming recreational minimum legal sizes

[3] as reported by the LSMS (Wynne-Jones et al. 2014)

Table 2: Available estimates of illegal catches (t) by CRA QMA from 1990, as provided by MPI 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 MPI 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	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	–	–	–	–	–	–	–	–	–	–

Table 3: Estimated CRA 4 catches (t) (commercial, recreational including S.111, illegal and customary), provided annually before 1979 and seasonally (AW and SS) from 1979 to 2015.

Calendar Year	Comm-ercial Annual	Recrea-tional Annual	Cus-tomary Annual	Illegal Annual	Fishing Year	Commercial		Recreational		Customary		Illegal	
						AW	SS	AW	SS	AW	SS	AW	SS
1945	254.7	12.0	20	45.6	1979	159.2	344.4	3.7	33.2	2	18	13.8	29.9
1946	225.4	12.8	20	40.3	1980	223.7	384.0	3.4	30.9	2	18	25.5	43.8
1947	253.7	13.5	20	45.4	1981	229.1	385.2	3.7	33.3	2	18	41.0	68.9
1948	253.2	14.2	20	45.3	1982	306.6	546.9	4.0	35.6	2	18	54.9	97.9
1949	273.9	15.0	20	49.0	1983	372.4	568.0	3.5	31.9	2	18	66.7	101.7
1950	503.5	15.7	20	90.1	1984	341.3	522.0	3.3	29.9	2	18	61.1	93.4
1951	673.7	16.4	20	120.6	1985	271.1	576.9	3.5	31.9	2	18	48.5	103.2
1952	653.8	17.1	20	117.0	1986	270.8	676.7	3.7	33.3	2	18	48.5	121.1
1953	678.8	17.9	20	121.5	1987	275.5	653.8	3.4	30.5	2	18	49.3	117.0
1954	666.6	18.6	20	119.3	1988	234.9	530.4	2.9	26.1	2	18	42.0	94.9
1955	503.8	19.3	20	90.2	1989	219.3	539.2	3.0	26.8	2	18	39.2	96.5
1956	434.0	20.1	20	77.7	1990	168.4	354.8	2.8	24.8	2	18	51.5	108.6
1957	327.7	20.8	20	58.7	1991	176.3	354.2	2.8	24.8	2	18	31.6	63.5
1958	340.6	21.5	20	61.0	1992	183.1	312.6	2.7	24.2	2	18	11.1	18.9
1959	294.0	22.3	20	52.6	1993	233.7	258.4	3.0	26.7	2	18	23.7	26.3
1960	361.9	23.0	20	64.8	1994	271.3	219.1	3.6	32.1	2	18	38.7	31.3
1961	419.8	23.7	20	75.1	1995	343.9	143.4	4.8	42.8	2	18	45.2	18.8
1962	501.4	24.4	20	89.7	1996	446.5	47.1	6.3	56.4	2	18	67.8	7.2
1963	310.3	25.2	20	55.5	1997	460.9	29.5	6.6	59.6	2	18	67.9	4.3
1964	459.9	25.9	20	82.3	1998	450.5	42.8	8.5	76.9	2	18	63.5	6.0
1965	581.4	26.6	20	104.1	1999	532.4	44.0	7.2	65.1	2	18	61.7	5.1
1966	663.5	27.4	20	118.7	2000	503.9	69.9	8.1	72.6	2	18	56.2	7.8
1967	512.6	28.1	20	91.7	2001	474.6	99.5	6.3	57.0	2	18	51.3	10.7
1968	509.6	28.8	20	91.2	2002	436.3	139.4	6.7	60.3	2	18	45.5	14.5
1969	606.7	29.6	20	108.6	2003	365.9	209.9	6.5	58.2	2	18	31.8	18.2
1970	559.0	30.3	20	100.0	2004	261.8	308.0	5.1	46.0	2	18	18.4	21.6
1971	419.3	31.0	20	75.1	2005	198.1	306.0	3.7	33.7	2	18	15.7	24.3
1972	426.3	31.7	20	76.3	2006	115.7	328.9	3.3	29.9	2	18	10.4	29.6
1973	373.8	32.5	20	66.9	2007	73.0	242.2	3.0	27.2	2	18	9.3	30.7
1974	375.0	33.2	20	48.0	2008	70.9	178.5	3.8	33.9	2	18	11.4	28.6
1975	404.0	33.9	20	97.8	2009	120.5	141.7	5.0	45.1	2	18	18.4	21.6
1976	456.0	34.7	20	88.6	2010	202.4	212.4	5.1	46.0	2	18	19.5	20.5
1977	438.0	35.4	20	112.5	2011	261.2	205.1	5.9	53.1	2	18	22.4	17.6
1978	496.3	36.1	20	127.3	2012	238.3	228.0	6.3	56.7	2	18	20.4	19.6
					2013	249.8	249.6	5.4	48.9	2	18	20.0	20.0
					2014	194.8	270.6	4.6	41.8	2	18	16.7	23.3
					2015	108.8	329.3	3.7	33.7	2	18	9.9	30.1

Table 4. Number of vessel/statistical area/month records in the dataset used to calculate the CRA 4 CPUE time series (based on the F2_LFX algorithm).

	AW						SS					
Fishing	CRA 4 Statistical Area						CRA 4 Statistical Area					
year	912	913	914	915	934	Total	912	913	914	915	934	Total
1979	89	80	92	50	1	312	136	113	136	96	1	482
1980	101	80	102	61	1	345	149	90	135	110	7	491
1981	109	72	103	55	–	339	146	76	122	97	1	442
1982	122	66	117	64	1	370	147	98	157	108	3	513
1983	109	84	121	74	2	390	137	111	157	101	5	511
1984	99	91	137	73	3	403	118	96	149	91	5	459
1985	112	77	134	71	1	395	133	79	158	97	8	475
1986	102	85	131	67	–	385	127	103	152	85	6	473
1987	98	80	125	53	–	356	121	94	160	79	3	457
1988	94	71	127	54	2	348	105	92	149	66	–	412
1989	94	91	125	44	–	354	115	111	148	54	–	428
1990	93	85	107	47	2	334	113	98	139	67	2	419
1991	117	103	138	42	1	401	126	105	136	53	4	424
1992	139	107	124	43	2	415	144	113	120	51	5	433
1993	136	101	138	49	7	431	99	98	85	44	4	330
1994	91	106	165	54	6	422	47	81	58	35	2	223
1995	80	76	161	35	6	358	41	49	42	15	1	148
1996	74	53	122	46	4	299	22	9	16	6	–	53
1997	63	41	132	34	–	270	10	4	13	6	–	33
1998	78	35	110	41	–	264	16	3	15	12	–	46
1999	73	38	104	36	4	255	16	2	20	6	2	46
2000	79	31	98	38	7	253	26	10	18	14	2	70
2001	75	42	101	44	6	268	27	20	30	9	–	86
2002	77	68	113	35	4	297	41	27	47	23	–	138
2003	68	75	106	39	–	288	52	41	48	34	–	175
2004	67	56	113	34	–	270	64	48	75	27	–	214
2005	46	53	83	31	–	213	54	47	93	37	–	231
2006	35	53	85	44	6	223	65	67	118	57	17	324
2007	30	29	68	31	10	168	57	49	91	43	17	257
2008	31	28	48	24	6	137	44	46	54	26	5	175
2009	36	40	47	25	5	153	44	35	39	35	5	158
2010	53	40	73	43	10	219	51	37	67	44	3	202
2011	45	56	85	26	7	219	37	35	61	26	9	168
2012	38	41	83	22	7	191	38	39	67	29	8	181
2013	34	31	88	19	4	176	39	33	78	22	2	174
2014	31	32	88	29	3	183	42	41	93	36	–	212
2015	30	32	87	25	5	179	46	50	113	39	5	253

Table 5: Total deviance (R^2) explained by each variable in the CRA 4 standardised seasonal CPUE model.

Variable	1	2	3
Period	0.2379		
Month	0.0617	0.2882	
Statistical Area	0.0171	0.2589	0.3078
Additional deviance explained	0.0000	0.0503	0.0196

Table 6: Standardised seasonal CPUE and standard errors (s.e.) for CRA 4.

Fishing Year	AW	s.e.	SS	s.e.	Fishing Year	AW	s.e.	SS	s.e.
1979	0.837	0.0323	0.859	0.0266	1998	1.410	0.0350	2.205	0.0813
1980	0.864	0.0308	0.790	0.0264	1999	1.289	0.0355	1.842	0.0813
1981	0.891	0.0311	0.861	0.0277	2000	1.137	0.0356	2.072	0.0660
1982	0.961	0.0299	0.933	0.0260	2001	0.993	0.0347	1.592	0.0597
1983	0.904	0.0292	0.819	0.0260	2002	0.978	0.0331	1.693	0.0476
1984	0.783	0.0287	0.757	0.0272	2003	1.020	0.0335	1.628	0.0423
1985	0.650	0.0289	0.818	0.0268	2004	0.748	0.0346	1.253	0.0386
1986	0.698	0.0293	0.862	0.0268	2005	0.766	0.0386	0.875	0.0373
1987	0.586	0.0304	0.776	0.0273	2006	0.599	0.0378	0.759	0.0319
1988	0.506	0.0307	0.642	0.0286	2007	0.507	0.0432	0.677	0.0356
1989	0.472	0.0305	0.662	0.0281	2008	0.621	0.0477	0.882	0.0425
1990	0.442	0.0313	0.600	0.0283	2009	0.882	0.0452	1.227	0.0447
1991	0.447	0.0288	0.602	0.0282	2010	0.863	0.0381	1.253	0.0396
1992	0.428	0.0283	0.582	0.0278	2011	1.082	0.0381	1.473	0.0434
1993	0.459	0.0278	0.661	0.0314	2012	1.251	0.0407	1.582	0.0419
1994	0.602	0.0282	0.827	0.0378	2013	1.065	0.0423	1.344	0.0426
1995	0.779	0.0303	1.156	0.0458	2014	0.980	0.0415	1.126	0.0388
1996	1.073	0.0330	1.573	0.0759	2015	0.641	0.0419	0.874	0.0358
1997	1.271	0.0346	1.671	0.0958					

Table 7: Sampling intensity by fishing year in CRA 4 by the logbook and observer catch sampling programme for the past 11 years. "Lobsters" are the numbers measured and may include some packhorse lobsters.

Fishing	Logbooks			Observers		
Year	Fishermen	Potlifts	Lobsters	Days	Potlifts	Lobsters
2005	2	498	2 462	46	5 409	26 433
2006	2	452	1 406	46	5 640	22 293
2007	1	278	1 400	45	5 191	19 952
2008	1	146	522	40	3 988	20 499
2009	2	143	945	41	4 318	20 506
2010	7	715	3 675	42	3 944	18 328
2011	11	711	5 674	43	4 143	19 455
2012	6	753	5 988	44	5 292	23 517
2013	4	548	3 559	45	5 620	22 600
2014	9	1 129	8 618	40	4 537	16 875
2015	11	1 821	10 194	40	4 922	15 065
Total		7 194	44 443		53 004	225 523

Table 8: Number of lobsters measured by the observer and logbook catch sampling programmes by fishing year and season. '–': no data.

Fishing	Logbook sampling			Observer sampling		
Year	AW	SS	Total	AW	SS	Total
1986	–	–	–	–	276	276
1987	–	–	–	1 194	1 564	2 758
1988	–	–	–	1 980	1 851	3 831
1989	–	–	–	3 661	4 613	8 274
1990	–	–	–	7 851	17 170	25 021
1991	–	–	–	2 984	15 655	18 639
1992	–	–	–	1 502	16 546	18 048
1993	–	–	–	1 112	10 791	11 903
1994	–	–	–	2 540	5 530	8 070
1995	–	–	–	2 395	7 373	9 768
1996	–	–	–	4 549	–	4 549
1997	1 774	70[1]	1 844	34 001	–	34 001
1998	811	586	1 397	19 132	–	19 132
1999	297	–	297	25 115	–	25 115
2000	331	–	331	22 524	–	22 524
2001	–	–	–	17 157	3 561	20 718
2002	494	98[1]	592	18 096	2 881	20 977
2003	1 252	246	1 498	15 122	3 436	18 558
2004	935	88[1]	1 023	13 237	9 849	23 086
2005	2 161	300	2 461	9 445	16 638	26 083
2006	1 299	107	1 406	8 635	13 703	22 338
2007	738	662	1 400	7 419	12 887	20 306
2008	522	–	522	4 323	15 983	20 306
2009	865	80[1]	945	6 160	14 170	20 330
2010	2 206	1 464	3 670	8 109	10 231	18 340
2011	3 740	1 932	5 672	11 629	7 658	19 287
2012	2 805	3 181	5 986	12 808	9 027	21 835
2013	1 690	1 868	3 558	8 369	8 500	16 869
2014	3 174	5 431	8 605	8 902	7 425	16 327
2015	4 060	6 109	10 169	5 965	9 053	15 018
Total	29 154	22 222	51 376	285 916	226 371	512 287

[1] samples with <100 measured lobsters were omitted.

Table 9: Raw sample weight based on Eq. 4 assigned to each LF sampling record described in Table 8. The base case model truncated to 10 those records that were greater than 10 and raised the weights below 1.0 to 1.0. '–': no data.

Fishing	Logbook sampling			Observer sampling		
Year	AW	SS	Total	AW	SS	Total
1986	–	–	–	–	0.11	0.11
1987	–	–	–	1.02	1.21	2.23
1988	–	–	–	1.32	0.79	2.11
1989	–	–	–	2.88	3.17	6.05
1990	–	–	–	5.61	8.73	14.34
1991	–	–	–	1.40	8.96	10.36
1992	–	–	–	0.67	7.42	8.10
1993	–	–	–	0.08	8.05	8.13
1994	–	–	–	0.42	5.85	6.27
1995	–	–	–	1.21	6.34	7.55
1996	–	–	–	2.25	–	2.25
1997	6.89	1.82[1]	8.70	17.31	–	17.31
1998	2.40	5.18	7.58	11.61	–	11.61
1999	2.83	–	2.83	6.37	–	6.37
2000	0.19	–	0.19	9.86	–	9.86
2001	–	–	–	8.15	1.99	10.14
2002	0.86	0.18[1]	1.04	9.95	2.52	12.47
2003	1.36	0.53	1.89	11.33	2.79	14.12
2004	0.94	0.13[1]	1.07	11.83	8.79	20.61
2005	3.15	0.62	3.77	7.32	9.51	16.83
2006	3.62	0.37	3.99	7.09	8.97	16.06
2007	3.92	1.46	5.38	7.07	8.64	15.71
2008	2.18	–	2.18	4.23	9.40	13.63
2009	2.58	0.38[1]	2.96	5.40	11.79	17.19
2010	7.57	4.83	12.40	4.99	6.64	11.63
2011	16.49	10.14	26.63	8.61	7.15	15.76
2012	14.29	10.28	24.57	9.53	6.10	15.64
2013	7.20	7.54	14.73	8.44	1.91	10.35
2014	13.12	14.89	28.01	8.03	6.93	14.96
2015	10.99	14.10	25.09	5.05	5.61	10.66

[1] sample with <100 measured lobsters were omitted.

Table 10: Statistics for the proportion-at-sex and mean tail width by sex, summarised over the 84 season/sampling programme strata.

	Proportion			Mean tail width (mm)		
		Immature	Mature		Immature	Mature
Statistic	Male	Female	Female	Male	Female	Female
Minimum	0.057	0.000	0.124	49.0	39.7	51.7
Maximum	0.873	0.082	0.943	57.1	58.9	63.5
Mean	0.560	0.018	0.422	52.4	47.6	58.3

Table 11: Bin ranges used for model fitting by sex category.

