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Assessment of the CRA 3 and NSS substocks of red rock lobster (*Jasus edwardsii*) for 2000

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New Zealand Fisheries Assessment Report 2001/69
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EXECUTIVE SUMMARY

Bentley, N.; Breen, P.A.; Starr, P.J.; Kendrick, T.H. (2001). Assessment of the CRA 3 and NSS substocks of red rock lobster (*Jasus edwardsii*) for 2000.

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A revised size-based model for assessing New Zealand rock lobster stocks is described. This model was used to assess the southern (NSS) stock of red rock lobster, *Jasus edwardsii*, and the CRA 3 substock. Considerable improvement in performance from that of the 1999 size-based model is described for this assessment which resulted from extensive changes to the growth model, revision of the parameter set being estimated, and improvements to the likelihood functions.

The assessment was based on Bayesian techniques. Markov chain-Monte Carlo simulations were used to estimate the posterior distributions of parameters and fishery indicators. Sensitivity trials were based on point estimates of the mode of the joint posterior distributions, and to a lesser extent on comparison of posterior distributions for CRA 3 only.

The model fitted well to both the CRA 3 and NSS data. Compared with previous assessments, minimal arbitrary choices about relative weights for data sets, bounds and prior weights were necessary to obtain credible base case fits.

The assessment for CRA 3 suggests that the current biomass is well above B_{MSY}. At the current level of removals, and with recruitment randomly selected from recent estimates, model results suggest that the stock is likely to increase, but this prediction will be sensitive to the assumption made about future recruitments. In comparisons of point estimates, the assessment was strongly dependent on the standardised CPUE data, was influenced less by the tagging data and the proportion-at-size data, and was robust to modelling choices explored through comparisons of posteriors.

For the NSS stock, the assessment suggests that the current biomass is only 4% of virgin biomass and less than half B_{MSY}. At the expected level of removals after the operation of the NSS decision rule (a 20% TACC reduction) for the 2001–02 season, and with recruitment randomly selected from recent estimates, model results suggest that the stock is likely to increase, but to remain below the estimated B_{MSY}. These conclusions were generally robust during sensitivity trials.

1. INTRODUCTION

The red rock lobster *Jasus edwardsii,* supports the most valuable inshore fishery in New Zealand, with annual exports worth over $100 million. Continuing sustainability and optimum use of this fishery are major management goals. For a literature review of New Zealand *J. edwardsii* see Breen & McKoy (1988). For fishery descriptions see Annala (1983) and Booth & Breen (1994). For recent management details see Annala & Sullivan (2000) and Booth et al. (1994). Recent assessments were described by Starr et al. (1999) and Breen & Kendrick (1999).

The commercial fishery (an inshore trap or pot fishery in the areas described here) has been managed since 1990 with a system of individual transferable quotas (ITQs). Before 1990, the fishery was primarily managed by "input control" methods. These included minimum legal sizes (MLS), recreational bag limits, protection of ovigerous females and soft-shelled lobsters, and some local closures. In 1990, the fishery was brought into the Quota Management System, but the input controls (size limits, protection of berried females, some spatial and seasonal restrictions) were retained. Ten Quota Management Areas (QMAs), each with a separate Total Allowable Commercial Catch (TACC), were put in place in 1990. The revision to the Fisheries Act in 1996 also requires the Minister to set a Total Allowable Catch (TAC) which includes all known sources of fishing mortality, including commercial catch, recreational catch, customary Maori catch, illegal catch, and fishing-related mortality.

The Fisheries Act 1996 requires that New Zealand Fishstocks be managed so that stocks are maintained near B_{MSY}, the biomass associated with the maximum sustainable yield (*MSY*). The Ministry of Fisheries (MFish) annually advises the Minister of Fisheries whether stocks are at or above B_{MSY} and whether current TACCs are sustainable and likely to move stocks toward B_{MSY}. The work described here was conducted by fisheries scientists under contract to the New Zealand Rock Lobster Industry Council (RLIC), which in turn was contracted by MFish, to provide assessments for the CRA 3 (Gisborne) substock and the NSS stock (Otago, Stewart Island, and Fiordland).

In 1996 and 1997, most rock lobster assessments involved an age-structured model (e.g., Breen & Kendrick 1998). For the 1998 assessments, NIWA scientists collaborated with the New Zealand Seafood Industry Council (SeaFIC) Science Group in developing and testing a length-based model of the type described by Punt & Kennedy (1997). For fished populations that cannot be aged, length-based models are becoming widely used after about a decade of development work. There are two basic approaches (Quinn et al. 1998): a) one can model age explicitly and convert age to length in some way (e.g., Fournier & Doonan 1987); or b) one can model growth with a transition matrix that has no reference to "age" except at the recruitment phase. Examples of the latter include Bergh & Johnston (1992) for South African rock lobsters, Sullivan et al. (1990) for Pacific cod, Zheng et al. (1995) for Alaskan king crabs, and Breen et al. (2000) for New Zealand abalone. The heart of such models is a stochastic growth transition matrix that calculates the probabilities of animals of a given length growing into a vector of possible future lengths.

The model used in the 2000 assessment evolved from the first length-based model used in the 1998 rock lobster assessments (Starr et al. 1999, Breen & Kendrick 1999). Deficiencies of the 1998 model were identified by the RLFAWG and were addressed for the 1999 assessments by revising and completely rewriting the model (Breen et al. 2001, Starr et al. in press). Deficiencies in the 1999 model were addressed in 2000.

The assessment uses Bayesian techniques to improve the representation of uncertainty in the assessment (see Punt & Hilborn 1997 for a discussion of Bayesian techniques and their use in fisheries

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"Fishstock is used here to denote a legally defined unit within a Quota Management Area (QMA), while "stock" and "substock" are used to denote units agreed to by the Rock Lobster Fishery Assessment Working Group (Working Group); "stock unit" is used to describe any arbitrary unit.

stock assessments). These techniques are becoming standard tools in this field (e.g., McAllister et al. 1994; Meyer and Millar 1999).

This report describes the revised size-based model, describes and lists the data used for the CRA 3 and NSS stock units, and presents and discusses the assessment results.

2. DESCRIPTION OF THE ASSESSMENT MODEL

The 2000 assessment was done with a model originally described by Starr et al. (1999) and Breen & Kendrick (1999). Much of the model structure and dynamics are based on a similar model developed for the rock lobster fishery in Tasmania by Punt & Kennedy (1997). This model was revised for the 1999 assessment (Breen et al. 2001, Starr et al. in press) and was then revised again, less extensively, for the 2000 assessment.

The revised model is described in general terms in this section, and full details are provided in Appendix A. Major changes made to the 1999 model were as follows.

- Instead of assuming a single value for the standard deviation of CPUE, individual values were estimated in the standardisation procedure and used in the likelihood for CPUE indices.
- The estimated recruitment deviations can optionally be made to apply to more than one year, so that in the early years, for which the data that suggest recruitment strength are sparse, the model need estimate only one deviation for two or three years.
- Three parameters (one for each of three different groups of periods) describing the point of maximum selectivity were estimated rather than assumed.
- Calculation of B_{MSY} was altered slightly.
- In making projections, recruitment for the period from 1996 to the end of the projection was obtained from randomly resampling the model's estimates from the period 1987-96 instead of assuming random variation around mean recruitment. This was done because of concerns that the latter might be too optimistic if recruitment were declining. The periods chosen reflect the lack of information about recruitment in the data after 1996.
- The growth model was changed. The parameters were changed to d_{50}^{g} and d_{80}^{g}, which are the mean expected growth increments for sex g and for animals of tail width 50 or 80 mm respectively. In the 1999 assessment, we attempted to estimate the size at which moulting for each sex switched from biannual to annual; these parameters were not estimated well and we abandoned this. Instead we assume that all females moult at the beginning of autumn-winter only, and (after exploring the data) that all males moult in both seasons. We moved from assuming a fixed standard deviation around the expected growth increment to a c.v. that decreases as the increment decreases; we assume a minimum for the standard deviation, and we added a model parameter to describe the observation error of growth in tagged animals.
- To give different weight to different data sets, we moved from arbitrarily weighting the likelihoods from different data sets to weighting through the assumed standard deviations.

2.1 Model structure

For each sex, the number of individuals in each tail width size class is updated each year from natural and fishing mortality, growth, and recruitment. Size-specific vulnerabilities and weights are used to calculate exploitation rates from catch data and to apply these to individual size classes.

The 1998 model used an annual time step, and was unable to incorporate changes in the seasonal distribution of catch. These changes are important because during the winter, mature females are ovigerous and cannot legally be retained, and because the fishery has recently shifted seasons. A half-yearly time step was introduced into the model in 1999, with the periods congruent with reproduction and moulting periods of both sexes. The two seasons are defined as the austral 'autumn-winter' (AW, 1 April to 30 September) season and the austral 'spring-summer' (SS, 1 October to 31 March).

Populations of males, immature females and mature females are modelled explicitly.

As in 1999, the approach was to assume no relation between stock and recruitment.

2.2 Model parameters

Parameters estimated are defined in Appendix A. Briefly, they are the natural logarithm of mean recruitment, the rate of natural mortality, several parameters for the selectivity-at-size for each sex, four parameters describing relative seasonal vulnerability by sex and season, two main growth parameters for each sex, three parameters dealing with growth variability and observation error, two female size-at-maturity parameters, and a series of recruitment deviations.

2.3 Initial conditions

At the beginning of the first period, corresponding to autumn-winter 1945, the model population is assumed to be in unexploited equilibrium determined by average recruitment, growth rates and natural mortality (Eq 1).

2.4 Dynamics

2.4.1 Recruitment

At the beginning of each period, equal numbers of males and females are recruited into the smaller size classes of the model. Annual recruitment is based on average recruitment, estimated as a parameter. Where sufficient data exist to allow estimation, recruitment deviations are estimated as parameters (Eq 2). The proportion of recruits entering each size class is modelled as a normal distribution with assumed mean and standard deviation, truncated at the smallest model size class (Eq 3).

2.4.2 Growth

The moult-based growth model used in 1999 was modified for this assessment. The end of spring-summer is defined as the moulting time for all females; the ends of both seasons are defined as moulting times for all males.

For each sex, the expected increment at each moult is a linear function of pre-moult size based on the intercept and slope parameters calculated from the model's growth parameters (Eqs 4–6). Associated with the expected increment is a standard deviation, which is a linear function of the increment down to a minimum value (Eq 7).

For lobsters of given sex in a given season, a stochastic size transition matrix is calculated from the moult probability (0 or 1), expected moult increments, and their standard deviations (Eq 9). This transition matrix is used with recruitment to update the number of individuals in each size class for each sex before fishing and natural mortality in the next period (Eq 10).

In theory, the growth variability parameters could be estimated. In the assessments described here, the c.v. and the minimum standard deviation of increments were assumed arbitrary; the standard deviation of observation error was also assumed after exploring the tag return data in which the animals did not experience a moulting season, and which could be assumed not to have moulted.

2.4.3 Selectivity and vulnerability

In the model, not all lobsters are equally vulnerable to the fishery. Sublegal sized lobsters and ovigerous females are protected from the commercial and recreational fisheries but not from the illegal and traditional fisheries. These two types of fishery, bounded or not bounded by the regulations, are termed the SLB and NSLB fisheries respectively.

In addition to these legal mechanisms, the model contains two other mechanisms that modify vulnerability. These are size-specific vulnerability of lobsters to fishing gear, and sex-based and seasonal-based changes in relative vulnerability overall. Both mechanisms involve vulnerability of lobsters to fishing, but for clarity we arbitrarily call the first mechanism **selectivity** and the second **relative seasonal vulnerability**. Taken together, together these describe **total vulnerability**.

The size-specific selectivity curve is incorporated, for males and females separately, as a compound normal distribution with separate width parameters (analogous to the variance of the normal distribution) for each side of the distribution. This results in increasing selectivity from the initial length class to a maximum, followed by decreasing selectivity (Eq 11).

The mode and width parameter for the ascending limb are assumed to have changed when escape gap and size limit regulations changed, changing the retention of small lobsters in traps. Accordingly, these parameters are estimated for each of three periods during the history of the fishery. The width parameter for the descending limb does not change, reflecting an assumption that escape gaps did not affect the selectivity for large lobsters.

The selectivity curves apply in both seasons. To incorporate differential selectivity between males and females in a season, and between sexes for the same season, relative seasonal vulnerability is estimated with four parameters. The relative vulnerability of males in the spring-summer season is assumed to be 1. The relative vulnerability of females in spring-summer is determined with an estimated parameter. Similarly, the relative vulnerabilities of immature females, mature females and males in autumn-winter are determined with three parameters.

For calculating the biomass vulnerable to fishing, total vulnerability is the product of selectivity and relative seasonal vulnerability.

2.4.4 Maturity

During each period, immature females become mature with a size-specific probability, determined by two estimated parameters (Eq 12). Maturation occurs at the beginning of a period, after growth and before mortality.

2.4.5 Mortality

Four sources of mortality are modelled: natural mortality, removals in the SLB fishery (commercial and recreational), handling mortality associated with the SLB fishery, and removals in the NSLB fisheries (traditional and illegal).

Natural mortality is estimated as a parameter and assumed to be constant over time, sex, and size.

The finite annual rate of mortality from the SLB fishery (SLB exploitation rate) is calculated from the estimated SLB catch and the model's SLB biomass (Eq 13). SLB biomass is defined as the mass of males and females in the size classes above their respective minimum legal size limits, adjusted for their selectivity and relative vulnerability (Eq 16). In the autumn-winter season, all mature females are assumed to be ovigerous and protected; they make no contribution to the legal biomass.

The handling mortality rate is a proportion, fixed at an assumed value, of sublegal lobsters and ovigerous females caught and released by the legal fishery; it is thus proportional to the legal exploitation rate.

The finite annual rate of NSLB fishing mortality is calculated in analogy with SLB fishing mortality (Eq 17). Calculation of NSLB biomass uses the same selectivity and relative vulnerability relations as for SLB biomass, but disregards the protection of sublegal lobsters and ovigerous females (Eq 20).

All sources of mortality are applied simultaneously at the beginning of each period (Eq 23) after recruitment, growth and maturation.

2.4.6 Observations and predictions

The model is "conditioned on" or "driven by" catch, in that it uses estimates of the actual legal and illegal catches for each period (Eqs 13 and 17).

The model can be fitted to five observed data sets: standardised CPUE from 1979 onwards, unstandardised CPUE from before 1979 (called "catch rate" to distinguish it from the first data set), size frequency distributions from catch sampling by observers and fishers, larval settlement, and tag return data. For each of these, the model generates an analogous set of "predicted" observations for comparison with the observed data set. Data sets used are described in more detail in the next section; fitting procedures are described below. Fitting to larval settlement was done only as a sensitivity trial.

CPUE and catch rate are predicted from the model's legal biomass in each period using calculated scaling coefficients (Eqs 24, 25,27 and 28).

Proportions-at-size of males and immature and mature females are predicted (Eq 30) from the number of each sex by length class in each period, combined with the selectivity and relative vulnerability relations.

Predicted increments for each tag in the tag return data set are made from the growth parameters, the number and season of moulting times during which the lobster was at liberty, and the sex and initial size of the lobster (Eq 36). When a lobster has been at liberty for more than one moulting period, the expected size at recovery is calculated iteratively, using the new size as input for the next calculation, and so on for the required number of moults. In this process, the variance of the increment is taken as the sum of the variances from each moult, and to this an assumed variance of the observation error is added (Eq 7).

Larval settlement for each year is predicted from the level of recruitment to the model in each year, using a calculated scaling coefficient and taking into account the time lag between larval settlement and recruitment to the model (Eqs 40 and 41).

2.4.7 Model fitting

Model parameters are estimated by minimising a total negative log-likelihood function, which is the sum of the following likelihood components:

- the likelihood of the fits between predicted and observed CPUE and catch rate,
- the likelihood of the fit between predicted and observed proportions-at-size,

- the likelihood of the fit between predicted and observed larval settlement only as a sensitivity,
- the likelihood of the fit between predicted and observed growth increments in tagged lobsters,
- the likelihood of the prior probability of estimated parameter values,
- the likelihood of the prior probability of the estimated recruitment deviations, and
- penalties incurred when the model exceeds specified bounds.

Likelihoods of the fits between observed and predicted CPUE and catch rate are calculated with a lognormal likelihood function (Eqs 26 and 29). Lognormal likelihood is also used for larval settlement. A normal likelihood is used for growth increments (Eq 37).

Likelihood of the fit between observed and predicted proportions-at-size, normalised across males, immature females, and mature females, iscalculated with a robust multinomial function (Eq 31). The robust likelihood eliminates the influence of observed outliers that have either high or low predicted probability (Fournier et al. 1990).

The prior probabilities of estimated parameters are estimated from normal or lognormal likelihood functions, depending on the specified type of prior distribution, using the mean and standard deviation specified by the prior distribution.

The prior probability of estimated recruitment deviations, which act lognormally, is estimated from a normal function assuming a mean of 1 and an assumed fixed standard deviation (Eq 43).

The model is implemented to allow specification of prior probability distributions on estimated parameters so that Bayesian posterior distributions can be generated for parameters and performance indicators. Parameter estimates associated with the mode of the joint posterior distribution, called the model posterior density (MPD) were found by minimising the total negative log-likelihood function described above, using quasi-Newton minimisation (AD Model Builder™, Otter Research Ltd.).

Bayesian estimation procedures were then used to estimate uncertainty in model parameters, quantities, and projected quantities. Posterior distributions for parameters and quantities of interest were estimated using a Markov Chain-Monte Carlo procedure (MCMC). The posteriors were based on 5000 samples taken at regular intervals from one million MCMC simulations. For each sample, 5-year projections (encompassing the 2000–01 to 2004–05 fishing years) were made under specific assumptions about the catches in this period. In these projections, recruitments for the years 1997–2005 were randomly resampled from the estimates by the model for 1987–96.

2.5 Fishery indicators

The Working Group agreed to use the following fishery indicators as measures of the status and risk for each stock unit that was assessed.

1. B_{00} / B_{MSY} The ratio of estimated current biomass to B_{MSY}. Current biomass was defined as total biomass above the legal size on 1 April 2000, the beginning of the autumn-winter season for the 2000–01 fishing year. B_{MSY} is calculated by finding the exploitation rate that maximises yield from a deterministic equilibrium population using the model's parameter vector. This rate is applied to whichever season had the higher exploitation rate in the 1999–2000 fishing year, and the same proportion of that rate is applied to the other season as was estimated by the model for 1999–2000.

2. B_{05} / B_{MSY} The ratio of projected biomass to B_{MSY}. Projected biomass was defined as total biomass above the legal size on 1 April 2005. Projections were made with the 1999 estimates of SLB and NSLB catch, but for the NSS these were reduced by the anticipated 20% reduction of TACC, under a decision rule, for the 2001–02 year. For the MPD estimates (i.e., the base case

estimate and for sensitivity trials) projections were deterministic, based on the model's estimate of R_0, to permit of comparison among runs. For MCMC simulations, the projections were stochastic, using recruitment estimates randomly selected from the model estimates 1987-96, and applied to 1997–2004.

3. B_{05} / B_{00} The ratio of projected biomass to current biomass.
4. B_{00} / B_0 The ratio of estimated current biomass to B_0. B_0 was defined as all biomass above the legal size on 1 April 1945, calculated using total vulnerability and minimum legal size definitions in force in 2000.
5. U_{99} The exploitation rate in 1999–2000. This was calculated from ratio of total catch for the year, SLB and NSLB, to the total recruited biomass in April 2000, calculated without reference to selectivity and vulnerability, and including ovigerous females.
6. U_{04} The exploitation rate in 2004–05, calculated as above using total recruited biomass on 1 April 2004.
7. B_{05} / B_0 The ratio of projected biomass to B_0.
8. P($B_{05} > 0.20B_0$) The percentage of samples in the MCMC simulations in which projected biomass is greater than 20% B_0.
9. P($B_{00} > B_{MSY}$) The percentage of samples in the MCMC simulations in which current biomass was greater than B_{MSY}.
10. P($B_{05} > B_{00}$) The percentage of samples in the MCMC simulations in which projected biomass was greater than B_{00}.

3. DEFINITION OF NEW ZEALAND LOBSTER SUBSTOCKS

The fishery for *Jasus edwardsii* occurs around the whole of New Zealand. Evidence for separate stocks based on genetics, morphology, movement, population parameters, catch per unit effort trends, larval distribution, and parasites has been reviewed (Booth & Breen 1992). Based on this work, in 1994 the RLFAWG agreed to define four stocks for assessment purposes from eight of the nine quota management areas:

Species	Quota Management Area	Fishstock
Red rock lobster	Northland	CRA 1} NSN
(*Jasus edwardsii*)	Bay of Plenty	CRA 2}
	Gisborne	CRA 3}
	Wellington/Hawkes Bay	CRA 4} NSC
	Canterbury/Marlborough	CRA 5}
	Chatham Islands	CRA 6 CHI
	Otago	CRA 7} NSS
	Southern	CRA 8}
	Westland/Taranaki	CRA 9
	Kermadec	CRA 10
Packhorse rock lobster (*Jasus verreauxi*)	All NZ fisheries waters	PHC 1

As yet, the CRA 9 Quota Management Area has not been assigned to a stock and no rock lobster catch has been recorded from CRA 10 (Kermadec Islands).

This document describes the 2000 assessments for the CRA 3 and NSS substocks.

4. ASSESSMENT MODEL INPUTS

This section describes the data and parameter inputs used for the NSS assessment. These inputs include the period over which the model was run, catch data, catch rate indices, annual proportions-at-size, and the priors and point values used for estimated and fixed parameters respectively.

There is considerable variation within the NSS stock in the proportions-at-size observed in the catch. There are substantial differences between the lobster populations on the Otago coast (CRA 7) compared to all of CRA 8. Within CRA 8, there are differences between the fisheries at Stewart Island (Area 924) and Fiordland (Areas 926 to 928). In the past, the NSS assessment has been conducted by fitting the model to Fiordland data but was scaled up to the NSS as a whole by using catch data for the entire stock. In 2000, data from Stewart Island and Fiordland were combined by weighting the relevant data sources (CPUE and length frequency data) by the relative amount of catch in the stratum being considered.

A summary of all the data and the data sources used in the 2000 CRA 3 and NSS stock assessment is provided in Table 1. A discussion of these data and their sources is provided later in this section of the document.

4.1 Period included in the model and definition of fishing year and season

The model simulation begins in 1945, the first year for which catch data are available. Until 1979, catch data were collated by calendar year. After that date, catch, catch rate, and size frequency data are summarised by fishing year, spanning the period 1 April to 31 March. Fishing years are labelled in in tables and figures using the first calendar year in each pair (for example, the 1996–97 assessment year which covers the period 1 April 1996 to 31 March 1997 is labelled as 1996).

Two seasons are defined in this model: a) "autumn-winter" which spans the period 1 April to 30 September; and b) "spring-summer" which includes the period 1 October to 31 March.

4.2 Structure of size frequency data

Tail width size frequency data from research sampling and from voluntary logbook programmes were binned into 2 mm size classes from 30 to 92 mm. These limits spanned the size range of most lobsters caught in the catch. Two-millimetre size classes were considered small enough to provide enough resolution in the model without being too small to be affected by measurement error. Note that the voluntary logbook programme measured lobster to an accuracy of 1.0 mm while the research sampling accuracy was 0.1 mm. As the convention has been to round down all measured lengths, 0.5 mm was added to each voluntary logbook measurement before binning to avoid introducing bias into the calculated proportions-at-size.

4.3 Control variables

4.3.1 Catches

The assessment model requires annual values of catch taken under existing regulations (size limit and the prohibition of the take of berried females) and catch taken without reference to existing regulations. These two catch categories are referred to as SLB and NSLB respectively in this document and three types of catches were considered when collating SLB and NSLB catch totals by season.

4.3.1.1 Commercial reported

From 1945 to 1978, total reported annual commercial catches were obtained from Breen & Kendrick (1998). Beginning on 1 January 1979, catches were taken from data compiled by the Fisheries Statistics Unit (FSU) and held by the Ministry of Fisheries. Three months of catch pertaining to 1 January 1979 to 31 March 1979 are added to the annual catch for 1978. From 1 April 1979 to 31 March 1986, catch totals from the FSU were used to calculate catch by fishing year. Beginning 1 April 1986, catch totals by fishing year were obtained from Quota Management Returns (QMRs) maintained by the Ministry of Fisheries. QMR catches were not available by QMA for the 1986–87 and 1987–88 fishing years. Therefore, the proportional splits by QMA from the FSU catch data for those fishing years were used to apportion the total New Zealand QMR catches into QMA totals. These catches were assigned to the SLB catch category.

4.3.1.2 Commercial unreported

Estimates of unrecorded commercial catch have been made for the calendar years 1974 to 1980 by comparing recorded catches with export weights of lobster and assigning the discrepancy to stocks in proportion to the recorded commercial catch (Breen 1991). These catches were assigned to the SLB catch category.

4.3.1.3 Recreational

The RLFAWG agreed to assume that in 1945 recreational catches were 20% of current levels and that they increased at a constant rate until 1980. After that year, it was assumed that catches have remained constant at current levels. Levels of recreational catch were estimated using the best estimate of mean weight available at the time of the survey (Table 2). These catches were assigned to the SLB catch category.

The method used to calculate the recreational catch was changed slightly compared to the 1998 lobster stock assessments. This was done to address a problem which arises because the stock assessment model assumes that the distribution of lobster by size is the same in the recreational fishery as in the commercial fishery. This can lead to problems if the average weight used to estimate the recreational catch was higher than the average weight in the equivalent commercial catch (e.g., due to different size limit regulations). If the recreational catch used in the model were estimated using a higher average weight than in the model, then the model assigns a larger number of lobster to that catch than actually were taken. It was decided to preserve the number of lobsters caught because this is the more accurate information coming from recreational survey. This was accomplished by using mean weights from logbook data corresponding to each recreational fishery to calculate the catch by weight based on the number (i.e., the mean of the available recreational catch estimates) of lobster caught by the recreational fishery. The revised recreational catch by weight was then applied to all model years from 1980 onwards (including future years). Estimates by weight of the recreational catch used are provided in Table 3.

4.3.1.4 Maori customary fisheries

The Ministry of Fisheries provided estimates of the Maori customary catches for some Fishstocks for the 1995–96 fishing year. The CRA 3 stock assessment used a constant estimate of Maori customary catch of 20 t for every year since 1945. The NSS stock assessment did not include an estimate of Maori customary catch. These catches were assigned to the NSLB catch category.

4.3.1.5 Illegal catch

There are two categories of illegal catch: one is the catch which is taken without regard to the existing regulations but will eventually be included in the legal catch totals. For instance, this category includes holding berried females in pots until they release their eggs. These catches were assigned to the SLB catch category. The other category of illegal catch includes lobster which never enter into the catch reporting system and are assigned to the NSLB catch category. It is necessary to separate these categories as the former category needs to be subtracted from the reported legal catch to avoid double counting of catch. Estimates of illegal catches used in the assessment modelling of the CRA 3 substock and the NSS stock are provided in Table 4.

Estimates were partitioned between "reported" and "unreported" illegal catch only for the 1996–97 fishing year. These proportions were applied to all previous years with illegal catch. It was assumed that no illegal catch was taken before 1978–79 and interpolation was used to fill the years without illegal catch estimates.

The Rock Lobster Fishery Assessment Working Group (RLFAWG) members have very little confidence in the estimates of illegal catch. However, because these figures cannot be verified, the RLFAWG is not in a position to modify these estimates.

4.3.1.6 Seasonal split of catches

Catch data were split into seasonal periods from 1 April 1979 to the present by applying calculated proportional splits from the FSU and Catch Effort Landing Returns (CELR: held by the Ministry of Fisheries) data to the reported catches by fishing year (Table 5). Seasonal catch information was not available for 1973 to 1978 and the mean seasonal split for 1 April 1979 to 31 March 1982 was applied to this period (Table 5). Monthly catch data spanning January 1963 to 31 December 1973 were available for statistical areas specific to CRA 8 and to CRA 3. These data have been summarised by year Annala & King (1983) and monthly data were used to calculate seasonal splits for 1 April 1963 to 31 March 1973.

Street (1970, 1973) provided tables of historical catches by month for an area labelled as "Bluff–Stewart Island, Riverton and Milford". Catches from these tables were summed over the appropriate months to provide estimates for the seasonal split by year for 1 April 1954 to 31 March 1971 for CRA 8 only. The seasonal split estimates using the Street data are comparable to the seasonal split estimates from the Annala & King data for the period of overlap and show a trend from an evenly divided fishery in the mid 1950s to a predominantly spring-summer fishery in the late 1960s. An average seasonal split for 1 April 1954 to 31 March 1957 was used to split the catch before 1954 for CRA 8 only (Table 5).

The recreational fishery was split between the two seasons by assuming that 90% of the recreational catch was taken during the spring-summer season. The Maori customary catch used in CRA 3 used the same seasonal split. Illegal catches were split between seasons by using the appropriate annual split from the legal commercial fishery.

4.3.2 Regulation history

4.3.2.1 Conversion of total length and tail width regulations

Conversion formulae were used to convert MLS regulations and historical data to tail width measurements. Sorenson (1970) provided conversion factors for total length to tail length in inches (Table 6). Breen et al. (1988) provide conversion factors for tail length to tail width in millimetres (Table 6).

MLS regulation history

Annala (1983) provided an overall summary of regulations in the New Zealand rock lobster fishery up to 1982, including the timing of the introduction of minimum size limit regulation changes in the 'Southern' conservancies (Table 7). Booth et al. (1994) summarised the regulation changes which occurred in the 'Southern' QMA during the changeover from a tail length to a tail width regulation (Table 7). Minimum legal size regulation changes were the same in the NSS and in CRA 3 up to 1988. After that year, regulations diverged for females and in males during the autumn-winter season (Table 8). The sequence of minimum legal sizes by sex, year, and stock modelled, expressed as tail width (in mm), is provided for each model season in Tables 18 and 20.

4.3.2.2 Escape gaps

Annala (1983) noted that, before June 1970, escape gaps were not used as a management measure in New Zealand. Street (1973) also discussed the introduction of escape gaps, but concluded, on the basis of limited sampling, that the escape gaps were not effective. Annala (1983) noted that the escape gap size was set at 54 x 305 mm in all New Zealand with the exception of Otago. Escape gap regulations were changed again in July 1993 and the assessment model incorporates these changes by fitting separate selectivity functions for three epochs: a) 1945 to 1969; b) 1970 to 1992; and c) 1993 to the present.

4.3.2.3 Prohibition on the taking of berried females

Historical information provided by Annala (1983) indicate that, in the period from 1945 to the present, there is only a two-year period (1950 & 1951) during which the taking of berried females was allowed by regulation. This is a short period relative to the total model period, so the different regulation for these two years was not addressed in the model.

4.4 State variables

4.4.1 Biomass indices

CPUE of reported catch is used as an index of legal biomass. Two sources of catch and effort data are available for the CRA3 and NSS stock: 1) catch and number of potlifts associated with the catch from the FSU and CELR data bases held by the Ministry of Fisheries; and 2) catch and the number of days associated with the catch from historical monthly data held by NIWA.

