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EXECUTIVE SUMMARY

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Ling in QMAs 3–7 and part of QMA 2 are treated as five biological stocks for assessment purposes: Chatham Rise (LIN 3 and LIN 4), Campbell Plateau and Stewart-Snares shelf (LIN 5, and LIN 6 west of 176° E), Bounty Plateau (LIN 6 east of 176° E), west coast South Island (LIN 7 west of Cape Farewell), and Cook Strait (those parts of LIN 2 and LIN 7 making up statistical areas 16 and 17 in Cook Strait). These stocks are subsequently referred to as LIN 3&4, LIN 5&6, LIN 6B, LIN 7WC, and LIN 7CK, respectively.

New model input data for all stocks are reported here. Updated assessments are presented for LIN 5&6 and LIN 7WC. The assessments incorporated all relevant biological parameters, the commercial catch histories, updated CPUE series, and series of catch-at-age and catch-at-length data into CASAL, a generalised age- or length-structured population model. The model structure allows the input of catch histories and relative abundance indices attributable to different fishing methods, seasons, and areas.

There is uncertainty about the absolute stock status of the LIN 5&6 stock owing to a lack of contrast in series of abundance indices collected throughout the 1990s. However, this lack of contrast does indicate that the status of the stock has changed little since 1990. A base case model estimate of current biomass is about 85% of B_0, but this value is entirely dependent on the chosen priors for the summer trawl survey catchability quotient (q). Additional model runs were completed using a range of summer survey qs (0.1–0.3) considered likely to bound the true q value, and, hence, produce an estimate of likely minimum biomass. The run using a q of 0.3 indicated that the MCY is higher than the current TACC, and the CAY is more than double the TACC. Hence, there is probably some surplus ling production available in the stock, at least in the short to medium term. Projected biomass out to 2008, assuming future catches at the level of the current TACC, was likely to increase under the base case scenario, but still be higher than 40% B_0 under even the most pessimistic model run. The LIN 5&6 trawl fishery selectivity ogives have been markedly improved by using catch-at-age data (derived using trawl survey age-length keys), rather than catch-at-length data only.

The status of the LIN 7WC stock is not well known, primarily because the assessment is driven by fishery-dependent relative abundance indices that may not reliably index abundance (the two series exhibit conflicting trends in recent years). Biomass in 2003 estimated from two model runs is likely to range from 21 to 46% of B_0. Stock projections to 2008 indicate that biomass is likely to continue to decline given future annual catches equivalent to the recent catch level (i.e., about 50% greater than the TACC), but likely to increase if future catches are about equal to the TACC. The current TACC is just higher than the estimates of MCY, but lower than the estimates of CAY.

1. INTRODUCTION

This document reports the results of Ministry of Fisheries Project LIN2002/01, Objectives 1, 3, and 4. The project objectives are as follows.

1. To determine the catch-at-age from ling fisheries in LIN 3 & 4, 5 & 6, and 7, and from Cook Strait, in 2001–02 from samples collected at sea by scientific observers and from other sources, with a target coefficient of variation of 30% for each Fishstock.
2. To update the standardised catch and effort analyses from the ling longline fisheries in LIN 3, 4, 5, 6 and 7 with the addition of data up to the end of the 2001–02 fishing year.
3. To update the stock assessments of ling in LIN 3 & 4, 5 & 6 (excluding the Bounty Plateau), and 7, including estimating biomass and yields.
4. To collect the otoliths required for determining the catch at age from the Cook Strait trawl fishery in winter 2003 and determine the length frequency distribution of this catch.

The results from Objective 2 have been reported by Horn (in press).

Ling are managed as eight administrative Fishstocks, although five of these (LIN 3, 4, 5, 6, and 7) (Figure 1) currently produce about 95% of landings. Research has indicated that there are at least four major biological stocks of ling in New Zealand waters (see Horn & Cordue 1996): the Chatham Rise, the Campbell Plateau (including the Stewart-Snares shelf and Puysegur Bank), the Bounty Platform, and the west coast of the South Island. The stock affinity of ling in Cook Strait is unknown.

In the stock assessment process, at least five biological stocks of ling are recognised in New Zealand waters, defined as follows: Chatham Rise (LIN 3 and LIN 4), Campbell Plateau and Stewart-Snares shelf (LIN 5, and LIN 6 west of 176° E), Bounty Plateau (LIN 6 east of 176° E), west coast South Island (LIN 7 west of Cape Farewell), and Cook Strait (those parts of LIN 2 and LIN 7 making up statistical areas 16 and 17 in Cook Strait). These stocks are referred to as LIN 3&4, LIN 5&6, LIN 6B, LIN 7WC, and LIN 7CK, respectively. The most recent assessments of these stocks were reported by Horn & Dunn (2003). This document presents assessments of ling on the Campbell Plateau and off the west coast of the South Island (WCSI). Although objective 4 of this project is to assess ling in LIN 3, 4, 5, 6, and 7, there was an understanding that not all stocks would be assessed, and that the stocks to be assessed would be determined by the Middle Depth Species Fishery Assessment Working Group. LIN 5&6 and LIN 7WC were the fishstocks chosen for full assessment. However, input files for all stocks were updated where possible (i.e., catch histories, CPUE series, catch-at-age and catch-at-length).

The current assessments use CASAL, a generalised age- or length-structured fish stock assessment model (Bull et al. 2003). The LIN 5&6 assessment incorporates new catch-at-age and catch-at-length data, and an updated longline CPUE series. The LIN 7WC assessment incorporates new catch-at-age data, an updated line CPUE series, and a new trawl CPUE series.

2. REVIEW OF THE FISHERY

Reported landings of ling are summarised in Tables 1 and 2. From 1975 to 1980 there was a substantial fishery on the Chatham Rise (and to a lesser extent in other areas) carried out by Japanese and Korean longliners. During the 1980s, most ling were taken by trawl. In the early 1990s a longline fishery developed, with a resulting increase in landings from LIN 3, 4, 5, and 6 (Table 2). Landings on the Bounty Plateau are taken almost exclusively by longline. A small, but important, quantity of ling is also taken by setnet in LIN 3 and LIN 7 (Horn 2001). In the west coast South Island section of LIN 7, about two-thirds of ling landings are taken as a trawl bycatch, primarily of the hoki fishery. In Cook Strait, about 80% of ling landings are taken as a bycatch of the hoki trawl fishery, with the remaining landings generally made by the target line fishery (Horn 2001).

Under the Adaptive Management Programme (AMP), TACCs for LIN 3 and 4 were increased by about 30% for the 1994–95 fishing year to a level that was expected to allow any decline in biomass to be detected by trawl surveys of the Chatham Rise (with c.v. 10% or less) over the 5 years following the increase. The TACCs were set at 2810 and 5720 t, respectively. These stocks were removed from the AMP from 1 October 1998, with TACCs maintained at the increased level. Recent anecdotal reports from the fishing sector, and the analysis of CPUE data, indicate that longline catch rates have declined in recent years, particularly in LIN 3 and 4. Consequently, fishing companies have reduced the effort in this fishery. From 1 October 2000, the TACCs for LIN 3 and LIN 4 were reduced to 2060 t and 4200 t, respectively, a level approximating the combined CAY estimate of 6260 t for LIN 3&4 from Horn et al. (2000).

The TACC for LIN 7 has been consistently exceeded throughout the 1990s, sometimes by as much as 50%.

3. RESEARCH RESULTS

3.1 Catch-at-age

New catch-at-age distributions are presented in Appendix A.

The accepted tender for Project LIN2002/01 listed the following samples for age determination, with numbers of otoliths to be prepared in parentheses.

LIN 3&4: Trawl survey, January 2003	(600)
LIN 3&4: Commercial longline, 2001–02	(500)
LIN 5&6: Trawl survey, December 2002	(570)
LIN 5&6: Commercial longline, 2001–02	(550)
LIN 7 (WCSI): Commercial trawl, Jun–Sep 2002	(550)
Cook Strait: Commercial trawl, Jun–Sep 2002	(500)

Otolith samples of sufficient quantity became available from five of the six sources. The sample from the Cook Strait trawl fishery in winter 2002 comprised only 440 otoliths; all of these were prepared. The Cook Strait sample area comprises those sections of LIN 7 and LIN 2 in Cook Strait.

Otoliths collected during trawl surveys were randomly selected from throughout the entire survey area. In general, about 20 otolith pairs were collected each day. The commercial longline fishery samples were obtained by scientific observers. Length-frequency data and 5–10 otolith pairs were sampled randomly from each observed set. The WCSI trawl sample was derived from the target fishery for spawning hoki. Length-frequency data and 3–5 otolith pairs were sampled randomly from each observed tow. The Cook Strait trawl sample was also derived from the target fishery for spawning hoki. Length-frequency data and otoliths were obtained both from observer sampling (3–5 otolith pairs from each observed tow) and shed sampling (18 landings, with 17 otoliths per sample).

Otoliths from each sample were selected, prepared, and read as follows. Otoliths (for each sex separately) from each 1 cm length class were selected proportionally to their occurrence in the scaled length frequency, with the constraint that the number of otoliths in each length class (where available) was at least one. In addition, all otoliths from fish in the extreme right hand tail of the scaled length frequency (i.e., large fish constituting 2% of that length frequency) were fully sampled. This provides a sample with a mean weighted c.v. similar to that from proportional sampling, but will do better than uniform sampling for the older age classes (A. Dunn, NIWA, pers. comm.). Otoliths were prepared and read using the validated ageing technique for ling reported by Horn (1993). Catch-at-age and catch-at-length estimates scaled to the commercial catch by stratum were produced using the 'catch.at.age' software developed by NIWA (Bull & Dunn 2002). The software scales the length frequency of fish from each landing up to the landing weight, sums over landings in each stratum, and scales up to the total stratum catch, to yield length frequencies by stratum and overall. An age-length key is constructed from otolith data and applied to the length frequencies to yield age frequencies. The precision of each length or age frequency is measured by the mean weighted c.v., which is calculated as the average of the c.v.s for the individual length or age classes weighted by the proportion of fish in each class. Coefficients of variation are calculated by bootstrapping: fish are resampled within each landing, landings are resampled within each stratum, and otoliths are simply randomly resampled.

For all these samples, the mean weighted c.v.s were lower than the target of 30% (i.e., 28% for the Cook Strait trawl sample, and between 20 and 22% for all other samples).

No catch-at-age data were available from the commercial trawl fishery on the Campbell Plateau (LIN 5&6); the selectivity ogive for this fishery has been derived from numbers-at-length data. However, because the von Bertalanffy curves are relatively flat for ling older than about 12 years old, the model cannot accurately determine the likely age of larger fish. Hence, the resulting ogives are poorly defined for fish older than about 12 years (Horn & Dunn 2003). The catch-at-length series has used data collected from January to July each year; this has been the period of most consistent observer coverage since 1991. Four trawl surveys have been completed in the approximate middle of the January to July period (i.e., May 1992, May 1993, April 1996, and April 1998), and samples of otoliths from these surveys have already been aged. To enable an investigation of the effects on the commercial trawl selectivity ogive of using catch-at-age data, the length distributions from the fishery in 1992, 1993, 1996, and 1998 were applied to the corresponding trawl survey age-length key to produce estimates of numbers-at-age from the trawl fishery. The resulting proportions-at-age data are listed in Appendix B.

3.2 Catch-at-length

The initial formulation of series of numbers-at-length for ling from various trawl and longline fisheries was described by Horn (2002). These series are included in the stock assessment model where a lack of age data precludes their input as catch-at-age.

Scientific observer data were used to update the commercial trawl series from the 2001–02 fishing year. For the Chatham Rise (LIN 3&4) fishery, data from November 2001 to May 2002 were subdivided into four groups (non-scampi and scampi target for each of LIN 3 and LIN 4), and scaled to the reported landings from each fishery and area. For the Campbell Plateau (LIN 5&6, excluding the Bounty Plateau and Puysegur Bank) fishery, data from January to July 2002 were subdivided into two groups (non-scampi and scampi target), and scaled to the reported landings from each fishery.

Details of the sampling programme for ling from the winter 2003 fishery for hoki in Cook Strait (Project LIN2002/01, Objective 4) are given in Appendix C. The resulting catch-at-length distribution is also presented there.

Previous length-frequency series for the longline fisheries have been derived using data from a logbook scheme set up in 1995 by SeaFIC (described by Langley 2001). SeaFIC logbook data were used to update the longline series for the 2001–02 fishing year. Data provided by SeaFIC from sampled sets in each fishery had simply been combined to produce distributions by sex; no scaling had been conducted. Series from the following fisheries were derived for use as model inputs.

Chatham Rise (LIN 4 only) — June to October 2002
Puysegur (part of LIN 5) — October to December 2001
Pukaki/Campbell (part of LIN 6) — March to July 2002
Bounty Plateau (part of LIN 6) — November 2001 to February 2002

4. MODEL INPUTS, STRUCTURE, AND ESTIMATION

4.1 Model input data

Estimated catch histories for the four stocks are listed in Table 3. The split between method (and pre-spawning and spawning seasons for the LIN 5&6 longline fishery) from 1983 to 2002 was based on reported estimated landings per month, pro-rated to equal total reported landings. Landings before 1983 were split into method and season based on anecdotal information of fishing patterns at the time.

Estimates of biological parameters and of model parameters used in the assessments are given in Table 4. M was derived by Horn (2000). The maturity ogive represents the proportion of fish (in the virgin stock) that are estimated to be mature at each age. Ogives for LIN 3&4, LIN 5&6, and LIN 7WC were derived from gonad stage data (see Horn et al. 2000). The LIN 6B and LIN 7CK ogives were assumed to be the same as for LIN 3&4 and LIN 7WC, respectively, in the absence of any data to otherwise determine them. The proportion spawning was assumed to be 1.0 in the absence of data to estimate this parameter. The stock-recruitment relationship (Beverton-Holt, with steepness 0.9) was used for projections only, otherwise no stock recruitment relationship was assumed.

Standardised CPUE series believed to reliably index relative abundance (see Horn in press) are listed in Table 5. A series of trawl survey indices was available for LIN 3&4 and LIN 5&6 (Table 6). Biomass estimates from the trawl surveys were used as relative biomass indices, with associated c.v.s estimated from the survey analysis. CPUE indices were used as relative biomass indices, with associated c.v.s estimated from the generalised linear model used to estimate relative year effects.

All the trawl survey series were also available as estimates of catch-at-age. For LIN 7WC, eight years of commercial trawl proportion-at-age data were available. For LIN 3&4, LIN 5&6, and LIN 6B various series of proportion-at-age and proportion-at-length from the commercial trawl and longline fisheries were available.

Catch-at-age data were fitted to the model as proportions-at-age, where estimates of the proportions-at-age and associated c.v.s by age were estimated using the NIWA catch-at-age software by bootstrap (see Section 3.1). Zero values were replaced with 0.0001. This replacement was because zero values cannot be used with the assumed error distribution for the proportions-at-data (i.e., lognormal). Ageing error was assumed to occur for the observed proportions-at-age data, by assuming a discrete normally distributed error with c.v.s as defined in Table 3. The c.v.s varied between stocks because of perceived differences between stocks in the difficulty of reading otoliths.

Catch-at-length data were fitted to the model as proportions-at-length with associated c.v.s by length class. These data were also estimated using the catch-at-age software described above. Zero values were replaced with 0.0001.

A summary of all input data series, by stock, is given in Table 7. Data from trawl surveys could be input either as a) biomass and proportions-at-age, or b) numbers-at-age. For the ling assessments the preference was for a), i.e., entering trawl survey biomass and trawl survey age data as separate input series. [Francis et al. (2003) presented an argument against the use of numbers-at-age data for hoki from trawl surveys.] The c.v.s applied to each data set would then give appropriate weight to the signal provided by each series.

4.2 Model structure

Two of the biological ling stocks were assessed in 2003, LIN 5&6 and LIN 7WC. The stock assessment model partitions each stock population into sexes and age groups 3–30, with a plus group. There are two fisheries (trawl and longline) in each stock. For LIN 5&6, the longline fishery is partitioned into spawning and non-spawning fisheries because of marked differences in the sex ratios of the catch from these two periods. The model's annual cycle for each stock is described in Table 8.

All selectivity ogives (i.e., for trawl surveys and commercial fisheries) were age-based and were estimated in the model, separately by sex, except the LIN 7WC longline fishery ogives. No length or age data are available from the LIN 7WC longline fishery, and estimating the ogives using CPUE data only did not give logical results. Consequently, the LIN 7WC longline ogives were assumed to be the same as those for the LIN 3&4 stock (from Horn & Dunn 2003), as ling on the Chatham Rise have lengths-at-age similar to those off west coast South Island. The estimated trawl survey and trawl fishery ogives were assumed to be double normal; longline fishery ogives were assumed to be logistic shaped. In all cases, male selectivity curves were estimated relative to female selectivity. The parameterisations of the double normal and logistic curves are given by Bull et al. (2003). In each fishery, selectivities were assumed constant over all years, i.e., there was no allowance for annual changes in selectivity.

Maximum exploitation rates are assumed to be 0.6 for both stocks. The choice of the maximum exploitation rate has the effect of determining the minimum possible virgin biomass allowed by the model. This value was set relatively high as there was little external information from which to determine it.

4.3 Model estimation

Model parameters were estimated using Bayesian estimation implemented using the CASAL software (Bull et al. 2003). However, only the mode of the joint posterior distribution (MPD) was estimated in preliminary runs. For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm.

Lognormal errors, with known c.v.s, were assumed for all relative biomass, proportions-at-age, and proportions-at-length observations. The c.v.s available for those observations of relative abundance and catch allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in early runs of the model, using all available data, from MPD fits. Hence, the overall c.v. assumed in the initial model runs for each observation was calculated by adding process error and observation error. The process errors added to each input series are listed in Table 7.

Year class strengths were assumed known (and equal to 1) for all years in which they were not estimated, i.e., when inadequate or no catch-at-age data were available. Otherwise year class strengths were estimated under the assumption that the estimates from the model must average 1.

MCMC chains were estimated using a burn-in length of 3×10^5 iterations for LIN 5&6 and 6×10^5 iterations for LIN 7WC, with every 1000^{th} sample taken from the next 10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). A longer burn-in length was required for the LIN 7WC stock to enable it to converge (see Horn & Dunn 2003). Single chain convergence tests of Geweke (1992) and Heidelberger & Welch (1983) were applied to resulting chains to determine evidence of non-convergence. The tests used a significance level of 0.05 and the diagnostics were calculated using the Bayesian Analysis Output software (Smith 2003).

4.4 Prior distributions and penalty functions

The assumed prior distributions used in the assessment are given in Table 9. Most priors were intended to be uninformed, and were estimated with wide bounds: the exception was the choice of informative priors for the LIN 5&6 summer trawl survey q. The informative priors were required to encourage the model to estimate a sensible range for B_0 by forcing it to fit the only clearly declining abundance series. The prior mean on q for the LIN 5&6 summer trawl survey series was set at a value close to the median posterior q estimated by Horn & Dunn (2003) for the summer trawl survey series on the Chatham Rise (which used the same vessel and gear). The Chatham Rise survey q had been estimated using uninformed priors.