	Lower TW		Upper TW	
Sex	Bin	midpoint (mm)	bin	midpoint (mm)
Male	6	41	26	81
immature Female	1	31	20	69
mature Female	7	43	28	87

Table 12: Number of tag recaptures by release fishing year, statistical area of release and by sex. '–': no data.

Fishing	Area 912			Area 913			Area 914			Area 915			CRA 4		
year	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
1982	–	–	–	7	3	10	–	–	–	–	–	–	7	3	10
1998	149	29	178	111	36	147	225	156	381	–	–	–	485	221	706
1999	112	8	120	110	25	135	103	52	155	16	36	52	341	121	462
2000	32	–	32	62	2	64	8	6	14	10	56	66	112	64	176
2001	–	–	–	4	–	4	–	1	1	–	–	–	4	1	5
2002	–	–	–	–	–	–	–	1	1	–	3	3	–	4	4
2003	–	–	–	–	–	–	–	–	–	–	6	6	–	6	6
2004	–	–	–	–	–	–	–	–	–	–	2	2	–	2	2
2005	–	–	–	16	5	21	53	12	65	49	55	104	118	72	190
2006	–	–	–	14	2	16	8	3	11	39	28	67	61	33	94
2007	8	3	11	5	–	5	61	7	68	39	25	64	113	35	148
2008	1	–	1	2	–	2	–	–	–	–	1	1	3	1	4
2009	19	10	29	3	–	3	35	6	41	–	1	1	57	17	74
2010	9	2	11	259	5	264	4	–	4	2	2	4	274	9	283
2011	–	–	–	50	–	50	1	1	2	–	–	–	51	1	52
2012	–	–	–	6	–	6	–	–	–	–	–	–	6	–	6
2014	3	–	3	6	–	6	194	40	234	–	–	–	203	40	243
2015	–	–	–	–	–	–	3	–	3	–	–	–	3	–	3
Total	333	52	385	655	78	733	695	285	980	155	215	370	1 838	630	2468

Table 13: CRA 4: numbers of tag release/recovery pairs by statistical area of release and recovery. '–': no data.

Area of	Area of Recovery						
release	912	913	914	915	916	934	Total
912	378	–	7	–	–	–	385
913	–	727	6	–	–	–	733
914	9	3	966	2	–	–	980
915	–	–	9	327	32	2	370
Total	387	730	988	329	32	2	2 468

Table 14: CRA 4: number of tag re-release events by sex; re-release code zero indicates the first recapture event.

Re-release	CRA 4		
event #	Male	Female	Total
0	1 421	575	1 996
1	298	45	343
2	87	6	93
3	27	3	30
4	4	1	5
5	1	–	1
Total	1 838	630	2 468

Table 15: Standardised puerulus index series and standard errors (SE) for Napier and Castlepoint (Forman et al. 2017). Also shown is the derived combined series and SE. '–': no data.

Fishing	Napier		Castlepoint		Combined	
year	Index	SE	Index	SE	Index	SE
1979	0.766	0.202	–	–	0.766	0.403
1980	1.227	0.166	–	–	1.227	0.333
1981	2.012	0.158	–	–	2.012	0.315
1982	1.115	0.173	2.444	0.189	1.780	0.256
1983	1.311	0.188	1.212	0.122	1.262	0.224
1984	0.402	0.224	0.736	0.136	0.569	0.261
1985	0.211	0.311	0.582	0.159	0.397	0.349
1986	–	–	0.848	0.130	0.848	0.260
1987	–	–	1.684	0.118	1.684	0.237
1988	1.343	0.269	0.951	0.127	1.147	0.298
1989	1.158	0.204	1.167	0.120	1.163	0.237
1990	1.022	0.200	1.110	0.117	1.066	0.232
1991	2.414	0.123	2.159	0.098	2.287	0.157
1992	2.069	0.122	2.143	0.086	2.106	0.149
1993	2.180	0.121	1.070	0.089	1.625	0.150
1994	1.521	0.119	0.886	0.085	1.204	0.146
1995	1.050	0.118	0.933	0.090	0.992	0.149
1996	1.523	0.110	1.287	0.079	1.405	0.136
1997	1.066	0.113	1.708	0.076	1.387	0.136
1998	0.957	0.121	1.083	0.090	1.020	0.150
1999	0.427	0.138	0.350	0.104	0.389	0.173
2000	0.724	0.139	0.527	0.101	0.626	0.171
2001	1.226	0.125	0.714	0.085	0.970	0.151
2002	1.446	0.125	0.773	0.083	1.110	0.151
2003	1.302	0.132	0.946	0.087	1.124	0.159
2004	1.055	0.131	0.496	0.091	0.776	0.159
2005	1.260	0.132	1.288	0.079	1.274	0.154
2006	0.640	0.149	0.481	0.094	0.561	0.176
2007	0.915	0.155	1.049	0.088	0.982	0.178
2008	0.639	0.150	1.059	0.090	0.849	0.175
2009	0.880	0.140	1.083	0.092	0.982	0.167
2010	0.930	0.142	1.183	0.085	1.057	0.166
2011	0.484	0.161	0.900	0.088	0.692	0.183
2012	0.695	0.166	0.589	0.101	0.642	0.195
2013	0.945	0.150	1.719	0.079	1.332	0.170
2014	1.023	0.140	0.699	0.094	0.861	0.169
2015	1.051	0.140	1.712	0.082	1.382	0.162

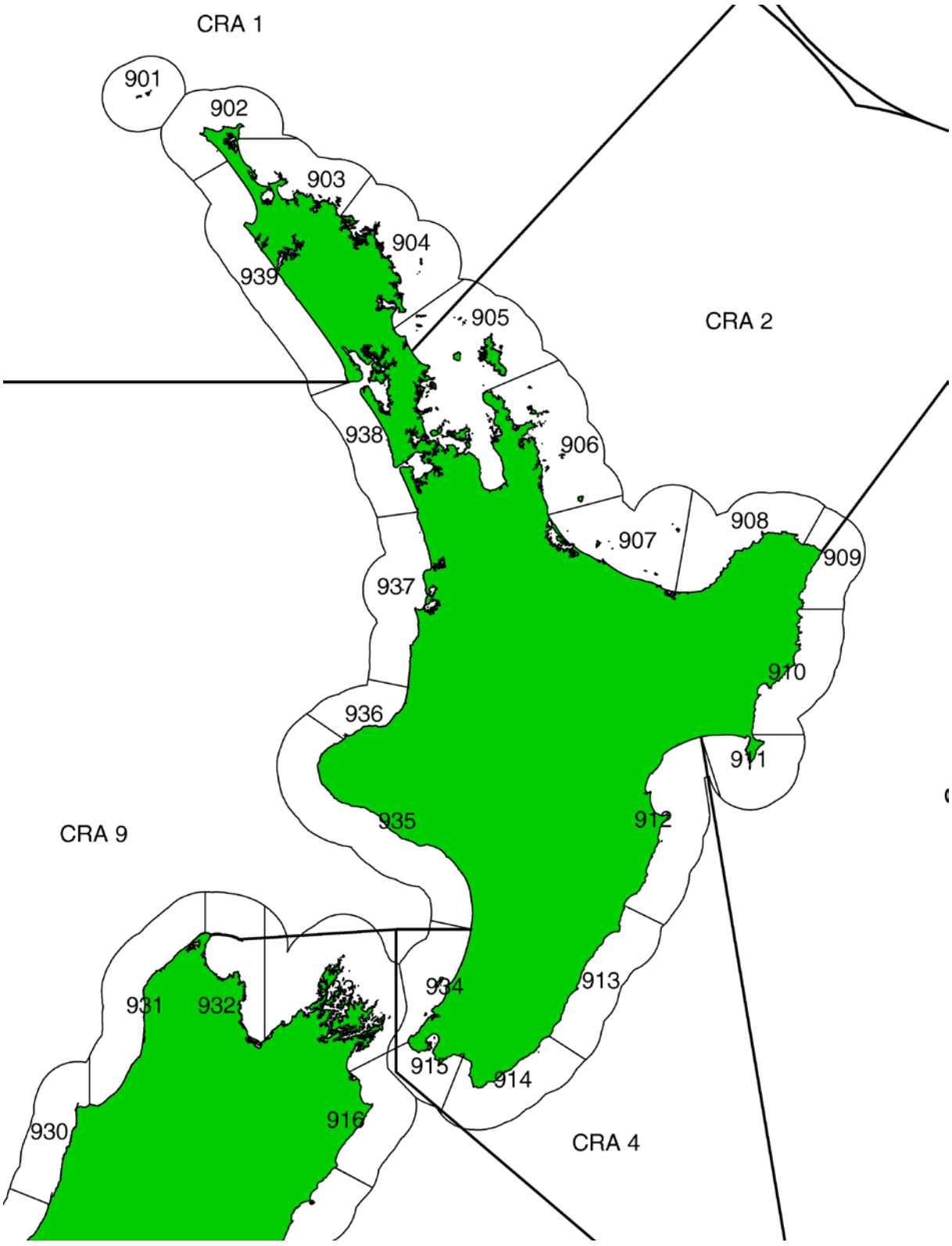

Figure 1: Map of the North Island, showing location of QMAs and statistical areas, including CRA 4.

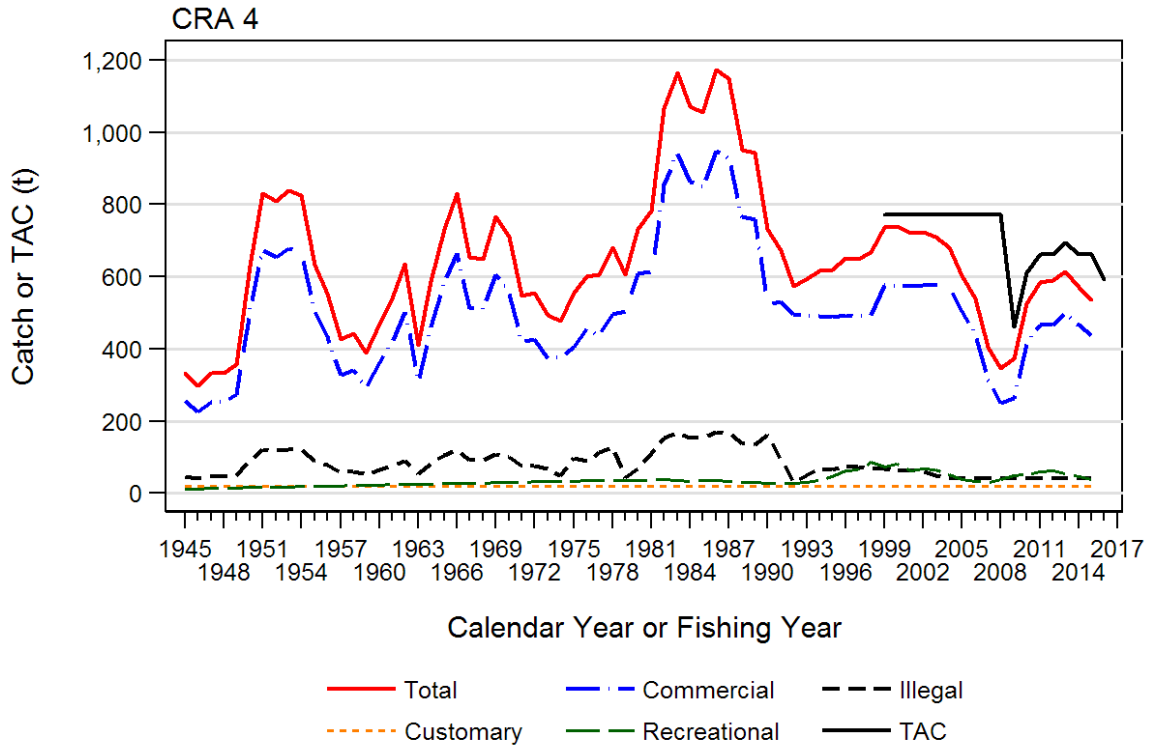

Figure 2: CRA 4 annual catches (t) by fishery.

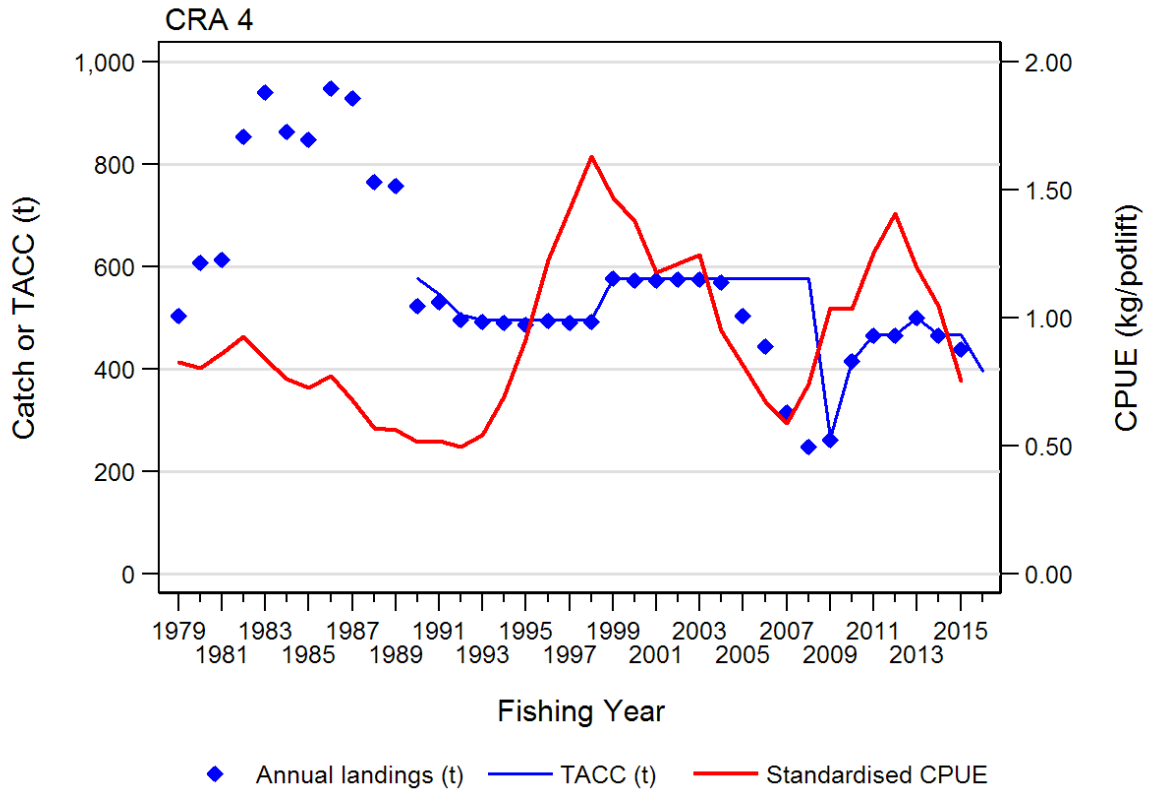

Figure 3: Plot of annual commercial landings (t), the TACC (t) and the annual standardised CPUE index for CRA 4 by fishing year from 1979 to 2015 with the 2016 TACC shown.

