Ministry for Primary Industries
Manatū Ahu Matua

Data for the 2013 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2

New Zealand Fisheries Assessment Report 2014/18

Paul J. Starr
Paul A. Breen
Charles T.T. Edwards
Vivian Haist

ISSN 1179-5352 (online)
ISBN 978-0-478-42394-5 (online)

April 2014

New Zealand Government

Growing and Protecting New Zealand

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-resources/publications.aspx
http://fs.fish.govt.nz go to Document library/Research reports

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Starr, P.J.; Breen, P.A.; Edwards, C.T.T.; Haist, V. (2014). Data for the 2013 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2.

***New Zealand Fisheries Assessment Report 2014/18.* 54 p.**

This document presents data for use in the 2013 stock assessment and management procedure evaluations for rock lobsters in CRA 2. Data sets described in this report include catch estimates for all sectors of this fishery, standardised CPUE indices, length frequencies and tag-recapture data.

Catch estimates are provided for the commercial, recreational, customary and illegal fisheries, collated by year to 1978 and then by season (spring-summer and autumn-winter), and by size-limited and non-size-limited fisheries. Recreational catch estimates were available from telephone/diary surveys in 1992, 1996 and from a recent large scale multi-species survey conducted using a population-based survey methodology. It was assumed that recreational catch has been proportional to spring-summer CPUE, and the method used in recent assessments was used to estimate recreational catches from 1979.

CPUE was standardised for the spring-summer and autumn-winter 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 various records were weighted. An analysis of retention by size was done to see if legal high-grading was a factor that required to be addressed; this found little evidence of high-grading in CRA 2.

Tag-recapture data provide strong information on growth rates for each sex. The document describes the data set and exploratory fits.

For this stock there was no time-series of puerulus settlement data to use for the assessment.

1. INTRODUCTION

This work addressed parts of Objectives 3, 4 and 5 of the Ministry for Primary Industries (MPI) contract CRA2012-01A. This three-year contract, which began in April 2013, was awarded to New Zealand Rock Lobster Industry Council Ltd. (NZ RLIC Ltd.), who sub-contract Objectives 3, 4 and 5 to the authors of this report.

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

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

Objective 5 - Decision rules: To evaluate new management procedures for rock lobster fisheries

The most recent previous assessment of CRA 2 was in 2002 (Starr et al. 2003). For 2013, the National Rock Lobster Management Group (NRLMG) agreed that Objective 4 should be addressed with a stock assessment for CRA 2, and that Objective 5 should be addressed by development of management procedures for CRA 2 and CRA 9. The CRA 9 work is described by Breen (2014). The data described here were collated for the CRA 2 modelling work, which is described by Starr et al. (2014). Decisions on data collation choices were discussed and approved by the Rock Lobster Fishery Assessment Working Group (RLFAWG). The stock assessment used the length-based Bayesian model described by Haist et al. (2009) and followed the pattern of recent lobster stock assessments (e.g. Haist et al. 2013).

CRA 2 extends from the Waipu River through the Hauraki Gulf and Bay of Plenty to East Cape (see Figure 1). The current 452.6 tonnes TAC for the fishery was set in 1997. The TAC includes 140 tonnes for amateur catch, 16.5 tonnes for customary harvest and 60 tonnes for illegal removals. The current TACC has been 236.1 tonnes since 1997, and since 1993 the TACC has been more than 85% caught, except for 2002–04.

In 2010 the TACC was distributed amongst 43 quota share owners (NRLMG 2010), and in 2012–13 there were 35 vessels reporting at least 1 t of commercial catches in CRA 2 (Starr 2013). The main operating period for commercial vessels generally extends from June to January. The estimated landed value of the CRA 2 catch was $13.1 million in 2010 (NRLMG 2010), based on the average port price. The industry sustains a number of processing and export companies in Tauranga, Whitianga and Auckland.

Recreational catch is taken by potting and diving, and there is a large recreational charter vessel industry. Rock lobsters have high cultural significance to Maori and a large Maori population in the Bay of Plenty ensures that rock lobster retains significant customary value.

This document describes catches – commercial, recreational, customary and illegal – CPUE, length frequencies and tag-recapture data. It includes some analysis of retention (the inverse of high-grading) and preliminary fits to the tag-recapture data. In contrast with stock assessments in other QMAs, for CRA 2 there is no time series of puerulus settlement data available for use in the stock assessment.

2. CATCH DATA

2.1 Commercial catch

The fishing year and calendar year were the same before 1979. From 1979 onwards, the fishing year has been April through March (Breen et al. 2001). Reported annual commercial catches from 1945 through 1978, summarised by calendar year, were obtained from sources described in Bentley et al. (2005). From 1 January 1979 through 31 March 1986, catches were taken from monthly data summarised by fishing year from the Fisheries Statistics Unit (FSU), a version of which is now held by 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 30 March 1988, monthly reported catch totals from all of New Zealand were obtained from Quota Management Returns (QMRs), maintained by MPI. 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 newer forms.

Annual commercial catches in CRA 2 averaged 196 t before 1979, with a short period in the late 1960s when catches exceeded 300 t/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 t in 1980–81 and averaging just over 300 t during that decade. Commercial catches in CRA 2 have closely matched the TACC since the introduction of rock lobster into the QMS in 1990–91 (Figure 3).

There has been increased use of intermediate destination codes (see Table 1) in many of the CRA QMAs, a practice which allows operators to wait for favourable market conditions for selling their catch. However, this breaks the link between effort and the catch (see Starr 2013 for a discussion of this problem). The landing information from Catch and Effort Landing Reports (CELRs) was used to explore this practice in CRA 2: it was relatively small (Figure 4).

There is uncertainty in the quality of the catch estimates in the years before the FSU system began in 1979, but catches in the 1980s were collected when the FSU system was operating and there is confidence in the quality of these estimates. 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 2 (Table 2). The estimates from the two Kingett Mitchell National Surveys (Boyd & Reilly 2004; Boyd et al. 2004) were not accepted by the RLFAWG for the CRA 3, CRA 4 or CRA 5 stock assessments. Estimated catches from these two surveys were thought to be biased in a review of the available recreational surveys (unpublished minutes: Recreational Technical Working Group [Auckland NIWA, 10–11 June 2004]).

A recently completed national recreational survey (National Research Bureau, unpublished data) provided an estimate of the CRA 2 recreational catch for 1 October 2011 through 30 September 2012. Most of the recreational catch is taken during the spring-summer season (SS, October through March), so this estimate was assigned to the 2011–12 fishing year[1].

MPI were asked to provide estimates of current and historical recreational catches, and an appreciation of their uncertainty (see Appendix A). MPI were unable to provide these estimates (see Appendix B).

The recreational catch vectors prepared for this assessment assume that recreational catch is proportional to the SS abundance, as reflected by SS CPUE. The standardised SS CPUE vector was calculated based on the F2 algorithm (see Starr 2013) using combined “L”, “F” and “X” destination codes. This was then scaled to the mean catch from the three recreational surveys listed in Table 2 by calculating the ratio of the survey catch estimate in each year to the respective SS CPUE. The mean of these ratios was then applied to the SS CPUE for all years from 1979–2012. This algorithm is analogous to that used for CRA 4 in 2011 (Starr et al. 2012) and CRA 7/CRA 8 in 2012 (Starr et al. 2013). Catch in 1945 was assumed to be 20% of that estimated for 1979 and was scaled proportionally for 1946 through 1978.

The resulting base case recreational catch vector is shown in Figure 5, after adding to each year the maximum reported recreational landings (1.37 t) from commercial vessels under Section 111 of the Fisheries Act (this procedure was agreed by the RLFAWG in 2006). Recreational catch was split between seasons, with 90% assumed taken in the SS and the remainder in autumn-winter (AW, April through September). The mean annual recreational catch for the period 1945–2012 from this vector was 62.0 t.

For sensitivity trials, alternative recreational vectors were created with half and twice the base case values.

[1] the convention for rock lobster data is to label fishing years by the first and longest part, *viz.* 2011–12 is called “2011”

2.3 Customary catch

MPI were asked to provide estimates of current and historical customary catches, and an appreciation of their uncertainty (see Appendix A). MPI provided tables of customary permits and realised catches for CRA 2 (see Appendix B), some by weight and some by numbers of lobsters. On the basis of the information in these tables, MPI concluded for CRA 2:

> *"Based on the information supplied above and its uncertainty, MPI considers it appropriate to continue to use a 10 tonne constant customary catch estimate for CRA 2."*

(Alicia McKinnon, MPI, pers. comm.).

Given this information, annual customary catches were assumed to be a constant 10 t. They were split between seasons, with 90% assumed taken in the SS.

2.4 Illegal catch

MPI were asked to provide estimates of current and historical illegal catches, and an appreciation of their uncertainty (see Appendix A). MPI were also asked to provide an estimate of the proportion of illegal catch that was eventually reported as legal catch. MPI pointed to estimates given in the past (Table 3) and suggested (see Appendix B) the following for CRA 2:

> *"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 CRA2 illegal catch. Given this uncertainty, MPI suggests that the 88 tonne estimate of illegal catch is used in the upcoming CRA2 stock assessment and sensitivity analyses are carried out with half of the illegal catch estimate (i.e., 44 tonnes). "* (Alicia McKinnon, MPI, pers. comm.)

Accordingly, a constant illegal catch of 88 t/year was used to fill in the missing years (Table 3) from 1996 to 2012. Years before 1996 without an estimated illegal catch were interpolated.

The MPI (formerly MFish) Compliance estimates for illegal catch were usually provided in two categories per QMA by year, although these categories had many missing estimates (Table 3). Missing categories were treated as zeroes by MPI Compliance and we have continued this practice. The category of "commercial illegal reported" or "reported" is assumed to represent illegal commercial catch that is eventually reported to the QMS as legitimate catch; this catch is subtracted from the reported commercial catch to avoid double-counting.

In past assessments, illegal catch estimates have been based on a belief that a large amount of unreported catch was taken before the introduction of lobsters to the QMS. Anecdotal evidence suggested that there were a lot of cash sales and unaccounted exports of lobster. These were thought to have been reduced after the change to tail width minimum legal size (MLS) and the introduction of lobsters into the QMS. Current illegal fishing is believed to be conducted mainly by fish thieves or poachers and consequently is rarely reported in the legal catch data.

The following procedure has been followed to estimate illegal catch in stock assessments since the 2004 assessment of CRA 3:

1. Starting with the estimates of export discrepancies for all of New Zealand for the period 1974 to 1980 (McKoy, unpublished data), the CRA 2 illegal catches for each of these seven years were estimated from the ratio of the reported commercial catch in CRA 2 relative to the total New Zealand reported commercial catch for the same years.
2. The average ratio of the export discrepancy catch to the reported commercial catch was calculated for the period 1974–80. This ratio was used to generate an illegal catch estimate for all years with no data (1945 through 1973 and 1981 through 1989) by multiplying the reported catch by the average ratio. This approach was agreed by the RLFAWG on 15 Aug 2002.

3. Beginning with 1990, the first year for which estimates were provided by QMA, illegal catch was based on MPI Compliance estimates (Table 3). For years without Compliance estimates, the level of illegal catch was interpolated between estimates (Figure 2).
4. Estimates for "commercial illegal reported" (shown as "reported" in Table 3) are used to split the illegal catch into the "SL illegal" and "NSL illegal" categories (see the next section). The percentage of catch allocated to "SL illegal" was 5.7% for CRA 2.
5. We assumed that both the reported and unreported annual illegal catches were distributed between seasons in the same proportion as the commercial catch for each year.

2.5 Size-limited and non-size-limited catch

The size-limited (SL) catch is taken under the MLS regulations and the restriction on landing berried females; it is the sum of the commercial and recreational catches minus the reported illegal catches (Figure 6). The non-size-limited (NSL) catch is taken without regard to those restrictions; it is the sum of reported and unreported illegal catches and the customary catches.

2.6 Seasonal catch proportions

Annual commercial catches were divided into seasons (Figure 7) beginning in 1979, based on catches reported seasonally to the FSU or QMR/MHR data systems. Illegal catches were divided into the same proportions. It was assumed that 90% of the customary and recreational catches were taken in SS. Table 4 shows the estimated catch components by season (but note that the model does not use two seasons until 1979).

3. CATCH RATES

3.1 Seasonal standardised CPUE

Catch and effort data were obtained from MPI in September 2013 (Replog 9121), loaded into the CRACE database and processed using standard error checks (Bentley et al. 2005). Data spanned the period 1 April 1979 through 31 March 2013 and originated from the FSU and CELR systems (Table 5).

As agreed by the RLFAWG in May 2013, data preparation for use in CPUE used the "F2" algorithm instead of the "B4" procedure used in all assessments from 2003–11. The F2 algorithm corrects the monthly estimated catch taken by a vessel in a statistical area using a truncated distribution of "vessel correction factors" (VCF: ratio of landed catch to estimated catch for one vessel in a year) (Starr 2013). The version of the F2 algorithm implemented for this analysis used 0.8 and 1.2 as lower and upper bounds for the observed VCF distribution, discarding data from those vessels outside these bounds in each year. The F2 algorithm was scaled to the combined "L" (LFR) landings, the "X" (discarded to sea) and "F" (Section 111 recreational catch) destination codes.

These analyses estimated separate [`month`] effects in each half-year period by using, as the reference [`month`], the [`month`] in each period with the lowest standard error.

The CPUE standardisation procedure used sequential six-month periods as the time-dependent explanatory variable. Three other explanatory variables were available for this analysis: [`month`] of capture, [`statistical_area`] of capture and [`vessel`]. The first two variables were offered as categorical explanatory factors, but [`vessel`] was not used, even though Starr (2012) showed that [`vessel`] was potentially an important factor. Vessel codes have not been consistently maintained between the FSU and CELR data systems, so using [`vessel`] would require estimating separate

CPUE series unless the vessel codes could be reconciled. Using [month] and [statistical_area] as explanatory variables is consistent with analyses done for all previous rock lobster stock assessments.

The total deviance explained by the CRA 2 seasonal standardised model was 22%, with the [period] variable having greatest explanatory power, followed by the [month] variable; [statistical_area] had relatively little explanatory power (Table 6). Residual patterns were generally good but showed some deviation from the lognormal assumption at both tails of the residual distribution (Figure 8). The [statistical_area] and [month] effects are shown in Figure 9. The months of June to September had similar catch rates, which were higher than the summer catch rates (Figure 9). There is very little contrast in the estimated catch rates by statistical area (Figure 9).

CPUE peaked in the late 1990s at slightly more than double the current catch rates (Figure 10). There is not much difference between the AW and SS catch rates, unlike in most other QMAs. The 2012 AW index showed an upturn relative to the 2011 AW index, but there was a slight drop between 2011 and 2012 in the SS season. Figure 10 also shows arithmetic CPUE (total catch divided by total effort for each season) and “unstandardised” CPUE (the geometric mean of the data): these are little different from the standardised indices.

Comparative plots of the two data preparation methods (B4 and F2) show only small sensitivity to the choice of catch allocation algorithm and to the addition of the F and X destination codes in this QMA (Figure 11).

3.2 Historical catch rate (CR)

Monthly catch and effort (days fishing) data from 1963 through 1973 were summarised by Annala & King (1983) and used to calculate unstandardised catch per day for each calendar year from 1963 to 1973 (Figure 12).

4. LENGTH FREQUENCIES (LFs)

Data were extracted in September 2013; they comprised both observer and voluntary logbook catch sampling from 1986 through 2012–13.

4.1 LF records and record weighting

Each data record compiled for input to the model was from either voluntary logbook or observer catch sampling, and from either the AW or SS season in one year. There were 70 records, with slightly more from the logbook system (Table 7), evenly divided between the two seasons. Record fields were:

- QMA (all CRA 2)
- fishing year
- season (1 for autumn winter AW, April through September, 2 for spring summer SS)
- source (in these data: 1 for logbooks and 2 for observers; there were no data from market sampling or other old codes)
- a relative weight field for the record, described below
- 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 record comprised measurements taken from various months within the period 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:

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

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, and their "representativeness" was used, i.e. the catch in the month/area cell ($C_{m,a}$) compared with the total catch for the season:

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

where P^{g}_{s} is a relative proportion-at-length for each sex in the record. The model re-normalises these to sum to 1 across the record or across each sex, depending on the choice of fitting procedure (see Starr et al. 2014).

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. This depended on representativeness in 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 ($D_{m,a}$):

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

The catch used to determine representativeness came from the CELR forms; it could not be obtained from MHRs because statistical area was required. For collating catches to calculate the representativeness of catch samples, the F algorithm was used (Starr 2013), scaled to the combined L, F and X landing codes. All vessels were used, irrespective of their vessel correction factor (this is called the "F0" algorithm).

To explore whether this decision had any effect on the resulting data collation, length frequencies were collated using three catch algorithms, all using the LFX landings: B4, F2 (as used for CPUE, see above) and F0. Results with the most difference are compared in Figure 13 and Figure 14. Of the 251 year/source/season/sex cells investigated, only two showed visible departure among the three catch preparation algorithms. The choice of catch algorithm does not appear to have substantial effects on the resulting length frequencies.

Record weights tended to be higher for the logbook data (Table 8) than for the observer data, and slightly higher in AW than SS. Following usage, record weights were truncated between 1 and 10 when put into the model: weights less than 1 were made 1 and those greater than 10 were made 10. The observer sampling had four records with weights less than 1; the logbook data had many records with weights greater than 10; thus, truncation increased the relative importance of the observer data, although the logbook data still had higher weighting.

4.2 Proportion by sex

Sex proportions were calculated from the normalised data records. Mature females were slightly more abundant than males in the data (Table 9), while immature females were only about 5% overall and were absent entirely from one record (logbook, SS 1997).

The proportion of immature females showed a clear pattern that was identical in both sources and nearly the same in both seasons (Figure 15): it decreased from the 1990s to a low in 1997 to 1999, increased to a peak in 2006 (AW) or 2004 (SS) and then decreased again. The proportions of mature females show a pattern that was similar in the seasons and sources but was a bit noisier: increasing to 1998 or 1999, decreasing to 2005 or 2006 and increasing again, with perhaps a recent decline. The proportion of males shows an inverse pattern. The logbook and observer data show similar trends.

4.3 Mean length

Mean length was also calculated from the data records (Figure 16). Mean length of AW males shows a clear increase to a peak of about 61 mm TW in 1999 or 2000, followed by a decline of about 5 mm. Males in SS do not show a clear pattern. Immature females similarly show an increase and decline of several mm TW in AW, but not in SS. Mature females in AW show an increase to a peak near 65 mm TW in years near 2000, then decline; the pattern in SS is not clear. In the AW the trends from logbook data are steadier than in the observer data.

4.4 Binning

Although the model contains size bins from 30 to 92 mm TW, few fish as small as 30 mm are measured, and few very large fish are measured, especially immature females. For sex/size bins with few observations, the model would be comparing many zero observations with very small predictions, resulting in a large population of very small residuals that distort the diagnostics, as well as taking up computing time.

Bins at both ends of the range for each sex were combined into “plus” and “minus” bins. The model was therefore given the length range of bins for each sex that contained a reasonable number of observations. These bins were determined arbitrarily by inspecting the proportion of cells in each sex/size bin that contained a minimum proportion of normalised observations. The threshold was set at 0.001, but the procedure was not very sensitive to the chosen value. Figure 17 shows the cumulative distribution of sex/size bins: 40% were zero.

Figure 18 suggested the appropriate binning: males should be fitted for all bins from 5 to 31 (38–92 mm TW), mature females for bins 7 to 31 (42–92 mm TW) and immature females only for bins 6 to 19 (40 to 66 mm). For each sex, smaller and larger bins were combined to form plus and minus bins.

4.5 Length frequency (LF) distributions

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 summarised frequency in a sequential six-month season by data source (logbook or observer) (Figure 19).

5. EXPLORATION OF RETENTION IN THE CRA 2 LOGBOOK DATA

5.1 Background

Because of differential grade prices, legal high-grading is a feature of some New Zealand lobster fisheries with high catch rates. High-grading is the returning of lower-value fish to the water. In some fisheries, fishers will put back big lobsters and wait to catch smaller lobsters that are worth more per unit weight. Beginning in 2012, this part of the fishing dynamic was incorporated into the stock assessment model (Haist et al. 2013). Retention curves were estimated for CRA 8 from logbook data (Haist et al. 2013), where industry volunteers measure a sample of lobsters voluntarily and record their size and sex code, and indicate whether the lobster was kept.