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken were strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that average to 1.

5. MODEL ESTIMATES

Estimates of spawning stock biomass and year class strengths were derived for the two assessed stocks using the fixed parameters (see Table 4) and the series of input data (see Table 7) described earlier. For the LIN 5&6 stock, the base case run used *informed* priors to encourage the summer trawl survey q to be about 0.06. Five sensitivity runs were completed: all involved fixing the summer trawl survey q at various levels between 0.1 and 0.3. For LIN 7WC, the input series comprised commercial trawl catch-at-age, and both trawl and line CPUE series. The two CPUE series had contradictory trends. Two model runs were completed; one incorporated both CPUE series, and the other used the trawl CPUE only. Horn (in press) concluded that the line CPUE was probably the least reliable of the two LIN7WC relative abundance series, so a model run incorporating this series only is not presented. The commercial trawl catch-at-age was input into both runs.

For each model run, MPD fits were obtained and quantitatively evaluated. Objective function values (negative log-likelihood) for the model runs are shown in Table 10. Summary plots of the base case MPD model fit for LIN 5&6 and both model fits for LIN 7WC are given as Appendix D. MCMC estimates of the posterior distribution were obtained for all model runs; these are presented below.

Convergence diagnostics for the model runs are given in Table 11. Diagnostics were run on chains of final length 10^6 iterations (following a burn-in period), after systematically subsampling ("thinning") to 1000 samples. The Geweke (1992) convergence diagnostic is based on a test that compares the means of the first 10% and last 50% of a Markov chain. Under the assumption that the samples were drawn from the stationary distribution of the chain, the two means are equal and Geweke's statistic has an asymptotically standard normal distribution. The resulting test statistic is a standard Z-statistic, with the standard error estimated from the spectral density at zero. Values of the Z-statistic that have a p-value less than 0.05 indicate that, at the 5% significance level, there is evidence that the samples were not drawn from a stationary distribution.

Heidelberger & Welch (1983) proposed two linked tests. The first is a stationarity test that uses the Cramer-von-Mises statistic to test the null hypothesis that the sampled values come from a stationary distribution. The test is successively applied, first to the whole Markov chain, then after discarding the first 10, 20, etc, percent of the chain until, either the null hypothesis is accepted, or 50% of the chain has been discarded. If more than 50% of the chain is discarded, then the test returns a failure of the stationarity test. Otherwise, the number of iterations to keep is reported. The second test is the half-width test that calculates a 95% confidence interval for the chain mean, using the portion of the chain that passed the Heidelberger & Welch stationarity test. Half the width of this interval is compared with the estimate of the mean. If the ratio between the half-width and the mean is lower than 2% of the mean, the half width test is passed.

No evidence of lack of convergence was found in the estimates of B_0 for any of the stocks (Table 11). Some estimates of selectivity parameters and YCS showed evidence of lack of convergence in all stocks. Trace diagnostics of B_0 from the base case LIN 5&6 stock model are shown in Figure 2, and for the LIN 7WC model runs in Figure 3.

Two stochastic yields (MCY and CAY) were determined for each stock using sample-based simulations. In this process the set of Bayesian posteriors expresses the uncertainty in the free parameters. One simulation run is done for each sample from the posterior, ultimately producing a single estimate of yield that has been averaged over all samples. Each run extended over 150 years with stochastic recruitment (assuming a Beverton and Holt stock recruit relationship), but with the first 100 of those years discarded to allow the population to stabilise under the chosen harvest rate. Yield calculation was based on the procedures of Francis (1992), where yields were maximised, under either constant-catch or constant-mortality-rate harvesting, subject to the constraint that spawning stock biomass should not fall below 20% of B_0 more than 10% of the time.

5.1 LIN 5&6

The estimated MCMC marginal posterior distributions for selected parameters for the LIN 5&6 stock base case are shown in Figures 4–8. Selectivity ogives for the trawl surveys and the line and trawl fisheries appear to be generally well estimated (Figure 4). This is an improvement on the previous assessment (Horn & Dunn 2003) owing to the inclusion of some catch-at-age data for the commercial trawl fishery. The ogives for the commercial trawl fishery were previously based only on catch-at-length data, and were poorly estimated because of the relatively flat von Bertalanffy growth curves at ages beyond about 12. The ogives derived for the commercial trawl fishery from the current assessment are similar to those for research trawl, except that fewer younger fish are selected (as would be expected). Ogives for the line fisheries on the spawning and home grounds are quite different; age at 50% recruitment is greater on the spawning ground for both sexes, and male selectivity on the home ground is only about half that on the spawning ground. It is not known why males are so poorly selected on the home ground.

The posterior distribution of the summer trawl survey q (Figure 5) occurs in the left-hand section of the prior distribution. Informed priors were used for this parameter in this stock to encourage the model to produce logical values for B_0. The median q for the autumn survey series is about 1.5 times that estimated for the summer series.

Year class strengths were not well estimated before about 1982 when only data from older fish were available to determine age class strength (Figure 6). The estimates suggest periods of generally higher than average recruitment from the mid 1970s to the early 1980s, and in the mid 1990s, with generally lower than average recruitment in the intervening period. Exploitation rates (Figure 7) were very low up to the mid 1990s, but even with the increased catches since then, it is estimated that fishing pressure (F) has not exceeded 0.1 in any year.

Biomass in 2000 was estimated to be at its lowest level since fishing began (Figure 8), but has increased since then. The stock appears to be very healthy, with estimated current biomass at about 85% of B_0, with a 95% credible interval of 78–90% (Table 12). [However, this estimate is entirely dependent on the summer trawl survey q, which has been forced to be about 0.07.] Estimated stock size has fluctuated only slightly since the fishery began. The most marked decline occurred throughout the 1990s when increased exploitation levels, combined with the recruitment of the weaker year classes spawned in the 1980s, resulted in the stock declining to about 75% B_0. However, the recruitment of the stronger year classes spawned in the mid 1990s indicates that stock size is likely to increase over the next three years, even at catch levels equivalent to the current TACC, before declining (Figure 8). Biomass in 2008 is likely to be higher than current biomass, assuming future annual catches at the level of the current TACC (Table 13).

Sensitivity runs were conducted to examine the effects of increasing the summer trawl survey q. The estimates of biomass, and hence, yield, are essentially driven by the trawl survey q, and the q for this survey could not be estimated in the base case model because of a lack of contrast in any of the relative abundance series. The summer q was set at values from 0.1 to 0.3, in steps of 0.05, and all other parameters were estimated as in the base case run. Estimates of B_0 and B_{2003} from these runs are listed in Table 12 and plotted in Figure 9. A doubling of the summer survey *q* does not result in an exact halving of the biomass estimates owing to a non-linear relationship between the summer survey *q* and the estimated autumn survey *q* (see Figure 9). Biomass in 2008 (assuming future catches at the TACC) under the sensitivity scenarios is likely to decline relative to current biomass, but even the lower bound of the worst case scenario still has B_{2008} at 40% of B_0 (see Table 13).

The base case yield estimates (Table 14) are much greater than the current TACC for LIN 5 and LIN 6 combined (about 10 100 t), as would be expected given the high estimates of B_{2003} as a percentage of B_0 (i.e., 78–90%). Increasing the summer survey *q* does reduce B_0 and B_{2003}, and, consequently, the yields. However, even for a summer survey *q* of 0.3 (implying that 30% of ling occurring between the trawl doors are captured in the net), the estimated MCY is slightly higher than the current TACC and the CAY is more than twice the TACC. These data indicate that the LIN 5&6 stock could sustain catch levels higher than the current TACC, at least in the short to medium term.

5.2 LIN 7WC

Two model runs were completed for the LIN 7WC stock; one incorporated both CPUE series, the other used the trawl CPUE only. The commercial trawl catch-at-age was input into both runs. The MPD fits to the CPUE series for both runs are shown in Figure 10. For the 'both CPUE series' run the model fits to the CPUE series are not good, particularly for the line CPUE. The model cannot reconcile the opposing trends of the two CPUE series, and consequently the increasing section of the line series is poorly fitted. Given these fits, it is apparent that the information from the trawl catch-at-age is more supportive of a recent decline in biomass, rather than a recent increase. In the 'trawl CPUE only' run, the CPUE series is fitted well. The information from the trawl catch-at-age data must be consistent with a declining biomass from 1994 to 2002.

The estimated MCMC marginal posterior distributions for selected parameters for the LIN 7WC model runs are shown in Figures 11–16. The selectivity ogive for males taken by the commercial trawl fishery was consistent between models, but had broad posterior density estimates at older ages (Figure 11). The female ogive was well estimated in the 'both CPUE series' run, but less well defined in the 'trawl CPUE only' run (Figure 11). The posterior distributions of the CPUE *q*s had well defined modes in the 'both CPUE series' and 'trawl CPUE only' runs (Figure 12).

Trends in year class strength estimates were consistent between the model runs (Figure 13). Year class strengths were poorly estimated before about 1982 when only data from older fish were available to determine age class strength. Two recent stronger than average year classes (1996 and 1997) were also relatively poorly estimated. There are no clear trends over time in recruitment. Exploitation rates were very low up to the late 1980s (Figure 14). With the increased catches in recent years, it is estimated that fishing pressure (*F*) may seldom have exceeded 0.25 (from the 'both CPUE series' model), or may have been as high as 0.4 (from the 'trawl CPUE only' model).

Biomass in 1972 was estimated to be just below 40 000 t, with relatively narrow bounds, from the 'both CPUE series' and 'trawl CPUE only' runs (Table 12, Figure 15). Both models indicated that biomass had steadily declined since 1972 to be currently at its lowest level since fishing began (Figure 16). However, the levels of current biomass, either in absolute terms or as a percentage of B_0, are still quite different between models (see Table 12). Biomass projections out to 2008 were calculated (see Table 13) assuming two future catch scenarios, i.e., 3100 t annually (being the level of recent catches as shown in Table 3), and 2050 t (being the current TACC discounted by 8% to account for the proportion of the LIN 7 catch that has been taken in recent years in Cook Strait, and allocated 70% to the trawl fishery and 30% to the line fishery). Under the higher catch scenario, stock rebuilding took place in only 21% of the 'both CPUE series' simulations and 6% of the 'trawl CPUE only' simulations. Under the lower catch scenario, stock rebuilding occurred in 82% and 58% of the 'both CPUE series' and 'trawl CPUE only' runs, respectively.

A third projection scenario was investigated but not run. It assumed that the expected ling catch by the trawl fishery is likely to be lower than in previous years given voluntary reductions in the WCSI spawning hoki catch from the winter 2004 season. There is a weak positive relationship between total trawl landings of hoki and ling off WCSI, with ling landed weight being about 2.3% of hoki weight (Figure 17). Therefore, an expected catch of about 80 000 t of hoki is likely to be associated with a ling bycatch of about 1800 t. Assuming a line fishery catch of about 800 t of ling, the total annual ling catch is likely to be about 2600 t. This is about midway between the two projection scenarios described above, and so would produce projections that are also about midway between those presented (i.e., little change in stock size relative to the 2003 level).

The two CAY estimates (Table 14) are both greater than the current TACC of 2225 t for LIN 7, but recent landings have been greater than the 'trawl CPUE only' estimate and close to the 'both CPUE series' estimate. The estimates of MCY are slightly lower than the TACC (Table 14). However, it must be remembered that this assessment does not include the ling stock in Cook Strait (which produces about 8% of the landings, and possibly makes up about 10% of the biomass in the LIN 7 administrative stock). For both model runs, B_{2003} is estimated to be less than B_{MCY} but greater than B_{MAY}.

6. DISCUSSION

Model estimates of the state of the LIN 5&6 stock indicate that current biomass is about 78–90% of B_0, and is likely to remain in this range in the short term at current catch levels. There was a general lack of contrast in the relative abundance series for this stock; only the series of four autumn trawl surveys exhibited a trend (a decline, see Table 6). As noted in the previous assessment of LIN 5&6 (Horn & Dunn 2003), this lack of strong contrast, when combined with uninformed priors on the trawl survey *q*s, resulted in the model estimating improbably large biomasses. Consequently, to produce more realistic estimates of biomass in the base case, informed priors encouraged the summer survey *q* to be similar to the value for the LIN 3&4 summer survey series (which used the same vessel and gear, and was estimated with uninformed priors). With this course of action, current biomass was estimated to be 85% of B_0, with a narrow 95% credible interval (see Table 12). Based on this estimate, stock size is likely to increase slightly in the short term with catch levels at the current TACC. However, it is apparent that there is little information concerning stock size in the trawl survey data, so absolute stock size from the base case is determined primarily by the prior for trawl survey *q*.

Because biomass is determined primarily by the prior for *q*, sensitivity runs were conducted to examine the effects of increasing the summer trawl survey *q*, and hence, determining what might be a minimum biomass level of the stock. The summer *q* was set at values from 0.1 to 0.3, in steps of 0.05, to estimate current biomass (see Table 12). A *q* of 0.3 implies that about 30% of the fish encountered by the trawl (i.e., in the water column between the trawl doors) are retained in the codend. Note that the percentage would actually be greater than 30% to account for ling inhabiting the areas of untrawlable ground in the survey area. The value of 0.3 is believed to be conservative, although little is known about the reaction behaviour of ling to a trawl net. The wingtip width of the trawl net is about a quarter of the door spread, so some fish are likely to be overtaken by the sweeps and bridles before they are herded into the net. Escapement will also occur under the groundrope (the space between seabed and net can be as much as 0.5 m), and above the headline (both by fish swimming upwards and by those already higher in the water column). Even large ling entering the net could still escape through the 300 mm mesh in the front section of the trawl. Estimates of survey catchability for the same trawl gear (posterior medians from MCMC runs) have ranged from 0.07 to 0.30 for hoki (Francis et al. 2003), and 0.07 for hake on the Chatham Rise (Dunn 2003). In conclusion, the true summer survey *q* for ling in LIN 5&6 is very likely to be less than 0.3. Given this, then the minimum current yield estimates (i.e., assuming a summer *q* of 0.3) are an MCY of 10 600 t and a CAY of 24 800 t (see Table 14).

Current stock size of LIN 5&6 is estimated to be well above B_{MAY} in all assessment runs, so catches at the level of the TACC are likely to be sustainable. The true absolute levels of B_0 and B_{2003} are poorly known, but the estimates of likely minimum biomass (and their associated yields) presented above are clearly indicative of some surplus ling production being available, at least in the short to medium term.

It should be noted that the LIN 6 administrative stock also includes a separate biological ling stock on the Bounty Plateau. This stock, and landings from it, have been excluded from the current analysis, as in previous assessments. The Bounty stock is relatively small, being perhaps about 5–10% of the size of the LIN 5&6 stock (Horn & Dunn 2003). Landings from it have fluctuated markedly since the beginning of the longline fishery there in 1991 (see Table 3); since 1992, 3–19% (mean = 10%) of the combined LIN 5 and LIN 6 landings have been taken from the Bounty Plateau. While the stock status of Bounty Plateau ling is poorly known, there are no reasons to believe that the fishery will not continue in the future much as it has in the past 12 years.

In past assessments (Horn & Dunn 2003), the selectivity ogives for the LIN 5&6 trawl fishery (which is responsible for most of the catch from this stock) were based on catch-at-length data only, and were poorly defined. This year, age-length keys from the four autumn trawl surveys (1992, 1993, 1996, and 1998) were used to convert commercial trawl numbers-at-length data from these four years into proportions-at-age. The surveys had been conducted in the middle of the commercial trawl sampling period. Consequently, in the current assessment, the commercial trawl fishery ogives were derived from four years of numbers-at-age data and seven years of numbers-at-length data. The ogives produced this year are compared in Figure 18 with those of Horn & Dunn (2003). The current ogives are more precisely defined, particularly for males. They are also more logical, in that the age at full selectivity (about 9–10 years) is just higher than for the trawl survey and just lower than for the longline fisheries (see Figure 4), as would be expected given the known gear parameters and length compositions of the catches from the various fisheries. It is probably desirable to confirm the shape of trawl fishery ogives derived from trawl survey age-length keys by calculating ogives from several years of commercial trawl age data. Sufficient otoliths and length data from the trawl fishery every year since 1997 are available to produce useful estimates of catch-at-age.

The size and status of the LIN 7WC stock are poorly known, even though the posterior distributions of absolute biomass by year (see Figure 15) all have relatively narrow distributions with strong modes. The assessment is driven by the two CPUE series (target line and trawl bycatch). Both these series have shortfalls (see Horn in press), and they exhibit conflicting trends in recent years. The lower limit of the 95% credible interval for current biomass is 21% of B_0 (from the 'trawl CPUE only' run), indicating that there may be some pending sustainability issues for this stock. However, in contrast to this, there has been no declining trend in catches. Landings have been consistently over 2800 t since 1996, and have averaged about 2700 t annually since 1989. The assessment of LIN 7WC is confounded by several difficulties. There are no fishery-independent indices of abundance. CPUE series are available from the trawl and line fisheries, but they exhibit different trends that cannot be well modelled. No age or length data are available from the line fishery, so the fishery ogive must be assumed. It is also known that the trawl fishery catch was under-reported in some years; some corrections have been made to account for this, but it is unknown how accurate they are. Deriving a more accurate catch history, calculating longline selectivity ogives from the LIN 7WC fishery, and reconciling the conflicts between the relative abundance series from the trawl and line fisheries are all likely to improve the estimation of stock status.

Current stock size of LIN 7WC is estimated to be above B_{MAY} (but close to B_{MAY} in the 'trawl CPUE only' run). Recent catch levels have been greater than both estimates of MCY. They have also been greater than the estimate of CAY from the 'trawl CPUE only' run, but less than the CAY estimate from the 'both CPUE series' run. However, the uncertainty of this assessment means it is not known whether the TACC or current catch levels are sustainable in the long term, or are at levels that will allow the stock to move towards a size that will support the MSY.

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Table 1: Reported landings (t) from 1975 to 1987–88. Data from 1975 to 1983 from MAF; data from 1983–84 to 1985–86 from FSU; data from 1986–87 and 1987–88 from QMS.

	New Zealand			Foreign licensed					
				Longline				Trawl	Grand
Fishing Year	Domestic	Chartered	Total	(Japan + Korea)	Japan	Korea	USSR	Total	total
1975*	486	0	486	9 269	2 180	0	0	11 499	11 935
1976*	447	0	447	19 381	5 108	0	1 300	25 789	26 236
1977*	549	0	549	28 633	5 014	200	700	34 547	35 096
1978–79#	657*	24	681	8 904	3 151	133	452	12 640	13 321
1979–80#	915*	2 598	3 513	3 501	3 856	226	245	7 828	11 341
1980–81#	1 028*	–	–	–	–	–	–	–	–
1981–82#	1 581*	2 423	4 004	0	2 087	56	247	2 391	6 395
1982–83#	2 135*	2 501	4 636	0	1 256	27	40	1 322	5 958
1983†	2 695*	1 523	4 218	0	982	33	48	1 063	5 281
1983–84§	2 705	2 500	5 205	0	2 145	173	174	2 491	7 696
1984–85§	2 646	2 166	4 812	0	1 934	77	130	2 141	6 953
1985–86§	2 126	2 948	5 074	0	2 050	48	33	2 131	7 205
1986–87§	2 469	3 177	5 646	0	1 261	13	21	1 294	6 940
1987–88§	2 212	5 030	7 242	0	624	27	8	659	7 901

* Calendar years (1978 to 1983 for domestic vessels only).
\# 1 April to 31 March.
§ 1 Oct to 30 Sept.