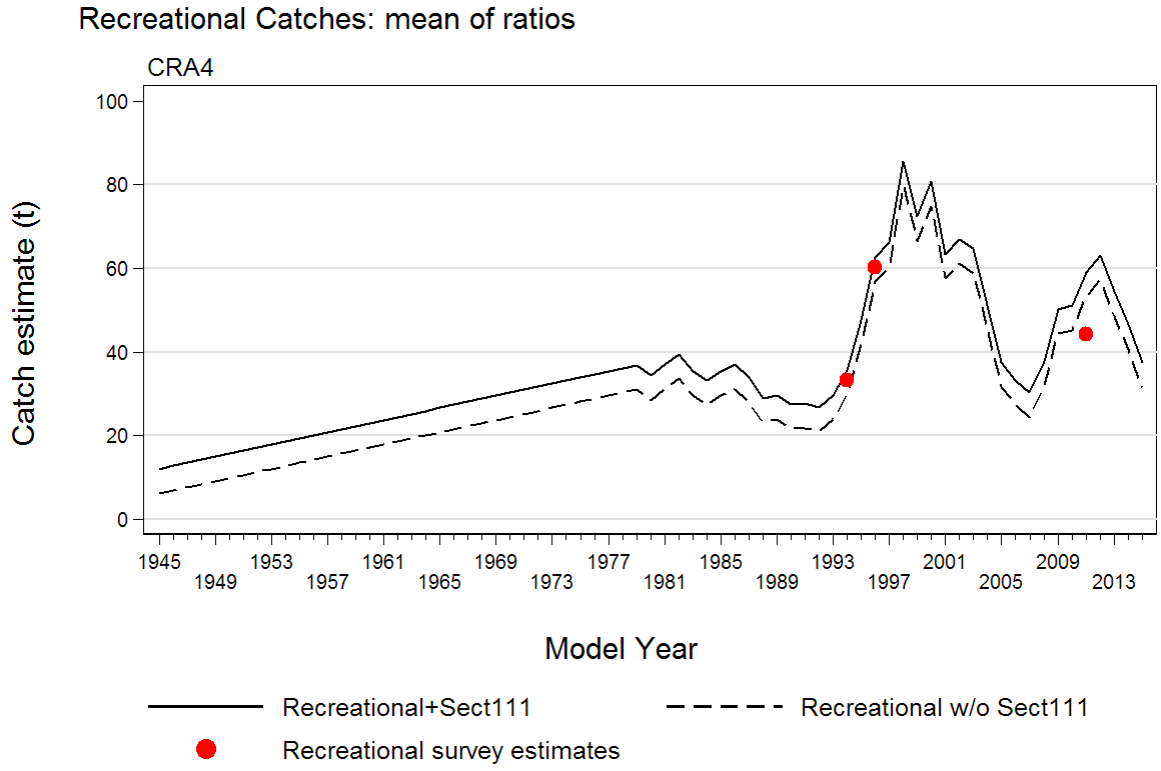

Figure 4: **Recreational catch trajectories (t) for the 2016 stock assessment of CRA 4. Trajectories with (solid line) and without the additional Section 111 catches are shown.**

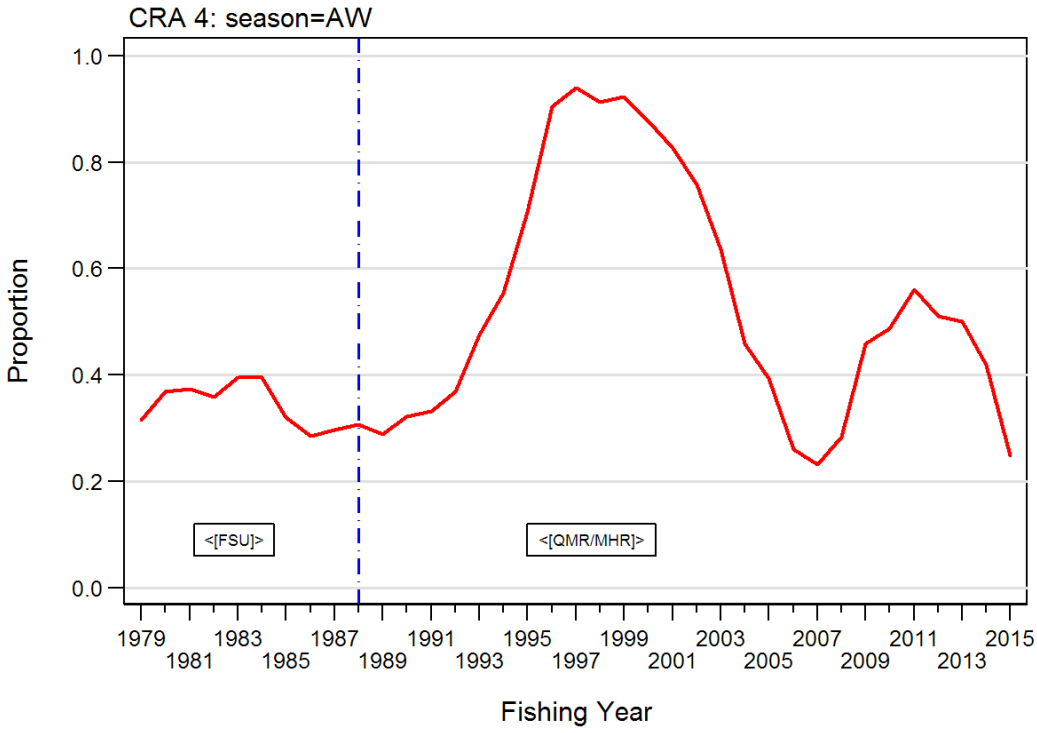

Figure 5: **Seasonal proportion of the commercial AW catch by fishing year for CRA 4, derived from reported landings by month from the FSU or QMR/MHR catch reporting systems.**

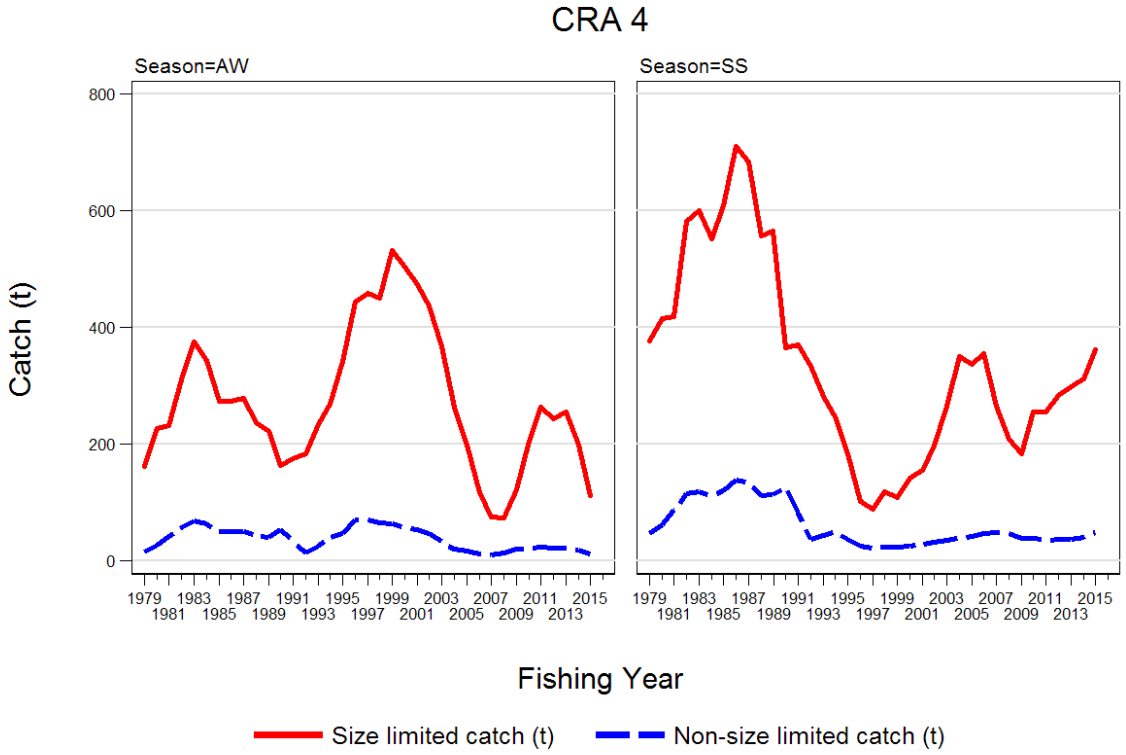

Figure 6: **The seasonal SL (size-limited) and NSL (non-size-limited) catches (t) for CRA 4 by fishing year from 1979.**

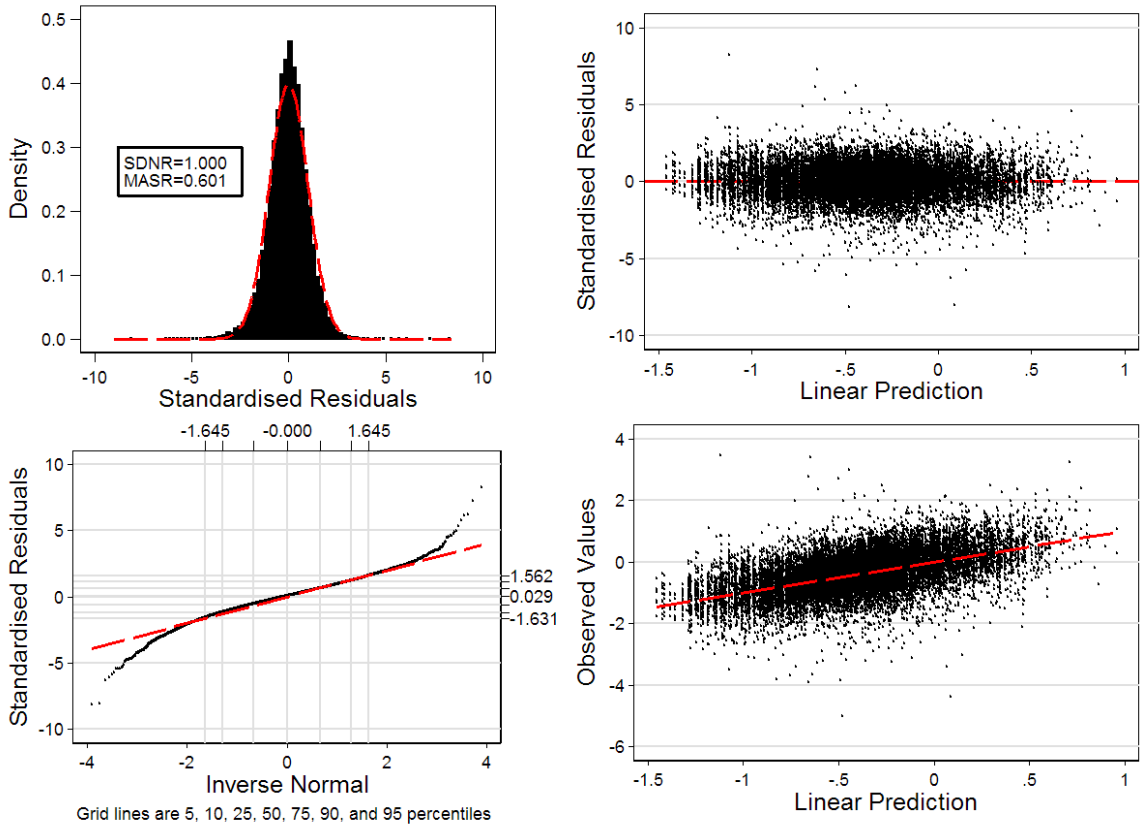

Figure 7: **Standardised residuals for the CRA 4 standardised seasonal F2_LFX CPUE analysis.**

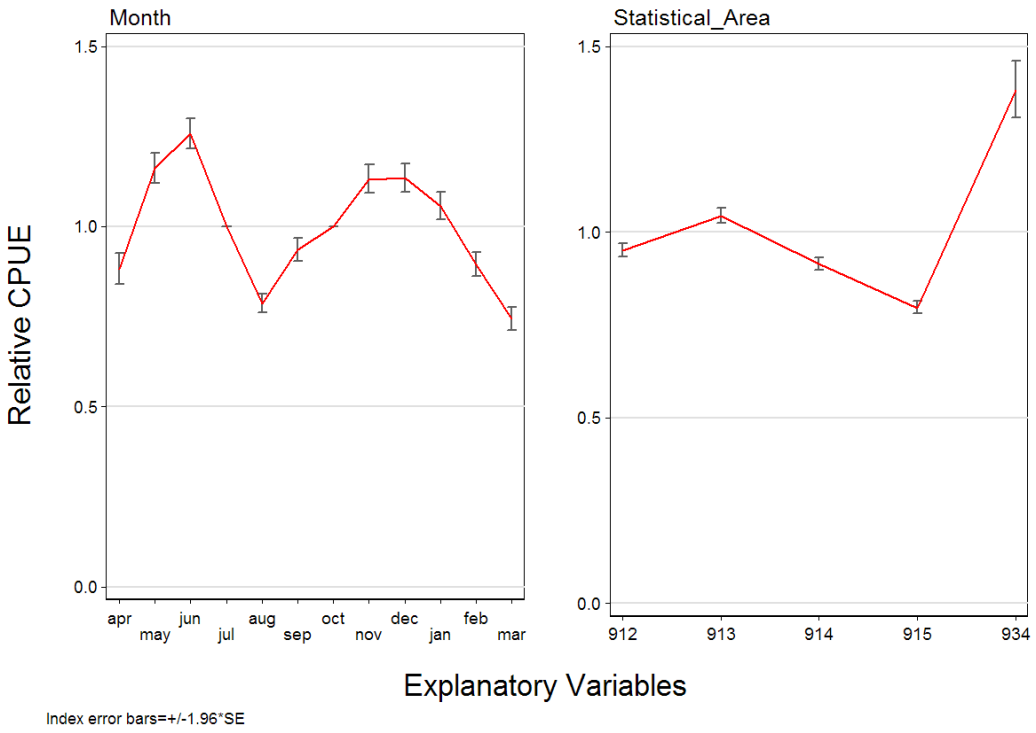

Figure 8: **Coefficients for month and statistical area from the CRA 4 seasonal F2_LFX CPUE standardisation. Month coefficients are not in canonical form, with each of the two reference months (September and October) set to 1.0 and the associated SE set to zero.**

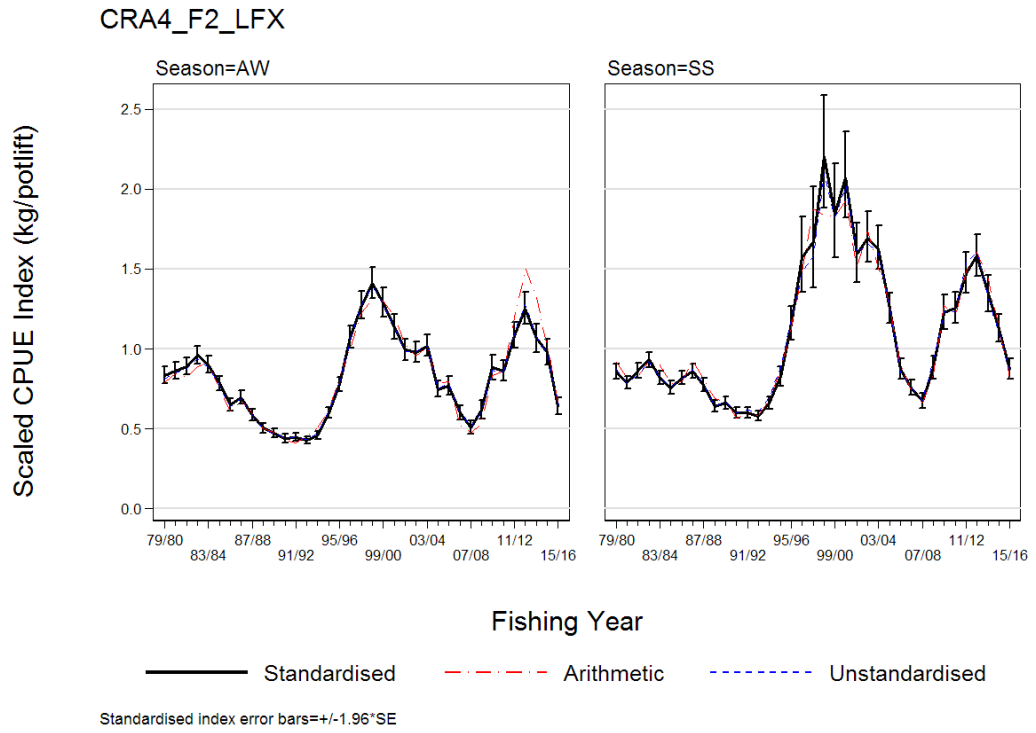

Figure 9: **Scaled standardised F2_LFX CPUE (kg/potlift) by year and season for CRA 4. Also shown are the arithmetic or "raw" CPUE series and the geometric mean of the CPUE ("unstandardised"). The standardised and unstandardised series were scaled by multiplying each index in the unscaled series (where the geometric mean=1) by the geometric mean of the arithmetic CPUE series for each seasonal category (geometric mean for AW=0.78 kg/potlift; geometric mean for SS=1.02 kg/potlift).**