This section describes using logbook data from CRA 2 to explore whether high-grading is a feature.

5.2 Data

Data through the 2011 fishing year were supplied by Nokome Bentley in August 2012 for each of the QMAs with substantial logbook programs. The period covered by these data was 1993–94 through 2011–12. Data from the 2012 fishing year were supplied by Nokome Bentley in July 2013.

Fields in the extract were:
- an anonymous fisher ID, which appeared to be originally sequential except for the last three IDs
- fishing year
- calendar month
- statistical area
- sex (codes differ from the observer codes):
    - 1 - male
    - 2 - immature female
    - 3 - mature female
    - 4 - berried female
    - 5 - spent female
- tail width (TW) (mm rounded down)
- caught: total measured for each ID/year/month/stat area/sex/TW cell
- retained: total retained for each cell.

CRA 2 data were extracted by choosing Statistical Areas 905 through 908. Records were deleted sequentially as follows:
- 58 records with no sex
- 73 records with TW = 0 through TW = 8 mm (the next smallest was 22 mm).

5.3 Analysis

No fish were reported retained before 2000, so only data from 2000 onwards were used; 107 676 measurements from 33 fisher IDs.

The seasonal pattern of breeding was explored (Table 10): low numbers of berried females were recorded from November through May, and the main egg-bearing period was June through October, with spent females appearing in September, peaking in October and ending in November.

A legal code was assigned as 0 or 1. A code of 0 was assigned for:
- males smaller than 54 mm TW
- all berried females
- all other females less than 60 mm TW.

Retention of non-legal animals was explored (Table 11). Retention rates of legal fish were about 70%, slightly lower for spent females. Retention of non-legal fish was low: less than 1% except for spent females at 1.3%.

Retention of legal animals (58 531 measurements) was explored by fisher and by sex. Gross retention by ID varied from 6% to 100%, averaging 80% across IDs and averaging 70% of fish overall. There was no ID who retained nothing, and the three who retained everything had measured only 19 to 305 fish. Legal fish measured were 61% male, only 1% immature female, 5% spent and the rest mature females. Retention of spent females was highly variable: eleven IDs never recorded a legal spent female. Of the rest, six retained zero or one spent females, eight retained at high rates with an average of 93% and seven retained at low rates averaging 31%.

Retention was explored for each ID by year and month to identify any obvious reporting problems. Retaining everything, either in total or during a particular year, was not counted as a problem. For 25 of the 33 IDs (61% of legal measurements), no obvious problems could be seen. Of the remaining eight IDs, some appeared to record retention in only some periods. Two of these began recording after a non-recording period and a partial data set could be used; the remaining six showed erratic retention reporting and were considered unreliable.

Over all years, the proportion of retained legal fish was quite flat for both males (sex code 1) and females (codes 2, 3 and 5) (Figure 20 and Figure 21), with a lower retention for males in the first size class at the MLS. This was also seen in CRA 8 in 2012 (Haist et al. 2013) and probably reflects caution in retaining fish close to MLS.

For individual years, there was no dramatic decline in retention with size (Figure 22 and Figure 23); for males, most years showed a slightly increasing retention with size. Logistic or inverse logistic curves (either one or the other would fit) were fitted with weighted least squares (Table 12). For females, some years showed increasing retention with size and some years showed decreasing retention. For all years and both sexes, the relation between size and retention was basically flat.

The flat retention curves suggest that differential high-grading was low or non-existent in CRA 2 between 2000 and 2011 and that the stock assessment can assume that fishery selectivity is the same as pot selectivity.

6. TAG-RECAPTURE DATA

Data were extracted in September 2012 and processed with purpose-built software developed by Nokome Bentley (Trophia, unpublished). This software:

- matches recaptures to releases, treating re-recaptures as having been released at the previous recapture
- calculates TW from CL where necessary, using relations developed in the Breen et al. (1988) morphometrics program
- discards records with missing tail widths at release or recapture
- discards records with inappropriate sex codes or apparent sex changes
- discards records with apparent shrinkage greater than 10 mm
- discards records with an increment greater than 40 mm.

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
- year of release, extracted from release date
- month of recovery, extracted from recovery date
- year of recovery, extracted from recovery date
- days at liberty, obtained by subtracting release from recovery dates
- TW at release and recovery
- number of re-releases
- statistical areas of release and recovery
- a condition code
- tag type code (3 for western rock lobster tag and 4 for Hallprint Floy-type tag).

The raw data extract for CRA 2 comprised 3663 records. Of these, 462 records had 30 or fewer days at liberty and were deleted as agreed by the RLFAWG, leaving 3201 records. When data were extracted again in September 2013, this increased the data set by only six records. The analyses reported below do not include these six records.

Of the 3201 records, 1625 were males and 1576 were females. Sizes at release by sex are shown in Figure 24. Although the records peak near the MLS for both sexes, both sexes show substantial numbers of releases above the MLS.

Releases were made in 1983, 1984 and 1986, and from 1996 through 2010, but not in every year (Table 13). All the 1983–86 releases (219) were western rock lobster tags, with size recorded in carapace length, and all the later releases were with Hallprint tags and measured as tail width.

Recaptures were concentrated in the years following releases. No recaptures were reported from 2012: this may reflect serious problems with tag-recapture data loading that affected all QMAs in 2012; data may be extracted again later in the year to obtain any recent recaptures. On the face of it, of 34000 tags released from 1998, only 2446 (7%) were recaptured.

Times at liberty retained in the dataset varied from 31 days to 3296 days (9 years), but the median was just over 300 days and 60% were at liberty for less than one year, 86% less than 2 years and 93% less than 3 years (Figure 25).

One fish was re-released 10 times (Table 14), but three-quarters of the data came from fish that were not re-released, and there were negligible numbers re-released more than 4 times.

Nearly all records had both the areas of release and recapture: one was missing both, and four others were missing the area of recapture. Releases were concentrated in Statistical Area 906 (Table 15), and the pattern suggested little movement away from the statistical area of release. All tags were recaptured within CRA 2. Nearly all (98%) were recaptured in the same area as release (Table 16), only five had moved further than the adjacent statistical area, and most of those that moved out of the statistical area of release had gone north.

Condition codes were nearly all (995) zero (no injuries) or missing (Table 17). Condition codes above zero indicate the number of missing legs or antennae.

Apparent increments ranged from -9.3 to 27.7 after the basic grooming described above. For exploration only (not for use by the model), increments were “annualised” based on days at large:

$$\Delta l_i^{ann} = \frac{365\left(l_i^{rec} - l_i^{rel}\right)}{d_i}$$

where Δl_i^{ann} is annualised increment for the *i*th record, l_i^{rel} and l_i^{rec} are the sizes at release and recapture and d_i is the number of days at liberty. These are shown for males and females in Figure 26.

6.1 Preliminary analyses

Preliminary fits were made using the single-stock 2011 version of the model. Likelihoods from only the tag data were used in fitting, and only the growth parameters were estimated. The growth parameters are:

- *Galpha*: annual increment at 50 mm TW
- *GBeta*: : annual increment at 80 mm TW
- *GrowthCV*: the relation between expected increment and its standard deviation

- *Gshape*: a shape parameter: 1 gives a linear relation between increment and initial size while greater than 1 gives a curve concave upwards
- *StdObs*: standard deviation of observation error
- *StdMin*: the minimum standard deviation of growth

All but the last two can be estimated separately by sex.

Preliminary fits were made using the single-stock 2011 version of the model. Likelihoods from only the tag data were used in fitting, and only the growth parameters were estimated; growth density-dependence was not estimated (see Starr et al. 2014 for explanation of this). Experimentation was carried out to determine the values to which the standard deviation of observation error, *StdObs*, and the minimum standard deviation of growth, *StdMin*, should be fixed (Table 18).

From the last of these fits, with *StdObs* and *StdMin* fixed at their estimated values and estimating the other four growth parameters for each sex, Figure 27 shows the predicted sizes at recapture versus the observed. These appear to be generally reasonable fits and the residuals plotted against the size at release show no obvious pattern (Figure 28). Figure 29 shows the resulting growth curves.

6.2 Comparison of older and newer data

In the 2008 assessment of CRA 3 (Breen et al. 2009), the older tag-recapture data from 1985–86 (Starr et al. 2009) showed substantially and significantly faster growth than the newer data from 1995 onwards. The CRA 3 data set was much more balanced between older and newer records than the CRA 2 data, where only 219 records are from 1983–86 and 2982 records come from 1996 and later. Given the small size of the older data set, a comparison of growth estimates from those two data subsets may show differences caused by chance.

The data were explored in two ways. First, residuals from the fit shown in Table 18 are shown plotted against date of release in Figure 30. The parameters for regressions are shown in Table 19, with males showing a slight upward slope and females showing a somewhat stronger upward slope. This analysis suggests that growth rates for males were similar over time; if anything, female growth rate has increased slightly over time.

Second, the data were divided into two roughly equal halves based on the date of tagging: the first half contained 1602 records from November 1983 through May 1997; the second contained 1599 records from July 1997 through October 2010. These were explored by fitting the assessment model to the data separately and estimating *Galpha* and *Gbeta* only. *GrowthCV* was fixed to 0.38, intermediate between the estimated values for males and females, and *Gshape* was fixed to 5 after experimentation (of whole number values, this gave the lowest function value). The resulting estimates are compared with the analogous fit to the whole data set and with each other in Table 20. Figure 31 compares the predicted growth curves for the older and newer data sets.

The CRA 2 tag-recapture dataset appeared to be a good one, with a substantial number of records, a good balance between males and females and a good range of sizes tagged and recaptured from each sex. No difficulties were encountered in preliminary fits to these data, and there was no evidence of a major change in growth rate over time, although the data were mostly from 1996 onwards.

7. ACKNOWLEDGEMENTS

This work was funded under Objectives 3 and 4 of MPI contract CRA2012-01A. We are grateful to David Fisher, Nokome Bentley and the data management staff at MPI for their help, to Daryl Sykes for discussion and encouragement, and members of the RLFAWG for helpful suggestions.

8. REFERENCES

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

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

Boyd, R.O.; Gowing, L; Reilly, J.L. (2004). 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. Final Research Report of Ministry of Fisheries project REC9803. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Boyd, R.O.; Reilly, J.L. (2004). 1999–2000 National Marine Recreational Fishing Survey: harvest estimates. Final Research Report for the Ministry of Fisheries Project REC9803. 28 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Breen, P.A. (2014). CRA 9 Management procedure evaluations. *New Zealand Fisheries Assessment Report 2014/20*.

Breen, P.A.; Booth, J.D; Tyson, P.J. (1988). Feasibility of a minimum size limit based on tail width for the New Zealand rock lobster *Jasus edwardsii*. *New Zealand Fisheries Research Technical Report 6*. 16 p.

Breen, P.A.; Haist, V.; Starr, P.J.; Kendrick, T.H. (2009). The 2008 stock assessment of rock lobsters (*Jasus edwardsii*) in CRA 3. *New Zealand Fisheries Assessment Report 2009/23*. 54 p.

Breen, P.A.; Starr, P.J.; Bentley, N. (2001). Rock lobster stock assessment for the NSN substock and the combined CRA 4 and CRA 5 areas. *New Zealand Fisheries Assessment Report 2001/7*. 42 p.

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

Haist, V.; Starr, P.J.; Breen, P.A. (2013). The 2012 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 7 and CRA 8, and review of management procedures. *New Zealand Fisheries Assessment Report 2013/60*. 90 p.

National Rock Lobster Management Group. 2010. NRLMG 2010 Annual Report to the Minister of Fisheries, Hon. Phil Heatley. Unpublished report, Wellington, 2010. 53 pp.

Starr, P.J. (2012). Standardised CPUE analysis exploration: using the rock lobster voluntary logbook and observer catch sampling programmes. *New Zealand Fisheries Assessment Report 2012/34.* 77 p.

Starr, P.J. (2013). Rock lobster catch and effort data: summaries and CPUE standardisations, 1979–80 to 2011–12. *New Zealand Fisheries Assessment Report 2013/58*. 107 p.

Starr, P.J.; Bentley, N.; Breen, P.A.; Kim, S.W. (2003). Assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1 and CRA 2 in 2002. *New Zealand Fisheries Assessment Report 2003/41*. 112 p.

Starr, P.J.; Breen, P.A.; Haist, V.; Pomarede, M. (2012). Data for the 2011 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 4. *New Zealand Fisheries Assessment Report 2012/08*. 48 p.

Starr, P.J.; Breen, P.A.; Kendrick, T.H.; Haist, V. (2009). Model and data used for the 2008 stock assessment of rock lobsters (*Jasus edwardsii*) in CRA 3. *New Zealand Fisheries Assessment Report 2009*/22. 62 p.

Starr, P.J.; Haist, V.; Breen, P.A. (2013). Data for the 2012 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 7 and CRA 8. *New Zealand Fisheries Assessment Report 2013/59*. 43 p.

Starr, P.J.; Haist, V.; Breen, P.A.; Edwards, C.T.T.E. (2014). The 2013 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 2 and development of management procedures. *New Zealand Fisheries Assessment Report 2014/19*.

Table 1: Destination codes used for landings reported on the CELR forms.

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

Table 2. Information used to estimate recreational catch for CRA 2.

Category	CRA 2
Catch estimates in numbers	
1994	142 000
1996	223 000
2000	NA
2001	NA
2011	60 100
Derived values	
1992/1996 SS mean weight (kg)	0.672[1]
2011 SS mean weight (kg)	0.701[2]
catch weight (t): 1994	95.424
catch weight (t): 1996	149.856
catch weight (t): 2011	42.161
Mean (1994, 1996, 2011) catch (t)	95.814
Reconstructed catch in 1979 (t)	75.717
20% of 1979 catch (t)	15.143
Maximum Section 111 catch (t)	1.37

[1] Starr et al. (2003)
[2] Bruce Hartill, NIWA, Hartill (pers .comm.)

Table 3: Available estimates of illegal catches (t) by QMA from 1990, as provided by MPI (formerly MFish) 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 left blank.

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		288.2		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										
2001		72		88	0	75												
2002					0	75	9	51		40		10		1		18		1
2003					0	89.5			5	47								
2004							10	30										
2005																		
2006																		
2007																		
2008																		
2009																		
2010																		
2011														1		3		
2012																		

Table 4: Estimated CRA 2 catches (commercial, recreational including s. 111, illegal and customary) by season: note that the model does not use two seasons until 1979.

	Commercial		Recreational		Illegal		Customary	
Year	AW	SS	AW	SS	AW	SS	AW	SS
1945	56.55	80.21	1.65	14.86	9.46	13.42	1.00	9.00
1946	48.34	68.56	1.83	16.47	8.09	11.47	1.00	9.00
1947	53.63	76.07	2.01	18.07	8.97	12.73	1.00	9.00
1948	87.77	124.48	2.19	19.67	14.68	20.82	1.00	9.00
1949	81.97	116.26	2.36	21.28	13.71	19.45	1.00	9.00
1950	86.47	122.64	2.54	22.88	14.47	20.52	1.00	9.00
1951	79.07	112.15	2.72	24.48	13.23	18.76	1.00	9.00
1952	73.97	104.91	2.90	26.09	12.37	17.55	1.00	9.00
1953	78.95	111.97	3.08	27.69	13.21	18.73	1.00	9.00
1954	62.00	87.92	3.25	29.29	10.37	14.71	1.00	9.00
1955	64.16	90.99	3.43	30.90	10.73	15.22	1.00	9.00
1956	66.13	93.79	3.61	32.50	11.06	15.69	1.00	9.00
1957	52.11	73.91	3.79	34.10	8.72	12.36	1.00	9.00
1958	64.10	90.90	3.97	35.71	10.72	15.21	1.00	9.00
1959	79.54	112.80	4.15	37.31	13.31	18.87	1.00	9.00
1960	69.07	97.97	4.32	38.91	11.56	16.39	1.00	9.00
1961	82.25	116.65	4.50	40.52	13.76	19.51	1.00	9.00
1962	84.01	119.15	4.68	42.12	14.05	19.93	1.00	9.00
1963	91.34	125.91	4.86	43.72	15.28	21.06	1.00	9.00
1964	117.98	142.51	5.04	45.33	19.74	23.84	1.00	9.00
1965	100.23	152.00	5.21	46.93	16.77	25.43	1.00	9.00
1966	115.22	185.32	5.39	48.53	19.28	31.00	1.00	9.00
1967	116.30	213.85	5.57	50.14	19.46	35.77	1.00	9.00
1968	99.64	208.14	5.75	51.74	16.67	34.82	1.00	9.00
1969	120.14	177.18	5.93	53.34	20.10	29.64	1.00	9.00
1970	60.83	140.69	6.11	54.95	10.18	23.54	1.00	9.00
1971	56.13	121.88	6.28	56.55	9.39	20.39	1.00	9.00
1972	65.38	137.32	6.46	58.15	10.94	22.97	1.00	9.00
1973	60.69	124.66	6.64	59.76	10.15	20.85	1.00	9.00
1974	50.76	104.24	6.82	61.36	6.50	13.34	1.00	9.00
1975	45.19	92.81	7.00	62.96	10.94	22.46	1.00	9.00

	Commercial		Recreational		Illegal		Customary	
Year	AW	SS	AW	SS	AW	SS	AW	SS
1976	47.15	96.85	7.17	64.57	9.16	18.81	1.00	9.00
1977	65.16	133.84	7.35	66.17	16.73	34.37	1.00	9.00
1978	78.55	161.34	7.53	67.78	20.15	41.39	1.00	9.00
1979	86.36	206.57	7.71	69.38	7.50	17.93	1.00	9.00
1980	168.20	277.76	8.20	73.76	19.18	31.68	1.00	9.00
1981	120.48	270.51	7.85	70.68	20.15	45.25	1.00	9.00
1982	109.48	217.10	6.13	55.18	18.31	36.32	1.00	9.00
1983	83.99	190.63	5.25	47.28	14.05	31.89	1.00	9.00
1984	92.13	178.13	4.73	42.56	15.41	29.80	1.00	9.00
1985	88.54	249.15	5.92	53.31	14.81	41.68	1.00	9.00
1986	82.38	192.49	5.08	45.76	13.78	32.20	1.00	9.00
1987	81.07	173.33	4.76	42.84	13.56	29.00	1.00	9.00
1988	79.41	142.77	4.93	44.33	13.28	23.88	1.00	9.00
1989	72.89	179.82	7.40	66.58	12.19	30.08	1.00	9.00
1990	96.74	140.89	7.05	63.45	28.50	41.50	1.00	9.00
1991	94.54	135.12	6.28	56.50	22.02	31.48	1.00	9.00
1992	72.73	117.53	5.66	50.97	14.14	22.86	1.00	9.00
1993	101.83	113.10	6.19	55.69	25.35	28.15	1.00	9.00
1994	126.29	86.53	7.48	67.34	41.54	28.46	1.00	9.00
1995	162.28	50.17	10.04	90.38	45.83	14.17	1.00	9.00
1996	189.71	23.45	15.19	136.70	78.32	9.68	1.00	9.00
1997	208.60	25.82	13.76	123.88	78.31	9.69	1.00	9.00
1998	202.29	30.03	14.11	127.02	76.63	11.37	1.00	9.00
1999	177.96	57.14	15.08	135.72	66.61	21.39	1.00	9.00
2000	133.71	101.71	11.25	101.21	49.98	38.02	1.00	9.00
2001	119.23	105.74	8.20	73.76	46.64	41.36	1.00	9.00
2002	72.88	132.82	7.26	65.31	31.18	56.82	1.00	9.00
2003	68.76	127.21	6.40	57.64	30.87	57.13	1.00	9.00
2004	76.97	120.37	7.58	68.19	34.32	53.68	1.00	9.00
2005	82.39	142.78	7.21	64.86	32.20	55.80	1.00	9.00
2006	90.59	135.95	8.69	78.19	35.19	52.81	1.00	9.00
2007	88.74	140.95	8.15	73.35	34.00	54.00	1.00	9.00
2008	87.91	144.42	7.55	67.96	33.30	54.70	1.00	9.00
2009	85.83	149.32	6.56	59.05	32.12	55.88	1.00	9.00
2010	74.04	150.78	6.00	53.98	28.98	59.02	1.00	9.00
2011	62.12	166.86	6.11	55.03	23.88	64.12	1.00	9.00
2012	86.79	146.21	5.77	51.97	32.78	55.22	1.00	9.00

Table 5: Number of vessel/statistical area/month records in the dataset used to calculate the CRA 2 seasonal CPUE time series. 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	36	175
Total	1 377	2 632	1 025	1 421	6 455	1 550	3 231	1 120	1 969	7 870

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
Period (68)	0.1592		
Statistical Area (4)	0.0380	0.2005	
Month (12)	0.0137	0.1748	0.2153
Additional deviance explained	0.0000	0.0412	0.0148

Table 7: Numbers of LF records by source (voluntary logbooks or observer catch sampling) and season.