4.4.1.1 FSU and CELR data

For CRA 3, standardised abundance indices were estimated from catch per potlift data from the FSU and CELR data bases using catch from statistical areas 909, 910, and 911. For the NSS, standardised abundance indices were estimated from catch per potlift data from the FSU and CELR data bases using catch from Stewart Island (statistical area 924) and Fiordland (statistical areas 926 to 928). Seasonal relative indices of catch rates are generated by standardising for month and statistical area (Maunder & Starr 1995, Breen & Kendrick 1998).

These indices are made relative to a base season which is defined as the season with the absolute index which has the lowest standard deviation. The raw mean catch per potlift is then used to adjust all the indices into absolute terms. These indices are reported in Tables 18 and 19.

4.4.1.2 Historical data

Monthly catch and effort (days fishing) data spanning the period 1963 to 1973 are available for statistical areas specific to Gisborne, Stewart Island, and Fiordland and have been summarised by Annala & King (1983). Monthly catch and effort data from this data set were used to calculate unstandardised catch per day for each season from 1 April 1963 to 31 March 1973 using the combined Stewart Island and Fiordland data (former statistical areas 18 to 21) for NSS and Gisborne (former statistical area 5) and one-half of Napier (former statistical area 6) for CRA 3. These results are reported in Tables 18 and 20.

4.4.2 Proportions-at-size

4.4.2.1 Recent data

Data on the size of lobsters entering pots in the CRA 8 SLB catch were available from research sampling on commercial vessels and from voluntary logbook programmes. Estimates of the proportions-at-size were obtained by using data that had been summarised by area/month strata and weighted by the relative proportion of the commercial catch taken in that stratum, the number of days sampled, and the number of lobsters measured.

4.4.2.2 Historical data

Small amounts of historical sampling data (from the 1970s and 1980s) have been found for both the NSS and CRA 3 (D. Banks, NIWA, pers. comm.). Street (1970) provided a figure containing size frequency data for males and females (immature and mature females not separated) from Fiordland for the years 1964 and 1966 to 1969 (Figure 1). The proportional frequencies in these figures were calculated by digitising from the published graphs and the lengths were converted from total length in inches to tail width in millimetres using the conversion factors provided in Table 6. These size frequency data were used in the model as if they were taken in the spring-summer season only.

4.4.3 Settlement indices

The model was fitted, in sensitivity trials only, to an index of recruitment based on puerulus settlement into collectors. Settlement data from the Castlepoint series (CPT001, Booth et al. 2000) were used for the CRA 3 assessment and are provided in Table 17. No index was used for the NSS assessment, because the RLFAWG did not consider that either Moeraki Halfmoon Bay or Chalky Inlet collectors were representative of the NSS as a whole.

4.4.4 Tagging data

For the NSS assessment, two sources of tag recovery data are available (Table 9). The first comes from tagging experiments reported by Annala & Bycroft (1988) performed in Fiordland in the early 1980s. The second come from tag recovery experiments conducted since 1996 by the Rock Lobster Industry Council (RLIC) under funding from the Ministry of Fisheries "required services" (D. Banks, NIWA, pers. comm.).

For CRA 3, the main sources of tag recovery data were the RLIC tag recovery experiments (D. Banks, NIWA, pers. comm.) and the data of McKoy & Esterman (1981). Data from recovery of tagged deep-water lobsters off Gisborne (Annala & Bycroft 1984) were not used because they were not considered to be representative of lobsters in the CRA 3 fishery.

Tag recovery data were handled as follows.

1. Recoveries made in the same period as the release were excluded, because according to the growth model they would not have been expected to show any moulting or growth.
2. For the RLIC tag recoveries, multiple recaptures were treated as series of separate and independent release/recovery events.
3. For the older tag recoveries, multiple recaptures were excluded. This was because a technical problem in the data extraction was discovered too late in the assessment process to be fixed, but it will be addressed in future assessments.
4. Records were excluded in which a) dates were missing, b) the size at release and the size at recapture were missing, and c) the recorded sex at recapture was not the same as the sex at release.
5. Records were automatically excluded if the apparent increment was less than -10 mm, but records with smaller negative increments were retained. Suspiciously large positive increments were excluded only if they emerged as obvious outliers on a plot of increment per season against original size. These were few and were much less than 1% of the total.
6. Release and recovery sizes in the older data, which had been recorded in carapace length, were converted to tail width using area-specific conversion factors (P. Breen, NIWA, unpub. data).

Each recovery event was introduced into the model with a release and recovery tail width (so that the increment can be calculated and the release tail width put in the correct size bin) and a release and recovery seasonal period. This latter information allows the number of expected moults to be calculated.

4.4.5 Parameter priors

For all parameters estimated, priors were set after discussions in the RLFAWG (Table 10). The basis for each prior is outlined below.

4.5 Natural mortality and recruitment

An informative prior was placed on M, based on the presumption that the mean of this distribution was reasonably well established. Initially a large standard deviation (0.5) was used to allow the model to choose from a wide distribution of possible values (Table 10), but in the CRA 3 assessment this was too weak to prevent the MPD estimate from going to the upper bound. A smaller standard deviation (0.1) was chosen to prevent this in this instance.

Wide uniform bounds were placed on the prior for average recruitment. Recruitment deviations were given a normal prior with bounds that cause recruitment multipliers to remain in the range 0.10 to 10.0.

4.6 Female size-at-maturity

Uniform priors with wide bounds were used for the two female size at maturity parameters m_{50} and $m_{95} - m_{50}$, except that a normal prior was used for the second parameter for the NSS only. This was based on the previous year's assessment results, and was done in an attempt to obtain a stable MPD estimate.

4.7 Vulnerability

Relative seasonal vulnerabilities, applied by sex and season, were calculated relative to males in the spring-summer season. This category was assumed to have the highest relative seasonal vulnerability (1.0) of all possible sex-season combinations. Only four relative seasonal vulnerability parameters were estimated because it was assumed that immature and mature females in the spring-summer season would have the same vulnerability. Priors for these four parameters were uniform between 0.0 and 1.0.

Uniform priors with wide bounds were used for the parameter describing the ascending side of each of the three size selectivity curves (see Section 4.3.2).

4.8 Growth rates

Uniform priors with wide bounds were used for the main growth parameters. One variability parameter was estimated in the NSS assessment, but the other two were fixed in both assessments. However, the values for observation error were based on examination of the tag records in which recapture and release were made in the same season, and thus for which no growth was expected: the observation error standard deviation was set at the standard deviation of the apparent increments in these data.

4.9 Structural and fixed variables

Values of structural and fixed variables are shown in Table 11.

4.10 Weighting of likelihoods

The two data sets with the greatest influence on MPD estimates were the standardised CPUE and the proportions-at-size. If pure likelihood functions were used, differences in the relative volumes of these data could allow the one with the greater volume to dominate the model fit.

In previous assessments this was addressed by multiplying the negative log-likelihood contribution for each data set by an arbitrary value. For this assessment, we used arbitrary weights only on these two major data sets and left the other likelihoods at their natural values (weighted by their standard deviations). We used weights that were applied to the standard deviations of the CPUE index for each period (Eq 26) and to the effective sample size for the proportions-at-size (Eq 33).

We set the initial values for each weight after examining trial runs where only that data set was fitted; we adjusted the weight to obtain values for the standardised residuals lying mostly between -2.5 and 2.5. In the assessment, we then altered the weights as required to obtain reasonable ranges of standardised residuals for both datasets. Weights were varied in sensitivity trials. The values used in the base cases are shown in Table 11.

4.11 Recruitment variation

The RLFAWG agreed to set the standard deviation of recruitment deviations at 0.40. Recruitment deviations were estimated only for those years where information existed in the data – from 1960 to the present. For both assessments, deviations in the early years were applied to more than one year, as shown in Tables 18 and 20.

4.12 Standard deviations used in fitting

An arbitrarily fixed standard deviation of 0.4 was used for "catch rate", the historical catch per day abundance index. An arbitrarily fixed standard deviation of 0.3 was used for settlement data.

4.12 Catches used for projections

The catch trajectory used for projections to estimate the performance indicators are provided in Table 12 (see Section A.13 for description of how the projections were done).

5. ASSESSMENT RESULTS

5.1 CRA 3 substock

5.1.1 Base case MPD estimate

Results of the base case MPD estimate are shown in the first column of Table 13. The fit to standardised CPUE is shown in Figure 2, along with the model residuals; the fit to catch rate is shown in Figure 3. The model's SLB and NSB biomass estimates vary between seasons (Figure 4) because mature females become legally unavailable in autumn-winter and because of seasonal vulnerability differences. The model's estimates of exploitation rates are shown in Figure 5, and of recruitment in Figure 6. Residuals from the fits to tagging data are shown in Figure 7. Fits to the proportion-at-size data sets are shown in Figure 8, which also shows the type of data, period, and the effective sample size for each data set.

The model fits reasonably well to the saw-tooth pattern of CPUE, in which autumn-winter CPUE is usually less than spring-summer CPUE (Figures 2 and 3). The worst fits were seen at the beginning of the catch rate and the end of the standardised CPUE series. The model also fits reasonably well to the tagging data (Figure 7) and to the size frequency data (Figure 8). Note the very low proportions of immature females, reflected in the small size-at-maturity parameters (Table 13).

In this fit, the MPD estimate suggests that a good recruitment in the mid 1990s (Figure 6) combined with the effects of reduced catches (Figure 9) and the CRA 3 management regime to produce a strong increase in biomass (Figure 4). The MPD base case estimate is that the current biomass is about 70% of virgin biomass and several times B_{MSY} (Table 13). Current exploitation rate is estimated in the MPD result to be about 18%, while it was estimated to be near the maximum value of 80% in the spring-summer season from 1985 to 1990 (Figure 5). Note the very high natural mortality estimated as 0.225 (Table 13) compared to the mean of the prior, 0.12.

The pattern of recruitment estimates from the MPD (Figure 6) suggests a period of lower than average recruitment from 1960 to 1975, then nearly a decade of higher than average recruitment, and some strong spikes of very high recruitment in the past decade. This pattern of recruitment explains the strongly increasing standardised CPUE in the mid-1990s.

With the current catches and at the model's estimate of mean recruitment, deterministic projections from the MPD estimate suggest that the stock would remain near its current level over the next 5 years.

5.1.2 Sensitivity of the base case

Sensitivity of the base case MPD estimate was explored by removing data sets one at a time (Table 13). These trials were made to determine whether any one of the data sets appeared to have an especially strong influence on the results. Removing each data set caused some change, but only removing the standardised CPUE caused a shift in the overall assessment. Results from this sensitivity suggested that current exploitation is high and the current biomass is only 20% of virgin biomass, but because there was no fit to the standardised CPUE, these results are not credible. Conversely, removing the proportions-at-size data had little effect. This part of the sensitivity trial implies that these two data sets are not entirely compatible, and that the MPD result is dominated by the CPUE data.

The results were not very sensitive to removal of the tag data or the catch rate data. When settlement data were fitted (Table 13), the results were also not affected.

The next four columns of Table 13 explore the effects of the relative weights used for the two major data sets. The results were changed significantly only in the trial in which the weight for standardised CPUE was increased several-fold. This caused the assessment to become even more optimistic, with a current biomass close to virgin biomass and 9 times B_{MSY}. But decreasing this weight, or changing the weight for proportions-at-size, caused little change.

The next experiment was to estimate the right-hand limb of the selectivity curve, which had been fixed in the base case. The result was a low estimate of this parameter for both sexes, and the consequent creation of a large cryptic biomass. However, there was little change in the other fishery indicators (Table 13).

Finally, M was fixed at the value used for the mean of the prior, 0.12. This increased the ratio of current and projected biomass to B_{MSY} and reduced the estimates of exploitation rates (Table 13).

Of the various fishery indicators, all were reasonably robust across the base case and sensitivity trials, except for those in the situations described above. The assessment appears to be somewhat sensitive to the inclusion of the standardised CPUE data and to the weight placed on those data; otherwise the MPD estimate appears robust.

5.1.3 MCMC simulations and Bayesian results

The sequence patterns ("traces") of some parameters and indicators from the 5000 samples, taken from one million MCMC simulations starting from the base case, are shown in Figure 10. Most of the patterns looked like Figure 10, varying with little sequential pattern and no trend during the run.

Some traces showed sequential wandering behaviour that was different from the majority of traces. These were for parameters for which estimates were on the bounds in the MPD, such as the first relative seasonal vulnerability parameter. Size-selectivity parameters for the first group of periods were also in this category, probably because there is little data from which the model could estimate these.

The MPD was close to the centre of most posteriors (Figure 11); exceptions were those discussed in the paragraph above, where the MPD estimate was on a bound or where the data contained little information about the parameter.

The posterior distributions were summarised by calculating the minimum, maximum, mean, median, and 5th and 95th percentiles (Table 14). There is high similarity between the MPD and Bayesian results. Projections in the Bayesian results are slightly more optimistic than the MPD estimate, because the former used recruitment randomly sampled from a period with better than average recruitment. These projections show considerably variability: the 5th and 95th percentiles of the posterior distributions are 78% to 145%.

Two other MCMC runs were made to test the sensitivity of results to two modelling decisions. In the first one, M was fixed at 0.12. In the second one, M was estimated as in the base case, and the right-hand limb of the selectivity curve was also estimated. The sensitivity trials based on the MPD results suggested that these two changes should have both led to somewhat more optimistic results, and estimating the right-hand limb of selectivity should decrease the estimate of current exploitation nearly by half. The MCMC results behaved similarly to the MPD sensitivity trials: both changes led to somewhat more optimistic results in terms of current biomass relative to B_{MSY} and the amount of increase expected in the next five years.

5.2 NSS stock

5.2.1 Base case MPD estimate

Results of the base case MPD estimate are shown in the first column of Table 15. The fit to standardised CPUE is shown in Figure 12, along with the model residuals; the fit to catch rate is shown in Figure 13. The model's SLB and NSB biomass estimates are shown in Figure 14. The model estimates of exploitation rates are shown in Figure 15, and of recruitment in Figure 16. Residuals from the fits to tagging data are shown in Figure 17. Fits to the proportion-at-size data sets are shown in Figure 18, which also shows the type of data, period, and effective sample size for each data set.

The model fits very well to the saw-tooth pattern of the abundance indices (Figures 12 and 13). It fits the tag data well (Figure 17), but note the relative scarcity of males larger than the MLS in this data set.

The model also fits reasonably well to the observed proportions-at-size data (Figure 18) – note that immature females are much more evident in the data than in CRA 3. No systematic problems in these fits were obvious. The figure shows fits to both research catch sample data and the industry's voluntary logbook data. Casual comparison shows there was no difference in the quality of fit to the two data types.

In this fit, model results suggest that biomass had been strongly reduced by the fishery by 1965 (Figure 14). They suggest that present biomass is about 4% of virgin biomass and is less than one-half B_{MSY}. Current exploitation rate is about 51%, but has decreased substantially over the past decade (Figure 15). The SLB catch is by far the main influence on the fishery (Figure 19).

The pattern of recruitment estimates (Figure 16) suggests above-average recruitment until the early 1980s, then a period of generally below-average recruitment. Deterministic forward projections based on the long-term mean recruitment, and with catches at their anticipated 2001–02 levels (after the decision rule has reduced commercial catch) suggest that the stock would increase strongly in the next five years, nearly doubling in that period (Table 15).

5.2.2 Sensitivity of the base case

Sensitivity of the base case to the data was explored (Table 15) as it was for CRA 3 (Section 5.1.2). In contrast with CRA 3, the data set with most influence was proportions-at-size. When this was omitted from the model fit, the assessment suggests a larger stock (at 30% of B0) with a very low exploitation rate. Although removing the tag data had little effect on the assessment of state of the stocks, the growth parameter estimates changed considerably in that trial, suggesting that the tag data were also important. These results reflect some level of inconsistency in information content among the data sets.

As in the CRA 3 assessment, estimating the right-hand limb of the size-selectivity curves led to lower values for this parameter and creation of cryptic biomass, but had no substantial effect on the estimated state of the stocks (Table 15).

Two additional sensitivities were run to explore slight differences between the NSS and CRA 3 assessments: these were to estimate the size at maximum size-selectivity (in the NSS base case it was fixed) and to increase the standard deviation of the prior on M to its original value of 0.5 (it was decreased in the CRA 3 assessment to give the prior more weight to prevent M from going to the upper bound). Neither change had much effect (Table 15).

5.2.3 MCMC simulations and Bayesian results

The traces for some parameters and indicators from the 3000 samples, taken from one million MCMC simulations starting from the base case MPD, are shown in Figure 20. They appear to be tighter than the CRA 3 traces – they vary with short-term patterns during the run, although they appear to be free of long-term trends. There was insufficient time to do further diagnostic work on these. The first relative seasonal vulnerability parameter had the problem described for CRA 3, because it was again on the upper bound as in the CRA 3 MPD estimate.

Posterior distributions are shown for the parameters and performance indicators in Figure 21. The posterior distributions are summarised in Table 16. The state of the stock implied by the MCMC results is similar to that seen in the MPD estimates: the current biomass appears to be 4% of virgin biomass, the current stock is about a quarter of B_{MSY}, and the biomass is projected to double in the next five years (but will almost certainly remain below B_{MSY}). The projections in the Bayesian results are less optimistic than the MPD estimate, because the former used recruitment sampled from a period with lower than average recruitment. There were large uncertainties in projections: the 5th and 95th percentiles for the derived parameter B_{05}/B_{00} range from 126% to 294%.

6. DISCUSSION

6.1 Model revisions and performance

Changes to the model made in 2000 should be viewed as refinements rather than major alterations: more parameters can be estimated, recruitment deviations are treated more realistically both in estimations and projections, and the likelihoods are calculated and used with less arbitrary interference caused by weighting the various data sets. The most substantial change was to rewrite the growth model by re parameterising, dropping a growth parameter for each sex that could not be estimated well, and moving from fixed variability in the expected increment-at-length to a c.v.

The current model clearly performed much better than the 1999 model. Breen et al. (2001) described the model for CRA 4 and CRA 5 failing to find a good minimum, and Starr et al. (in press) described serious problems in finding a good base case from which to start an MCMC. We experienced neither of these troubles in 2000, although some difficulties with finding results with positive definite Hessian matrices did persist.

Both assessments were based on base cases found with a minimum of intervention: the most serious problem here was that M tended to go to its upper bound in the CRA 3 assessment until we arbitrarily strengthened its prior. In CRA 3 it was also necessary to adjust the relative weight of CPUE data to force the model to fit the pattern seen in standardised CPUE, which is considered credible for external reasons. The estimate of relative seasonal vulnerability for males in the autumn–winter season also tended to go to its upper bound of 1.0, but this may be biologically reasonable.

Sensitivity testing suggested some contradictory signals among the various data sets for both assessments reported here. The CRA 3 assessment is heavily dependent on standardised CPUE; conversely the NSS assessment is heavily dependent on the proportions-at-size data sets. Other modelling choices, although they did affect the results, appear to be relatively weak in their effect.

Results from fitting larval settlement indices with the CRA 3 model must be considered preliminary. When fitted with their natural likelihood weight, the settlement data have very little effect.

6.2 Status of the stocks

6.2.1 CRA 3 substock

Standardised CPUE in both seasons for the CRA 3 area increased dramatically in the second half of the last decade (see Figure 2). The model results suggest that increased abundance came about partly because of higher than average recruitment (to the 30 mm TW size) in the 1990s (see Figure 6). Reduced catches caused by decreased commercial quotas, reduced handling mortality as a result of escape gap requirements, and reduced mortality as a result of management measures introduced for CRA 3 in 1993 (Breen & Kendrick 1998) were undoubtedly also involved.

The assessment (see Table 14) suggests that this stock was, at the beginning of the 2000–01 fishing year, at about 70% of B_0 (90% posterior probability interval 58–86%) and well above B_{MSY} at 440% B_{MSY} (358–542%). With recent recruitment and at the current levels of removals, the biomass would be expected to increase by 25% (10% decrease to 82% increase) in the next 5 years, and would remain well above B_{MSY}. These predictions are based on recent recruitment, which the model estimates was above the long-term average.

The current exploitation rate is 18% (15–21%) and the predicted rate in 5 years is 14% (9–21%). The calculation for B_{MSY} is based on a simplistic equilibrium model, using deterministic processes; the estimates of B_{MSY} and optimum exploitation rate must be treated with caution.

The assessment depends strongly on the standardised CPUE data. Conclusions are not very different when proportion-at-size data and tagging data are excluded. The assessment assumes that large lobsters are not substantially less available to pots than smaller legal lobsters, but is not overly sensitive to this assumption. MPD estimates were not sensitive to other modelling choices. Thus this appears to be a reasonably robust assessment.

6.2.2 NSS stock

Standardised CPUE for the NSS has changed little since 1989 (see Figure 12) even though catches have decreased substantially (see Figure 19). Recruitment during the 1990s was estimated by the model to have been below average (see Figure 16).

The assessment (Table 16) suggests that this stock was, at the beginning of the 2000–01 fishing year, at about 4% of B_0 (3.4–5%) and below B_{MSY} at 23% (19–28%). With recent recruitment and after catch reductions expected for the 2001–02 season, biomass is expected to increase by about 100% (26–194% increase) in the next 5 years, but would remain less than B_{MSY} (27–73%). These projections are based on recent recruitments, which the models estimates have been below the long-term average.

The current exploitation rate of 50% (41–59%) is high and from the model results is likely to remain high over the next 5 years. The calculation for B_{MSY} is based on a simplistic equilibrium model, using deterministic processes; the estimates of B_{MSY} must be treated with caution.

The assessment is sensitive to the inclusion of proportion-at-size data. Conclusions are not very different when abundance indices and tagging data are excluded. The assessment assumes that large lobsters are not substantially less available to pots than smaller legal lobsters, but is not overly sensitive to this assumption. Thus this appears to be a reasonably robust assessment.

6.3 Concluding remarks

The revised length-based model produced a much better assessment for the NSS than the 1999 model, and delivered a reasonably robust assessment for CRA 3. The results emphasise the utility of collecting detailed catch sampling data and fitting all available data within a single model.

For both stock units, the uncertainty in these assessments is greater than the Bayesian posteriors imply. This is because of uncertainties associated with choices made outside the Bayesian procedure, for instance which data sets should be included, how much weight to give them, whether to fix the right-hand selectivity-at-size curves, etc.

At some stage the revised model should be thoroughly tested with simulated data, as described for the 1998 model by Starr et al. (1999). This work is planned for 2001.

Finally, the results involving B_{MSY} should be treated cautiously, remembering that B_{MSY} was calculated with a simple approach based on the maximum yield from deterministic equilibrium conditions. This approach is unlikely to conform with any realistic view of optimum yield or the biomass that supports it (see Francis 1999).

7. ACKNOWLEDGMENTS

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Table 1: Data types and sources for the 2000 assessments in CRA 3 and NSS. Year codes apply to the first 9 months of each fishing year, *viz* 1998-99 is called 1998. NA, not applicable or not used; RLIC, Rock Lobster Industry Council.

		CRA 3		NSS	
		Begin	End	Begin	End
Data type	Data source	Year	Year	Year	Year
Historical catch rate	Annala & King (1983)	1963	1972	1963	1972
CPUE	FSU & CELR	1979	1999	1979	1999
Historical proportions-at-size	various	1977	1977	1964	1977
Research proportions-at-size	MFish	1986	1999	1986	1999
Logbook proportions-at-size	RLIC	1993	1998	1993	1999
Settlement indices[1]	MFish (Booth et al. 2000)	1983	1999	NA	NA
Historical tag recovery data	MFish various	1975	1983	1974	1987
Current tag recovery data	RLIC & MFish	1995	1999	1997	1999
Historical MLS regulations	Annala (1983)	1945	1999	1945	1999
Escape gap regulation changes	Annala (1983)	1945	1999	1945	1999

[1] Castlepoint (CPT001) for CRA 3 (Booth et al. 2000)

Table 2: Estimates of the recreational rock lobster harvest (t) from telephone and diary surveys in 1992 (NSS QMAs) or 1993 (CRA 3) and in 1996 (– = not available). Mean weights are based either on weights reported in the diaries or from boat ramp surveys (Teirney *et al.* 1997)

	1992 or 1993 survey		1996 survey	
QMA	Estimated number of lobsters	Estimate (t)	Estimated number of lobsters	Estimate (t)
CRA 3	8 000	2 – 8 t	27 000	–
CRA 7	6 000	1 – 6	3 000	–
CRA 8	32 000	15 – 60	22 000	16

Table 3: Estimates of annual recreational catch for the period 1980 to 1999 used in the 2000 assessment project for CRA 3 and the NSS.

Substock or QMS	Recreational Catch Estimate used in 2000 Assessment
CRA 3	14.1 t
NSS	20.1 t

Table 4: Estimates of illegal catches (t) for 2000 assessments for CRA 3 and the NSS. For the years not listed, the assessment interpolated linearly.

Year	CRA 3	NSS
1979	30.4	11.0
1987	228.7	55.0
1990	228.7	74.0
1992	228.7	104.0
1993	40.0	-
1994	40.0	90.0
1995	60.0	60.0
1996	80.0	78.0
1997	85.0	78.0
1998	90.0	78.0
1999	100.0	78.0

Table 5: Data sets used to calculate seasonal proportions in the CAR 3 and NSS assessment models.

Period	Data set
Pre-1954[1]	Average (1954-1957) from Street data
1954–1962[1]	Street data
1963–1972	Annala & King (1983) data
1973–1978	Average (1979-1982) from FSU data
1979–present	FSU-CELR data

[1] NSS only.

Table 6: Parameter estimates for the conversion of total length to tail length and from tail length to tail width. Conversion factors for total length to tail length (in inches) are taken from Sorensen (1970). Conversion factors for tail length to tail width (in mm) are taken from Breen et al. (1988)

	Total length (in.) to tail length (in.)		Tail length (in.) to tail width (mm)	
	Male	Female	Male	Female
Slope	0.571	0.604	0.369	0.475
Intercept	0.196	-0.032	-2.75	-16.24

Table 7: Summary of historical minimum size limit regulations for the NSS stock. The regulation changes up to 1959 taken from Annala (1983). The regulation changes from 1988 to 1990 are summarised from Table 1 in Booth et al. (1994). Regulations are expressed in inches (designated as ") or in mm. Equivalent measurements in mm tail width have been made using the conversion factors provided in Table 6. The lower size limit of 5.75 inches tail length was used from 1952 to 1958. Abbreviations: TL, total length; tl, tail length; TW, tail width

	Regulation		Model interpretation in tail width (mm)	
Year	Males	Females	Males	Females
1945	No limit	No limit	No limit	No limit
1950	9" TL	9" TL	47	49
1952	10" TL or 5.75" tl	10" TL or 5.75" tl	51	53
1959	6" tl	6" tl	53	56
1988	54 mm TW	58 mm TW	54	58
1989	54 mm TW	152 mm tl	54	56
1990	54 mm TW	57 mm TW	54	57

Table 8: Minimum legal size regulations as applied in CRA 3 from 1988 by season and year of regulation change. All measurements are in tail widths (mm).

	Males		Females	
Year	Autumn-winter	Spring-summer	Autumn-winter	Spring-summer
1988	54	54	58	58
1992	54	54	60	60
1993	52	54	100	60

Table 9: Summary of the number of tag release and recovery data used in the 2000 assessment.

	CRA3		NSS	
Data source	male	female	male	female
RLIC	1 284	589	869	993
Older data	200	31	734	1 206
Total	1 484	620	1 603	2 199

Table 10: Parameters estimated in the model and their prior distributions. Prior types: U, uniform; N, normal; L, lognormal. For definitions of parameters see Table A1. Initial values in bold indicate a parameter that was held fixed in the base case. '–' not applicable.

Parameter	Prior Type	Bounds	Mean	Standard Deviation	CRA3 initial value	NSS initial value
ln $(R0)$	U	1–50	–	–	17	20
ε_y	N	-2.3 to 2.3	0.0	0.4	0.0	0.0
M	L	0.01 to 0.35	0.12	0.1	0.12	0.12
r_{AW}^{male}	U	0 to 1	–	–	0.80	0.90
r_{AW}^{female}	U	0 to 1	–	–	0.25	0.90
r_{SS}^{female}	U	0 to 1	–	–	0.50	0.90
r_{AW}^{femmat}	U	0 to 1	–	–	0.25	0.90
η_z^{male}	N	40 to 80	54	2	54	54
η_z^{female} (CRA 3)	N	40 to 80	60	2	60	–
η_z^{female} (NSS)	N	40 to 80	57	2	–	57
$v_z^{g,l}$	U	10 to 500	–	–	40 to 200	10 to 100
$v^{g,r}$	L	100 to 10 000	–	–	**10 000**	**10 000**
d_{50}^{g}	U	1 to 8	–	–	2.0, 2.0	2.0, 3.5
d_{80}^{g}	U	-10 to 3	–	–	-1.0, 1.4	1.1, 0.8
CV^j	U	0.01 to 1.00	–	–	**0.40**	0.38
$\varphi^{j,\min}$	U	0.01 to 5.00	–	–	**1**	**1**
$\sigma^{j,obs}$	U	0.01 to 5.00	–	–	**1.8**	**1.7**
m_{50}	U	30 to 90	–	–	58	62
$m_{95}-m_{50}$	U	0 to 30	–	–	–	8.0
$m_{95}-m_{50}$	N	0 to 30	14.7	2	14.7	–

Table 11: Structural and fixed variables used in the base case assessments. For definitions of parameters, see Table A1.

Variable	CRA3	NSS
$\bar{S}_{s_{\min}}$	30	30
$\bar{S}_{\max}$	91	91
a^{male}	4.16E-06	3.39E-06
a^{female}	1.30E-05	1.04E-05
b^{male}	2.935	2.967
b^{female}	2.545	2.632
ϕ	32	32
γ	2	2
t^R	2	-
c	0.1	0.1
$u^{\max}$	0.8	0.8
ϖ^I	0.15	0.10
ϖ^P	5	10

Table 12: Catches (t) used in the five-year projections. Projected catches are based on the 2000–01 TACC for CRA 3 and on 80% of the current TACC for the NSS (NSS base) or the 2000–01 TACC (NSS 2000–01), and on the current estimates of recreational and illegal catches.