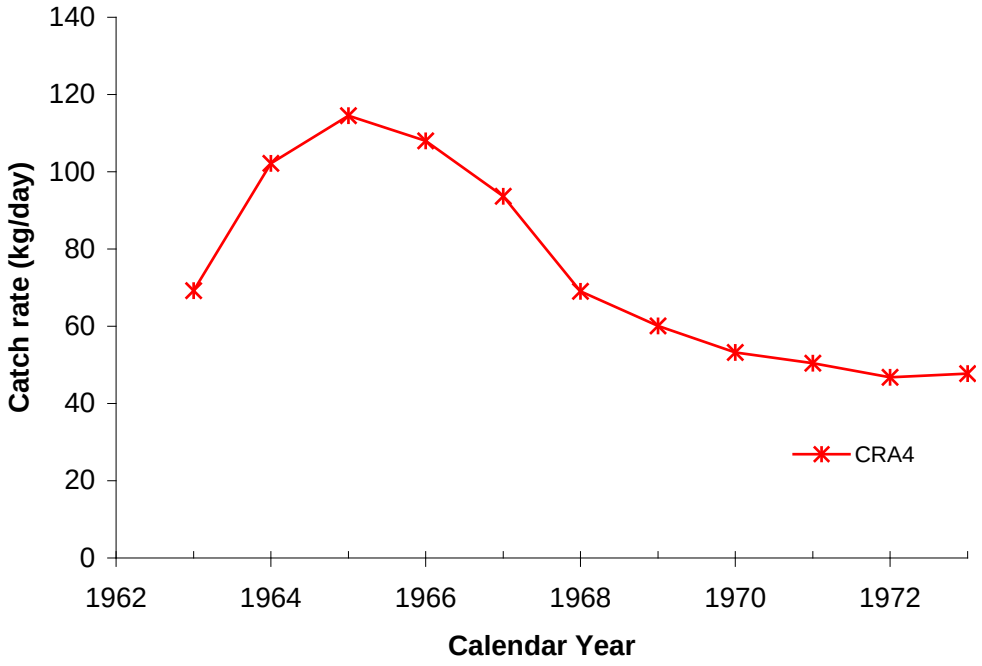

Figure 10: Catch rate (kg/day) by year (1963–1973) for CRA 4. Data from Annala & King (1983).

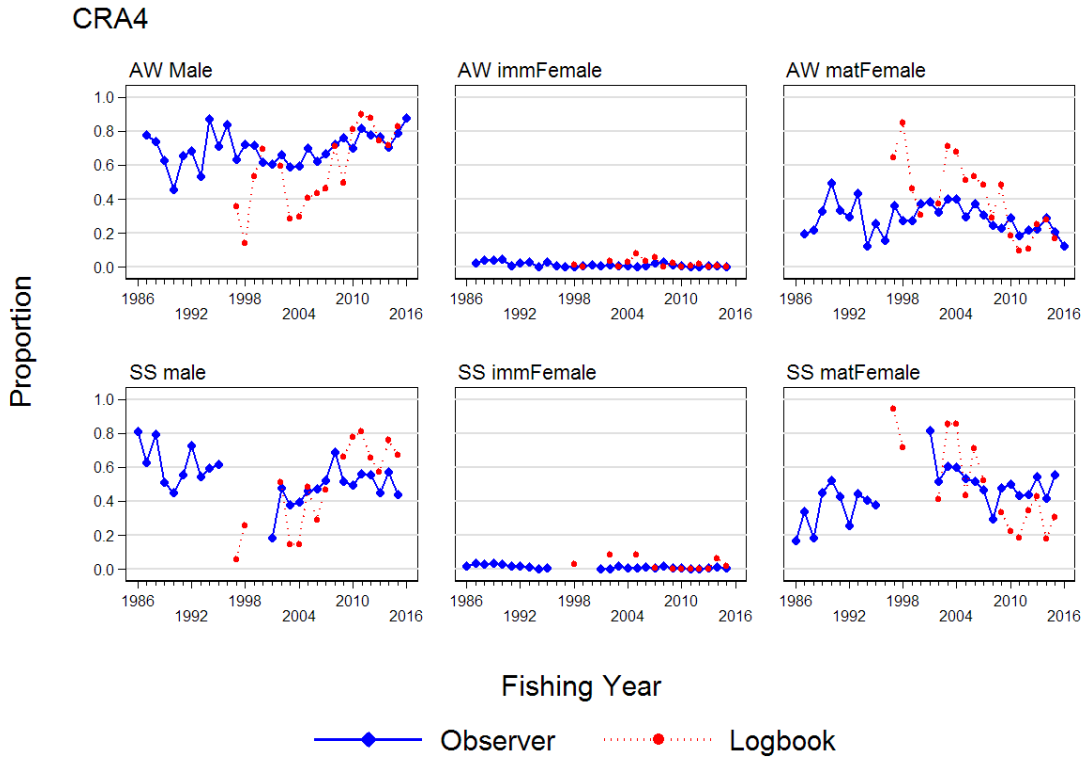

Figure 11: Proportion-at-sex by year, season and sampling source.

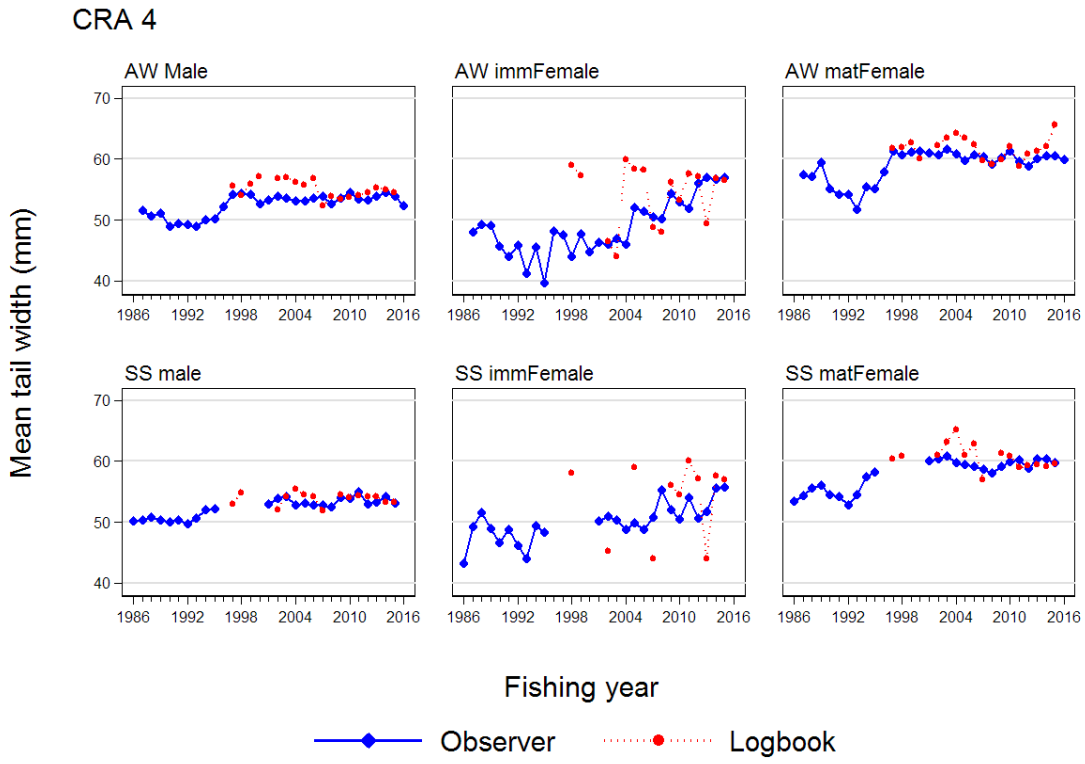

Figure 12: Mean length by year, season, sex and sampling source.

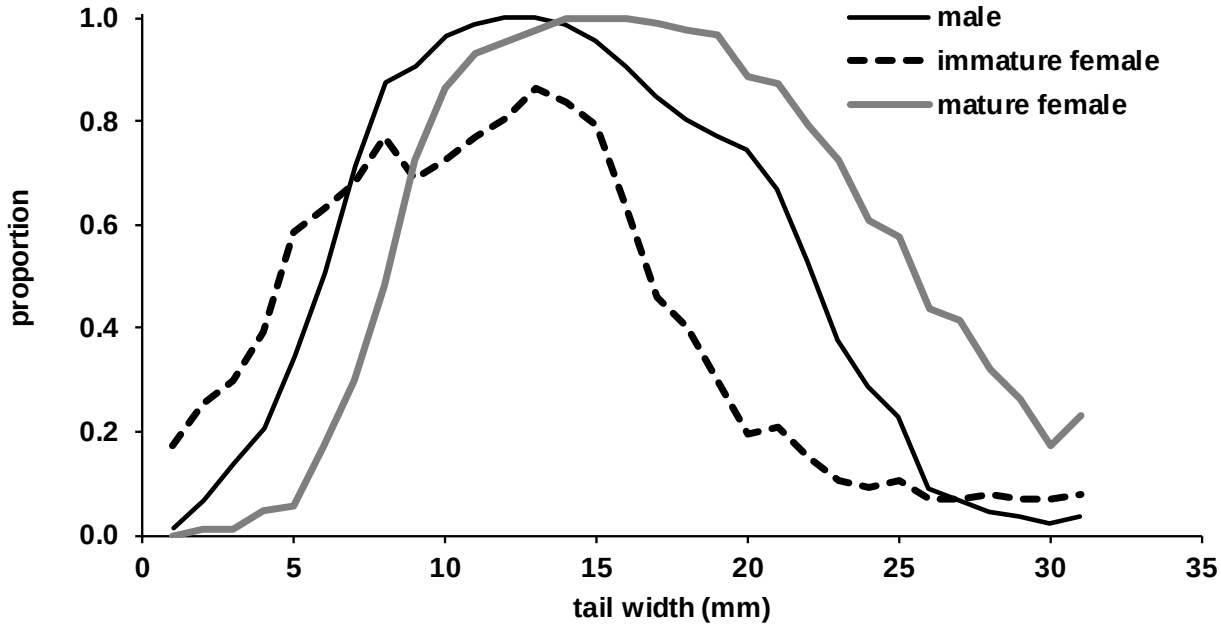

Figure 13: The proportion of size bins (across 87 year/season/sampling source strata) that contain a proportion of 0.001 or higher when the data are normalised by sex.

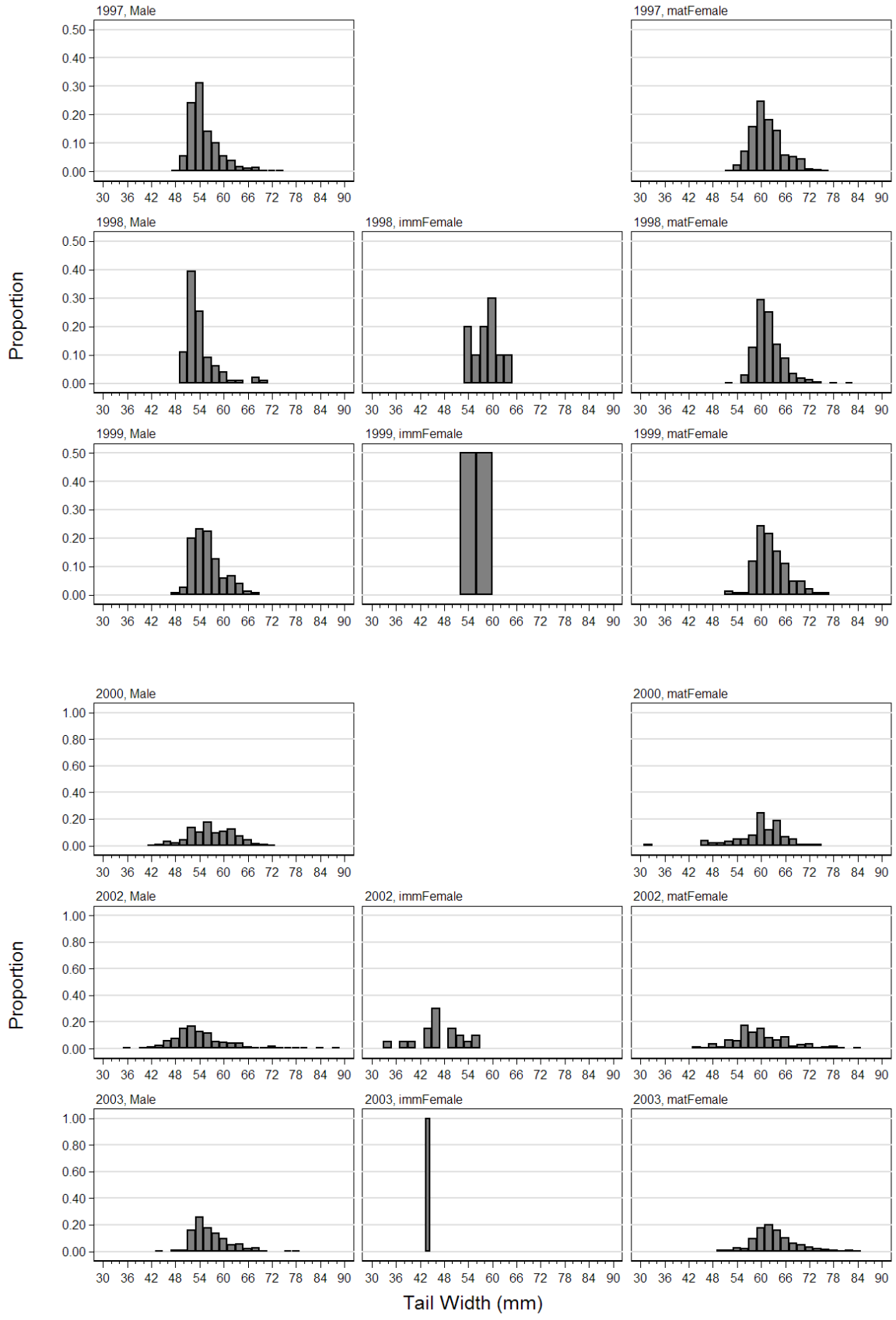

Figure 14A: Length frequency histograms by sex category for AW logbook samples, 1997–2003.