Table 2: Reported landings (t) of ling by Fishstock from 1983–84 to 2000–01 and actual TACs (t) from 1986–87 to 2000–01. Estimated landings for LIN 7 from 1987–88 to 1992–93 include an adjustment for ling bycatch of hoki trawlers, based on records from vessels carrying observers.

Fishstock	LIN 1		LIN 2		LIN 3		LIN 4		LIN 5	
QMA (s)	1 & 9		2		3		4		5	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1983–84*	141	–	594	–	1 306	–	352	–	2 605	–
1984–85*	94	–	391	–	1 067	–	356	–	1 824	–
1985–86*	88	–	316	–	1 243	–	280	–	2 089	–
1986–87#	77	200	254	910	1 311	1 850	465	4 300	1 859	2 500
1987–88#	68	237	124	918	1 562	1 909	280	4 400	2 213	2 506
1988–89#	216	237	570	955	1 665	1 917	232	4 400	2 375	2 506
1989–90#	121	265	736	977	1 876	2 137	587	4 401	2 277	2 706
1990–91#	210	265	951	977	2 419	2 160	2 372	4 401	2 285	2 706
1991–92#	241	265	818	977	2 430	2 160	4 716	4 401	3 863	2 706
1992–93#	253	265	944	980	2 246	2 162	4 100	4 401	2 546	2 706
1993–94#	241	265	779	980	2 171	2 167	3 920	4 401	2 460	2 706
1994–95#	261	265	848	980	2 679	2 810	5 072	5 720	2 557	3 001
1995–96#	245	265	1 042	980	2 956	2 810	4 632	5 720	3 137	3 001
1996–97#	313	265	1 187	982	2 963	2 810	4 087	5 720	3 438	3 001
1997–98#	303	265	1 032	982	2 916	2 810	5 215	5 720	3 321	3 001
1998–99#	208	265	1 070	982	2 706	2 810	4 642	5 720	2 937	3 001
1999–00#	313	265	983	982	2 799	2 810	4 402	5 720	3 136	3 001
2000–01#	296	265	1 104	982	2 330	2 060	3 861	4 200	3 430	3 001
2001–02#	303	265	1 034	982	2 165	2 060	3 602	4 200	3 305	3 001

Fishstock	LIN 6		LIN 7			LIN 10		Total	
QMA (s)	6		7 & 8			10			
	Landings	TAC	Reported Landings	Estimated Landings	TAC	Landings	TAC	Landings§	TAC
1983–84*	869	–	1 552	–	–	0	–	7 696	–
1984–85*	1 283	–	1 705	–	–	0	–	6 953	–
1985–86*	1 489	–	1 458	–	–	0	–	7 205	–
1986–87#	956	7 000	1 851	–	1 960	0	10	6 940	18 730
1987–88#	1 710	7 000	1 853	1 777	2 008	0	10	7 901	18 988
1988–89#	340	7 000	2 956	2 844	2 150	0	10	8 404	19 175
1989–90#	935	7 000	2 452	3 171	2 176	0	10	9 028	19 672
1990–91#	2 738	7 000	2 531	3 149	2 192	<1	10	13 506	19 711
1991–92#	3 459	7 000	2 251	2 728	2 192	0	10	17 778	19 711
1992–93#	6 501	7 000	2 475	2 817	2 212	<1	10	19 065	19 737
1993–94#	4 249	7 000	2 142	–	2 213	0	10	15 961	19 741
1994–95#	5 477	7 100	2 946	–	2 225	0	10	19 841	22 111
1995–96#	6 314	7 100	3 102	–	2 225	0	10	21 428	22 111
1996–97#	7 510	7 100	3 024	–	2 225	0	10	22 522	22 113
1997–98#	7 331	7 100	3 027	–	2 225	0	10	23 145	22 113
1998–99#	6 112	7 100	3 345	–	2 225	0	10	21 034	22 113
1999–00#	6 707	7 100	3 274	–	2 225	0	10	21 615	22 113
2000–01#	6 177	7 100	3 352	–	2 225	0	10	20 552	19 843
2001–02#	5 949	7 100	3 204	–	2 225	0	10	19 564	19 843

* FSU data.
\# QMS data.
§ Includes landings from unknown areas before 1986–87, and areas outside the EEZ since 1995–96.

Table 3: Estimated catch histories (t) for LIN 3&4 (Chatham Rise), LIN 5&6 (Campbell Plateau excluding the Bounty Platform), LIN 6B (Bounty Platform), LIN 7WC (WCSI section of LIN 7), and LIN 7CK (Cook Strait sections of LIN 7 and LIN 2). Landings have been separated by fishing method (trawl or line), and, for the LIN 5&6 line fishery, by pre-spawning (Pre) and spawning (Spn) season. The 2003 value in each column is assumed, and was allocated to method and season based on 2002 landings. For LIN 6B, all landings up to 1990 were taken by trawl, and over 98% of all landings after 1990 were taken by line.

Year	LIN 3&4		LIN 5&6			LIN 6B	LIN 7WC		LIN 7CK	
	trawl	line	trawl	line Pre	line Spn	line	trawl	line	trawl	line
1972	0	0	0	0	0	0	0	0	0	0
1973	250	0	500	0	0	0	85	20	45	45
1974	382	0	1 120	0	0	0	144	40	45	45
1975	953	8 439	900	118	192	0	401	800	48	48
1976	2 100	17 436	3 402	190	309	0	565	2 100	58	58
1977	2 055	23 994	3 100	301	490	0	715	4 300	68	68
1978	1 400	7 577	1 945	494	806	10	300	323	78	78
1979	2 380	821	3 707	1 022	1 668	0	539	360	83	83
1980	1 340	360	5 200	0	0	0	540	305	88	88
1981	673	160	4 427	0	0	10	492	300	98	98
1982	1 183	339	2 402	0	0	0	675	400	103	103
1983	1 210	326	2 778	5	1	10	1 040	710	97	97
1984	1 366	406	3 203	2	0	6	924	595	119	119
1985	1 351	401	4 480	25	3	2	1 156	302	116	116
1986	1 494	375	3 182	2	0	0	1 082	362	126	126
1987	1 313	306	3 962	0	0	0	1 105	370	97	97
1988	1 636	290	2 065	6	0	0	1 428	291	107	107
1989	1 397	488	2 923	10	2	9	1 959	370	255	85
1990	1 934	529	3 199	9	4	11	2 205	399	362	121
1991	2 563	2 228	4 534	392	97	172	2 163	364	488	163
1992	3 451	3 695	6 237	566	518	1 430	1 631	661	498	85
1993	2 375	3 971	7 335	1 238	474	1 575	1 609	716	307	114
1994	1 933	4 159	5 456	770	486	875	1 136	860	269	84
1995	2 222	5 530	5 348	2 355	338	387	1 750	1 032	344	70
1996	2 725	4 863	6 769	2 153	531	588	1 838	1 121	392	35
1997	3 003	4 047	6 923	3 412	614	333	1 749	1 077	417	89
1998	4 707	3 227	6 032	4 032	581	569	1 887	1 021	366	88
1999	3 282	3 818	5 593	2 721	489	771	2 146	1 069	316	216
2000	3 739	2 779	7 089	1 421	1 161	1 319	2 247	923	317	131
2001	3 467	2 724	6 629	818	1 007	1 153	2 304	977	258	80
2002	2 979	2 788	7 030	430	1 230	628	2 250	810	230	171
2003	3 000	2 800	7 000	500	1 200	700	2 300	800	250	150

Table 4: Biological and other input parameters used in the ling assessments.

1. Natural mortality (M)

	Female	Male
All stocks	0.18	0.18

2. Weight = a (length)^b (Weight in g, total length in cm)

	Female		Male	
	a	*b*	*a*	*b*
LIN 3&4	0.00114	3.318	0.00100	3.354
LIN 5&6	0.00128	3.303	0.00208	3.190
LIN 6B	0.00114	3.318	0.00100	3.354
LIN 7WC	0.00094	3.366	0.00125	3.297
LIN 7CK	0.00094	3.366	0.00125	3.297

3. von Bertalanffy growth parameters (n, sample size)

	Male				Female			
	n	*k*	t_0	L_∞	*n*	*k*	t_0	L_∞
LIN 3&4	3 964	0.127	–0.70	113.9	4 133	0.083	–0.74	156.4
LIN 5&6	2 884	0.188	–0.67	93.2	4 093	0.124	–1.26	115.1
LIN 6B	296	0.141	0.02	120.5	386	0.101	–0.53	146.2
LIN 7WC	2 366	0.067	–2.37	159.9	2 320	0.078	–0.87	169.3
LIN 7CK	348	0.080	–1.94	158.9	332	0.097	–0.54	163.6

4. Maturity ogives

Age	4	5	6	7	8	9	10	11
LIN 3&4 (and assumed for LIN 6B)								
Male	0.0	0.100	0.20	0.35	0.50	0.80	1.0	1.0
Female	0.0	0.001	0.10	0.20	0.35	0.50	1.0	1.0
LIN 5&6								
Male	0.0	0.10	0.30	0.50	0.80	1.00	1.0	1.0
Female	0.0	0.05	0.10	0.30	0.50	0.80	1.0	1.0
LIN 7WC (and assumed for LIN 7CK)								
Male	0.0	0.05	0.20	0.60	0.90	1.00	1.00	1.0
Female	0.0	0.00	0.10	0.20	0.40	0.60	0.80	1.0

5. Miscellaneous parameters

Stock	3&4	5&6	6B	7WC	7CK
Stock-recruitment steepness	0.9	0.9	0.9	0.9	0.9
Recruitment variability c.v.	0.6	0.6	1.0	0.6	0.7
Ageing error c.v.	0.05	0.06	0.05	0.05	0.07
Proportion by sex at birth	0.5	0.5	0.5	0.5	0.5
Proportion spawning	1.0	1.0	1.0	1.0	1.0
Spawning season length	0	0.25	0	0	0
Maximum exploitation rate (U_{max})	0.6	0.6	0.6	0.6	0.6

Table 5: Unstandardised (Unstd) and standardised (Std, with 95% confidence intervals and c.v.s) year effects for the ling target line fisheries on the Chatham Rise, Campbell Plateau, Bounty Plateau, and WCSI, and for the ling bycatch in the hoki target trawl fishery in Cook Strait and WCSI.

Year	Unstd	Std	95% CI	c.v.	Unstd	Std	95% CI	c.v.
	Line: Chatham Rise (LIN 3&4)				Line: Campbell Plateau (LIN 5&6)			
1990	0.21	1.58	1.36–1.85	0.08	–	–	–	–
1991	0.46	1.29	1.18–1.40	0.04	0.84	0.94	0.76–1.15	0.10
1992	1.53	1.75	1.61–1.91	0.04	0.88	1.22	1.04–1.44	0.08
1993	1.34	1.29	1.19–1.39	0.04	0.79	1.23	1.05–1.44	0.08
1994	1.27	1.24	1.16–1.34	0.04	0.76	0.97	0.86–1.11	0.06
1995	1.91	1.25	1.16–1.34	0.04	1.18	1.15	1.01–1.31	0.06
1996	1.62	1.06	0.99–1.14	0.04	1.13	1.02	0.90–1.16	0.06
1997	0.95	0.76	0.71–0.81	0.03	1.11	1.10	1.00–1.21	0.05
1998	0.99	0.75	0.70–0.82	0.04	0.96	0.98	0.89–1.08	0.05
1999	0.74	0.65	0.60–0.71	0.04	0.89	0.74	0.66–0.83	0.06
2000	1.00	0.76	0.69–0.83	0.04	1.09	0.83	0.72–0.96	0.07
2001	1.55	0.75	0.68–0.82	0.05	1.28	0.94	0.81–1.10	0.08
2002	1.14	0.62	0.57–0.68	0.04	1.27	0.98	0.83–1.15	0.08
	Line: Bounty Plateau (LIN 6B)				Line: WCSI (LIN 7WC)			
1990	–	–	–	–	0.63	0.97	0.85–1.11	0.07
1991	–	–	–	–	0.79	1.18	1.06–1.32	0.06
1992	1.02	1.68	1.32–2.15	0.12	0.90	1.16	1.06–1.28	0.05
1993	0.94	1.48	1.22–1.80	0.10	1.03	0.93	0.84–1.04	0.05
1994	0.82	1.01	0.79–1.30	0.13	1.06	0.97	0.88–1.06	0.05
1995	1.07	1.07	0.83–1.37	0.13	1.06	0.99	0.91–1.08	0.04
1996	0.86	0.98	0.78–1.22	0.11	0.93	0.77	0.71–0.84	0.04
1997	0.78	0.80	0.62–1.03	0.13	1.03	0.86	0.79–0.94	0.04
1998	1.37	0.99	0.77–1.26	0.12	1.29	0.97	0.88–1.06	0.05
1999	1.29	1.01	0.81–1.26	0.11	1.15	0.99	0.90–1.09	0.05
2000	1.19	0.91	0.74–1.10	0.10	1.11	1.01	0.92–1.10	0.05
2001	0.93	0.77	0.62–0.94	0.10	1.20	1.15	1.05–1.26	0.05
2002	0.91	0.69	0.56–0.84	0.10	1.02	1.12	1.02–1.24	0.05
	Trawl: Cook Strait (LIN 7CK)				Trawl: WCSI (LIN 7WC)			
1990	1.94	1.60	1.44–1.77	0.05	–	–	–	–
1991	1.45	1.39	1.29–1.50	0.04	–	–	–	–
1992	1.31	1.28	1.18–1.39	0.04	–	–	–	–
1993	1.36	1.33	1.23–1.45	0.04	–	–	–	–
1994	1.05	0.93	0.86–1.00	0.04	1.07	1.08	1.00–1.17	0.04
1995	0.95	0.81	0.76–0.87	0.03	1.20	1.17	1.10–1.25	0.03
1996	0.95	0.80	0.76–0.85	0.03	1.13	1.26	1.19–1.33	0.03
1997	0.81	0.76	0.72–0.80	0.03	1.05	1.08	1.02–1.14	0.03
1998	0.78	0.80	0.75–0.85	0.03	0.86	0.95	0.90–0.99	0.02
1999	0.69	0.76	0.72–0.81	0.03	1.07	1.07	1.03–1.12	0.02
2000	0.69	0.85	0.80–0.90	0.03	0.93	0.92	0.88–0.96	0.02
2001	0.75	1.05	0.99–1.12	0.03	0.88	0.81	0.78–0.84	0.02
2002	0.92	1.06	0.98–1.14	0.04	0.87	0.77	0.74–0.80	0.02

Table 6: Series of relative biomass indices (t) from *Tangaroa* trawl surveys (with coefficients of variation, c.v.) available for the assessment modelling.

Fishstock	Area	Trip code	Date	Biomass	c.v. (%)
LIN 3&4	Chatham Rise	TAN9106	Jan-Feb 1992	8 930	5.8
		TAN9212	Jan-Feb 1993	9 360	7.9
		TAN9401	Jan 1994	10 130	6.5
		TAN9501	Jan 1995	7 360	7.9
		TAN9601	Jan 1996	8 420	8.2
		TAN9701	Jan 1997	8 540	9.8
		TAN9801	Jan 1998	7 310	8.3
		TAN9901	Jan 1999	10 310	16.1
		TAN0001	Jan 2000	8 350	7.8
		TAN0101	Jan 2001	9 350	7.5
		TAN0201	Jan 2002	9 440	7.8
		TAN0301	Jan 2003	7 300	10.0
LIN 5&6	Campbell Plateau	TAN9105	Nov-Dec 1991	24 090	6.8
		TAN9211	Nov-Dec 1992	21 370	6.2
		TAN9310	Nov-Dec 1993	29 750	11.5
		TAN0012	Dec 2000	33 020	6.9
		TAN0118	Dec 2001	25 060	6.5
		TAN0219	Dec 2002	25 630	10.0
LIN 5&6	Campbell Plateau	TAN9204	Mar-Apr 1992	42 330	5.8
		TAN9304	Apr-May 1993	37 550	5.4
		TAN9605	Mar-Apr 1996	32 130	7.8
		TAN9805	Apr-May 1998	30 780	8.8

Table 7: Summary of the relative abundance series available for the assessment modelling, including source years (Years). The process error that was added to the observation error in the two stocks that were modelled is also listed.

Data series	Years	Process error c.v.
LIN 3&4		
Trawl survey proportion at age (*Amaltal Explorer*, Dec)	1990	
Trawl survey biomass (*Tangaroa*, Jan)	1992–2003	
Trawl survey proportion at age (*Tangaroa*, Jan)	1992–2003	
CPUE (longline, all year)	1990–2002	
Commercial longline length-frequency (LIN 4, Jul–Oct)	1995–2002	
Commercial longline proportion-at-age (Jul–Oct)	2002	
Commercial trawl length-frequency (Nov–May)	1991–92, 1994–2002	
LIN 5&6		
Trawl survey proportion at age (*Amaltal Explorer*, Nov)	1990	0.15
Trawl survey biomass (*Tangaroa*, Nov–Dec)	1992–94, 2001–03	0.2
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–03	0.1
Trawl survey biomass (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	0.01
Trawl survey proportion at age (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	0.15
CPUE (longline, all year)	1991–2002	0.1
Commercial longline length-frequency (Puysegur, Oct–Dec)	1993, 1996,1999–2001	0.3
Commercial longline proportion-at-age (Puysegur, Nov–Dec)	2000–02	0.3
Commercial longline length-frequency (Campbell, Apr–Jun)	1998–2002	0.5
Commercial longline proportion-at-age (Campbell, Jun)	1999, 2001	0.3
Commercial trawl length-frequency (Jan–Jul)	1991, 1994–95, 1999–2002	0.3
Commercial trawl proportion-at-age (Jan–Jul)	1992–93, 1996, 1998	0.25
LIN 6B		
CPUE (longline, all year)	1992–2002	
Commercial longline length-frequency (Nov–Feb)	1996, 2000–02	
Commercial longline proportion-at-age (Dec–Feb)	2000–01	
LIN 7WC		
CPUE (longline, all year)	1990–2002	0.2
CPUE (hoki trawl, Jun–Sep)	1994–2002	0.15
Commercial trawl proportion-at-age (Mar–Sep)	1991, 1994–2002	0.25
LIN 7CK		
CPUE (hoki trawl, all year)	1990–2002	
Commercial trawl proportion-at-age (Mar–Sep)	1999–2002	

Table 8: Annual cycles of the assessment models for each stock, showing the processes taking place at each time step, their sequence within each time step, and the available observations of relative abundance. Any fishing and natural mortality within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and after the fishing mortality. An age fraction of 0.5 for a time step means that a 6+ fish is treated as being of age 6.5 in that time step. Trawl surveys and CPUE indices occur during the fishing time step. The last column ("propn. mort.") shows the proportion of that time step's mortality that is assumed to have taken place when each observation is made (see Table 7 for descriptions of the observations).