	Logbooks	Observers	Total
AW	20	14	34
SS	20	16	36
Total	40	30	70

Table 8: Summary information about record weights by source and season.

Weight	Logbooks	Observers
<1	0	4
1 to 10	3	26
>10	37	0
min.	2.7	0.5
max.	46.0	4.5
AW	28.0	2.2
SS	21.8	2.1
Mean	24.9	2.1

Table 9: Proportion by sex in the 70 records: minimum, maximum and average sex proportion in a record, and the average of proportions across records.

	male	Immature female	Mature female
Min.	0.201	0.000	0.299
Max.	0.624	0.127	0.783
Mean	0.461	0.051	0.488

Table 10: The seasonal pattern of sex codes (see Table 11) measured in CRA 2 data from 2000–2011.

	Sex code					
Month	1	2	3	4	5	Total
1	4 616	794	3 881	5		9 296
2	3 157	435	2 313	35		5 940
3	2 134	256	1 106	69		3 565
4	717	58	562	1		1 338
5	456	31	263	19	1	770
6	716	19	97	347		1 179
7	6 515	246	200	4 018	10	10 989
8	9 744	1 029	383	5 679	61	16 896
9	6 940	1 308	2 644	3 721	996	15 609
10	7 299	1 170	9 197	1 313	2 061	21 040
11	5 087	608	5 774	103	431	12 003
12	4 987	671	3 363	21	9	9 051
total	52 368	6 625	29 783	15 331	3 569	107 676

Table 11: Retention of legal (code 1) and non-legal (code 0) lobsters by sex code in CRA 2, 2000–2011.

Sex	Sex code	Legal	Measured	Retained	%retained
Male	1	0	16 757	54	0.3%
	1	1	35 611	24 989	70.2%
Immature female	2	0	5 883	9	0.2%
	2	1	742	514	69.3%
Mature female	3	0	11 174	74	0.7%
	3	1	18 609	12 848	69.0%
Berried female	4	0	15 331	35	0.2%
	4	1	0	n.a.	n.a.
Spent female	5	0	686	9	1.3%
	5	1	2 883	1 861	64.6%
Overall		0	49 145	172	0.3%
		1	58 531	40 221	68.7%

Table 12: Parameter estimates for the logistic or inverse logistic curves fitted to retention curves by year; asterisks in the year indicate that the inverse logistic was fitted.

	Males				Females		
Year	L50	L50–L95	SS	Year	L50	L95–50	SS
2003	53.3	1.46	2.99	2003*	174.7	105.9	1.11
2004	53.7	1.68	10.19	2004	-4444.5	4839.8	1.41
2005	-33.9	83.25	1.48	2005	-6964.9	6359.3	1.54
2006	0.0	0.0	3.21	2006*	1858.6	2153.8	1.61
2007*	117.1	60.14	2.86	2007*	261.0	204.4	1.92
2008	-14.8	86.89	2.69	2008*	1673.6	1714.2	0.91
2009	25.1	35.37	1.36	2009	-2745.6	2803.2	0.81
2010	49.5	8.31	0.80	2010*	336.2	209.3	0.33
2011	51.3	3.14	0.42	2011*	217.5	118.4	0.76

Table 13: CRA 2 tag-recapture data: the first column shows, from NIWA (David Fisher, NIWA, pers. comm.), the number of fish released each fishing year from 1998; the second column shows numbers of releases by fishing year among the tag-recapture records and the final column shows recaptures by fishing year.

Year	Total released	Recaptures released	Recaptures
1983	n.a.	154	
1984	n.a.	50	122
1985	n.a.	14	85
1986	n.a.	1	12
1996	n.a.	1 197	
1997	n.a.	444	845
1998	9 272	169	588
1999	6 583	45	305
2000	3 018		5
2001	62	12	69
2002		245	38
2003		573	240
2004		111	445
2005	4 351	41	220
2006	3 863	9	59
2007	2 922	1	18
2008		114	40
2009	1 927	20	85
2010	1 926	1	23
2011			2
Total	33 924	3 201	3 201

Table 14: CRA 2 tag-recapture data: records by the number of re-releases, in numbers and percent.

Re-releases	Number	Percent
0	2 446	76%
1	441	14%
2	180	6%
3	80	2%
4	29	1%
5	15	0%
6	4	0%
7	4	0%
8	1	0%
10	1	0%
Total	3 201	100%

Table 15: CRA 2 tag-recapture data: records by areas of release and recapture.

Area	Released	Recaptured
905	83	111
906	2 215	2 197
907	463	461
908	395	397
909	44	30
Missing	1	5
Total	3 201	3 201

Table 16: CRA 2 tag-recapture data: movements from one statistical area to another, showing the direction and number of areas moved.

Moves	Number
North 2	5
North 1	52
No move	3 134
South 1	6
Total	3 197

Table 17: CRA 2 tag-recapture data: records by condition code.

Condition code	Number	Percent
Missing	936	29%
0	2 233	70%
1	24	1%
2	5	0%
3	2	0%
4	1	0%
Total	3 201	100%

Table 18: CRA 2 tag-recapture data: MPD results from preliminary fits to the tag-recapture data only; shading and asterisks indicate fixed parameters.

	Fixed *StdObs* *StdMin*	Estimated *StdObs*	Estimated *StdMin*	Fixed *StdObs* *StdMin*
Tags-sdnr	1.323	1.301	1.197	1.202
Tags-MAR	0.698	0.696	0.696	0.696
Tags-LL	7579.6	7578.1	7534.1	7533.8
GalphaM	7.178	7.220	7.506	7.407
GbetaM	1.636	1.588	1.317	1.238
GshapeM	3.658	3.655	4.047	3.547
GrowthCVM	0.382	0.372	0.315	0.335
GalphaF	5.658	5.774	7.614	7.611
GbetaF	0.840	0.811	0.678	0.691
GshapeF	5.823	5.939	8.957	9.015
GrowthCVF	0.678	0.657	0.428	0.430
StdMin	0.5*	0.5*	1.653	1.6*
StdObs	0.5*	0.611	0.6*	0.6*

Table 19: CRA 2 tag-recapture data: calculated parameters for the regressions of residuals versus date of release (Figure 30), based on the final fit shown in Table 18.

	Male	Female
Intercept	-15.68	-71.74
Slope	0.00782	0.03589

Table 20: Estimates from fitting the whole data set, the older half and the newer half; "*M*" appended to a parameter name indicates male, "*F*" indicates female; shading and asterisks indicate fixed parameters.

	All data	Older half	Newer half
Tags-sdnr	1.19	1.26	1.10
Tags-MAR	0.68	0.70	0.63
Tags-LL	7560.2	3925.5	3586.0
GalphaM	7.374	7.135	7.563
GbetaM	1.815	2.390	1.060
GshapeM	5*	5*	5*
GrowthCVM	0.38*	0.38*	0.38*
GalphaF	6.528	5.410	7.257
GbetaF	0.007	0.021	0.240
GshapeF	5*	5*	5*
GrowthCVF	0.38*	0.38*	0.38*
StdMin	1.6*	1.6*	1.6*
StdObs	0.6*	0.6*	0.6*

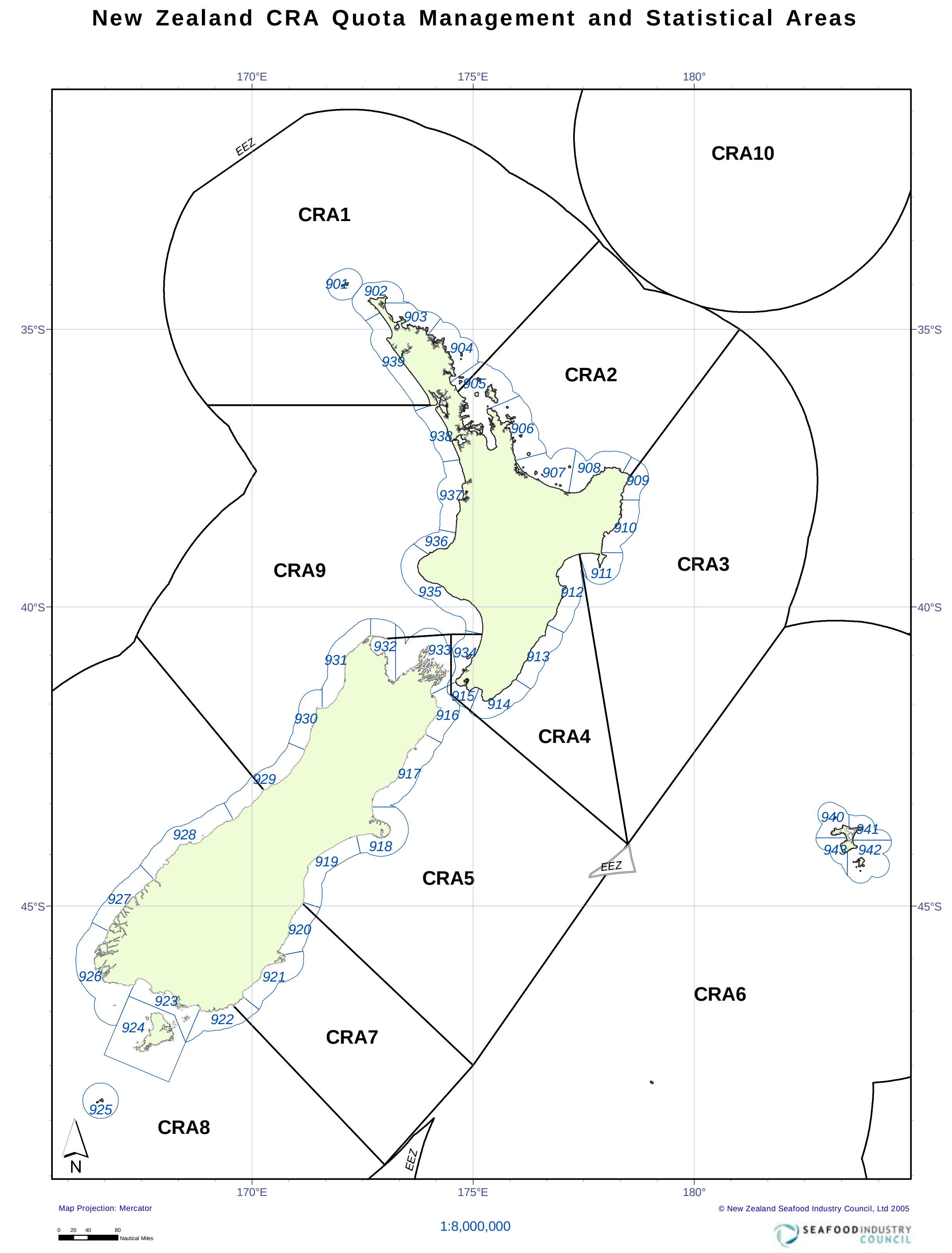

Figure 1: Rock lobster Quota Management Areas and statistical areas.

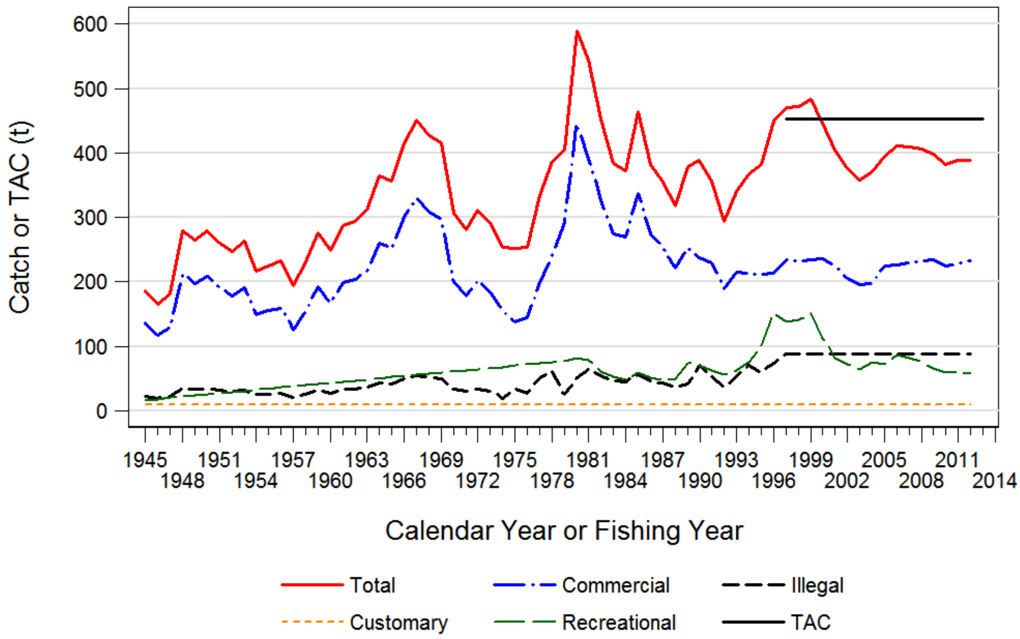

Figure 2: **Annual estimated CRA 2 catches (t) by fishery.**

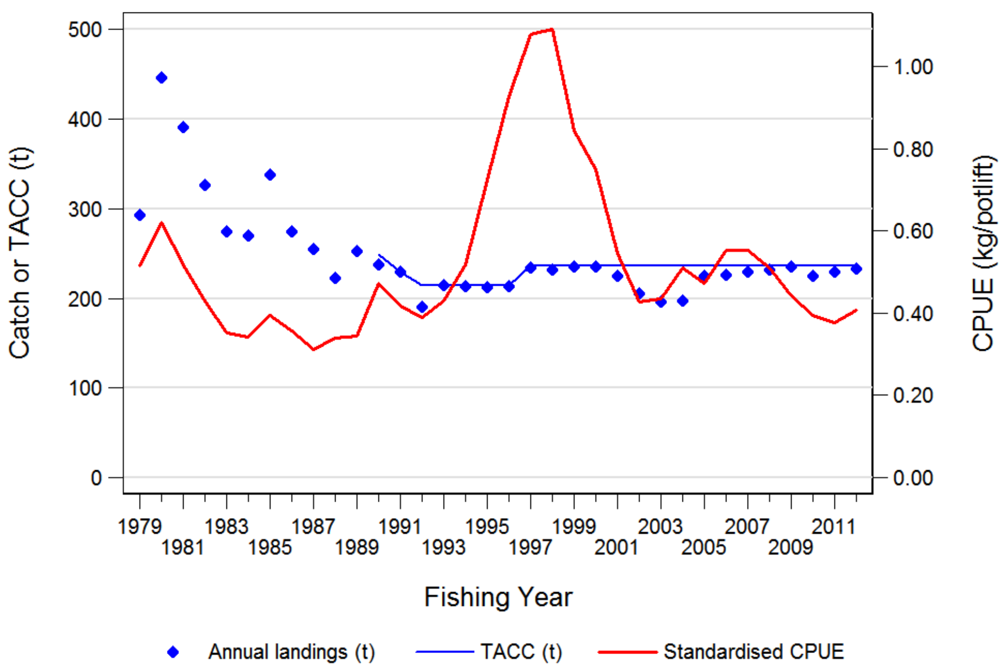

Figure 3: **Annual CRA 2 commercial landings (t), the TACC (t) and the annual standardised CPUE index by fishing year, 1979–2012.**

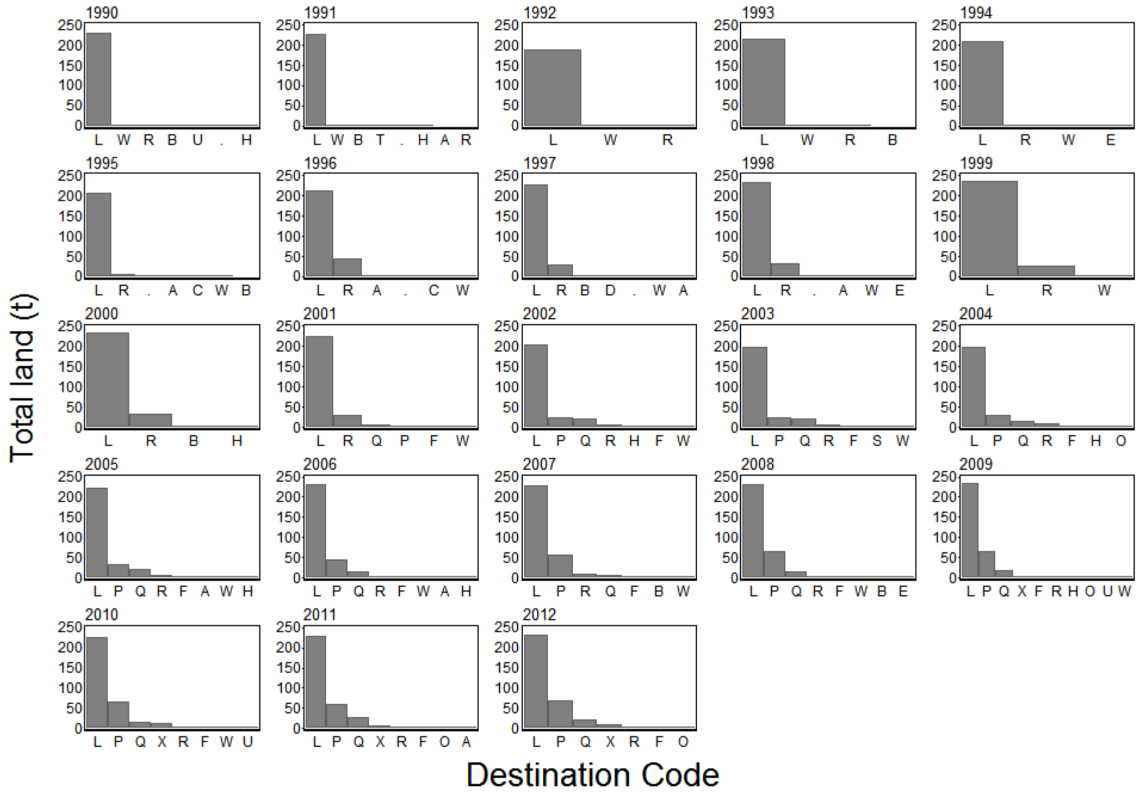

Figure 4: CRA 2 landings reported to various landing destination codes (see Table 1). Plots show only the destination codes used each year, organised in descending order of catch.