Population modelled	Commercial Catch (t)	Recreational Catch (t)	Reported Illegal Catch (t)	Unreported Illegal Catch (t)	Traditional
CRA 3	327	14	8	95	20
NSS base	641[1]	20	31[2]	33	0
NSS 2000–01	783[3]	20	31[2]	33	0

[1] Consists of 72 t for CRA 7 (=average catch from 1994-95 to 1998-99) and 80% of the current CRA 8 TACC (569 t)
[2] Estimated at 5% of the combined CRA 7 and CRA 8 catch
[3] Consists of 72 t for CRA 7 (=average catch from 1994-95 to 1998-99) and the current CRA 8 TACC (711 t)

Table 13: MPD parameter estimates, negative log likelihoods and performance indicators for CRA 3. SF: Size frequency data; VR: $\nu^{g,r}$ estimated

	Base	No CPUE	No CR	No tags	No SF	Use settlement index	CPUE weight high	CPUE weight low	SF weight high	SF weight low	VR estimated	M fixed
Parameter Estimates												
$\ln(R_0)$	14.774	14.502	14.739	14.829	14.282	14.714	13.559	14.705	14.920	14.624	14.792	13.954
M	0.225	0.187	0.212	0.181	0.149	0.222	0.147	0.221	0.248	0.191	0.176	0.120
d_{50}^{male}	1.840	1.940	1.841	1.322	2.002	1.847	2.284	1.872	1.770	1.950	1.933	1.800
d_{50}^{female}	2.020	1.922	2.015	1.584	2.045	2.012	2.100	2.021	2.045	1.956	1.969	1.657
d_{80}^{male}	-1.961	-1.288	-2.000	-1.890	-1.159	-2.285	-4.175	-1.754	-1.807	-1.491	-0.903	-2.728
d_{80}^{female}	1.187	0.890	1.191	0.389	1.045	1.190	-2.099	1.051	0.867	1.375	1.553	1.140
CV^{j}	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
$\varphi^{j,\min}$	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
$\sigma^{j,obs}$	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800
m_{50}	53.565	53.635	53.705	54.185	62.604	53.581	45.429	53.531	53.726	53.678	54.070	54.594
$m_{95}-m_{50}$	15.415	15.331	15.443	15.393	14.698	15.414	14.649	15.388	16.622	14.801	15.493	15.366
r_{AW}^{male}	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
r_{AW}^{female}	0.365	0.261	0.350	0.387	0.996	0.370	1.000	0.334	0.363	0.171	0.310	0.241
r_{SS}^{female}	1.000	0.689	1.000	0.965	0.342	1.000	1.000	0.897	1.000	0.608	0.834	0.499
r_{AW}^{femmat}	0.452	0.252	0.441	0.422	0.001	0.451	0.143	0.379	0.497	0.351	0.362	0.212
η_1^{male}	40.000	53.017	40.000	56.454	40.000	40.000	79.882	40.002	57.976	40.000	51.731	40.000
η_1^{female}	40.000	80.000	40.000	40.000	80.000	40.000	40.005	40.000	40.000	80.000	40.000	40.000
η_2^{male}	51.284	51.401	51.281	51.555	57.983	51.244	57.644	51.442	52.240	49.822	50.659	51.249
η_2^{female}	57.634	53.151	57.372	58.787	80.000	57.644	69.376	57.385	58.021	54.948	55.641	55.808
η_3^{male}	52.524	56.007	52.464	53.083	56.522	52.506	51.027	52.809	53.326	51.712	51.964	52.096

	Base	No CPUE	No CR	No tags	No SF	Use settlement index	CPUE weight high	CPUE weight low	SF weight high	SF weight low	VR estimated	M fixed
η_3^{female}	61.603	63.639	61.882	62.094	54.496	61.536	61.283	62.738	62.595	57.921	60.810	61.663
$\nu_1^{male,l}$	10.000	499.999	499.993	13.166	499.955	10.000	353.279	10.021	10.000	499.972	10.000	499.983
$\nu_1^{female,l}$	499.997	10.000	499.994	499.997	10.000	499.997	499.809	499.580	499.998	10.000	499.998	499.993
$\nu_2^{male,l}$	21.014	24.062	20.869	18.670	10.000	21.585	10.000	22.166	22.418	14.892	15.322	23.863
$\nu_2^{female,l}$	39.737	36.302	37.802	48.733	10.000	40.014	10.017	39.228	38.531	32.795	22.477	33.555
$\nu_3^{male,l}$	18.591	21.201	18.534	21.116	10.000	19.549	19.199	19.432	22.502	18.707	14.801	19.222
$\nu_3^{female,l}$	65.343	75.019	67.503	67.723	499.999	65.455	87.974	71.747	69.363	58.837	62.010	71.835
$\nu^{male,r}$	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000
$\nu^{female,r}$	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000
Hessian positive definite?[1]	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	No
Negative Log Likelihoods												
CPUE	25.296	0.000	25.172	26.636	-35.566	25.764	1000.289	13.561	38.748	-7.367	8.975	33.734
CR	0.089	-6.091	0.000	0.935	-6.323	0.013	29.806	-0.866	1.402	-5.452	-5.598	2.775
SF	-8 461.785	-8 479.988	-8 464.247	-8 482.290	0.000	-8 454.218	-7 907.987	-8 478.991	-8 113.090	-8 620.126	-8 466.637	-8 441.059
Tags	4 588.603	4 582.106	4 588.791	0.000	4 579.351	4 590.310	4 677.095	4 585.255	4 596.348	4 580.663	4 580.620	4 607.305
Priors	19.971	10.009	16.581	8.830	2.579	19.094	2.229	18.956	27.066	10.994	14.780	1.668
Rdevs	20.695	5.958	22.580	20.896	12.935	16.867	87.516	16.179	25.444	16.343	14.876	39.019
Penalty on U	0.169	0.318	0.210	0.000	0.000	0.155	0.040	0.313	0.457	0.000	0.155	0.164
Settlement	0.000	0.000	0.000	0.000	0.000	3.360	0.000	0.000	0.000	0.000	0.000	0.000
Total	-3 806.962	-3 887.688	-3 810.913	-8 424.993	4 552.977	-3 798.655	-2 111.013	-3 845.593	-3 423.625	-4 024.945	-3 852.828	-3 756.392
Derived Parameters												
B_{05}/B_{00}	0.991	1.253	1.053	1.002	0.842	0.878	0.684	1.031	0.989	0.850	1.104	1.065
B_{00}/B_{MSY}	4.205	1.665	4.235	4.407	4.610	3.942	9.969	3.453	4.082	4.743	4.630	6.106
B_{05}/B_{MSY}	4.168	2.086	4.462	4.417	3.882	3.462	6.817	3.559	4.039	4.030	5.113	6.501
B_{00}/B_0	0.694	0.204	0.650	0.621	0.592	0.652	1.033	0.550	0.769	0.633	0.602	0.581

[1] If the hessian is not positive definite, there are problems with the run.

	Base	No CPUE	No CR	No tags	No SF	Use settlement index	CPUE weight high	CPUE weight low	SF weight high	SF weight low	VR estimated	M fixed
U_{99}	0.183	0.515	0.178	0.180	0.131	0.201	0.159	0.234	0.187	0.154	0.113	0.151
U_{05}	0.184	0.410	0.169	0.179	0.156	0.228	0.232	0.226	0.188	0.181	0.102	0.141

Table 14: Summary statistics for performance indicators from posterior distributions for three CRA 3 assessments.

	Estimate M /Fixed $\nu^{g,r}$ (Base case)				Fixed M /Fixed $\nu^{g,r}$				Estimate M / Estimate $\nu^{g,r}$			
	Mean	Median	0.05	0.95	Mean	Median	0.05	0.95	Mean	Median	0.05	0.95
Function value	-3783.0	-3783.3	-3790.4	-3774.7	-3669.9	-3670.1	-3677.0	-3661.8	-3828.4	-3828.7	-3836.0	-3819.4
$\ln(R_0)$	14.733	14.734	14.534	14.930	13.941	13.941	13.834	14.047	14.781	14.782	14.585	14.972
M	0.218	0.218	0.198	0.241	0.120	0.120	0.120	0.120	0.176	0.176	0.157	0.197
d_{50}^{male}	1.83	1.83	1.76	1.89	1.77	1.77	1.71	1.83	1.93	1.93	1.86	1.99
d_{50}^{female}	2.01	2.01	1.90	2.12	1.64	1.64	1.57	1.72	1.96	1.96	1.85	2.08
d_{80}^{male}	-2.10	-2.08	-2.65	-1.59	-3.36	-3.39	-3.91	-2.70	-0.92	-0.90	-1.46	-0.43
d_{80}^{female}	1.03	1.03	0.53	1.55	1.28	1.28	0.67	1.90	1.50	1.50	0.99	2.01
$\sigma^{j,obs}$	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
m_{50}	50.58	51.40	42.71	55.32	52.31	53.12	44.21	56.69	50.51	51.57	41.90	55.62
$m_{95}-m_{50}$	15.27	15.26	12.04	18.52	15.25	15.20	12.12	18.49	15.24	15.26	11.95	18.53
$r_{\text{AW}}^{\text{male}}$	0.999	0.999	0.997	1.000	0.998	0.998	0.996	1.000	0.992	0.991	0.987	0.997
$r_{\text{AW}}^{\text{female}}$	0.456	0.427	0.065	0.925	0.507	0.495	0.085	0.941	0.480	0.462	0.069	0.932
$r_{\text{SS}}^{\text{female}}$	0.822	0.813	0.687	0.979	0.757	0.759	0.543	0.965	0.840	0.856	0.640	0.985
$r_{\text{AW}}^{\text{femmat}}$	0.400	0.394	0.301	0.518	0.338	0.334	0.241	0.448	0.377	0.374	0.275	0.487
$v_1^{\text{male},l}$	18.6	16.6	10.5	33.4	428.7	423.5	359.0	494.2	13.9	13.2	10.2	18.8
$v_1^{\text{female},l}$	264.6	261.2	66.5	473.4	243.5	239.4	21.2	485.0	419.3	427.1	319.7	491.9
$v_2^{\text{male},l}$	23.2	22.3	12.9	36.3	24.4	23.5	12.8	38.9	16.4	15.9	10.8	24.1
$v_2^{\text{female},l}$	44.7	41.9	19.2	80.1	39.9	37.6	18.9	68.5	28.3	26.8	13.7	48.2
$v_3^{\text{male},l}$	18.9	18.8	14.6	23.7	20.2	20.0	15.3	25.9	14.6	14.5	11.4	18.2

	Estimate M /Fixed $\nu^{g,r}$ (Base case)				Fixed M /Fixed $\nu^{g,r}$				Estimate M / Estimate $\nu^{g,r}$			
	Mean	Median	0.05	0.95	Mean	Median	0.05	0.95	Mean	Median	0.05	0.95
$\nu_3^{female,l}$	66.0	65.3	46.4	87.8	71.5	70.2	49.0	97.9	62.5	61.5	45.7	82.5
η_1^{male}	47.9	47.9	42.8	53.1	66.4	69.6	44.3	74.5	63.2	66.7	50.9	71.4
η_1^{female}	44.4	44.6	40.2	47.5	40.7	40.6	40.1	41.6	44.6	43.3	40.3	51.9
η_2^{male}	51.4	51.4	50.2	52.7	51.0	51.0	49.6	52.4	50.7	50.7	50.0	51.5
η_2^{female}	57.7	57.5	55.2	60.6	57.0	56.9	54.9	59.6	56.2	56.1	54.7	58.1
η_3^{male}	52.5	52.5	51.9	53.1	51.8	51.8	51.2	52.5	51.9	51.9	51.4	52.4
η_3^{female}	61.3	61.3	59.5	63.1	61.8	61.8	59.9	63.8	61.0	60.9	59.4	62.7
$\nu^{male,r}$	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	100.6	100.6	100.3	100.9
$\nu^{female,r}$	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	100.4	100.3	100.0	101.0
B_{MSY}	588.4	586.9	505.7	675.4	493.7	492.5	442.5	546.5	878.3	872.1	735.8	1038.8
MSY	498.8	497.4	429.5	571.2	358.5	358.3	322.7	396.2	595.5	592.8	509.4	688.2
B_{05}/B_{00} (%)	129.1	125.3	90.5	182.4	139.9	136.9	106.5	185.1	133.8	131.6	102.6	173.5
B_{00}/B_{MSY}(%)	443.7	440.1	357.6	542.2	711.3	708.6	606.1	824.1	481.3	477.5	396.4	579.9
B_{05}/B_{MSY}(%)	574.1	549.6	369.7	854.4	995.6	969.0	722.5	1357	643.5	630.9	458.2	873.1
B_{00}/B_0(%)	71.1	70.5	58.1	85.8	70.3	70.1	60.6	81.0	63.7	63.2	52.5	76.0
U_{99}(%)	17.8	17.7	15.0	21.0	13.1	13.1	11.5	15.0	11.0	11.0	9.2	13.0
U_{04}(%)	14.4	14.1	9.1	20.6	9.6	9.5	6.9	12.7	8.4	8.3	5.9	11.3
B_{00}	2594.3	2579.1	2176.2	3051.3	3500.3	3489.8	3050.8	3987.8	4197.9	4168.3	3508.3	4950.7
B_{05}	3358.6	3234.3	2211.3	5002.1	4901.0	4782.1	3579.1	6649.3	5621.5	5494.0	4027.9	7667.0
B_0	3671.9	3658.9	3138.2	4234.5	4989.0	4986.6	4485.8	5500.4	6652.4	6590.6	5369.7	8168.1
B_{05}/B_0 (%)	91.8	88.0	60.1	136.1	98.4	96.1	71.9	134.3	85.0	83.5	62.1	114.4
B_{MSY}/B_0 (%)	16.1	16.0	14.3	18.1	9.9	9.9	9.4	10.4	13.3	13.2	11.6	15.1
P(B_{05}>20%B_0) (%)	100.0				100.0				100.0			
P($B00$ > B_{MSY}) (%)	100.0				100.0				100.0			
P(B_{05} > B_{00}) (%)	87.1				97.8				96.4			

Table 15: MPD parameter estimates, negative log likelihoods and performance indicators for NSS assessment. SF, Size frequency data; VR, $\nu^{g,r}$ estimated. NA, not available

	Base	No CPUE	No CR	No tags	No SF	Use Settlement index	CPUE weight high	CPUE weight low	SF weight high	SF Weight low	VR estimated	M fixed	S_{max} estimated	M standar deviatio = 0.
Parameter Estimates														
$\ln(R_0)$	14.891	14.693	14.847	14.795	15.502	14.789	15.269	14.747	14.780	15.068	14.898	15.216	15.192	14.70
M	0.098	0.086	0.098	0.107	0.113	0.092	0.130	0.090	0.092	0.111	0.092	0.120	0.121	0.08
d_{50}^{male}	1.901	1.957	1.897	2.238	1.996	1.909	1.944	1.932	1.923	1.976	1.906	1.873	1.902	1.91
d_{50}^{female}	3.479	3.392	3.482	4.295	3.502	3.466	4.123	3.422	3.412	3.520	3.483	3.515	3.568	3.46
d_{80}^{male}	1.644	1.359	1.646	2.523	1.059	1.588	0.459	1.536	1.502	1.181	1.634	1.827	1.475	1.55
d_{80}^{female}	1.032	1.155	1.035	4.710	0.754	1.037	0.325	1.110	1.263	0.741	1.016	0.996	0.950	1.04
CV^{j}	0.373	0.373	0.373	0.455	0.379	0.361	0.159	0.374	0.370	0.379	0.373	0.371	0.370	0.37
$\varphi^{j,min}$	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.00
$\sigma^{j,obs}$	1.710	1.710	1.710	1.710	1.710	1.710	1.710	1.710	1.710	1.710	1.710	1.710	1.710	1.71
m_{50}	61.924	61.958	61.899	60.649	67.111	61.975	62.069	61.918	61.868	62.610	61.929	61.894	61.903	61.94
$m_{95}-m_{50}$	8.016	7.938	7.999	6.542	30.000	8.067	8.975	7.943	8.034	8.866	8.012	8.010	7.988	8.03
r_{AW}^{male}	1.000	1.000	0.997	0.992	0.745	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.982	1.00
r_{AW}^{female}	0.697	0.670	0.693	0.823	1.000	0.693	0.918	0.679	0.679	0.748	0.695	0.699	0.691	0.69
r_{SS}^{female}	0.757	0.697	0.756	1.000	0.030	0.748	1.000	0.721	0.695	0.839	0.750	0.767	0.795	0.75
r_{AW}^{femmat}	0.462	0.422	0.456	0.637	0.000	0.454	0.507	0.436	0.415	0.510	0.460	0.473	0.488	0.45
η_1^{male}	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	69.692	54.00
η_1^{female}	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	53.590	57.00
η_2^{male}	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	NA	54.00
η_2^{female}	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	NA	57.00

	Base	No CPUE	No CR	No tags	No SF	Use Settlement index	CPUE weight high	CPUE weight low	SF weight high	SF Weight low	VR estimated	M fixed	S_{max} estimated	M standar deviatio = 0.
η_3^{male}	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	NA	54.00
η_3^{female}	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	57.000	NA	57.00
$\nu_1^{male,l}$	55.520	58.233	56.433	51.878	1.000	56.240	47.863	58.896	56.526	1.000	51.847	49.117	244.739	60.04
$\nu_1^{female,l}$	108.381	114.250	109.769	88.310	82.309	109.739	91.648	114.999	111.302	103.781	101.846	97.884	45.802	115.46
$\nu_2^{male,l}$	35.064	37.042	35.035	33.611	500.000	35.787	39.470	35.729	32.756	45.703	35.564	33.907	35.554	35.68
$\nu_2^{female,l}$	58.711	61.537	58.729	51.603	1.000	60.055	61.629	59.610	62.426	65.957	59.688	56.982	52.490	59.59
$\nu_3^{male,l}$	10.329	11.055	10.319	10.533	500.000	10.576	12.964	10.747	10.172	11.796	10.356	10.050	9.064	10.53
$\nu_3^{female,l}$	19.204	20.119	19.250	17.327	499.999	19.617	20.519	19.876	18.848	20.846	19.320	18.605	13.866	19.49
$\nu^{male,r}$	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	1114.136	10 000	10 000	10 00
$\nu^{female,r}$	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	1297.712	10 000	10 000	10 00
Hessian positive definite?	Yes	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	
Negative Log Likelihoods														
CPUE	-31.813	0.000	-31.701	-32.797	-42.175	-31.289	1004.710	-5.876	-25.261	-38.221	-31.524	-32.684	-33.577	-31.16
CR	-2.900	-1.580	0.000	-1.598	-9.827	-2.601	-0.359	-2.233	-0.484	-8.592	-2.215	-3.203	-4.894	-2.52
SF	-10842.085	-10868.491	-10846.503	-10882.098	0.000	-10844.431	-10693.603	-10857.753	-10356.189	-11491.160	-10848.582	-10837.789	-10831.774	-10844.98
Tags	8269.942	8269.388	8270.279	0.000	8262.602	8269.634	8343.453	8269.540	8274.337	8262.810	8269.307	8273.355	8269.419	8268.67
Priors	0.695	4.050	0.736	-0.690	-1.182	2.185	-1.050	2.867	2.121	-1.082	3.983	0.000	-1.378	0.43
Rdevs	21.141	28.159	22.459	27.855	12.631	46.133	79.957	25.169	26.542	15.896	21.044	21.211	21.854	22.93
Penalty on U	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Settlement	0.000	0.000	0.000	0.000	0.000	24.194	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Total	-2585.021	-2568.474	-2584.729	-10889.308	8222.048	-2536.175	-1266.892	-2568.286	-2078.934	-3260.347	-2587.987	-2579.110	-2580.349	-2586.63
Derived Parameter Estimates														
B_{05}/B_{00}	2.210	1.802	2.077	2.568	1.174	1.907	2.578	1.705	1.764	2.628	2.296	2.653	2.696	1.88
B_{00}/B_{MSY}	0.233	0.102	0.240	0.149	0.655	0.196	0.624	0.129	0.179	0.441	0.258	0.335	0.341	0.18
B_{05}/B_{MSY}	0.515	0.183	0.499	0.383	0.769	0.374	1.609	0.219	0.316	1.159	0.592	0.890	0.920	0.35
B_{00}/B_0	0.041	0.019	0.042	0.034	0.292	0.037	0.079	0.026	0.033	0.064	0.038	0.049	0.048	0.03

	Base	No CPUE	No CR	No tags	No SF	Use Settlement index	CPUE weight high	CPUE weight low	SF weight high	SF Weight low	VR estimated	M fixed	S_{max} estimated	M stand deviati = (
U_{99}	0.509	1.020	0.511	0.646	0.051	0.553	0.328	0.786	0.626	0.347	0.484	0.460	0.486	0.5
U_{05}	0.235	0.578	0.251	0.257	0.044	0.296	0.130	0.470	0.362	0.135	0.215	0.177	0.184	0.2

Table 16: Summary statistics for performance indicators from posterior distributions for NSS base case assessment.

	Estimate M /Fixed $v^{g,r}$ (Base case)			
	Mean	Median	0.05	0.95
Function value	-2561.73	-2562.08	-2568.94	-2553.00
$\ln(R_0)$	14.92	14.92	14.79	15.05
M	0.10	0.10	0.09	0.11
d_{50}^{male}	1.89	1.88	1.83	1.96
d_{50}^{female}	3.46	3.46	3.37	3.55
d_{80}^{male}	1.67	1.75	1.22	2.06
d_{80}^{female}	1.05	1.05	0.86	1.22
$\sigma^{j,obs}$	1.71	1.71	1.71	1.71
m_{50}	62.0	62.0	61.4	62.6
$m_{95}-m_{50}$	8.1	8.1	7.2	8.9
$r_{\text{AW}}^{\text{male}}$	0.989	0.987	0.983	0.999
$r_{\text{AW}}^{\text{female}}$	0.695	0.694	0.648	0.744
$r_{\text{SS}}^{\text{female}}$	0.756	0.756	0.698	0.819
$r_{\text{AW}}^{\text{femmat}}$	0.458	0.457	0.407	0.512
$v_1^{\text{male},l}$	57.9	57.1	39.3	79.8
$v_1^{\text{female},l}$	113.4	111.5	81.3	153.2
$v_2^{\text{male},l}$	35.4	35.4	31.2	40.0
$v_2^{\text{female},l}$	58.9	58.8	51.3	67.1

$\nu_3^{\text{male},l}$	10.3	10.3	9.6	11.2
$\nu_3^{\text{female},l}$	19.0	19.0	17.6	20.5
η_1^{male}	54.0	54.0	54.0	54.0
η_1^{female}	57.0	57.0	57.0	57.0
η_2^{male}	54.0	54.0	54.0	54.0
η_2^{female}	57.0	57.0	57.0	57.0
η_3^{male}	54.0	54.0	54.0	54.0
η_3^{female}	57.0	57.0	57.0	57.0
$\nu^{\text{male},r}$	10000	10000	10000	10000
$\nu^{\text{female},r}$	10000	10000	10000	10000
B_{MSY}	7120	7106	6364	7898
MSY	1561	1562	1466	1656
B_{05}/B_{00} (%)	202.0	197.9	125.6	294.1
B_{00}/B_{MSY} (%)	23.4	23.3	19.1	28.1
B_{05}/B_{MSY} (%)	47.6	46.4	26.7	72.9
B_{00}/B_0 (%)	4.2	4.1	3.4	5.0
U_{99} (%)	49.8	49.6	41.2	59.1
U_{04} (%)	22.5	21.1	13.4	36.5
B_{00}	1664	1653	1387	1989
B_{05}	3384	3284	1900	5197
B_0	39962	39895	38493	41585
B_{05}/B_0 (%)	8.5	8.2	4.7	13.0
B_{MSY}/B_0 (%)	17.8	17.8	15.9	19.7
P(B_{05}>20%B_0) (%)	0.2			
P(B_{00} > B_{MSY}) (%)	0.5			
P(B_{05} > B_{00}) (%)	99.1			

Table 17: Catch data in kilograms used for the CRA 3 assessment. Catches were reported by calendar year up to 1978. From 1979 onwards, catches are reported by fishing year (1 April to 31 March).

Fishing year	Season[1]	Sequential season number	Commercial Reported[2]	Export Discrepancy Unreported[3]	Recreational[4]	Reported Commercial Illegal[5]	Unreported Illegal[6]	Customary[7]
1945	1	1	21 665	0	282	0	0	2 000
1945	2	2	21 467	0	2 539	0	0	18 000
1946	1	3	19 471	0	314	0	0	2 000
1946	2	4	19 293	0	2 829	0	0	18 000
1947	1	5	27 662	0	347	0	0	2 000
1947	2	6	27 409	0	3 119	0	0	18 000
1948	1	7	28 606	0	379	0	0	2 000
1948	2	8	28 345	0	3 409	0	0	18 000
1949	1	9	16 102	0	411	0	0	2 000
1949	2	10	15 955	0	3 699	0	0	18 000
1950	1	11	20 848	0	443	0	0	2 000
1950	2	12	20 658	0	3 989	0	0	18 000
1951	1	13	27 279	0	476	0	0	2 000
1951	2	14	27 030	0	4 280	0	0	18 000
1952	1	15	18 348	0	508	0	0	2 000
1952	2	16	18 180	0	4 570	0	0	18 000
1953	1	17	17 659	0	540	0	0	2 000
1953	2	18	17 497	0	4 860	0	0	18 000
1954	1	19	10 463	0	572	0	0	2 000
1954	2	20	10 367	0	5 150	0	0	18 000
1955	1	21	7 936	0	604	0	0	2 000
1955	2	22	7 864	0	5 440	0	0	18 000
1956	1	23	6 712	0	637	0	0	2 000
1956	2	24	6 650	0	5 730	0	0	18 000
1957	1	25	11 279	0	669	0	0	2 000
1957	2	26	11 176	0	6 020	0	0	18 000
1958	1	27	13 601	0	701	0	0	2 000
1958	2	28	13 477	0	6 311	0	0	18 000
1959	1	29	14 622	0	733	0	0	2 000
1959	2	30	14 488	0	6 601	0	0	18 000
1960	1	31	17 480	0	766	0	0	2 000
1960	2	32	17 320	0	6 891	0	0	18 000
1961	1	33	28 708	0	798	0	0	2 000
1961	2	34	28 445	0	7 181	0	0	18 000
1962	1	35	32 153	0	830	0	0	2 000
1962	2	36	31 859	0	7 471	0	0	18 000
1963	1	37	92 487	0	862	0	0	2 000
1963	2	38	131 268	0	7 761	0	0	18 000
1964	1	39	190 968	0	895	0	0	2 000
1964	2	40	124 204	0	8 051	0	0	18 000
1965	1	41	178 009	0	927	0	0	2 000
1965	2	42	191 975	0	8 341	0	0	18 000
1966	1	43	166 464	0	959	0	0	2 000
1966	2	44	160 700	0	8 632	0	0	18 000

Fishing year	Season[1]	Sequential season number	Commercial Reported[2]	Export Discrepancy Unreported[3]	Recrea-tional[4]	Reported Commercial Illegal[5]	Unreported Illegal[6]	Customary[7]
1967	1	45	206 532	0	991	0	0	2 000
1967	2	46	288 835	0	8 922	0	0	18 000
1968	1	47	204 274	0	1 024	0	0	2 000
1968	2	48	215 515	0	9 212	0	0	18 000
1969	1	49	180 794	0	1 056	0	0	2 000
1969	2	50	188 186	0	9 502	0	0	18 000
1970	1	51	115 242	0	1 088	0	0	2 000
1970	2	52	182 397	0	9 792	0	0	18 000
1971	1	53	75 888	0	1 120	0	0	2 000
1971	2	54	131 786	0	10 082	0	0	18 000
1972	1	55	70 064	0	1 152	0	0	2 000
1972	2	56	125 311	0	10 372	0	0	18 000
1973	1	57	44 288	0	1 185	0	0	2 000
1973	2	58	71 712	0	10 663	0	0	18 000
1974	1	59	57 091	8 817	1 217	0	0	2 000
1974	2	60	125 909	19 445	10 953	0	0	18 000
1975	1	61	50 540	14 027	1 249	0	0	2 000
1975	2	62	111 460	30 936	11 243	0	0	18 000
1976	1	63	61 771	13 827	1 281	0	0	2 000
1976	2	64	136 229	30 494	11 533	0	0	18 000
1977	1	65	68 635	19 880	1 314	0	0	2 000
1977	2	66	151 365	43 844	11 823	0	0	18 000
1978	1	67	68 323	23 254	1 346	0	0	2 000
1978	2	68	150 677	51 285	12 113	0	0	18 000
1979	1	69	106 713	10 392	1 378	371	6 377	2 000
1979	2	70	373 549	36 376	12 403	1 298	22 322	18 000
1980	1	71	155 456	16 945	1 410	777	13 365	2 000
1980	2	72	450 893	49 147	12 694	2 254	38 764	18 000
1981	1	73	157 165	0	1 410	1 200	20 633	2 000
1981	2	74	418 392	0	12 694	3 193	54 927	18 000
1982	1	75	184 312	0	1 410	1 445	24 861	2 000
1982	2	76	549 587	0	12 694	4 310	74 130	18 000
1983	1	77	243 139	0	1 410	2 266	38 975	2 000
1983	2	78	520 566	0	12 694	4 852	83 446	18 000
1984	1	79	198 019	0	1 410	2 369	40 739	2 000
1984	2	80	510 911	0	12 694	6 111	105 112	18 000
1985	1	81	149 126	0	1 410	2 244	38 596	2 000
1985	2	82	504 951	0	12 694	7 598	130 687	18 000
1986	1	83	99 900	0	1 410	1 992	34 262	2 000
1986	2	84	462 002	0	12 694	9 212	158 451	18 000
1987	1	85	81 777	0	1 410	2 862	49 234	2 000
1987	2	86	277 235	0	12 694	9 704	166 910	18 000
1988	1	87	57 743	0	1 410	2 575	44 291	2 000
1988	2	88	224 047	0	12 694	9 991	171 853	18 000
1989	1	89	34 737	0	1 410	1 131	19 458	2 000
1989	2	90	351 133	0	12 694	11 435	196 686	18 000
1990	1	91	82 835	0	1 410	3 212	55 241	2 000
1990	2	92	241 278	0	12 694	9 355	160 903	18 000

Fishing year	Season[1]	Sequential season number	Commercial Reported[2]	Export Discrepancy Unreported[3]	Recrea-tional[4]	Reported Commercial Illegal[5]	Unreported Illegal[6]	Customary[7]
1991	1	93	64 767	0	1 410	3 028	52 080	2 000
1991	2	94	204 029	0	12 694	9 539	164 064	18 000
1992	1	95	41 330	0	1 410	2 712	46 646	2 000
1992	2	96	150 181	0	12 694	9 855	169 499	18 000
1993	1	97	117 788	0	1 410	220	3 780	2 000
1993	2	98	61 677	0	12 694	1 978	34 022	18 000
1994	1	99	140 625	0	1 410	220	3 780	2 000
1994	2	100	20 058	0	12 694	1 978	34 022	18 000
1995	1	101	137 465	0	1 410	330	5 670	2 000
1995	2	102	19 410	0	12 694	2 967	51 033	18 000
1996	1	103	198 651	0	1 410	440	7 560	2 000
1996	2	104	4 895	0	12 694	3 956	68 044	18 000
1997	1	105	220 005	0	1 410	467	8 033	2 000
1997	2	106	3 396	0	12 694	4 203	72 297	18 000
1998	1	107	304 437	0	1 410	495	8 505	2 000
1998	2	108	21 269	0	12 694	4 451	76 549	18 000
1999	1	109	295 005	0	1 410	549	9 451	2 000
1999	2	110	33 480	0	12 694	4 945	85 055	18 000

[1] 1=autumn/winter season; 2=spring/summer season

[2] These are the total reported commercial catches from catch statistics. Seasonal splits calculated as reported in Section 4.3.1. The size limits are applied to this catch category.