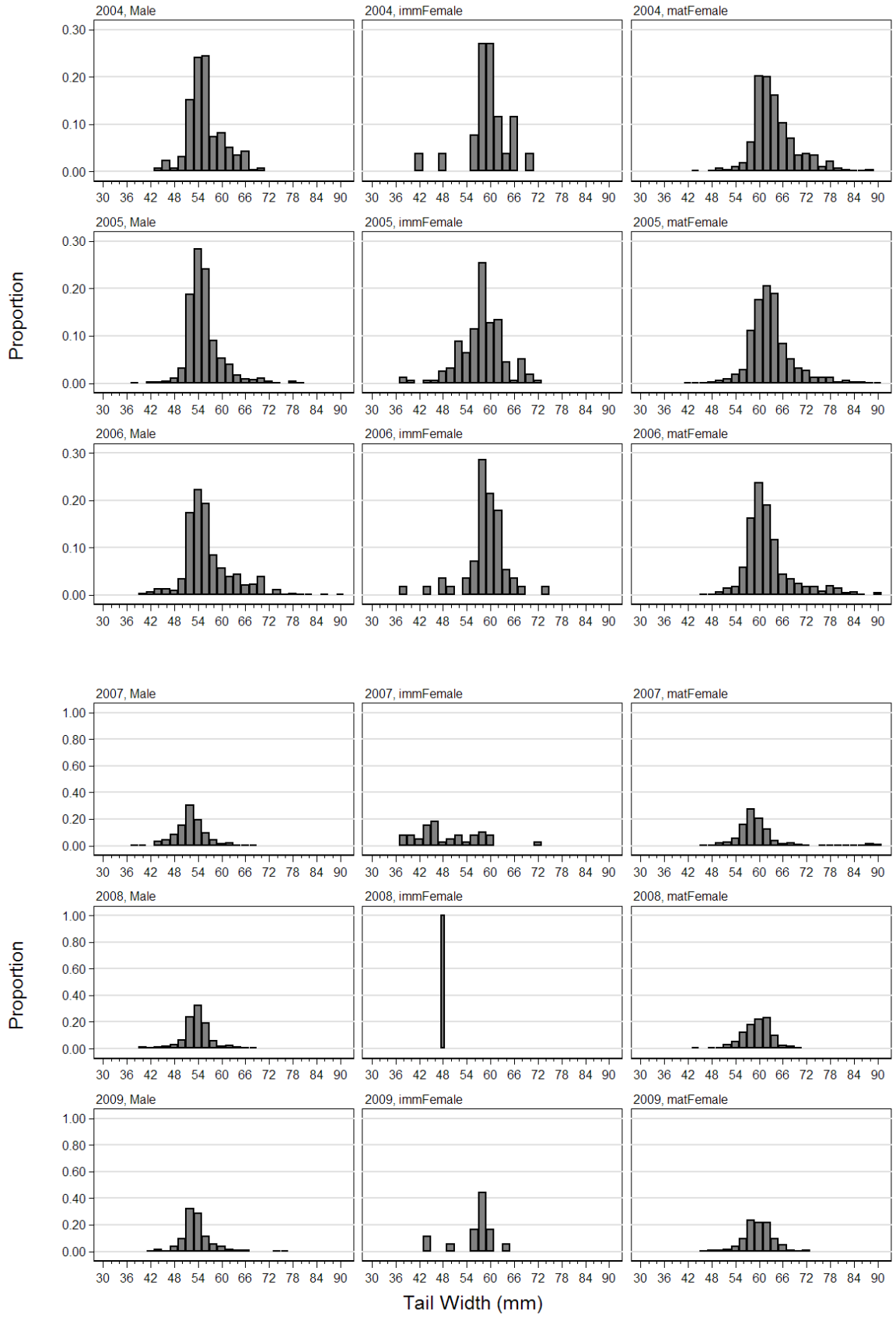

Figure 14B: Length frequency histograms by sex category for AW logbook samples, 2004–2009.

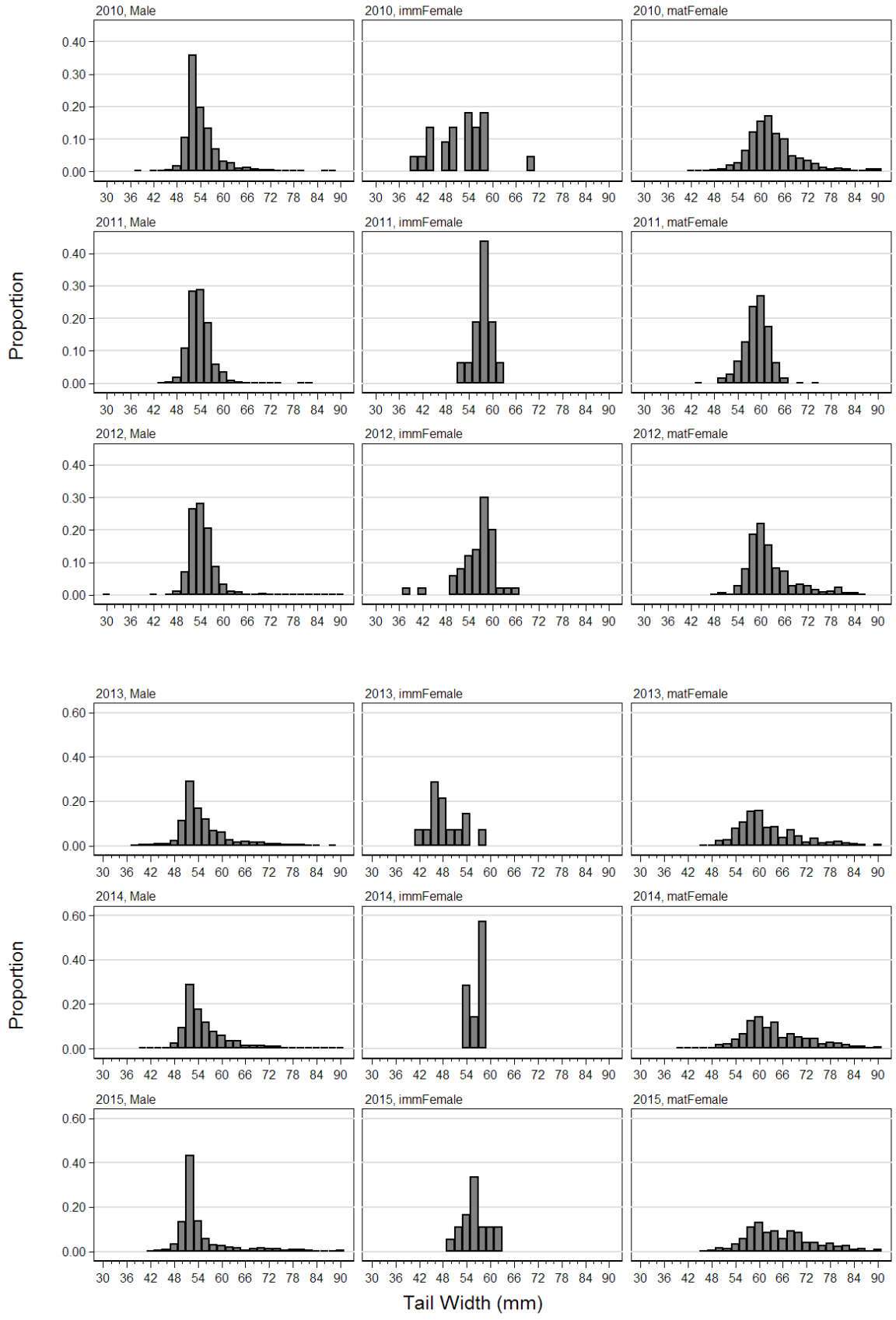

Figure 14C: Length frequency histograms by sex category for AW logbook samples, 2010–2015.

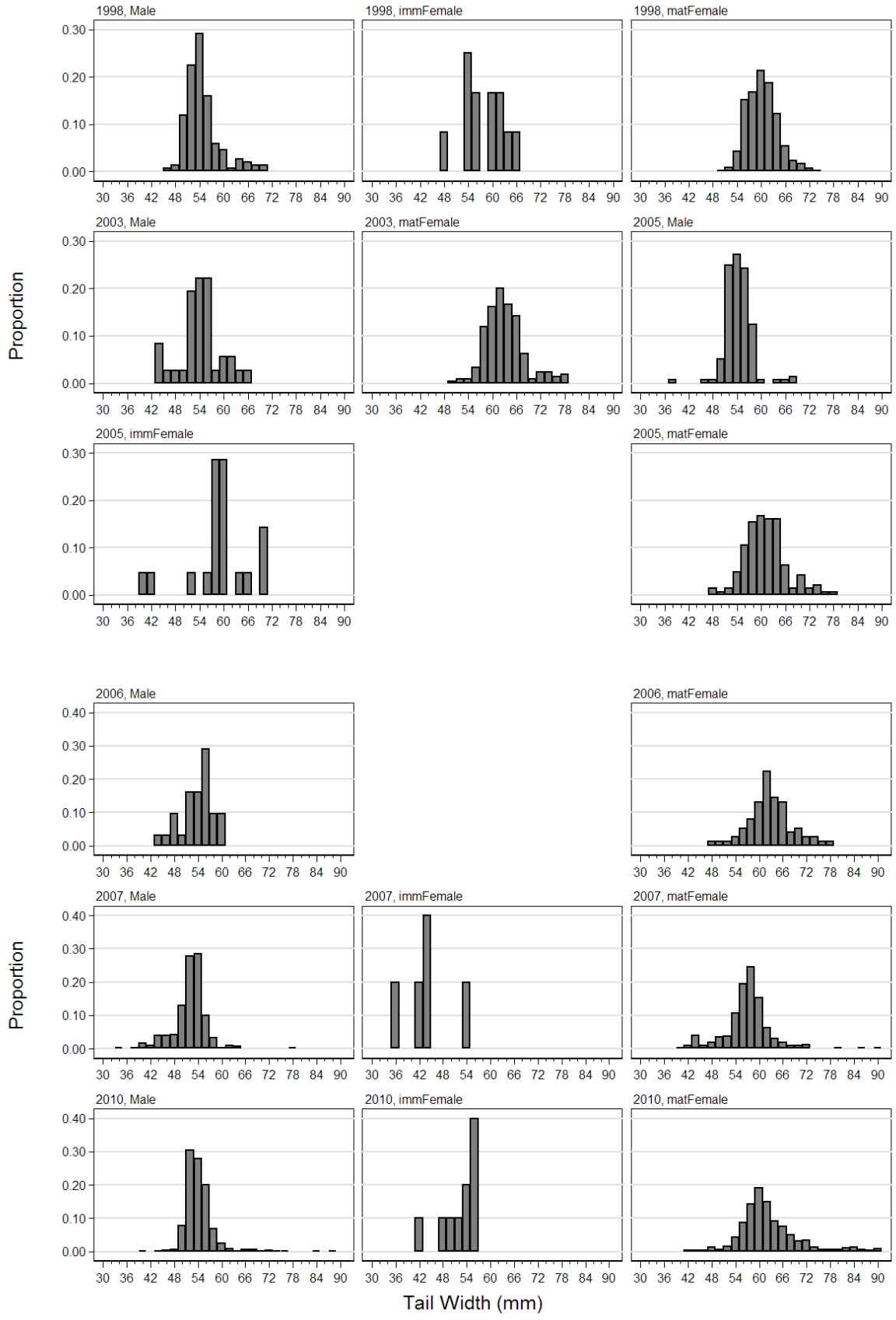

Figure 15A: Length frequency histograms by sex category for SS logbook samples, 1998–2010.

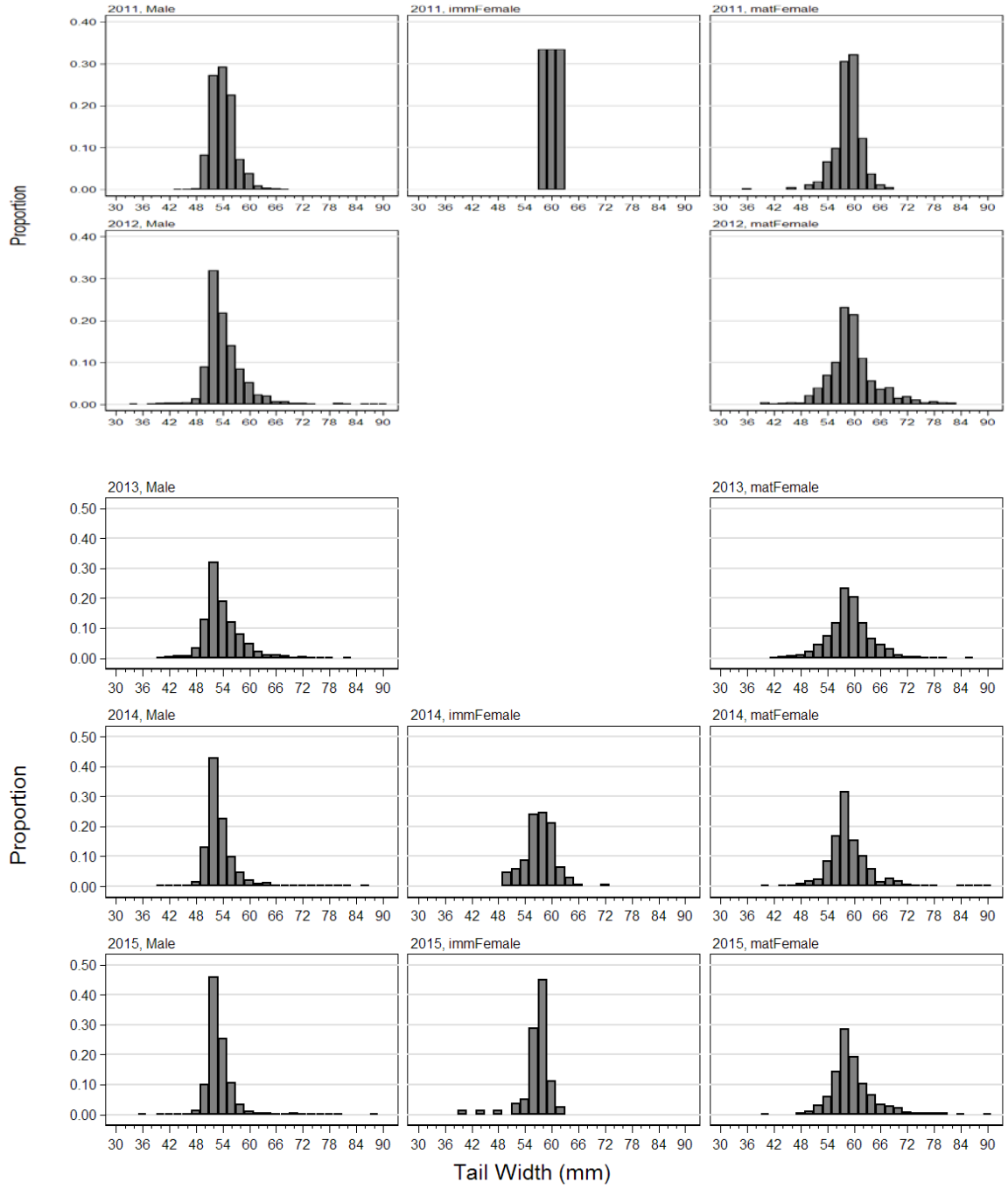

Figure 15B: Length frequency histograms by sex category for SS logbook samples, 2011–2015.