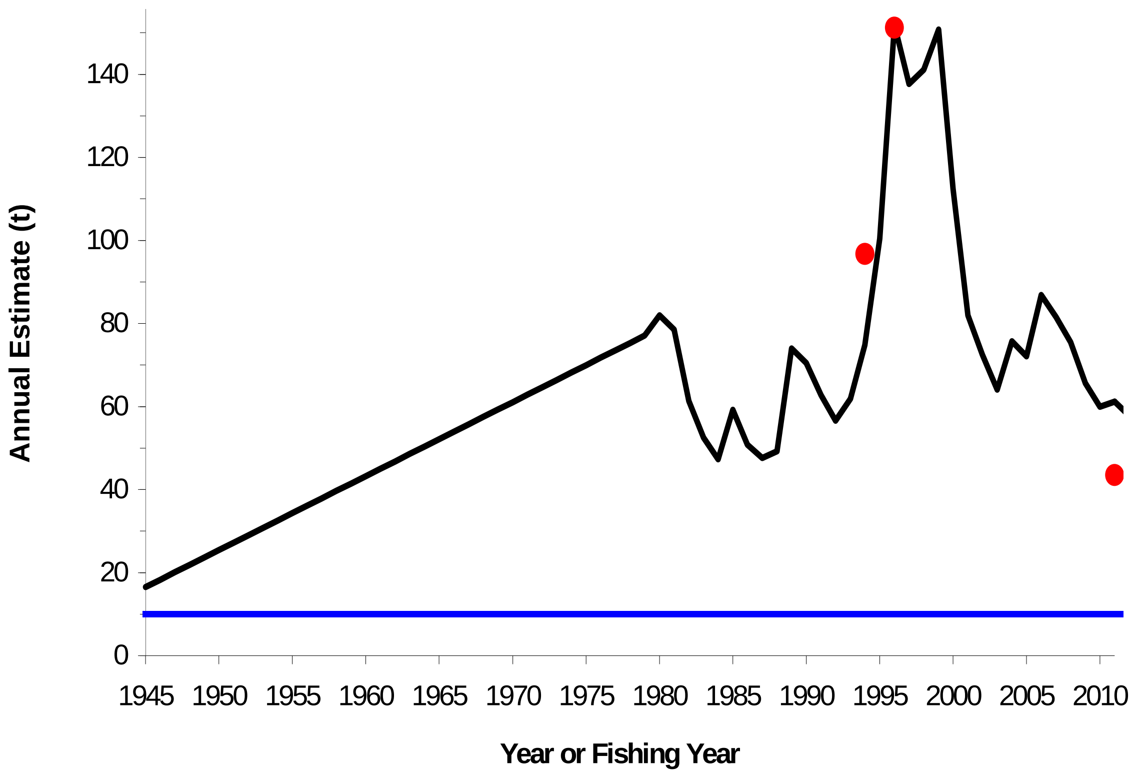

Figure 5: Estimated CRA 2 recreational catch (black line) compared with the three survey estimates (green dots) described in Table 2; the blue line shows customary catch.

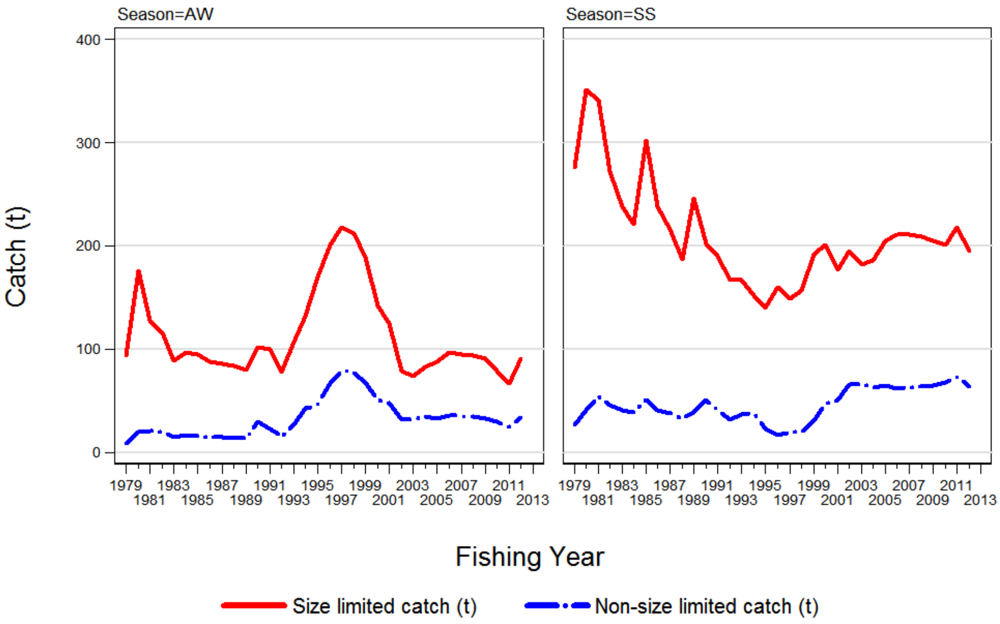

Figure 6: CRA 2 seasonal Size Limited (SL) and Non-Size Limited (NSL) catches (t).

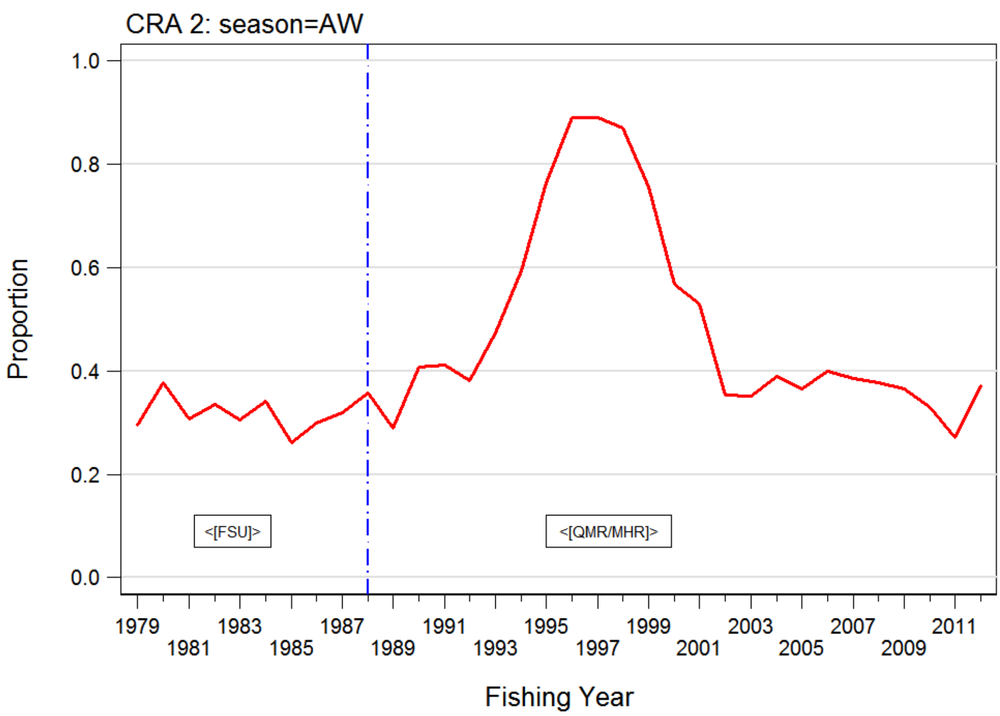

Figure 7: Proportion of the AW commercial catch by fishing year for CRA 2; before 1989 the FSU data were used and afterwards the QMR/MHR data were used.

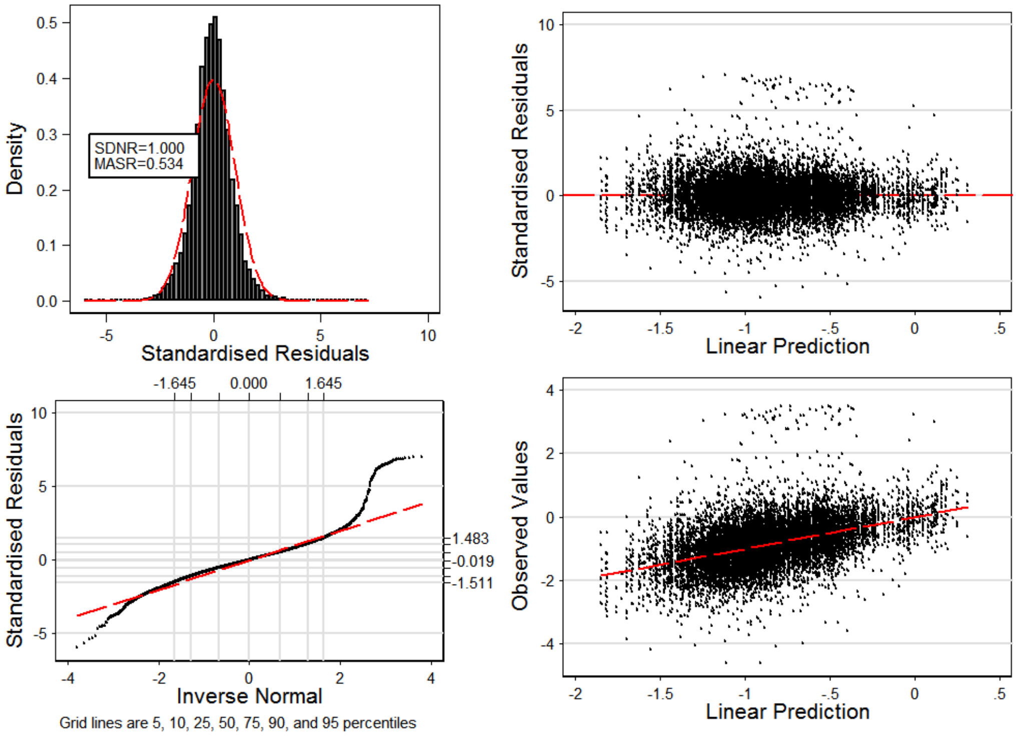

Figure 8: Standardised residuals for the CRA 2 standardised seasonal CPUE analysis; grid lines show the 5th, 10th, 25th, 50th, 75th, 90th and 95th quantiles.

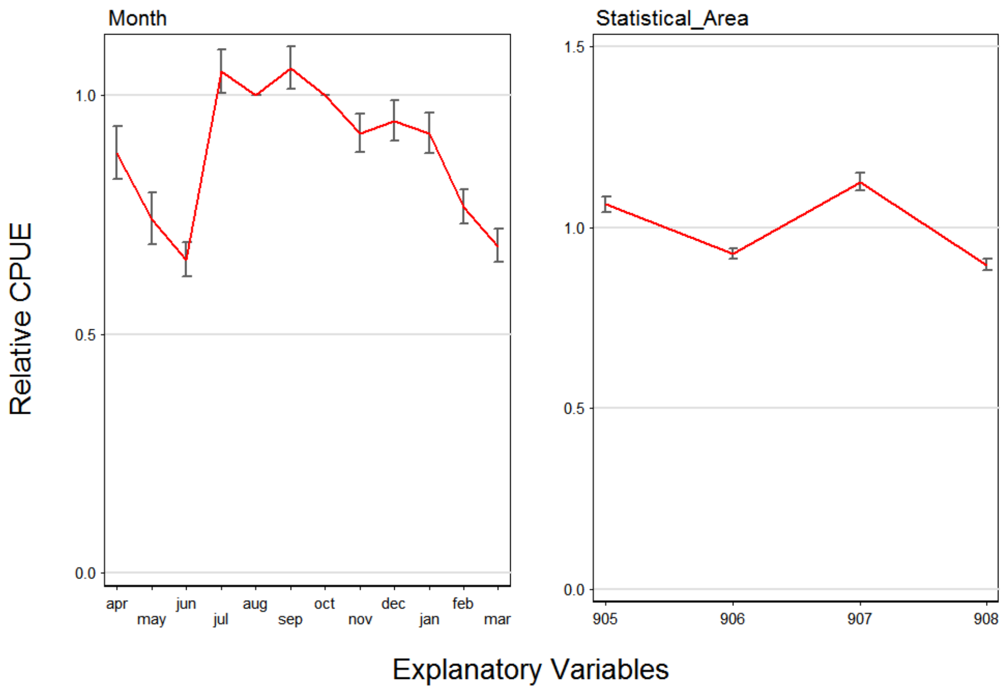

Figure 9: Coefficients for month and statistical area from the CRA 2 seasonal CPUE standardisation. Month coefficients are not in canonical form, with each of the two reference months (August and October) set to 1.0 and the associated SE set to zero. Error bars show plus and minus 1.96 standard deviations.

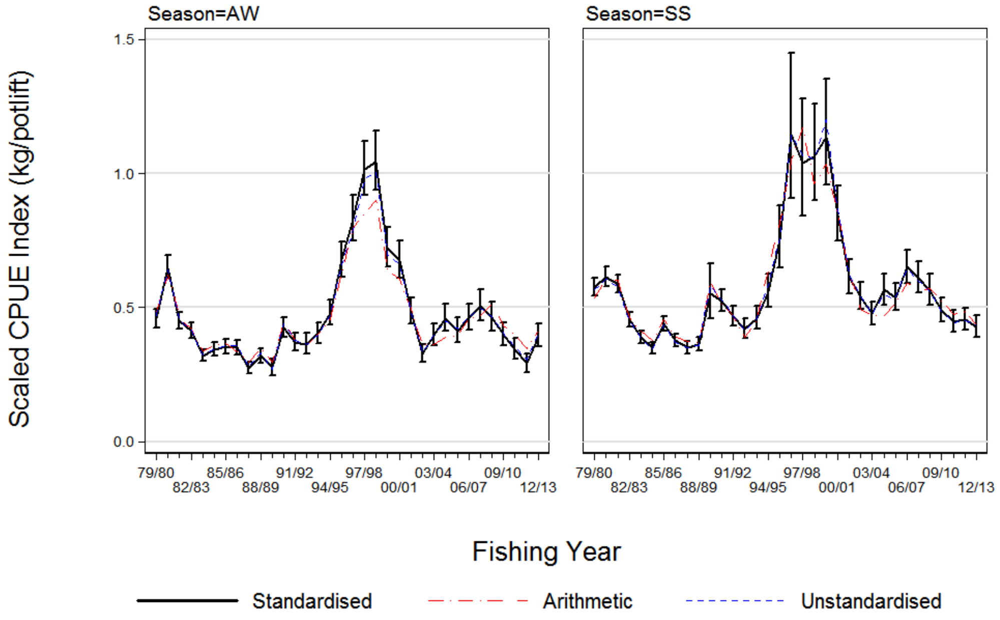

Figure 10: CRA 2 CPUE: Standardised, unstandardised, and arithmetic CPUE indices (kg/potlift) (see definitions in the text) by season and fishing year using the F2-LFX algorithm; errors bars on standardised indices show the 95% confidence interval.

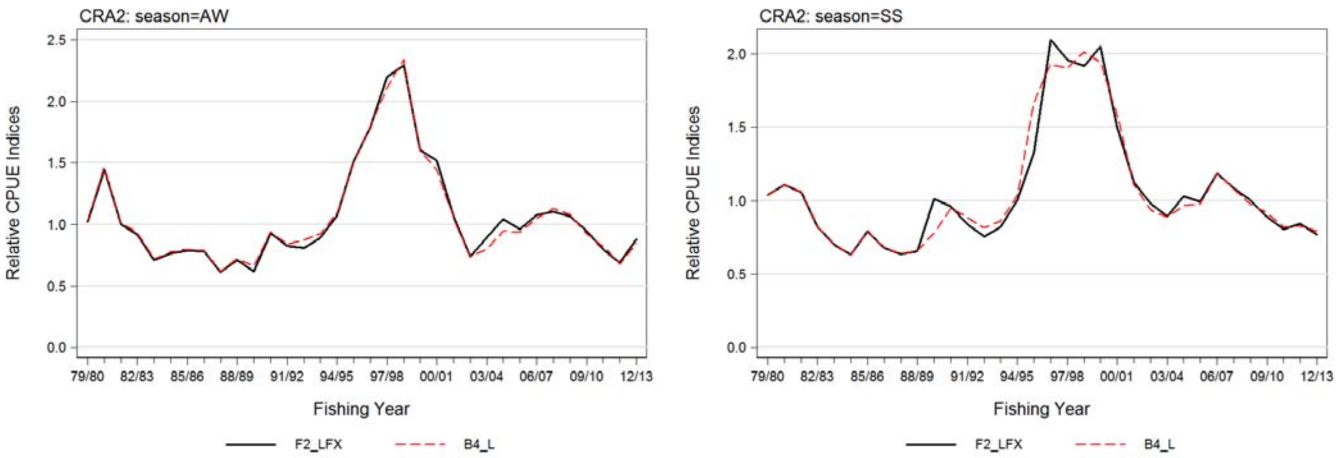

Figure 11: CPUE from the B4 and the F2 algorithm in the CRA 2 seasonal analysis: [left panel]: AW; [right panel]: SS.

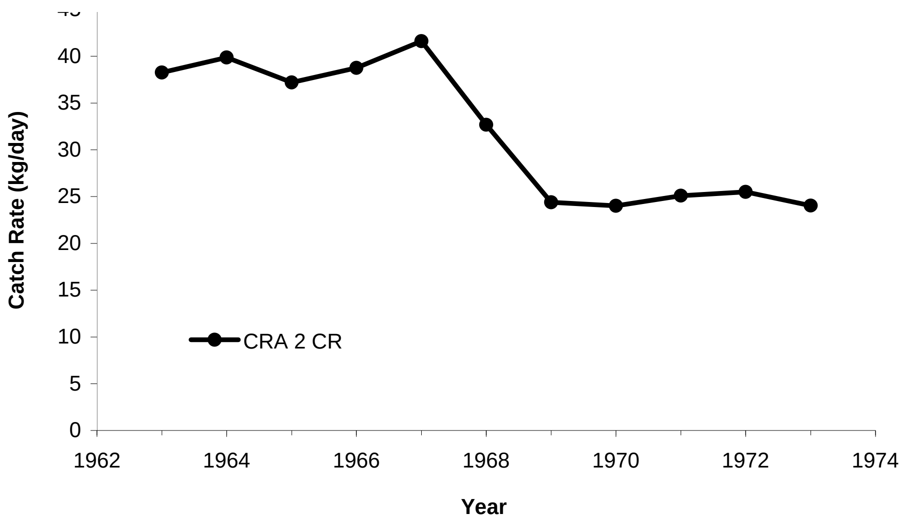

Figure 12: Catch rate (kg/day) by year for CRA 2 from Annala & King (1983).

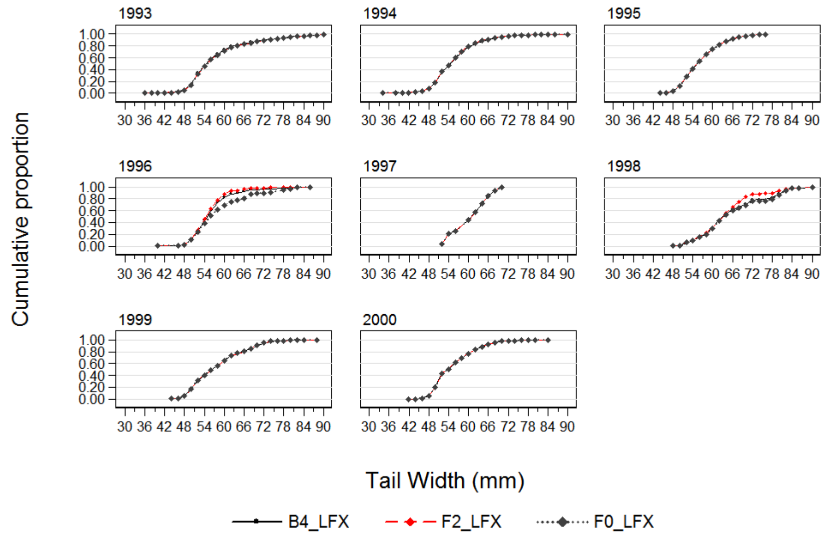

Figure 13: Cumulative distributions of logbook male tail widths from season SS for fishing years 1993 to 2000 for CRA 2, using the three different catch algorithms described in the text (the lines lie on top of each other).

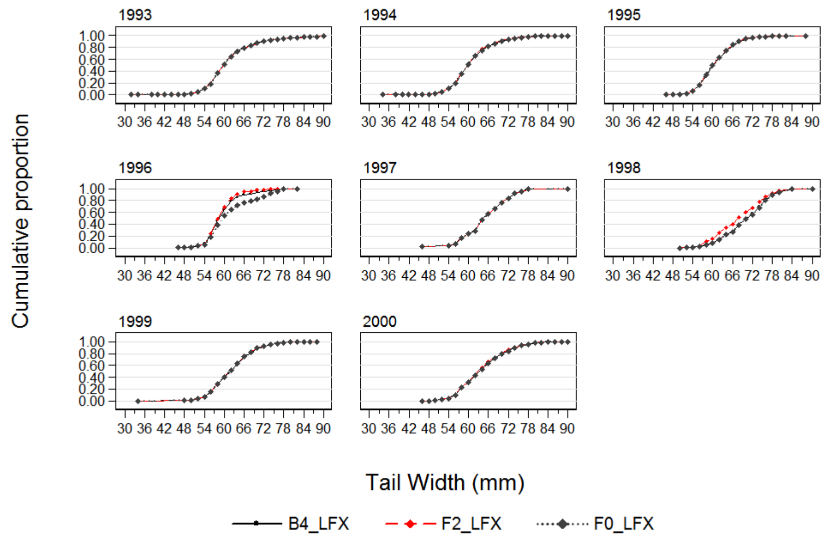

Figure 14: Cumulative distributions of logbook mature female tail widths from season SS for fishing years 1993 to 2000 for CRA 2, using the three different catch algorithms described in the text (the lines lie on top of each other).