[3] The estimates for unreported export discrepancies are calculated from a comparison of total reported commercial catch with published export statistics (Breen 1991). The appropriate seasonal splits and size limits are applied to this category.

[4] Recreational catch has been set to 20% of the best estimate in 1945. This value is then increased linearly to 100% which is assumed to be reached in 1980. The best estimate of recreational catch estimate is the mean of all available recreational catch estimates in numbers of lobster. The conversion to catch in weight is based on 1993-96 commercial logbook data. The seasonal split was obtained by assuming a 90%–10% split between the spring/summer and autumn/winter fisheries. Size limits were applied to this category.

[5] This is the fraction of illegal catch which is thought to have been processed through normal legal channels by the Ministry of Fisheries Compliance Unit. This value is subtracted from the total reported commercial catch when calculating the total legal catch in order to avoid double counting of catch. This value has only been estimated in the most recent years (1996) and this fraction has been applied retrospectively to the period of illegal catch estimates. Size limits were applied to this catch.

[6] This is the remaining fraction of illegal catch which is thought to have been processed through other channels by the Ministry of Fisheries Compliance Unit. No size limit is applied to this catch category. The total illegal catch is the sum of these two illegal components.

[7] Customary catches have been set to a constant level of 20 t per year. No size limits are applied to this category and a 10%–90% (autumn/winter – spring/summer) seasonal split has been used.

Table 18: Recent CPUE biomass indices and associated standard errors, historical CPUE biomass indices, settlement indices and male and female size limits used for the CRA 3 assessment.

Fishing Year	Season[1]	Sequential season number	CPUE Biomass Indices[2]	S. E. CPUE Indices[3]	Historical CPUE [4]	Settlement Indices [5]	Male size limit [6]	Female size limit [6]	Recruitment Period[7]
1945	1	1	0	0	0	0	0	0	0
1945	2	2	0	0	0	0	0	0	0
1946	1	3	0	0	0	0	0	0	0
1946	2	4	0	0	0	0	0	0	0
1947	1	5	0	0	0	0	0	0	0
1947	2	6	0	0	0	0	0	0	0
1948	1	7	0	0	0	0	0	0	0
1948	2	8	0	0	0	0	0	0	0
1949	1	9	0	0	0	0	0	0	0
1949	2	10	0	0	0	0	0	0	0
1950	1	11	0	0	0	0	47	49	0
1950	2	12	0	0	0	0	47	49	0
1951	1	13	0	0	0	0	47	49	0
1951	2	14	0	0	0	0	47	49	0
1952	1	15	0	0	0	0	51	53	0
1952	2	16	0	0	0	0	51	53	0
1953	1	17	0	0	0	0	51	53	0
1953	2	18	0	0	0	0	51	53	0
1954	1	19	0	0	0	0	51	53	0
1954	2	20	0	0	0	0	51	53	0
1955	1	21	0	0	0	0	51	53	0
1955	2	22	0	0	0	0	51	53	0
1956	1	23	0	0	0	0	51	53	0
1956	2	24	0	0	0	0	51	53	0
1957	1	25	0	0	0	0	51	53	0
1957	2	26	0	0	0	0	51	53	0
1958	1	27	0	0	0	0	51	53	0
1958	2	28	0	0	0	0	51	53	0
1959	1	29	0	0	0	0	53	56	0
1959	2	30	0	0	0	0	53	56	0
1960	1	31	0	0	0	0	53	56	1
1960	2	32	0	0	0	0	53	56	1
1961	1	33	0	0	0	0	53	56	1
1961	2	34	0	0	0	0	53	56	1
1962	1	35	0	0	0	0	53	56	1
1962	2	36	0	0	0	0	53	56	1
1963	1	37	0	0	78	0	53	56	2
1963	2	38	0	0	77	0	53	56	2
1964	1	39	0	0	107	0	53	56	2
1964	2	40	0	0	50	0	53	56	2
1965	1	41	0	0	81	0	53	56	2
1965	2	42	0	0	48	0	53	56	2
1966	1	43	0	0	63	0	53	56	3
1966	2	44	0	0	44	0	53	56	3
1967	1	45	0	0	72	0	53	56	3

Fishing Year	Season[1]	Sequential season number	CPUE Biomass Indices[2]	S. E. CPUE Indices[3]	Historical CPUE [4]	Settlement Indices [5]	Male size limit [6]	Female size limit [6]	Recruitment Period[7]
1967	2	46	0	0	58	0	53	56	3
1968	1	47	0	0	48	0	53	56	3
1968	2	48	0	0	40	0	53	56	3
1969	1	49	0	0	44	0	53	56	4
1969	2	50	0	0	35	0	53	56	4
1970	1	51	0	0	36	0	53	56	4
1970	2	52	0	0	38	0	53	56	4
1971	1	53	0	0	32	0	53	56	4
1971	2	54	0	0	32	0	53	56	4
1972	1	55	0	0	32	0	53	56	5
1972	2	56	0	0	32	0	53	56	5
1973	1	57	0	0	33	0	53	56	5
1973	2	58	0	0	41	0	53	56	5
1974	1	59	0	0	0	0	53	56	5
1974	2	60	0	0	0	0	53	56	5
1975	1	61	0	0	0	0	53	56	6
1975	2	62	0	0	0	0	53	56	6
1976	1	63	0	0	0	0	53	56	6
1976	2	64	0	0	0	0	53	56	6
1977	1	65	0	0	0	0	53	56	6
1977	2	66	0	0	0	0	53	56	6
1978	1	67	0	0	0	0	53	56	7
1978	2	68	0	0	0	0	53	56	7
1979	1	69	0.798	0.727	0	0	53	56	7
1979	2	70	0.892	0.595	0	0	53	56	7
1980	1	71	0.936	0.688	0	0	53	56	7
1980	2	72	0.960	0.582	0	0	53	56	7
1981	1	73	0.895	0.681	0	0	53	56	8
1981	2	74	0.967	0.595	0	0	53	56	8
1982	1	75	1.061	0.664	0	0	53	56	8
1982	2	76	0.996	0.588	0	0	53	56	8
1983	1	77	0.944	0.647	0	70.2	53	56	9
1983	2	78	0.922	0.594	0	70.2	53	56	9
1984	1	79	0.711	0.642	0	54.8	53	56	10
1984	2	80	0.794	0.589	0	54.8	53	56	10
1985	1	81	0.629	0.650	0	35.0	53	56	11
1985	2	82	0.786	0.600	0	35.0	53	56	11
1986	1	83	0.534	0.724	0	15.9	53	56	12
1986	2	84	0.723	0.627	0	15.9	53	56	12
1987	1	85	0.403	0.707	0	62.4	53	56	13
1987	2	86	0.495	0.642	0	62.4	53	56	13
1988	1	87	0.419	0.836	0	42.3	54	58	14
1988	2	88	0.529	0.695	0	42.3	54	58	14
1989	1	89	0.379	0.973	0	51.4	54	58	15
1989	2	90	0.556	0.613	0	51.4	54	58	15
1990	1	91	0.426	0.705	0	31.4	54	58	16
1990	2	92	0.503	0.649	0	31.4	54	58	16
1991	1	93	0.280	0.687	0	81.6	54	58	17

Fishing Year	Season[1]	Sequential season number	CPUE Biomass Indices[2]	S. E. CPUE Indices[3]	Historical CPUE [4]	Settlement Indices [5]	Male size limit [6]	Female size limit [6]	Recruitment Period[7]
1991	2	94	0.355	0.618	0	81.6	54	58	17
1992	1	95	0.213	0.679	0	93.7	54	60	18
1992	2	96	0.327	0.643	0	93.7	54	60	18
1993	1	97	0.441	0.748	0	50.6	52	100	19
1993	2	98	0.896	1.252	0	50.6	54	60	19
1994	1	99	0.984	0.895	0	40.2	52	100	20
1994	2	100	1.366	2.030	0	40.2	54	60	20
1995	1	101	1.572	0.950	0	47.7	52	100	21
1995	2	102	2.247	2.420	0	47.7	54	60	21
1996	1	103	2.027	0.971	0	51.6	52	100	22
1996	2	104	2.453	3.043	0	51.6	54	60	22
1997	1	105	2.915	0.963	0	43.1	52	100	23
1997	2	106	3.165	3.638	0	43.1	54	60	23
1998	1	107	2.405	0.967	0	64.2	52	100	24
1998	2	108	3.245	2.499	0	64.2	54	60	24
1999	1	109	1.988	0.987	0	64.2	52	100	24
1999	2	110	2.245	1.998	0	64.2	54	60	24

[1] 1=autumn/winter season; 2=spring/summer season
[2] These CPUE indices are standardised CPUE indices calculated from commercial catch and effort data scaled to the 1980 unstandardised index to preserve the units of kg per potlift
[3] Standard error of the CPUE estimates for each period
[4] Unstandardised CPUE indices in kg per day from Annala & King (1983)
[5] Annual settlement indices from Castlepoint (CPT001) (Booth et al. 2000)
[6] In units of TW (mm) converted using parameters provided in Section 4.3.2
[7] Recruitment deviations were calculated as an average over a specified number of periods. This flag shows the periods over which average recruitment deviation parameters were calculated.

Table 19: Catch data in kilograms used for the NSS assessment. Catches were reported by calendar year up to 1978. From 1979 onwards, catches are reported by fishing year (1 April to 31 March). No estimates of customary catch were available for this assessment.

Fishing year	Season[1]	Sequential season number	Commercial Reported[2]	Export Discrepancy Unreported[3]	Recreational[4]	Reported Commercial Illegal[5]	Unreported Illegal[6]
1945	1	1	92 138	0	402	0	0
1945	2	2	110 159	0	3 617	0	0
1946	1	3	78 232	0	448	0	0
1946	2	4	93 533	0	4 031	0	0
1947	1	5	77 260	0	494	0	0
1947	2	6	92 371	0	4 444	0	0
1948	1	7	88 043	0	540	0	0
1948	2	8	105 263	0	4 858	0	0
1949	1	9	239 394	0	586	0	0
1949	2	10	286 216	0	5 271	0	0
1950	1	11	338 729	0	632	0	0
1950	2	12	404 979	0	5 685	0	0
1951	1	13	431 377	0	678	0	0
1951	2	14	515 748	0	6 098	0	0
1952	1	15	585 527	0	723	0	0
1952	2	16	700 047	0	6 511	0	0
1953	1	17	1039 209	0	769	0	0
1953	2	18	1242 464	0	6 925	0	0
1954	1	19	1735 022	0	815	0	0
1954	2	20	2015 219	0	7 338	0	0
1955	1	21	1978 001	0	861	0	0
1955	2	22	2312 329	0	7 752	0	0
1956	1	23	2023 414	0	907	0	0
1956	2	24	2749 445	0	8 165	0	0
1957	1	25	1794 636	0	953	0	0
1957	2	26	1989 795	0	8 579	0	0
1958	1	27	1251 567	0	999	0	0
1958	2	28	1992 065	0	8 992	0	0
1959	1	29	777 276	0	1 045	0	0
1959	2	30	2014 868	0	9 405	0	0
1960	1	31	759 888	0	1 091	0	0
1960	2	32	1777 284	0	9 819	0	0
1961	1	33	632 619	0	1 137	0	0
1961	2	34	1914 501	0	10 232	0	0
1962	1	35	495 877	0	1 183	0	0
1962	2	36	2331 169	0	10 646	0	0
1963	1	37	1132 509	0	1 229	0	0
1963	2	38	2272 491	0	11 059	0	0
1964	1	39	752 347	0	1 275	0	0
1964	2	40	2113 653	0	11 473	0	0
1965	1	41	751 202	0	1 321	0	0
1965	2	42	2272 798	0	11 886	0	0
1966	1	43	530 511	0	1 367	0	0
1966	2	44	2550 489	0	12 299	0	0

Fishing year	Season[1]	Sequential season number	Commercial Reported[2]	Export Discrepancy Unreported[3]	Recrea-tional[4]	Reported Commercial Illegal[5]	Unreported Illegal[6]
1967	1	45	425 392	0	1 413	0	0
1967	2	46	2335 608	0	12 713	0	0
1968	1	47	495 541	0	1 458	0	0
1968	2	48	2233 459	0	13 126	0	0
1969	1	49	398 361	0	1 504	0	0
1969	2	50	2150 639	0	13 540	0	0
1970	1	51	323 568	0	1 550	0	0
1970	2	52	2628 432	0	13 953	0	0
1971	1	53	420 564	0	1 596	0	0
1971	2	54	2385 436	0	14 366	0	0
1972	1	55	320 100	0	1 642	0	0
1972	2	56	1672 900	0	14 780	0	0
1973	1	57	545 767	0	1 688	0	0
1973	2	58	1800 741	0	15 193	0	0
1974	1	59	415 370	54 697	1 734	0	0
1974	2	60	1370 501	180 473	15 607	0	0
1975	1	61	375 862	93 764	1 780	0	0
1975	2	62	1240 147	309 373	16 020	0	0
1976	1	63	419 256	83 689	1 826	0	0
1976	2	64	1383 323	276 128	16 434	0	0
1977	1	65	375 215	99 152	1 872	0	0
1977	2	66	1238 010	327 150	16 847	0	0
1978	1	67	495 732	139 049	1 918	0	0
1978	2	68	1635 654	458 788	17 260	0	0
1979	1	69	620 436	53 217	1 964	1 743	1 278
1979	2	70	1638 008	140 498	17 674	4 603	3 375
1980	1	71	458 959	59 279	2 010	2 374	1 741
1980	2	72	1381 626	178 451	18 087	7 146	5 240
1981	1	73	525 383	0	2 010	3 940	2 889
1981	2	74	1167 100	0	18 087	8 752	6 418
1982	1	75	533 952	0	2 010	5 017	3 679
1982	2	76	1154 533	0	18 087	10 848	7 955
1983	1	77	392 224	0	2 010	4 501	3 301
1983	2	78	1266 676	0	18 087	14 537	10 661
1984	1	79	628 916	0	2 010	7 949	5 829
1984	2	80	1128 530	0	18 087	14 263	10 460
1985	1	81	931 651	0	2 010	10 767	7 896
1985	2	82	1264 877	0	18 087	14 618	10 720
1986	1	83	623 366	0	2 010	9 015	6 611
1986	2	84	1351 366	0	18 087	19 543	14 331
1987	1	85	555 210	0	2 010	8 924	6 544
1987	2	86	1418 952	0	18 087	22 807	16 725
1988	1	87	316 603	0	2 010	8 880	6 512
1988	2	88	944 950	0	18 087	26 504	19 437
1989	1	89	55 616	0	2 010	1 606	1 178
1989	2	90	1295 944	0	18 087	37 432	27 450
1990	1	91	285 020	0	2 010	12 573	9 220
1990	2	92	682 795	0	18 087	30 119	22 088

Fishing year	Season[1]	Sequential season number	Commercial Reported[2]	Export Discrepancy Unreported[3]	Recreational[4]	Reported Commercial Illegal[5]	Unreported Illegal[6]
1991	1	93	340 901	0	2 010	15 349	11 256
1991	2	94	799 517	0	18 087	35 997	26 398
1992	1	95	352 859	0	2 010	21 002	15 402
1992	2	96	655 191	0	18 087	38 998	28 598
1993	1	97	517 622	0	2 010	28 011	20 542
1993	2	98	516 487	0	18 087	27 950	20 497
1994	1	99	448 324	0	2 010	23 852	17 492
1994	2	100	527 610	0	18 087	28 071	20 585
1995	1	101	352 617	0	2 010	13 458	9 869
1995	2	102	554 327	0	18 087	21 157	15 515
1996	1	103	324 951	0	2 010	15 803	11 589
1996	2	104	600 363	0	18 087	29 197	21 411
1997	1	105	299 018	0	2 010	16 377	12 010
1997	2	106	522 621	0	18 087	28 623	20 990
1998	1	107	271 805	0	2 010	14 122	10 356
1998	2	108	594 312	0	18 087	30 878	22 644
1999	1	109	349 229	0	2 010	20 536	15 060
1999	2	110	416 010	0	18 087	24 464	17 940

[1] 1=autumn/winter season; 2=spring/summer season

[2] These are the total reported commercial catches from catch statistics. Seasonal splits calculated as reported in Section 4.3.1. The size limits are applied to this catch category.

[3] The estimates for unreported export discrepancies are calculated from a comparison of total reported commercial catch with published export statistics (Breen 1991). The appropriate seasonal splits and size limits are applied to this category.

[4] Recreational catch has been set to 20% of the best estimate in 1945. This value is then increased linearly to 100% which is assumed to be reached in 1980. The best estimate of recreational catch estimate is the mean of all available recreational catch estimates in numbers of lobster. The conversion to catch in weight is based on 1993–96 commercial logbook data. The seasonal split was obtained by assuming a 90%–10% split between the spring/summer and autumn/winter fisheries. Size limits were applied to this category.

[5] This is the fraction of illegal catch which is thought to have been processed through normal legal channels by the Ministry of Fisheries Compliance Unit. This value is subtracted from the total reported commercial catch when calculating the total legal catch in order to avoid double counting of catch. This value has only been estimated in the most recent years (1996) and this fraction has been applied retrospectively to the period of illegal catch estimates. Size limits were applied to this catch.

[6] This is the remaining fraction of illegal catch which is thought to have been processed through other channels by the Ministry of Fisheries Compliance Unit. No size limit is applied to this catch category. The total illegal catch is the sum of these two illegal components.

Table 20: Recent CPUE biomass indices and associated standard errors, historical CPUE biomass indices, settlement indices and male and female size limits used for the NSS assessment.

Fishing Year	Season[1]	Sequential season number	CPUE Biomass Indices[2]	S. E. CPUE Indices[3]	Historical CPUE [4]	Settlement Indices [5]	Male size limit [6]	Female size limit [6]	Recruitment Period[7]
1945	1	1	0	0	0	0	0	0	0
1945	2	2	0	0	0	0	0	0	0
1946	1	3	0	0	0	0	0	0	0
1946	2	4	0	0	0	0	0	0	0
1947	1	5	0	0	0	0	0	0	0
1947	2	6	0	0	0	0	0	0	0
1948	1	7	0	0	0	0	0	0	0
1948	2	8	0	0	0	0	0	0	0
1949	1	9	0	0	0	0	0	0	0
1949	2	10	0	0	0	0	0	0	0
1950	1	11	0	0	0	0	47	49	0
1950	2	12	0	0	0	0	47	49	0
1951	1	13	0	0	0	0	47	49	0
1951	2	14	0	0	0	0	47	49	0
1952	1	15	0	0	0	0	51	53	0
1952	2	16	0	0	0	0	51	53	0
1953	1	17	0	0	0	0	51	53	0
1953	2	18	0	0	0	0	51	53	0
1954	1	19	0	0	0	0	51	53	0
1954	2	20	0	0	0	0	51	53	0
1955	1	21	0	0	0	0	51	53	0
1955	2	22	0	0	0	0	51	53	0
1956	1	23	0	0	0	0	51	53	0
1956	2	24	0	0	0	0	51	53	0
1957	1	25	0	0	0	0	51	53	0
1957	2	26	0	0	0	0	51	53	0
1958	1	27	0	0	0	0	51	53	0
1958	2	28	0	0	0	0	51	53	0
1959	1	29	0	0	0	0	53	56	0
1959	2	30	0	0	0	0	53	56	0
1960	1	31	0	0	0	0	53	56	1
1960	2	32	0	0	0	0	53	56	1
1961	1	33	0	0	0	0	53	56	1
1961	2	34	0	0	0	0	53	56	1
1962	1	35	0	0	0	0	53	56	1
1962	2	36	0	0	0	0	53	56	1
1963	1	37	0	0	209	0	53	56	2
1963	2	38	0	0	231	0	53	56	2
1964	1	39	0	0	134	0	53	56	2
1964	2	40	0	0	182	0	53	56	2
1965	1	41	0	0	112	0	53	56	2
1965	2	42	0	0	153	0	53	56	2
1966	1	43	0	0	101	0	53	56	3
1966	2	44	0	0	167	0	53	56	3
1967	1	45	0	0	94	0	53	56	3

Fishing Year	Season[1]	Sequential season number	CPUE Biomass Indices[2]	S. E. CPUE Indices[3]	Historical CPUE [4]	Settlement Indices [5]	Male size limit [6]	Female size limit [6]	Recruitment Period[7]
1967	2	46	0	0	152	0	53	56	3
1968	1	47	0	0	75	0	53	56	3
1968	2	48	0	0	109	0	53	56	3
1969	1	49	0	0	58	0	53	56	4
1969	2	50	0	0	109	0	53	56	4
1970	1	51	0	0	108	0	53	56	4
1970	2	52	0	0	128	0	53	56	4
1971	1	53	0	0	92	0	53	56	4
1971	2	54	0	0	99	0	53	56	4
1972	1	55	0	0	53	0	53	56	5
1972	2	56	0	0	78	0	53	56	5
1973	1	57	0	0	0	0	53	56	5
1973	2	58	0	0	0	0	53	56	5
1974	1	59	0	0	0	0	53	56	6
1974	2	60	0	0	0	0	53	56	6
1975	1	61	0	0	0	0	53	56	6
1975	2	62	0	0	0	0	53	56	6
1976	1	63	0	0	0	0	53	56	7
1976	2	64	0	0	0	0	53	56	7
1977	1	65	0	0	0	0	53	56	8
1977	2	66	0	0	0	0	53	56	8
1978	1	67	0	0	0	0	53	56	9
1978	2	68	0	0	0	0	53	56	9
1979	1	69	1.183	0.953	0	0	53	56	10
1979	2	70	1.842	0.862	0	0	53	56	10
1980	1	71	1.158	0.977	0	0	53	56	11
1980	2	72	1.570	0.872	0	0	53	56	11
1981	1	73	1.098	1.033	0	0	53	56	12
1981	2	74	1.382	0.925	0	0	53	56	12
1982	1	75	0.914	0.973	0	0	53	56	13
1982	2	76	1.356	0.886	0	0	53	56	13
1983	1	77	0.609	0.985	0	0	53	56	14
1983	2	78	1.148	0.868	0	0	53	56	14
1984	1	79	0.745	0.986	0	0	53	56	15
1984	2	80	0.997	0.887	0	0	53	56	15
1985	1	81	0.953	0.972	0	0	53	56	16
1985	2	82	1.048	0.912	0	0	53	56	16
1986	1	83	0.673	1.012	0	1.0	53	56	17
1986	2	84	1.108	0.897	0	1.0	53	56	17
1987	1	85	0.717	1.033	0	53.3	53	56	18
1987	2	86	1.138	0.914	0	53.3	53	56	18
1988	1	87	0.505	1.155	0	49.1	54	58	19
1988	2	88	0.895	0.986	0	49.1	54	58	19
1989	1	89	0.536	1.781	0	67.0	54	56	20
1989	2	90	0.857	0.879	0	67.0	54	56	20
1990	1	91	0.515	1.083	0	35.5	54	57	21
1990	2	92	0.898	0.898	0	35.5	54	57	21
1991	1	93	0.507	0.997	0	37.9	54	57	22

Fishing Year	Season[1]	Sequential season number	CPUE Biomass Indices[2]	S. E. CPUE Indices[3]	Historical CPUE [4]	Settlement Indices [5]	Male size limit [6]	Female size limit [6]	Recruitment Period[7]
1991	2	94	0.902	0.882	0	37.9	54	57	22
1992	1	95	0.478	0.999	0	13.5	54	57	23
1992	2	96	0.749	0.897	0	13.5	54	57	23
1993	1	97	0.613	1.007	0	5.3	54	57	24
1993	2	98	0.918	0.978	0	5.3	54	57	24
1994	1	99	0.527	1.002	0	90.5	54	57	25
1994	2	100	0.879	0.968	0	90.5	54	57	25
1995	1	101	0.575	1.063	0	19.0	54	57	26
1995	2	102	0.893	0.997	0	19.0	54	57	26
1996	1	103	0.479	1.054	0	37.6	54	57	27
1996	2	104	0.915	1.004	0	37.6	54	57	27
1997	1	105	0.416	1.048	0	47.3	54	57	28
1997	2	106	0.781	0.991	0	47.3	54	57	28
1998	1	107	0.384	1.119	0	5.0	54	57	29
1998	2	108	0.833	0.990	0	5.0	54	57	29
1999	1	109	0.501	1.172	0	5.0	54	57	29
1999	2	110	0.801	1.104	0	5.0	54	57	29

[1] 1=autumn/winter season; 2=spring/summer season

[2] These CPUE indices are standardised CPUE indices calculated from commercial catch and effort data scaled to the 1980 unstandardised index to preserve the units of kg per potlift

[3] Standard error of the CPUE estimates for each period

[4] Unstandardised CPUE indices in kg per day from Annala & King (1983)

[5] Annual settlement indices from Chalky Inlet (Booth et al. 2000)

[6] In units of TW (mm) converted using parameters provided in Section 4.3.2

[7] Recruitment deviations were calculated as an average over a specified number of periods. This flag shows the periods over which average recruitment deviation parameters were calculated.

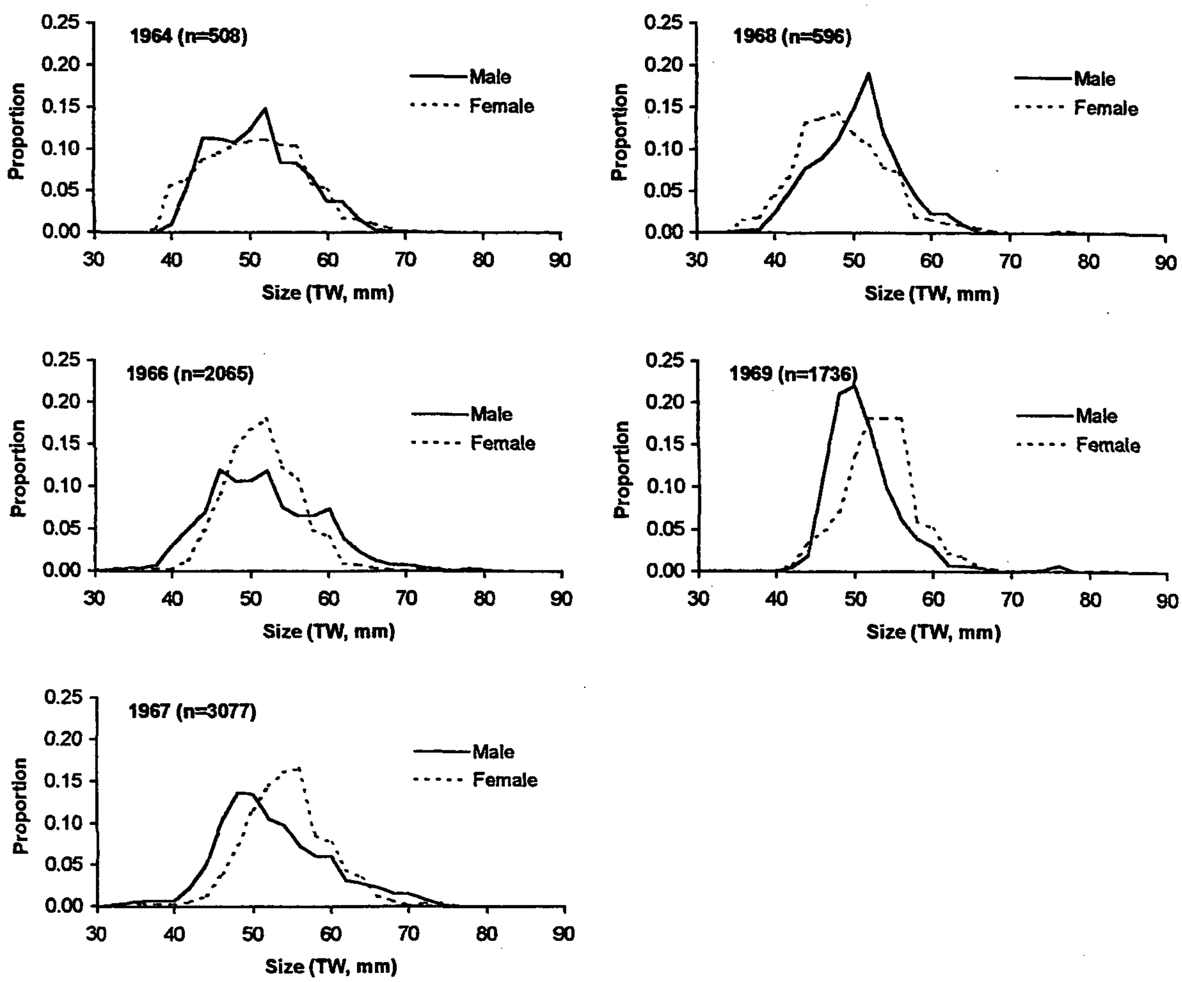


Figure 1: Five years of historical proportions-at-size from Fiordland published by Street (1970). The proportional frequencies have been calculated by digitising from the published graph and the lengths have been converted from total length in inches to tail width in mm using the conversion factors provided in Table 6. Frequencies have been converted from bins of 0.5 inches to bins of 2 mm tail width for inclusion in the model.

