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EXECUTIVE SUMMARY

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This document describes the assessment model and data used in the 2008 stock assessment of CRA 3. This was the first assessment done for this area since 2004. The assessment was conducted with a previously described multi-stock length-based model (MSLM) that was purpose-built for lobster stock assessments. For the CRA 3 assessment, the model was used as a single-stock model. Some generic changes were made to the model since the previous documentation and these are described. In addition, some non-generic changes (incompatible with the multi-stock option of the model) were made to address specific problems in the CRA 3 assessment.

The data used in the assessment are also described. The model is driven by catch information. Four types of catch are described: commercial, recreational, customary and illegal. These are aggregated into size-limited and non-size-limited series, and by season (autumn-winter or spring-summer), beginning in 1974. The model can be fitted to standardised CPUE from 1979 onwards, to an older catch rate series, to length frequency data from observer catch sampling and from voluntary logbooks, to tag-recapture data and to puerulus settlement data. These series are described.

Exploratory analyses of the tag-recapture data showed that growth rates estimated from an older set of data from 1975 through 1981 were much greater than those estimated from data from 1995 through 2006. An independent study confirmed the slow growth observed in the later series. This finding required a substantial change to the assessment model.

1. INTRODUCTION

This document describes the assessment model and data used in the 2008 stock assessment of CRA 3. The stock assessment was done under Objectives 3 and 4 of Ministry of Fisheries (MFish) contract CRA2006/01, a three-year contract awarded to the New Zealand Rock Lobster Industry Council Ltd. (NZRLIC). In New Zealand there are nine rock lobster stocks, not all of which can be assessed each year. The choice of stock to assess was made by the National Rock Lobster Management Group (NRLMG). The stock assessment was guided by the Rock Lobster Fishery Assessment Working Group (RLFAWG).

The stock assessment was conducted with a previously described multi-stock length-based model (MSLM) that was purpose-built for lobster stock assessments (Haist et al. 2009). For the CRA 3 stock assessment, the model was used as a single-stock model. Some generic changes were made to the model and these are described. In addition, some non-generic changes (incompatible with the multi-stock option of the model) were made to address specific problems; these are also described.

The data used in the assessment are also described. The model is driven by catch information. Four types of catch are described: commercial, recreational, customary and illegal. These are aggregated into size-limited and non-size-limited series, and by season (autumn-winter or spring-summer) beginning in 1974. The model can be fitted to standardised catch per unit of effort (CPUE) from 1979 onwards, to an older catch rate (CR) series, to length frequency data from observer catch sampling and from voluntary logbooks, to tag-recapture data and to puerulus settlement data. These series are described.

Exploratory analyses of the tag-recapture data showed that growth rates estimated from an older set of data, from 1975 through 81, were much greater than those estimated from data from 1995 through 2006. An independent study confirmed the slow growth observed in the recent series. This finding required a substantial change to the assessment model.

Because of the complexity of this stock assessment, the documentation has been divided into two publications: this one, describing the model and data, and a companion document (Breen et al. 2009) describing fitting the model to data, the Markov chain – Monte Carlo simulations, forward projections and assessment results.

The document refers to two seasons: autumn-winter (AW), from 1 April through 30 September, and spring-summer (SS), from 1 October through 31 March. The rock lobster fishing year extends from 1 April through 31 March. Where a fishing year is referred to by a single year, the year is the April-December calendar year portion of the fishing year; *viz.* “2003” refers to the 2003–04 fishing year. Minimum legal size is abbreviated as MLS, tail width (the measurement on which MLS is based) as TW.

2. MODEL

2.1 Overview

Stock assessments of New Zealand rock lobster have been based on length structured models since 1998 (Starr et al. 1999). The original model was rewritten and extensively revised in 2000 (Bentley et al. 2001) and in 2006 was replaced by a multi-stock length-based model (MSLM) (Haist et al. 2009). All these models have been integrated that fit simultaneously to CPUE, length frequencies (LFs) sampled from the commercial fishery, and tag-recapture data.

This document describes the MSLM model as it was after modification before the stock assessment, and modifications added to MSLM for the 2008 assessment of the CRA 3 stock. Changes from previous documentation include the addition of an inverse logistic equation for modelling growth, an option for estimating fully recruited fishing mortality parameters for the instantaneous fishing mortality equations, an option for fitting puerulus settlement data to model recruitment estimates, and the capacity to fit to two growth datasets from different periods as described below. This model is also capable of estimating *MSY* and *Bmsy* (maximum sustained yield and the biomass associated with that quantity) under a range of recruitment assumptions.

The model is implemented in AD Model Builder™. It is a Bayesian model, so prior information or belief can be formally incorporated in prior probability distributions for parameters. Assessments are based on the marginal posterior distributions of parameters, estimated using Markov chain–Monte Carlo (McMC) simulation.

The population is represented as numbers of individuals kept separate by region, sex, and size-class. The time step is variable: the population can be initialised with an annual time step, changing to a semi-annual time step for the SS and AW seasons.

Population processes modelled include differential selectivity and seasonal vulnerability among three sex groups (males, immature females and mature females), a flexible growth equation, handling mortality, maturation, the effects of marine reserves, movements among stocks and historical changes in selectivity curves. The estimated parameters include: the log of base numbers of recruits, annual deviations in recruitment, natural mortality, catchability for two abundance series, growth and its variability, female maturation, size- and sex-specific selectivity, sex-specific seasonal vulnerability, and a parameter for the shape of the relation between biomass and CPUE. Relative vulnerability parameters can be shared among sexes. For stability of convergence, any parameter can be fixed at a specified value. Prior distributions and bounds are specified for all parameters.

MSLM allows simultaneous modelling of two or more stocks with a mixture of common and stock-specific parameters. Recruitment is always stock-specific; all other parameters can be specified as common or stock-specific. Natural mortality, for instance, may be considered a parameter that ought to be the same in two adjacent stocks – information from both stocks can be to estimate this parameter, leading to more robust assessments of both stocks. For the CRA 3 assessment, MSLM was used as a single-stock model.

Additional extensions of the model are also programmed as user options. The program allows a choice of likelihood functions for the various data sets. The user can also choose between finite and instantaneous fishing dynamics and two forms of selectivity curve. The choice of time step is flexible and can be changed during the period being modelled to accommodate better quality in recent data. Lobster movement between stocks can be estimated; density-dependent growth can be modelled with estimated parameters; a stock-recruit relation can be estimated.

2.2 Model description

The dynamics operate over a variable number of time steps, n_y, that are specified for each year *y*. The sequence in each time step is: fishing and natural mortality, growth, maturation, movement, and recruitment. Region and sex are denoted by superscripts *r* and *g* respectively; year, time-step and size-class are denoted by subscripts *y*, *p*, and *s*, respectively. Three sex categories are modelled: males, immature females and mature females, coded 1, 2, and 3. Model notation is described in

Table 1.

Changes to lobster numbers caused by fishing mortality, natural mortality and growth are given by:

$$\dot{N}^{r,g}_{y,p,s'} = \sum_s \left(N^{r,g}_{y,p,s} \exp\left(-F^{r,g}_{y,p,s} - {M^r}/{n_y} \right) X^{r,g}_{y,p,s,s'} \right) \qquad (1)$$

Maturation affects only females. After maturation the number of lobsters is given by:

$$\begin{aligned} \ddot{N}^{r,2}_{y,p,s} &= \dot{N}^{r,2}_{y,p,s}\left(1 - Q^r_{y,p,s}\right) \\ \ddot{N}^{r,3}_{y,p,s} &= \dot{N}^{r,3}_{y,p,s} + \left(\dot{N}^{r,2}_{y,p,s} Q^r_{y,p,s}\right) \\ \ddot{N}^{r,1}_{y,p,s} &= \dot{N}^{r,1}_{y,p,s} \end{aligned} \qquad (2)$$

Following maturation, numbers are adjusted for recruitment and movement into and out of each region; the year was incremented for the last time step:

$$\begin{aligned} N^{r,g}_{y,p+1,s} &= \ddot{N}^{r,g}_{y,p,s} + R^{r,g}_{y,p,s} + G^{r,g}_{y,p.s} - E^{r,g}_{y,p,s} \qquad 1 \le p \le n_y \\ N^{r,g}_{y+1,1,s} &= N^{r,g}_{y,n_y+1,s} \end{aligned} \qquad (3)$$

Movements were not estimated in this stock assessment.

To calculate the initial population, 500 iterations of the equations above were conducted with constant recruitment, no movement and a constant estimated historical fishing mortality rate.

2.2.1 Mortalities

All catches are designated as size-limited (SL) or non-size-limited (NSL). NSL catches comprise all lobsters that are vulnerable and selected by the fishery; SL catches comprise lobsters that are vulnerable, selected, greater than MLS and not berried females. We assume that all mature females are berried (carry eggs) in the AW season. For the SL fishery we assumed a handling mortality (*h*) on sub-legal lobsters and berried females, which must be released. Thus the total fishing mortality has three components:

$$\begin{aligned} {}^nF^{r,g}_{y,p,s} &= {}^nf^r_{y,p}\, v^{r,g}_{y,p,s} \\ {}^lF^{r,g}_{y,p,s} &= {}^lf^r_{y,p}\, v^{r,g}_{y,p,s}\, l^{r,g}_{y,p,s} \\ {}^hF^{r,g}_{y,p,s} &= {}^lf^r_{y,p}\, h v^{r,g}_{y,p,s}\left(1 - l^{r,g}_{y,p,s}\right) \end{aligned} \qquad (4)$$

where ${}^nf^r_{y,p}$ and ${}^lf^r_{y,p}$ are the fully selected (and vulnerable) fishing mortality rates for the NSL and SL fisheries respectively.

Fishing mortality can be modelled using either the instantaneous (Baranov) or discrete form of catch equations. For the instantaneous catch equations the catches for the size limited $\left({}^{l}C^{r}_{y,p}\right)$ and non-size limited $\left({}^{n}C^{r}_{y,p}\right)$ fisheries are given by:

$$ {}^{l}C^{r}_{y,p} = \sum_{s}\sum_{g} \frac{{}^{l}F^{r,g}_{y,p,s}}{Z^{r,g}_{y,p,s}} \left(1-\exp(-Z^{r,g}_{y,p,s}\right) w^{r,g}_{s} N^{r,g}_{y,p,s} \qquad (5) $$

$$ {}^{n}C^{r}_{y,p} = \sum_{s}\sum_{g} \frac{{}^{n}F^{r,g}_{y,p,s}}{Z^{r,g}_{y,p,s}} \left(1-\exp(-Z^{r,g}_{y,p,s}\right) w^{r,g}_{s} N^{r,g}_{y,p,s} \qquad (6) $$

where $Z^{r,g}_{y,p,s} = F^{r,g}_{y,p,s} + M^{r}\big/n_{y}$ and $F^{r,g}_{y,p,s} = {}^{n}F^{r,g}_{y,p,s} + {}^{l}F^{r,g}_{y,p,s} + {}^{h}F^{r,g}_{y,p,s}$. When no error in the catch observations is assumed, the fully selected fishing mortality rates $\left({}^{n}f^{r}_{y,p},\ {}^{l}f^{r}_{y,p}\right)$ are estimated analytically with a Newton-Raphson iteration procedure.

It is possible that that approach results in a local minimum solution. The model now has an option to estimate the fully selected fishing mortality rates as free parameters. When these parameters are estimated, the negative log-likelihood for the predicted catch is added to the objective function; a normal-log distribution is assumed:

$$ 0.5\sum_{r}\sum_{y}\sum_{p}\left(\left(\frac{\ln\left({}^{l}C^{r}_{y,p}\big/{}^{l}\hat{C}^{r}_{y,p}\right)^{2}}{{}^{l}\sigma^{2}}\right)+\left(\frac{\ln\left({}^{n}C^{r}_{y,p}\big/{}^{n}\hat{C}^{r}_{y,p}\right)^{2}}{{}^{n}\sigma^{2}}\right)\right), \qquad (7) $$

where ${}^{l}\sigma$ and ${}^{n}\sigma$ are the standard errors of the size limited and the non-size limited catches, respectively. In general these standard errors are fixed at small values (0.01) to ensure an almost perfect fit between observed and predicted catches. Thus, results for fits where fully selected fishing mortality are free parameters should be virtually identical to those where they are estimated analytically, and differences should occur only where solutions represent local minima.

An alternative use for the “free fishing mortality rate” parameterisation is for investigation of the influence of uncertainty in the NSL catches on the stock reconstructions. Setting the ${}^{n}\sigma$ variable to higher values (say, 0.5) allows potentially large differences between the observed and predicted NSL catches.

For the discrete form of the catch equations, the catch equations are:

$$ {}^{n}C^{r}_{y,p} = \sum_{s}\sum_{g}\left({}^{n}F^{r}_{y,p,s}\, w^{r,g}_{s} \exp\left(-0.5M^{r}\big/n_{y}\right) N^{r,g}_{y,p,s}\right) \qquad (8) $$

$$ {}^{l}C^{r}_{y,p} = \sum_{s}\sum_{g}\left({}^{l}F^{r}_{y,p,s}\, w^{r,g}_{s} \exp\left(-0.5M^{r}\big/n_{y}\right) N^{r,g}_{y,p,s}\right) \qquad (9) $$

which implies that fishing occurs after half of the natural mortality has occurred. For this form of the catch equations total fishing mortality is:

$$F_{y,p,s}^{r,g} = -\ln\left(1-\left({}^{n}F_{y,p,s}^{r,g} + {}^{l}F_{y,p,s}^{r,g} + {}^{h}F_{y,p,s}^{r,g}\right)\right), \qquad (10)$$

and, assuming no error in the total catch observations, the fully selected fishing mortality rates $\left({}^{n}f_{y,p}^{r} \text{ and } {}^{l}f_{y,p}^{r}\right)$ are estimated analytically.

2.2.2 Selectivity and vulnerability

The relative probability of a lobster being caught has two components: selectivity, which is dependent on lobster size and sex, fishery epoch and relative vulnerability, which is sex-and season-dependent. Fishery epochs (indexed by *z*) account for historical changes affecting selectivity, for example, from changes in escape gap regulations. The vector z_y contains the epoch associated with each year *y*.

Two options for the selectivity parameterisation can be modelled: double-normal and logistic. For the double-normal, the ascending and descending limbs of the selectivity curve are modelled using halves of two normal curves with the same mean $\left({}^{1}\eta_z^{r,g}\right)$ but with different shapes, one for the left half $\left({}^{2}\eta_z^{r,g}\right)$ and one for the right half $\left({}^{3}\eta_z^{r,g}\right)$. These shapes are determined by parameters analogous to the variance of a normal curve. The form for the double-normal selectivity is:

$$V_{y,p,s}^{r,g} = \left(\left(1-T_{z,s}^{r,g}\right)\exp\left(\frac{\ln(0.5)\left(\bar{S}_s - {}^{1}\eta_z^{r,g}\right)^2}{\left({}^{2}\eta_z^{r,g}\right)^2}\right) + T_{z,s}^{r,g}\left(\frac{\ln(0.5)\left(\bar{S}_s - {}^{1}\eta_z^{r,g}\right)^2}{\left({}^{3}\eta_z^{r,g}\right)^2}\right)\right) \qquad (11)$$

where $T_{z,s}^{r,g} = 1/\left(1+\exp\left(-5\left(\bar{S}_s - {}^{1}\eta_z^{r,g}\right)\right)\right)$, $z = z_y$; $g \in (1,2)$ and the $T_{z,s}^{r,g}$ term allows the two halves to be combined in a differentiable way.

The logistic selectivity function has a parameter representing the size at which 50% of the lobsters are selected $\left({}^{1}\eta_z^{r,g}\right)$ and a parameter related to the size where 95% are selected $\left({}^{2}\eta_z^{r,g}\right)$:

$$V_{y,p,s}^{r,g} = \left(1+\exp\left(\frac{-\ln(19)}{{}^{2}\eta_z^{r,g}}\left(\bar{S}_s - {}^{1}\eta_z^{r,g}\right)\right)\right)^{-1} \qquad (12)$$

where $z = z_y$ and $g \in (1,2)$. Mature females are assumed to have the same selectivity as immature females, $V_{y,p,s}^{r,3} = V_{y,p,s}^{r,2}$.

Total vulnerability is the product of the selectivity curve and the relative seasonal vulnerability for each sex, $\tau_p^{r,g}$:

$$v_{y,p,s}^{r,g} = \tau_p^{r,g} V_{y,p,s}^{r,g} \ . \qquad (13)$$

One of the relative vulnerability parameters is fixed at 1 and the others are bounded between 0 and 1 to ensure a maximum size-based vulnerability of 1. For years in which annual dynamics are simulated, the relative seasonal vulnerability estimated for time-step 1 $(p=1)$ is used.

2.2.3 Growth

Growth functions are estimated for each regional tag data set (a set of tag-recapture data can be assigned to a region or group of regions). The growth transition matrix for each region is based on one of the tag data sets: the vector t_r contains the tag data set associated with each region *r*. For notational ease, the equations used to describe the growth model are written here using generic variables that omit some of the subscript and superscript notation.

Growth can be modelled with two options: a form of the Schnute (1981) continuous growth model, or with the inverse logistic (Haddon et al. 2008). The Schnute model here is:

$$Y_2 = \left\{Y_1^{\gamma} \exp(-\kappa\Delta t) + \xi^{\gamma}\left(1-\exp(-\kappa\Delta t)\right)\right\}^{1/\gamma} \tag{14}$$

where Y_1 and Y_2 are the sizes at time 1 and time 2, respectively, Δt is the time interval between time 1 and time 2, and $\kappa, \xi,$ and γ are parameters of the growth model. This growth model is re-parameterised, replacing κ and ξ with parameters that reflect the expected size increments for lobsters of size 50 mm TW and 80 mm TW, d_{50} and d_{80} respectively:

$$\kappa = -\ln\left(1 - \frac{a-b}{\left(50^{\gamma} - 80^{\gamma}\right)}\right) \tag{15}$$

$$\xi = \frac{50^{\gamma} - 50^{\gamma}(b/a)}{1-(b/a)} \tag{16}$$

where $a = (50+d_{50})^{\gamma} - (50)^{\gamma}$ and $b = (80+d_{80})^{\gamma} - (80)^{\gamma}$. To ensure that d_{80} is positive and smaller than d_{50}, d_{80} can be expressed relative to d_{50} and the parameter d_d is estimated $(d_{80} = d_d d_{50})$. The growth functions are tag dataset- and sex-specific, thus the parameters d_{50}, d_d, and γ represent the tag set and sex-specific parameters, $d_{50}^{t,g}, d_d^{t,g}$, and $\gamma_{50}^{t,g}$. Immature and mature females are assumed to have the same growth curves.

The form of the inverse logistic function is:

$$Y_2 = Y_1 + \frac{p\Delta t}{\left(1+\exp\left(\ln(19)\left((Y_1 - l_{50})/(l_{95} - l_{50})\right)\right)\right)} \tag{17}$$

where Y_1 and Y_2 are the sizes at time 1 and time 2, respectively, Δt is the time interval between time 1 and time 2 (in years), and $p, l_{50},$ and l_{95} are the estimated parameters of the growth model. The parameter p represents the theoretical maximum growth rate and the parameters l_{50} and l_{95} represent the sizes at which growth is reduced by 50% and 95% of the maximum, respectively.

