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Analysis of longline CPUE, and stock assessment of ling (*Genypterus blacodes*) off the northwest coast of the South Island (Fishstock LIN 7)

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1. EXECUTIVE SUMMARY

Ling in LIN 7 are taken primarily as a bycatch of other fisheries, particularly the west coast South Island (WCSI) spawning hoki trawl fishery, though some target longlining does occur. Landings peaked briefly in 1976 and 1977 as a result of foreign longlining. Landings since 1988–89 have been relatively constant at about 3000 t annually despite a TAC of about 2200 t.

Landings from LIN 7 are concentrated in two general areas: off WCSI, and around Cook Strait. The stock affinity of Cook Strait ling is currently uncertain, and it is possible that two stocks could be represented in the LIN 7 area. For this assessment, two stocks are assumed. However, only the WCSI stock was modelled; in recent years it has produced about 90% of the total landings from LIN 7. The ling landings reported from LIN 2, but caught adjacent to Cook Strait, are almost certainly from the same biological stock as the Cook Strait catches reported from LIN 7.

Longline CPUE data were analysed keeping WCSI and Cook Strait data separate. The WCSI series calculated using all CELR data since 1990 was considered a useful abundance index as it showed a consistent trend and was based on a large number of data points. The Cook Strait series was not considered a useful index as it was based on relatively few data points and showed no consistent trend. The WCSI CPUE series, which indicated a steady decline in abundance since 1991, was the only abundance index available for inclusion in the LIN 7 model.

For the assessment of ling in the WCSI section of LIN 7, all relevant biological parameters, the commercial catch history, the WCSI longline CPUE series, and three series of catch-at-age data were incorporated into a population model using the MIAEL estimation technique. The model appears to be largely driven by the CPUE series, although the catch-at-age data do provide useful information. The model results suggest that the stock has declined since 1990, and will continue to decline further at current catch levels. However, the estimates of virgin biomass had low information indices (4–17%) and are therefore not well defined within the B_{min} to B_{max} range derived from catch history and exploitation rate assumptions. The estimates of current biomass have better information indices (7–47%), but a very wide range. Results from the model indicate that the LIN 7 stock is likely to be below the level that would support the MSY and likely to decline further if catches at the level of the 1997–98 TACC are taken. However, the very high uncertainty associated with this assessment must be noted.

2. INTRODUCTION

2.1 Description of the fishery

The area of the LIN 7 Fishstock includes much of west-central New Zealand and western Cook Strait (Figure 1). Most ling landings from this area are taken as bycatch of other fisheries, particularly the winter trawl fishery for spawning hoki off the west coast of the South Island (WCSI). There is some target longline fishing for ling with peak catches off WCSI generally from August to October, and in Cook Strait with peak catches generally from April to June. A small, but important, quantity of ling is also taken by set net. Catch by method in the 1990s shows that trawl-caught ling make up 50–70% of annual landings (Figure 2).

2.2 Literature review

Previous assessments of ling in LIN 7 were carried out by Horn (1993a) and Horn & Cordue (1996). Horn (1993a) presented preliminary estimates of virgin biomass (B_0) and MCY from a stock reduction analysis that was constrained to give mean instantaneous fishing mortality (*F*) of 0.03 over the known period of exploitation. A B_0 of 75 000 t was indicated, but it was shown to be very sensitive to the chosen value of mean *F*. Horn & Cordue (1996) produced new estimates of B_0 and MCY using the MIAEL estimation technique of Cordue (1995, 1996). A B_0 of 52 300 t was indicated, but it was based on very little data (a catch history, and estimates of likely maximum and minimum levels of exploitation) and had an information index of 0%.

3. REVIEW OF THE FISHERY

3.1 Landings and TACCs

Estimated and reported catches from 1973 to 1997–98 are shown in Table 1. The landings peak in 1977 was due primarily to foreign licensed longliners. The sharp increase in landings from the 1988–89 fishing year, and subsequent maintenance at these levels, resulted from the development of the trawl fishery targeting spawning hoki off WCSI. Recent estimated landings from the two main fishing areas in LIN 7 (WCSI and Cook Strait) indicate that most derive from WCSI (Table 2).

There is evidence, from comparison of catches from vessels carrying observers with those not carrying observers, to suggest that the bycatch of ling in the hoki fishery was not always fully reported. The actual ling catch in this fishery for the years 1987–88 to 1992–93 was estimated (*see* Table 1) by multiplying the total hoki catch (which was assumed to be correctly reported by vessels both with and without observers) by the ratio of ling to hoki in the catch of vessels carrying observers (Horn 1993a). Non-reporting of ling since 1992–93 is believed to be slight.

Reported landings from LIN 7 have consistently exceeded the TACC since 1988–89. Overruns since the 1994–95 fishing year have been about 30–40% of the TACC.

3.2 Other sources of mortality

There is likely to be some mortality associated with escapement from trawl nets, but the level of this is not known.