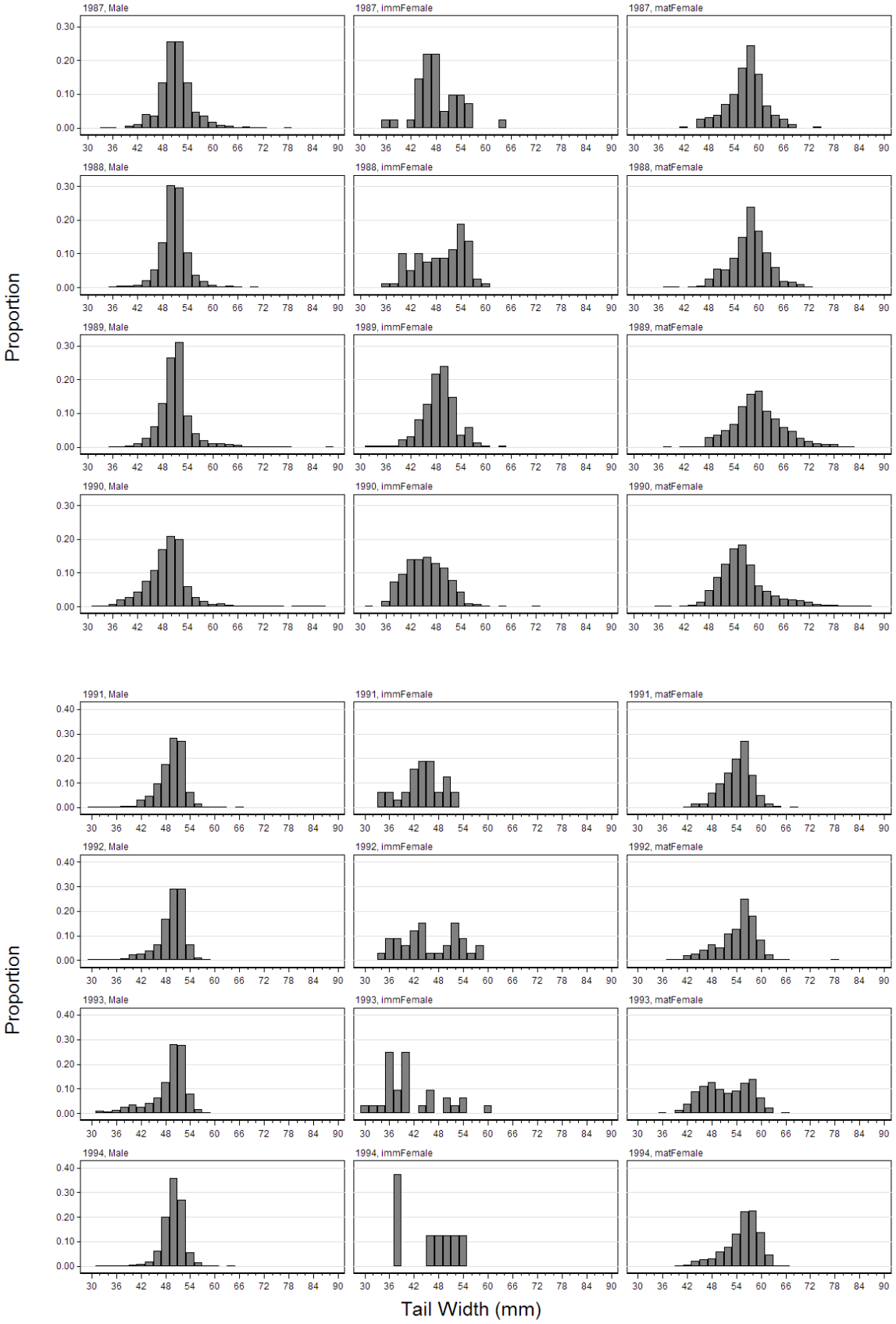

Figure 16A: Length frequency histograms by sex category for AW observer samples, 1987–1994.

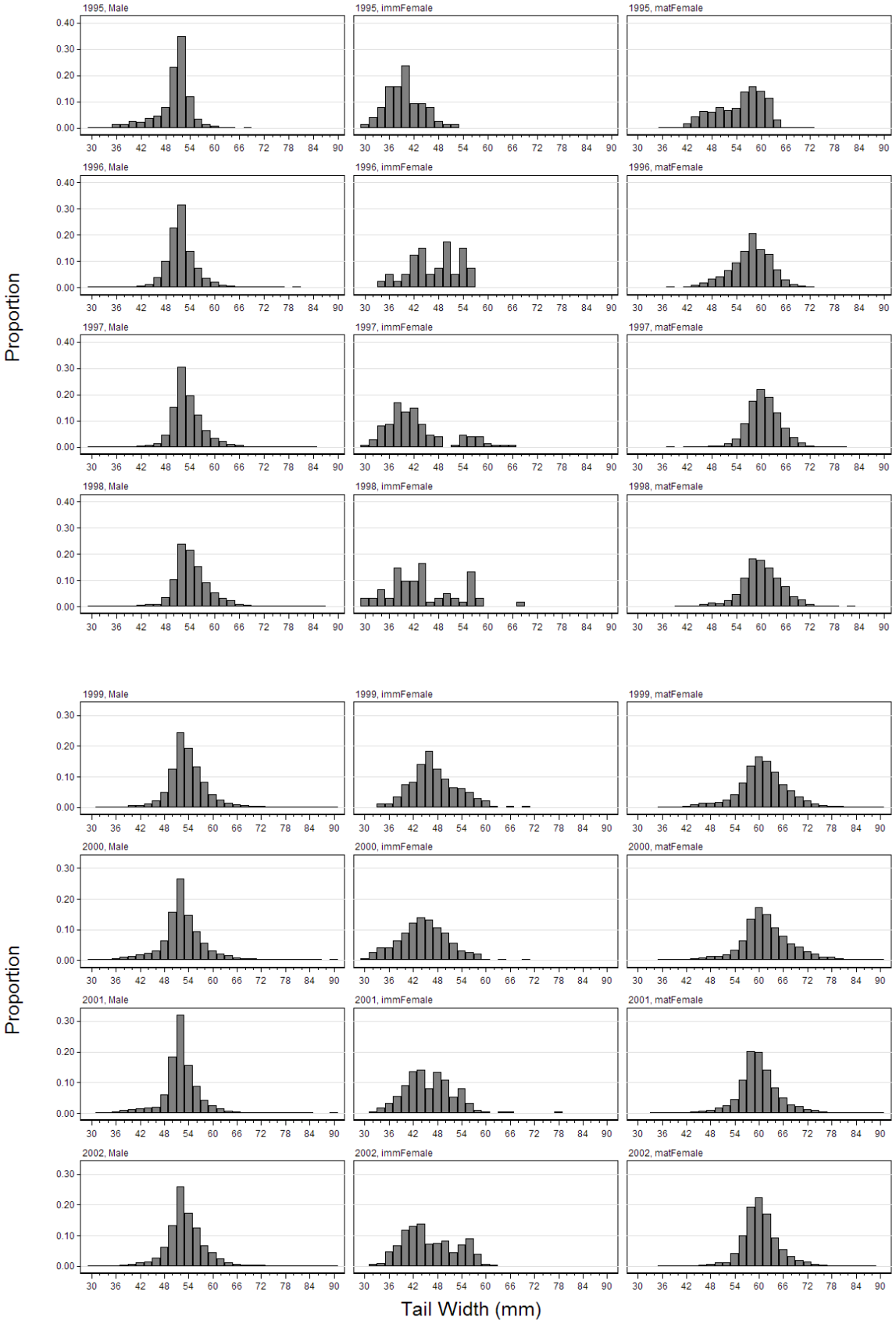

Figure 16B: Length frequency histograms by sex category for AW observer samples, 1995–2002.

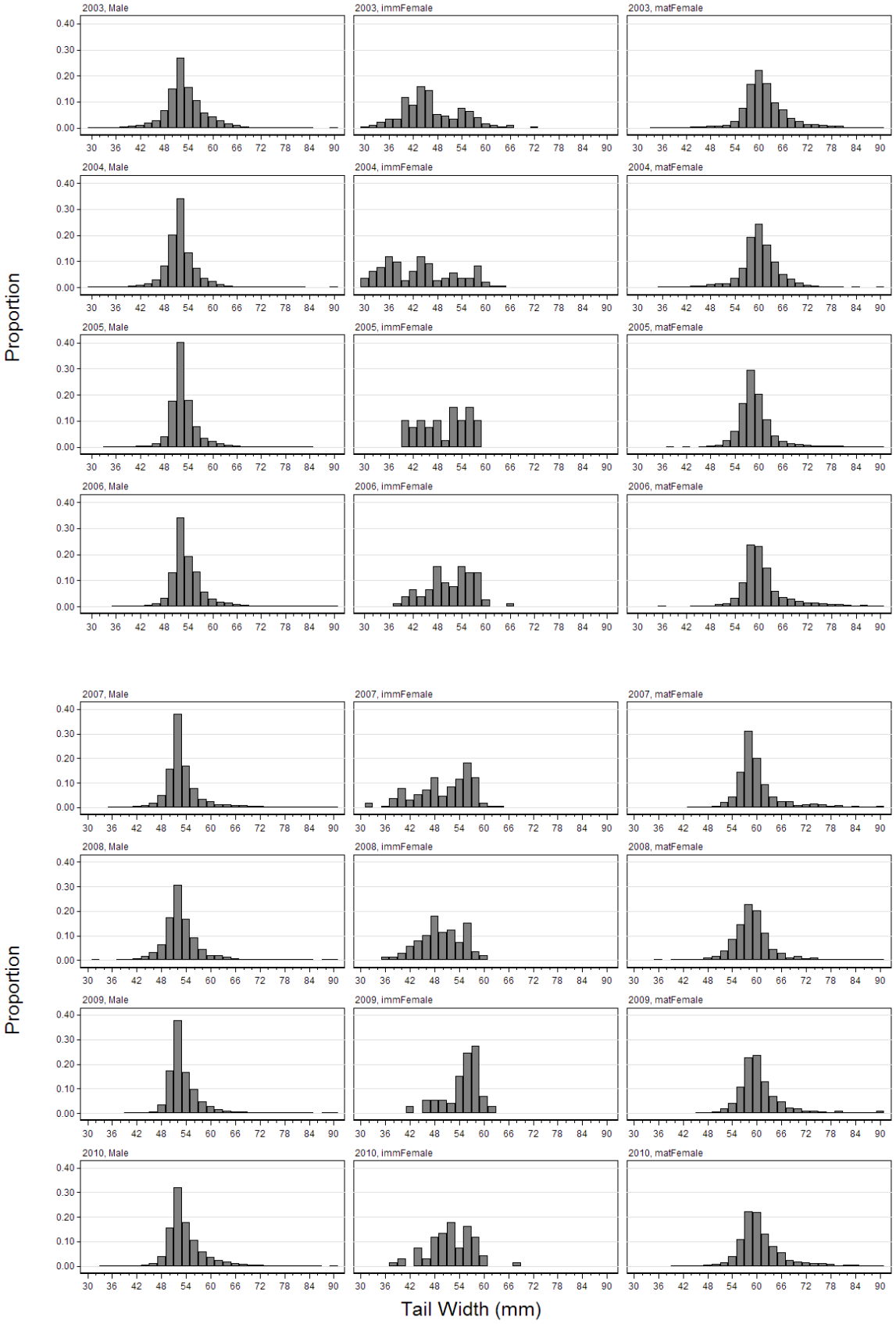

Figure 16C: Length frequency histograms by sex category for AW observer samples, 2003–2010.

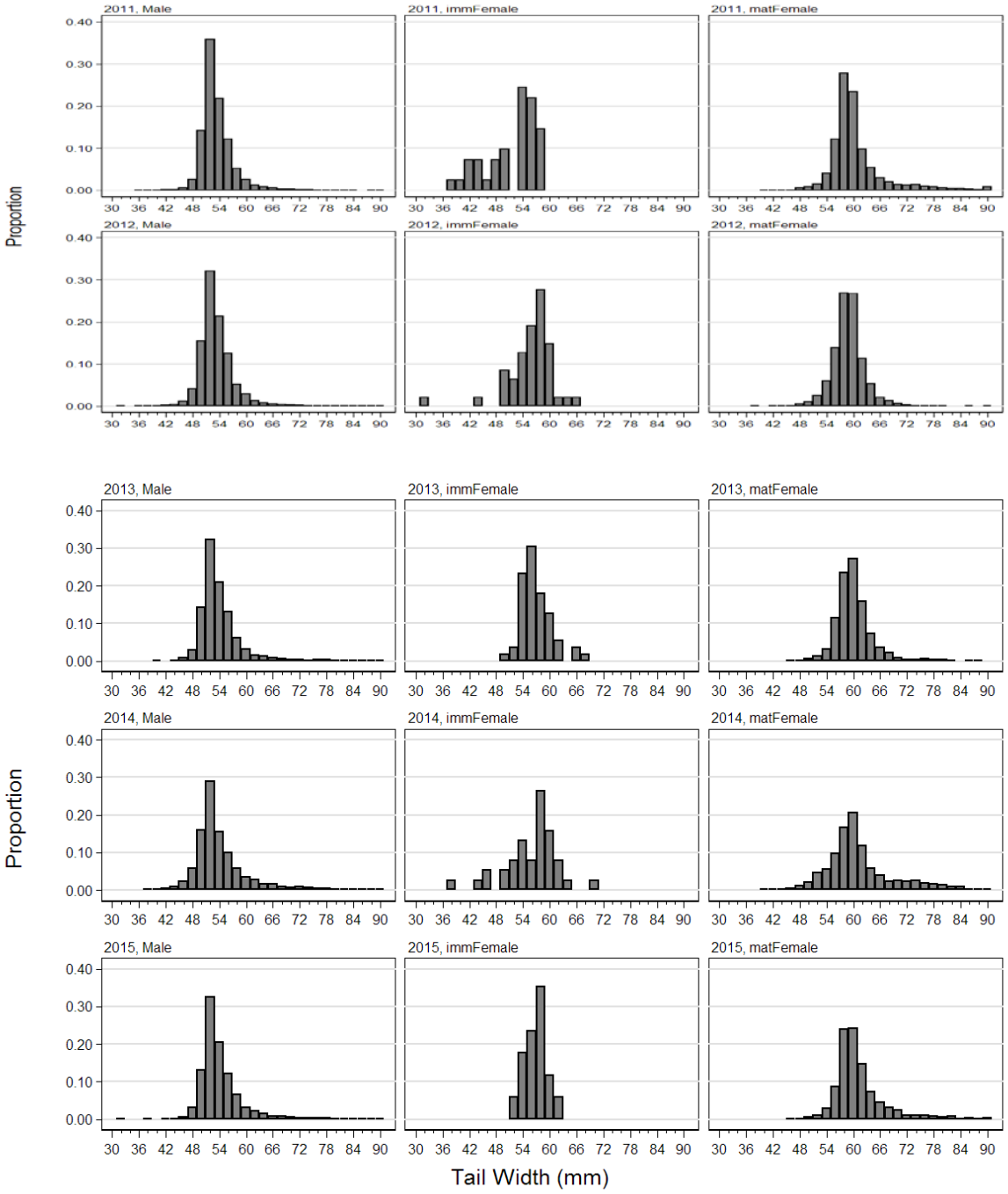

Figure 16D: Length frequency histograms by sex category for AW observer samples, 2011–2015.