When estimating density-dependent growth, the biomass of the stock during the growth interval is calculated:

$$ {}^{T}B_{y,p}^{t} = \sum_{r}\sum_{g}\sum_{s} w_{s}^{r,g}\, N_{y,p,s}^{r,g} \quad \text{for } t_r = t, \qquad (18) $$

and $w_s^{r,g}$ is the mean weight of a lobster of size *s* and sex *g* in region *r*. Then, given density-dependent growth, the expected growth increments j $\left(Y_2 - Y_1, \text{ equation } 1\right)$ are replaced with increments j':

$$ j' = j\left(1 - \xi^{t}\, {}^{T}B_{y,p}^{t} \big/ {}^{T}B_{0}^{t}\right), \qquad (19) $$

where ${}^{T}B_0^t$ is the virgin biomass of the stock associated with tag data set *t*. Variability in the growth increment is assumed to be normally distributed about the expected increment *j* with a standard deviation, ${}^{j}\sigma$, that is a constant proportion of the expected increment, but that is truncated at a minimum value φ. The equation below gives a smooth differentiable function for growth increment *j*:

$$ {}^{j}\sigma = \left(\left(j\chi - \varphi\Delta t\right)\left(\frac{1}{\pi}\times\tan^{-1}\left(\left(j\chi - \varphi\Delta t\right)\times 10^{6}\right) + 0.5\right) + \varphi\Delta t\right) \Big/ \sqrt{\Delta t} \qquad (20) $$

From the growth model, the growth transition matrices are generated as follows. The expected size after growth of an individual of sex *g* and size $\overline{S}_s$ in time step *p* of year *y* whose growth is associated with that of tag set *t* is $Y_{y,p,s}^{t,g}$. Because of variability in growth, not all individuals move into the size class containing $Y_{y,p,s}^{t,g}$; some move into smaller or larger size classes, depending on ${}^{j}\sigma_{y,p,s}^{t,g}$. For each size class *s*, the probability that the individual will grow into each of the other size classes, s', is calculated by integrating over a normal distribution with mean $Y_{y,p,s}^{t,g}$ and standard deviation ${}^{j}\sigma_{y,p,s}^{t,g}$. Elements of the growth transition matrices are given by:

$$ X_{y,p,s,s'}^{r,g} = \int_{\overleftarrow{S}_s}^{\overrightarrow{S}_s} \frac{1}{\sqrt{2\pi}\, {}^{j}\sigma_{y,p,s}^{t,g}} \exp\left(-\frac{\left(\overline{S}_s - Y_{y,p,s}^{t,g}\right)^2}{2\left({}^{j}\sigma_{y,p,s}^{t,g}\right)^2}\right)\partial S \qquad t = t_r \qquad (21) $$

where $\overleftarrow{S}_s$ and $\overrightarrow{S}_s$ are the smallest and largest sizes modelled in size class *s*, respectively.

2.2.4 Maturation, recruitment, and movement

The probability that a female from region *r* and size class *s* matures is modelled as a logistic curve:

$$ Q_{y,p,s}^{r} = \frac{1}{n_y}\left(1 + \exp\left(\frac{-\ln(19)}{{}^{95}\omega^{r}}\left(\overline{S}_s - {}^{50}\omega^{r}\right)\right)\right)^{-1} . \qquad (22) $$

The product of the maturation process over a number of time steps in a year is not the same as that for an annual time step because growth occurs at each time step.

Recruitment is assumed to be lognormally distributed about a mean level (R_0^r) and independent of stock size. Recruitment deviations are estimated for years y_{r_1} to y_{r_2}:

$$\dot{R}_y^r = \begin{cases} R_0^r \exp\left(\delta_y^r - 0.5\left({}^{\delta}\sigma\right)^2\right) & y_{r_1} \geq y \leq y_{r_2} \\ R_0^r \exp\left(\delta_{y_{r_1}}^r - 0.5\left({}^{\delta}\sigma\right)^2\right) & y < y_{r_1} \\ R_0^r \exp\left(\delta_{y_{r_2}}^r - 0.5\left({}^{\delta}\sigma\right)^2\right) & y > y_{r_2} \end{cases} \qquad (23)$$

The number of lobsters recruiting is assumed to be equal for males and immature females and null for mature females. The parameters $\dot{R}_y^r$ relate to the numbers that recruit to each sex in year y. Recruitment is dispersed over the size-classes, assuming a normal distribution (with mean x_1 and standard deviation x_2) truncated at the smallest size-class. The number that recruit to each sex and size class in each time step is given by:

$$R_{y,p,s}^{r,g} = \dot{R}_y^r \exp\left(\frac{-\left(\bar{S}_s - x_1\right)^2}{2\left(x_2\right)^2}\right)\left(n_y \sum_s \exp\left(\frac{-\left(\bar{S}_s - x_1\right)^2}{2\left(x_2\right)^2}\right)\right)^{-1}. \qquad (24)$$

where x_1 and x_2 are specified.

Movement is specified by the size range of lobsters that move (s_1 through s_2), the year range when movement occurs $\left(y_{m_1} \text{ through } y_{m_2}\right)$, and the direction of movement (e.g. $r_1 \rightarrow r_2$ for movement from region r_1 to region r_2). Annual movement parameters are estimated, representing the proportion of lobsters that moved. Estimating movement parameters results in a loss of lobsters from region r_1 $\left(E_{y,p,s}^{r_1,g}\right)$ and a gain of lobsters in region r_2 $\left(G_{y,p,s}^{r_2,g}\right)$:

$$E_{y,p,s}^{r_1,g} = G_{y,p,s}^{r_2,g} = \ddot{N}_{y,p,s}^{r_1,g} \rho_y^{r_1 \rightarrow r_2} \quad s_{m_1} \leq s \leq s_{m_2}, \quad y_{m_1} \leq y \leq y_{m_2} \qquad (25)$$

2.2.3 Model predictions

The model predicts two relative abundance indices – CPUE and historical catch rate – based on the biomass vulnerable to the commercial fishery. The biomass of lobsters vulnerable to the commercial fishery $\left({}^{C}B_{y,p}^{r}\right)$ is:

$${}^{C}B_{y,p}^{r} = \sum_g \sum_s \left(\exp\left(-0.5 Z_{y,p,s}^{r,g}\right) v_{y,p,s}^{r,g} \, w_s^{r,g} \, l_{y,p,s}^{r,g} \, N_{y,p,s}^{r,g}\right). \qquad (26)$$

Predicted values for the CPUE $\left({}^{I}\hat{I}^{r}_{y,p}\right)$ and historical catch rate $\left({}^{C}\hat{I}^{r}_{y,p}\right)$ indices are:

$$ {}^{I}\hat{I}^{r}_{y,p} = \exp\left({}^{I}q^{r}\right)\left({}^{C}B^{r}_{y,p}\right)^{\vartheta^{r}} \tag{27}$$

$$ {}^{C}\hat{I}^{r}_{y,p} = \exp\left({}^{C}q^{r}\right)\left({}^{C}B^{r}_{y,p}\right) \tag{28}$$

The predicted size-at-recapture for tagged lobsters is given by equation (14).

For the instantaneous dynamics, the predicted size frequency of fish of size *s* and sex *g* in the size-limited fishery $\left(\hat{p}^{r,g}_{y,p,s}\right)$ is:

$$\hat{p}^{r,g}_{y,p,s} = \frac{v^{r,g}_{y,p,s}\left(1-\exp\left(-Z^{r,g}_{y,p,s}\right)\right)N^{r,g}_{y,p,s} \Big/ Z^{r,g}_{y,p,s}}{\sum_{s}\sum_{g}\left(v^{r,g}_{y,p,s}\left(1-\exp\left(-Z^{r,g}_{y,p,s}\right)\right)N^{r,g}_{y,p,s} \Big/ Z^{r,g}_{y,p,s}\right)} \tag{29}$$

This equation does not include the parameters that designate whether a fish of size s and sex *g* is legal, because observed size distributions are for the whole catch, not just the retained catch. For the discrete catch equations, the predicted size frequency of fish of size *s* and sex *g* is:

$$\hat{p}^{r,g}_{y,p,s} = \frac{v^{r,g}_{y,p,s}N^{r,g}_{y,p,s}}{\sum_{s}\sum_{g}\left(v^{r,g}_{y,p,s}N^{r,g}_{y,p,s}\right)}. \tag{30}$$

Predicted puerulus indices are:

$$ {}^{P}\hat{I}^{r}_{y} = \exp\left({}^{P}q^{r}\right)\left(\dot{R}^{r}_{y+lag}\right) \tag{31}$$

where ${}^{P}\hat{I}^{r}_{y}$ is the predicted puerulus index for region *r* in year *y*, $\dot{R}^{r}_{y+lag}$ is the model estimate of recruitment for region *r* in year *y* plus *lag* years, and ${}^{P}q^{r}$ is the puerulus index proportionality constant for region *r* . The lag between puerulus settlement and recruitment to the model is user-specified. A number of statistical distributions can be used for fitting the puerulus data, but the most appropriate for this type of data is the lognormal.

2.2.4 Likelihoods

A number of alternative statistical distributions are available for fitting to the abundance index data, the tag-recapture data, and the fishery size frequency data. The distributions are expressed as negative log-likelihoods with constant terms omitted.

The likelihood options for fitting the proportion-at-size (length frequency) data include the multinomial, which was used in this assessment. The model code allows for binning of the smallest and largest size classes that are used in the fitting procedure. Thus if there are many null observations in the smaller and larger size categories these can be amalgamated to reduce the number of null observations. The binning is done as follows:

$$
\begin{aligned}
p^{r,g}_{y,p,s_{p_1}} &= \sum_{s=1}^{s=s^{r,g}_{p_1}} p^{r,g}_{y,p,s} \qquad \hat{p}^{r,g}_{y,p,s_{p_1}} = \sum_{s=1}^{s=s^{r,g}_{p_1}} \hat{p}^{r,g}_{y,p,s} \\
p^{r,g}_{y,p,s_{p_2}} &= \sum_{s=s^{r,g}_{p_2}}^{s=n_s} p^{r,g}_{y,p,s} \qquad \hat{p}^{r,g}_{y,p,s_{p_2}} = \sum_{s=s^{r,g}_{p_2}}^{s=n_s} p^{r,g}_{y,p,s}
\end{aligned}
\quad . \tag{32}
$$

For notational ease, let p represent the observations $p^{r,g}_{y,p,s}$, $\hat{p}$ represent the fitted values $\hat{p}^{r,g}_{y,p,s}$, and σ represent the variance-related terms $\tilde{\sigma}\big/\left(k^{r}_{y,p}\ {}^{S}\varpi\right)$ in the following likelihood functions. In all cases the likelihood is calculated for size categories s ranging from $s^{r,g}_{p_1}$ to $s^{r,g}_{p_2}$.

For the multinomial distribution, the negative log-likelihood for the observation p is:

$$-\log\left(L\right) = \frac{p}{\sigma}\left(\ln\left(p\right) - \ln\left(\hat{p}\right)\right). \tag{33}$$

The Pearson residual is then calculated as:

$$\frac{\left(p-\hat{p}\right)}{\sqrt{p\left(1-p\right)\sigma}} \ . \tag{34}$$

Likelihood function options for fitting the abundance index data, puerulus data and the tag-recovery size increment data are: normal, lognormal, robust normal and robust lognormal. For notational ease, let O represent the observations, P represent the fitted values, and σ represent the standard deviation of the observation in the likelihood functions. For the normal distribution, the negative log-likelihood for observation O is:

$$-\log\left(L\right) = \ln\left(\sigma\right) + 0.5\left(\frac{O-P}{\sigma}\right)^2, \tag{35}$$

and Pearson residuals are calculated as:

$$\left(O-P\right)\big/\sigma \ . \tag{36}$$

For the lognormal distribution, the negative log-likelihood for observation O is:

$$-\log\left(L\right) = \ln\left(\sigma\right) + 0.5\left(\frac{\ln\left(O/P\right) + 0.5\sigma}{\sigma}\right)^2 \tag{37}$$

and Pearson residuals are calculated as:

$$\left(\ln\left(O/P\right) + 0.5\sigma\right)\big/\sigma \tag{38}$$

For the robust normal distribution, the negative log-likelihood for observation O is:

$$-\log(L) = \ln(\sigma) - \log\left(\exp\left(\frac{-0.5(O-P)^2}{\sigma^2}\right) + 0.01\right) \qquad (39)$$

For the robust log-normal distribution, the negative log-likelihood for observation O is:

$$-\log(L) = \ln(\sigma) - \log\left(\exp\left(\frac{-0.5\left(\ln\left(O/P\right) + 0.5\sigma\right)^2}{\sigma^2}\right) + 0.01\right) \qquad (40)$$

The assumption of a log-normal distribution (mean zero and standard deviation ${}^{\delta}\sigma$) for the recruitment residuals results in the following contribution to the objective function for observations δ_y^r:

$$-\log(L) = \sum_{y=y_{r_1}}^{y=y_{r_2}} \left(\ln\left({}^{\delta}\sigma\right) + 0.5\left(\frac{\delta_y^r}{{}^{\delta}\sigma}\right)^2\right). \qquad (41)$$

2.2.5 Model changes specific to this assessment

Some model changes were made in the version of MSLM used to conduct the CRA 3 assessment. These changes were made in response to specific problems encountered during the assessment workshop, and were not coded to be compatible with the multi-stock option and other MSLM options because of time limitations.

To allow investigation of the effect of uncertainty in the NSL catch data, an option was added for an estimated parameter that scales the observed catches. This parameter treats the catch observations as being consistently biased to over- or under-estimate the true NSL catches. Given q as the scale parameter, not defined to be region-specific, ${}^{n}C_{y,p}^{r}$ as the non-size selective catch data and ${}^{n}\tilde{C}_{y,p}^{r}$ as the non-size selective catches fitted in the model, then:

$${}^{n}\tilde{C}_{y,p}^{r} = q\,{}^{n}C_{y,p}^{r}\,. \qquad (42)$$

The major change was made in response to our discovery that growth data show a regime shift. The model was altered so that it can be fitted to tag-recapture data sets from two different periods. Growth parameters were doubled so that two sets are estimated. The user specifies the dates to which these datasets apply. Within the first set of dates, the model uses the earlier tag-recapture data set (along with the length frequency and other data) to estimate the first set of growth parameters and calculate growth transition matrices for both sexes; the model similarly estimates the second set of growth parameters using the later data set. For dates between the end of the first dataset and beginning of the second, a transitional growth transition matrix is calculated for each year.

Another specific change involved calculating *MSY* and *Bmsy* by doing deterministic forward projections for 50 years, using the mean of estimated recruitments from a specified period. It was agreed in the RLFAWG to hold the NSL catches constant at their assumed 2007 values and to vary the SL fishery mortality rate *F* to maximise the annual SL catch, and to record the associated AW vulnerable biomass.

MSY was the maximum yield (the sum of AW and SS SL catches) found by searching across a range of multipliers (from 0.1 to 2.5) on the AW and SS *F* values that were estimated for 2007 for the SL catch for each of the 3000 samples from the joint posterior distribution. The model used a Newton-Raphson algorithm to find the NSL fishery mortality rates. The AW vulnerable biomass associated with the *MSY* was taken to be *Bmsy*. If the *MSY* were still increasing with the highest F multiplier, the *MSY* and *Bmsy* obtained with that multiplier were used. The *MSY* and *Bmsy* calculations were based on the growth parameters estimated from both the first (1975–1981) and second (1996–2006) tag datasets (see below), and named *MSY1* and *MSY2*, &c., but the values most relevant to the assessment were taken from the second tag dataset.

3. DATA

The model was driven by catch information, and is fitted to two abundance indices, two tag-recapture datasets, a set of length frequency data and the puerulus settlement index. Any data set can be removed from the fitting, and each data set has an associated weight that acts on the standard deviation used in the likelihood. The weights are adjusted iteratively to obtain a balance in which each dataset is appropriately weighted.

3.1 Catch

Four kinds of catch are used by the model: commercial, recreational, customary and illegal. The commercial and recreational catches are assumed to be restricted by the MLS and berried female regulations are and summed as the size-limited (SL) catch; the other two are summed as the non-size-limited (NSL) catch. The NSL catch is assumed to be taken from the whole population that is vulnerable to pots. Each series is divided into the AW and SS seasons beginning in 1974.

3.1.1 Commercial catch

Before 1979, the rock lobster fishing year was the same as the calendar year; the fishing year changed in 1979 to an April to March year. Reported annual commercial catches from 1945 through 1978, summarised by calendar year, were obtained from Annala (unpublished), slightly modified as described below. From 1 January 1979 through 31 March 1986, catches were taken from monthly data that were compiled by fishing year from data collected by the Fisheries Statistics Unit (FSU), a version of which is now held by the Ministry of Fisheries. 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 a calendar year to a fishing year basis.

From 1 April 1986 through 30 March 1988, monthly reported catch totals for all of New Zealand were obtained from Quota Management Returns (QMRs), now maintained by the Ministry of Fisheries. These total New Zealand catches were divided into QMA catches based on the proportional landings reported on FSU forms. From 1 April 1988 through 30 September 2001, catches have been summarised from monthly returns from QMRs which are available for each QMA. The QMRs were replaced by Monthly Harvest Returns (MHRs) on 1 October 2001, but the same information is used from these new forms.

Very high commercial catches (near 800 t/year) were recorded in CRA 3 during the mid 1980s (Figure 1). Commercial catches were also reasonably large in the early 1960s (near 400 t/year). Otherwise, historical catches recorded from this QMA have been low. Catches since 1990 have been relatively low, except for a period of 5 years from 1998–99 to 2002–03, when commercial catches reached 300 t/year as a result of a pulse of good recruitment.

There is some uncertainty in the quality of the catch estimates in the years before the beginning of the FSU system in 1979, but the catches in the 1980s were collected when the FSU system was operating well and there is confidence in the quality of these catch 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.

Historical annual catch data (Annala, unpublished) for CRA 3 were compared against the catch data used as input for CRA 3, based on the data available in the CRACE database (Bentley et al. 2005) (Table 2). The annual totals in CRACE are reasonably similar for most years to those in the unpublished Annala data, with the exceptions of 1961, 1963 to 1973 and 1977. The annual totals in CRACE between 1963 and 1973 are considered to be superior because they are based on a detailed reconstruction of the Annala & King (1983) data set. While the differences observed in 1961 and in 1977 are large, it is unclear which data source is preferable. The stock assessment team decided in 2004 to continue using the data in CRACE as they are based on published information from Annala & Esterman (1986).

3.1.2 Recreational catch

Four annual recreational catch estimates are available for CRA 3 (Table 3). The estimates from the Kingett Mitchell National Surveys (Boyd & Reilly 2004, Boyd et al. 2004) have not been accepted by the RLFAWG since 2003 because these estimates appear to be substantially higher than the estimates from the earlier surveys and in many instances approach the levels of the commercial catches; thus these estimates lack credibility. 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]).

For the 2001 CRA 3 assessment , the RLFAWG decided to use the catch estimate from the 1996 survey only. In 2004, the RLFAWG decided, for the 2004 CRA 3 assessment, to adopt a fixed catch estimate of 20 t for the CRA 3 recreational catch which would apply to all years (Figure 2). This represented a departure from the procedure used to develop recreational catch estimates in previous rock lobster stock assessments. The reasons provided in 2004 for this change were as follows.