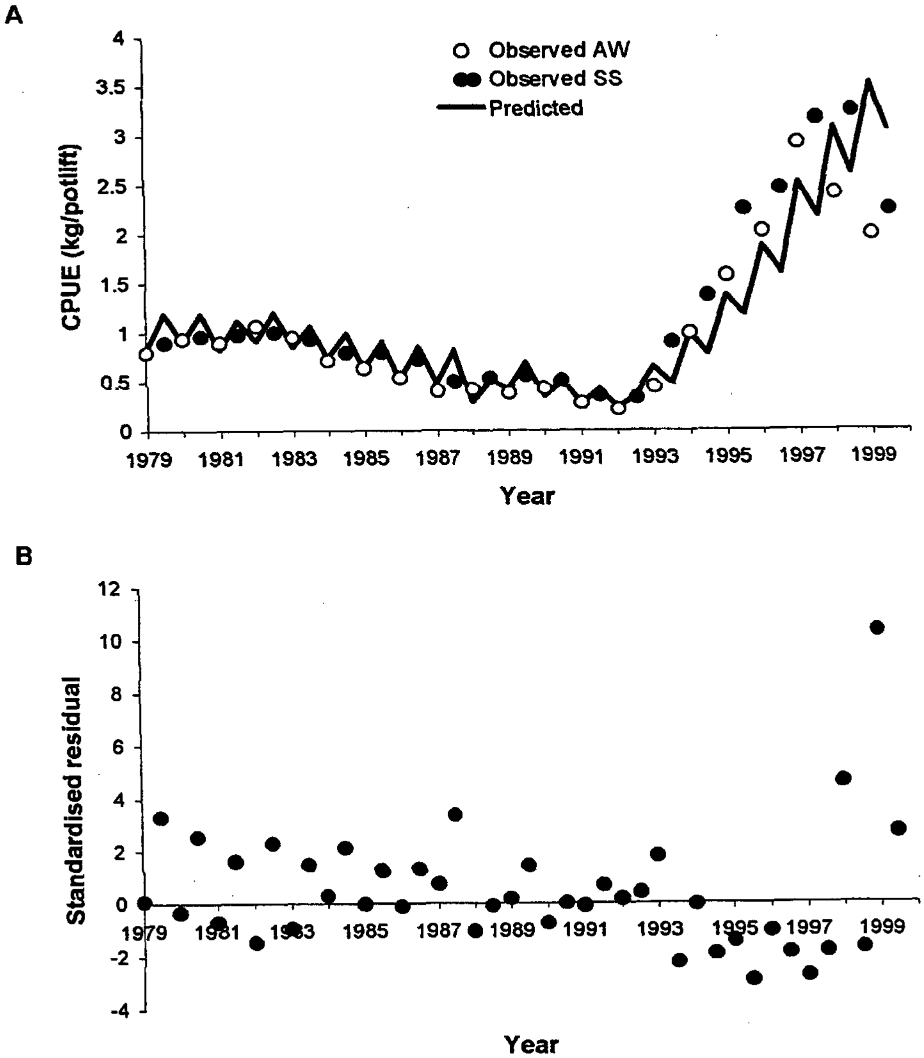


Figure 2: **[Upper panel] Fit to the CPUE biomass indices for the CRA 3 base case assessment; [Lower panel] Residuals from the fit to the CPUE biomass indices for the CRA 3 base case assessment. AW: autumn-winter season; SS: spring-summer season.**

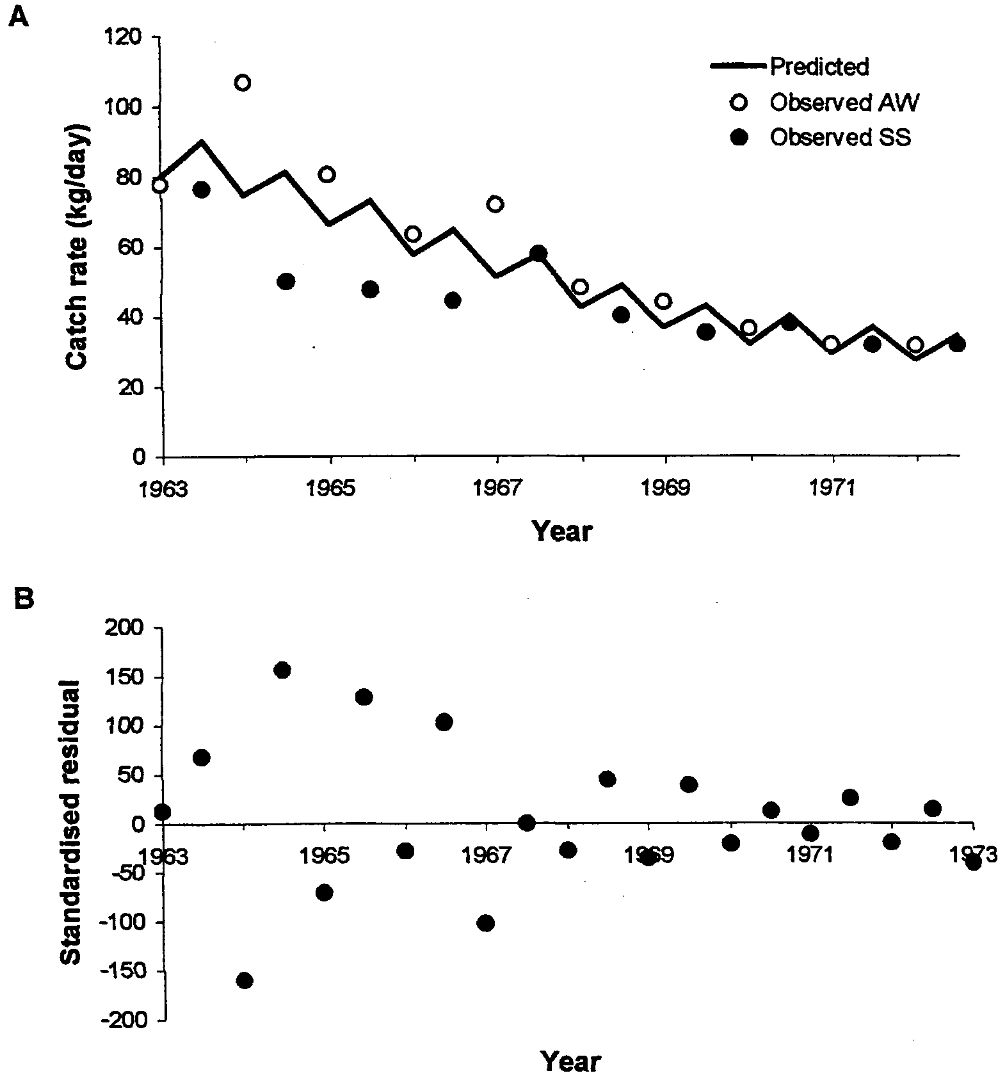


Figure 3: [Upper panel] Fit to the historical unstandardised catch rate (CR) biomass indices for the CRA 3 base case assessment; [Lower panel] Residuals from the fit to the historical unstandardised catch rate (CR) biomass indices for the CRA 3 base case assessment. AW, autumn-winter season; SS, spring-summer season.

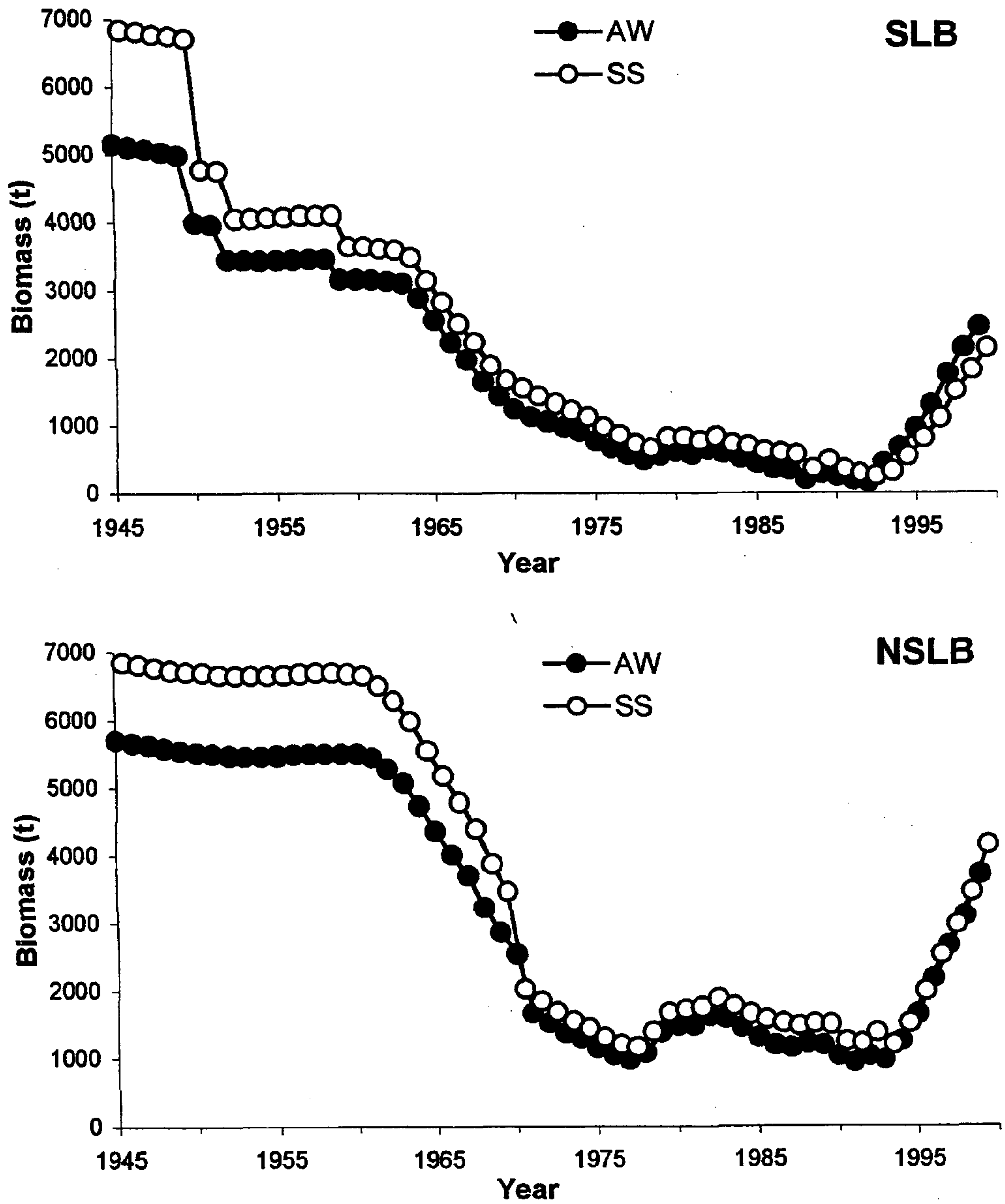


Figure 4: **Biomass trajectories for CRA 3 base case assessment. [upper panel] biomass based on vulnerabilities constrained by regulations (SLB: Eq 16); [lower panel] biomass based on vulnerabilities not constrained by regulations (NSLB: Eq 20). AW, autumn-winter season; SS, spring-summer season.**

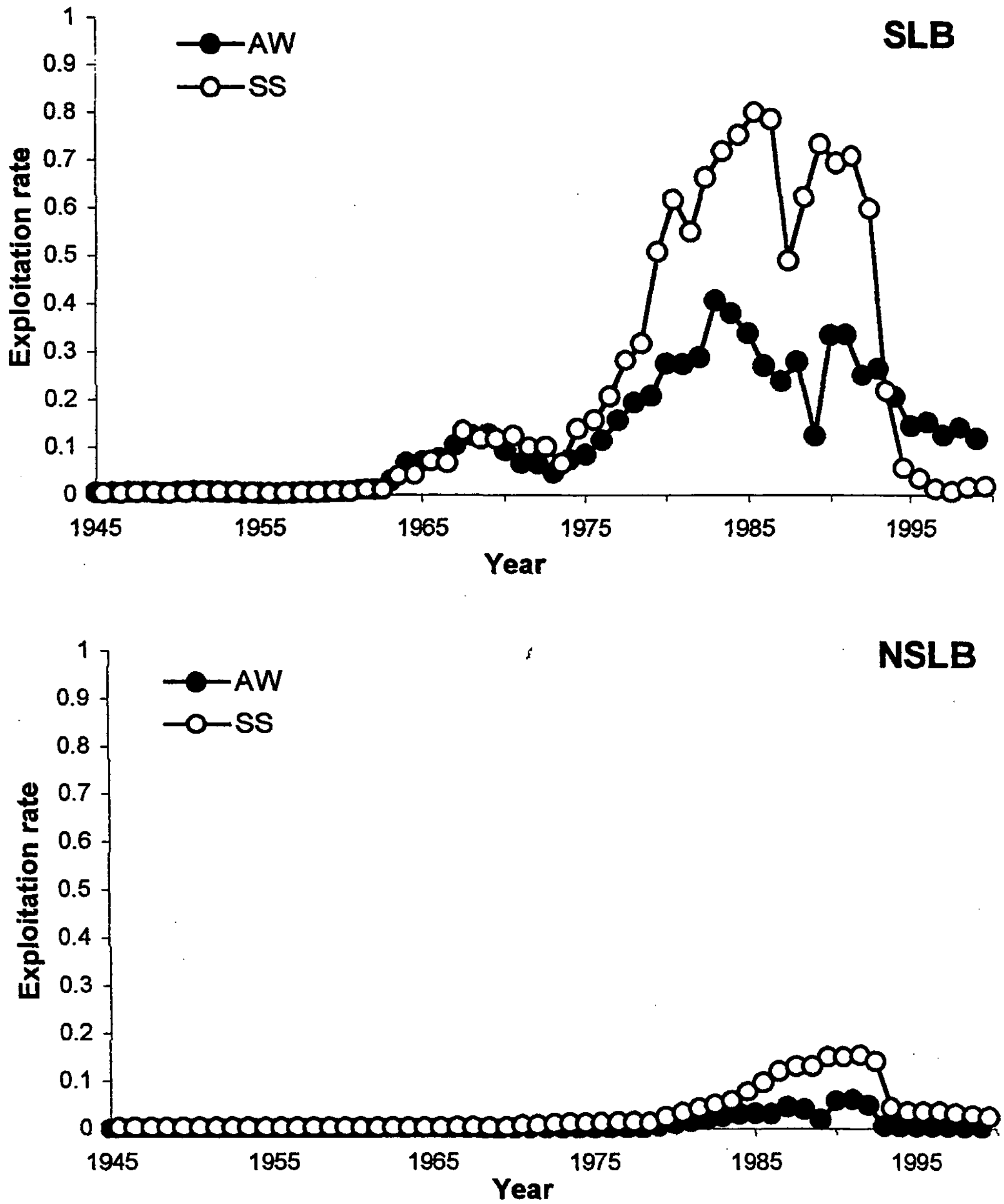


Figure 5: **Exploitation rate trajectories for CRA 3 base case assessment. [upper panel] exploitation rates using catches and vulnerabilities constrained by regulations (SLB); [lower panel] exploitation rates using catches and vulnerabilities not constrained by regulations (NSLB). AW: autumn-winter season; SS: spring-summer season.**

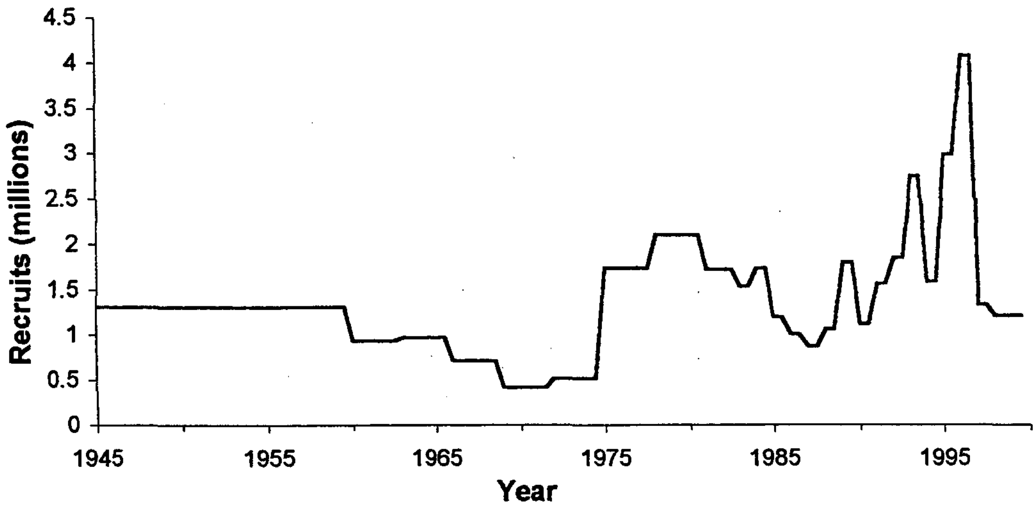


Figure 6: Estimated recruitment by year for the CRA 3 base case assessment.

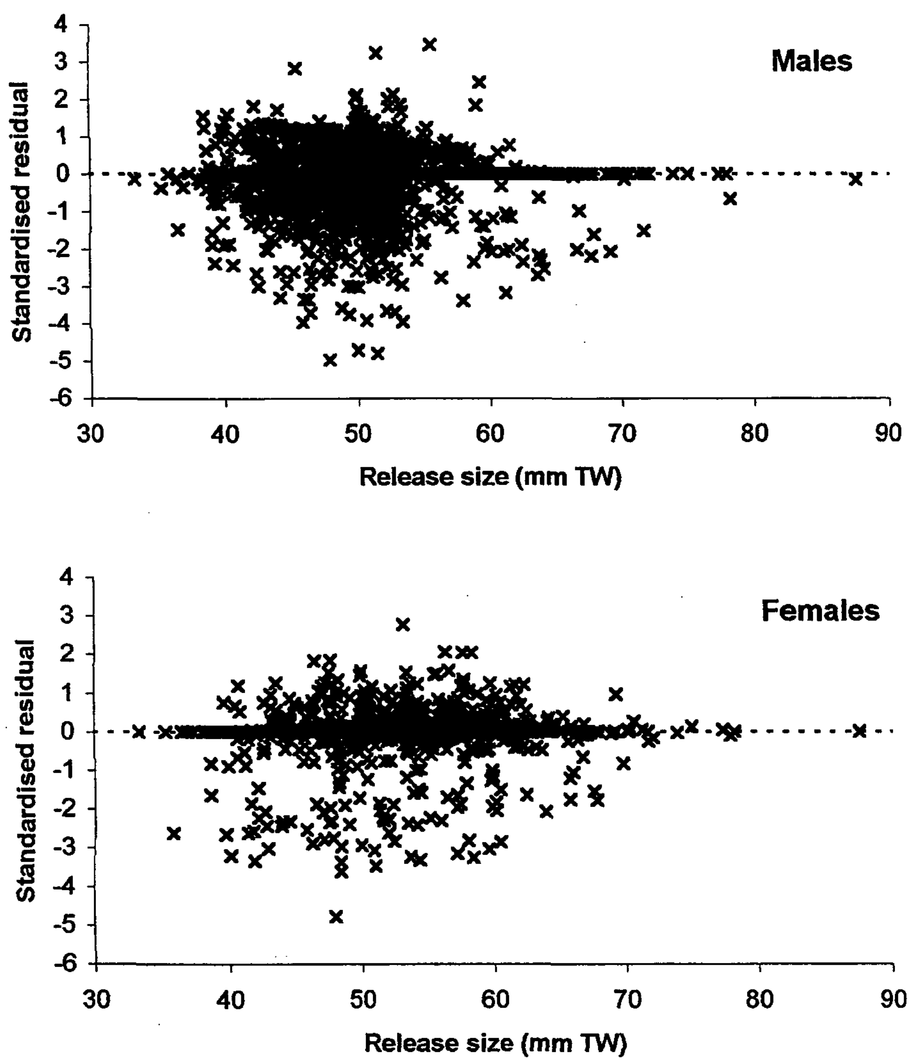


Figure 7: Standardised residuals ([predicted tag growth – observed tag growth]/estimated standard deviation) from the fit to the growth sub-model from the CRA 3 base case assessment. [Upper panel] males; [Lower panel] females.

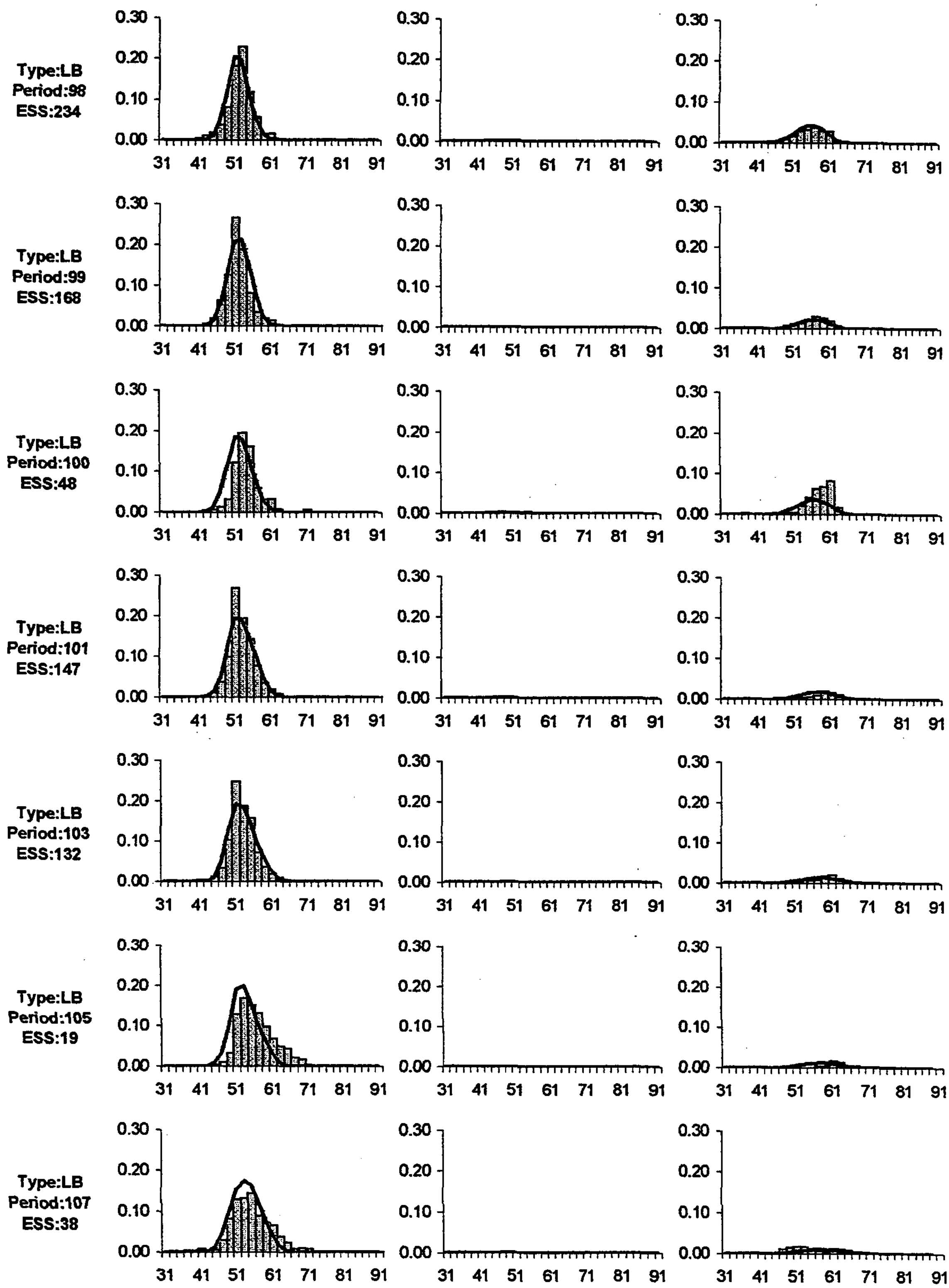
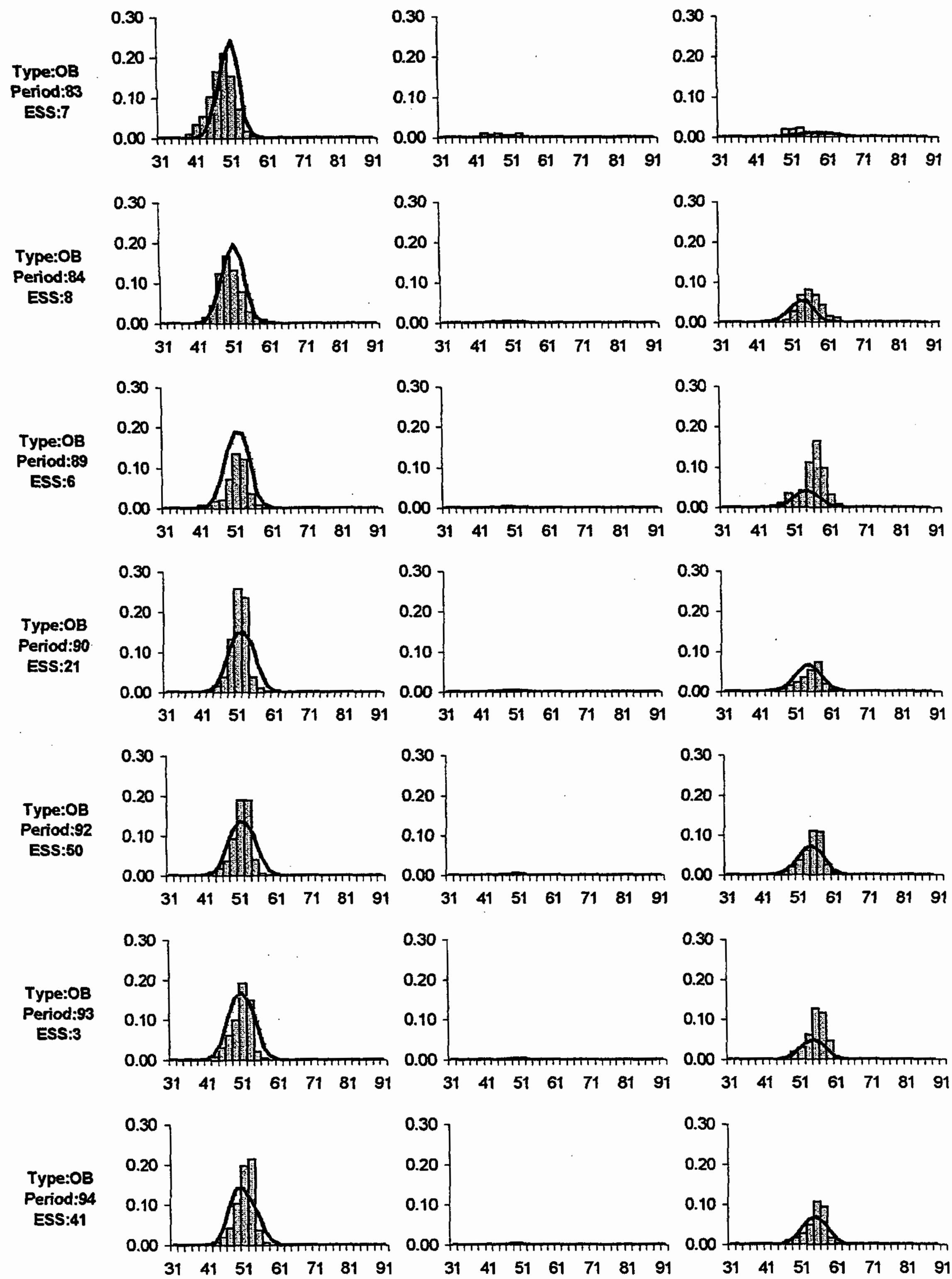


Figure 8: **Fit to the size frequency data for the CRA 3 base case assessment by period, sex category, and data source type. [Left column] males; [Centre column] immature females; [Right column] mature females. Observed data are shown as vertical bars and the model predictions are shown as a solid line. For each row, the information on the left is data type (LB - logbook, OB - observer sampling, HI - historical data), model period (AW 1945 = 1), and effective sample size.**



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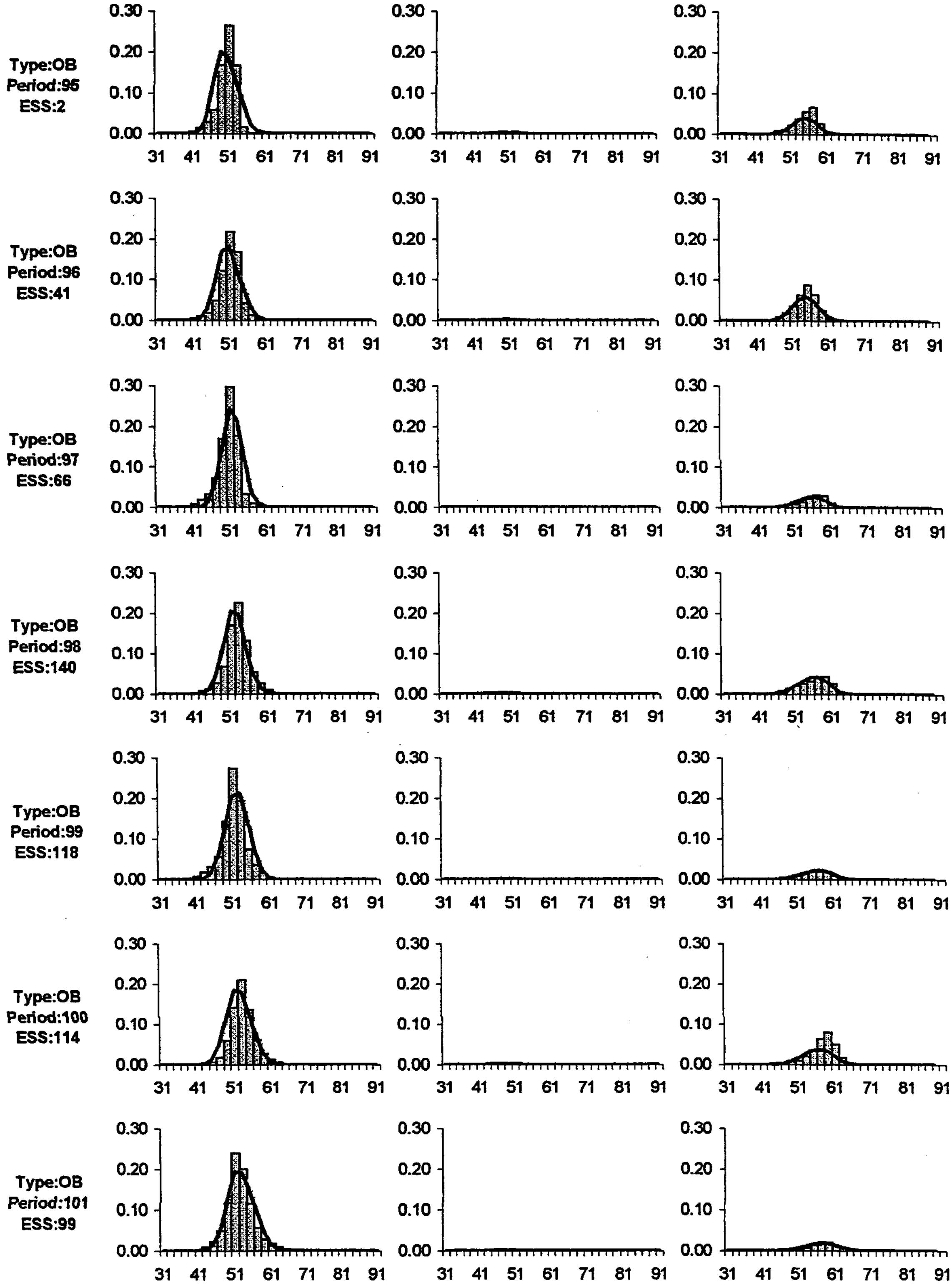