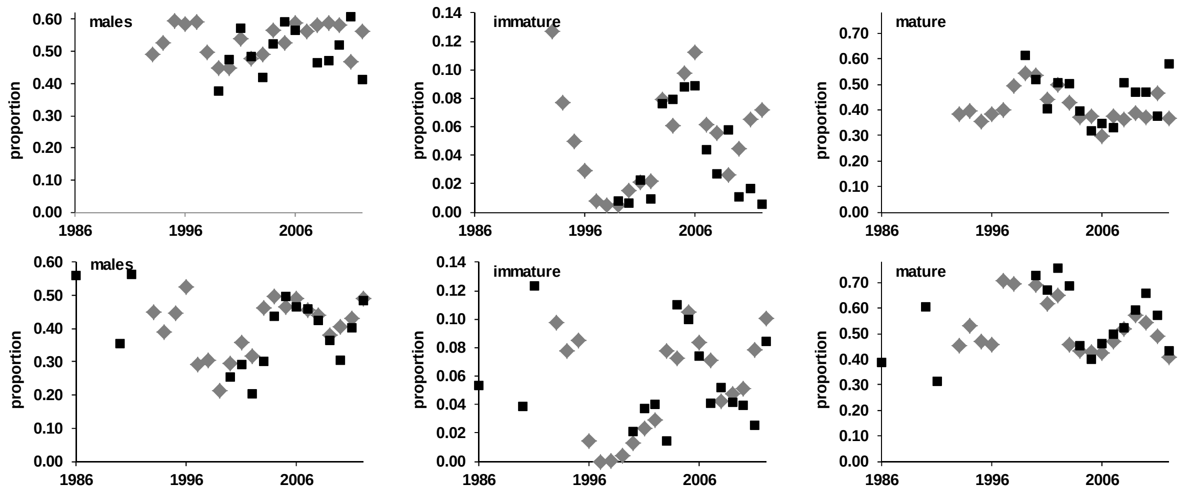

Figure 15: CRA 2 length frequencies: relative proportion of sex classes – males, immature females and mature females – in the data over time, by source and season: top row is AW; diamonds are logbook data, squares are observer data.

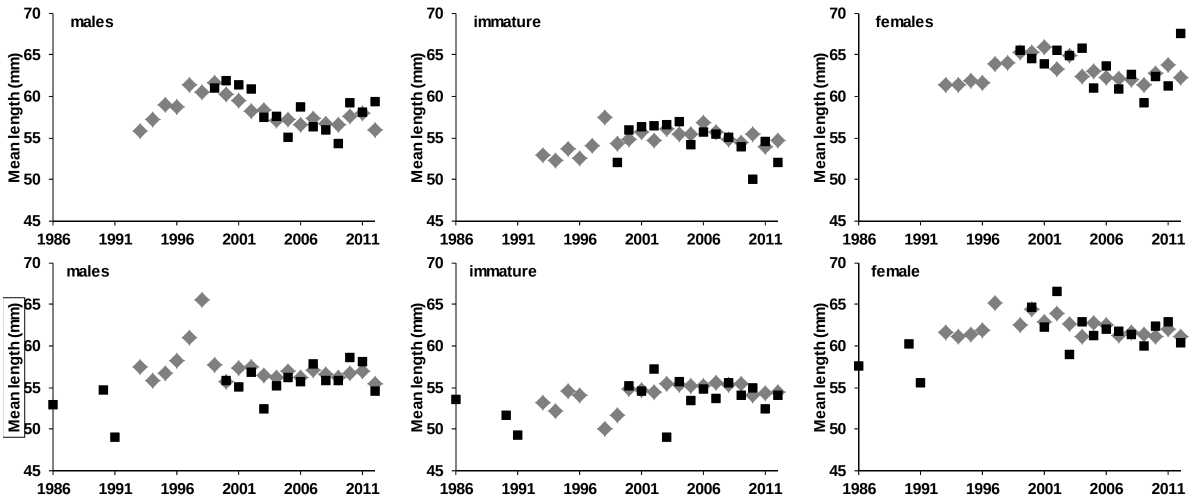

Figure 16: Mean lengths over time by sex classes – males, immature females and mature females – season and source: top row is AW; diamonds are logbook data, squares are observer data.

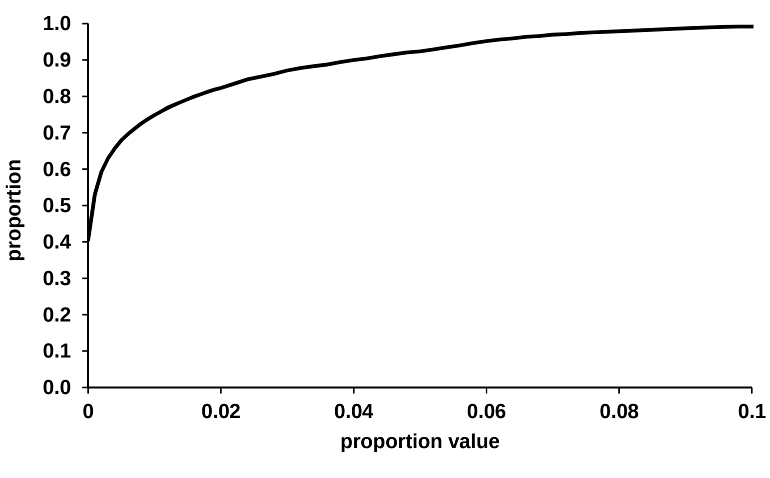

Figure 17: Cumulative proportion of cells in the LF data records with proportions at least as high as the value on the x-axis.

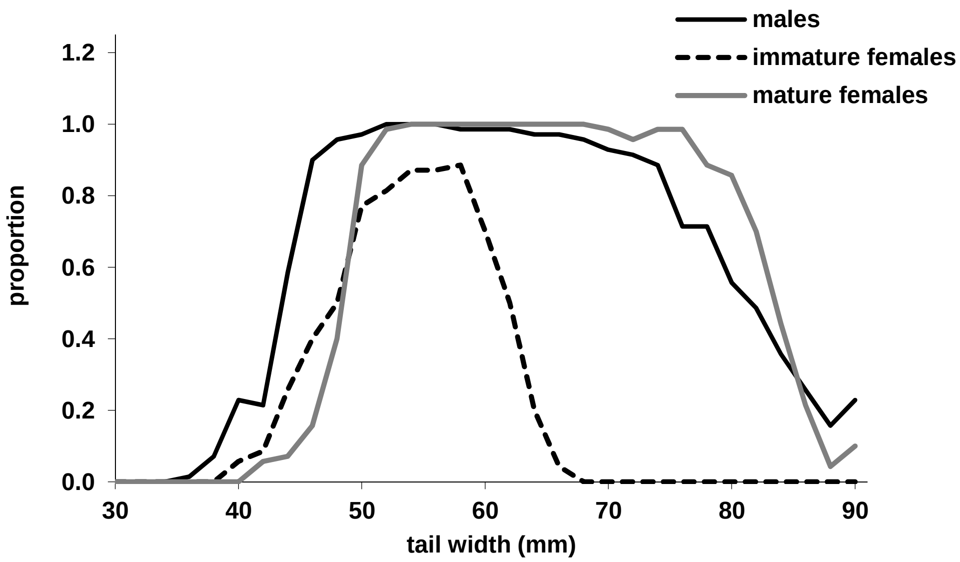

Figure 18: For each sex class and each size, the prevalence of records with a proportion of 0.001 or greater in that bin.

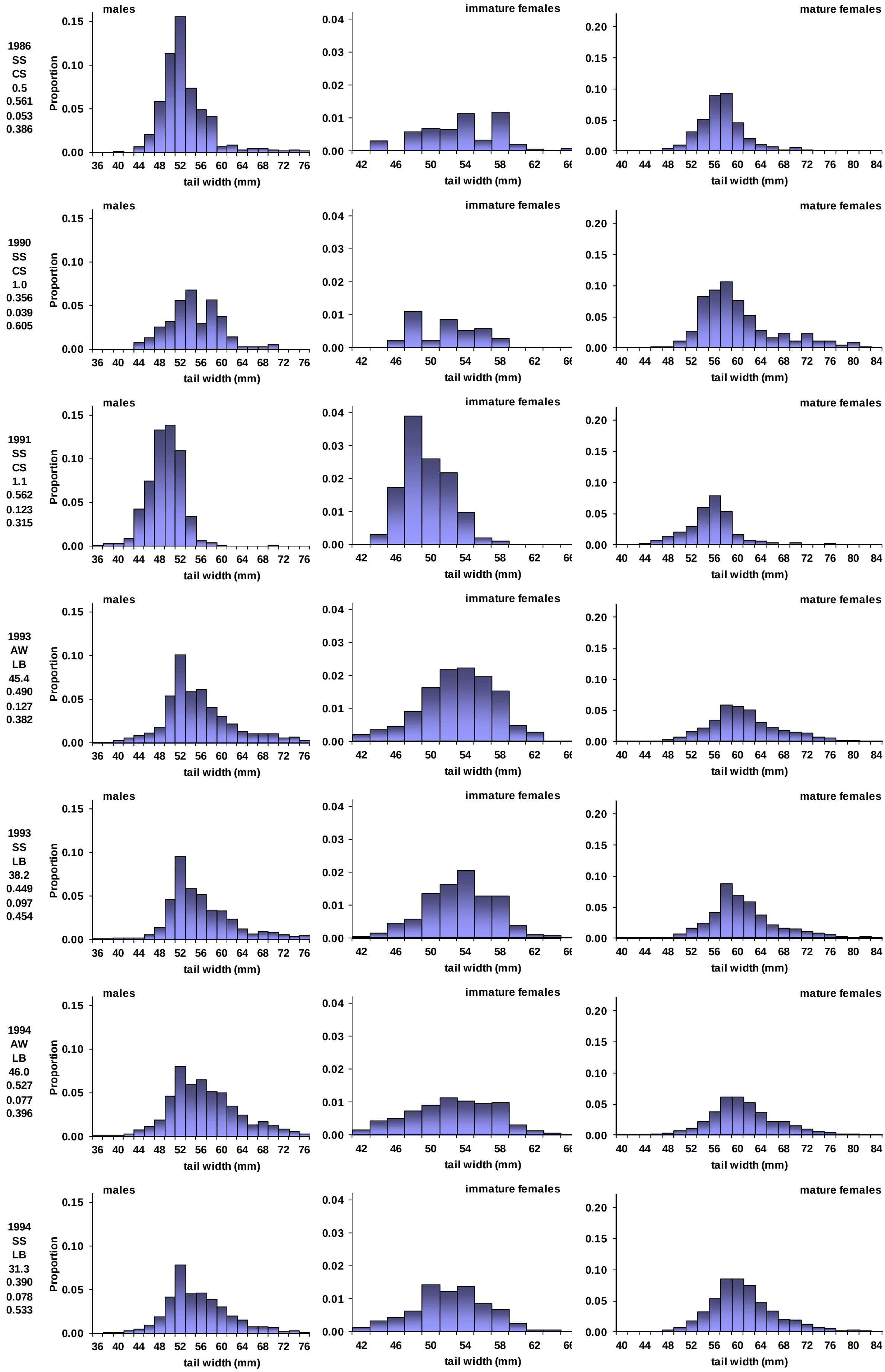

Figure 19: LF records with normalisation across all sex codes: the legend at the left gives, from top to bottom: year, season, source, relative record weight, proportions of males, immature and mature females.

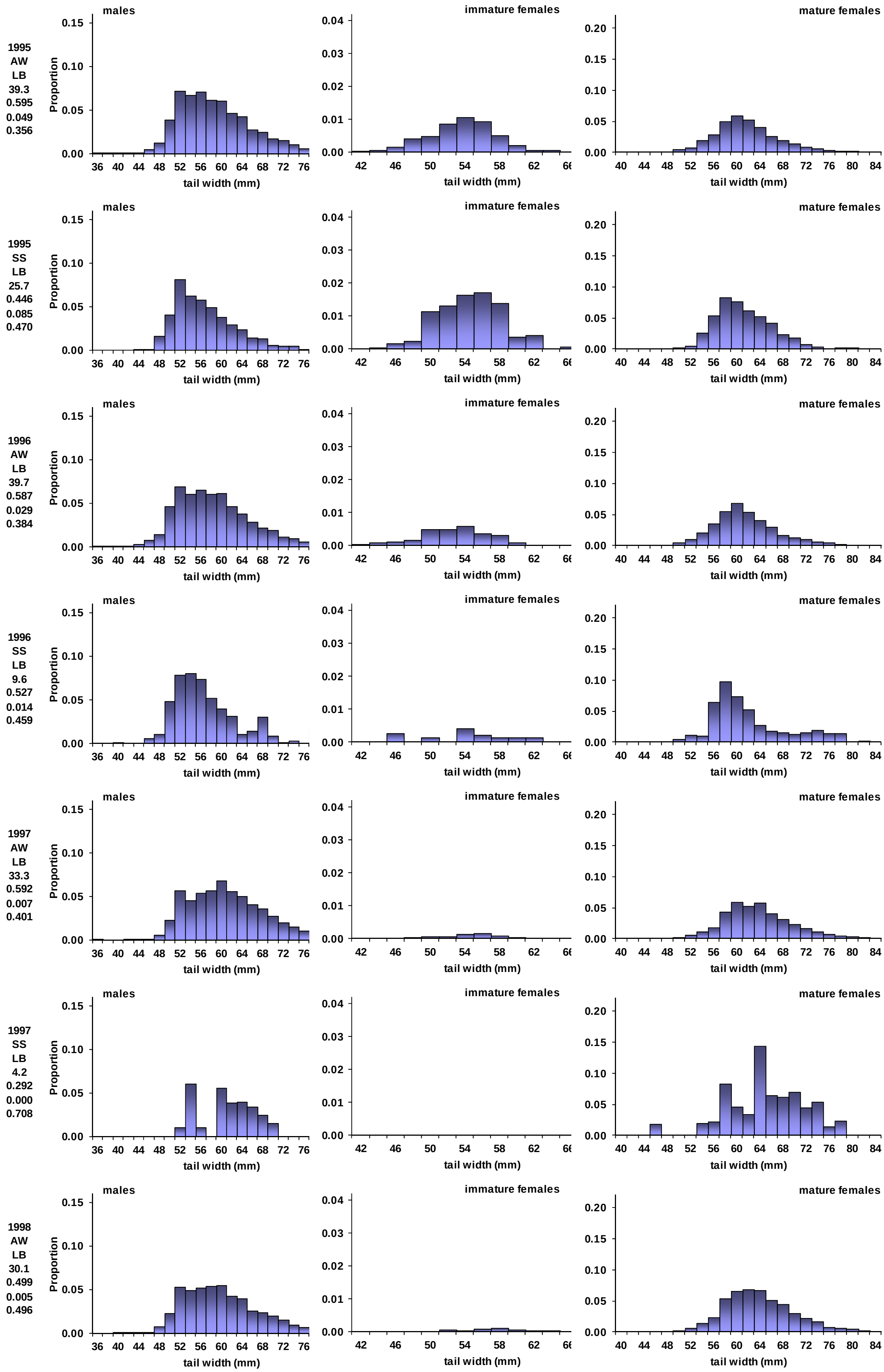

Figure 19 cont.

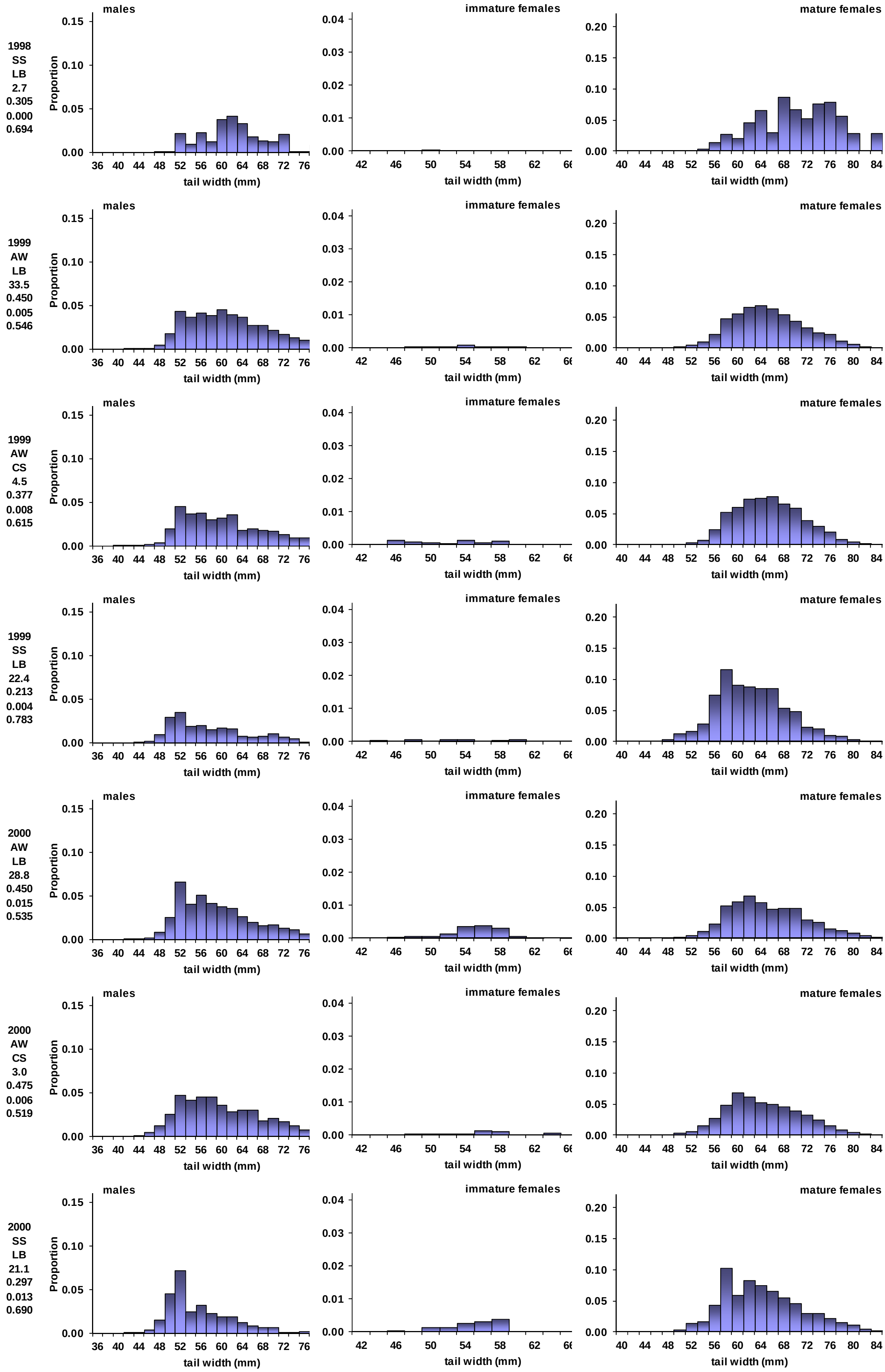

Figure 19 cont.