The recreational fishery for ling is negligible, but would comprise a small quantity of line-caught fish from the Cook Strait region. The amount of ling caught by Maori is not known but is believed to be negligible.

4. BIOLOGY

4.1 Stock structure

Horn & Cordue (1996) noted, in a review of information on stock structure of ling, that the stock affinities of fish in Cook Strait and around the North Island were unknown. There is still no information available to clearly resolve this problem. Ling off WCSI were considered to constitute a separate stock from those on either the Chatham Rise or in the Puysegur Bank and Campbell Plateau regions. Since the development of the WCSI hoki fishery, at least 70% of the annual LIN 7 landings would have derived from the WCSI stock. However, there are three possible scenarios for the stock affinity of ling taken from the Cook Strait region: they could derive from the WCSI stock, the Chatham Rise stock, or from a distinct 'North Island' stock.

Ling are known to spawn at times in both Cook Strait and off WCSI (Horn & Cordue 1996). However, the presence of two spawning grounds is not sufficient to indicate separate stocks; spawning activity has been recorded from at least three sites in the Puysegur Bank and Campbell Plateau region, which is considered to hold a single ling stock.

Longline CPUE from two separate areas in LIN 7 (Cook Strait and WCSI) is presented in Section 6. The analyses indicate no consistent trend in CPUE for Cook Strait fish, but a consistent downward trend during the 1990s for ling off the west coast. This information tentatively suggests that there is a stock boundary between these two areas.

Until more concrete information on the likely stock affinity of Cook Strait ling is available, landings from this area reported in LIN 7 will be treated as coming from a stock separate from that off WCSI. [Additional landings of ling from the eastern side of Cook Strait are probably from the same biological stock as western Cook Strait ling, but will be reported in landings from LIN 2. Estimates of recent landings from LIN 2 originating from the "Cook Strait stock" are given in Table 2.]

4.2 Productivity parameters

Horn (1993b) validated the use of otoliths to age ling and showed that they reach a maximum age of about 30–35 years, with no apparent sexual differences in longevity. Females in all areas grow larger than males. All age data from the LIN 7 area were derived from fish caught in the trawl fisheries for hoki and hake off the WCSI. Ling off WCSI had the fastest growth rates of all the New Zealand stocks examined, and had maximum lengths for males and females of about 140 cm and 160 cm, respectively.

No length-weight information is available for ling from LIN 7. The relationship used in all assessments to date has been that derived for ling on the Chatham Rise (which have similar growth rates and maximum sizes to WCSI fish).

The rate of instantaneous natural mortality (*M*) was estimated for all ling stocks using the slope of the right hand limb of the catch curve (and assuming a low level of fishing mortality), and the equation $M = (\log_e 100)/A_{max}$ where A_{max} is the age to which 1% of the population survives in an unexploited stock. Horn (1993a) estimated A_{max} from five samples as 23–27, giving *M* in the range 0.17 to 0.20 (with a mean of 0.18). Less than 0.2% of aged ling were older than 30 years, and an A_{max} of 30 gives a likely minimum value of *M* of 0.15.

No data are available to enable the calculation of the maturity ogive for WCSI ling so the ogive used in the current assessment was based on data collected during trawl surveys of the Chatham Rise (Figure 3). Those data indicated that the youngest mature fish were age 5 years for males and aged 6 for females, and that immature fish of either sex older than 10 years were rare. Lengths at 50% maturity were about 74 cm for males and 88 cm for females, corresponding to ages of 8 and 9 years, respectively. Hence, ogives were estimated which, at ages 5, 6, 7, 8, 9, and 10, had 10, 20, 35, 50, 80, and 100% of males mature, and 0, 10, 20, 35, 50, 100% of females mature.

Biological parameters relevant to the stock assessment are listed in Table 3.

4.3 Catch-at-age data

New catch-at-age distributions are calculated here from samples collected by observers in the hoki trawl fishery in winter 1991, 1997, and 1998. The distributions have been scaled to the total ling catch for the season in the trawl fishery (Tables 4, 5, and 6).

5. TRAWL SELECTIVITY

Catch curves produced from two of the aged samples of trawl-caught ling indicate that full recruitment in this fishery occurs at an age of about 12–13 years (Figure 4a). Selectivities, by age class and sex, were derived in the following manner. The linear regression equation of the right hand limb of the catch curve (ages 12 years and over) was calculated. Then, the regression line was projected back to provide estimates of the abundance of each age class less than 12 years, under an assumption of 100% selectivity for all fish. Finally, the proportion of the observed versus the expected abundance (i.e., the selectivity) of each age class less than 13 years was calculated and plotted (Figure 4b). Curves were fitted to the two combined data sets for each sex using a non-linear multivariate parameter estimation procedure (SAS Institute 1988). Selectivities used in the stock assessment model for each year class were obtained from the curves (Figure 4b) and are listed in Table 7.