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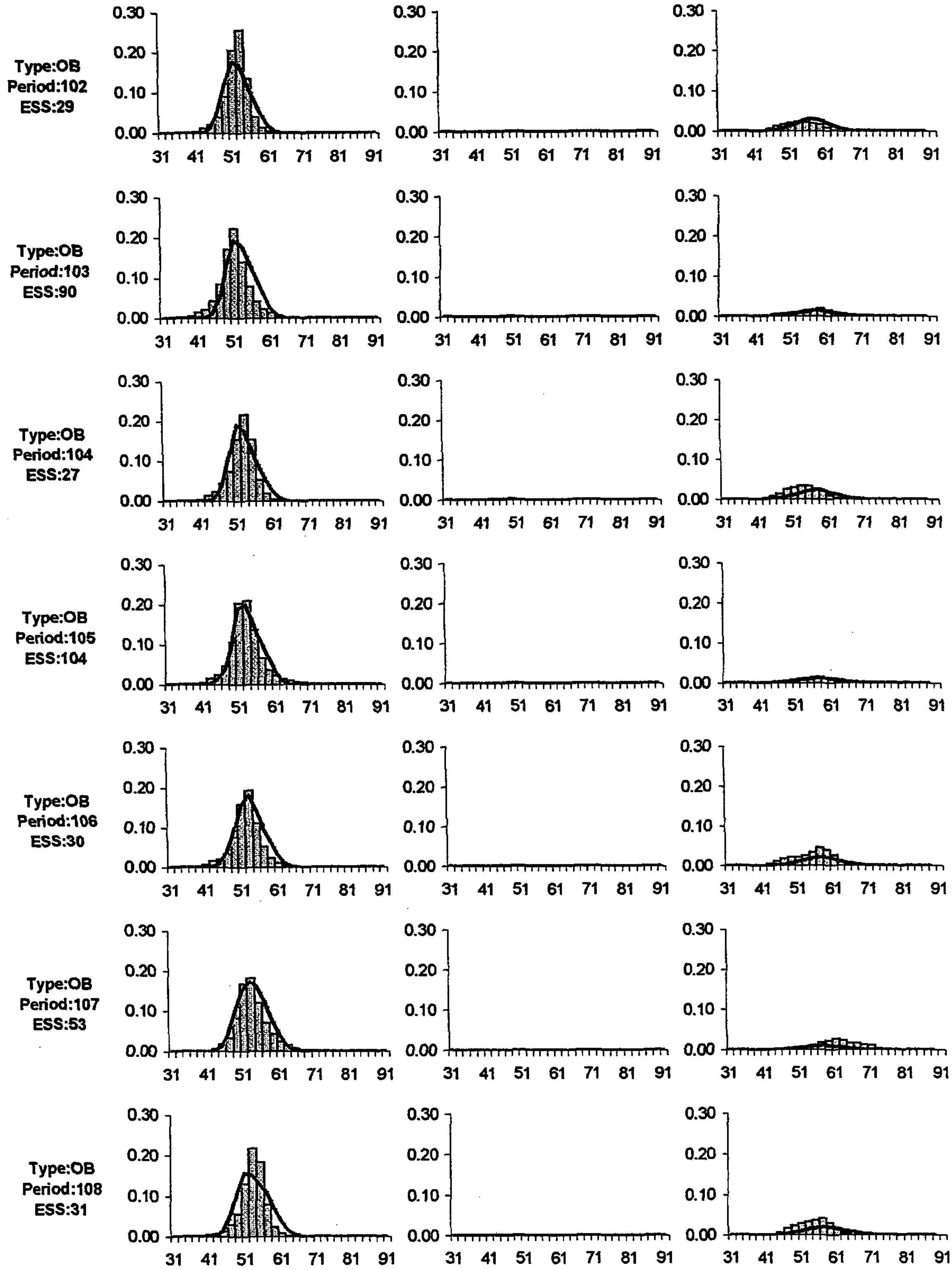

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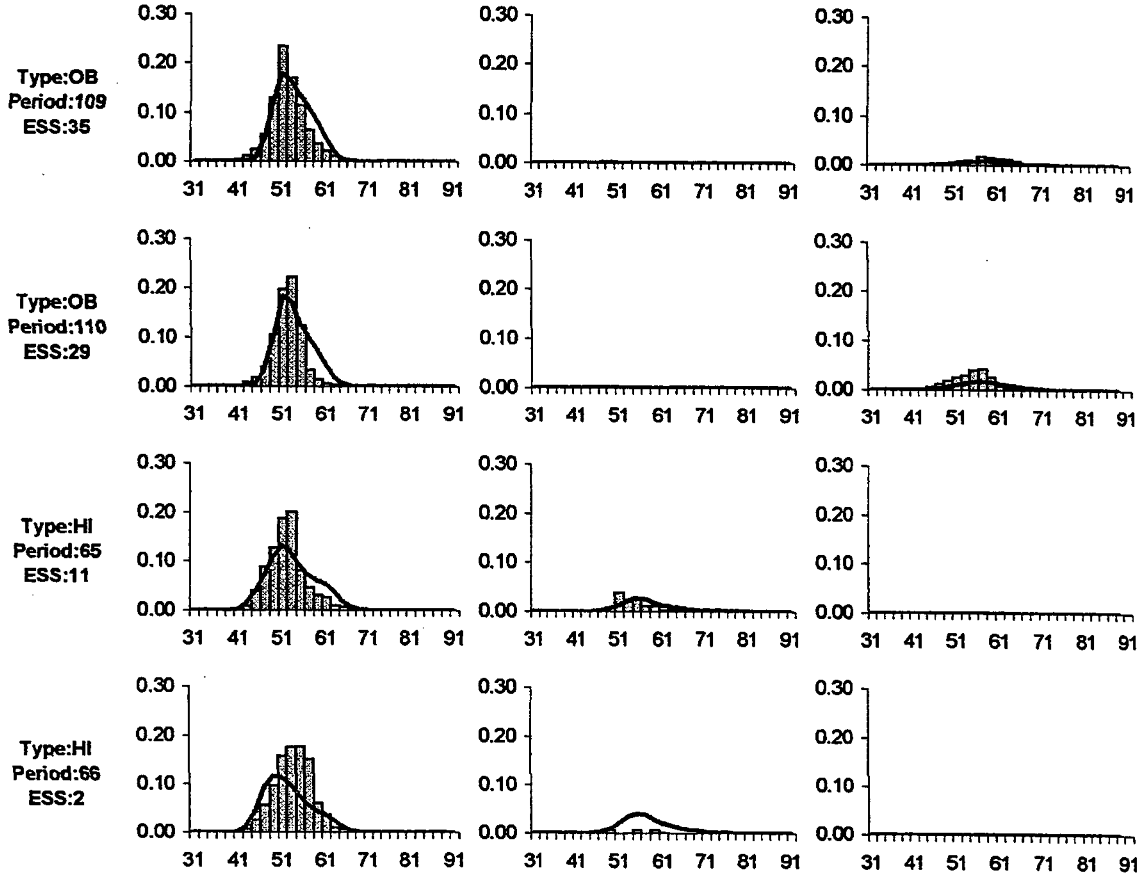

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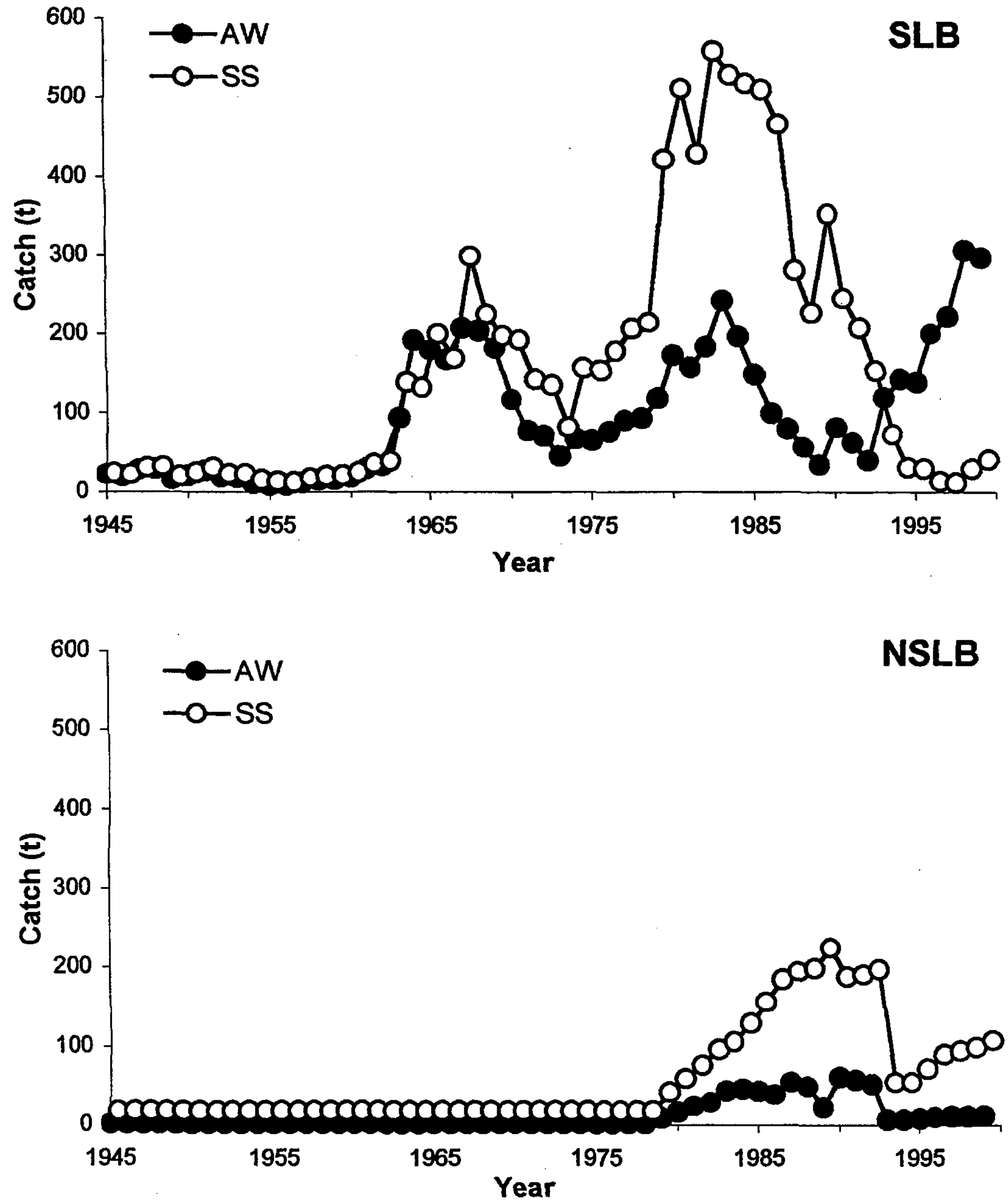


Figure 9: **Catch trajectories for CRA 3 assessment. [Upper panel] catch constrained by regulations (SLB); [Lower panel] catch not constrained by regulations (NSLB). AW, autumn-winter season; SS, spring-summer season.**

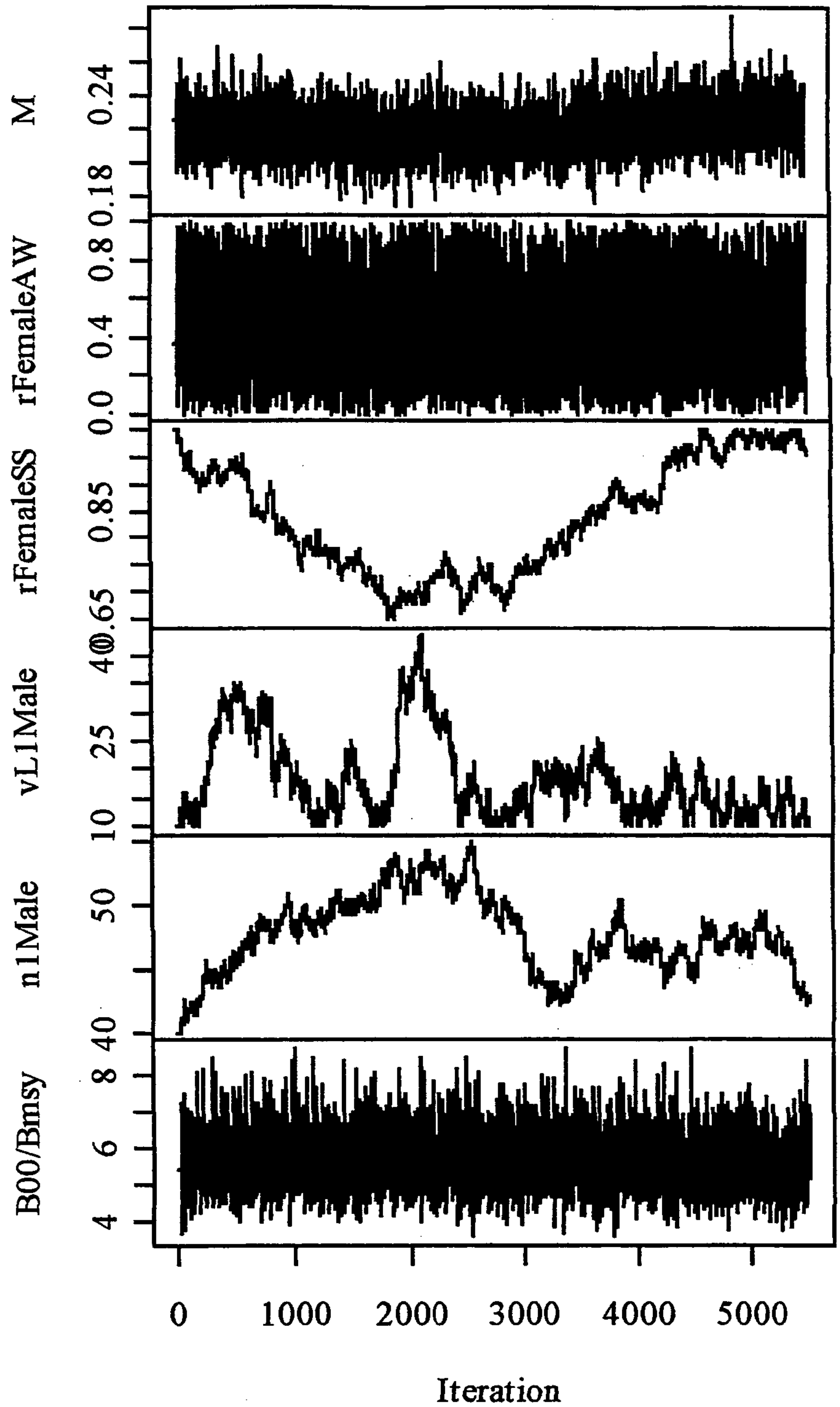


Figure 10: Examples of traces from the MCMC simulation for CRA 3 base case assessment. Parameters from top panel downwards: M; $r_{\mathrm{AW}}^{\mathrm{female}}$; r_{SS}^{female} ; $v_1^{male,l}$; η_1^{male} ;B_{00}/B_{MSY}

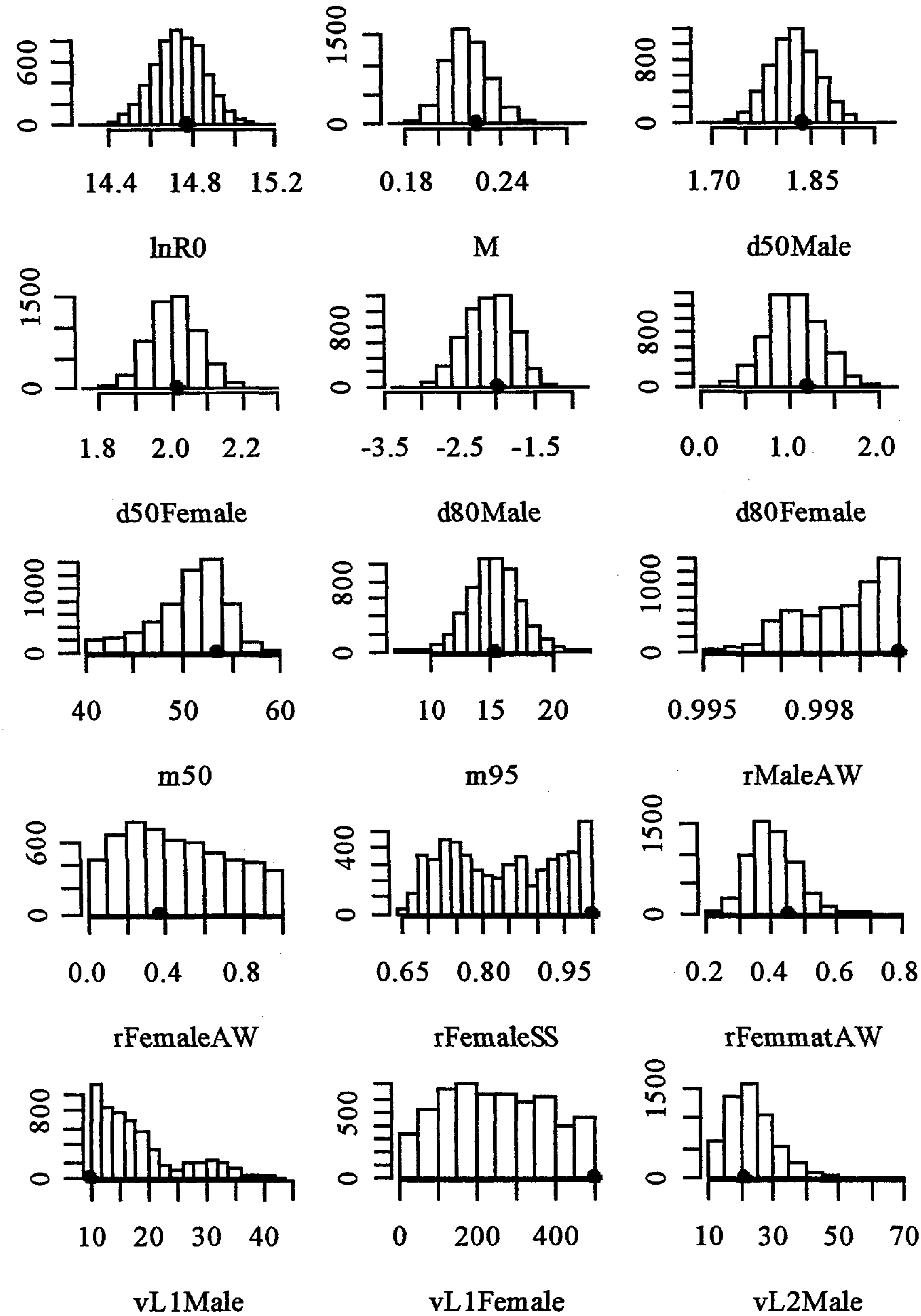
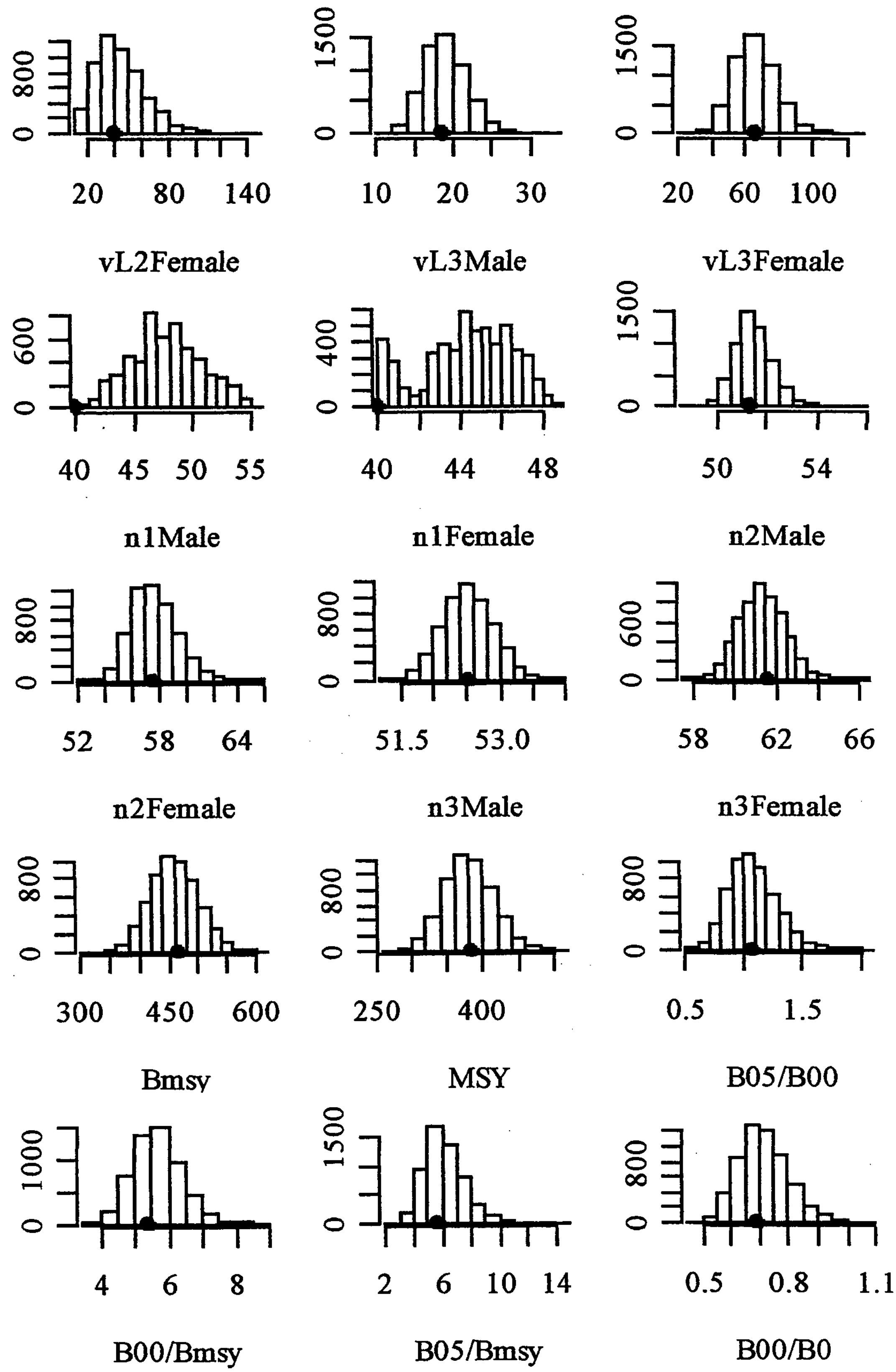


Figure 11: Posterior distributions of parameters and performance indicators for CRA 3 base case assessment. Parameters and performance indicators are in the same order as presented in Table 13. Note that the MPD estimate for each parameter or performance indicator is indicated by a dot on the x-axis.



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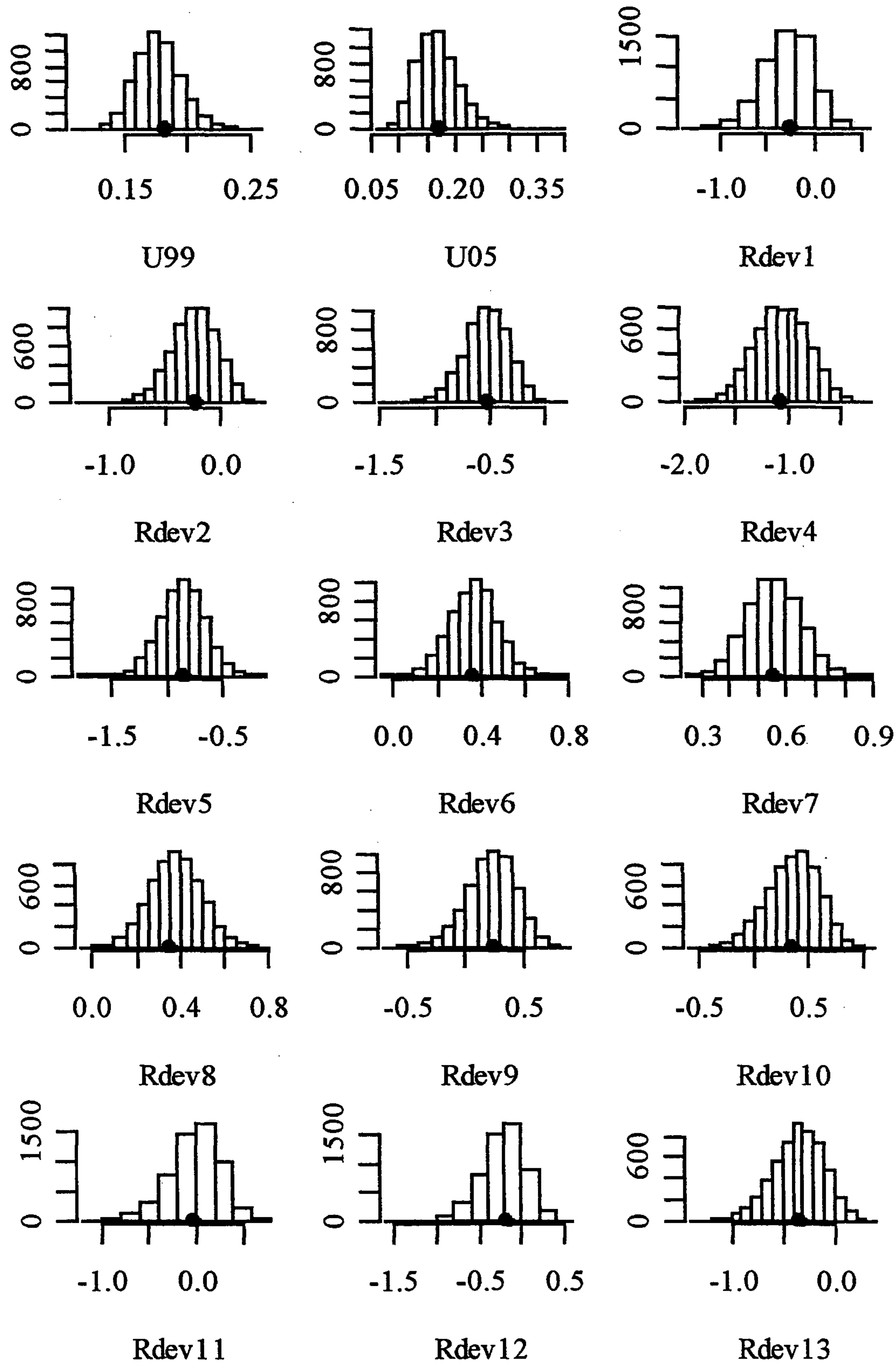

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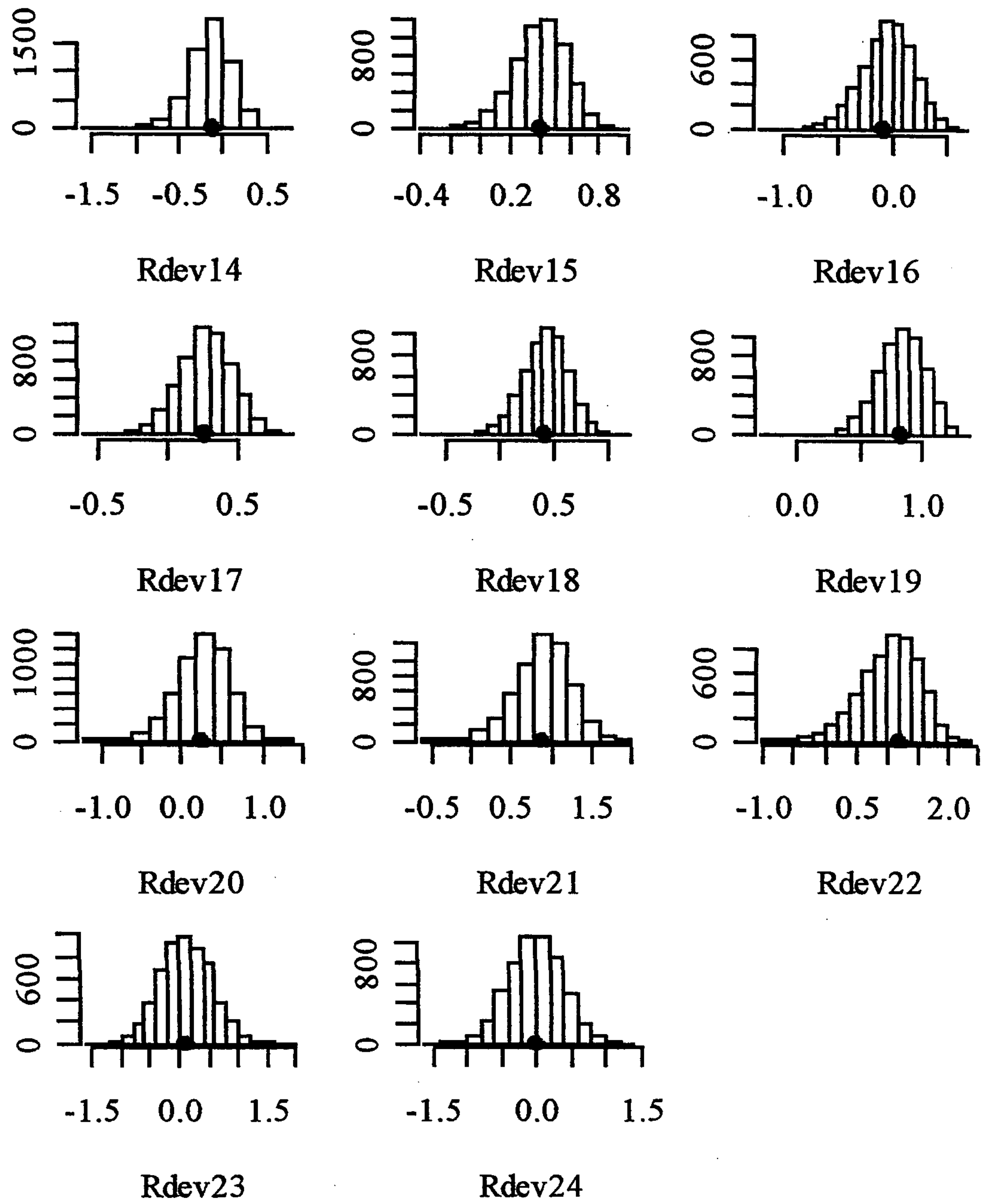


Figure 11 continued.