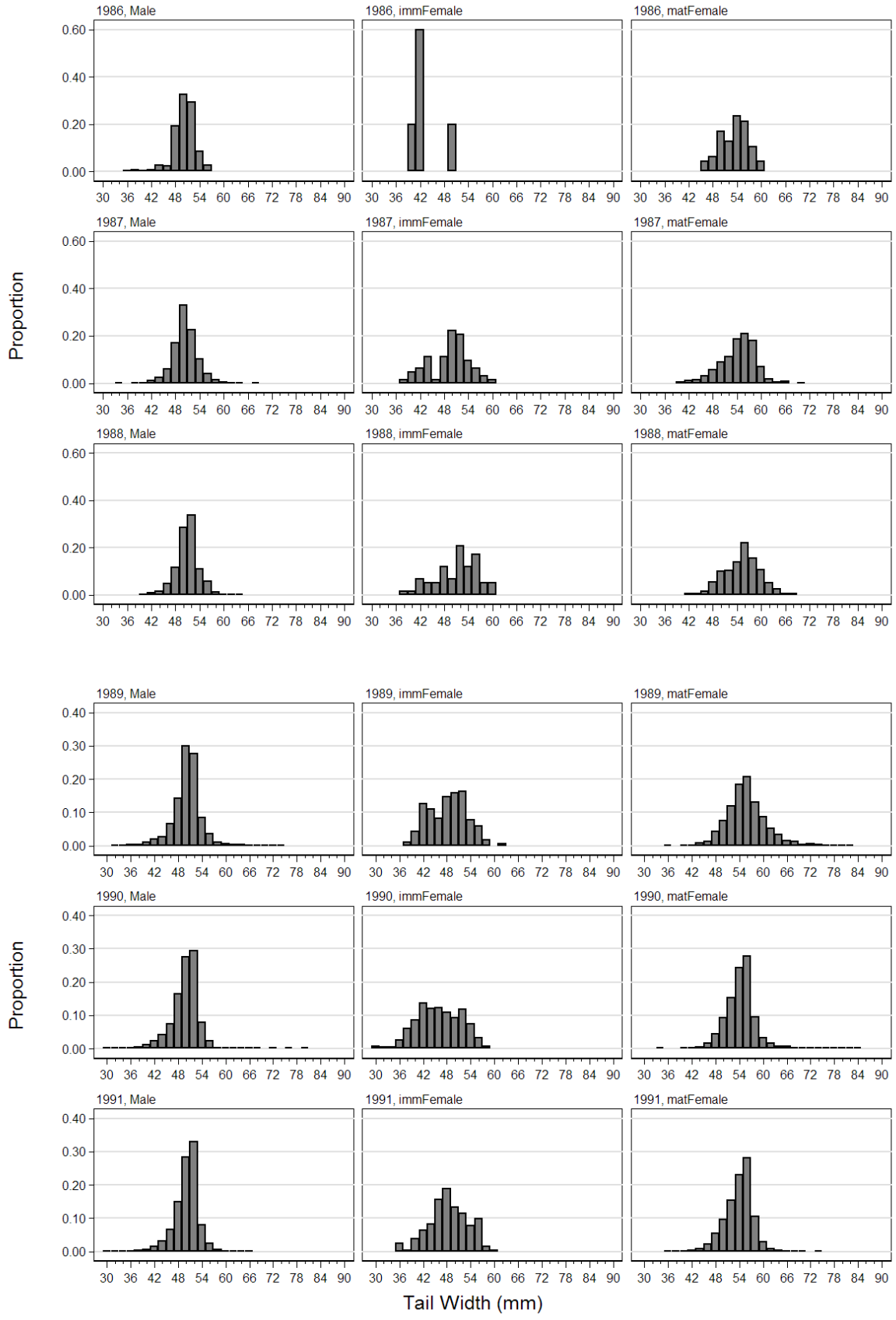

Figure 17A: Length frequency histograms by sex category for SS observer samples, 1986–1991.

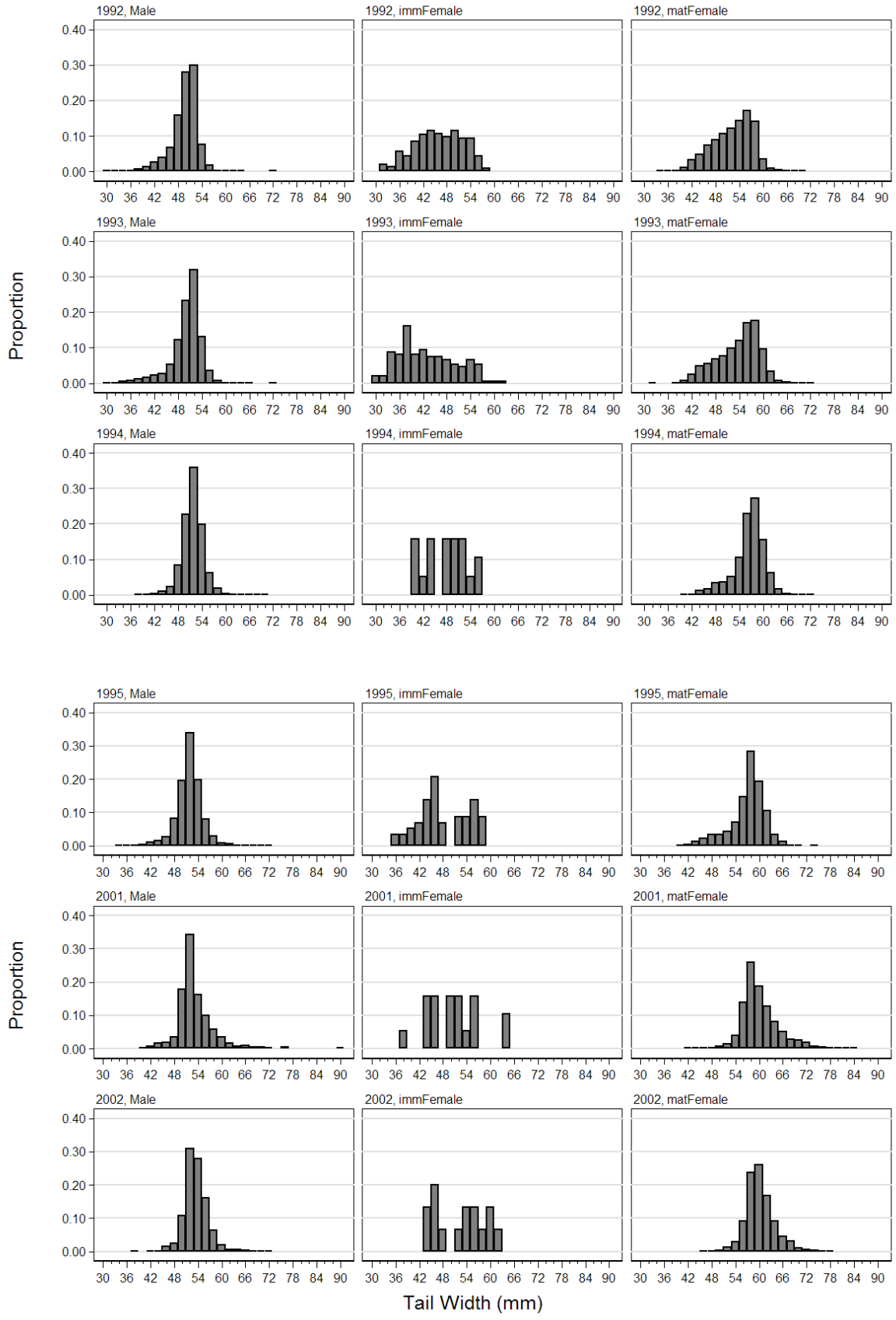

Figure 17B: Length frequency histograms by sex category for SS observer samples, 1992–2002.

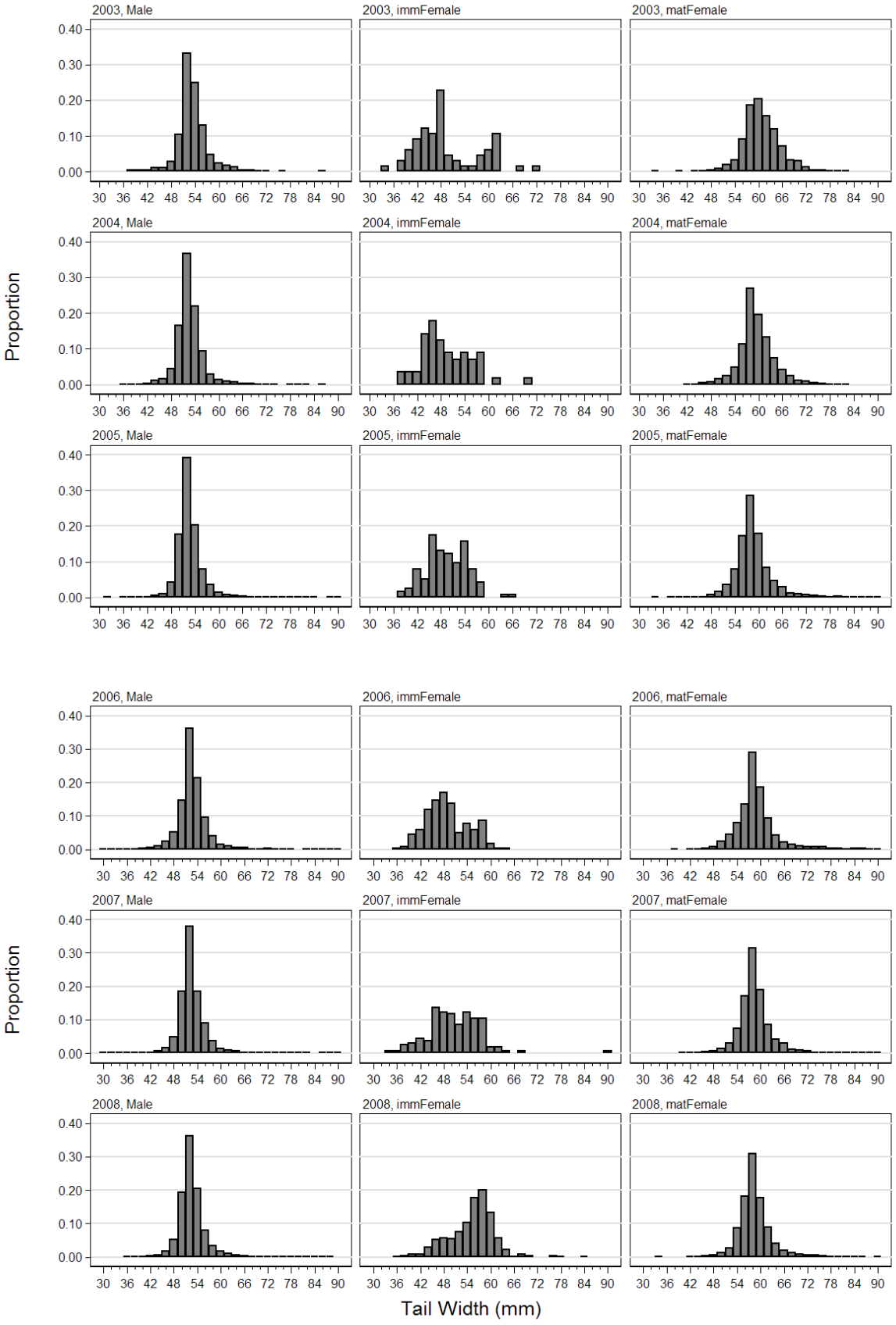

Figure 17C: Length frequency histograms by sex category for SS observer samples, 2003–2008.

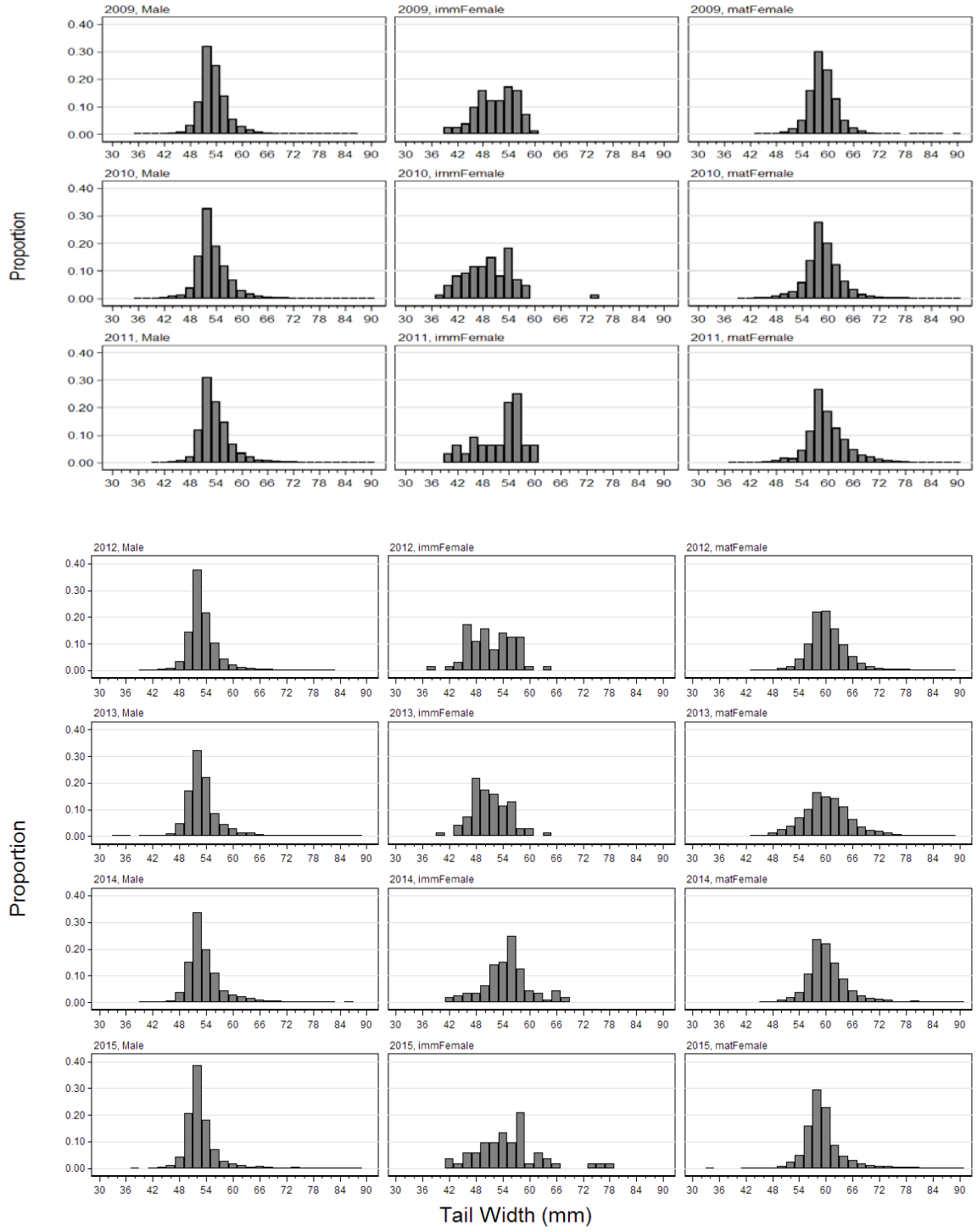

Figure 17D: Length frequency histograms by sex category for SS observer samples, 2009–2015.

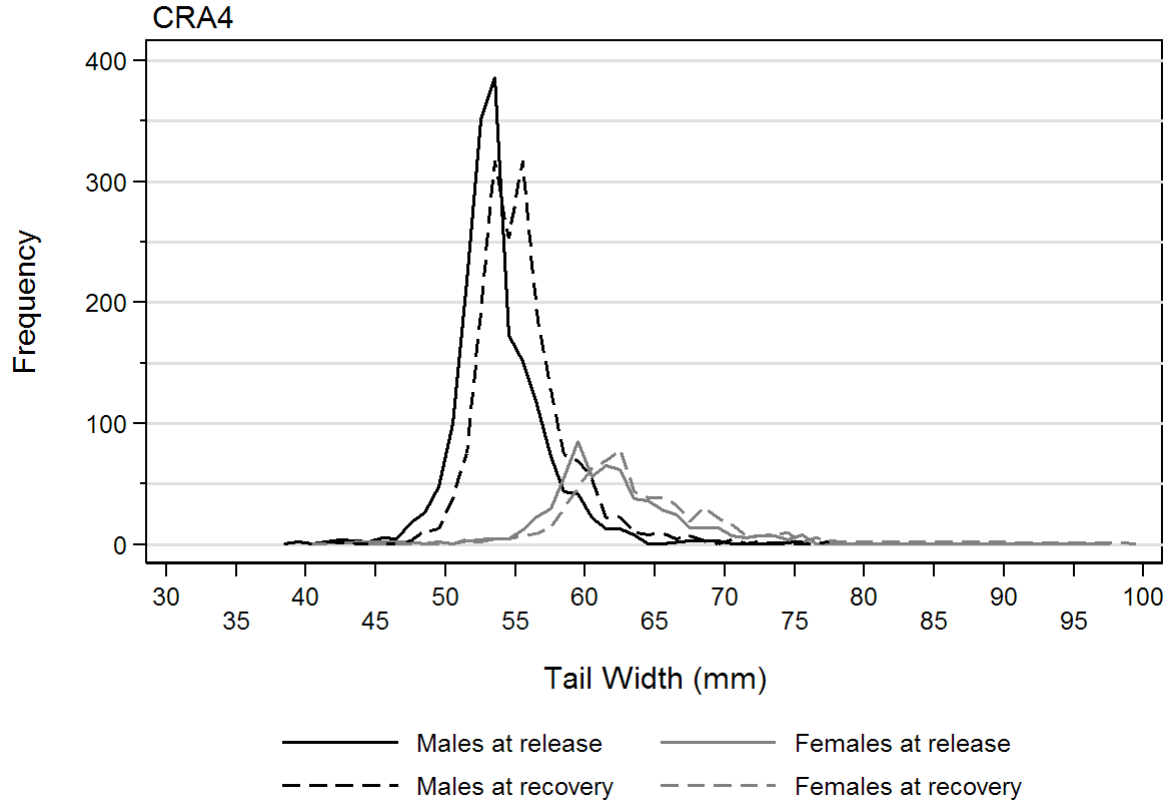

Figure 18: CRA 4: frequency polygons of size at release (solid lines) and recapture (dashed lines) by sex. A bin width of 1 mm was used.