Step	Approx. months	Processes	M fraction	Age fraction	Observations Description	propn. mort.
LIN 5&6						
1	Dec-Aug	recruitment	0.75	0.5	Trawl survey (summer)	0.1
		non-spawning fisheries (trawl & line)			Trawl survey (autumn)	0.5
					Line CPUE	0.7
2	Sep-Nov	increment ages	0.25	0.0	–	
		spawning fishery (line)				
LIN 7WC						
1	Oct-Jun	recruitment	0.75	0.5	Line CPUE	0.5
		fishery (line)				
2	Jul-Sep	increment ages	0.25	0.0	Trawl CPUE	0.5
		fishery (trawl)				

Table 9: Assumed prior distributions and bounds for estimated parameters in the LIN 5&6 and LIN 7WC assessments. Parameter values are mean (in natural space) and c.v. for lognormal.

Parameter description	Stock	Distribution	Parameters		Bounds	
B_0	5&6	uniform-log	–	–	50 000	800 000
	7WC	uniform-log	–	–	10 000	400 000
Year class strengths	Both	lognormal	1.0	0.7	0.01	100
CPUE q	Both	uniform-log	–	–	1e-8	1e-3
Survey q (summer)	5&6	lognormal	0.07	0.15	0.01	0.4
Survey q (autumn)	5&6	uniform-log	–	–	0.001	10
Selectivity	Both	uniform	–	–	0	20–200
Process error c.v.	Both	uniform-log	–	–	0.001	2

Table 10: Objective function values (negative log-likelihood) for MPD fits to data, priors, penalties resulting from penalties to catch (Catch) and to year class strengths averaging to one (YCS), and the total objective function (negative log-likelihood) value.

Stock	Run	Data	Priors	Penalties Catch	Penalties YCS	Total
5&6	Base case	-204.01	-4.32	0	1.2e-4	-208.33
	Summer $q = 0.10$	-192.20	-3.63	0	4.8e-5	-195.83
	Summer $q = 0.15$	-187.49	-2.81	0	2.7e-5	-190.30
	Summer $q = 0.20$	-181.66	-2.26	0	3.8e-5	-183.92
	Summer $q = 0.25$	-175.06	-1.85	0	9.5e-6	-176.91
	Summer $q = 0.30$	-167.91	-1.52	0	7.4e-7	-169.43
7WC	Both CPUE series	-113.03	-9.05	0	0.15	-121.91
	Trawl CPUE only	-101.19	1.02	0	0.04	-100.12

Table 11: Percentage of parameters that passed the Geweke (1992) and Heidelberger & Welch (1983) convergence diagnostics tests for selected parameters from the MCMC chains of the base case LIN 5&6 run and the three LIN 7WC runs. *n*, number of parameters estimated.

Stock/Run	Parameter	*n*	Geweke (%)	Heidelberger & Welch (%)	
				Stationarity	Half width test
LIN 5&6					
Base case	B_0	1	100	100	100
	Selectivity	24	83	96	96
	YCS	26	92	96	92
LIN 7WC					
Both CPUE series	B_0	1	100	100	100
	Selectivity	7	57	86	100
	YCS	24	88	100	96
Trawl CPUE only	B_0	1	100	100	100
	Selectivity	7	100	86	86
	YCS	24	100	100	96

Table 12: Bayesian median and 95% credible intervals (in parentheses) of B_0, B_{2003}, and B_{2003} as a percentage of B_0 for all model runs for LIN 5&6 and LIN 7WC.

Model run	B_0		B_{2003}		B_{2003} (%B_0)	
LIN 5&6						
Base case	429 500	(305 400–579 600)	362 600	(242 800–513 800)	85	(78–90)
Summer q = 0.10	277 100	(237 200–331 100)	217 800	(174 000–268 100)	78	(73–83)
Summer q = 0.15	208 200	(183 800–235 700)	144 200	(119 500–175 200)	70	(65–75)
Summer q = 0.20	178 600	(162 200–200 500)	115 600	(96 700–139 900)	65	(59–70)
Summer q = 0.25	162 600	(147 700–179 300)	98 100	(82 500–117 500)	61	(55–66)
Summer q = 0.30	152 300	(139 400–169 800)	89 100	(74 800–107 000)	58	(53–64)
LIN 7WC						
Both CPUE series	39 700	(35 100–46 200)	15 000	(10 800–21 300)	38	(30–46)
Trawl CPUE only	35 900	(32 400–42 500)	10 500	(7 000–16 300)	29	(21–39)

Table 13: Bayesian median and 95% credible intervals (in parentheses) of projected B_{2008}, B_{2008} as a percentage of B_0, and B_{2008}/B_{2003} (%) for LIN 5&6 and LIN 7WC model runs. Future annual catches are assumed equal to the TACC in LIN 5&6, and equal either to recent catch levels (3 100 t) or to the WCSI portion of the LIN 7 TACC (2 050 t) in LIN 7WC.

Model run	Future catch (t)	B_{2008}		B_{2008} (%B_0)		B_{2008}/B_{2003} (%)	
LIN 5&6							
Base case	10 100	383 800	(250 500–569 100)	89	(77–106)	105	(98–124)
Summer q = 0.10	10 100	220 300	(167 100–290 200)	79	(68–95)	101	(90–119)
Summer q = 0.20	10 100	108 600	(81 800–147 700)	60	(49–77)	94	(83–110)
Summer q = 0.30	10 100	79 600	(57 500–112 200)	52	(40–69)	89	(75–108)
LIN 7WC							
Both CPUE series	3 100	13 000	(6 300–23 500)	33	(17–51)	87	(57–110)
Trawl CPUE only	3 100	7 100	(2 800–15 600)	20	(8–39)	67	(38–101)
Both CPUE series	2 050	17 100	(9 800–27 500)	43	(28–60)	114	(91–129)
Trawl CPUE only	2 050	11 100	(5 600–19 100)	31	(17–48)	106	(80–117)

Table 14: Yield estimates (MCY and CAY) and associated parameters for the base and sensitivity cases for LIN 5&6 and LIN 7WC.

Model run	B_{MCY} (t)	MCY (t)	B_{MAY} (t)	MAY (t)	F_{CAY}	CAY (t)
LIN 5&6						
Base case	211 700	26 400	117 600	35 300	0.23	99 800
Summer $q = 0.10$	120 200	18 700	75 900	22 800	0.23	59 600
Summer $q = 0.15$	87 000	14 200	56 500	17 000	0.23	40 100
Summer $q = 0.20$	74 900	12 300	48 700	14 600	0.23	32 200
Summer $q = 0.25$	67 600	11 100	44 200	13 300	0.23	27 400
Summer $q = 0.30$	62 800	10 600	41 500	12 500	0.23	24 800
LIN 7WC						
Both CPUE series	17 000	2 190	10 600	2 570	0.20	3 600
Trawl CPUE only	15 200	1 990	9 600	2 330	0.20	2 500

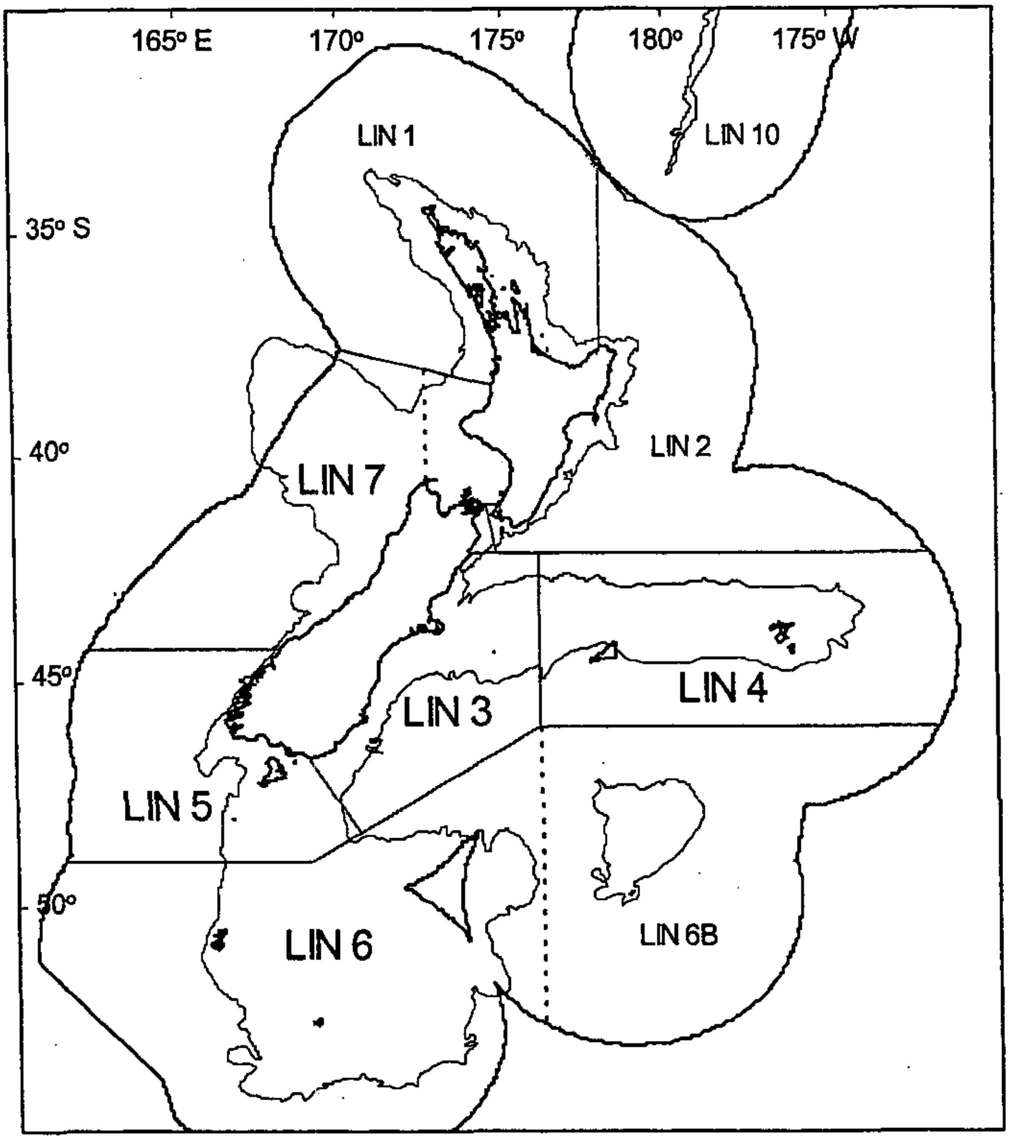


Figure 1: Area of Fishstocks LIN 3, 4, 5, 6, and 7. Adjacent ling fishstock areas are also shown, as is the 1000 m isobath. The boundaries used to separate biological stock LIN 6B from the rest of LIN 6, and the west coast South Island section of LIN 7 from the Cook Strait section, are shown as broken lines.

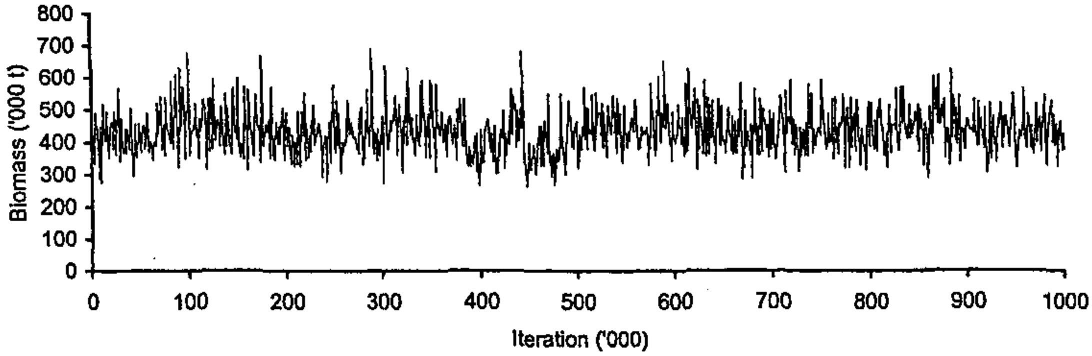


Figure 2: Trace diagnostic plot of the base case MCMC chain for estimates of B_0 for LIN 5&6.

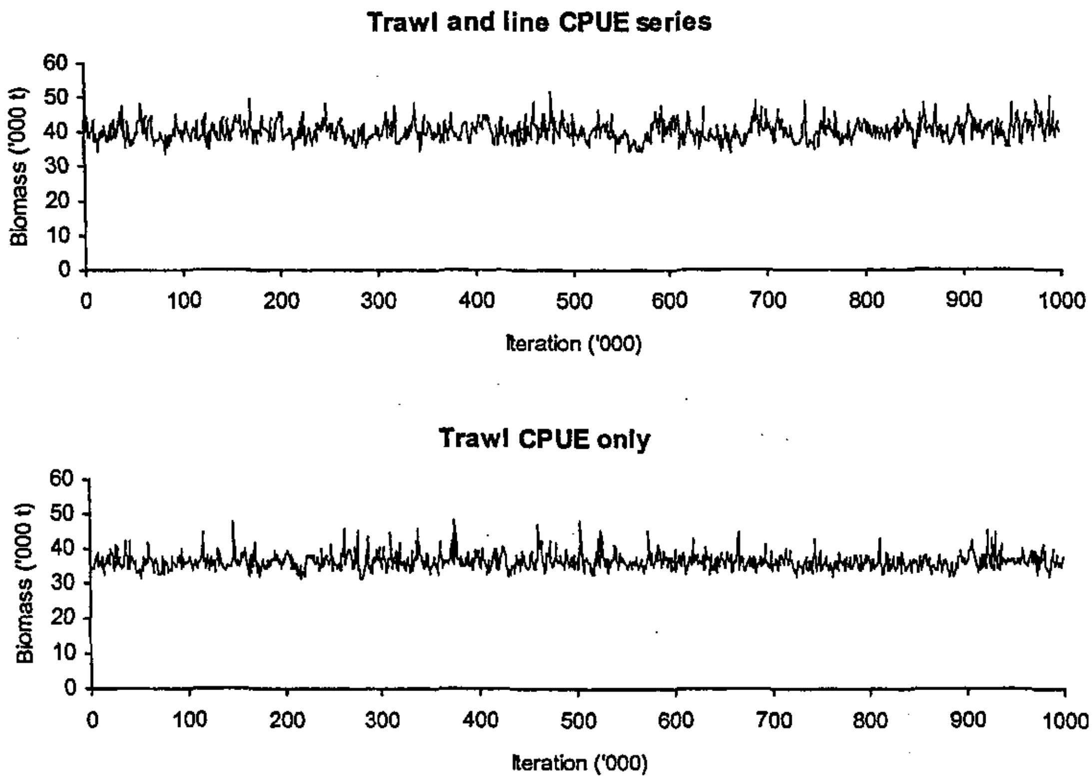


Figure 3: Trace diagnostic plot of the MCMC chains for estimates of B_0 for LIN 7WC from the two model runs.

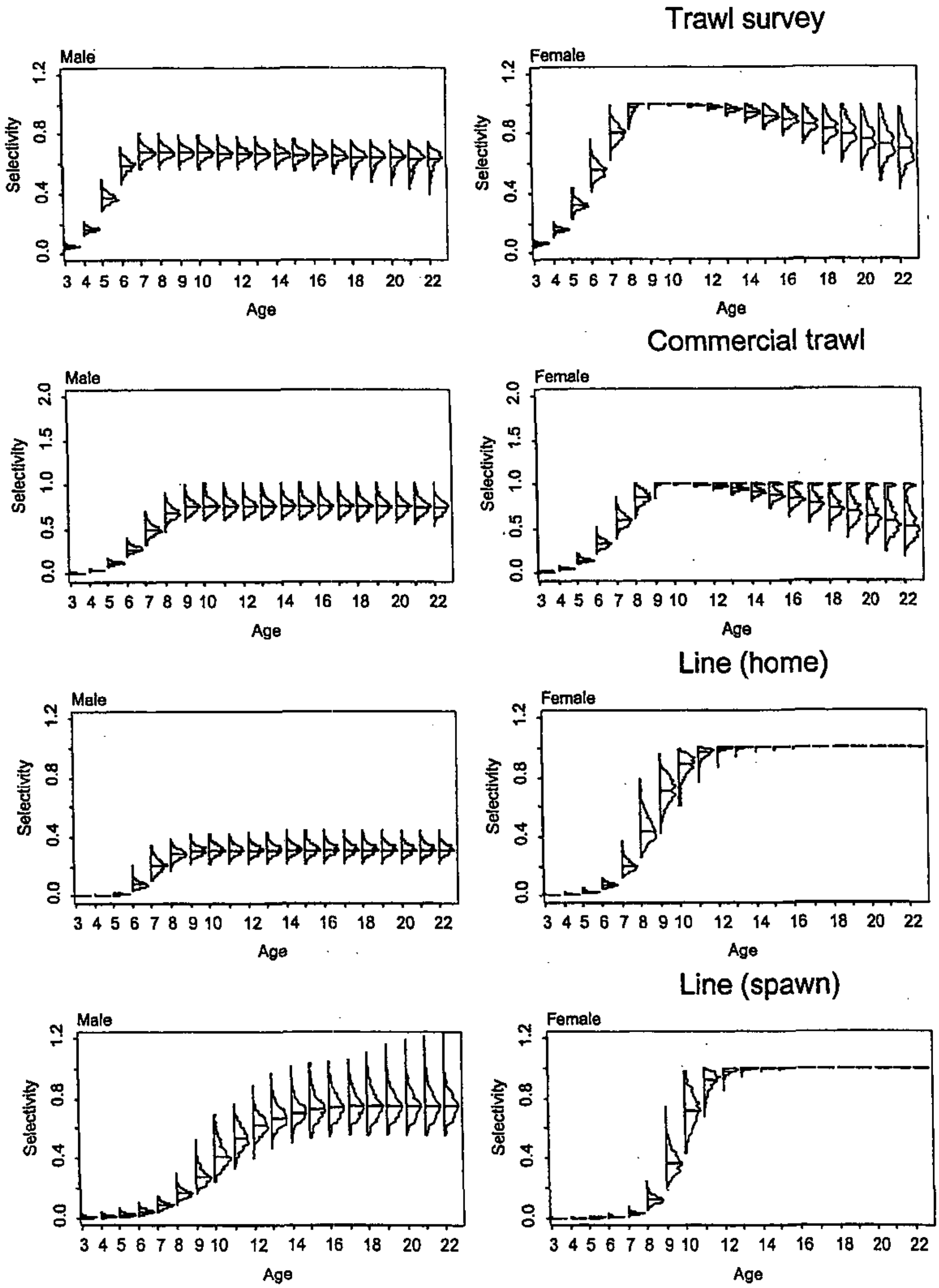


Figure 4: LIN 5&6 base case — Estimated posterior distributions of relative selectivity, by age and sex, for the trawl survey series, the trawl fishery, and the home ground and spawning ground line fisheries. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

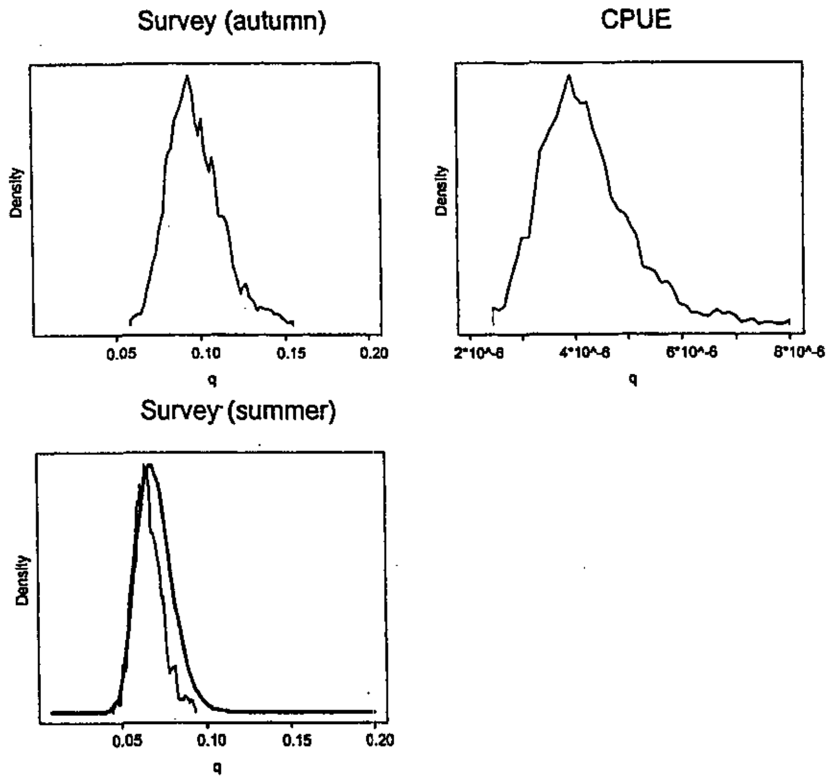


Figure 5: LIN 5&6 base case — Estimated posterior distributions (thin lines) of relativity constants for the autumn and summer trawl survey series and the longline CPUE series. The distribution of the prior is also shown for the summer trawl survey (thick line).