A

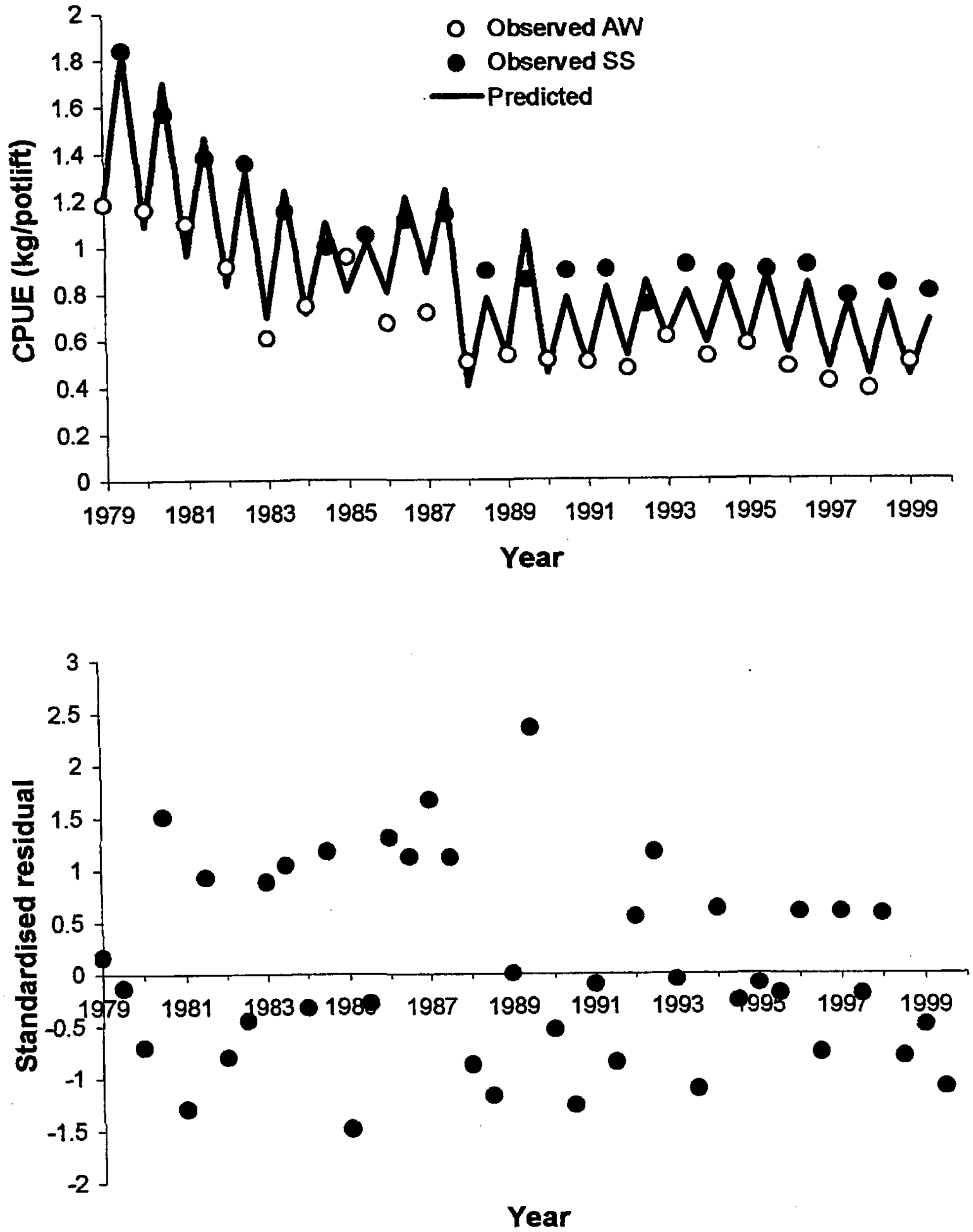


Figure 12: [Upper panel] Fit to the CPUE biomass indices for the NSS base case assessment; [Lower panel] Residuals from the fit to the CPUE biomass indices for the NSS base case assessment. AW: autumn-winter season; SS: spring-summer season.

A

B

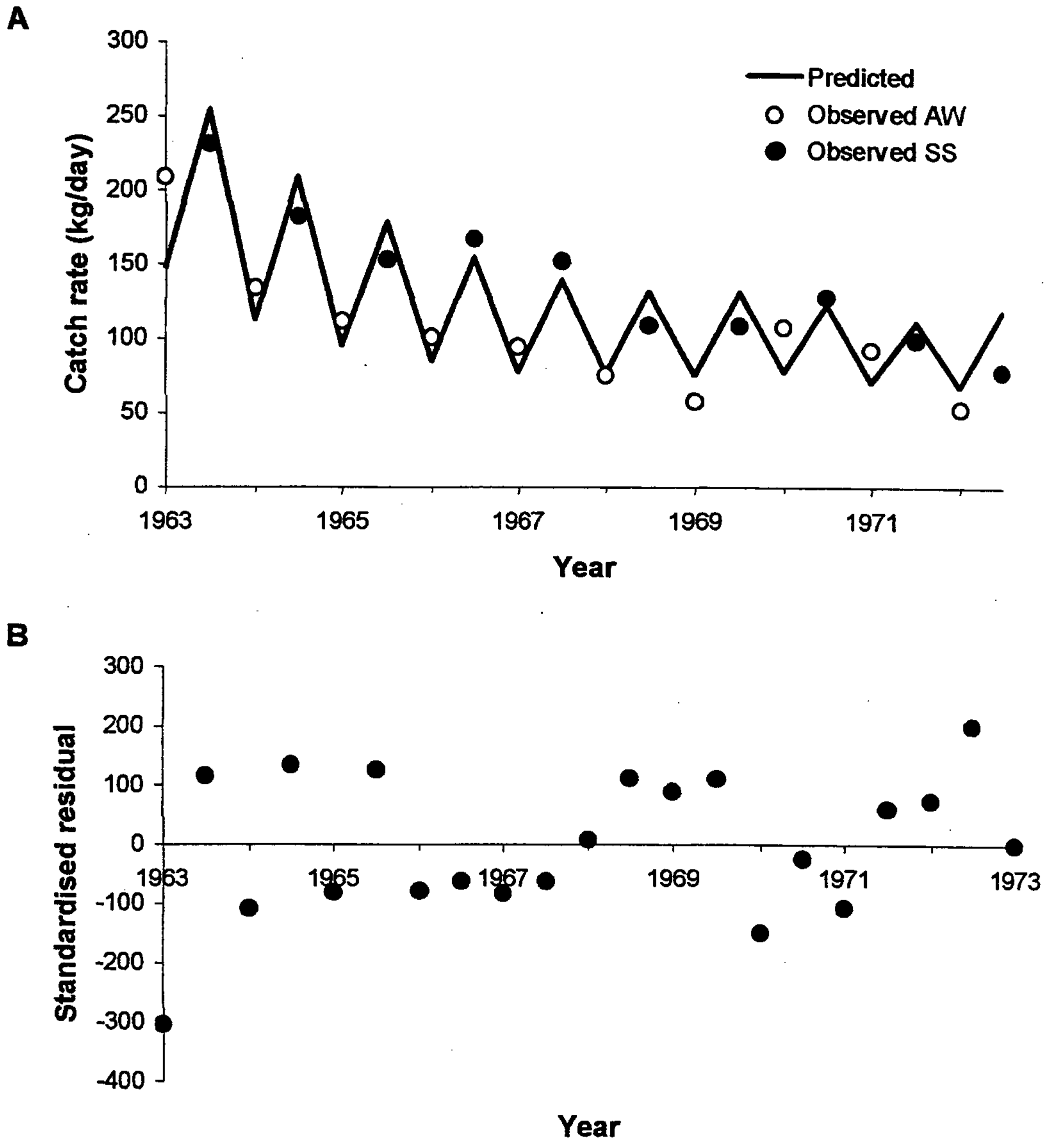


Figure 13: [Upper panel] Fit to the historical unstandardised catch rate (CR) biomass indices for the NSS base case assessment; [Lower panel] Residuals from the fit to the historical unstandardised catch rate (CR) biomass indices for the NSS base case assessment. AW, autumn-winter season; SS, spring-summer season.

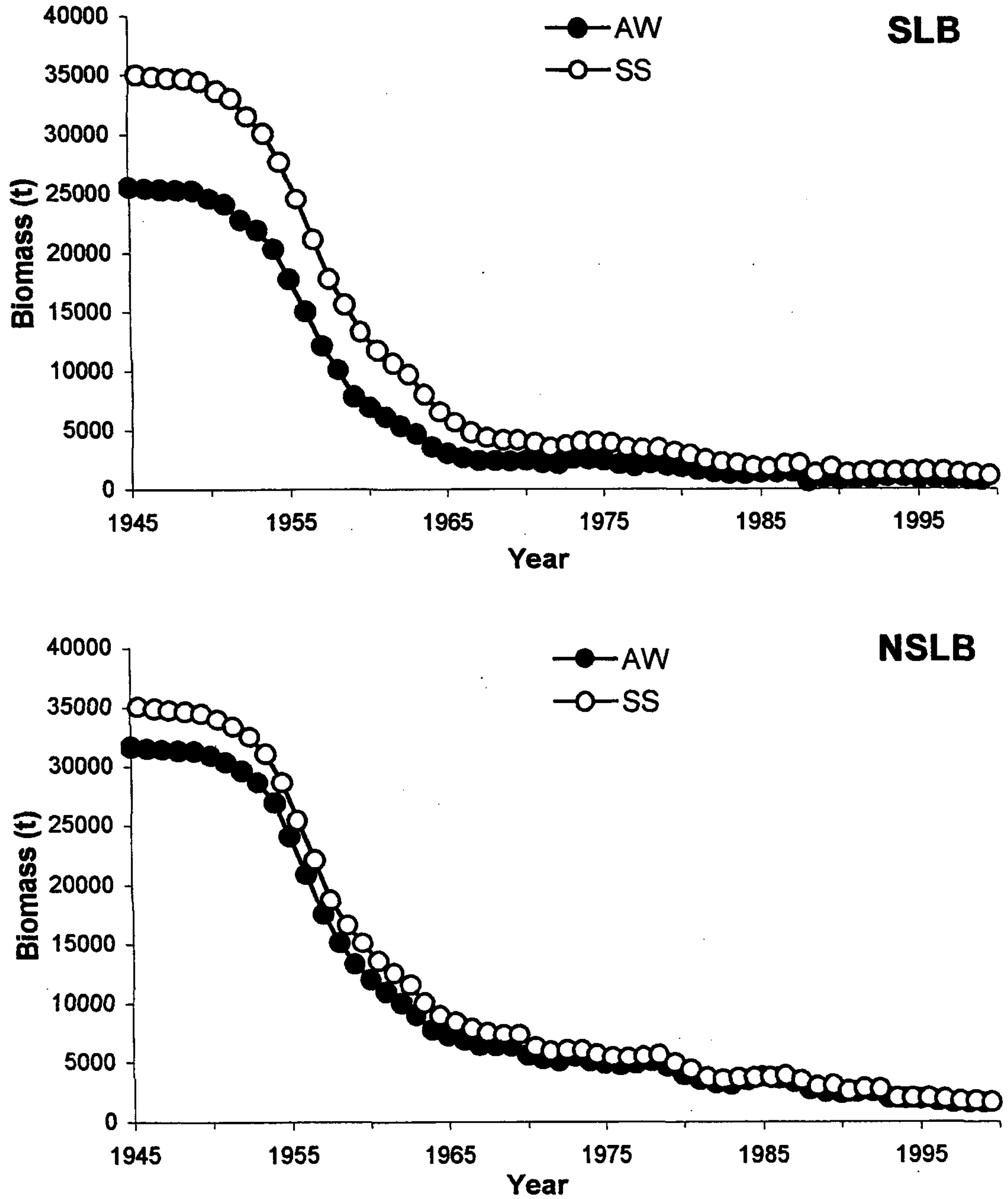


Figure 14: Biomass trajectories for NSS base case assessment. [upper panel] biomass based on vulnerabilities constrained by regulations (SLB: Eq 16); [lower panel] biomass based on vulnerabilities not constrained by regulations (NSLB: Eq 20). AW, autumn-winter season; SS, spring-summer season.

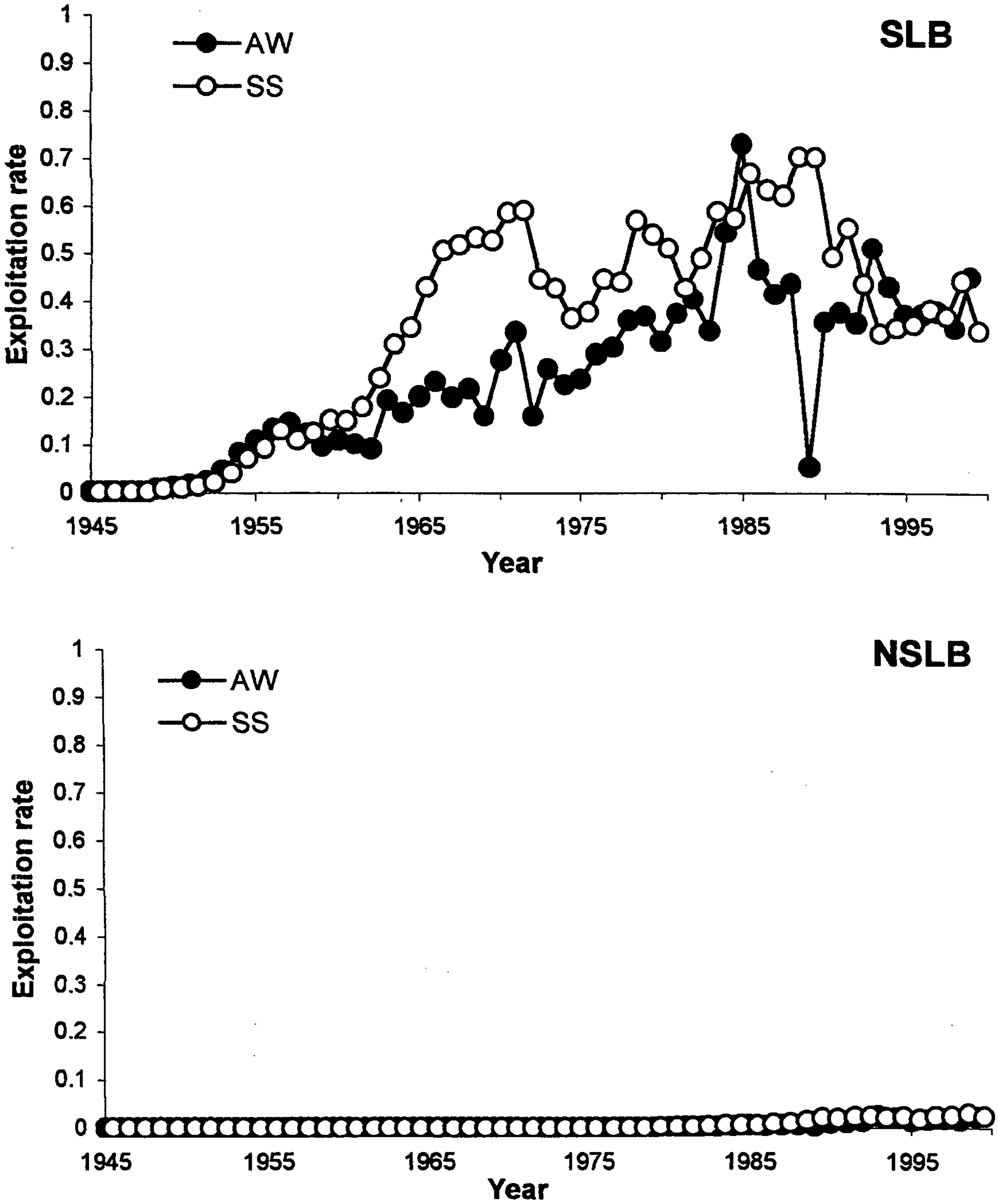


Figure 15: Exploitation rate trajectories for NSS base case assessment. [upper panel] exploitation rates using catches and vulnerabilities constrained by regulations (SLB); [lower panel] exploitation rates using catches and vulnerabilities not constrained by regulations (NSLB). AW, autumn-winter season; SS, spring-summer season.

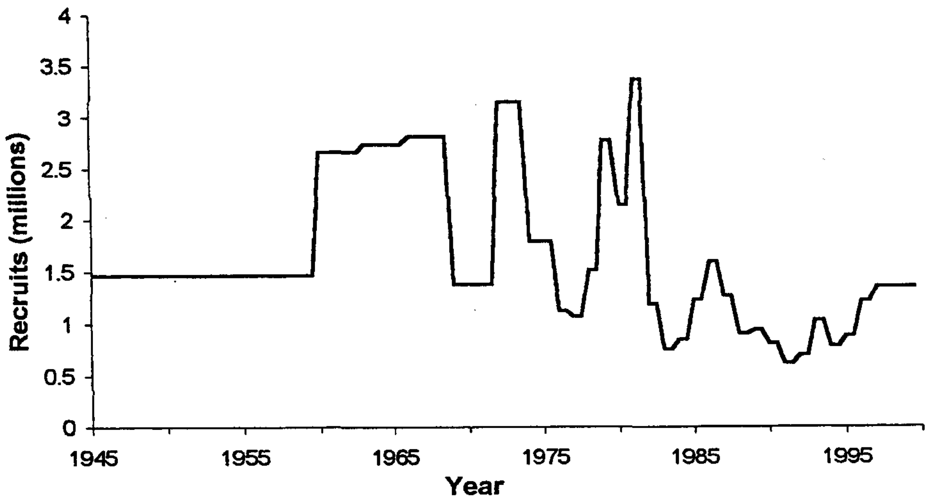


Figure 16: Estimated recruitment by year for the NSS base case assessment.

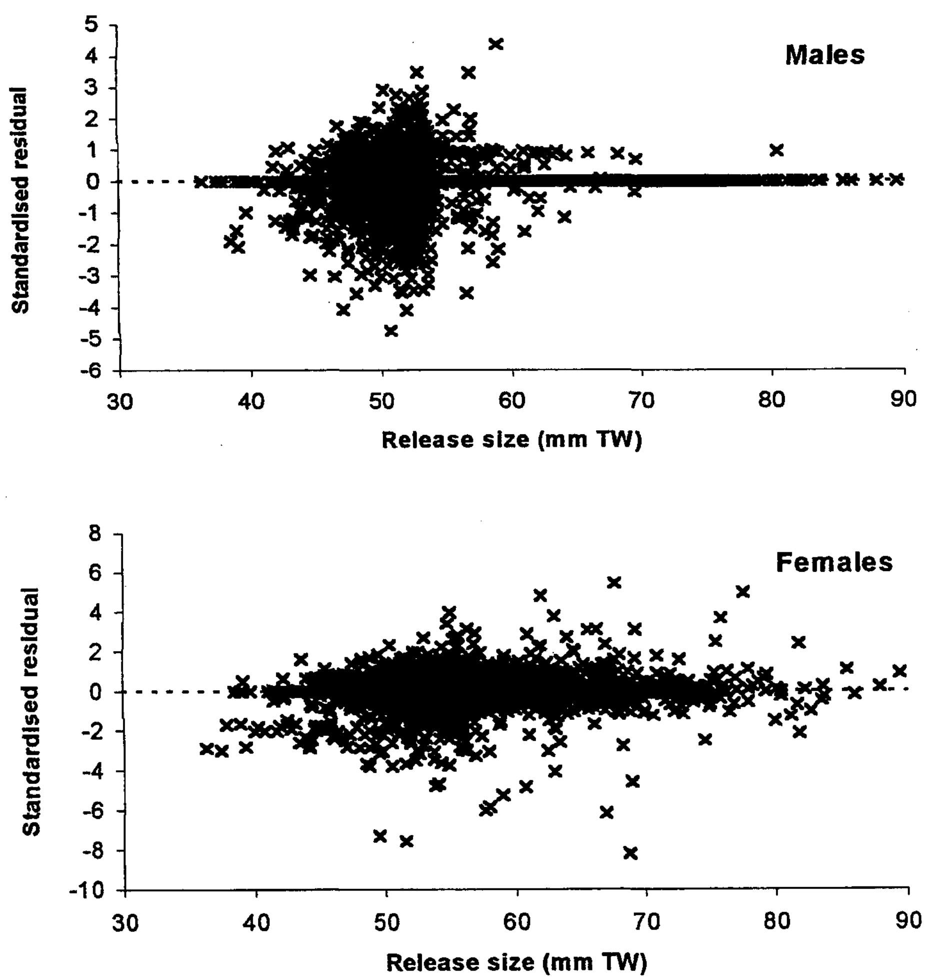


Figure 17: Standardised residuals ([predicted tag growth – observed tag growth]/estimated standard deviation) from the fit to the growth sub-model from the NSS base case assessment. [Upper panel] males; [Lower panel] females.

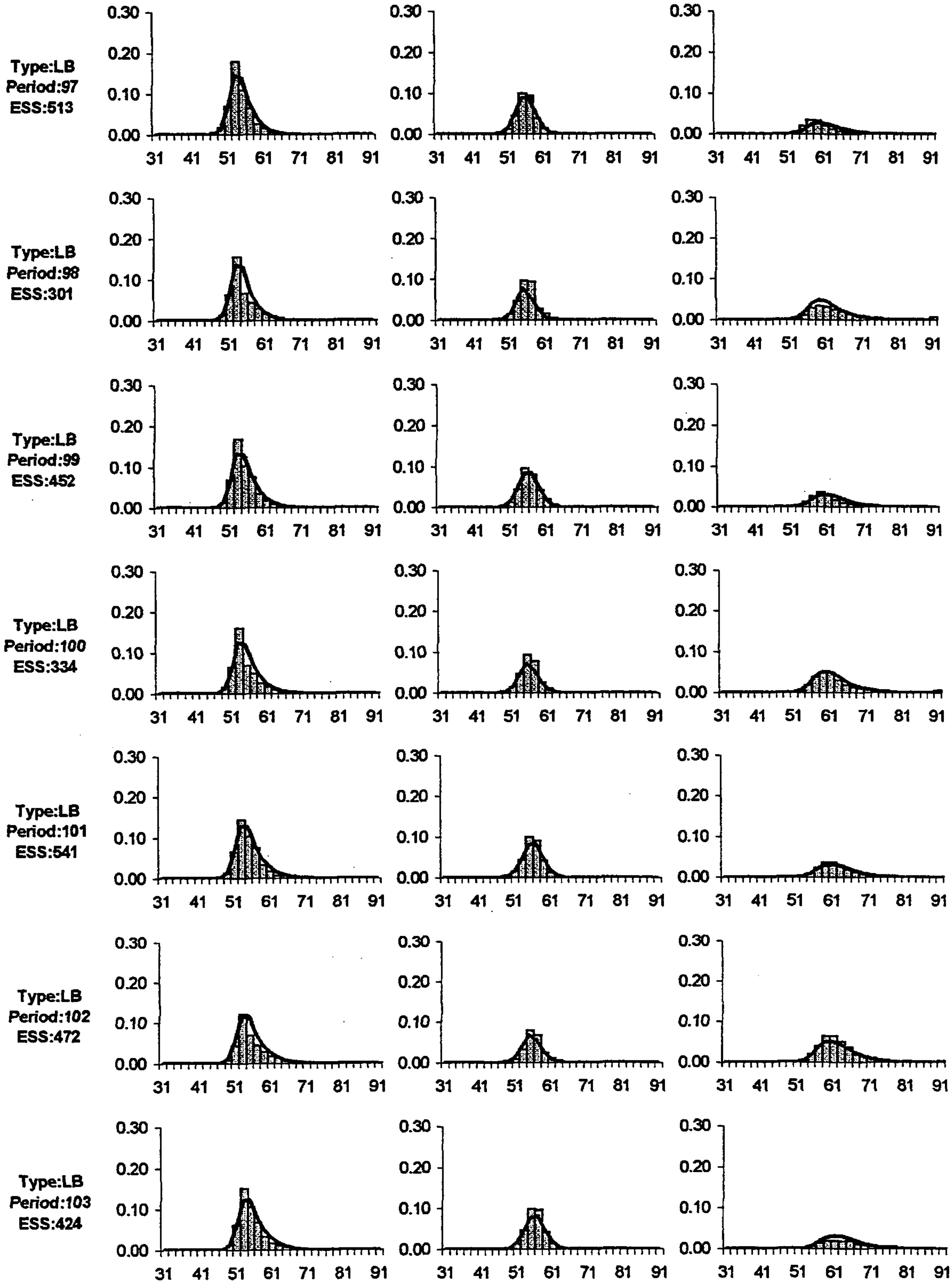
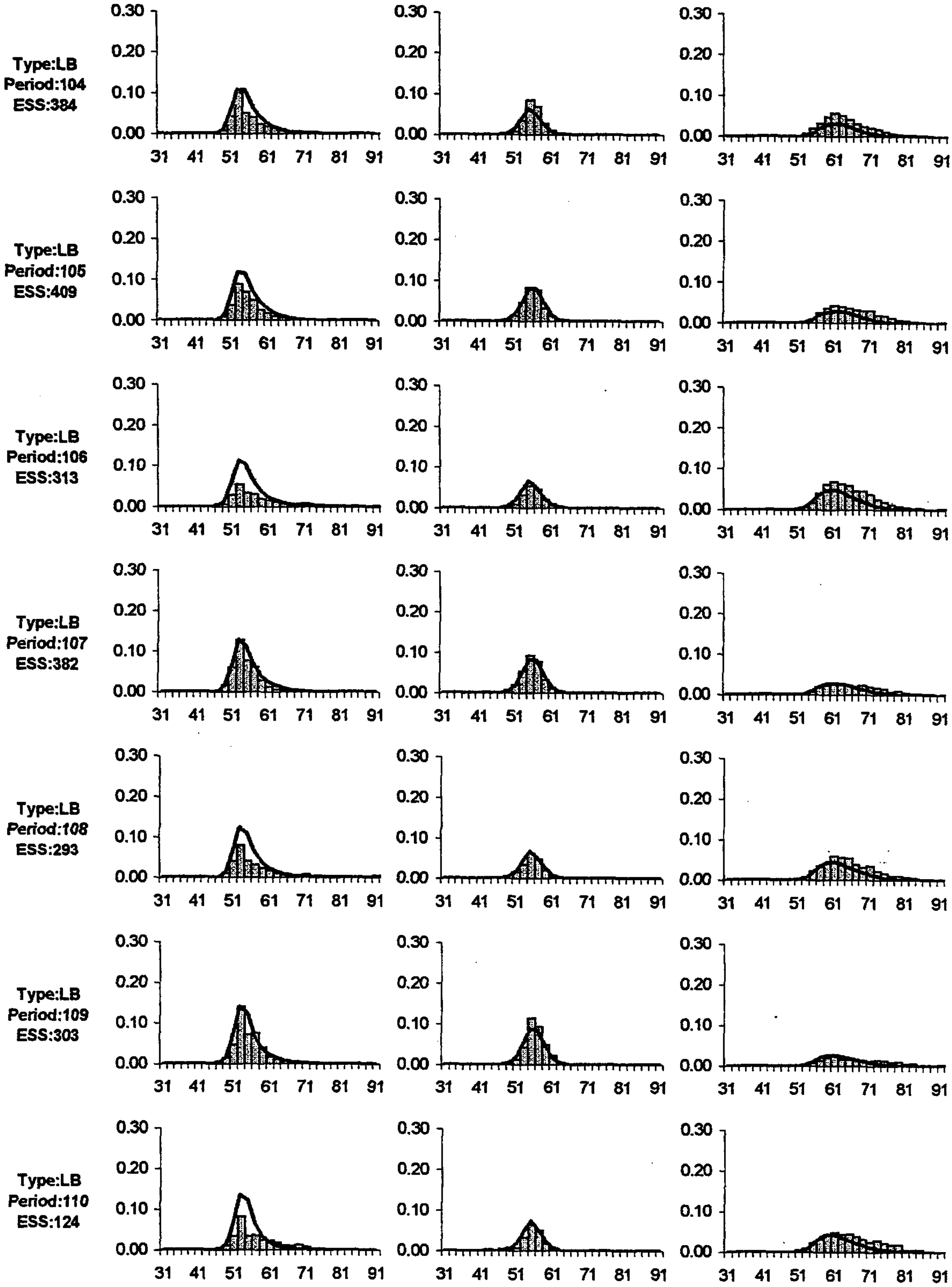


Figure 18: Fit to the size frequency data for the NSS base case assessment by period, sex category, and data source type. [Left column] males; [Centre column] immature females; [Right column] mature females. Observed data are shown as vertical bars and the model predictions are shown as a solid line. For each row, the information on the left is data type (LB - logbook, OB - observer sampling, HI - historical data), model period (AW 1945 = 1), and effective sample size.