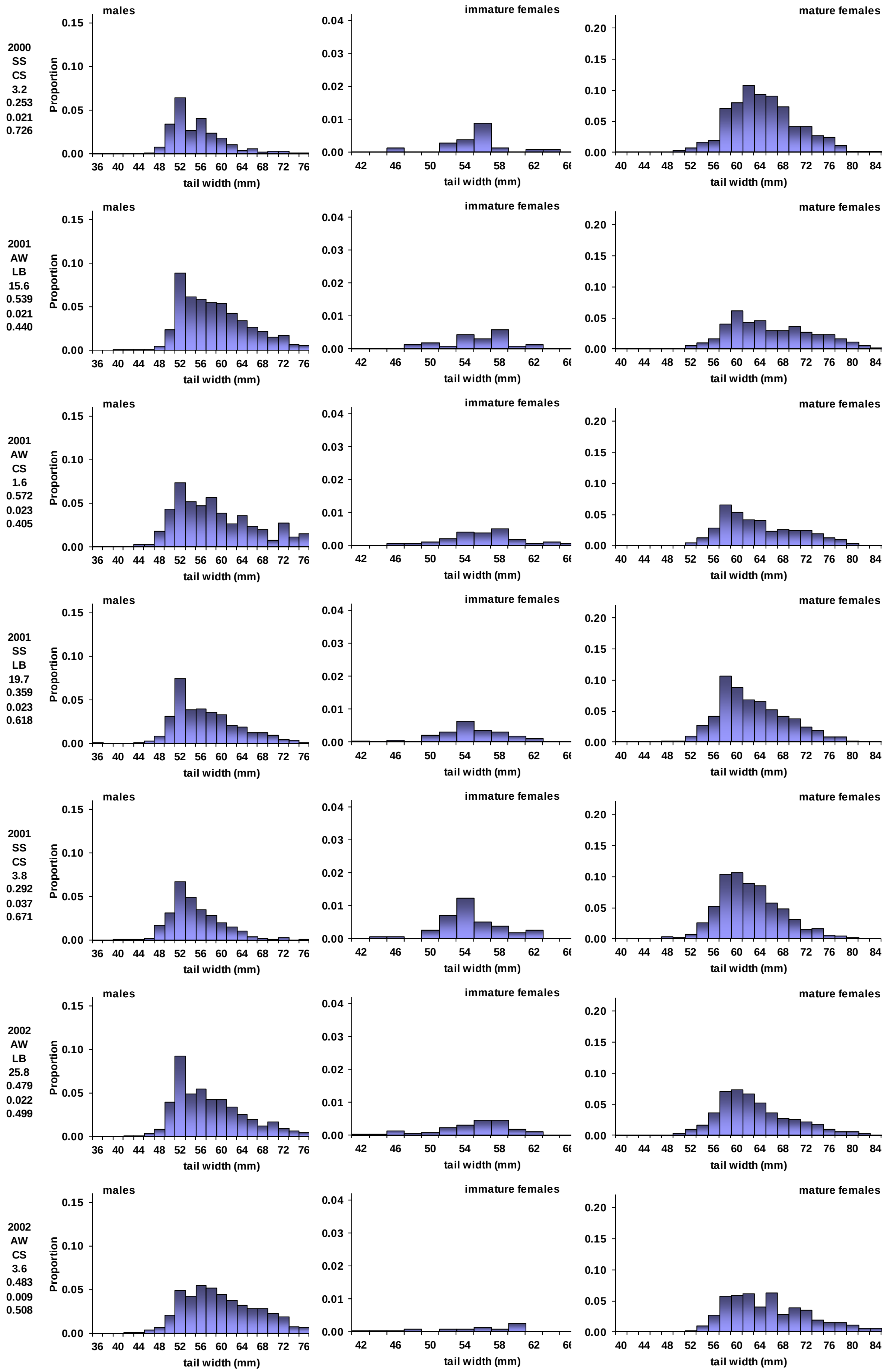

Figure 19 cont.

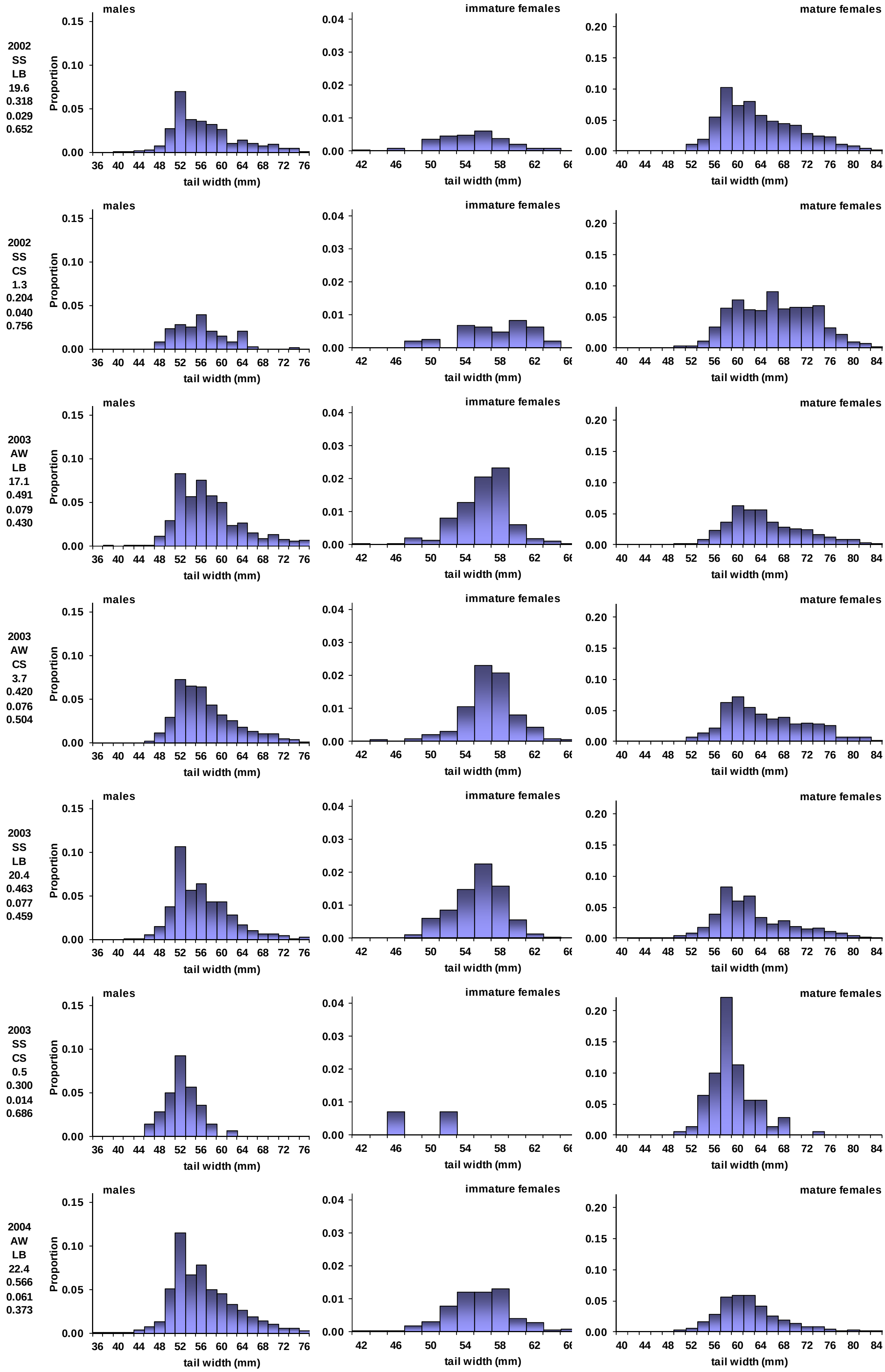

Figure 19 cont.

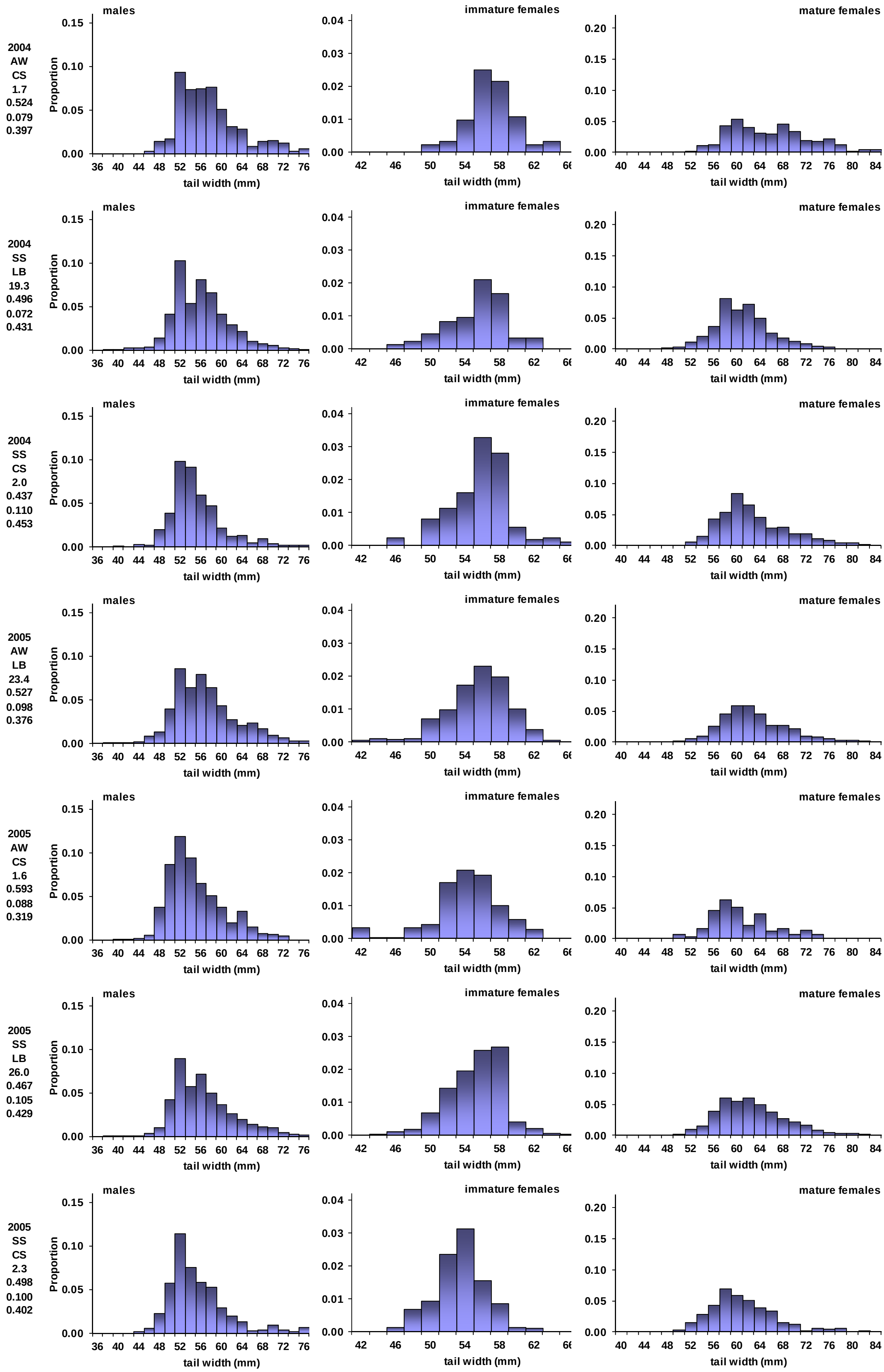

Figure 19 cont.

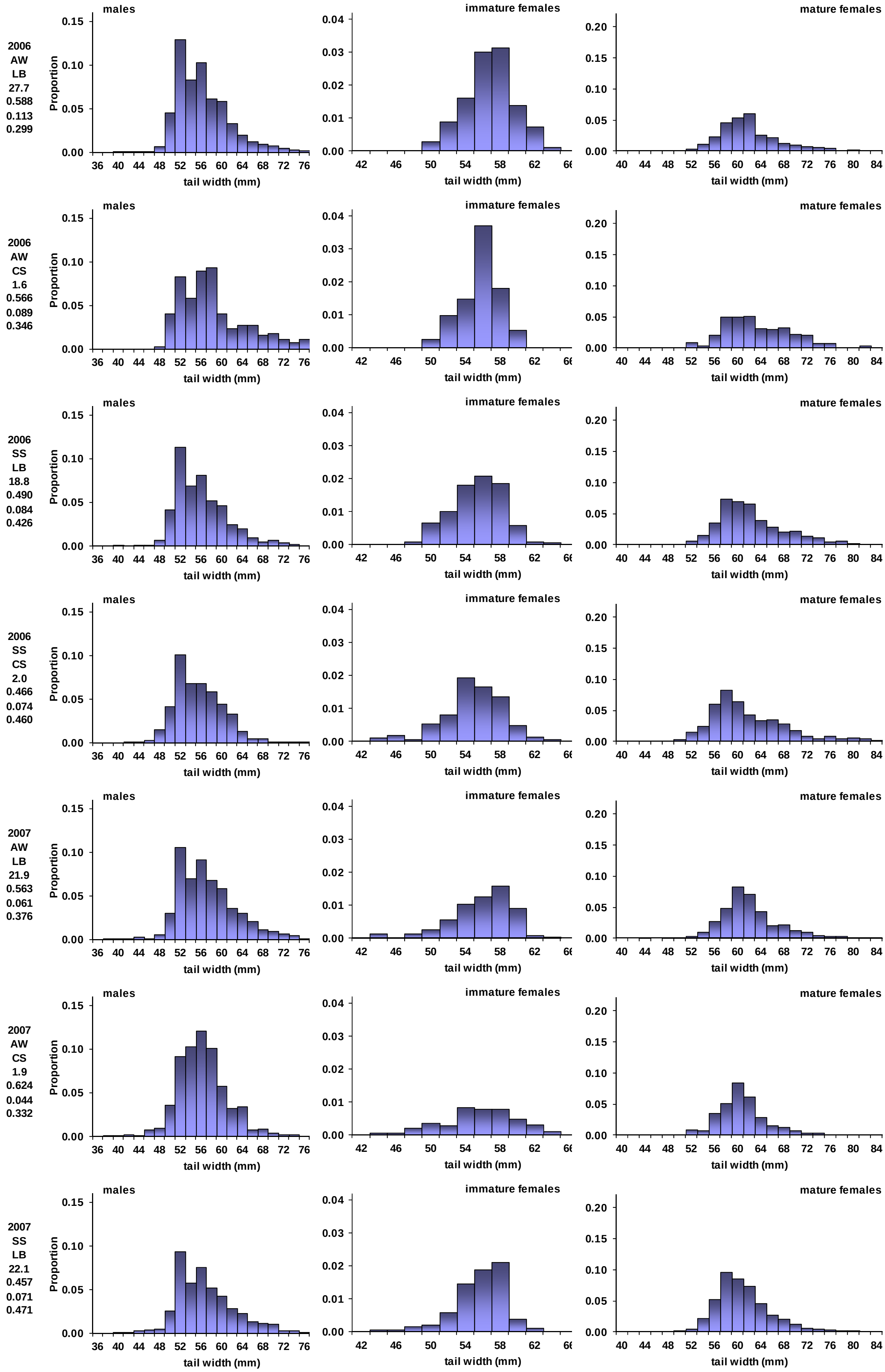

Figure 19 cont.

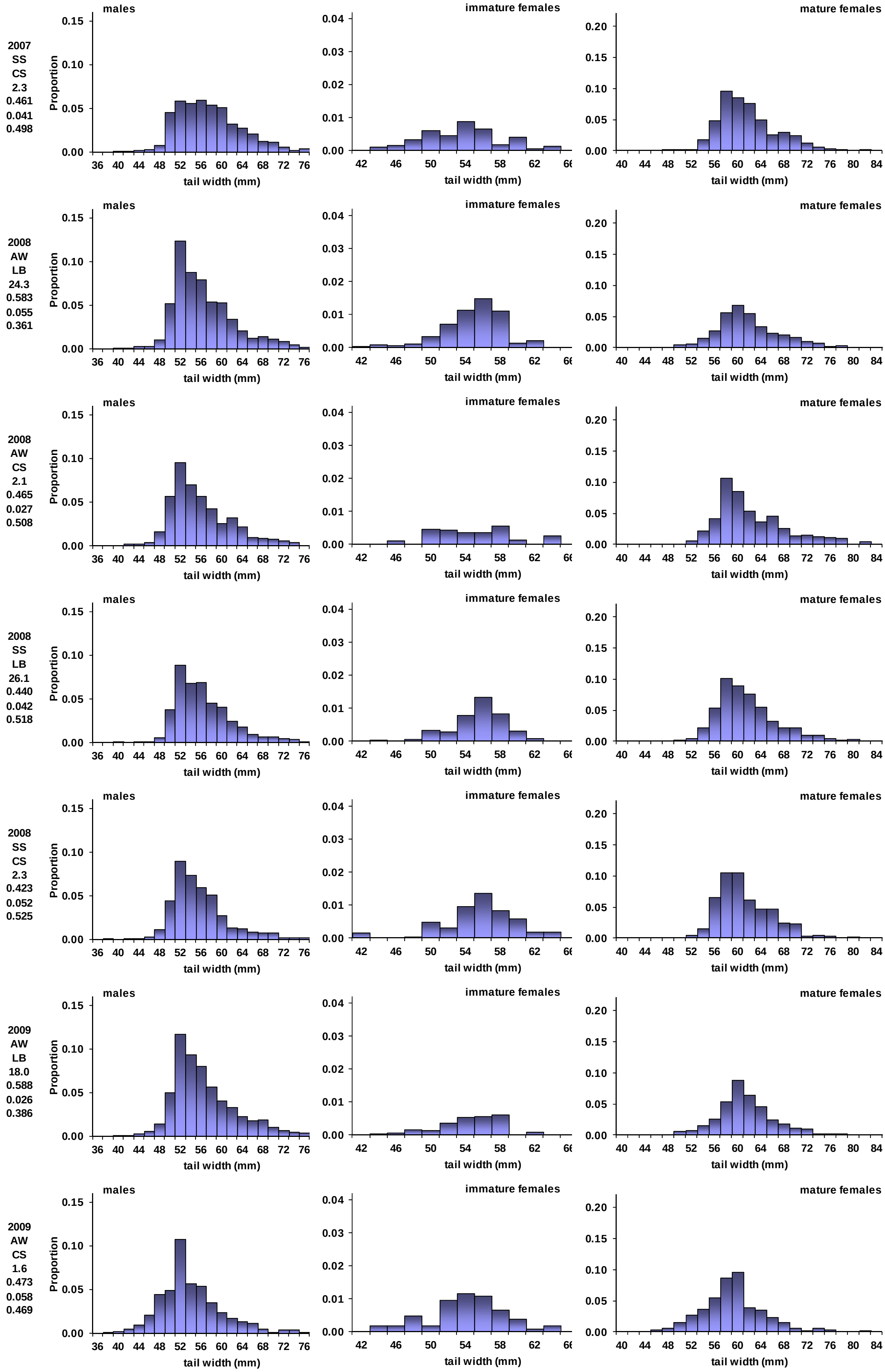

Figure 19 cont.