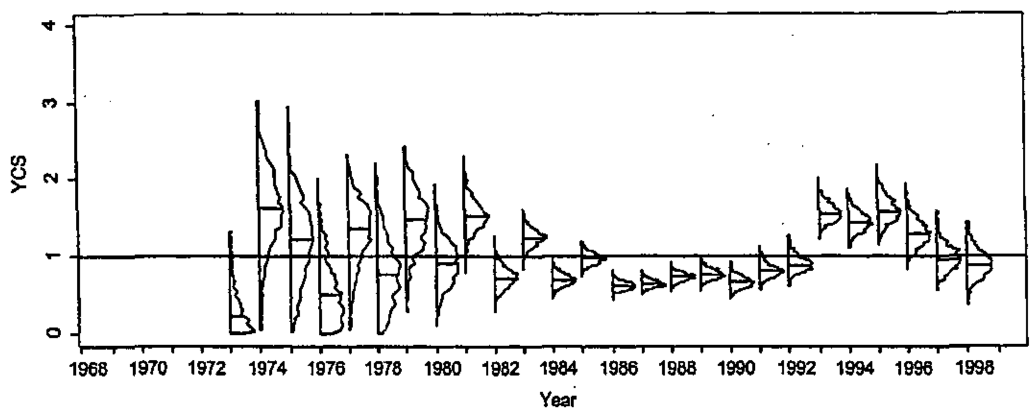


Figure 6: LIN 5&6 base case — Estimated posterior distributions of year class strength. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

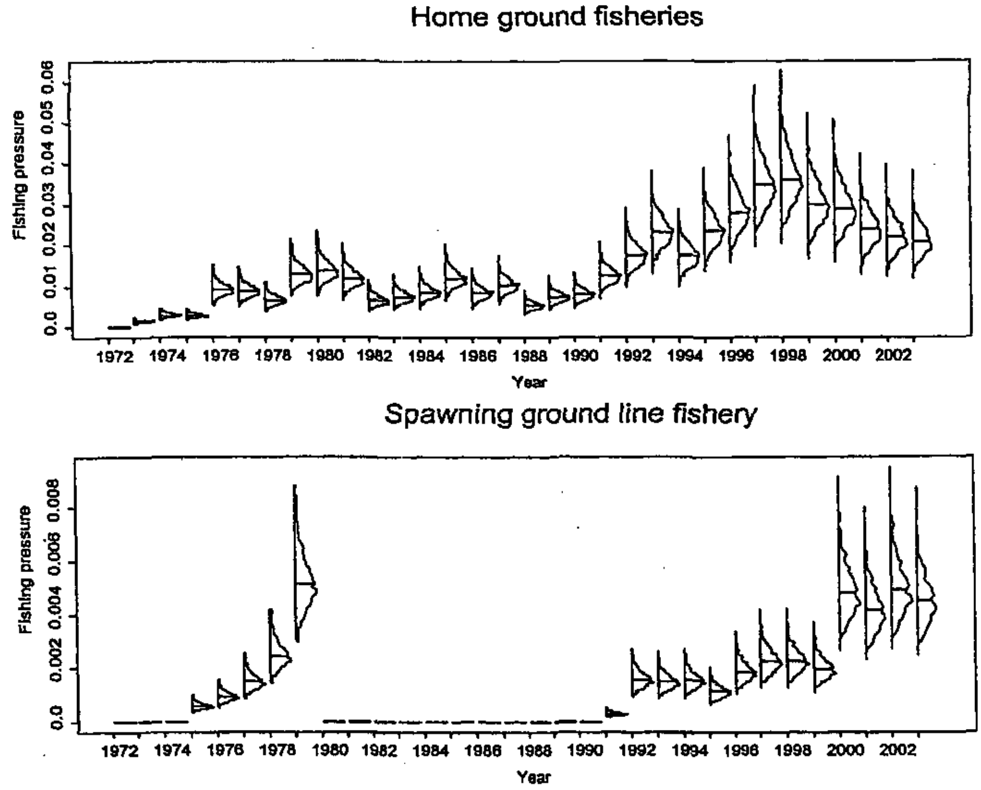


Figure 7: LIN 5&6 base case — Estimated posterior distributions of exploitation rates. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

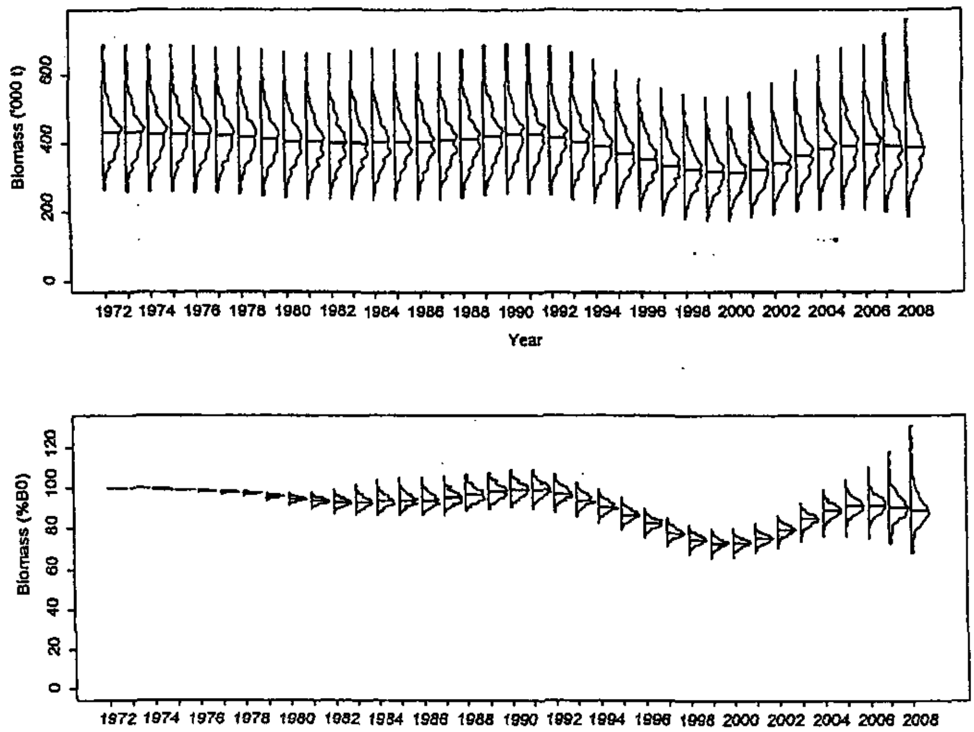


Figure 8: LIN 5&6 base case — Estimated posterior distributions of biomass trajectories (in tonnes, and as $\%B_0$). Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median. Projections (2004–2008) are based on an annual catch equal to the combined LIN 5 and LIN 6 TACC (10100 t).

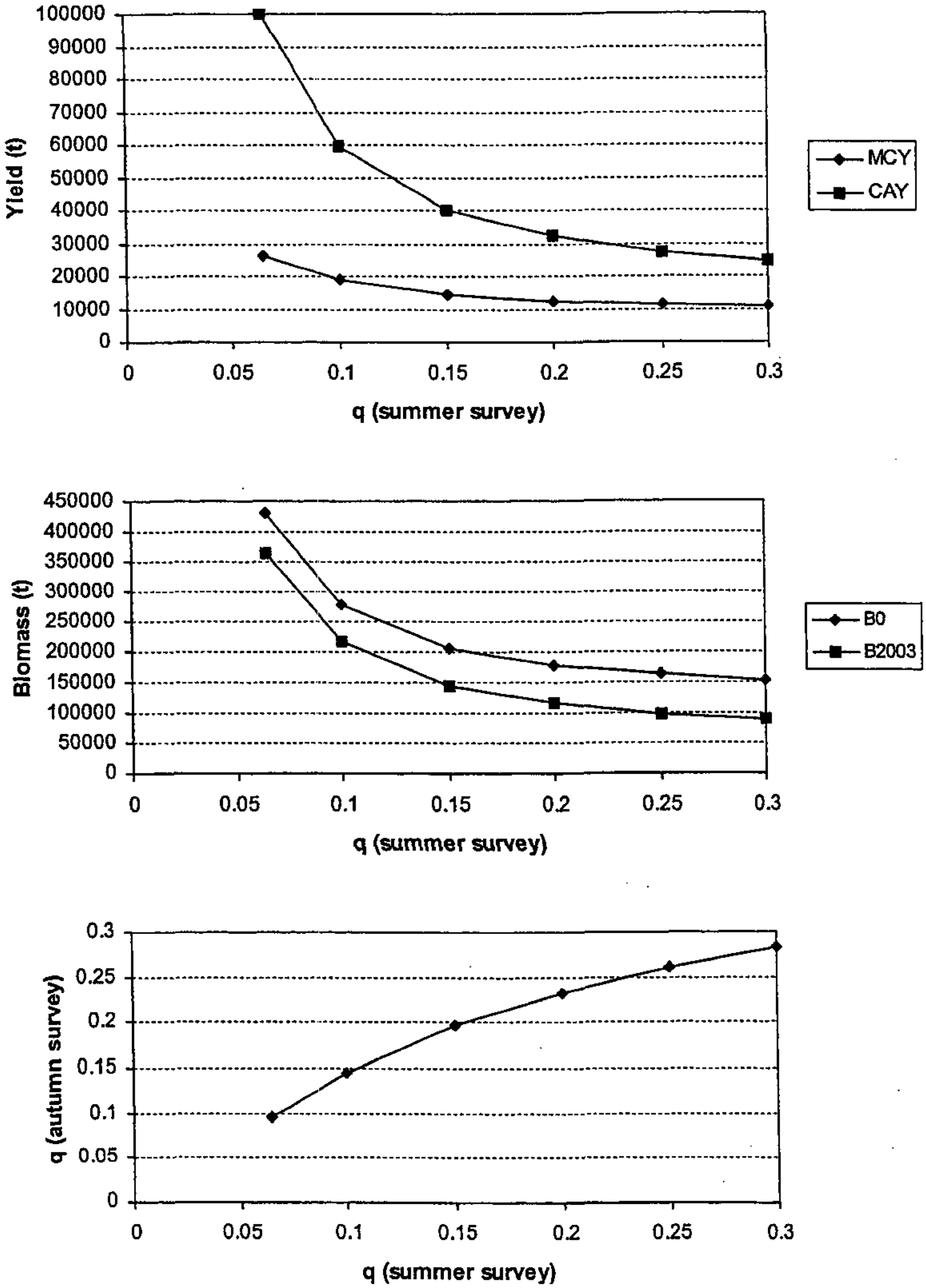


Figure 9: LIN 5&6 — Yields (MCY and CAY), biomass (B_0 and B_{2003}), and autumn trawl survey *q* estimated from the MCMC base case run (median summer *q* = 0.065), and runs where the summer trawl survey *q* was set at various values between 0.1 and 0.3. Plotted estimates are medians of the posterior distributions.

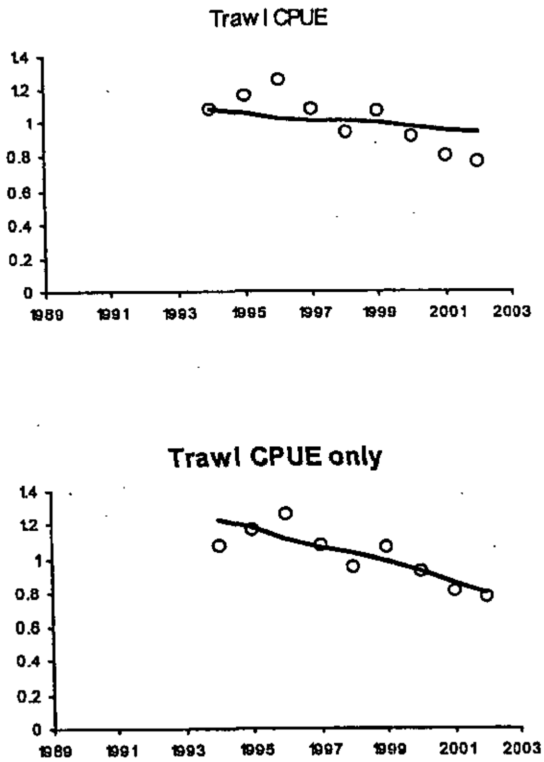


Figure 10: LIN 7WC — MPD fits (solid lines) to CPUE series (open circles) from the two model runs, i.e., using both CPUE series, and using trawl CPUE only.

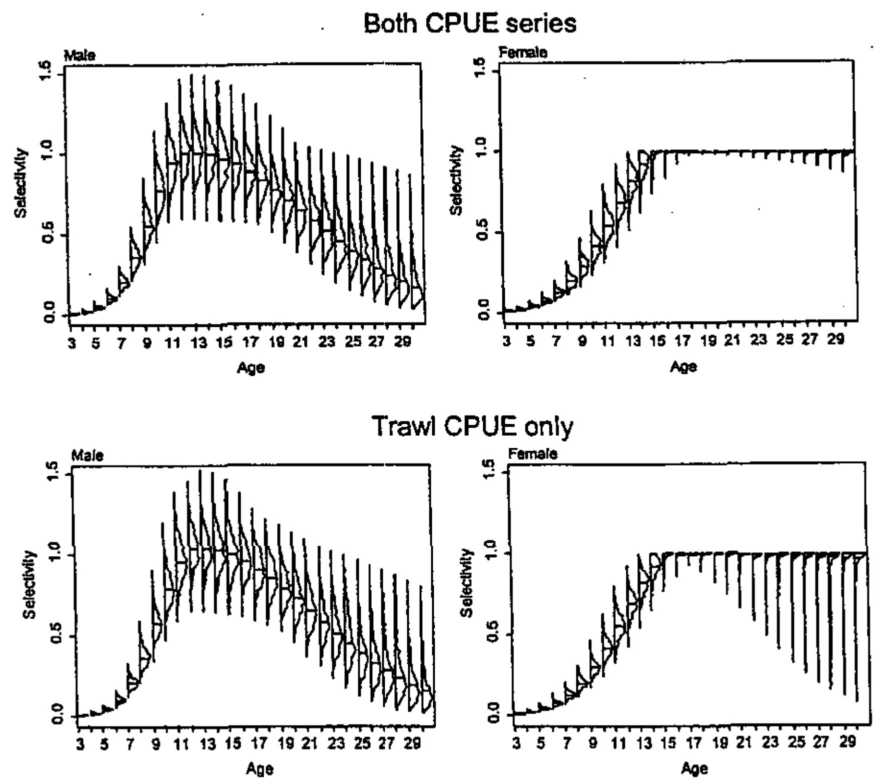


Figure 11: LIN 7WC — Estimated posterior distributions of relative selectivity, by age and sex, for the trawl fishery from the two model runs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

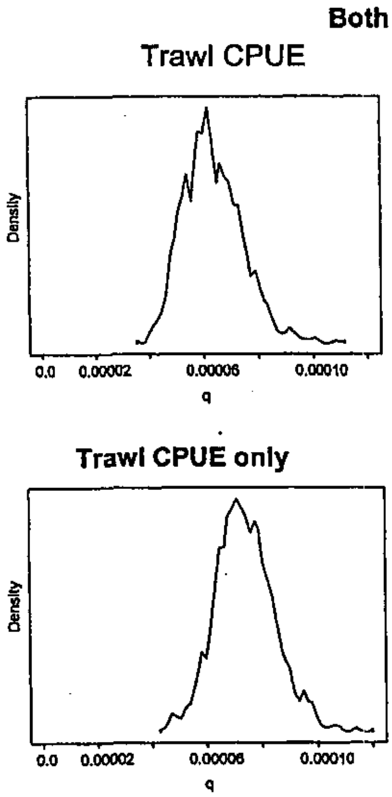


Figure 12: LIN 7WC — Estimated posterior distributions of relativity constants for the longline CPUE series from the two model runs.