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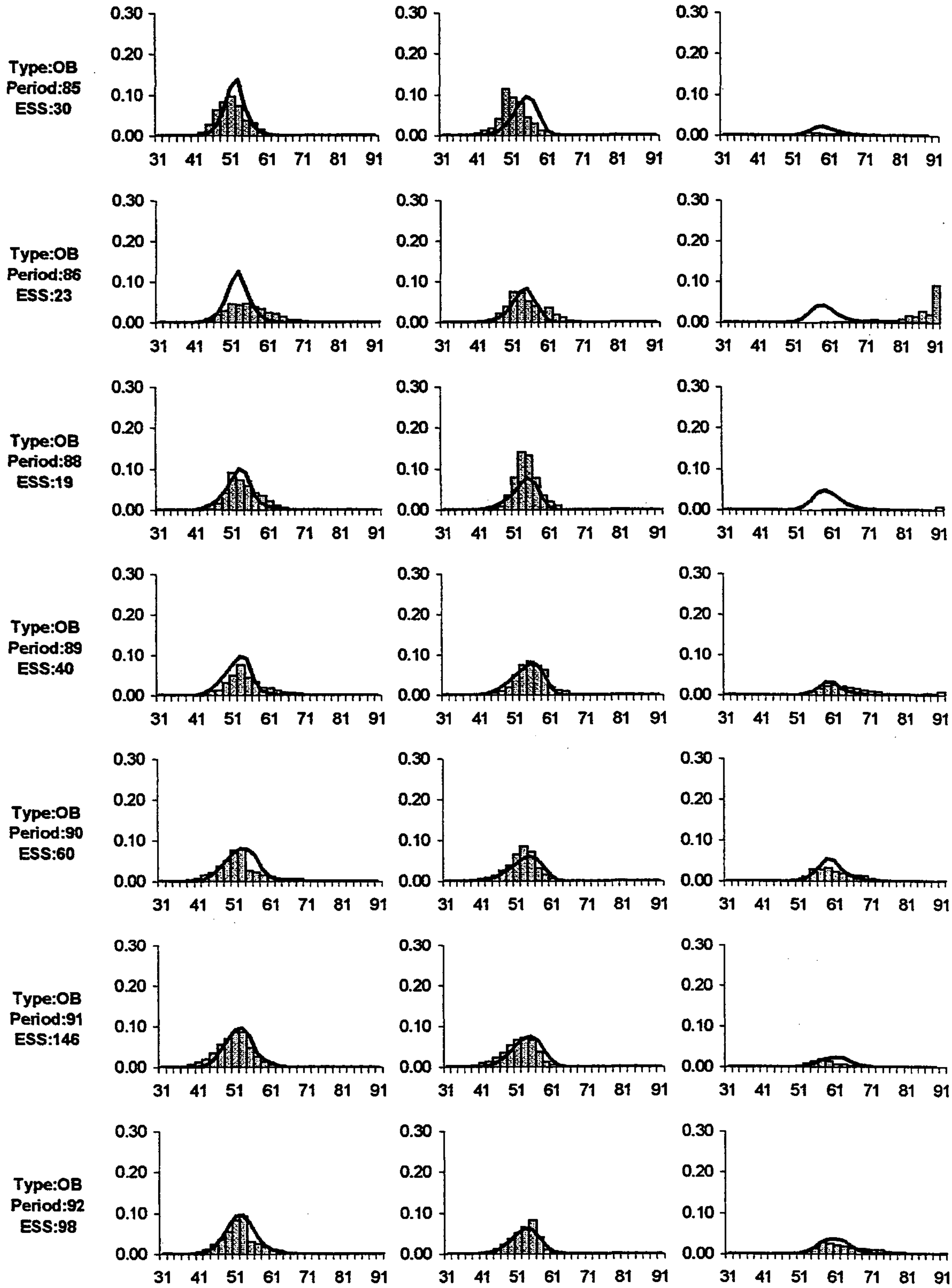

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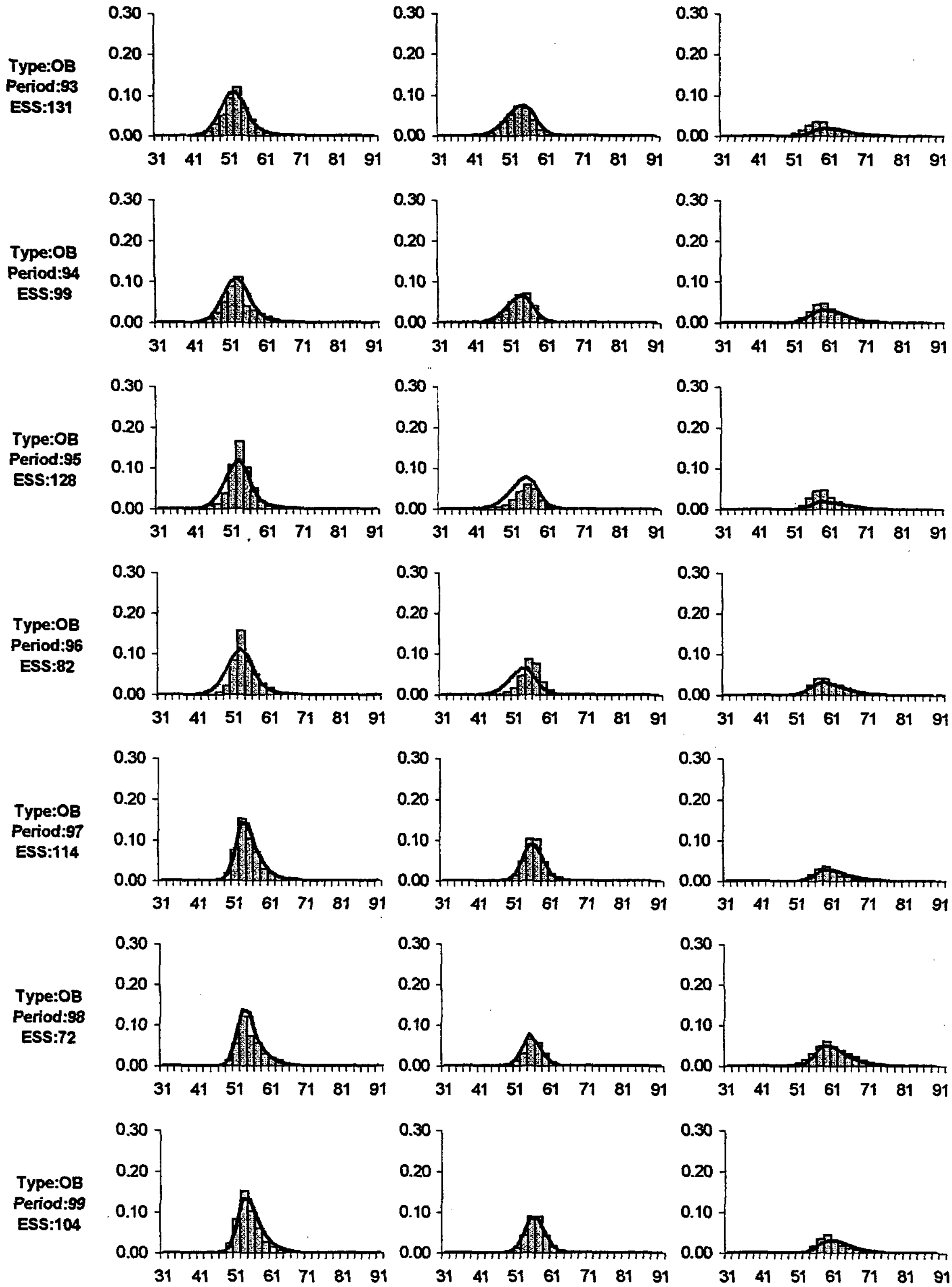

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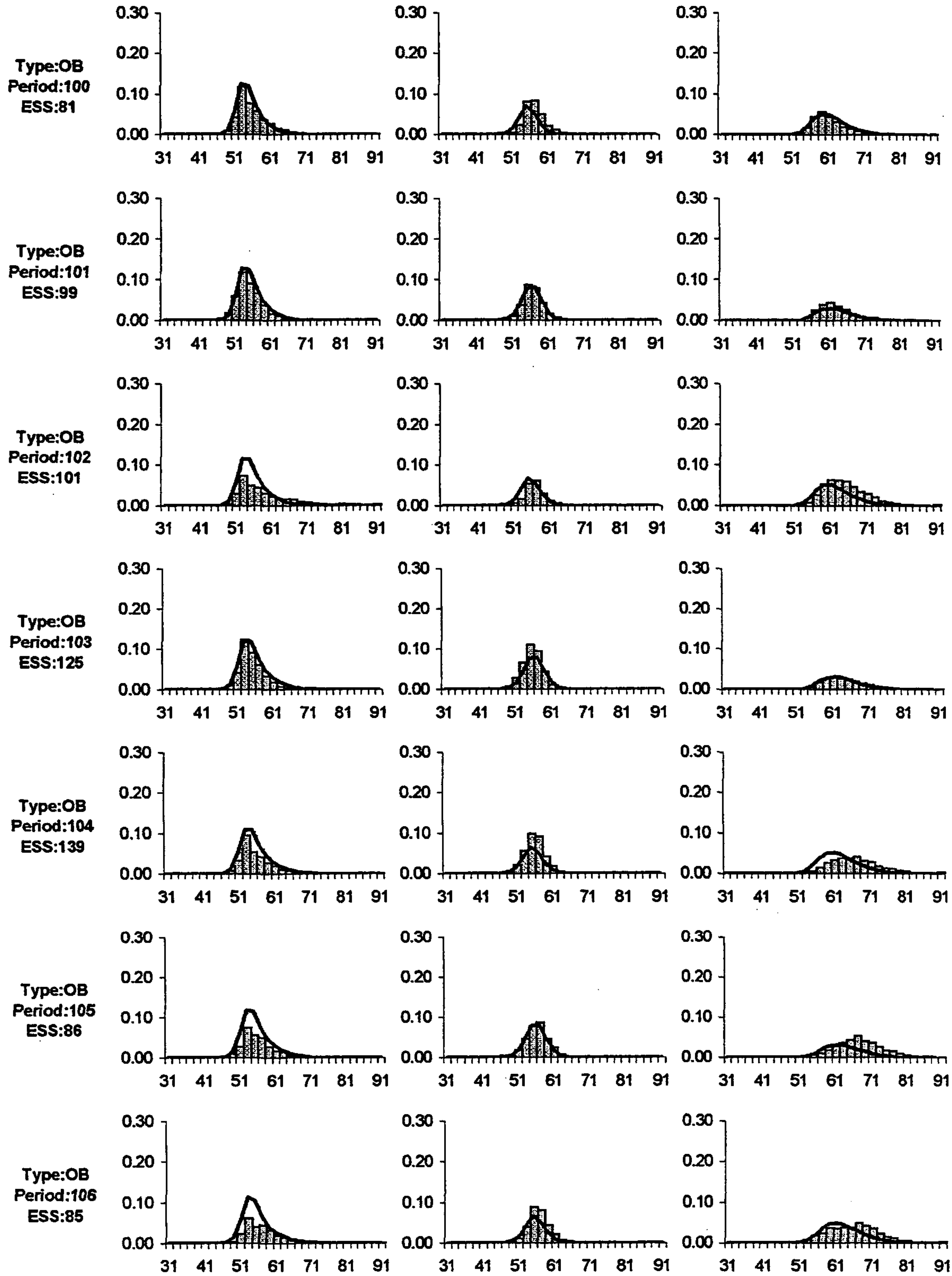

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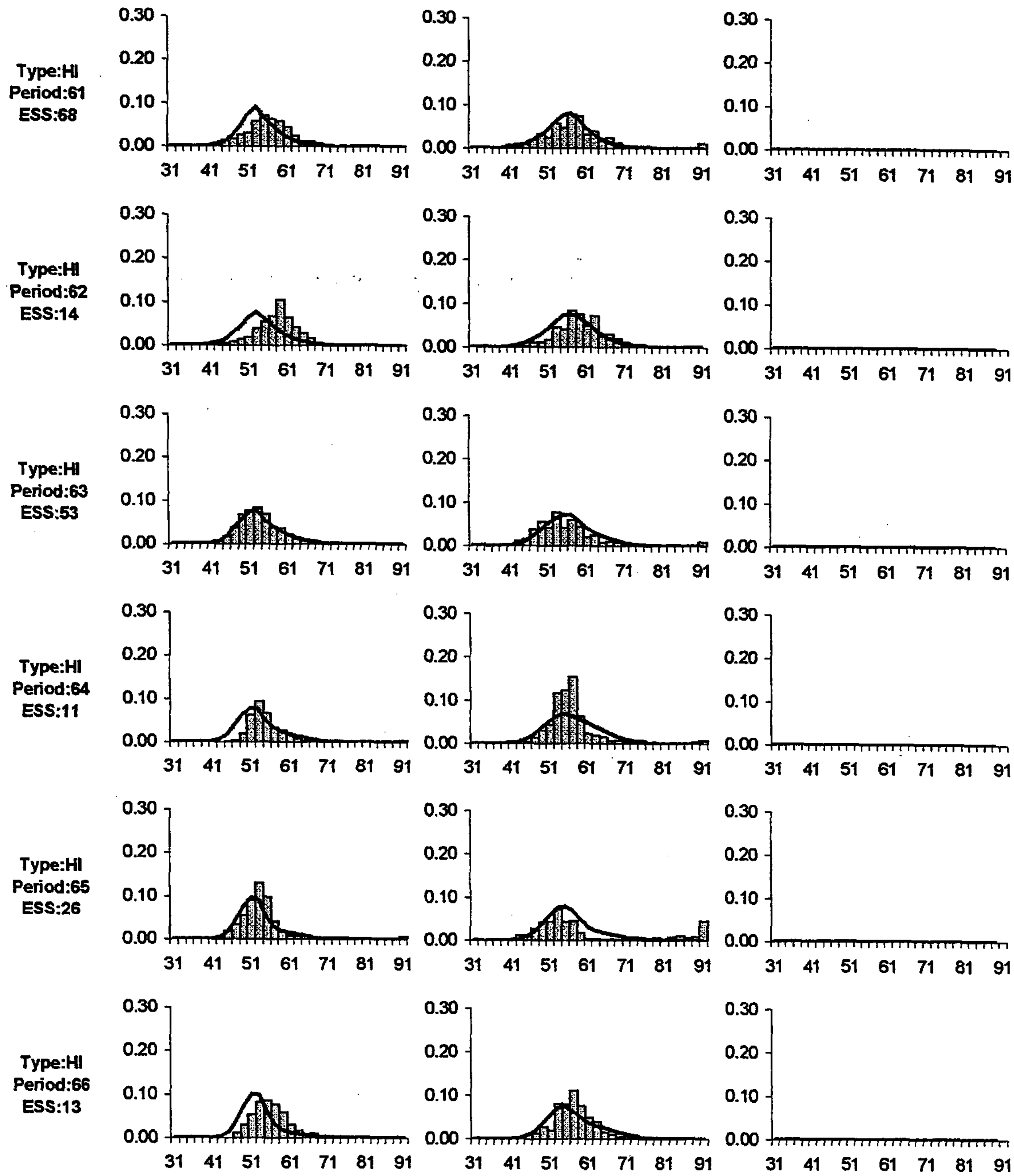

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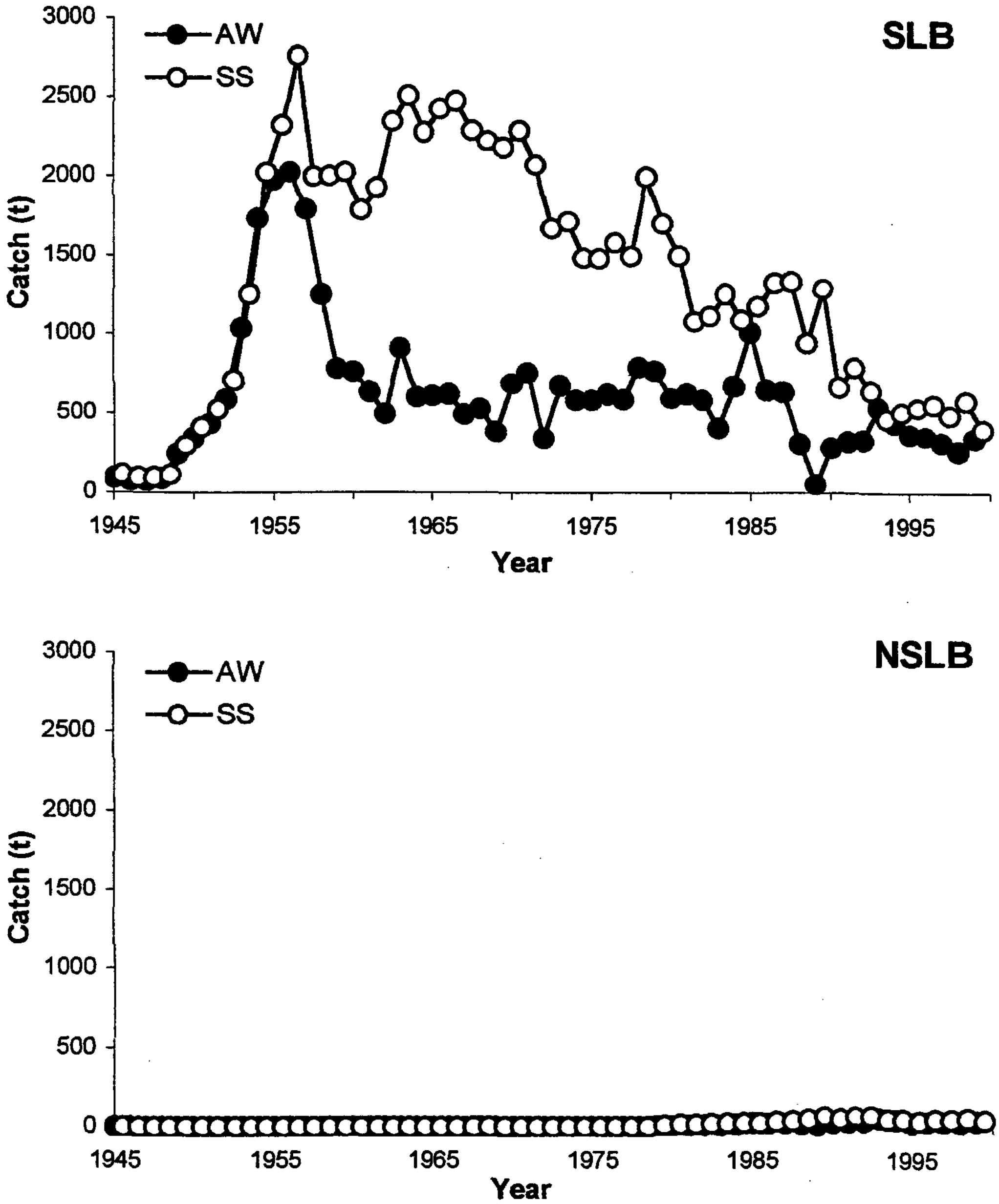


Figure 19: Catch trajectories for NSS assessment. [Upper panel] catch constrained by regulations (SLB); [Lower panel] catch not constrained by regulations (NSLB). AW, autumn-winter season; SS, spring-summer season.

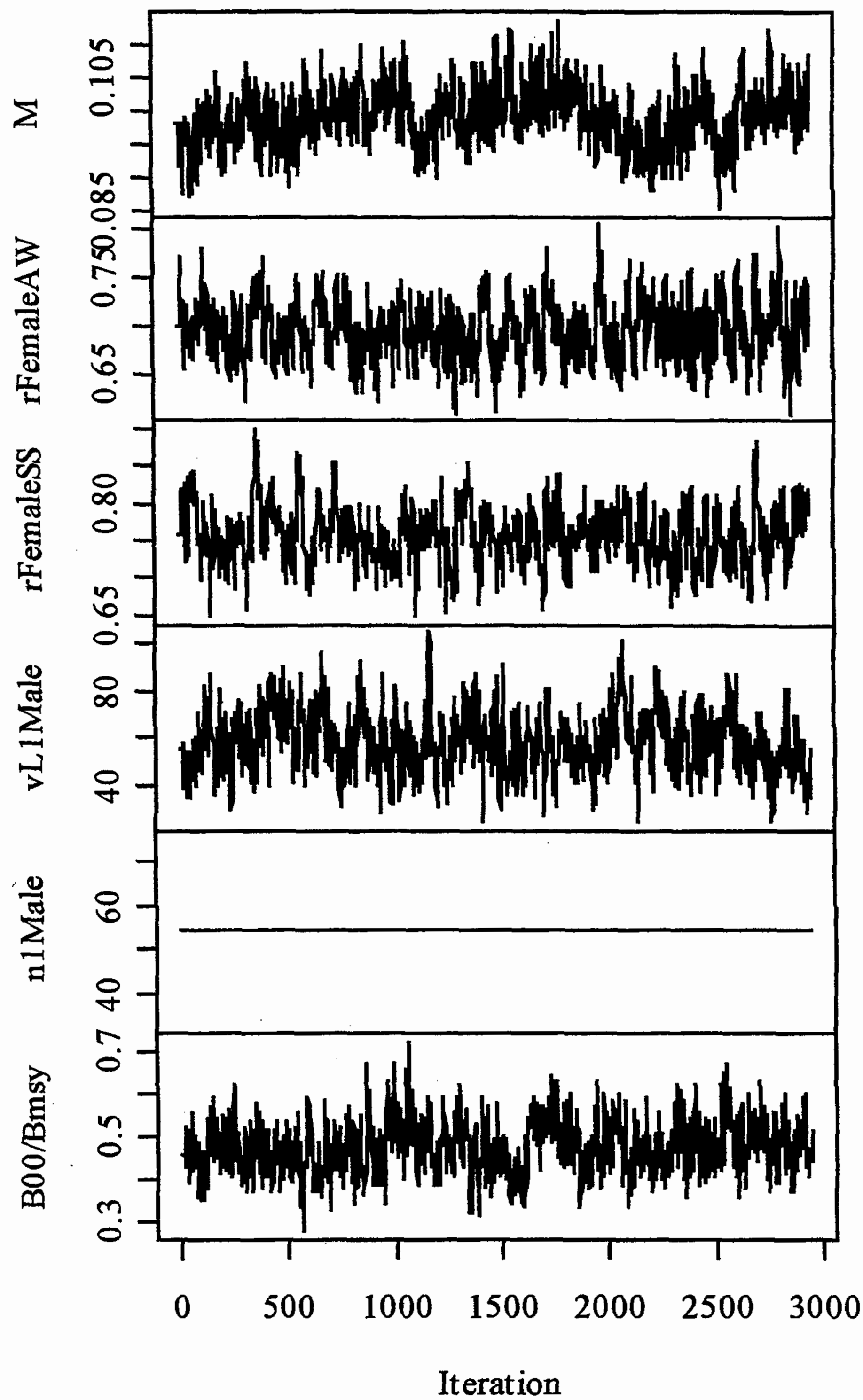


Figure 20: Examples of traces from the MCMC simulation for NSS base case assessment. Parameters from top panel downwards: M; r_{AW}^{female}; r_{SS}^{female}; $v_1^{male,1}$; η_1^{male}; B_{00}/B_{MSY}

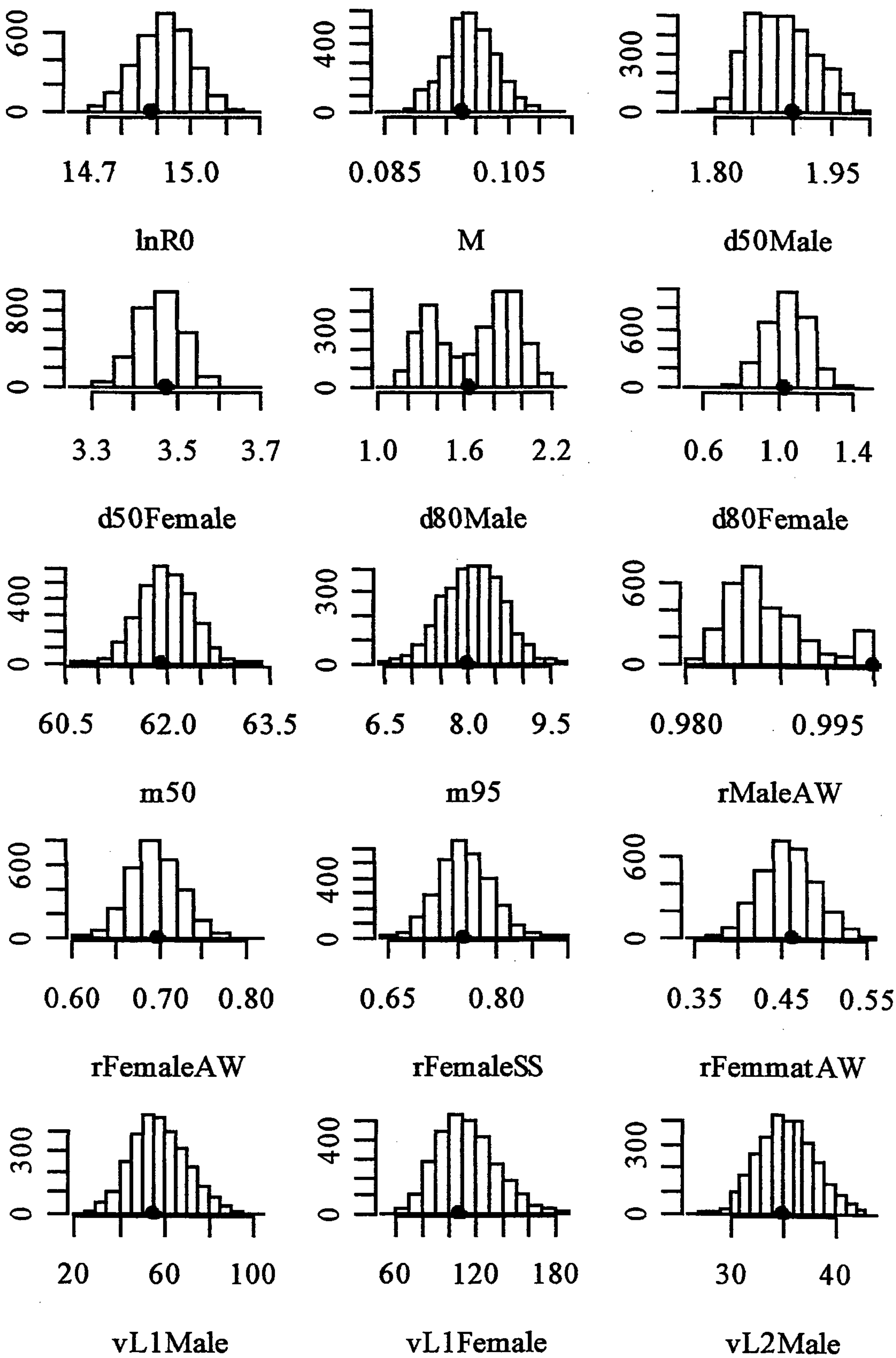
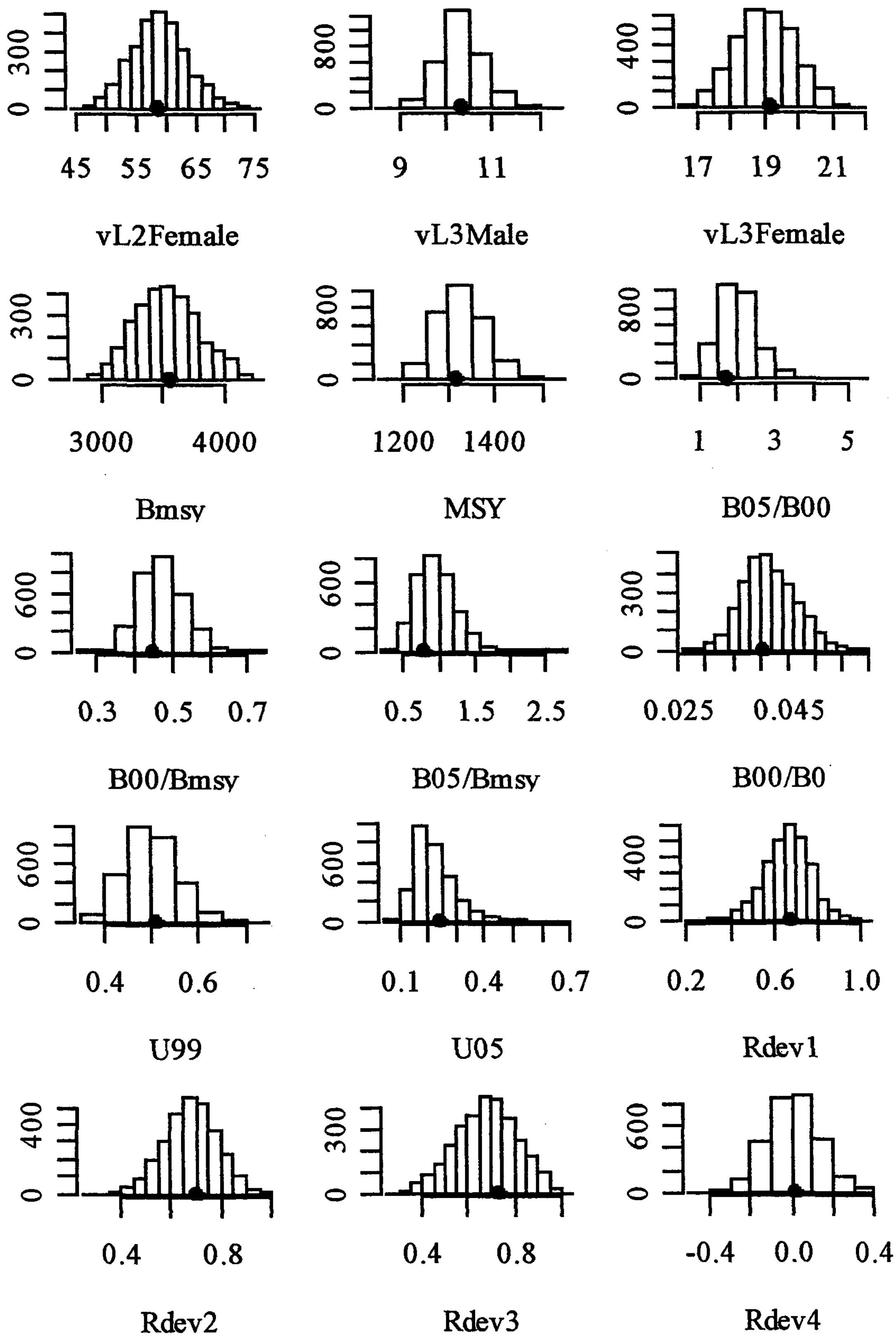


Figure 21: **Posterior distributions of parameters and performance indicators for NSS base case assessment. Parameters and performance indicators are in the same order as presented in Table 13. Note that the MPD estimate for each parameter or performance indicator is indicated by a dot on the x-axis.**



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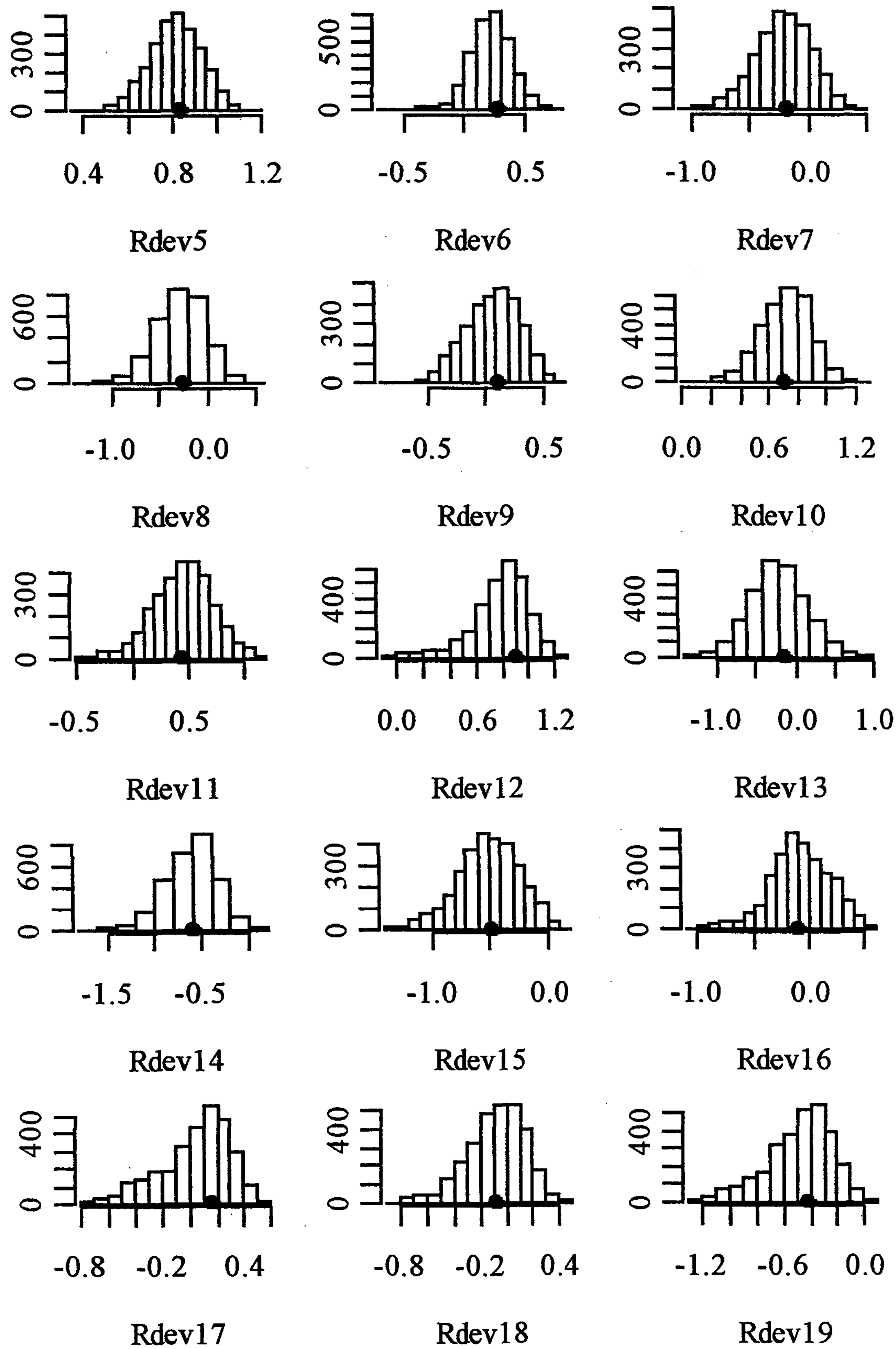

Figure 21 continued.