1. The 1994 and 1996 surveys were known to be unreliable due to a methodological error in the way that fisher participation was estimated. This bias is likely to underestimate the total recreational catch.
2. The 1996 survey estimate of 27000 lobster translates to about 14 t of lobster based on the mean weight using weighted length frequencies (commercial catch sampling and logbook data) for CRA 3 during the spring/summer seasons for 1994, 1995 and 1996. Mean weight was based on the proportion of rock lobsters above the recreational size limits of 54 mm for males and 60 mm for females. A rounded annual total catch of 20 t is larger than the survey estimate of 14 t, possibly compensating for the bias identified in Paragraph 1.
3. Twenty tonnes of rock lobster represent about 1400 to 1500 lobster per week over a 26 week summer period, using the mean weight calculated to generate the estimate of catch by weight. An annual catch of 30 t was thought, in 2004, to be too high by some members of the RLFAWG.

Recreational catch is split between seasons, with 90% assumed to be taken in SS and the remainder in AW.

The RLFAWG recommended, for the 2006 CRA 7 and CRA 8 assessments, to include recreational landings made by commercial vessels under the provisions of Section 111 of the Fisheries Act . Greenweight landings with destination code “F” were extracted from the CRACE database (Bentley et al. 2005), and showed maximum annual values of 1 167 kg for CRA 3, occurring in 2007–08 (Table 3). Equivalent values for CRA 7 and CRA 8 were confirmed in 2006 by Kim George (MFish pers. comm.) to be the estimated weight of the Section 111 landed lobsters rather than numbers of lobsters, as noted in the instructions for filling out the CELR landing form. The RLFAWG agreed that this catch estimate should be included in the fixed estimated recreational catch of 20000 kg which was applied to all assessment years (Figure 2).

3.1.3 Customary catch

MFish Compliance provided two estimates of customary catches for the 2001 CRA 3 assessment. These were 20 t in 2000 and 30 t in 2001. The 2001 CRA 3 assessment assumed that the estimate for 2000 was constant from 1945 through to the 1999–2000 fishing year and that the 30 t estimate applied to the 2000–01 fishing year. The basis for the higher estimate of 30 t was thought to be increased harvest associated with the millennium celebrations.

For the 2004 CRA 3 assessment, the RLFAWG thought that an annual harvest estimate of 30 t was too high to apply to other years. Consequently, the RLFAWG agreed to use a constant estimate of annual catch of 20 t for the entire assessment period (Figure 2), on the basis that this estimate is plausible as well as highly uncertain.

The Ministry of Fisheries provided information in 2008 on two categories of non-commercial customary catches (see the Appendix): those taken under the Kaimoana Customary Fishing Regulations 1998 and those allowed under the Section 27A permitting process of the Amateur Fishing Regulations. These estimates are summed because they represent catches from different sources, although the level of confidence in the totals differs between reporting categories. The Kaimoana Regulations report the actual fish taken while the Section 27A reporting is only for permits issued, and there is no provision for reconciling the number authorised through permits with the number actually taken. When these data are converted to catch weight using a mean weight of 0.40 kg/lobster (mean weight derived from all observer catch samples taken from 2003 to 2007), the maximum catch in any fishing year was about 10 t, smaller than the assumed constant 20 t customary fishery used in the assessment model (Table 4).

Customary catch is split between seasons using the same proportions as for the recreational catch, with 90% assumed to be taken in SS and the balance in AW.

3.1.4 Illegal catch

Illegal catch estimates are based on a belief that a large amount of unreported catch was taken before the introduction of lobsters to the QMS. Anecdotal evidence suggests that there were a lot of cash sales and unaccounted exports of lobster. These are thought to have been reduced after the change to tail width MLS and the introduction of lobsters to the QMS. Current illegal fishing is believed to be conducted mainly by poachers.

The stock assessment team corresponded in 2004 with Aoife Martin (at that time with MFish Compliance), who provided estimates of illegal catch in CRA 3 for the preceding decade (Table 5). Updates to these estimates were sought from the Ministry of Fisheries in 2008 (see the Appendix), but no updates were available. However, in its response, MFish stood by the estimates provided in 2004 and suggested that the final estimate for 2003–04 (89.5 t; Table 5) be used for the years following, 2004–05 to 2007–08.

The 2004 MFish estimates for illegal catch were provided in four categories by year, although all of the categories have missing estimates for some years. Missing categories were treated as zeroes by MFish Compliance and we have continued this practice. The MFish Compliance category "illegal commercial take" (Table 5) is equated with the category of "commercial illegal reported" used in previous rock lobster assessments. This category is assumed to represent illegal commercial catch subsequently reported to the QMS as legitimate catch. Therefore, this catch is subtracted from the reported commercial catch to avoid double-counting.

We used the following procedure to prepare the series of illegal catches. This procedure is similar to that followed for recent assessments of CRA 3, CRA 4, CRA 5, CRA 7 and CRA 8.

1. Starting with the estimates of total export discrepancies for all of New Zealand for each year in 1974 through 1980 (J.L. McKoy, NIWA, unpub. data), the annual CRA 3 illegal catches are estimated from the ratio of the legal commercial catch in CRA 3 to the total New Zealand legal commercial catch for the same year.
2. The average ratio in CRA 3 of the export discrepancy catch to the reported commercial catch was calculated for 1974–1980. This ratio was applied to all years with no data (1945 through 1973 and 1981 through 1989) by multiplying the reported catch by the average ratio. This approach is consistent with the decision reached by the RLFAWG on 15 August 2002. We do not use the MFish Compliance estimates provided for 1979 and 1987, for NSN, NSC and NSS combined, because they are of uncertain provenance.
3. Beginning with 1990, the first year that Compliance provided estimates by QMA, illegal catches are based on MFish Compliance estimates. We use previously provided estimates for 1990 and 1992 and estimates provided by A. Martin are used from 1994 through 2003 (Table 5). For years without Compliance estimates (1991 and 1993), estimates are obtained through interpolation (*see* Figure 1).

4. As discussed above, we apply the average proportional estimate from Table 5 for “illegal commercial take” to split the illegal catch into the "SL illegal" and "NSL illegal" categories. This mean percentage of the catch allocated to "SL illegal" is less than 5%, which is consistent with proportions used in past assessments. We apply this percentage beginning in 1990, as agreed by the RLFAWG in September 2005. . It is assumed that the category “reported illegal commercial take” is not relevant prior to the introduction of the QMS.

5. We assume that both the reported and unreported annual illegal catch is distributed between seasons in the same proportion as the commercial catch for each year.

Compliance estimates of total illegal catch (t) for 1990 and 1992 are shown below:

Year	CRA 3
1990	288
1992	250
Mean 1994–2003 “reported illegal” %	4.5

3.1.5 SL and NSL catch

The size-limited (SL) catch is the sum of the commercial and recreational catches minus the reported illegal catches (Figure 3). The non-size-limited (NSL) catch is the sum of reported and unreported illegal catches and the customary catches. The term “size-limited” includes the restriction on landing berried females: NSL catches include berried females; the model assumes that all mature females in the AW season are berried.

3.1.6 Seasonal catch proportions

Annual catches are divided into AW and SS seasons (Figure 4). Monthly catches are available from 1979 onwards from the FSU/CELR system and from 1963–1973 from Annala & King (1983). The years 1974–1978 are split using the average seasonal proportion from 1971, 1972, 1979 and 1980. Model data were divided seasonally beginning in 1974 for this assessment.

3.2 CPUE

Catch and effort data for rock lobster were obtained from MFish in September 2008 (Replog 7131A). These data were loaded into the CRACE database and error checks (Bentley et al. 2005) were used to prepare the data.

The estimated catch from the top part of the CELR form was corrected from the landing data using the B4 algorithm (Bentley et al. 2005), first used and described to the RLWG in 2003, which summarised the data for every vessel by month by statistical area cell and corrected total estimated catch from the total landed catch for the cell. Data were excluded for vessel cells where the landed catch was zero and effort was non-zero; in this case data from the following month for that vessel were also excluded. The presumption is that some of the catch landed in the second month was held over from the first month, thus breaking the link between the catch and effort data.

Data span 1 April 1979 through 31 March 2008; their format and handling are documented in Bentley et al. (2005). The analysis is performed on a data set collapsed by vessel, statistical area and month in recognition of the design of the FSU system which collected much of its data on a monthly basis (Table 6).

The standardisation procedure was documented by Bentley et al. (2005), using a six-month period (model period) rather than a full fishing year as the time-dependent explanatory variable. The only other explanatory variables offered to the model are month and statistical area, because in previous analyses, other variables had little power to explain model deviance (Maunder & Starr 1995). A separate relative month effect is estimated for each season (AW, SS) by using the month in each period with the lowest standard error as the reference month. The total deviance explained by the CRA 3 model is 48% (Table 7), with the greatest explanatory power lying with model period, followed by month. This is consistent with other rock lobster standardisation analyses. Residual patterns show some deviation from the lognormal assumption at both tails of the residual distribution (Figure 5).

There is some contrast in the month categorical variable for the CRA 3 analysis, with a peak in June and low expected catch rates after Christmas (Figure 6, Table 7). Statistical areas 909 and 911 have slightly higher expected catch rates than Area 910 (Figure 6). The CRA 3 AW CPUE series by model period shows a strong peak around period 105 (AW 1997) which is slightly offset from periods 106 (SS 1997) and 108 (SS 1998) in the SS CPUE series (Figure 7). Since then, CPUE in both seasons has declined to levels near, but slightly above, the lowest levels observed in the early 1990s (Figure 7).

3.3 CR – historical catch rate

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 8).

3.4 Length frequencies (LFs)

There are two main sources of length frequency data (also called proportions-at-length): voluntary logbooks and observer catch sampling. These data are summarised (Table 8) by year and season over three sex categories (male, immature female and mature female). Historical (pre-1986) sampling data have not been included for CRA 3, primarily because there is strong uncertainty regarding the representative nature of the samples. The logbook data intermittently cover the period 1993 through 2006 and the observer catch sampling data cover the period 1986 through 2007 in every year except 1987 and 1988. Observer data from SS 1986 were not used in the assessment because of the small sample size and some large outliers associated with this record.

Data are summarised by season and sex into 2-mm size classes from 30 through 90 mm. The voluntary logbook program measures lobsters with a precision of 1.0 mm while the observer catch sampling precision is 0.1 mm. The measuring convention for observers is to round down all measured lengths, so 0.5 mm was added to each voluntary logbook measurement before binning to avoid introducing bias to the calculated proportions-at-size.

Each data record used in model fitting represents a single period for a single data source, either logbook or catch sampling. This record may comprise data collected from several months and more than one statistical area. Observations from multiple statistical areas and months within a period are weighted within the record by the proportion of catch taken in each month/area cell, the cube root of the number of sample days and the cube root of the number of fish measured.

Comparing the length frequency data that were used for the 2004 assessment with the data obtained for this assessment indicated that, in some instances, fewer data were available in 2004. Comparative plots of the 2004 and 2008 assessment length frequency distributions showed that the actual differences were minor, confined mainly to mature females in a few years in the late 1990s and early 2000s. In addition, data appeared for the 1996 spring/summer season that had not been available to the 2004 assessment.

Figure 9 through Figure 12 show the proportion at length by sex for each year/season combination for CRA 3 from the observer catch sampling program and Figure 13 and Figure 14 provide the same information from the CRA 3 logbook sampling program. The proportions-at-length are normalised so that they sum to 1 across all sex categories and length bins. Annotations beside each figure show the year, season, sampling type (CS: catch sampling) and the relative weight given to that proportion-at-length set as described by Starr et al. (2003).

Preliminary analyses were performed on the length frequency data to determine the suitability of the data from each data source. The proportion of males from each data source for CRA 3 showed reasonable consistency across years and season, with the proportion of males clearly very high in the autumn/winter period (Figure 15). There is a possible increase in the proportion of females in the more recent spring/summer seasons (Figure 15). In general, the logbook data appear to be less stable than the catch sampling data, reflecting the smaller sample sizes for this data collection method in this QMA.

Mean lengths increased for both sexes in the autumn/winter season up to the early 2000s (Figure 16 and Figure 17), after which they appeared to decline. Mean lengths for males in the spring/summer season appear to be stable while mean lengths for females are more variable.

3.5 Puerulus settlement

Puerulus settlement is measured on artificial reef collectors at several sites around New Zealand (Booth & Forman 1995). These data have been standardised using month, year and area as factors (Bentley et al. 2004). The standardised puerulus settlement data for CRA 3 were provided to the assessment team by Andy McKenzie (NIWA, pers. comm.) (Table 9, Figure 18).

3.6 Tag-recapture data

Tag-recapture data for each of CRA 3, CRA 4 and CRA 5 were extracted from the MFish tag database. CRA 4 and CRA 5 were extracted because we wished to explore whether growth appeared similar in these other areas, with a view to combining data. In a previous assessment we had determined that CRA 2 did not show similar growth.

We used a purpose-built tag processing program (Nokome Bentley, Trophia, unpublished) to exclude data with errors, including missing items, sex that changed between release and recapture, etc. For CRA 3 records, we excluded 603 records for which recoveries were made less than 32 days after release because the probability of growth was considered to be low. Records with more than 4 mm apparent shrinkage were also excluded on the basis that such large negative growth was unlikely and was probably a data error. Similar exclusions were made for CRA 4 and CRA 5.

For CRA 3, we investigated a procedure used previously, involving the exclusion of "non-moulters": those that had been at large for less than four months, when those months did not include the September-October or March-April periods. However, the average increment for those data was not much different from the remaining data and so these were not excluded from the initial dataset.

Table 10 shows the number of records for each stock by sex, year and tag type. For CRA 3, more than three quarters of the available data records come from the older experiments, before 1995, and for females very few data come from the modern tagging experiments. The size frequencies of lobsters (at release) in the three sets of recapture data are shown in Figure 19.

Various preliminary analyses were reported to the RLFAWG, based on fitting the model to the tag-recapture data only and estimating only the growth parameters. These need not be described here in detail. We experimented with, but rejected, the new inverse logistic growth model option for two reasons: the fit was worse in each of four trials than for the Schnute model, and the estimated parameters of the inverse logistic lay outside the range of the data. We experimented with removing records with large positive annualised increments, but chose to use robust likelihood fitting instead. As in previous assessments, the minimum standard deviation was fixed to one, based on explorations reported in the CRA 7 and CRA 8 assessment of 2006 (Haist, Starr & Breen unpublished data), and the standard deviation of observation error was fixed at 0.5.

In a simple analysis we made to compare the data sets from CRA 4 and CRA 5, we calculated the mean annualised increment for each sex/year/tag type cell (Table 11). A striking result in CRA 3 is the difference in increments for both males and females between the early (1981 and earlier) and later data (1995 onwards). For males in the earlier data, the increment averages between 3 and 4; in the later data it averages about 2. For females these numbers are 1.35 in the early data and zero in the later data. The difference cannot really be explained by a change in the mean size at release between the older and more recent data (Table 12).

In CRA 4, it is not possible to compare increments from older and newer data sets, because in the database there are no older tagging experiments. However, the same comparison is possible for CRA 5 (Table 11), and it suggests no substantial change in mean increments between the older and more recent data. The recent increments from CRA 4 are consistent with the CRA 5 increments.

The differences seen in Table 11 were large enough to cause some concern. We fitted the model to the CRA 3 data divided into the earlier and later periods. The results (Table 13) show strong differences in the pre- and post-1995 data, with much larger growth parameters in the pre-1995 section. Estimated female growth was very small for the post-1995 onwards dataset, but this model was fitted only to 86 records and the estimate is highly uncertain.

We requested and obtained growth information from Dr. Debbie Freeman, who did her PhD thesis (Freeman 2008) in and around the Te Tapuwae o Rongokako marine reserve near Gisborne, and in and around another reserve in CRA 4. In Chapter 3 of her thesis she describes her growth studies: she tagged lobsters in 2003–06 in the same way as modern MFish contract studies, using HallPrint T-bar tags (type 5). A difference was that she did pleopod clipping so that moulting could be assessed in recaptures.

She graciously provided us with the raw data for recaptured animals from the Gisborne part of her study. We made a dataset in the same form as the MFish data, by making a record for each re-recapture, mechanically re-arranging the data elements, coding for moulting at re-capture, removing records with fewer than 31 days at liberty (365) and removing 84 records with missing lengths. We coded releases as being inside or outside the reserve, ignoring a few records that showed movement between inside and outside.

Too few records of moulted animals outside the reserve were available to be useable by themselves, but the remainder permitted of comparisons between the reserve and outside, and between all records and moulted records inside the reserve. We fitted the MSLM model to these three data sets, termed AllInside, MoultedInside and AllOutside. We used the Schnute growth model option and robust normal likelihood.

We concluded that *Galpha* parameter for males was comparable between the MFish dataset and the AllInside dataset, but female *Galpha* and both *GBeta*s were smaller than in the MFish dataset. Females in the AllOutside dataset were too few for the estimates to be robust. However, the small observed growth of the 116 males outside the reserve was consistent with the MFish data in the more recent dataset. Accordingly, we combined the Freeman data from outside the marine reserve with the MFish data.

As a related exploration, we looked at size at maturity over time. The average proportion of mature females in each size class is shown in Figure 20. Data from the logbooks and observer catch sampling were binned over 3-year intervals, unweighted by sample size. The size at which 50% of females mature appears to have been higher in the earlier years than for all but 2006 and 2007 (the most recent two years of data). The proportion mature at size from these samples does not continue the trend, however, and runs through the middle of the series. Thus, there appears to be no trend in maturity, at least for the period for which we have data.

3.61. Tag-recapture discussion

Estimates of growth appear to be different from the two sets of data from 1975 through 81 and 1995 through 2006. Growth rates from an independent study conducted outside the Te Tapuwae o Rongokako marine reserve are comparable with the estimates from the post-1995 MFish data, at least for males (while females were too sparse to support a credible estimate).

A difference between the pre- and post-1995 data is the tag type, and there is no overlap in tag type between the two datasets. The earlier data are predominantly based on the western rock lobster tag, and the later data are based on the HallPrint T-bar tag. *A priori*, one would expect the western rock lobster tag to be far more invasive and damaging than the HallPrint tag, which is why the latter, and the similar Floy T-bar tag, are used almost universally now. The difference in estimated growth rate is unlikely to be due to tag type.

Handling can cause decreased growth, especially when lobsters are damaged. Density-dependence might also decrease growth rate. These two hypotheses act against each other: growth would be low because of handling when the stock was low and low because of high density when the stock was high. The simple fact is that estimated growth was higher in the pre-

1995 data, when exploitation rates are thought to have been moderate and the stock was near its optimum size.

Handling is unlikely to explain the difference, because the stock was heavily exploited in the early 1990s and then increased to the highest abundance ever seen by the late 1990s, declining after 2000. Exploitation rates were low in much of the period from which we have the post-1995 tag recaptures, although Freeman (2008) suggested that handling in the fishery and removal of fast-growing animals may explain the low growth she estimated from outside the reserve.

Density-dependence similarly seems unlikely to be the cause. The stock was very high in 1995–2001, but was declining rapidly at the end of that period and has been low since 2002. Nearly 300 male recoveries show small growth increments compared with the pre-1995 data (Table 11). Additionally, CRA 5 abundance has become high over the same period as the post-1995 CRA 3 data, yet growth data from there show no decrease from the earlier period.

Whatever the cause, it appears that there has been a systematic change in growth rate in CRA 3, but not in CRA 5. This change must be taken into account properly in the stock assessment.

Size at maturity has shown some shifting towards smaller sizes through most of the data series, but this trend has reversed in the most recent years. Given the pattern of stock size changes over time, this change also seems very unlikely to be density-dependent.