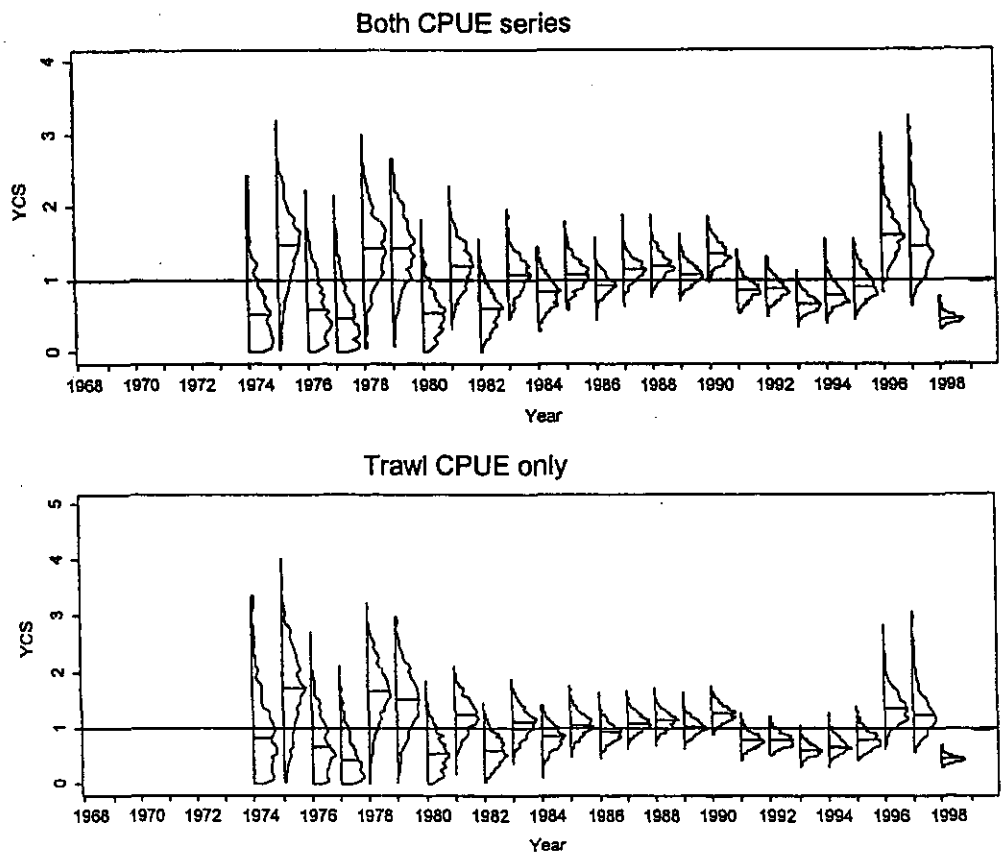
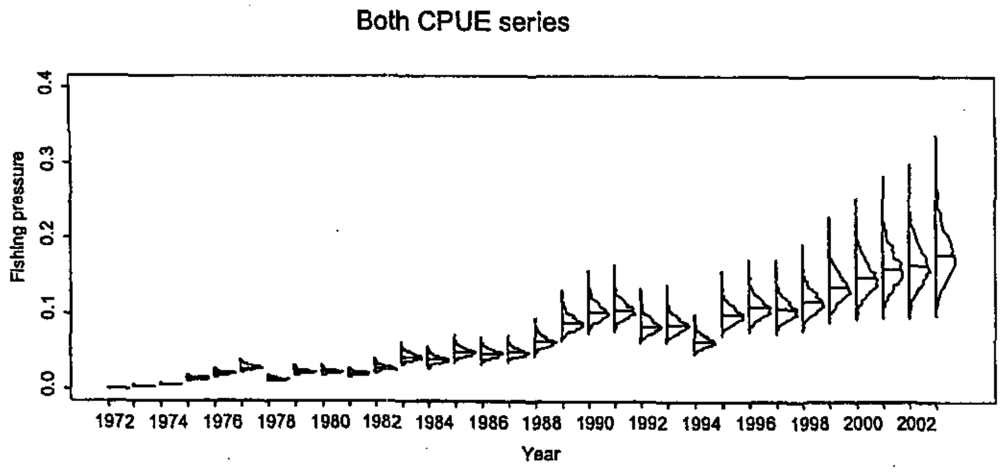


Figure 13: LIN 7WC — Estimated posterior distributions of year class strength from the two model runs. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.



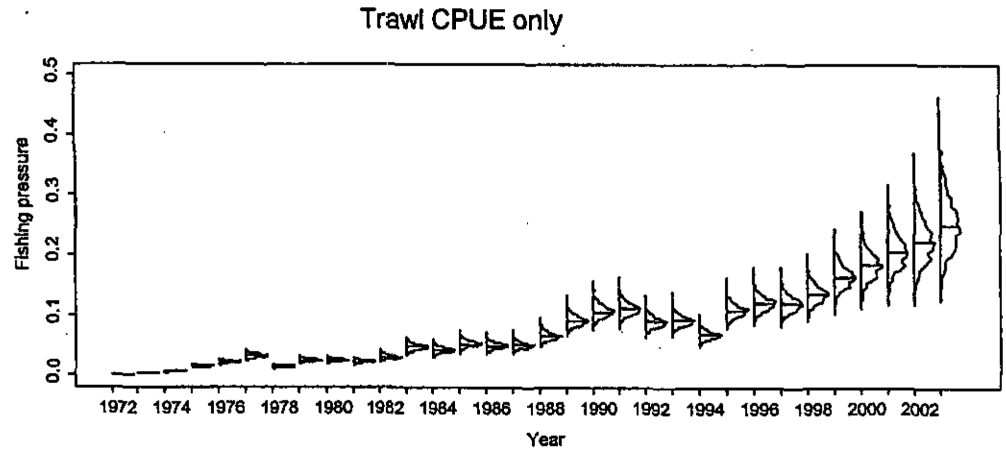


Figure 14: LIN 7WC — Estimated posterior distributions of exploitation rates from the two model runs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

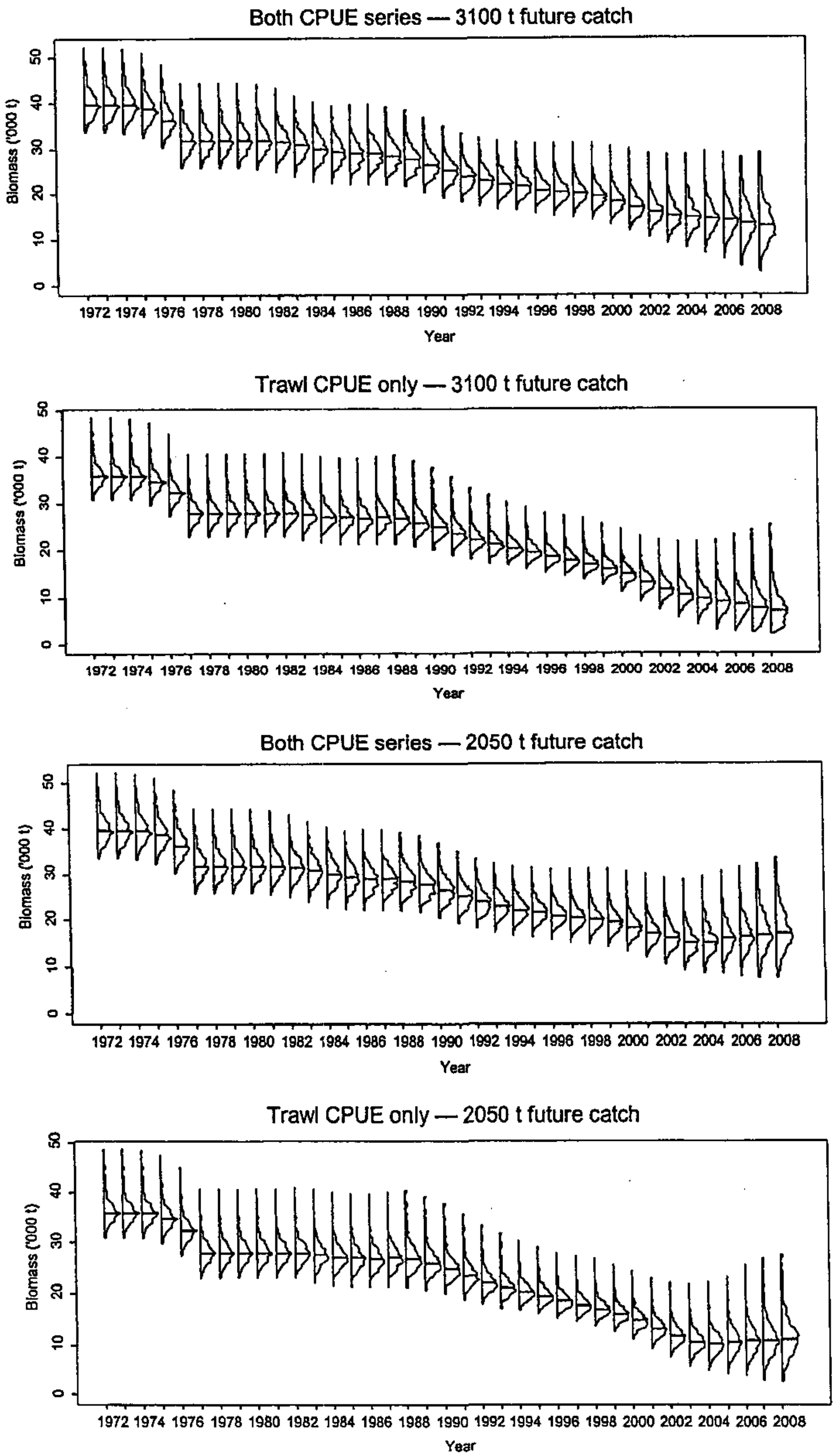


Figure 15: LIN 7WC — Estimated posterior distributions of the biomass trajectory in tonnes from the two model runs, with projections (2004–2008) for two annual catch scenarios (3100 t and 2050 t). Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

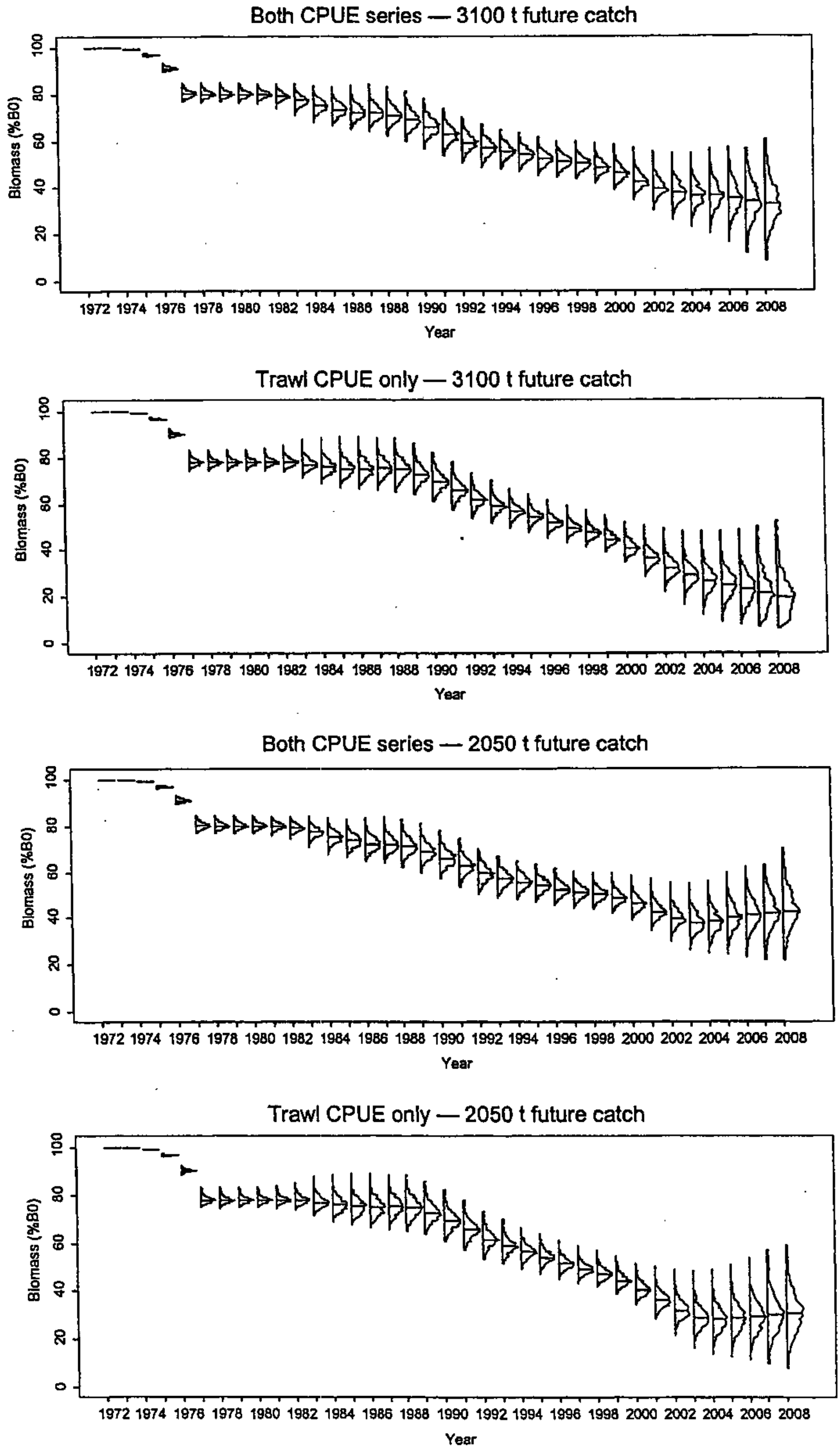


Figure 16: LIN 7WC — Estimated posterior distributions of the biomass trajectory as %B_0 from the two model runs, with projections (2004–2008) for two annual catch scenarios (3100 t and 2050 t). Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

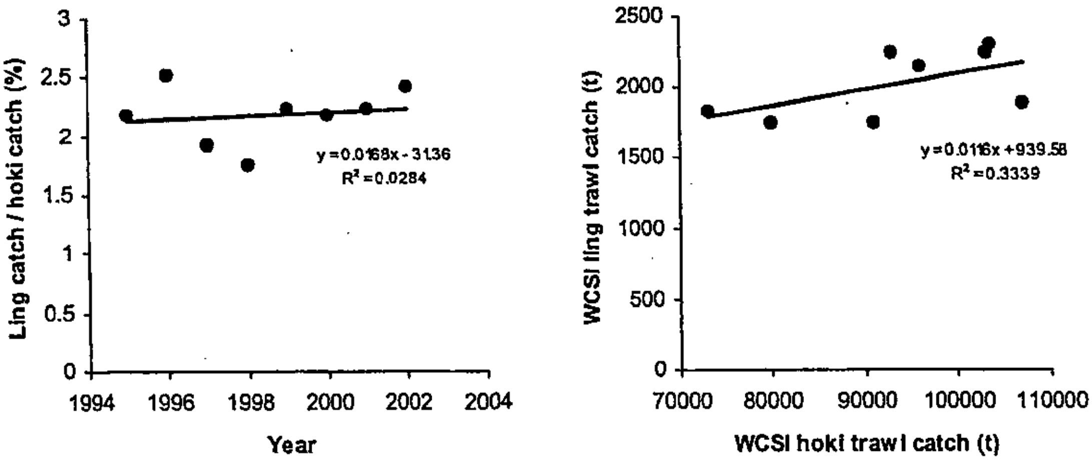


Figure 17: Relationships between the hoki catch taken by the trawl fishery off WCSI and the associated ling bycatch from the same fishery, for the years 1995 to 2002 when reported landings are believed to be relatively accurate. Linear regressions are presented for both relationships.

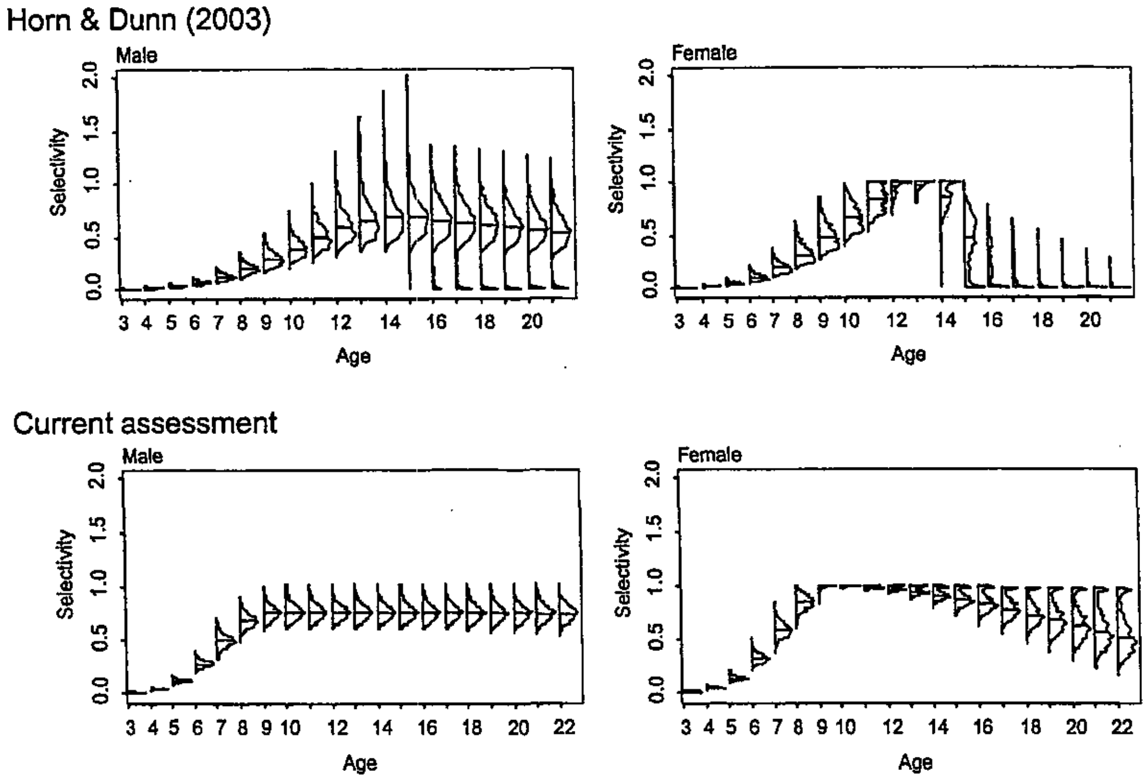


Figure 18: Estimated posterior distributions of relative selectivity, by age and sex, for the LIN 5&6 commercial trawl fishery, calculated from 10 years of numbers-at-length data (Horn & Dunn 2003), and from four years of numbers-at-age data and seven years of numbers-at-length data (Current assessment). Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

Appendix A: New calculated catch-at-age distributions for ling

Table A1: Calculated numbers at age, separately by sex, with c.v.s, for ling caught during trawl surveys of the Campbell Plateau in December 2002 (survey TAN0219) and the Chatham Rise in January 2003 (survey TAN0301). Summary statistics for the samples are also presented.