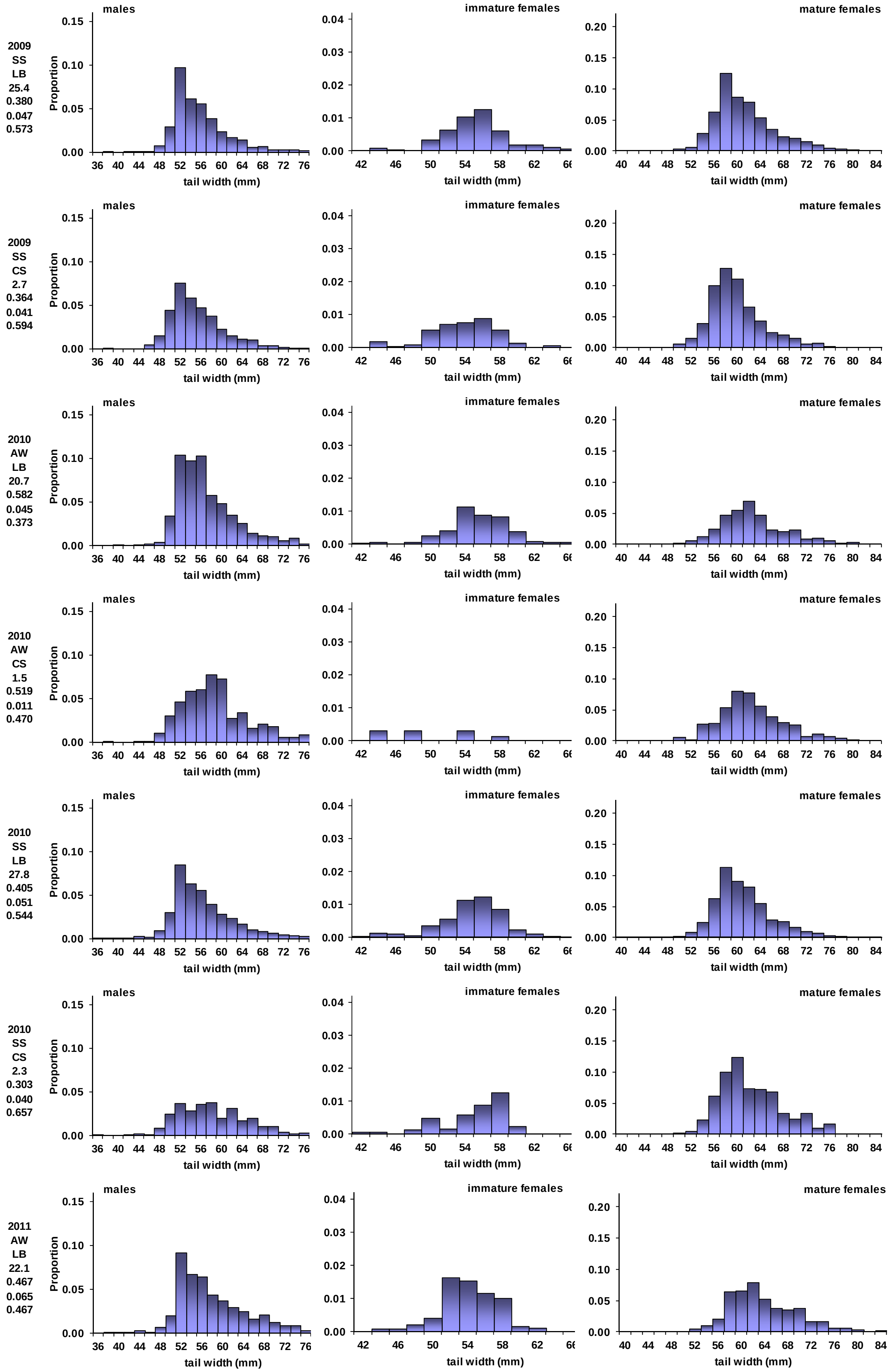

Figure 19 cont.

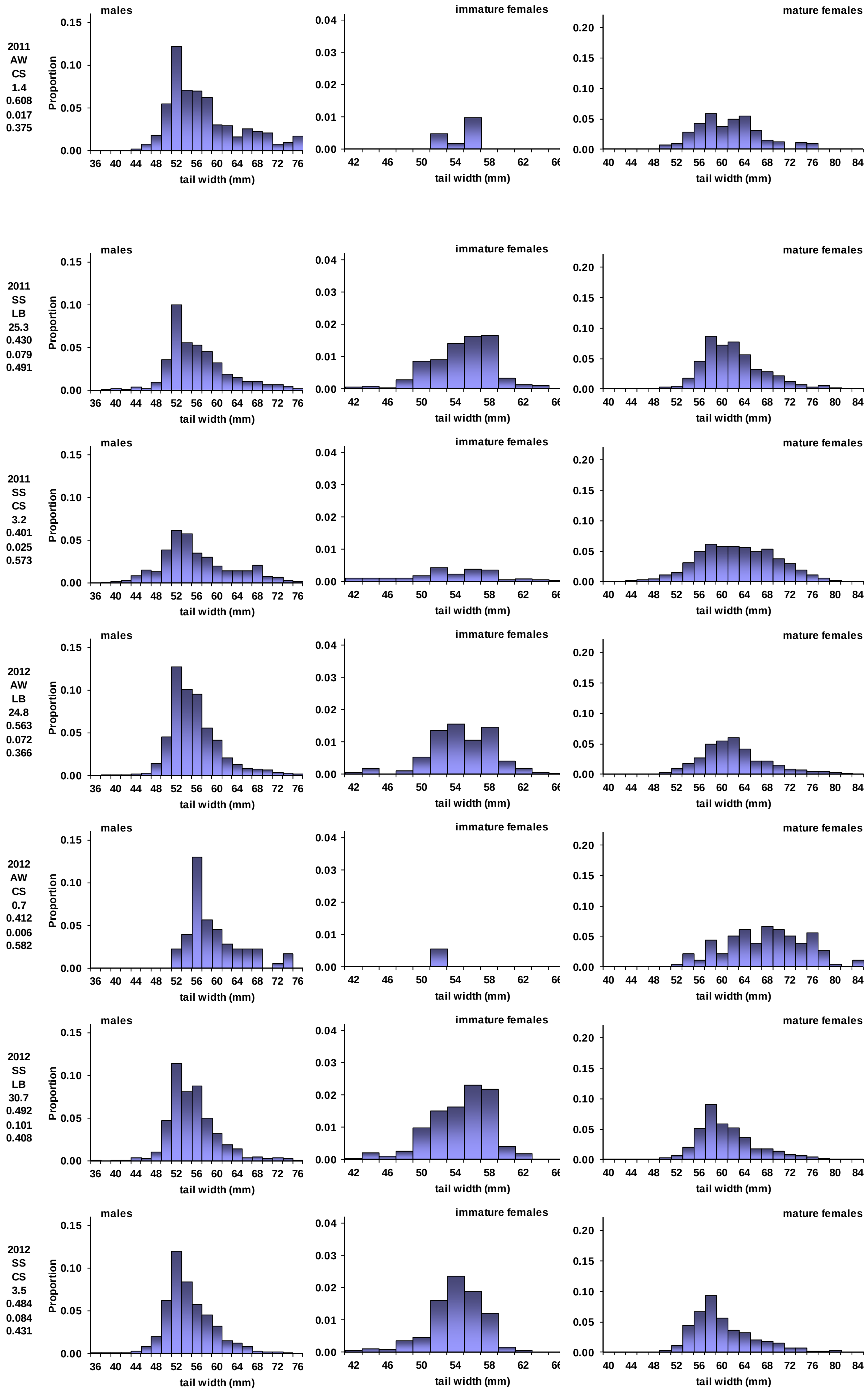

Figure 19 concluded.

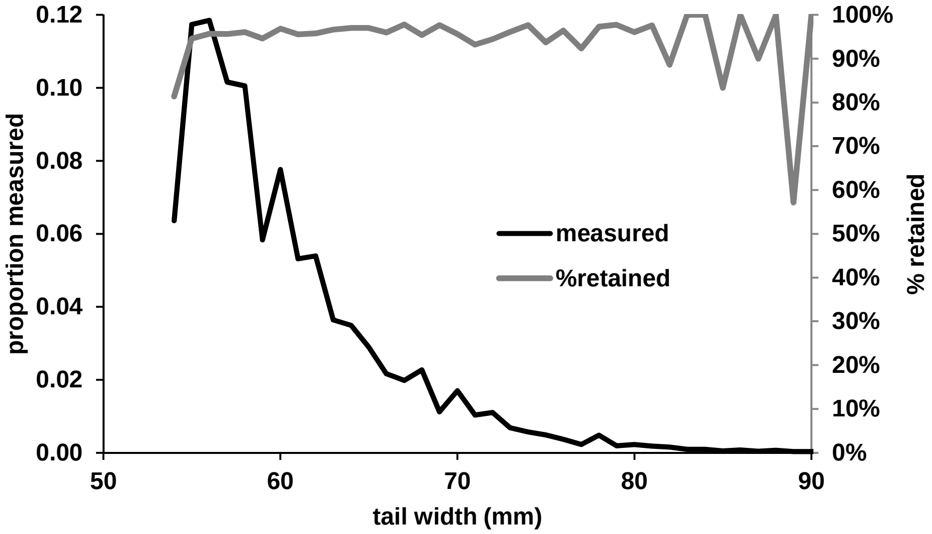

Figure 20: The overall size composition of males measured (black line) and the percent retained as a function of tail width (grey line).

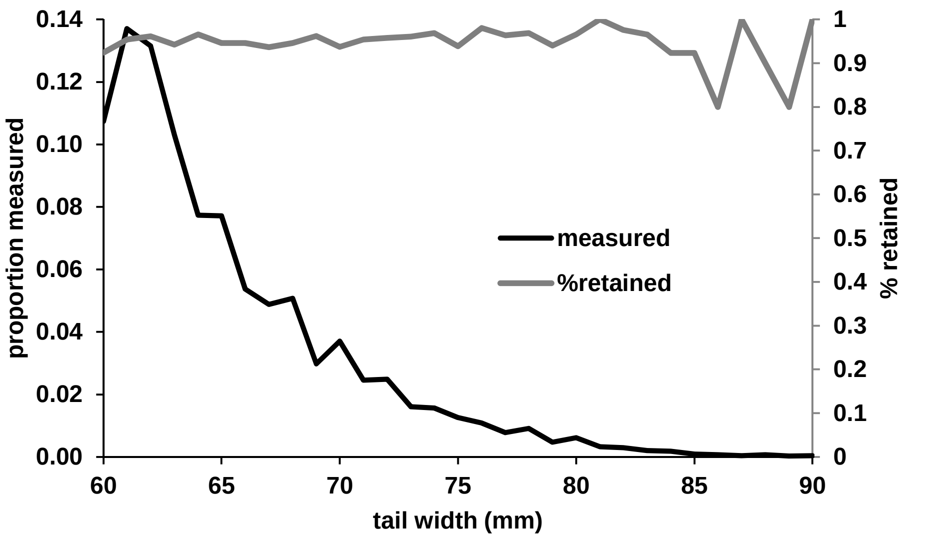

Figure 21: The overall size composition of females measured (black line) and the percent retained as a function of tail width (grey line).

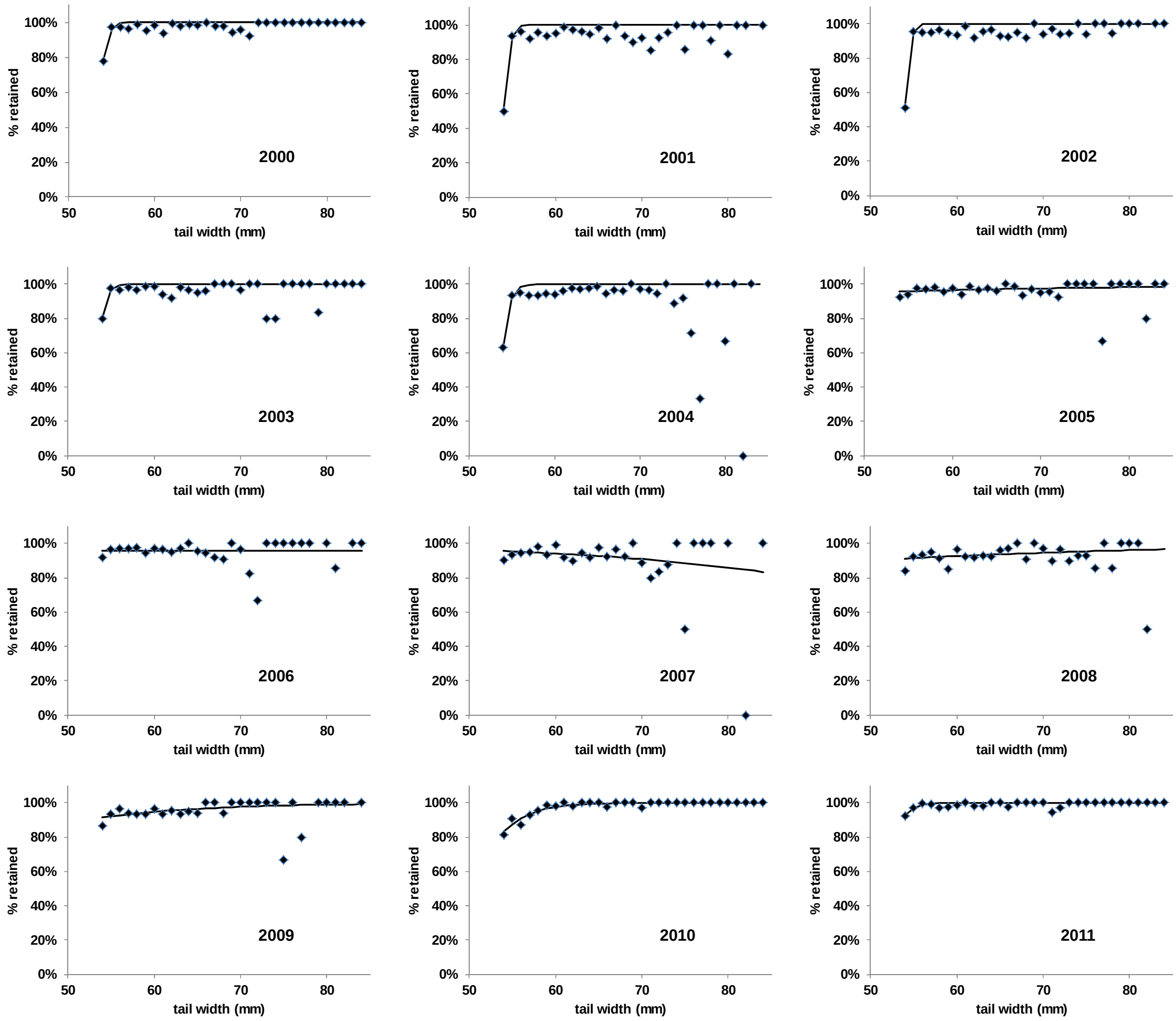

Figure 22: Retention by year for males (diamonds), with fitted logistic or inverse logistic curves (lines).

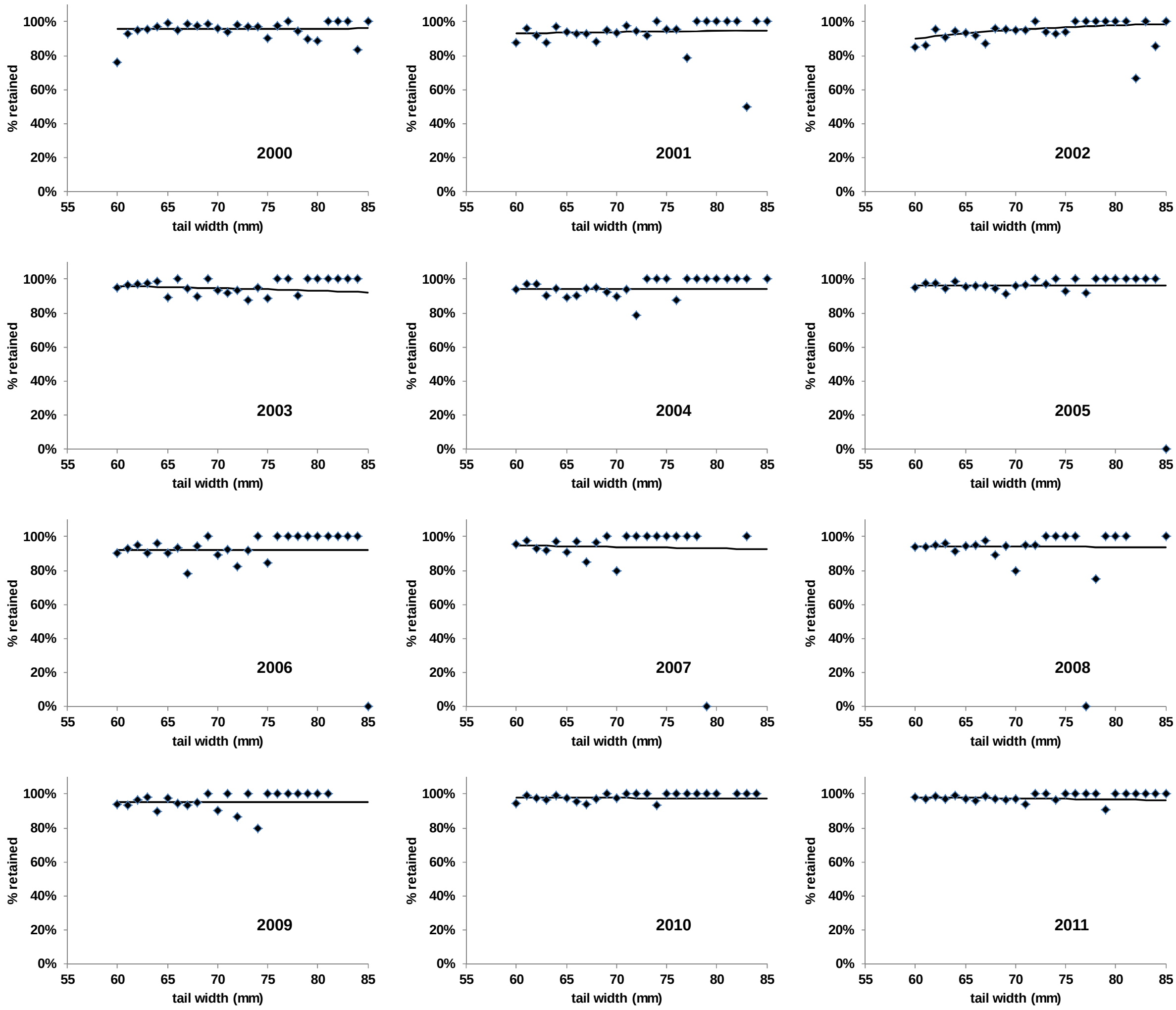

Figure 23: Retention by year for females (diamonds), with fitted logistic or inverse logistic curves (lines).

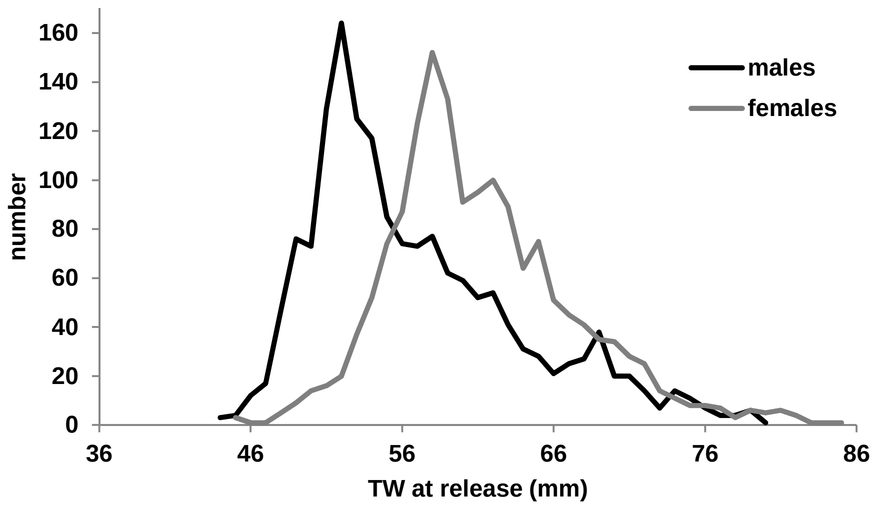

Figure 24: CRA 2 tag-recapture data: numbers in the recaptures that had been tagged at each size by sex.

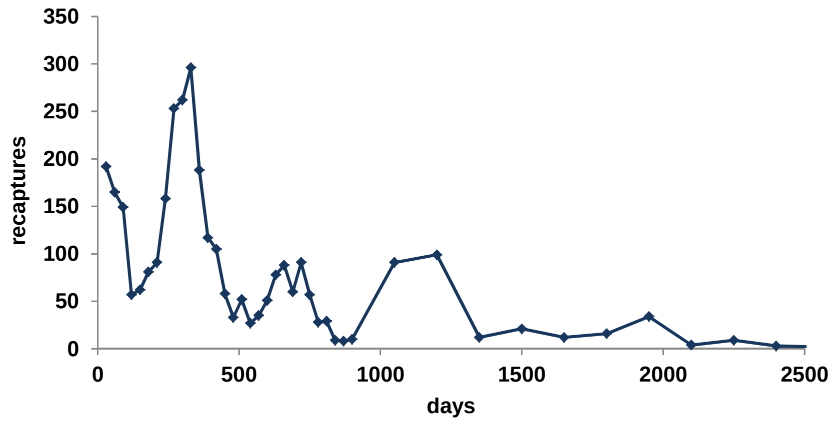

Figure 25: CRA 2 tag-recapture data: numbers of tag-recaptures by days at liberty (the x-axis is truncated and extends to 3300 days).