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5. REFERENCES

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

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.; Booth, J.D.; Breen, P.A. (2004). Calculating standardised indices of annual rock lobster settlement. *New Zealand Fisheries Assessment Report 2004/32.* 45 p.

Bentley, N.; Breen, P.A.; Starr, P.J.; Kendrick, T.H. (2001). Assessment of the CRA 3 and NSS stock of red rock lobster (*Jasus edwardsii*) for 2000. *New Zealand Fisheries Assessment Report 2001/69*. 27 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.

Booth, J.D.; Forman, J.S. (1995): Larval recruitment in the red rock lobster, *Jasus edwardsii*. New Zealand Fisheries Assessment Research Document 95/7. (Unpublished report held in the NIWA library, 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 of Fisheries, Wellington.)

Boyd, R.O.; Gowing, L.; Reilly, J.L. (2004). 2000–2001 National Marine Recreational Fishing Survey: diary results and harvest estimates. Final Research Report for the Ministry of Fisheries Project REC9803. (Unpublished report held by the Ministry of Fisheries, Wellington.)

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

Freeman, D.J. (2008). The ecology of spiny lobsters (*Jasus edwardsii*) on fished and unfished reefs. Unpublished PhD thesis, University of Auckland. 306 p.

Haddon, M.; Mundy, C.; Tarbath, D. (2008). Using an inverse-logistic model to describe growth increments of blacklip abalone (*Haliotis rubra*) in Tasmania. *Fishery Bulletin 106*: 58–71.

Haist, V.; Breen, P.A.; Kim, S.W.; Starr, P.J. (2005). Stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 3 in 2004. *New Zealand Fisheries Assessment Report 2005/38*. 126 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):* 511–523.

Maunder, M.N.; Starr, P.J. (1995): Rock lobster standardised CPUE analysis. New Zealand Fisheries Assessment Research Document 95/11. 28 p. (Unpublished report held in the NIWA library, Wellington.)

Schnute, J. (1981). A versatile growth model with statistically stable parameters. *Canadian Journal of Fisheries and Aquatic Sciences 38*: 1128–1140.

Starr, P.J.; Bentley, N.; Maunder, M. (1999). Stock assessment of two New Zealand rock lobster substocks. N.Z. Fisheries Assessment Research Document 99/34. 34 p. (Unpublished report held in the NIWA library, Wellington.)

Table 1: Major variables and parameters of the assessment model. The first entry in the second column shows the informal name for each variable.

Structural and fixed variables	
y_f	First year of the stock reconstruction
$\overline{S}_s$	Size of an individual in size class *s* (mid point of the size class bounds)
$l_{y,p,s}^{r,g}$	Binary variable that indicates whether an individual of size *s* and sex *g* in region *r* in time step *p* of year *y* can be legally retained in the commercial and recreational fisheries (1 or 0 for yes or no)
Estimated parameters	
$\ddot{R}_0^r$	*lnR0* Natural logarithm of the base recruitment parameter, R_0^r , for region *r*
δ_y^r	*Rdev*
M^r	*M* Natural mortality rate for region r
λ^r	*InitER* The initial exploitation rate for region r $\left(F_{y_f,p,s}^{r,g} = -\ln\left(1-\lambda^r v_{y_f,p,s}^{r,g} l_{y_f,p,s}^{r,g}\right)\right)$
${}^{50}\omega^r$, ${}^{95}\omega^r$	*mat50* and *mat95* Parameters determining the size-based probabilities of female lobster maturing for region r
ϑ^r	*CPUEpow* Non-linearity parameter for relationship between catch-per-unit-of-effort and abundance for region r
${}^1\eta_z^{r,g}$, ${}^2\eta_z^{r,g}$, ${}^3\eta_z^{r,g}$	*SelMax*, *varL* and *varR* Parameters determining the shape of the selectivity curve for sex *g*, region r , and epoch *z*. (Note: for logistic-shaped selectivity only the first two parameters are used: *Sel50* and *Sel95*.
$\tau_p^{r,g}$	*vuln* Relative vulnerability for region r and sex g in time-step *p*.
$\rho_y^{r_1\to r_2}$	The proportion of lobster that move from region r_1 to region r_2 in year *y*.
$d_{50}^{t,g}$	*Galpha* Mean expected annual increment for a lobster of size 50 mm and sex *g* for tag data set *t*.
$d_d^{t,g}$	*Gdiff* Parameter to calculate the mean expected annual increment for a lobster of size 80 mm and sex *g* $\left(d_{80}^{t,g}\right)$, for tag data set *t*, $d_{80}^{t,g} = d_{50}^{t,g} d_d^{t,g}$
$\gamma^{t,g}$	*Gshape* Growth curve shape parameter for sex *g* and tag data set *t*
ξ^t	Growth density-dependence parameter for tag data set *t*
$\chi^{t,g}$	*GrowthCV* The coefficient of variation of the expected growth increment for sex *g* and tag data set *t*
$\varphi^{t,g}$	*StdMin* Minimum standard deviation of the expected growth increment for sex *g* and tag data set *t*
${}^I q^r$	*lnqCPUE* Natural logarithm of catchability for CPUE for region r
${}^C q^r$	*lnqCR* Natural logarithm of catchability for historical catch rate for region r
Derived variables	
$N_{y,p,s}^{r,g}$	Numbers of sex *g* and size *s* at the start of time-step *p* of year *y* in region *r*
$F_{y,p,s}^{r,g}$	Total fishing mortality rate for sex *g*, size *s*, and region *r* lobster in time-step *p* of year *y* in region *r*. Composed of size-limited (${}^l F_{y,p,s}^{r,g}$), non-size-limited (${}^n F_{y,p,s}^{r,g}$), and handling (${}^h F_{y,p,s}^{r,g}$) fishing mortalities.
$X_{y,p,s,s'}^{r,g}$	The proportion of lobsters of size *s* that grow to size s' in time step *p* of year *y* for lobster of sex *g* in region *r*.

$Q_{y,p,s}^{r}$	Proportion of size *s* and region *r* lobsters that mature in time-step *p* of year *y*
$G_{y,p,s}^{r,g}$	The number of sex *g* and size *s* lobsters migrating to region *r* during time-step *p* of year *y*
$E_{y,p,s}^{r,g}$	The number of sex *g* and size *s* lobsters emigrating from region *r* during time-step *p* of year *y*
$R_{y,p,s}^{r,g}$	The number of recruits of sex *g* and size *s* in region *r* in time-step *p* of year *y*
$v_{y,p,s}^{r,g}$	Total vulnerability of size *s* and sex *g* lobsters in time step *p* of year *y* in region *r*. Product of selectivity ($V_{y,p,s}^{r,g}$) and relative vulnerability $\left(\tau_{p}^{r,g}\right)$.

Table 2. Comparison of annual CRA 3 catch data (kg) in CRACE with annual CRA 3 catch data (kg) from Annala (unpublished). The shaded area in dark grey represents years with annual catch totals from Annala & King (1983) reports. Shaded years in light grey are the years outside of the years with Annala & King data where there are relatively large differences between the two annual catch estimates.

Year	CRACE data	Annala, unpublished	Difference (kg)
1945	43132	43200	-68
1946	38763	38800	-37
1947	55070	55200	-130
1948	56951	57100	-149
1949	32057	32100	-43
1950	41506	41600	-94
1951	54309	54400	-91
1952	36528	36600	-72
1953	35156	35200	-44
1954	20830	20900	-70
1955	15800	15800	0
1956	13362	13400	-38
1957	22455	22500	-45
1958	27078	27100	-22
1959	29110	29200	-90
1960	34801	34900	-99
1961	57154	61800	-4646
1962	64012	64100	-88
1963	117064	112200	4864
1964	212176	229500	-17324
1965	186665	213400	-26735
1966	236785	238800	-2015
1967	349438	384700	-35262
1968	363049	382500	-19451
1969	260849	244300	16549
1970	206150	184700	21450
1971	146876	143800	3076
1972	131728	136400	-4672
1973	102971	116300	-13329
1974	183000	183000	0
1975	162000	162000	0
1976	198000	198000	0
1977	220000	309000	-89000

Table 3. Information used to estimate recreational catch for CRA 3.

	Catch estimate in numbers
1994	8000
1996	27000
2000	270000
2001	215000
	Derived values
1996 numbers	27000
1994/95/96 mean weight (kg)	0.533
1996 average catch (kg)	14390
	Section 111 reported landings
Maximum reported landings (kg)	1167

Table 4. Weight (kg) of customary lobsters in CRA 3 taken under Section 27A of the Amateur Fishing Regulations and under the Kaimoana Customary Fishing Regulations 1998, assuming a mean weight of 0.402 kg for all rock lobster (measured by observers from 2003 to 2007).

Fishing year	Section 27A	Kaimoana	Total
2003	7136	0	7136
2004	5530	56	5586
2005	5212	80	5293
2006	3992	365	4357
2007	4893	4671	9564

Table 5. Estimates of CRA 3 illegal catch provided by Aoife Martin (MFish Compliance). Shaded cells indicate years for which no estimate was provided.

	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04
Illegal Recreational Take	24				7.5	8	5	5	5	5
Illegal Customary Take	13				9					
Illegal Commercial Take	5		20	4	4		3			0
Poaching		63	64	60	70	128	70	70	70	84.5
Total	42	63	84	64	90.5	136	78	75	75	89.5

Table 6. Number of vessel/statistical area/month records in the dataset used to calculate the CRA 3 CPUE time series. AW: autumn/winter; SS: spring/summer.

Year	Season	Period	909	910	911	Total	Year	Season	Period	909	910	911	Total
1979	AW	69	25	117	83	225	1994	AW	99	18	61	52	131
1979	SS	70	46	223	151	420	1994	SS	100	5	7	11	23
1980	AW	71	29	138	94	261	1995	AW	101	12	54	44	110
1980	SS	72	50	228	169	447	1995	SS	102	4	1	10	15
1981	AW	73	40	124	98	262	1996	AW	103	16	57	39	112
1981	SS	74	54	209	150	413	1996	SS	104	2	2	5	9
1982	AW	75	47	150	102	299	1997	AW	105	17	52	33	102
1982	SS	76	81	216	138	435	1997	SS	106	0	4	2	6
1983	AW	77	40	176	107	323	1998	AW	107	18	63	33	114
1983	SS	78	53	232	162	447	1998	SS	108	4	11	3	18
1984	AW	79	44	173	129	346	1999	AW	109	19	57	38	114
1984	SS	80	69	223	166	458	1999	SS	110	2	20	6	28
1985	AW	81	47	157	121	325	2000	AW	111	17	74	51	142
1985	SS	82	66	201	149	416	2000	SS	112	4	27	10	41
1986	AW	83	31	121	94	246	2001	AW	113	17	58	47	122
1986	SS	84	49	204	147	400	2001	SS	114	12	30	22	64
1987	AW	85	40	155	97	292	200	AW2	115	18	76	55	149
1987	SS	86	58	189	125	372	2002	SS	116	11	61	64	136
1988	AW	87	26	88	71	185	2003	AW	117	13	64	62	139
1988	SS	88	47	141	114	302	2003	SS	118	14	47	80	141
1989	AW	89	17	148	65	230	2004	AW	119	15	56	56	127
1989	SS	90	39	217	123	379	2004	SS	120	15	25	73	113
1990	AW	91	28	129	87	244	2005	AW	121	11	57	41	109
1990	SS	92	40	151	131	322	2005	SS	122	12	52	63	127
1991	AW	93	27	125	112	264	2006	AW	123	12	58	46	116
1991	SS	94	51	156	163	370	2006	SS	124	13	59	64	136
1992	AW	95	24	109	143	276	2007	AW	125	9	50	45	104
1992	SS	96	32	124	176	332	2007	SS	126	6	42	73	121
1993	AW	97	25	86	99	210							
1993	SS	98	16	29	22	67							
							Total	AW		702	2833	2144	5679
							Total	SS		855	3131	2572	6558
							Total		AW+SS	1557	5964	4716	12237

Table 7. Proportion of the total deviance explained by each variable in the CRA 3 standardised CPUE model.

Variable	1	2	3
Period	0.405		
Month	0.071	0.454	
Statistical Area	0.015	0.425	0.475
Additional deviance explained	0.000	0.050	0.021

Table 8. Number of days sampled and number of fish sampled for length by fishing year, season and data source. Shaded cells were not used in the assessment data because of too few samples and fish measured.

	Number days sampling				Number fish sampled			
Fishing	Logbook data		Observer data		Logbook data		Observer data	
year	AW	SS	AW	SS	AW	SS	AW	SS
1986				3				483
1989			2	8			1263	3913
1990				17				13494
1991			1	20			1086	13301
1992			3	20			1749	11408
1993		208	30	26		6174	12593	16059
1994	337	25	36	15	8097	460	26731	16748
1995	211		29	8	6808		23377	9018
1996	164		25	7	6710		24229	7657
1997	41		21	8	1471		21595	9424
1998	51		24	8	894		11752	11016
1999	28	2	13	8	440	77	6511	8490
2000	39		12	8	769		9066	10985
2001	24		13	16	348		7356	16085
2002			16	13			9593	9073
2003			16	12			9169	4442
2004			14	15			6997	6390
2005		12	15	14		118	7942	5236
2006	2		15	13	32		8742	4521
2007			14	14			6757	4784
Total	897	247	299	253	25569	6829	196508	182527

Table 9. Puerulus settlement indices for CRA 3. Analysis by Andy McKenzie (NIWA, pers. comm.)

Year	Arithmetic	Standardised	Upper 97.5%	Lower 2.5%	Standard error
1991	1.88	1.44	2.73	0.76	0.33
1992	3.18	2.04	3.01	1.38	0.20
1993	2.42	1.52	2.24	1.04	0.20
1994	2.90	2.83	4.00	2.00	0.18
1995	1.00	1.07	1.55	0.74	0.19
1996	0.77	0.99	1.46	0.67	0.20
1997	0.98	1.05	1.52	0.72	0.19
1998	1.30	1.43	2.03	1.00	0.18
1999	0.09	0.10	0.19	0.05	0.36
2000	0.84	0.93	1.35	0.64	0.19
2001	1.10	1.24	1.78	0.87	0.18
2002	0.96	1.09	1.58	0.76	0.19
2003	1.70	2.14	3.03	1.51	0.18
2004	0.69	0.75	1.11	0.51	0.20
2005	2.23	2.44	3.42	1.73	0.17
2006	0.35	0.37	0.58	0.23	0.23
2007	0.34	0.29	0.52	0.16	0.30

Table 10: Numbers of records by sex, year of release and tag type after initial screening of the data. Tag type 3 is sphyrion, type 4 is the western rock lobster tag, and type 5 is the HallPrint T-bar tag.

					male				female
Stock	RelYear	3	4	5	Total	3	4	5	Total
CRA 3	1975		171		171		29		29
	1976		459		459		225		225
	1977		610		610		154		155
	1978		127		127		79		79
	1979	240	15		255	268			268
	1980	36	192		228	41	131		172
	1981		3		3		1		1
	1995			50	50			6	6
	1996			120	120			20	20
	1997			25	25			2	2
	1999			1	1			32	32
	2001			198	198			1	1
	2002			8	8			1	1
	2004			179	179			9	9
	2005			92	92			14	14
	2006			5	5			1	1
CRA 3 Total		276	1577	678	2531	309	619	86	1015
CRA 4	1998			286	286			85	85
	1999			444	444			209	209
	2000			58	58			82	82
	2001			1	1			1	1
	2002							4	4
	2003							3	3
	2004							1	1
	2005			74	74			59	59
	2006			23	23			3	3
	2007			54	54			32	32
CRA 4 Total				940	940			479	479
CRA 5	1975		9		9		4		4
	1976		49		49		63		63
	1977		2		2		6		6
	1979		3		3		11		11
	1980		6		6		7		7
	1981		4		4		13		13
	1983		25		25		15		15
	1984						1		1
	1985		2		2				
	1996			2	2				
	1997			808	808			469	469
	1998			52	52			29	29
	1999			93	93			312	312
	2000			424	424			85	85
	2001			358	358			209	209
	2002			376	376			45	45
	2003			46	46			21	21
	2004			636	636			234	234
	2005			175	175			44	44

		male				female			
Stock	RelYear	3	4	5	Total	3	4	5	Total
	2006			23	23			8	9
	2007							4	4
CRA 5 Total			100	2993	3093		120	1460	1581
Total		276	1677	4611	6564	309	739	2025	3075

Table 11: Means of the annualised increments by sex and year for the three stocks examined. Columns headed 3, 4, and 5 refer to the tag types.

		male				female			
Stock	RelYear	3	4	5	Total	3	4	5	Total
CRA 3	1975		3.99		3.99		0.56		0.56
	1976		4.65		4.65		1.90		1.90
	1977		4.05		4.05		0.74		0.74
	1978		5.34		5.34		0.91		0.91
	1979	8.16	2.60		7.83	8.10			8.10
	1980	12.40	5.01		6.18	24.73	1.77		7.24
	1981		1.06		1.06		2.22		2.22
	1995			1.95	1.95			-3.12	-3.12
	1996			1.67	1.67			0.10	0.10
	1997			0.43	0.43			-1.08	-1.08
	1999			2.37	2.37			0.71	0.71
	2001			2.60	2.60			-2.44	-2.44
	2002			1.84	1.84			0.00	0.00
	2004			2.56	2.56			1.34	1.34
	2005			1.80	1.80			1.56	1.56
	2006			1.95	1.95			2.54	2.54
CRA 3 Total		8.71	4.42	2.17	4.29	10.31	1.39	0.44	4.03
CRA 4	1998			2.53	2.53			1.33	1.33
	1999			2.85	2.85			2.45	2.45
	2000			5.00	5.00			4.30	4.30
	2001			0.00	0.00			0.55	0.55
	2002							2.41	2.41
	2003							-0.93	-0.93
	2004							0.00	0.00
	2005			6.08	6.08			2.88	2.88
	2006			0.97	0.97			0.82	0.82
	2007			4.79	4.79			2.18	2.18
CRA 4 Total				3.20	3.20			2.56	2.56
CRA 5	1975		3.66		3.66		4.59		4.59
	1976		3.10		3.10		3.31		3.31
	1977		2.00		2.00		2.63		2.63
	1979		3.43		3.43		2.95		2.95
	1980		-		-2.01		2.84		2.84

		male				female			
Stock	RelYear	3	4	5	Total	3	4	5	Total
			2.01						
	1981		3.95		3.95		3.00		3.00
	1983		4.42		4.42		0.69		0.69
	1984						0.00		0.00
	1985		3.54		3.54				
	1996			0.49	0.49				
	1997			4.24	4.24			3.36	3.36
	1998			4.31	4.31			2.56	2.56
	1999			3.45	3.45			3.03	3.03
	2000			2.32	2.32			1.43	1.43
	2001			4.19	4.19			1.50	1.50
	2002			2.20	2.20			1.71	1.71
	2003			2.37	2.37			1.21	1.21
	2004			2.76	2.76			2.59	2.59
	2005			0.17	0.17			2.23	2.23
	2006			1.71	1.71			0.65	0.58
	2007							0.00	0.00
CRA 5 Total			3.20	3.08	3.08		2.87	2.63	2.65
Total		8.71	4.35	2.97	3.56	10.31	1.63	2.52	3.09

Table 12: mean size at release for the tag-recapture data by stock, sex, tag type and year of release.

		males				females			
Stock	RelYear	3	4	5	Total	3	4	5	Total
CRA 3	1975		47.5		47.5		49.6		49.6
	1976		48.7		48.7		54.3		54.3
	1977		50.5		50.5		56.2		56.3
	1978		54.1		54.1		58.1		58.1
	1979	44.0	60.0		44.9	46.1			46.1
	1980	40.9	46.5		45.6	44.6	51.1		49.6
	1981		48.9		48.9		44.6		44.6
	1995			51.6	51.6			53.3	53.3
	1996			53.0	53.0			58.1	58.1
	1997			55.7	55.7			56.8	56.8
	1999			54.2	54.2			61.7	61.7
	2001			51.0	51.0			64.5	64.5
	2002			53.0	53.0			65.5	65.5
	2004			49.5	49.5			59.0	59.0
	2005			52.5	52.5			57.7	57.7
	2006			53.1	53.1			61.5	61.5
CRA 3 Total		43.6	49.5	51.4	49.4	45.9	54.4	59.3	52.2
CRA 4	1998			53.9	53.9			61.0	61.0
	1999			55.1	55.1			62.6	62.6
	2000			54.8	54.8			64.8	64.8
	2001			57.5	57.5			58.9	58.9
	2002							67.8	67.8

					males				females
Stock	RelYear	3	4	5	Total	3	4	5	Total
	2003							69.8	69.8
	2004							72.5	72.5
	2005			50.9	50.9			59.9	59.9
	2006			52.4	52.4			58.2	58.2
	2007			52.4	52.4			62.6	62.6
CRA 4 Total				54.1	54.1			62.4	62.4
CRA 5	1975		47.3		47.3		54.8		54.8
	1976		46.1		46.1		63.2		63.2
	1977		50.4		50.4		68.3		68.3
	1979		54.9		54.9		57.8		57.8
	1980		52.8		52.8		66.2		66.2
	1981		52.2		52.2		80.3		80.3
	1983		49.1		49.1		57.3		57.3
	1984						47.6		47.6
	1985		42.5		42.5				
	1996			52.0	52.0				
	1997			53.9	53.9			60.0	60.0
	1998			58.7	58.7			63.1	63.1
	1999			61.6	61.6			67.2	67.2
	2000			56.4	56.4			65.4	65.4
	2001			53.0	53.0			62.7	62.7
	2002			54.9	54.9			63.8	63.8
	2003			59.3	59.3			68.5	68.5
	2004			52.2	52.2			63.8	63.8
	2005			54.6	54.6			66.7	66.7
	2006			55.5	55.5			68.0	69.2
								70.0	70.0
CRA 5 Total			47.9	54.4	54.2		63.8	63.4	63.5
Total		43.6	49.4	53.9	52.3	45.9	55.9	63.0	59.6

Table 13: Estimated growth parameters and likelihood values for alternative fits to the CRA3 tag release-recapture data. "M" denotes male and "F" female.