			TAN0219					TAN0301	
Age	Male	c.v.	Female	c.v.	Age	Male	c.v.	Female	c.v.
1	0	–	0	–	1	0	–	0	–
2	0	–	0	–	2	1 008	1.147	3 231	1.180
3	14 155	1.175	30 135	0.751	3	120 935	0.219	70 685	0.324
4	178 916	0.349	209 364	0.287	4	158 849	0.208	196 644	0.189
5	305 590	0.359	470 681	0.256	5	217 204	0.200	203 206	0.194
6	813 987	0.190	1 075 382	0.177	6	220 542	0.224	170 168	0.211
7	653 331	0.228	1 121 362	0.172	7	201 253	0.216	220 998	0.191
8	858 053	0.225	951 938	0.167	8	203 708	0.223	162 233	0.204
9	432 896	0.296	506 013	0.238	9	83 371	0.300	115 044	0.258
10	355 763	0.306	454 329	0.238	10	78 204	0.291	47 440	0.311
11	299 642	0.302	388 492	0.252	11	66 133	0.303	37 860	0.390
12	61 960	0.624	255 305	0.316	12	44 128	0.357	57 013	0.313
13	164 811	0.391	179 729	0.342	13	47 601	0.378	22110	0.419
14	96 891	0.477	160 622	0.358	14	41 273	0.405	24 962	0.431
15	40 952	0.680	100 394	0.402	15	32 455	0.431	26 562	0.428
16	126 179	0.418	181 065	0.320	16	14 400	0.712	11 498	0.643
17	59 530	0.580	61 324	0.443	17	8 265	0.709	5 672	0.826
18	17 448	1.002	99 073	0.357	18	11 015	0.725	13 446	0.516
19	37 568	0.672	40 850	0.590	19	17 018	0.543	13 914	0.609
20	39 805	0.678	34 536	0.631	20	8 046	0.750	1 289	1.443
21+	83 125	0.419	85 038	0.391	21+	40 513	0.353	31 532	0.366

	TAN0219	TAN0301
Measured males	1 061	813
Measured females	1 606	808
Aged males	224	315
Aged females	350	345
No. of shots		98
Meanweighted c.v. (sexes poled)	20.6	21.5

Table A2: Calculated numbers at age, separately by sex, with c.v.s, for ling caught during commercial longline operations on the Chatham Rise in July–September 2002, and on the Puysegur Bank in November 2001. Summary statistics for the samples are also presented.

Chatham Rise					Puysegur Bank				
Age	Male	c.v.	Female	c.v.	Age	Male	c.v.	Female	c.v.
1	0	–	0	–	1	0	–	0	–
2	0	–	0	–	2	0	–	0	–
3	0	–	0	–	3	0	–	0	–
4	0	–	40	1.479	4	0	–	0	–
5	137	0.656	55	1.123	5	0	–	0	–
6	1 023	0.362	376	0.424	6	211	1.000	0	–
7	2 452	0.244	750	0.315	7	1 885	0.366	61	1.753
8	4 410	0.243	2 800	0.213	8	3 643	0.300	3 328	0.284
9	6 135	0.191	2 718	0.258	9	2 837	0.364	5 258	0.208
10	5 830	0.204	3 562	0.213	10	3 433	0.318	2 221	0.302
11	5 537	0.218	3 528	0.219	11	3 519	0.307	6 359	0.192
12	6 485	0.193	3 853	0.222	12	3 000	0.272	5 208	0.200
13	4 734	0.208	4 277	0.186	13	1 893	0.352	6 955	0.176
14	4 688	0.217	3 752	0.201	14	2 592	0.333	3 277	0.256
15	2 948	0.294	2 205	0.290	15	1 859	0.336	3 475	0.257
16	2 109	0.389	1 764	0.306	16	1 516	0.391	3 495	0.228
17	278	0.797	1 672	0.310	17	1 237	0.412	3 148	0.263
18	600	0.601	1 190	0.288	18	804	0.523	2 529	0.312
19	2 240	0.271	1 112	0.338	19	1 755	0.345	1 573	0.378
20	1 780	0.357	386	0.534	20	1 645	0.495	1 287	0.380
21	1 011	0.469	461	0.503	21+	4 936	0.282	2 269	0.301
22	990	0.406	570	0.394					
23+	4 343	0.202	1 875	0.211					

	Chatham Rise	Puysegur Bank
Measured males	4 966	670
Measured females	2 998	898
Aged males	283	197
Aged females	306	284
No. of shots	538	157
Meanweighted c.v. (sexes poled)	20.1	23.0

Table A3: Calculated numbers at age, separately by sex, with c.v.s, for ling caught during commercial trawl operations off the west coast of the South Island (WCSI) and in Cook Strait, during June–September 2002. Summary statistics for the samples are also presented.

	WCSI					Cook Strait			
Age	Male	c.v.	Female	c.v.	Age	Male	c.v.	Female	c.v.
1	0	–	0	–	1	0	–	0	–
2	63	3.523	0	–	2	0	–	0	–
3	0	–	26	2.099	3	17	1.742	3	2.501
4	5 131	0.689	2 682	0.609	4	771	0.545	937	0.516
5	8 431	0.365	6 716	0.486	5	2 524	0.445	1 346	0.497
6	12 518	0.286	10 229	0.321	6	2 194	0.412	3 454	0.401
7	11 216	0.357	4 647	0.446	7	2 735	0.303	3 370	0.405
8	32 209	0.198	12 887	0.319	8	2 668	0.277	4 654	0.227
9	23 207	0.214	14 478	0.300	9	2 471	0.275	1 789	0.279
10	24 653	0.231	16 686	0.294	10	2 624	0.319	2 980	0.237
11	29 833	0.165	20 257	0.238	11	2 570	0.273	1 762	0.304
12	17 814	0.231	29 049	0.186	12	1 917	0.333	2 027	0.277
13	15 108	0.251	21 420	0.185	13	1 194	0.332	1 139	0.367
14	7 682	0.337	17 635	0.230	14	770	0.433	602	0.497
15	4 007	0.481	11 830	0.279	15	661	0.462	283	0.780
16	3 274	0.491	4 244	0.365	16	83	1.371	231	0.766
17	2 474	0.511	3 842	0.408	17+	778	0.426	715	0.593
18	927	0.833	3 886	0.434					
19	498	1.142	2 123	0.540					
20	81	1.366	743	0.540					
21+	3 763	0.438	4 142	0.354					
Measured males				1 492					583
Measured females				1 507					644
Aged males				283					207
Aged females				321					225
No. of shots				403					58
Meanweighted c.v. (sexes poled)				20.8					28.2

Appendix B: Catch-at-age distributions for ling from the Campbell Plateau trawl fishery derived from trawl survey age-length keys

Table B1: Calculated percentages at age, separately by sex, with c.v.s, for ling caught during commercial trawl operations on the Campbell Plateau during January–July in 1992, 1993, 1996, and 1998. The age-length keys used to derive these data were from the *Tangaroa* autumn trawl survey series. The sum of the percentages for males and females from each year is 100%.

	1992		1993		1996		1998	
Age	%	cv	%	cv	%	cv	%	cv
Male								
1	0	–	0	–	0	–	0	–
2	0	–	0.00	2.543	0	–	0.33	0.755
3	1.42	0.394	0.05	0.972	0.28	0.590	0.33	0.351
4	0.66	0.439	0.04	0.899	0.43	0.867	2.70	0.364
5	1.16	0.406	1.86	0.528	0.14	1.193	3.77	0.359
6	5.50	0.271	4.22	0.373	1.60	0.635	3.41	0.368
7	5.85	0.280	5.22	0.300	3.58	0.531	4.34	0.272
8	7.90	0.217	4.04	0.309	2.21	0.436	4.53	0.295
9	3.61	0.346	3.10	0.420	2.16	0.373	3.04	0.309
10	2.64	0.316	3.69	0.412	2.78	0.383	1.88	0.473
11	2.01	0.365	3.30	0.390	1.81	0.397	3.01	0.343
12	2.08	0.316	3.92	0.448	2.83	0.440	2.66	0.314
13	0.70	0.624	1.67	0.583	3.28	0.357	0.98	0.618
14	1.34	0.323	2.89	0.495	3.30	0.368	2.15	0.417
15	1.16	0.399	2.95	0.541	2.45	0.480	2.26	0.410
16	0.78	0.597	1.08	0.674	3.76	0.738	2.31	0.387
17	0.53	0.607	1.54	0.618	2.71	0.474	1.63	0.461
18	0.26	0.815	1.31	0.627	1.49	0.783	0.63	0.656
19	0.14	0.978	0.77	0.769	0.07	1.254	0.32	0.755
20+	4.21	0.274	6.13	0.404	3.91	0.474	2.90	0.520
Female								
1	0	–	0	–	0	–	0	–
2	0	–	0	–	0	–	0.36	0.556
3	0.94	0.404	0.09	0.793	0.11	0.576	0.38	1.494
4	1.10	0.312	0.10	1.418	0.70	0.904	1.89	0.721
5	1.18	0.403	1.92	0.549	1.48	0.979	5.31	0.558
6	4.51	0.280	3.40	0.395	4.18	0.631	4.96	0.333
7	6.84	0.262	6.15	0.343	2.82	0.548	6.02	0.278
8	9.95	0.195	5.21	0.331	3.75	0.461	5.71	0.288
9	6.11	0.240	7.18	0.269	3.22	0.365	7.09	0.261
10	6.84	0.204	3.64	0.333	3.66	0.347	4.20	0.318
11	4.34	0.266	5.96	0.272	4.12	0.421	3.62	0.320
12	4.17	0.250	3.70	0.373	2.93	0.463	3.29	0.379
13	2.76	0.280	2.93	0.323	9.63	0.384	2.35	0.384
14	1.48	0.330	2.16	0.321	7.02	0.421	2.58	0.382
15	2.04	0.316	1.74	0.427	4.88	0.368	2.15	0.377
16	1.16	0.373	0.86	0.494	1.44	0.625	1.73	0.453
17	0.87	0.673	1.37	0.507	4.15	0.653	2.08	0.449
18	1.21	0.409	1.60	0.506	2.26	0.647	1.67	0.555
19	0.42	0.611	0.75	0.709	2.95	0.756	0.54	0.683
20+	2.12	0.316	3.48	0.559	1.91	1.202	0.91	0.655

Appendix C: Catch sampling of the ling bycatch in the winter 2003 Cook Strait trawl fishery for hoki

Objective 4 of Project LIN2002/01 is "To collect the otoliths required for determining the catch at age from the Cook Strait trawl fishery in winter 2003 and determine the length frequency distribution of this catch".

In previous years, observers have sporadically sampled the ling bycatch from the spawning hoki target trawl fishery in Cook Strait, collecting length and sex data and otoliths. The volumes of data collected have been insufficient to calculate precise estimates of numbers-at-age in the catch (see table A5 of Horn & Dunn 2003). Consequently, since winter 2001, additional on-shore market sampling has been conducted to increase available data, enabling the calculation of catch-at-age distributions from 2001 (see table A5 of Horn & Dunn 2003) and 2002 (see Table A3 above) that met the target coefficient of variation of less than 30% over all age classes. Market sampling continued in winter 2003.

The stated sampling programme aimed to collect 18 samples, from June to September 2003, each of 50 ling (length, sex, and gonad stage), with otoliths taken from every third fish. As in previous years, samples were difficult to obtain. Although trips to target hoki in Cook Strait by trawlers based in Wellington and Nelson tend to be short (generally 1–3 days duration), there is a strong reluctance to icing green ling because of the relatively rapid tainting of the flesh by the gut contents and gills. Consequently, ling are normally headed and gutted at sea before being iced. However, Sealord Group Ltd in Nelson agreed to land green ling taken in the last trawl of each of their Cook Strait hoki trips.

Because ling landings have been found to be generally greater at the start of the season than at the end, and because some of the landed catches comprised fewer than 50 ling, sample sizes ranged from 15 to 79 fish (mean = 42). Fifteen individual landings samples were collected. Some additional landings, each comprising fewer than 8 ling, were combined into a single additional sample that provided otoliths. In total, 649 ling were measured and 452 otoliths collected from the 16 samples.

The scaled length-frequency distributions, by sex, from this sampling programme were calculated using the 'catch.at.length' software developed by NIWA (Bull & Dunn 2002), and are presented below (Figure C1). However, it should be noted that before these data will be incorporated into any assessment model, the distributions will be recalculated after inclusion of length data collected by observers, otoliths will be aged to produce an age-length key, and catch-at-age will be calculated as in previous years.

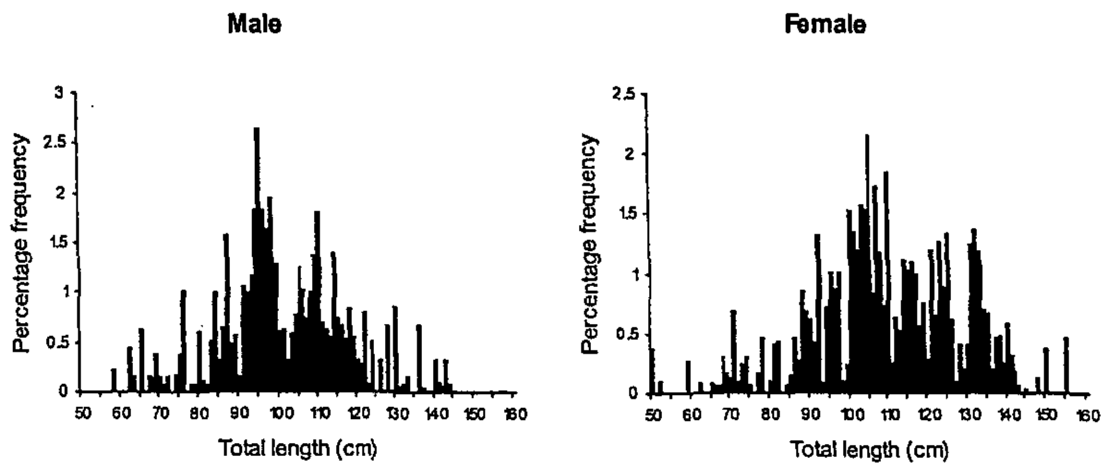


Figure C1: Scaled length-frequency distributions, by sex, of the catch of ling from the winter 2003 hoki target trawl fishery in Cook Strait, calculated using data derived from a market sampling programme.

Appendix D: Summary MPD (base case) model fits for all stocks

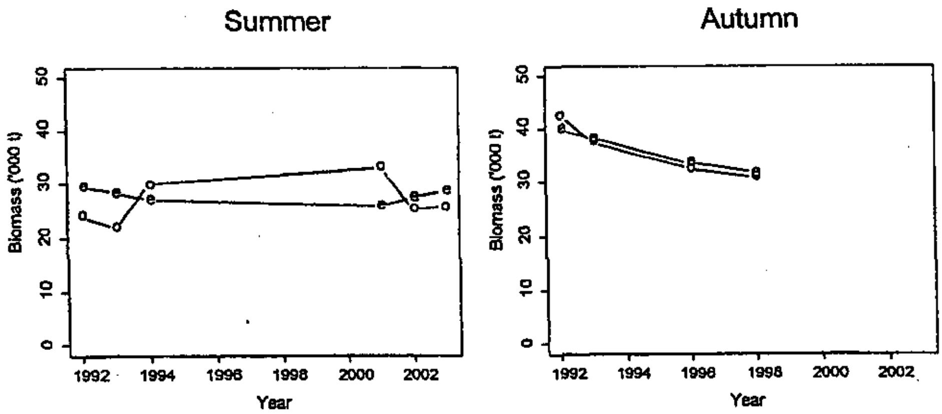


Figure D1: LIN 5&6 — MPD fits to the summer and autumn trawl survey biomass indices, where 'o' indicated the observed value and 'e' indicated the fitted (expected) value.

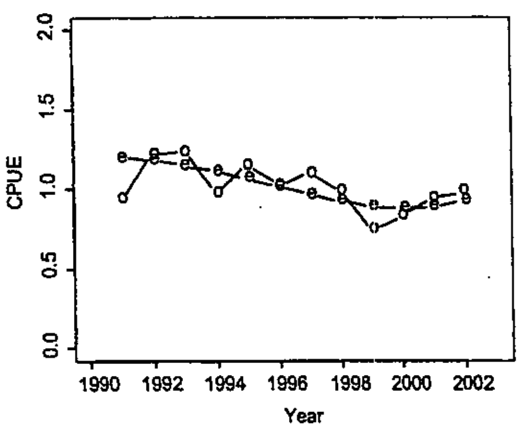


Figure D2: LIN 5&6 — MPD fits to the longline CPUE indices, where 'o' indicated the observed value and 'e' indicated the fitted (expected) value.

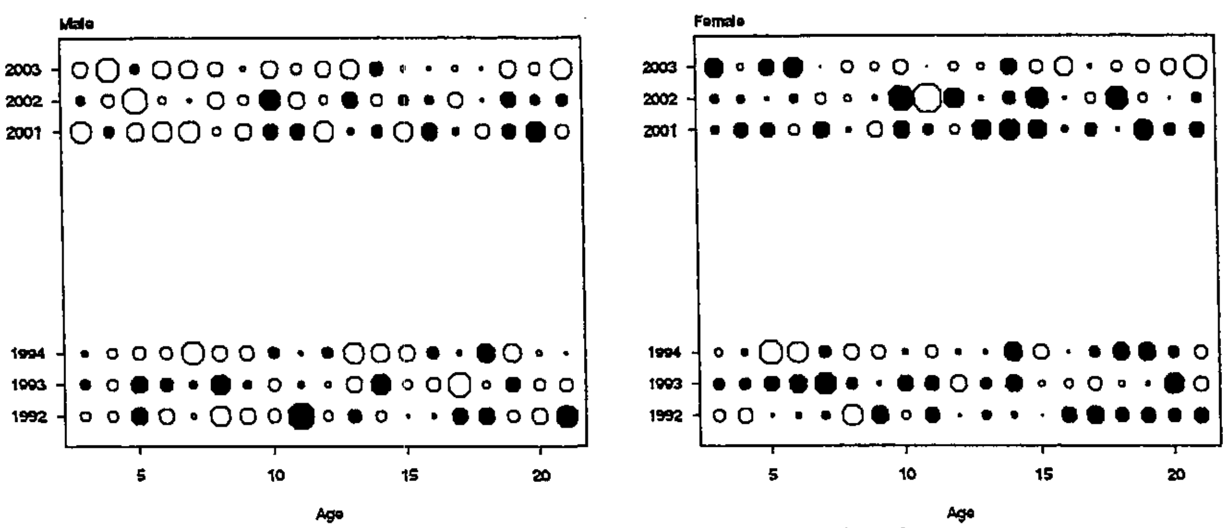


Figure D3: LIN 5&6 — MPD residual values for the proportions-at-age data for the summer trawl survey series. Symbol area is proportional to the absolute value of the residual, with open circles indicating positive residuals and black circles indicating negative residuals.