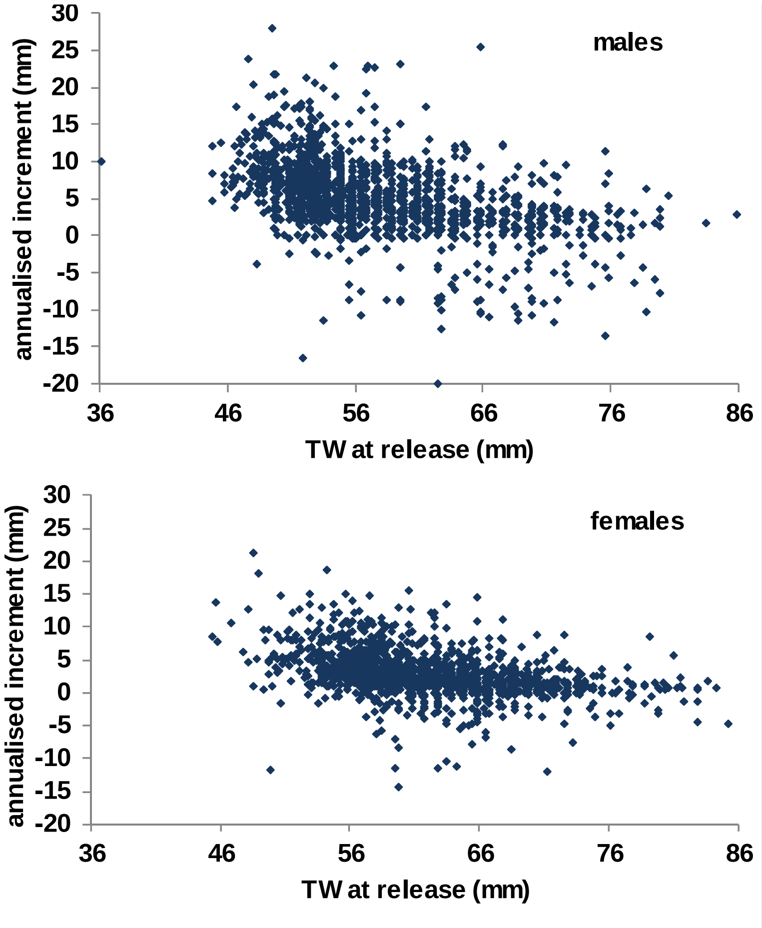

Figure 26: CRA 2 tag-recapture data: annualised increments plotted against size at release for each sex; the y-axis has been truncated to show contrast in the main body of records: actual values range from -64 to 51 but truncation omitted only 12 records from the figure.

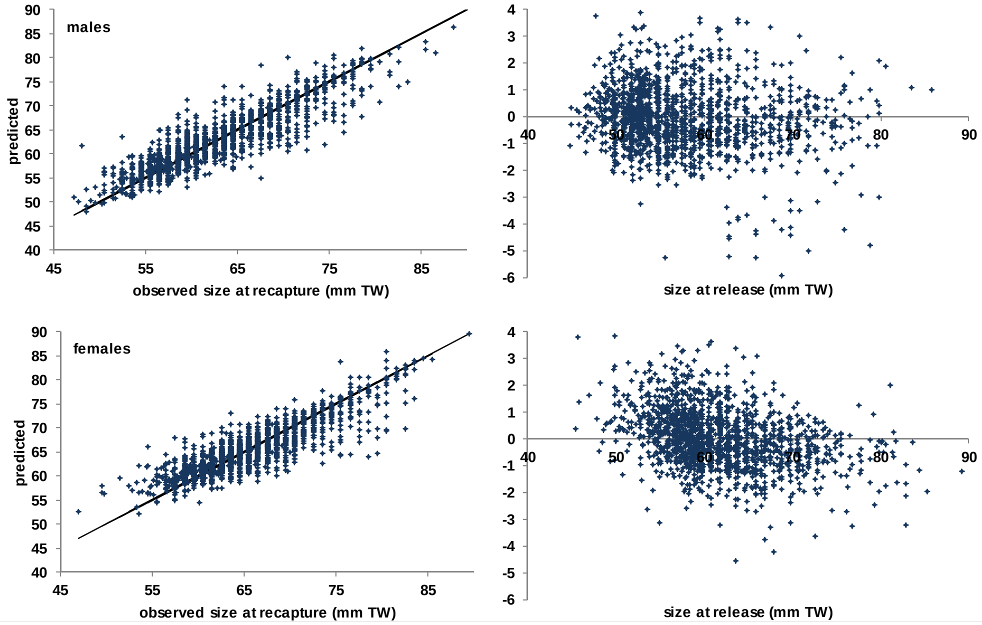

Figure 27: CRA 2 tag-recapture data: preliminary fits to tag-recapture data only: left: observed versus predicted size at recapture; right: normalised residuals plotted against size at release.

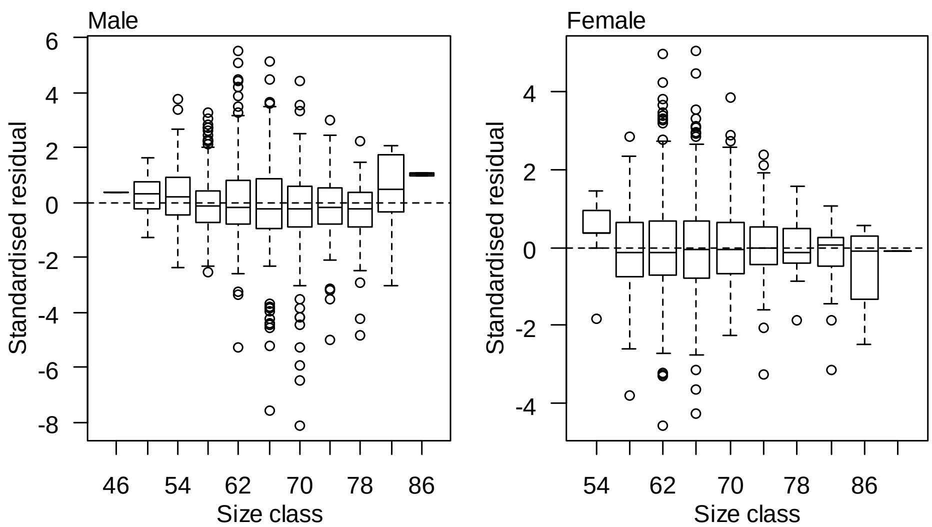

Figure 28: CRA 2 tag-recapture data: preliminary fits to tag-recapture data only: normalised residuals by size at release.

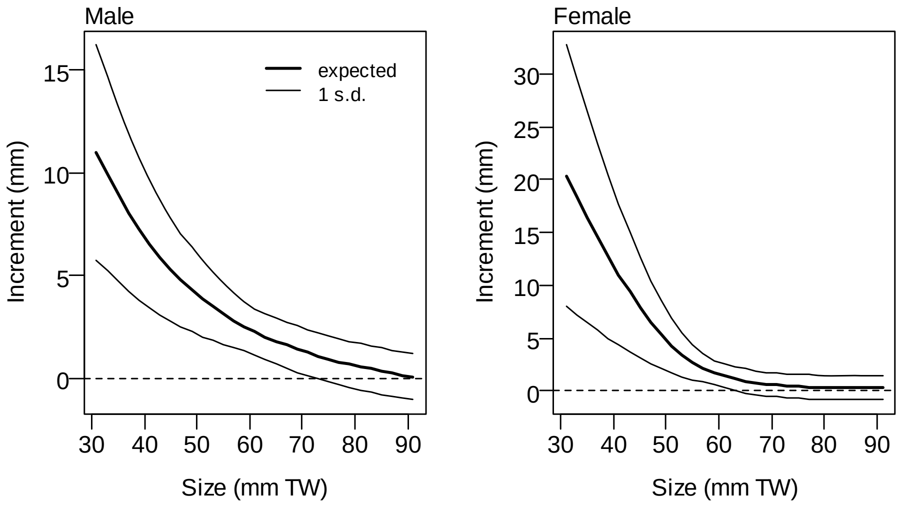

Figure 29: CRA 2 tag-recapture data: fits to tag-recapture data only: predicted growth curves (density-dependent growth turned off).

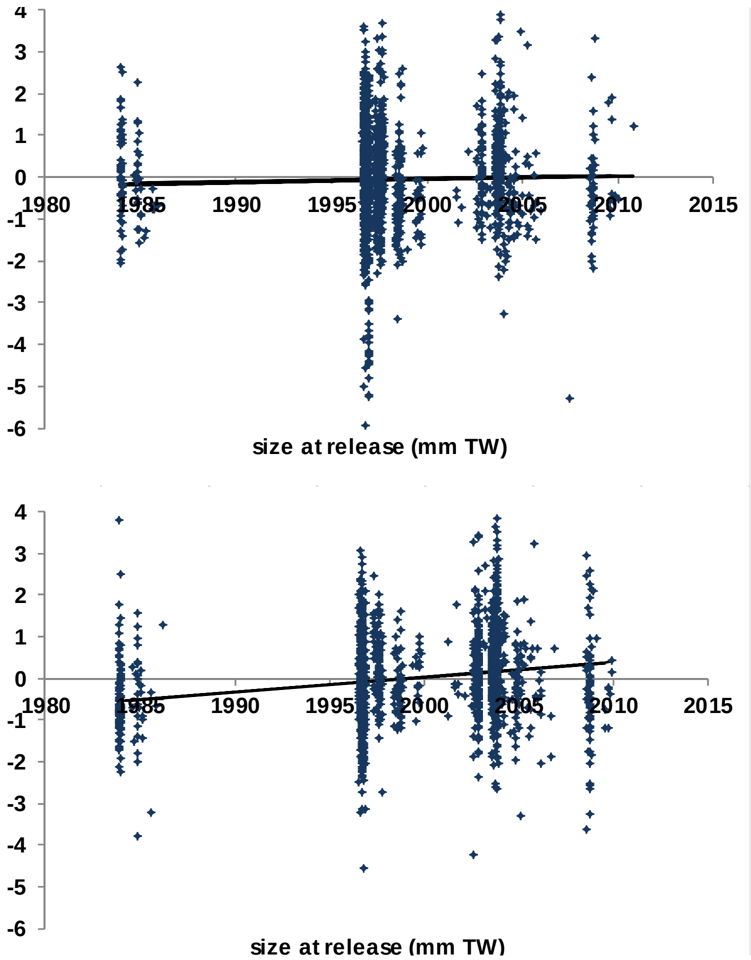

Figure 30: CRA 2 tag-recapture data: fits to tag-recapture data only: residuals from the last fit shown in Table 18, males above and females below, and regressions of the residuals versus date of release (see Table 19). The line is a simple regression.

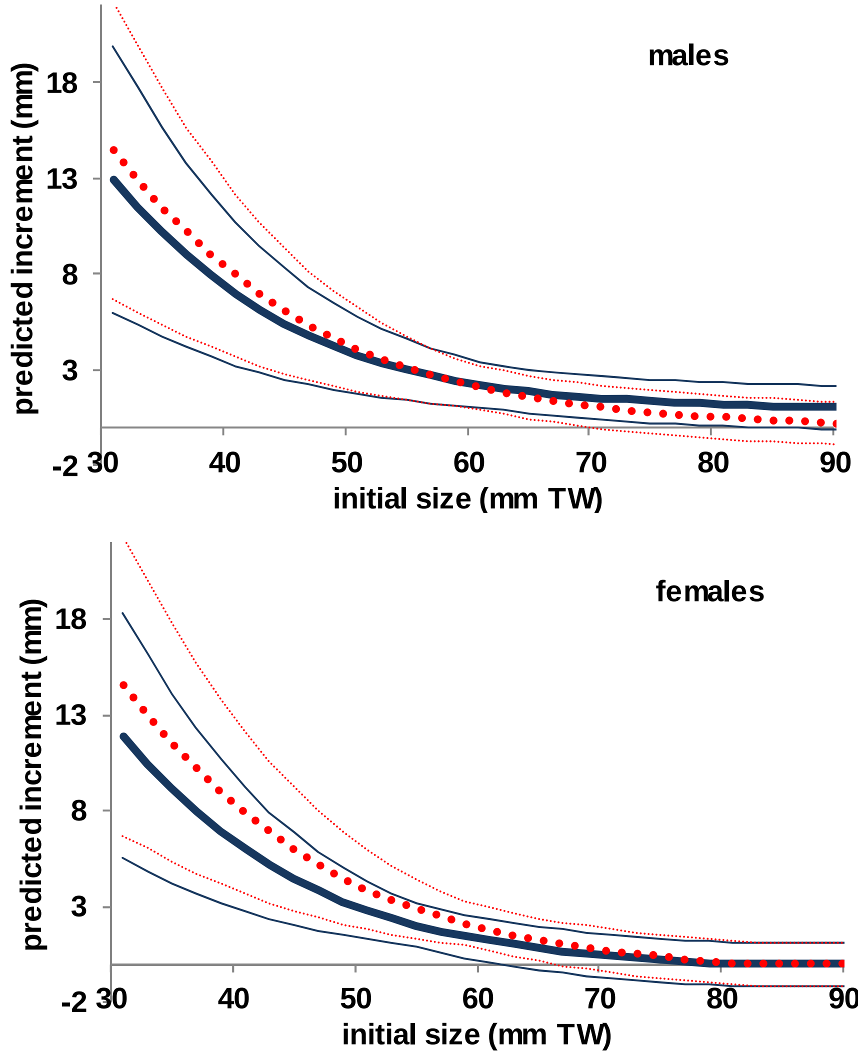

Figure 31: Predicted growth curves (heavy lines) and their standard errors (light lines) from separate fits to the older half of the data set (solid blue lines) and the newer half (dotted red lines).

APPENDIX A

Request for non-commercial catch estimates from MPI

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

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

cc Kevin Sullivan, Chair, RLFAWG
by email: Kevin.Sullivan@fish.govt.nz

Dear Alicia:

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

The stock assessment team has access to good 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 catch information.

In the past, MFish provided estimates of illegal catches, but these were highly uncertain and since 2004 there have been no estimates except for advice in response to requests about 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 in CRA 2 were available from surveys in 1994-96 and 2000-01. We are content to obtain estimates from the Marine Amateur Fisheries WG when the recent estimates become available.

The stock assessment cannot ignore the current and historical customary and illegal 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 customary and illegal 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 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 reported to the QMS. Otherwise, if commercial fishermen report to an MHR 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 requests an appreciation of the uncertainty in the MPI illegal catch estimates.

For customary catch, the requirements are similar: the assessment team requires MPI to 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.

Without these estimates from MPI, it will not be possible to produce a credible CRA 2 stock assessment.

The input data, including these estimates, are scheduled to be discussed at a RLFAWG meeting on 13 May. These MPI estimates of illegal and customary catches are thus required by 6 May 2013.

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

6 May 2013

Daryl Sykes
Research Programme Manager
NZ Rock Lobster Industry Council
lobster@seafood.co.nz

Dear Daryl:

Data request for CRA 2 Stock Assessment

Thank-you for your letter of 8 April 2013 requesting non-commercial catch data for this year's CRA 2 stock assessment and management procedure evaluations. A response to this request is provided below.

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).

2. CRA 2 customary catch estimates

CRA 2 customary harvest information is collected under two types of regulations: the Fisheries (Kaimoana) Regulations 1998 (Kaimoana Regulations), and Regulation 27A of the Fisheries (Amateur Fishing) Regulations 1986 (Amateur Regulations).

Under the Kaimoana Regulations, Tangata kaitiaki are responsible for providing quarterly reports of their harvest authorisations to MPI. Table B1 below provides a summary of the information MPI holds on the quantity of CRA 2 rock lobsters harvested under the Kaimoana Regulations. Harvest information is reported by various unit types (i.e. from no., kg, bin to 'blank'), which makes collation of the information difficult.

Table B1: Summary of CRA 2 customary harvest information from 2005–06 to 2012–13, as collected under the Kaimoana Regulations.

April fishing year	Unit type	Sum of quantity approved	Sum of actual quantity harvested
2005-06	(blank)	84	0
2006-07	NO.	209	161
	(blank)	25	25
2007-08	BIN	1	-
	KG	86	74
	NO.	383	335
	(blank)	98	24
2008-09	BIN	2	-
	NO.	364	197
	(blank)	686	548
2009-10	BIN	2	-
	KG	30	0
	NO.	514	201
	(blank)	48	30
2010-11	BAG	2	-
	BIN	2	-
	KG	100	20
	NO.	1644	606
	(blank)	633	413
2011-12	NO.	706	307
	(blank)	407	180
2012-13 (incomplete)	NO.	140	45

Figure B1 provides an indication of the proportion of the CRA 2 fishery that is covered by the Kaimoana Regulations (shown as red lines). A considerable proportion of the fishery (particularly the Coromandel and Hauraki Gulf areas) is not covered by these regulations. Customary rock lobster from areas not covered by the Kaimoana Regulations, can instead occur under Regulation 27A of the Amateur Regulations.

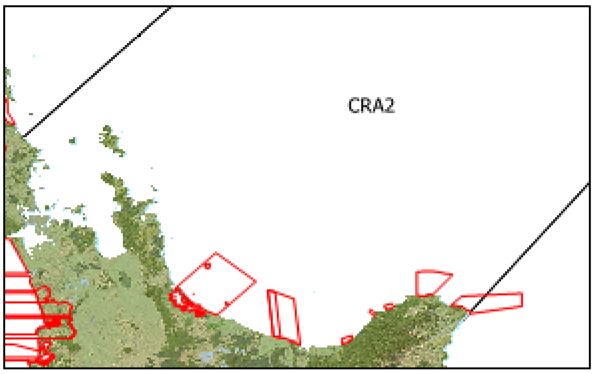

Figure B1: Map showing areas where Tangata Kaitaiki have been appointed, under the Kaimoana Regulations, for the management of customary food gathering within an area/rohe moana.

Under the Amateur Regulations, harvest of rock lobsters can be authorised for the purpose of hui or tangi. There is no mandatory requirement for regulation 27A permit issuers to provide MPI with details of customary fishing authorisations, therefore, this information is considered incomplete. Table B2 provides a summary of the information MPI holds on the quantity of CRA 2 rock lobsters harvested under the Amateur Regulations.

Table B2: Summary of CRA 2 customary harvest information from 2005-06 to 2012-13, as collected under the Amateur Regulations.

April fishing year	Unit type	Sum of quantity approved	Sum of actual quantity harvested
2005-06	NO.	1388	1139
	(blank)	109	40
2006-07	KG	64	20
	NO.	276	130
	(blank)	275	-
2007-08	BIN	6	0
	NO.	1276	287
	(blank)	319	94
2008-09	KG	200	1
	NO.	528	82
	(blank)	893	72
2009-10	NO.	1028	321
	(blank)	1066	60
2010-11	BIN	1	-
	KG	75	0
	NO.	806	178
	(blank)	1388	65
2011-12	NO.	248	110
	(blank)	1441	270
2012-13 (incomplete)	NO.	120	-
	(blank)	291	49

Based on the information supplied above and its uncertainty, MPI considers it appropriate to continue to use a 10 tonne constant customary catch estimate for CRA 2.

2. CRA 2 recreational catch estimates

As noted in your letter, you will obtain recent CRA 2 recreational catch estimates from the Marine Amateur Fisheries Working Group when they become available. Outside of this is amateur charter vessel activity reporting information that you have requested access to.

Charter vessel operators were required to report catches of CRA 2 rock lobsters from October 2012. Many operators also voluntarily provided CRA 2 catch information before this time.

Information MPI holds on CRA 2 rock lobsters reported under the charter boat reporting scheme from 1 January 2012 to 16 April 2013 is provided in Table B3. There is some uncertainty in the information because free text is currently accepted on amateur charter returns and no verification of the raw data has been undertaken. The information is also considered incomplete (note: many operators do not report the number of fish retained).

Table B3: Summary of CRA 2 harvest information by month from 1 January 2012 to 16 April 2013, as collected under the amateur charter vessel activity reporting scheme.

Calendar Year	Month	Sum of number caught	Sum of number retained
2012	January	117	91
	February	116	61
	March	210	80
	April	83	15
	May	162	112
	June	29	8
	August	3	3
	September	80	8
	October	332	119
	November	322	206
	December	166	86
2013	January	236	117
	February	190	70
	March	86	86

If you would like any of the details of this letter clarified, please do not hesitate to contact me on 06 831 0279.

Kind regards

Alicia McKinnon
Fisheries Analyst