TagRuns	003	009	010
DataFile	All	<1995	>=1995
Likelihood	robust	robust	robust
Growth model	Schnute	Schnute	Schnute
Function value	21294.8	16668.0	4276.2
number of males	2531	1853	678
galphaM	3.221	4.370	2.128
gBetaM	2.197	4.370	0.231
GshapeM	7.303	6.473	8.283
GrowthCVM	0.550	.453	0.714
number of females	1015	928	86
galphaF	1.569	1.655	1.000
gBetaF	1.158	1.424	0.001
GshapeF	14.720	15.000	2.550
GrowthCVF	0.773	.758	1.775

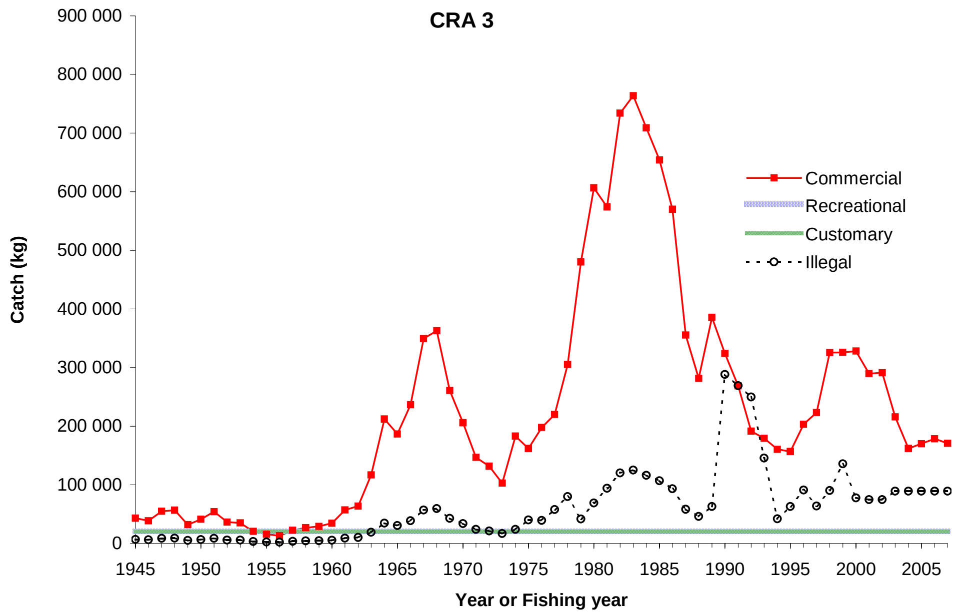


Figure 1. CRA 3 annual catches (in kg) by fishery (commercial, illegal, recreational & customary) .

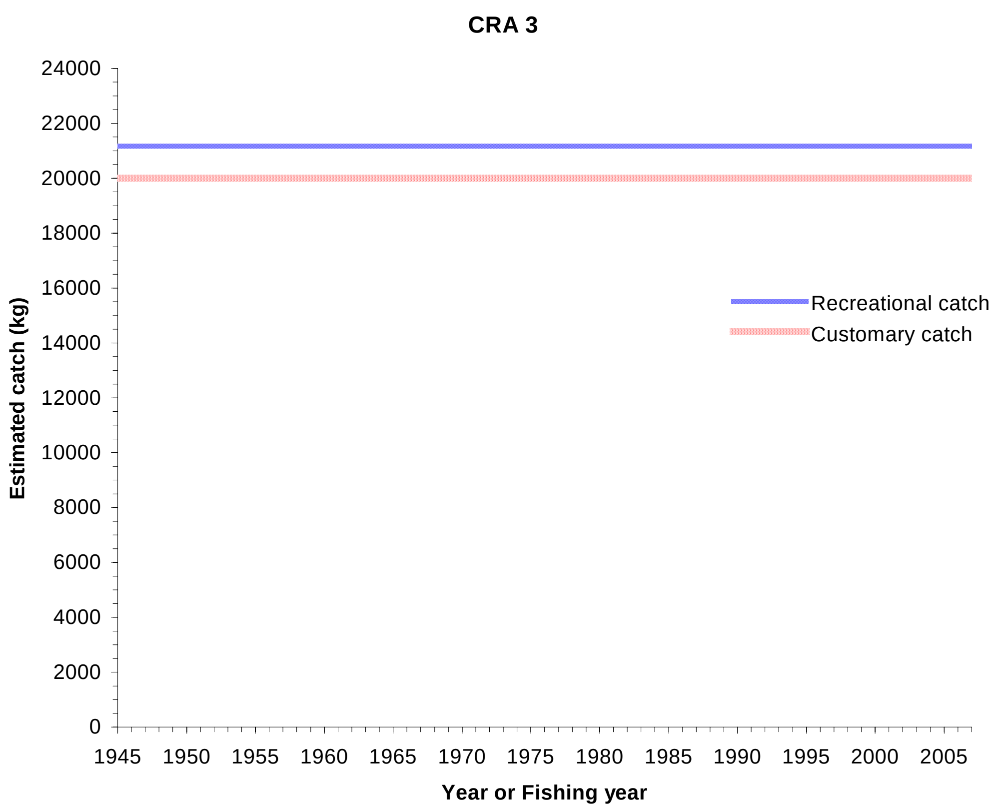


Figure 2. Assumed recreational and customary catches (kg) for CRA 3.

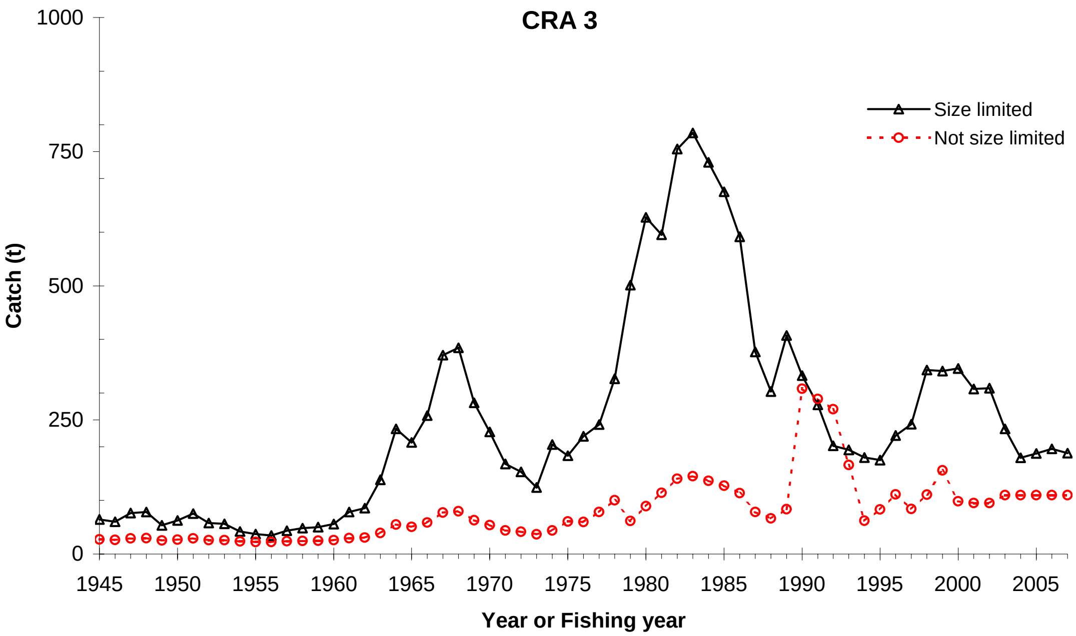


Figure 3. The annual SL (size-limited) and NSL (non-size-limited) catches (t) for CRA 3.

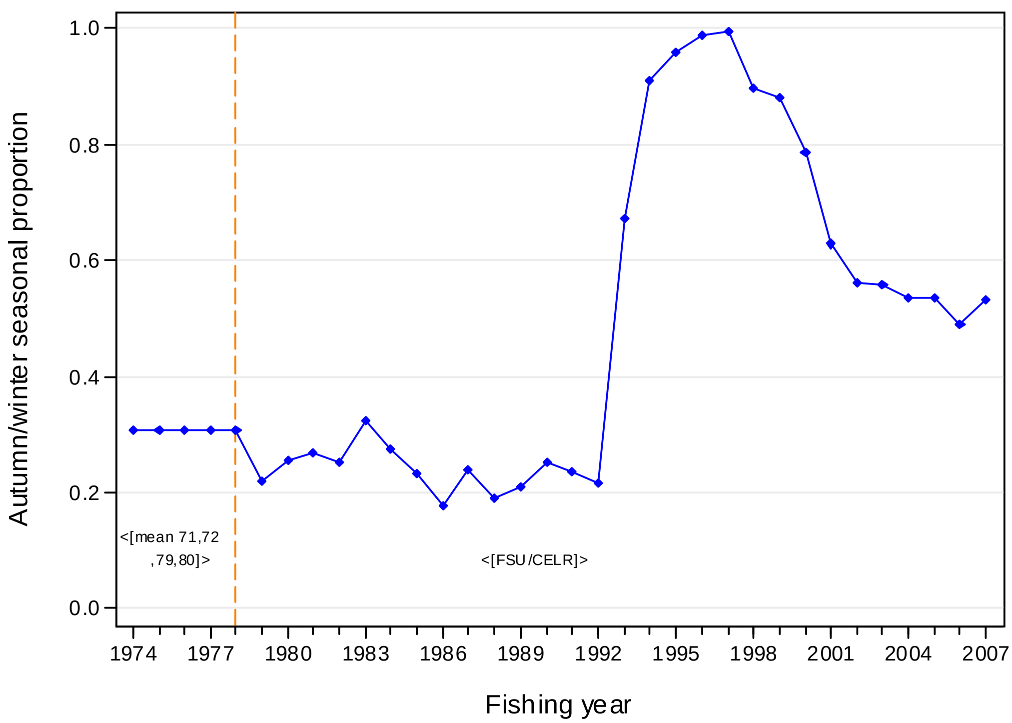


Figure 4. Seasonal proportion of the AW commercial catch by calendar year or fishing year for CRA 3 from 1974 to 2007. These proportions have been derived beginning in 1979 from reported landings by month from the FSU or CELR catch reporting systems. Before 1979, the seasonal proportions are the mean proportion AW for 1971, 1972, 1979 and 1980.

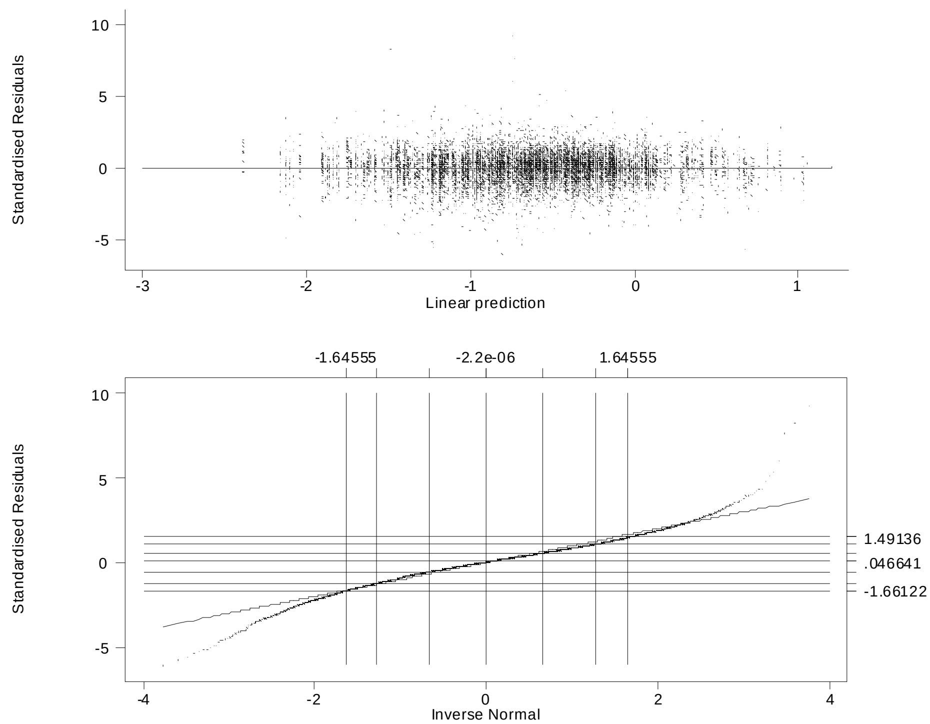


Figure 5. Standardised residuals for the CRA 3 standardised CPUE analysis.

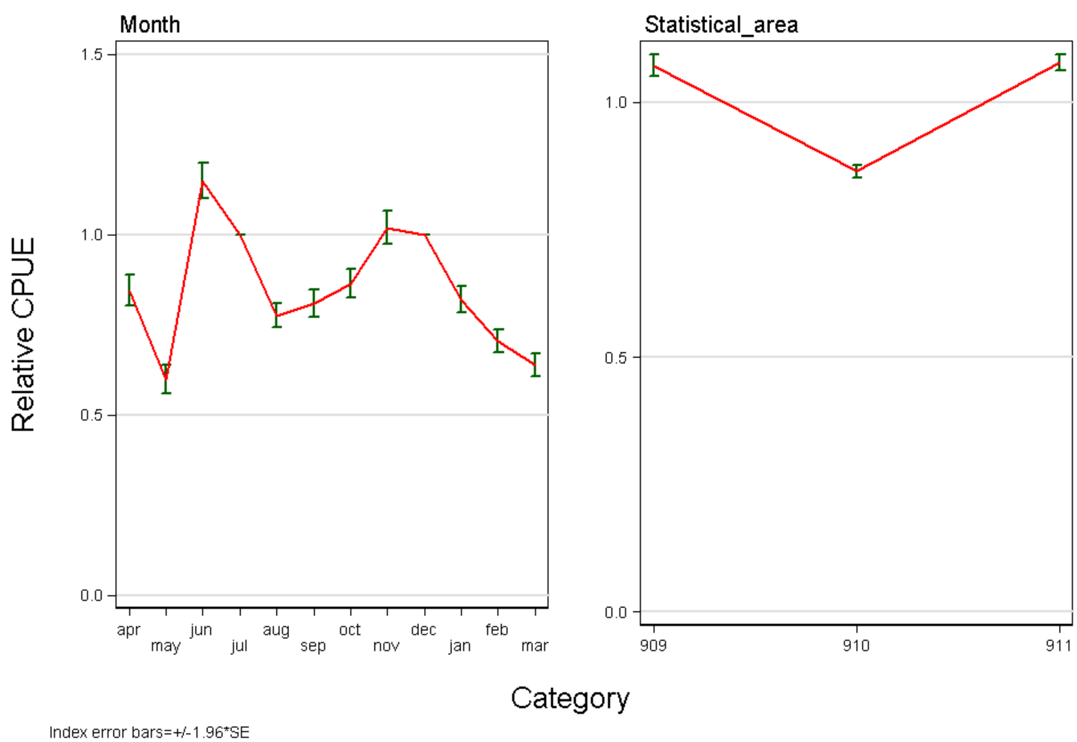


Figure 6. Coefficients for month and statistical area from the CRA 3 CPUE standardisation. Month coefficients are not in canonical form, and each of the two reference months are set to 1.0 and with no estimated error bars for those months because the SE is set to zero for the reference months.