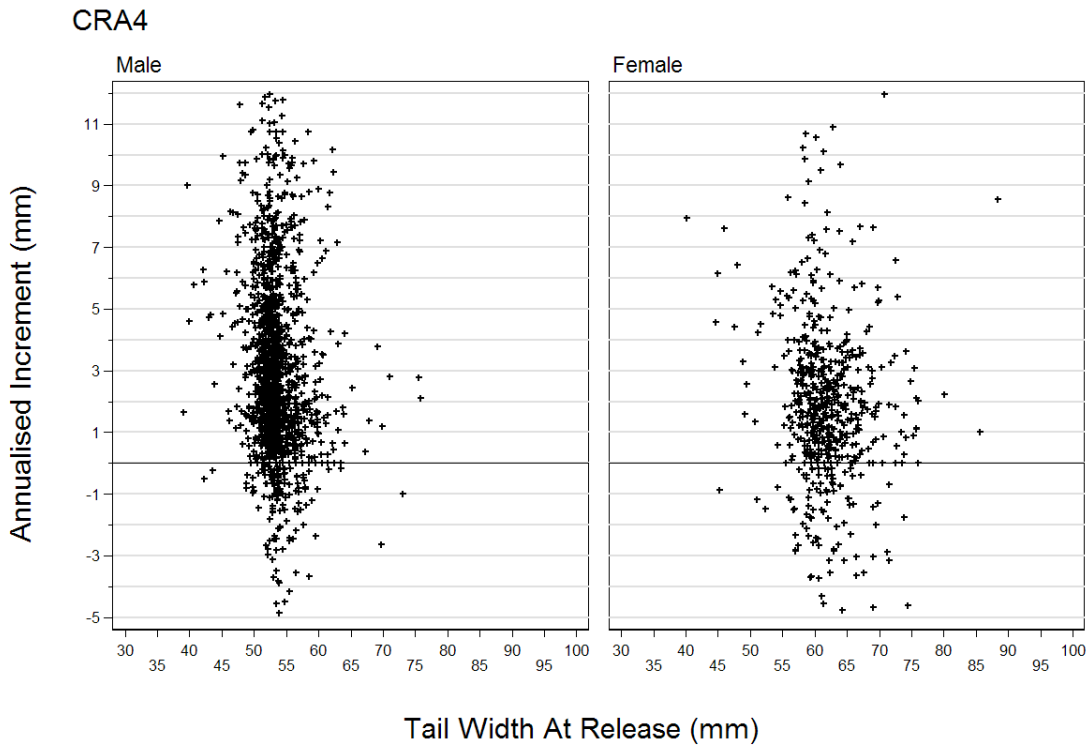

Figure 19: CRA 4: annualised increments versus size at release by sex. The y-axes have been truncated to the 5% and 95% quantiles to exclude the extreme outliers.

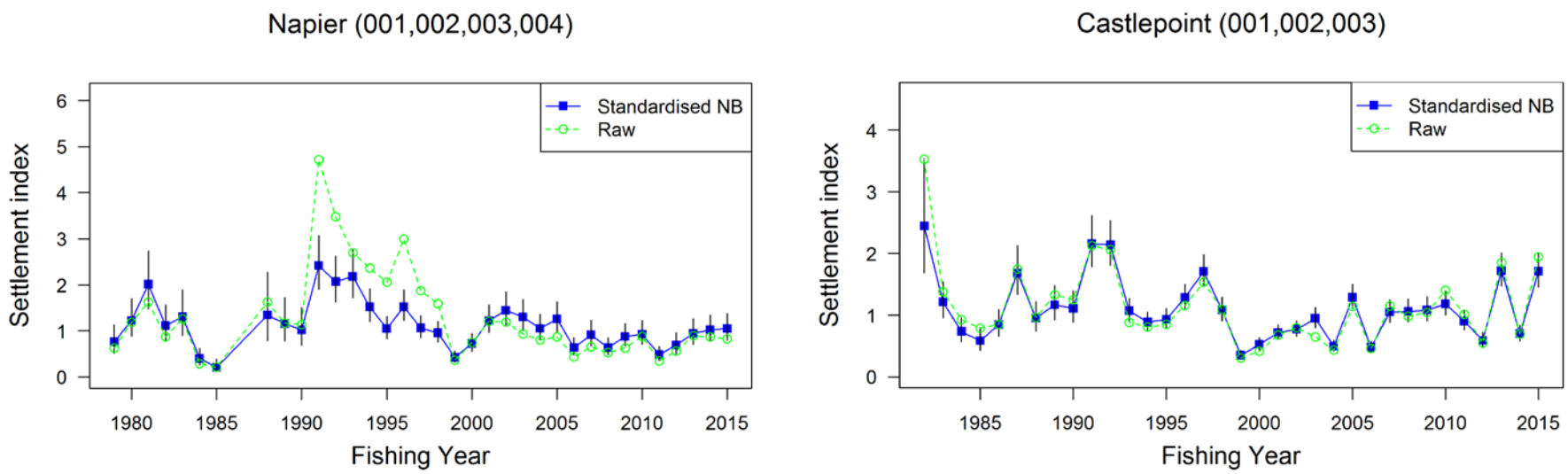

Figure 20: Standardised puerulus series based on a negative binomial (NB) distribution for Napier [left panel] and Castlepoint [right panel], showing the unstandardised (raw) series as well as the standardised series and the associated error bars (plots taken from Forman et al. 2017).

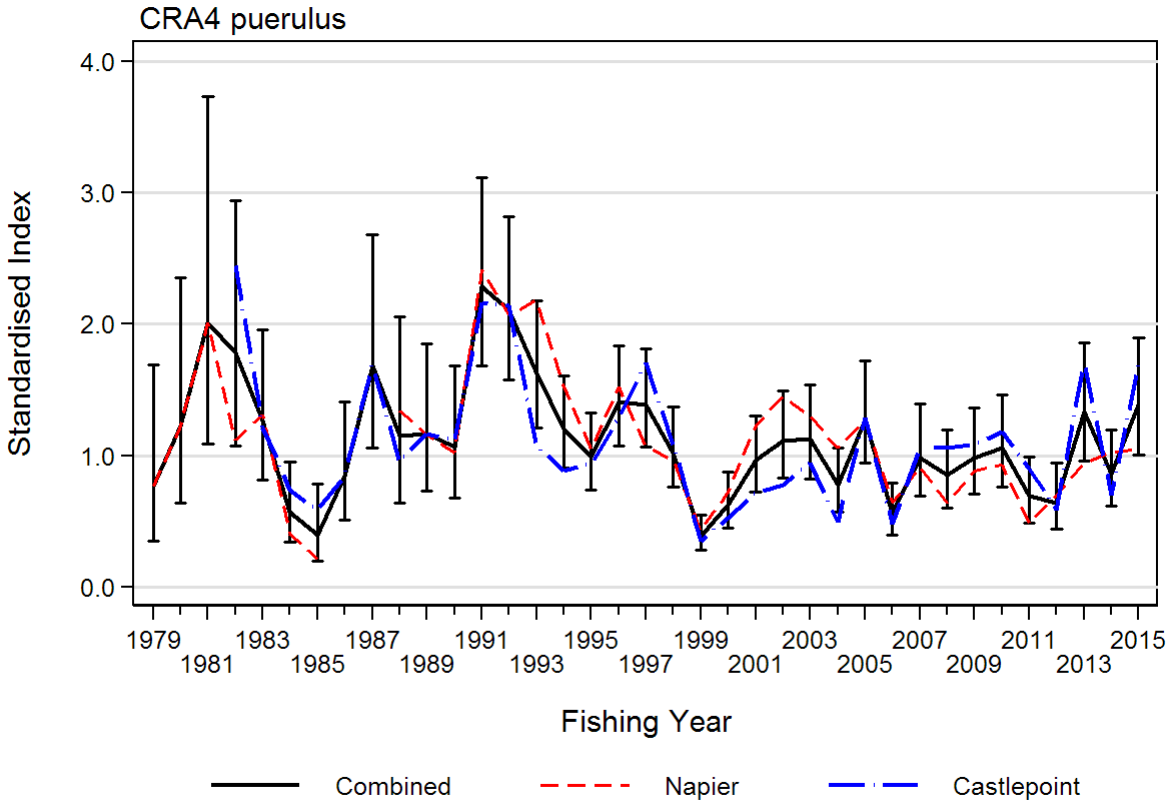

Figure 21: Plot of the two available standardised puerulus series for CRA 4 (Napier and Castlepoint) and the combined series. Error bars are 95% confidence intervals using the combined SE (Eq. 6) while assuming a lognormal distribution.

APPENDIX A. REQUEST TO MPI FOR NON-COMMERCIAL CATCH ESTIMATES

NZ ROCK LOBSTER INDUSTRY COUNCIL

Ka whakapai te kai o te moana

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

23 June 2016

Alicia McKinnon, Ministry of Fisheries
by email: *Alicia.McKinnon@mpi.govt.nz*

cc Dr. Julie Hills, Chair, RLFAWG
by email: Julie.Hills*@fish.govt.nz*
cc ECs:
bb26@inspire.net.nz
charles.edwards@niwa.co.nz
haistv@shaw.ca
paul@starrfish.net
darcy@quantifish.co.nz

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 4 stock assessment and reviewing the CRA 4 management procedure.

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 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 4 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 4 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 4 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

- **1 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 queries you may have.

Sincerely,

Daryl R Sykes

Daryl Sykes
Research Programme Manager
NZ Rock Lobster Industry Council

APPENDIX B. MPI RESPONSE TO NON-COMMERCIAL DATA REQUEST

5 September 2016

Dear the Rock Lobster Stock Assessment Team

NON-COMMERCIAL CATCH ESTIMATES FOR THE CRA 4 STOCK ASSESSMENT
This is a response to your request of 23 June 2016 for MPI advice on customary, recreational and illegal take estimates to use in the upcoming CRA 4 stock assessment.

Customary catch estimates

Summaries of the information MPI holds on CRA 4 customary harvest since the 2003/04 April fishing year is provided at the end of this letter (Tables A and B).

Under the Fisheries (Kaimoana) Regulations 1998, Tangata Kaitiaki/Tiaki are responsible for providing quarterly reports of their harvest authorisations to MPI. In areas not covered by the Kaimoana Regulations, customary harvest can be authorised for the purpose of hui or tangi under the Fisheries (Amateur Fishing) Regulations 2013 (previously Regulation 27A of the Fisheries (Amateur Fishing) Regulations 1986). There is no mandatory requirement for permit issuers under the Amateur Regulations to provide MPI with details of customary fishing authorisations.

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

Recreational harvest estimates

All available estimates of recreational rock lobster harvest by Quota Management Area are presented in the November 2015 Fisheries Assessment Plenary. The harvest estimates provided by the historical telephone diary surveys (1992, 1993, 1994, 1996, 2000 and 2001) are no longer considered reliable by the MPI Marine Amateur Fisheries Working Group.

A recreational harvest estimate is available for CRA 4 from the 2011-12 National Panel Survey (NPS), which includes any charter fishing activity (Table 1).

Table 1: Total estimated harvest for CRA 4 from the 2011-12 fishing year from the National Panel Survey:

Stock	Fishers (n)	Events (n)	Harvest (n)	CV	Mean Weight (kg)	Harvest (t)	CV
CRA 4	69	206	53,847	0.17	0.82	**44.17**	0.17

MPI recommends that the 2011/12 NPS estimate for CRA 4 is used in the upcoming stock assessment. Given that there were a number of panellists making quite a few trips and the CV is relatively low, the NPS estimate for CRA 4 is considered reasonably robust. However,

this is said in recognising that the NPS is unlikely to be reaching a high proportion of rock lobster fishers as finfish fishers, which could mean there is a negative bias in the catch estimates, but this has not been tested or quantified.

Illegal take estimates

MPI acknowledges that there is currently no robust and defensible methodology that can be used to accurately estimate illegal catches from any rock lobster fishery.

MPI has considered available information on detected illegal removals from prosecutions, observed activities, intelligence and intangible anecdotal knowledge, and other information provided by Fishery Officers for the CRA 4 fishery. Based on this assessment, MPI suggests that a 40 tonne illegal catch estimate continues to be used in the upcoming CRA 4 stock assessment. MPI notes that illegal take of rock lobster has likely decreased in the CRA 4 fishery and that the majority of the illegal activity in the area relates to paua. However, there is no robust way to estimate the magnitude of any decrease due to the uncertainty in the available information on illegal take.

Yours sincerely

Alicia McKinnon
Senior Fisheries Analyst

Table A: Summary of CRA 4 customary harvest information MPI holds that was collected under the Kaimoana Regulations from the 2003/04 April fishing year

APRIL FISHING YEAR	QUANTITY APPROVED		ACTUAL QUANTITY HARVESTED	
	Unit Type	Total	Unit Type	Total
2003/04	NO.	495	NO.	275
	(blank)	11387	(blank)	4039
2004/05	NO.	680	NO.	635
	(blank)	11936	(blank)	5522
2005/06	NO.	522	NO.	376
	(blank)	15845	(blank)	3828
2006/07	NO.	266	NO.	232
	(blank)	13173	(blank)	3608
2007/08	NO.	483	NO.	410
	(blank)	17827	(blank)	8195
2008/09	NO.	3146	NO.	1987
	(blank)	21675	(blank)	8733
2009/10	NO.	3973	NO.	2314
	(blank)	13798	(blank)	5653
2010/11	NO.	1408	NO.	829
	(blank)	9912	(blank)	4126
2011/12	BIN	2	-	-
	NO.	1656	NO.	1515
	(blank)	14176	(blank)	6762
2012/13	KG	1306	KG	1222
	NO.	1464	NO.	1347
	(blank)	25393	(blank)	13555
2013/14	NO.	2879	NO.	2326
	(blank)	13759	(blank)	8413
2014/15	NO.	140	NO.	47
	(blank)	14044.33	(blank)	6173
2015/16	NO.	600	NO.	505
	(blank)	3126.67	(blank)	1269

Table B: Summary of CRA 4 customary harvest information MPI holds that was collected under the Amateur Regulations from the 2003/04 April fishing year

APRIL FISHING YEAR	QUANTITY APPROVED		ACTUAL QUANTITY HARVESTED	
	Unit Type	Total	Unit Type	Total
2003/04	(blank)	4581	(blank)	476
2004/05	(blank)	12035	(blank)	385
2005/06	BIN	2	-	-
	(blank)	5512	(blank)	309
2006/07	NO.	40	-	-
	(blank)	590	(blank)	55
2011/12	(blank)	5420	(blank)	1269
2012/13	(blank)	3300	(blank)	-