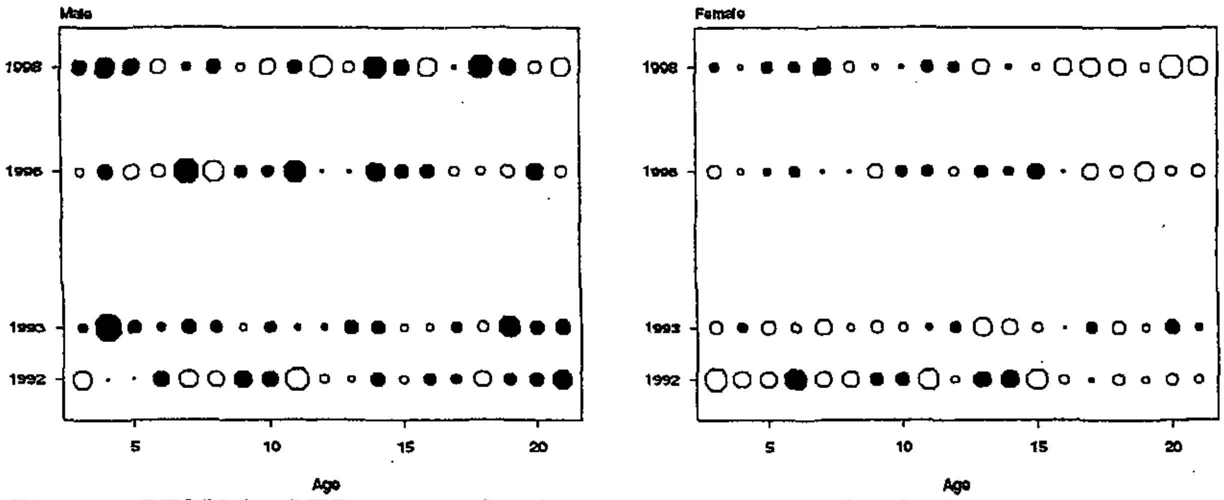


Figure D4: LIN 5&6 — MPD residual values for the proportions-at-age data for the autumn trawl survey series. Symbol area is proportional to the absolute value of the residual, with open circles indicating positive residuals and black circles indicating negative residuals.

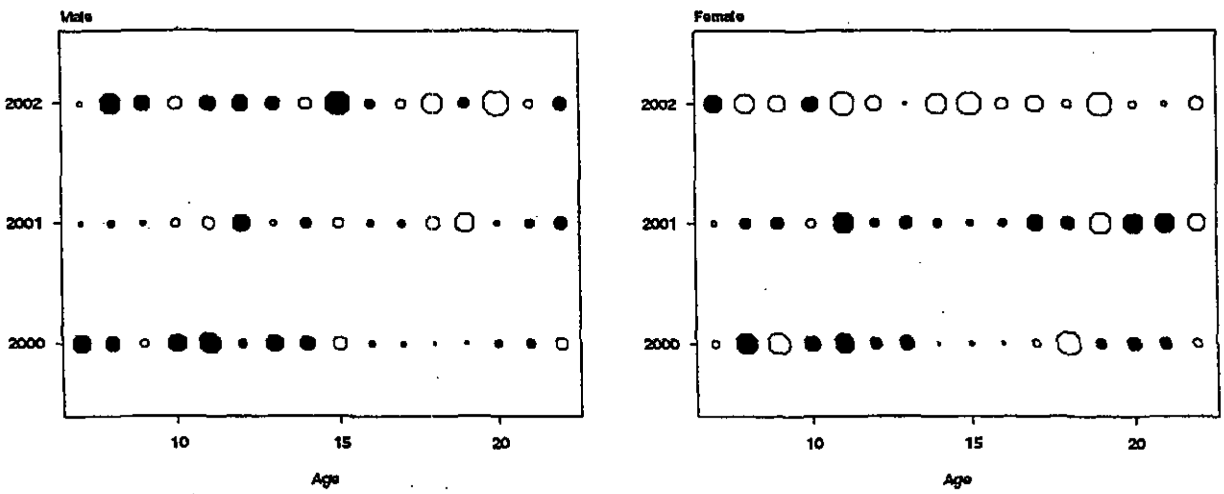


Figure D5: LIN 5&6 — MPD residual values for the proportions-at-age data for the longline spawning season series. Symbol area is proportional to the absolute value of the residual, with open circles indicating positive residuals and black circles indicating negative residuals.

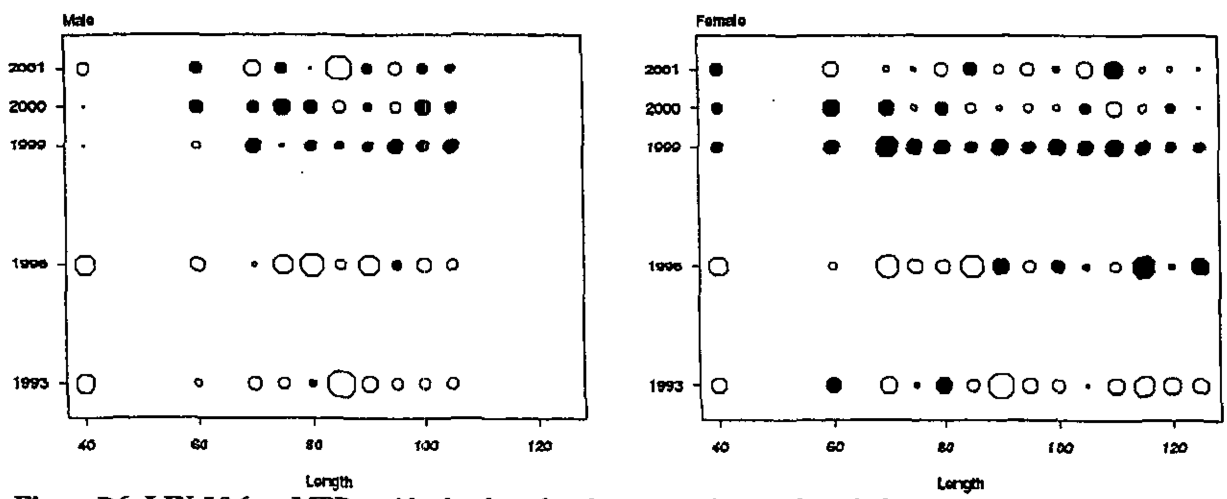


Figure D6: LIN 5&6 — MPD residual values for the proportions-at-length data for the longline spawning season series. Symbol area is proportional to the absolute value of the residual, with open circles indicating positive residuals and black circles indicating negative residuals.

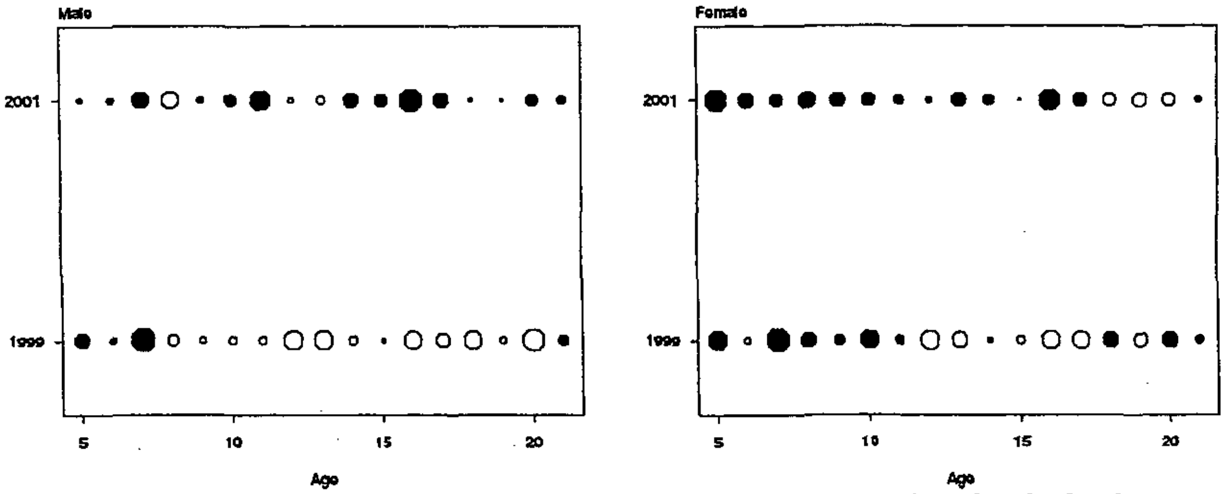


Figure D7: LIN 5&6 — MPD residual values for the proportions-at-age data for the longline non-spawning season series. Symbol area is proportional to the absolute value of the residual, with open circles indicating positive residuals and black circles indicating negative residuals.

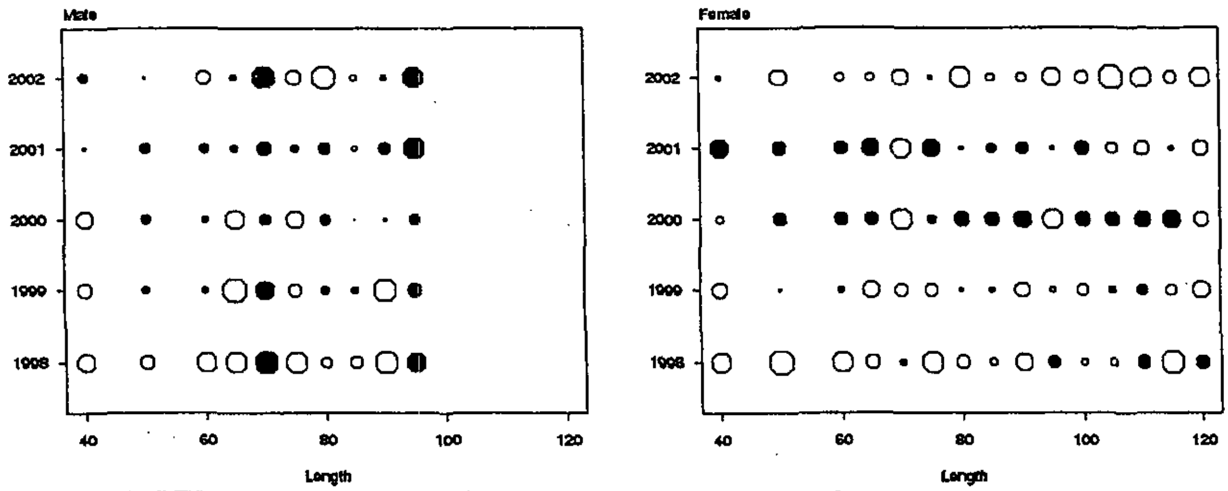


Figure D8: LIN 5&6 — MPD residual values for the proportions-at-length data for the longline non-spawning season series. Symbol area is proportional to the absolute value of the residual, with open circles indicating positive residuals and black circles indicating negative residuals.

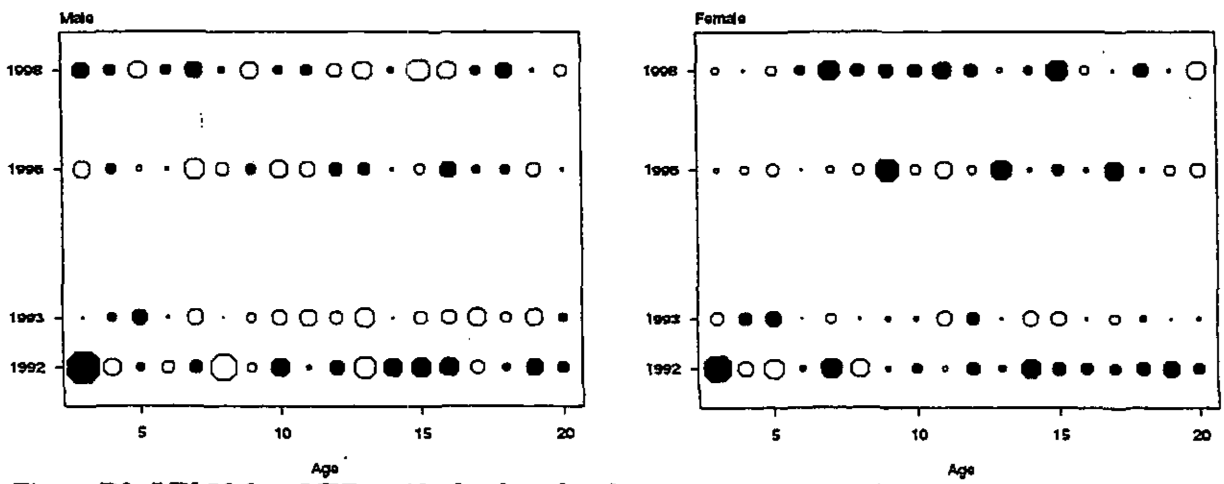


Figure D9: LIN 5&6 — MPD residual values for the proportions-at-age data for the commercial trawl fishery series. Symbol area is proportional to the absolute value of the residual, with open circles indicating positive residuals and black circles indicating negative residuals.

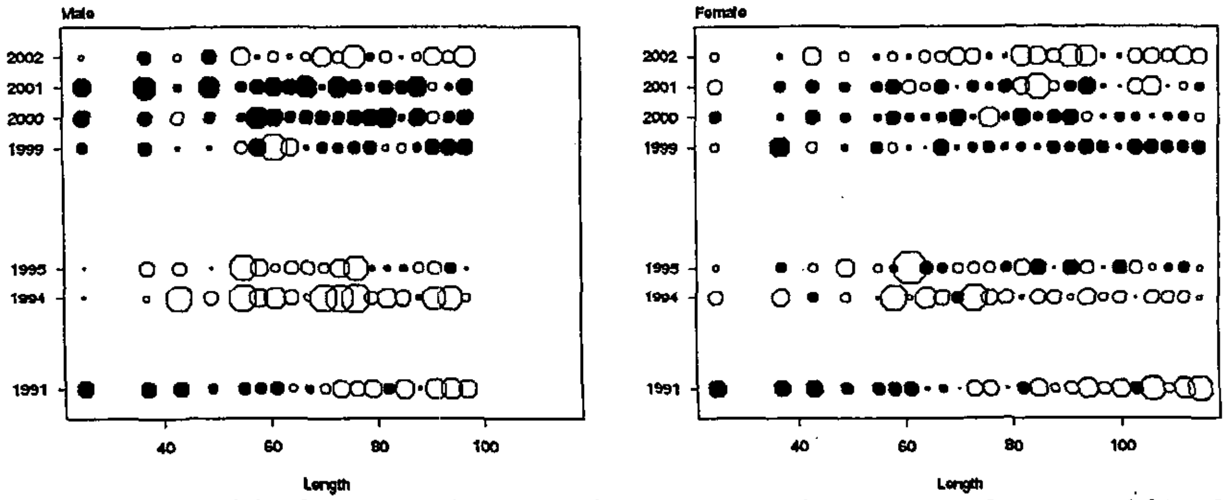


Figure D10: LIN 5&6 — MPD residual values for the proportions-at-length data for the commercial trawl fishery series. Symbol area is proportional to the absolute value of the residual, with open circles indicating positive residuals and black circles indicating negative residuals.

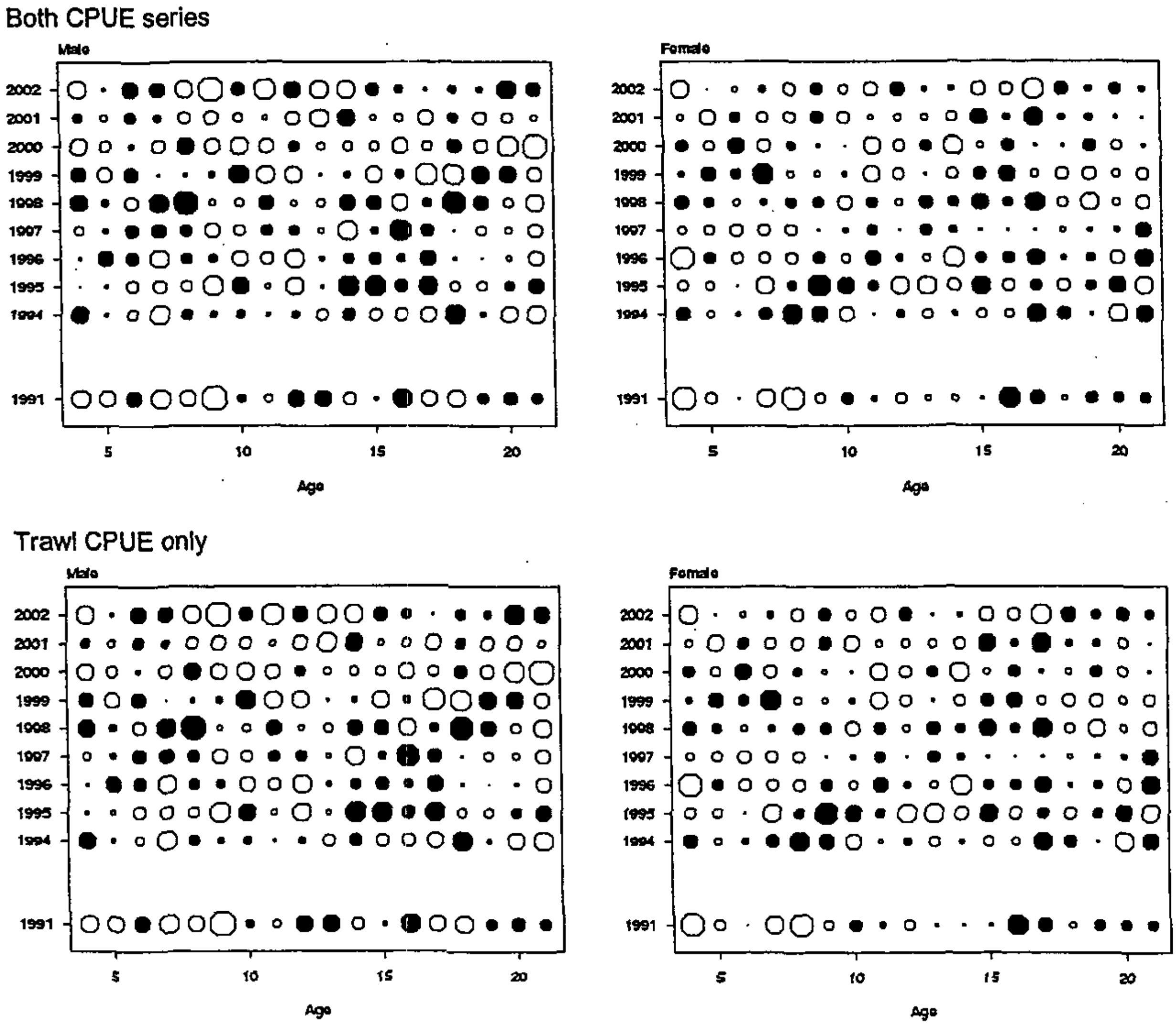


Figure D11: LIN 7WC — MPD residual values for the proportions-at-age data for the commercial trawl fishery series. Symbol area is proportional to the absolute value of the residual, with open circles indicating positive residuals and black circles indicating negative residuals.