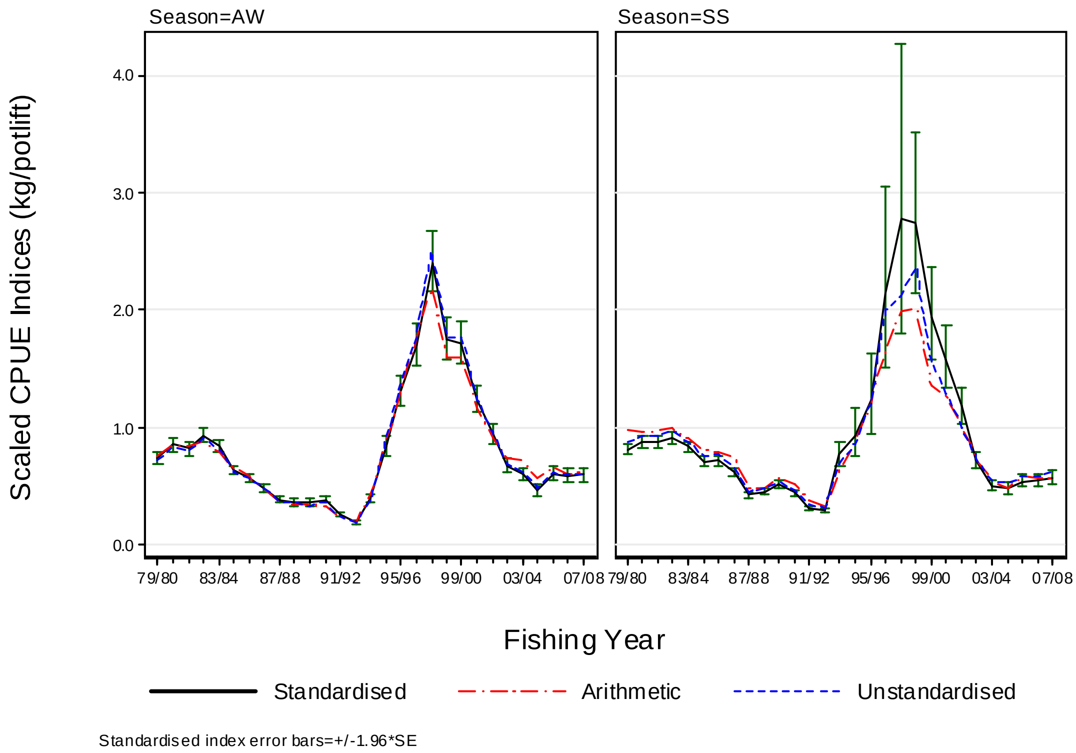


Figure 7. Scaled standardised CPUE (kg/potlift) by period for CRA 3 with the Autumn/Winter (AW) and Spring/Summer (SS) seasons plotted separately. Also shown are the arithmetic or "raw" CPUE series and the geometric mean of the CPUE ("unstandardised"). The standardised and unstandardised series are scaled 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=0.68 kg/potlift; geometric mean for SS=0.78 kg/potlift).

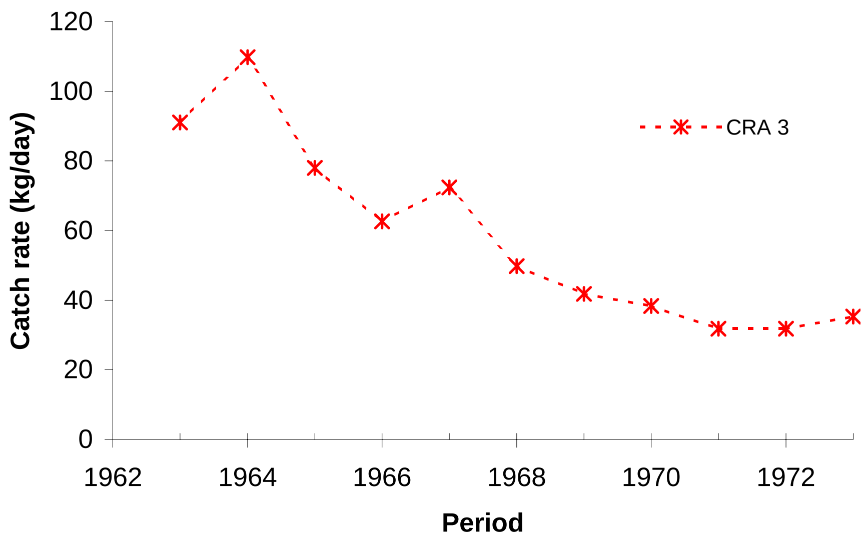


Figure 8. Catch rate (kg/day) by year for CRA 3. Data from Annala & King (1983).

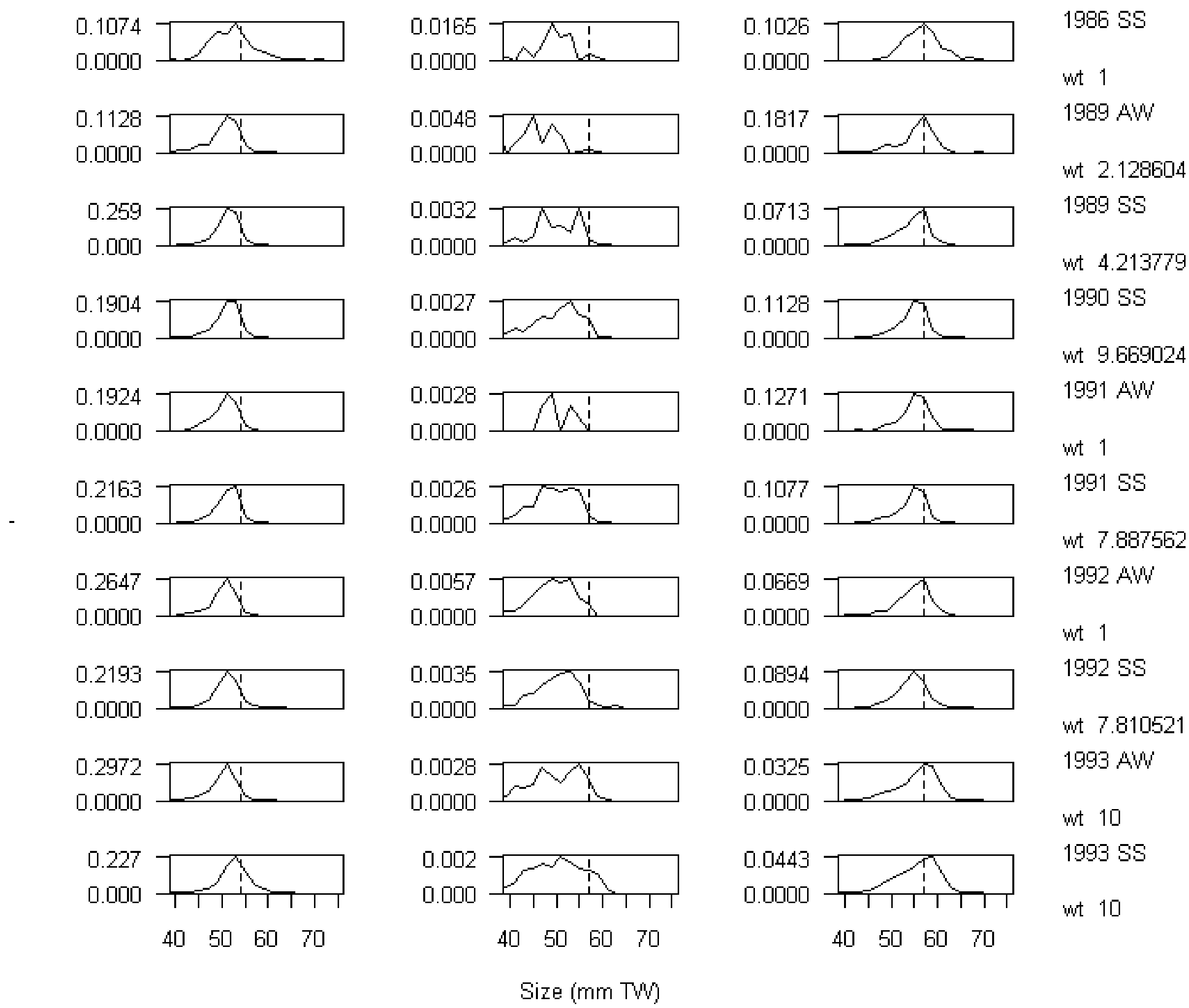


Figure 9. **Proportions-at-length for the observer catch sampling programme from 1986 AW to 1993 SS for CRA 3. The fishing year, season and sample weight are indicated for each sample. Left: males, centre: immature females; right: mature females; note changes in scale among the figures.**

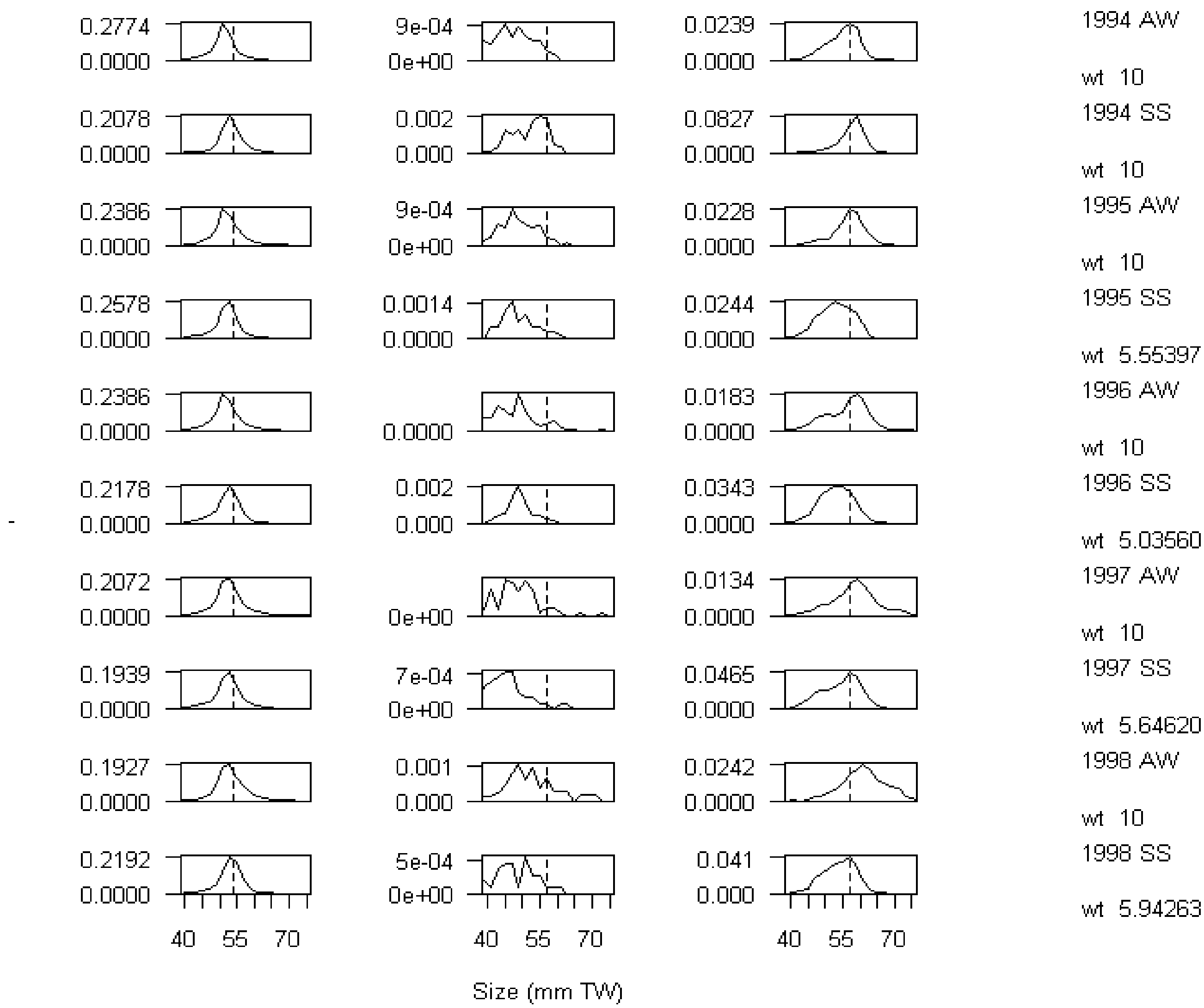


Figure 10. **Proportions-at-length for the observer catch sampling programme from 1994 AW to 1998 SS for CRA 3. The fishing year, season and sample weight are indicated for each sample. Left: males, centre: immature females; right: mature females; note changes in scale among the figures.**

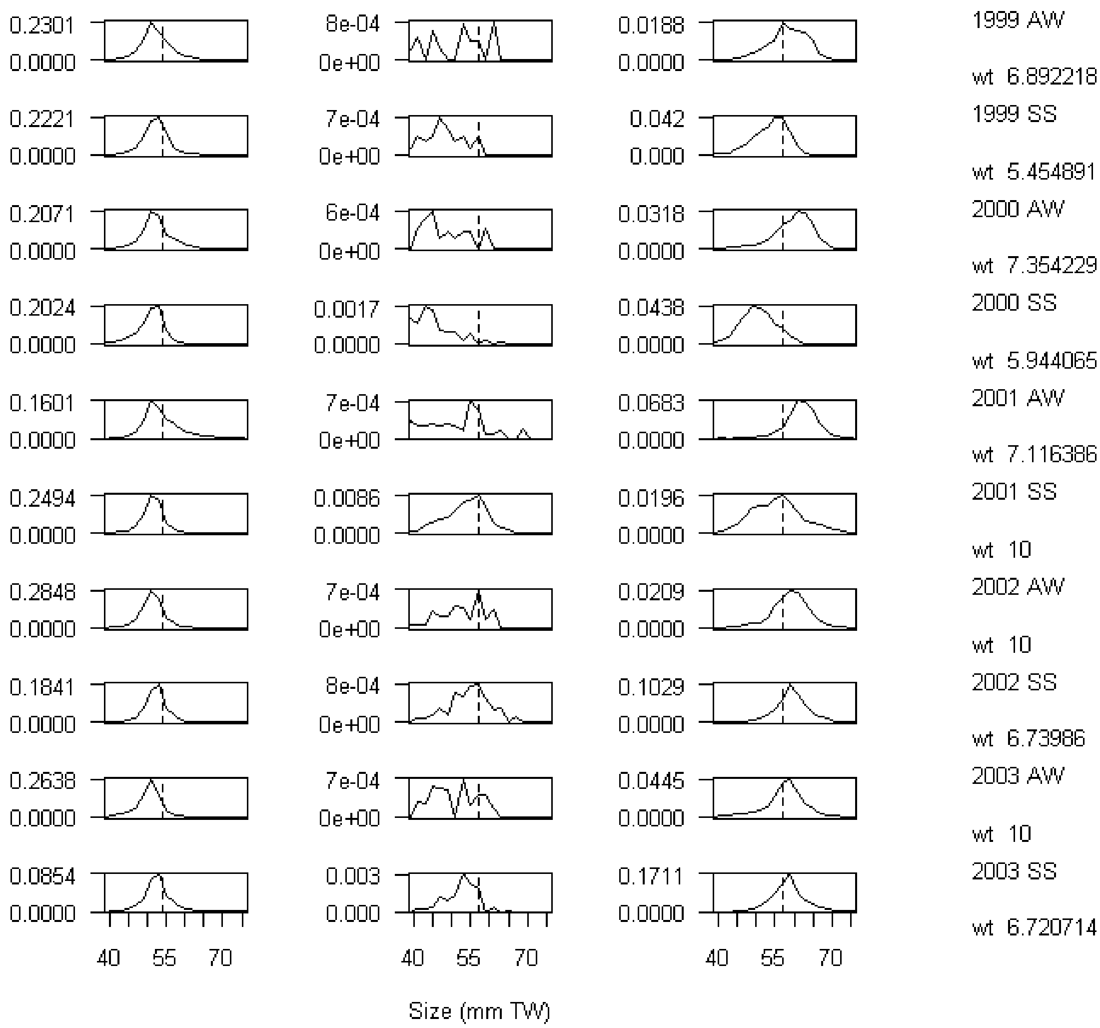


Figure 11. **Proportions-at-length for the observer catch sampling programme from 1999 AW to 2003 SS for CRA 3. The fishing year, season and sample weight are indicated for each sample. Left: males, centre: immature females; right: mature females; note changes in scale among the figures.**

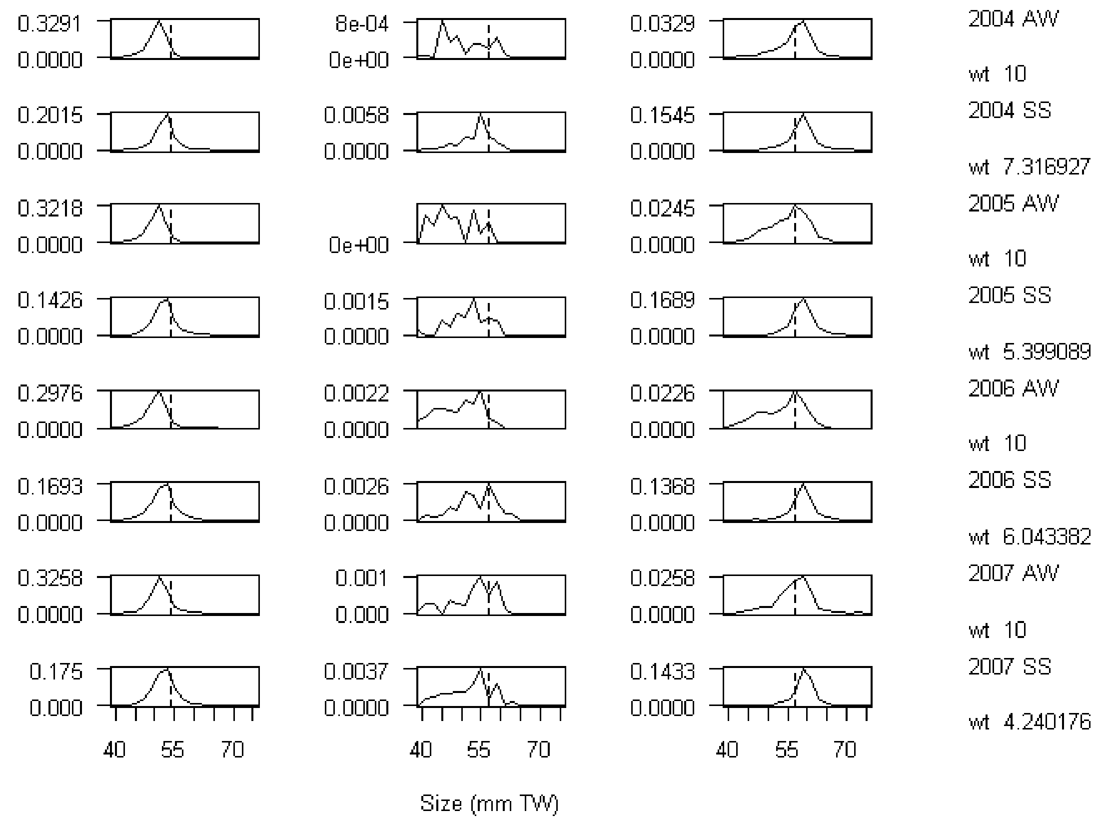


Figure 12. **Proportions-at-length for the observer catch sampling programme from 2004 AW to 2007 SS for CRA 3. The fishing year, season and sample weight are indicated for each sample. Left: males, centre: immature females; right: mature females; note changes in scale among the figures.**

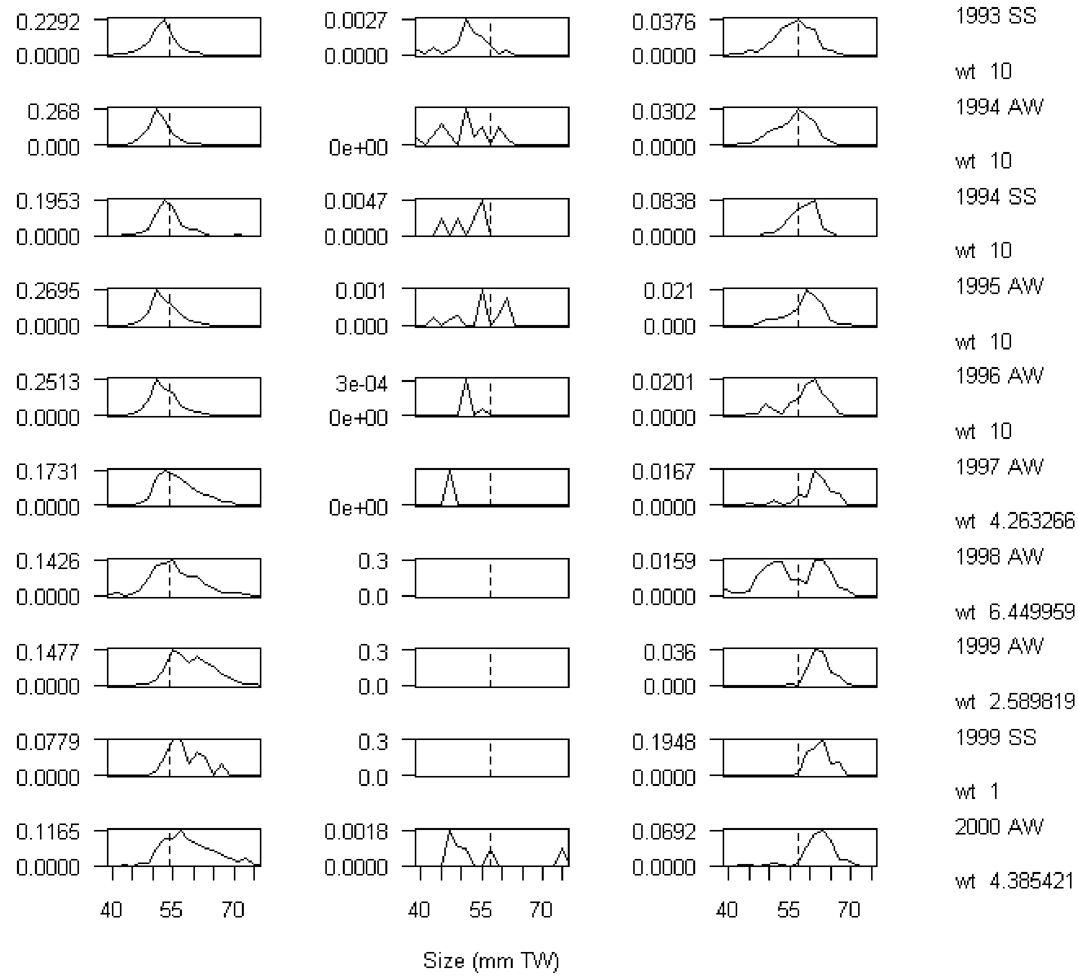


Figure 13. **Proportions-at-length for the logbook sampling programme from 1993 AW to 2000 AW for CRA 3. The fishing year, season and sample weight are indicated for each sample. Left: males, centre: immature females; right: mature females; note changes in scale among the figures.**

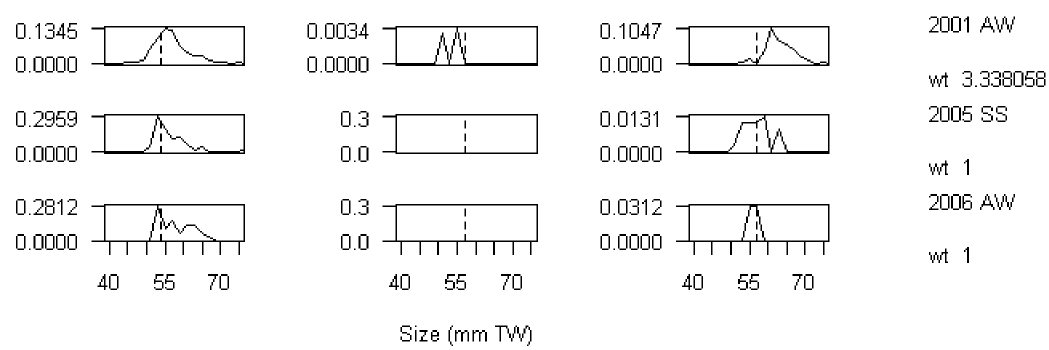


Figure 14. **Proportions-at-length for the logbook sampling programme from 2001 AW to 2006 AW for CRA 3. The fishing year, season and sample weight are indicated for each sample. Left: males, centre: immature females; right: mature females; note changes in scale among the figures.**

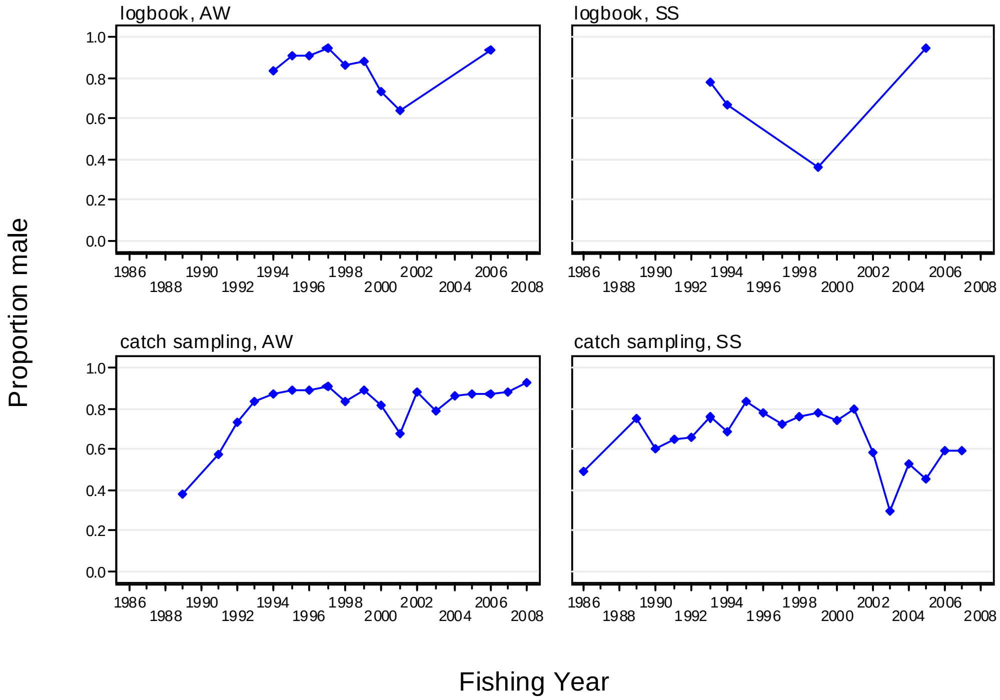


Figure 15. Plot of proportion males by sample data source, season and fishing year and data source for CRA 3.

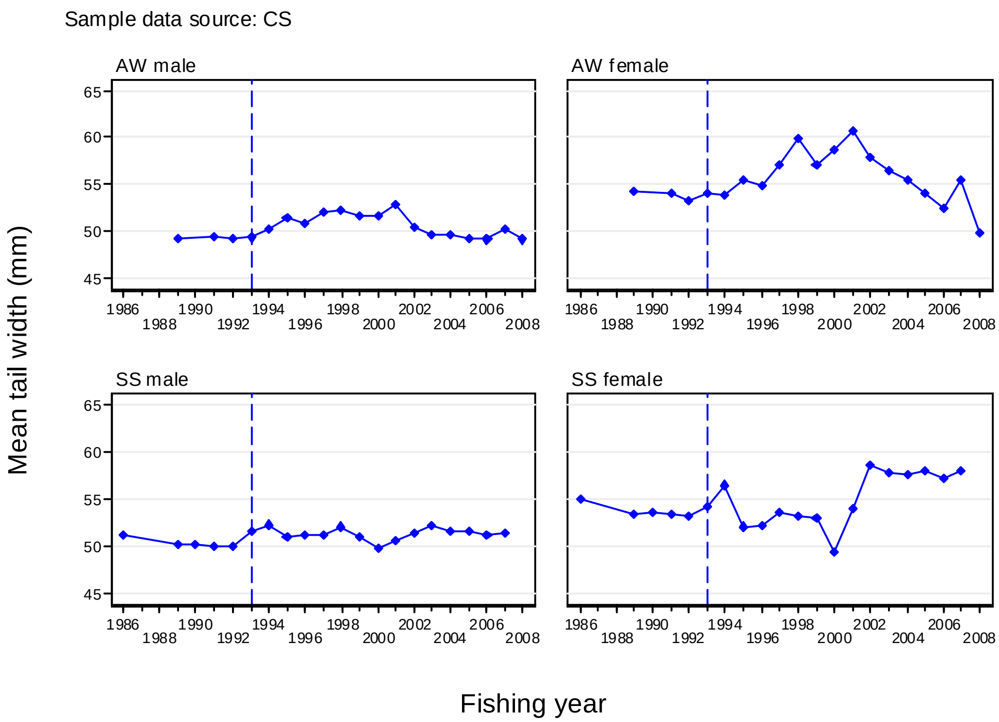


Figure 16. Mean length by fishing year, season and sex for all measured lobsters from the CRA 3 observer (CS) catch sampling programme. The vertical line indicates the fishing year when escape gap regulations were changed.

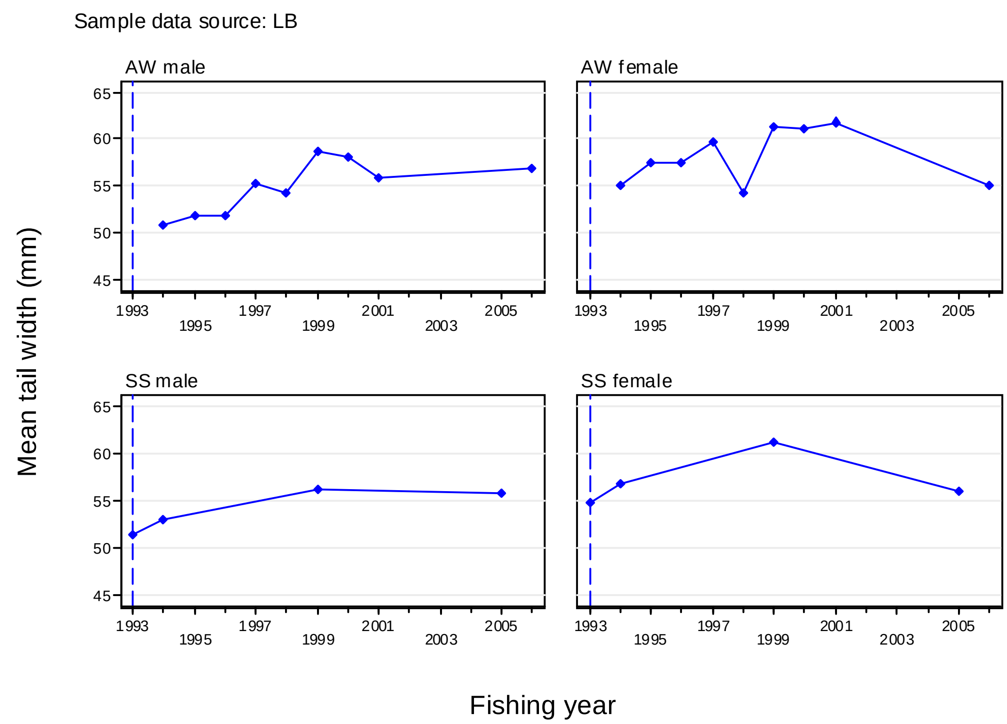


Figure 17. Mean length by fishing year, season and sex for all measured lobsters from the CRA 3 logbook (LB) catch sampling programme. The vertical line indicates the fishing year when escape gap regulations were changed.

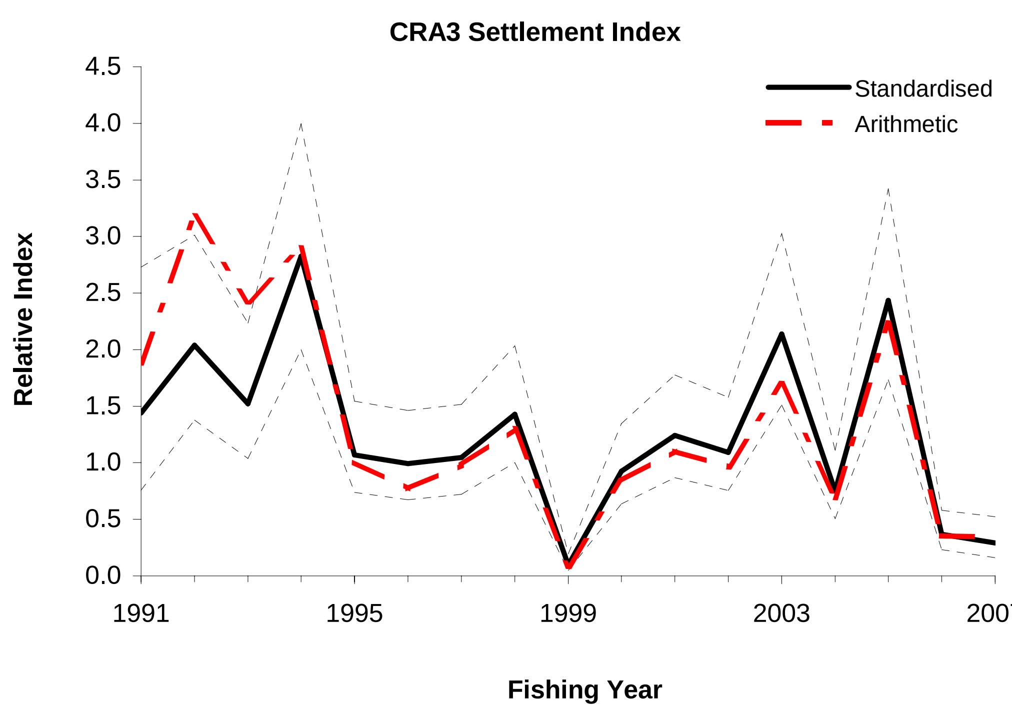


Figure 18. Puerulus settlement indices for CRA 3. Analysis by McKenzie (NIWA, pers. comm.).

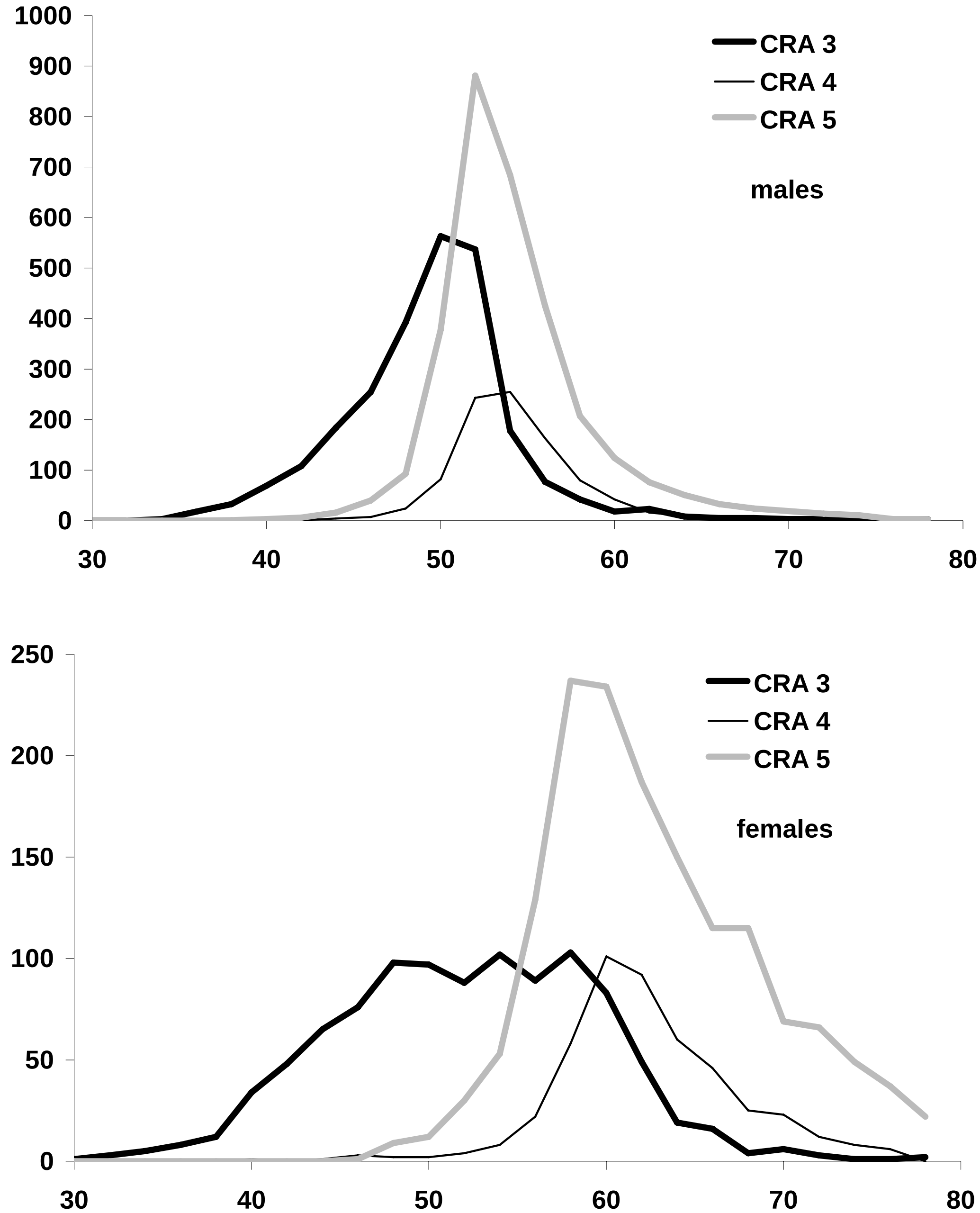


Figure 19: Tail width frequencies (size at release) from the tag-recapture data for three stocks.

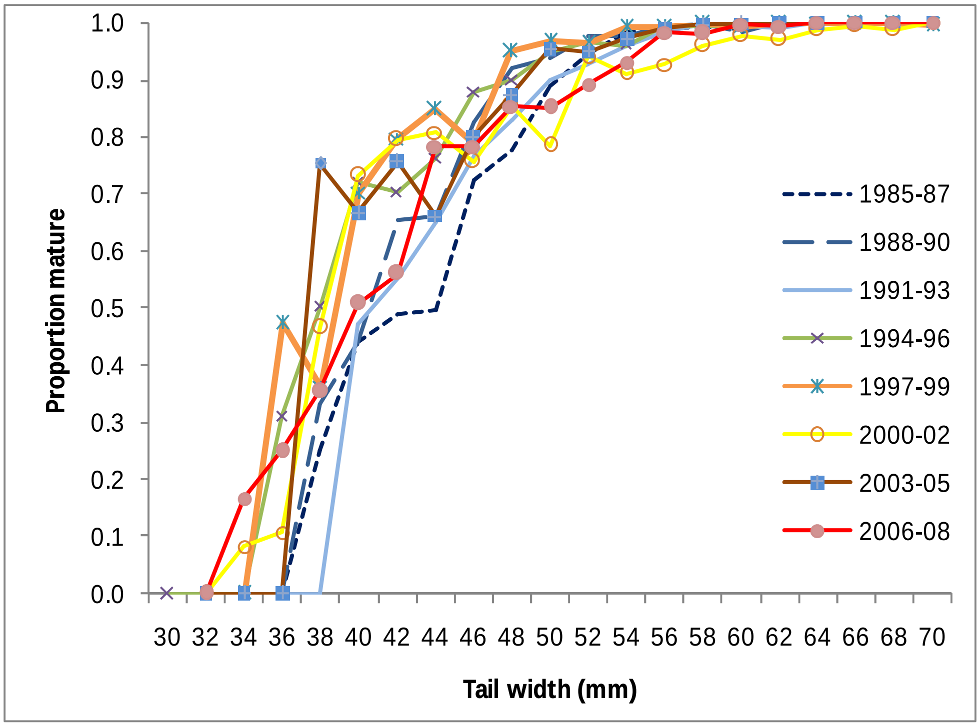


Figure 20: Proportion of mature females by tail width for 3 year intervals.

Appendix Record of correspondence with MFish

(Spelling, grammar and punctuation are as in the original documents; some formatting has been rationalised).

A1 Original request

Paul Breen
Level 4 Scientist
Phone 644 386 0518
email p.breen@niwa.co.nz

Leigh Mitchell, Ministry of Fisheries
by email: Leigh.Mitchell@fish.govt.nz

cc Kevin Stokes, Chair, NRLMG
cc Kevin Sullivan, Chair, RLFAWG
cc Santiago Bermeo-Alvear
cc Paul Starr, Vivian Haist, Terese Kendrick, Daryl Sykes

8 September 2008

Dear Leigh:

On behalf of my esteemed colleagues on the assessment team, I write to request the MFish estimates of illegal, customary and recreational catches for red rock lobster stock CRA 3. These estimates are essential for the upcoming stock assessment of these two areas (MFish project CRA200601, Objective 4). They are needed for inclusion in the modelling no later than 25 September. Because of the assessment timetable and MFish milestones, non-commercial catch assumptions must be agreed by the RLFAWG on 25 September at the latest, and after that date the assessment will proceed on those agreed assumptions.

Please be aware that, because of the importance of these non-commercial catch estimates to the assessment results, our practice is to discuss the estimates within the RLFAWG and to report both the estimates and all correspondence on the subject in the relevant Fishery Assessment Report.

For illegal catches, the assessment team needs to know the most recent MFish estimate from CRA 3 and also needs some estimate of the historical trends in these catches. MFish has provided estimates in the past from CRA 3: we are interested in whether MFish supports these previously-supplied estimates, and whether it can provide guidance on the likely pattern of illegal catches before 1994, as well as the likely level of current illegal catches.

For these estimates, the assessment team also needs to know what uncertainly attaches to them. For instance, if the estimate is 54 t, the uncertainty envelope might be expressed as “25 to 100 t”, or “plus and minus 50%”, or “within a factor of three”. However the uncertainty is expressed, such an expression is required to guide the sensitivity trials component of the assessment.

In addition to the simple quantum of illegal catch from CRA 3, the model requires us to specify the source of catch: for instance, does the illegal catch in a season come mostly from scrubbed or berried females, or alternatively is it mostly undersized fish caught in pots, or does it come from the whole range of fish available to pots?

With equal importance, we need to know what proportion of the estimated illegal catch is reported to the QMS. If commercial fishers land scrubbed females or undersized fish to an LFR, this catch may be reported against quota. To avoid double-counting this catch, we need to know the proportion of illegal catch that is reported against quota.

In two previous years we sent MFish a suggested form in which we thought this information could be supplied; in both years our form was ignored, so we leave the form of the report to MFish.

For customary catch, the requirements are roughly similar: we need the current magnitude and likely historical trends of customary catches in CRA 3, their source with respect to sex and size, and the uncertainty envelope. The source of customary catch is extremely important: we need to know whether customary catch is taken from the whole range of fish available to pots (or divers), or alternatively whether it comprises mostly commercially undersized lobsters or berried females.

For recreational catches, we need to know what MFish currently considers to be the best available information for current and historical landings from CRA 3.

Thanks in advance for your assistance with this request. We will be happy to answer any queries that MFish may have.

Sincerely,

Paul A. Breen

A2 Response

23 September 2008

Paul Breen
Level 4 Scientist
National Institute of Water and Atmospheric Research
P O Box 14901
Wellington

Dear Paul

Thank you for your request for MFish estimates of illegal, customary and recreational catches for the upcoming stock assessment of the red rock lobster stock – CRA 3. I have responded to each of your information requests in turn below:

<u>CRA 3 Illegal Catch Estimates</u>

1. The most recent MFish estimate of CRA 3 illegal catch

The most recent estimate of illegal catch from CRA 3 is 89.5 tonnes per fishing year. This estimate was produced for the 2003-04 fishing year and since then there has been no additional information which would give MFish strong enough reason to amend the values supplied previously.

At the National Rock Lobster Management Group meeting on 18 September 2008, it was asked if declining CRA 3 abundance was taken into account when considering the most recent estimate of illegal catch from CRA 3. As indicated by one of my colleagues after the meeting, the abundance of the stock was taken into account as one of many factors that influence illegal take. I note the illegal catch estimate of 89.5 tonnes was produced for the 2003-04 fishing year when the fishery was in a similar state to what it is now (standardised CPUE for 2003-04 was 0.57kg/potlift, whereas in 2006-07 standardised CPUE was 0.59 kg/potlift).

Please refer to the enclosed Memorandum from Aoife Martin to Paul Breen on 17 August 2004 – *Validation of illegal take estimates in the CRA 3 fishery* – for further information.

2. An estimate of historical trends in CRA 3 illegal catches

Please refer to the enclosed Memorandum from Aoife Martin to Paul Breen for further information.

3. Does MFish support previously supplied estimates?

MFish supports illegal estimates previously supplied for the CRA 3 fishery as they reflect the best available information, given existing data and indicators of offending.

The method used to estimate illegal take in CRA 3 is based on information provided by Fishery Officers, consisting of detected illegal removals based on prosecutions, observed activities, intelligence and intangible anecdotal knowledge. However, as indicated previously, the method used to produce these estimates is rudimentary and therefore the estimates are not able to be verified and are subject to high levels of uncertainty. MFish is working to develop a more robust method to estimate illegal take and expects concrete outcomes from this work in late 2009.

4. Can MFish provide guidance on the likely pattern of illegal catches before 1994?

Given available information, MFish is unable to confidently provide guidance on the likely pattern of illegal catches in CRA 3 prior to 1994. The quality of information gathered by MFish Compliance has improved incrementally over the years; however, MFish is not confident that for the years prior to 1994 the information available is a good reflection of reality at the time.

5. The uncertainty associated with the illegal estimates

The illegal estimates produced are not based on robust statistical analysis; consequently MFish is unable to provide a quantitative indication of the uncertainty associated with these estimates. The estimation of these values is difficult and the greater the specificity of the estimates (e.g. linked to a specific area), the greater the difficulty in identifying ‘complete’ take. Nonetheless, the weaknesses of the method used, as described above, mean that the estimates are subject to high levels of uncertainty.

6. The source of illegal catch ie, does the illegal catch in a season come mostly from scrubbed or berried females, undersized fish caught in pots, or from the whole range of fish available in pots?

Due to the rudimentary nature of the method used to produce these estimates, it is not possible to breakdown illegal catch into different sources (ie. states or sizes).

7. The proportion of the estimated illegal catch reported to the QMS

As outlined in the enclosed Memorandum, of the 89.5 tonnes estimated to be removed illegally from the CRA 3 fishery each fishing year, 5 tonnes are estimated to be removed by recreational fishers and 84.5 tonnes by poachers (including that performed under the guise of legitimate fishing). As you know, illegal fishers do not report their illegal catch under the QMS. None of the 89.5 tonnes is reported.

<u>CRA 3 Customary Catch Estimates</u>

1. The current and likely historical trends of customary catches in CRA 3

MFish currently has little information on the quantity of rock lobster harvested under customary fishing permits from CRA 3, however this information is improving over time as more Kaitiaki are gazetted under the Kaimoana Regulations and improvements are made to data collection and storage.

The Kaimoana Regulations

Under the Fisheries (Kaimoana Customary Fishing) Regulations 1998, Tangata Kaitiaki are responsible for issuing customary fishing permits and providing quarterly reports to MFish on customary fishing authorisations.

Within CRA 3, two iwi and two hapu report under the Kaimoana Regulations. The framework for collecting and storing authorisation information is relatively new, therefore the available information is considered incomplete.

The best available information for customary fishing permits issued under the Kaimoana Regulations for CRA 3 lobsters is provided in the table below:

Calendar Year	Quarter	Actual Quantity Harvested (Number of lobsters)
2000	Jan-Mar	220
2004	Jan-Mar	138
2005	Jan-Mar	200
2006	Apr-Jun	50
2006	Jul-Sep	277
2006	Oct-Dec	567
2007	Jan-Mar	12
2007	Apr-Jun	1806
2007	Jul-Sep	2242
2007	Oct-Dec	3901
2008	Jan-Mar	3661
2008	Apr-Jun	108

Regulation 27A of the Amateur Fishing Regulations

Under Regulation 27A (previously Regulation 27) of the Fisheries (Amateur Fishing) Regulations 1986 there is no requirement for permit issuers to provide MFish with details of their customary fishing authorisations.

On an ad-hoc basis, MFish Fishery Officers are provided with used permit books, generally when new books are allocated, by permit issuers within CRA 3. These used permit books provide MFish with some information on details of customary fishing permits issued under the Amateur Regulations.

Included in the table below is the best available information (ie, information from books returned to MFish) on numbers of CRA 3 lobsters authorised to be taken under the Amateur Regulations from 2003 to current:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	500	1165	150	895	1250	811	500	645	520	1450	1660	4501
2004	2207	1070	2227	1650	300	910	340	380	425	922	1093	2065
2005	2370	1560	1730	480	1320	643	660	793	555	542	1604	3182
2006	1805	950	420	110	-	290	104	230	934	280	1708	2732
2007	1670	932	932	745	125	395	590	567	255	1875	2269	1379
2008	1470	950	1540	1440	600	240	200	-	-	-	-	

<u>Please note:</u>

Regulation 27 information previously supplied for the 2004 CRA 3 stock assessment differs from the figures provided in the table above. This is because used permit books have subsequently been collected from permit issuers and entered into the database. Therefore, the information has been updated but is still considered incomplete by MFish.

2. The Source of Customary catch

Customary fishing permit information collected under the Kaimoana or Amateur Regulations is not collected at the scale to determine the sex or size of each individual lobster that is authorised to be taken. Likewise, permit information is not collected at the scale to determine whether lobsters are taken from the whole range of fish available to pots (or divers) or what proportion of the catch comprises lobsters smaller than the national MLS or berried female lobsters.

CRA 3 Recreational Catch Estimates

1. The best available information for current and historical recreational landings from CRA 3

MFish considers the best available information of current and historical recreational harvest estimates from CRA 3 are those derived from regional and national telephone and diary surveys. However, these estimates are highly uncertain given challenges with the sampling methodology.

If you should require clarification for any of the information contained in this letter, please do not hesitate to contact me: alicia.mckinnon@fish.govt.nz or 06 831 0279.

Kind regards

Alicia McKinnon
Ministry of Fisheries

Validation of illegal take estimates in the CRA 3 fishery

To	Paul Breen (National Rock Lobster Management Group)
From	Aoife Martin (Compliance Policy and Planning Team)
Issue	To validate previous estimates of illegal removals from the CRA 3 fishery.
File	24/23/2/1
Date	17 August 2004

Overview This paper on validation of illegal take estimates in the CRA 3 fishery has been updated in response to Paul Starr's request for additional information and clarification.

Introduction

The Ministry of Fisheries has been asked to validate previous estimates on illegal removals from the CRA 3 fishery. This paper will validate previous estimates, provide an overview of past methodologies used and fill data gaps where appropriate.

Estimates of illegal removals from the CRA 3 fishery were provided for the following periods covering 01 April to 31 March:

- 1994 to 1995
- 1995-96
- 1998-99
- 1999-2000
- 2000-01

Estimates of illegal removals from the CRA 3 fishery were not provided for the following periods:

- 1996-97
- 1997-98
- 2001-02
- 2002-03

Provisional estimates have been made for these missing periods and are discussed below.

Validation

In reviewing the past estimates of illegal removals from the fishery and the methodologies used to calculate these estimates, there has been no additional information which would give us reason to amend the values supplied previously.

Methods used to estimate the illegal take in the CRA 3 fishery are based on information provided by fishery officers. This data consists of actual illegal removals based on successful prosecutions, observed activity and intelligence, and intangible knowledge that fishery officers have built up through their day-to-day activities. The estimates are based on actual values of illegal activity which have been aggregated upwards using a combination of observed activity and local knowledge on how the fishery is operating.

Difficulties arise in trying to verify and cross check the figures provided and this is a limiting factor of the methodology. Therefore, estimates cannot be verified and have an associated low level of confidence. This process is currently the best available and until a more comprehensive methodology can be developed, it is the most accurate way of estimating illegal removals.

Recent estimates (years?) have also incorporated data from the ministry's intelligence and offence systems. Annex 1 discusses in more detail previous methods used to calculate illegal removals.

Provisional estimates for data gaps: 1996-1998

The 1999-2000 estimate makes reference to illegal removals in both 1996-97 and 1997-98 as follows:

- 1996-97: 84 tonnes
- 1997-98: 64 tonnes

The figures provided are based on removals by poaching and illegal commercial activity, and do not include illegal removals by the recreational or customary sectors. The data used is a combination of actual removals, observed activity and intelligence, and fishery officer knowledge.

These estimates were calculated internally for management purposes.

Provisional estimates for data gaps: 2001-03

Estimates for the 2001-02 and 2002-03 period were produced for the purpose of this paper. Estimates were calculated by aggregating upwards the actual and observed illegal activity and then comparing the results with the 2000-2001 and 2003-04 estimates to see how they compare. Factors which could have contributed to an increase or decrease in the volumes removed (e.g. Operation Pacman) were also assessed and the provisional estimates were revised.

The Ministry estimate that 75 tonnes of illegal rock lobster were removed from the fishery in 2001-02 and 2002-03. Estimates have been calculated using the same methodology as the 2003-04 estimates.

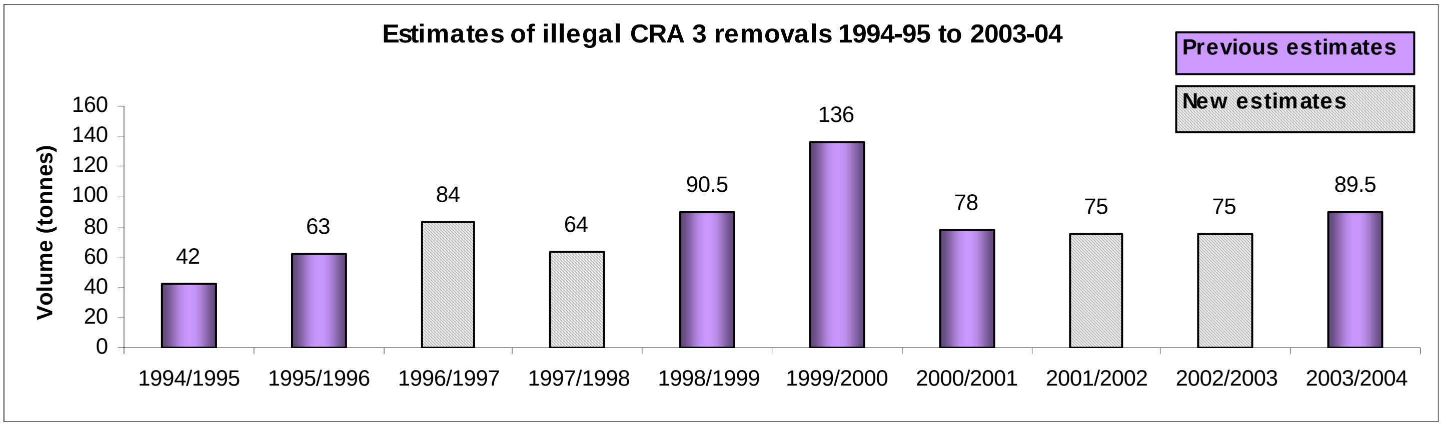
Poachers are estimated to have taken 70 tonnes of rock lobster each year during the 2001-3 period. Poaching activity is believed to have been below current levels because some poachers are thought to have limited their activity while they awaited the outcome of the prosecutions following Operation Pacman.

The provisional estimate for illegal recreational activity is assumed to stay constant at 5 tonnes. No estimate is provided for removals through illegal customary activity.

Overview of previous estimates

An overview of the estimates for 1994-95 to 2003-04 is provided in the chart and table below. The missing cells have been left empty to show those areas where we have not been able to make a reasonable estimate of illegal activity because of insufficient intelligence or knowledge on what is happening in the fishery.

All poaching activity is unreported, but it is not easy to make a distinction between reported and unreported illegal commercial/customary/recreational activity. For example a recreational fisher could land the correct daily bag limit but some of the rock lobster could be in breach of state offences and therefore are illegal.



Activity (tonnes removed)	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000 (1)	2000/2001	2001/2002	2002/2003	2003/2004
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Illegal Recreational take	24				7.5	8	5	5	5	5
Illegal Customary take	13				9					
Illegal Commercial take	5		20	4	4		3			(2)
Poaching		63	64	60	70	128	70	70	70	84.5
Estimated Total	42	63	84	64	90.5	136	78	75	75	89.5

Table 1: Estimates of illegal removals from the CRA 3 fishery 1994-2004.
Data gaps exist where there was no estimate provided or when the anaysis was unable to place a value on a particular activity.
Data source: This table has been compiled from data produced for annual illegal take estimates from 1994-2004
(1) The high value recorded in 1999-2000 is attributed to increased removals from the fishery for millenium celebrations.
(2) Illegal commercial activity is estimated to be negligble in the 2003-04 period

Future research into developing a robust methodology

Methodologies to estimate illegal take are difficult to develop and to apply. The Ministry of Fisheries is contracting research to review and critique methodologies in use, both internationally and within New Zealand, with the aim of developing a reliable and robust methodology for future use in New Zealand.

Conclusion

If you would like any further information on the points raised in this paper please do not hesitate to contact Scott Williamson..

Annex 1

Previous methodologies used to estimate illegal removals

Methodology: 1994-96	The methodology used was rudimentary, resulting in conservative estimates considered to be 'within the realms of possibility'. Illegal estimates were provided across three areas: • Commercial • Recreational poaching • Marae/customary Poaching was categorised as recreational poaching and no distinction had been made between recreational poaching activity and illegal recreational activity. The 1995-96 estimates also attempted to categorise the quantity removed from the fishery through legitimate customary take. The figure estimated was 70.5 tonnes in addition to the 62.3 tonnes of illegal removals. The customary removals calculated by first identifying the average quantities taken by a Marae for customary purposes such as a hui, tangi or koha. 120 Marae were understood to be operating in the area and 50 of these were believed to be active in utilising their customary fishing rights. Using this information it was estimated that 70.5 tonnes were taken from the fishery through legitimate customary take.

Methodology: 1998-99	The methodology used to calculate estimates changed in 1998. Fishery officers continued to supply the information but a more specific quantative approach was adopted. Estimates were provided for: • recreational take • customary take • commercial take • poaching/blackmarket. Fishery officers provided information on actual quantities removed based on known incidents and observed activity, and estimated quantities removed based on intelligence and operations. Estimates were assessed to identify what proportion of the total quantity illegally removed these figures accounted for. Finally, fishery officers recorded how confident they were of estimates provided. This methodology was in place in 1997 although no analysis was undertaken for the CRA 3 fishery.
Methodology: 1999-2001	In 1999 the methodology focussed on similar quantitative data used to supply the previous estimates in addition to qualitative information, supplied by fishery officers, describing what was happening in the fishery. This information included factors which could influence illegal removals such as regulation changes, increased enforcement activity, etc. Estimates provided for 2003-04 have also used this methodology. For the first time, poaching take was estimated within specified parameters based on the categorisation of poaching activity. Factors that may have influenced the extent of illegal activity in the fishery were also provided.