Selectivities were assumed to be zero for all ling less than 4 years old, and one for all fish older than 12 years.

6. CPUE ANALYSIS

Ling in LIN 7 are taken primarily as a bycatch of other target trawl fisheries, but also by small domestic longline vessels. About one third of the LIN 7 catch is taken by longline, with most of the rest being trawl-caught, primarily as a bycatch of the hoki fishery. A CPUE analysis of ling bycatch in trawl fisheries targeting other species in LIN 7 is considered unlikely to provide a useful series of abundance indices because of changes in fishing practice over time and perceived inaccuracies in the reporting of the ling catch.

An analysis of target longline CPUE for LIN 3 and 4 has provided a useful series of abundance indices (Ballara 1997), and it is considered that data from this fishing method would probably provide the most reliable CPUE series for LIN 7.

Catch and effort data were extracted from the fishery statistics database managed by the Ministry of Fisheries. All catch effort landing returns (CELR), and domestic records for the LIN 7 lining fishery catching or targeting ling were extracted. Longlining in LIN 7 is concentrated in two areas: Cook Strait, and WCSI. Because the stock affinities of the Cook Strait fish are unknown, data from the two areas were analysed separately. For the WCSI, data sets used in the analysis were: FSU domestic, and CELR data, all lining methods, 1983 to 1997 ("All data"); CELR data only, all target species, and lining methods ("All CELR data"); and CELR data only, target ling, bottom longlining ("CELR target ling only"). In recent years, about one third of the landings from WCSI were taken by longline (*see* Table 2). Cook Strait data sets used included the "All data", and "All CELR data" sets as for the WCSI, but did not include the "CELR target ling only" data set, as there was not enough data for an analysis. Cook Strait data also included landings from statistical area 016, the eastern section of the strait which falls in the LIN 2 QMA.

Data were accepted according to Ballara (1997) although data for a vessel were used if for each vessel the number of longline sets were more than or equal to 5 sets in 1 year, or 15 sets in 5 consecutive years. Data points were examined and outliers were altered if the cause of the anomaly was apparent for that set, or removed. The WCSI and Cook Strait data sets were reduced by 556 and 448 records, respectively, after data cleaning.

The number of vessels for the WCSI fluctuated for each year (Table 8a), and there were very few vessels in the fishery, or catch taken (after data grooming), from 1987 to 1989. There were no individual vessels present in the WCSI fishery in all years in the "All data" set, and for the "All CELR" and "CELR target ling only" data sets there were four vessels that were present in the fishery in all years. Most of the catch that was in the WCSI "All CELR data" set was encompassed in the target ling data set. There was one auto-longliner present in the WCSI data set. It fished in 1992 and 1994 to 1996, but in any one year accounted for no more than 5 t of catch, or nine sets. In retrospect, these data probably should have been excluded from the analysis.

For Cook Strait, the number of vessels has fluctuated from 11 to 18 vessels in a year, except for 1996 and 1997 where there were fewer vessels (Table 8b). In the Cook Strait "All data" set there was only one vessel which fished in all years, and in the "All CELR data" set there were two vessels present in all years.

The checked data were applied to two standardised multivariate CPUE models, both of which attempt to minimise residual deviance: a lognormal linear (LNL) model (Vignaux 1993) and a generalised linear (GLL) model incorporating a Gamma distribution and log-link function described by Vignaux (1994). Parameters were be added to the models using a stepwise procedure until less than 0.5% improvement in the R^2 is seen following the inclusion of an additional variable.

A summary of available data by calendar year, and area (and the three data sets into which they were classified) is given in Table 8. The data sets for 1997 are probably incomplete (based on the number of sets reported in November and December relative to previous years), but the number of data points for this year is still high. The overall number of zero catches was very low at about 1% of the data, for both area data sets.

Variables used in the analysis are presented in Table 9. Data are analysed by calendar year (rather than fishing year) to avoid splitting the data when a weak seasonal peak was apparent (from June to December). For the "All data" data set (Domestic and CELR), the variables target species and lining methods were not included, as domestic data was not by target species, and lining method also included an unknown category for the lining method. Zero sets were also not included, as domestic data has been summarised without zero information.

Variables entering the models are listed in Table 10. For the WCSI, 'Month of year' 'Statistical area', and 'Year' were important variables, as they all entered the model in each run, often quite early on in the analysis, indicating their importance. Higher catch rates were generally seen from August to October, and in statistical areas 032, 033, and 034. In the "All CELR" data run with all target species, 'Target species' was the most important variable where catch rates were the highest for ling as the target species. A range of vessel characteristics also entered each model run, explaining in some way the efficiency of vessels. In both data sets comprising only CELR data, 'Season', or 'Southern Oscillation Index' (SOI) also entered the model. The overall model explained about 36% and 35% of the variance for the "All CELR" data LNL and GLL runs, respectively.

For Cook Strait, 'Month', 'Year', and 'Statistical area' also entered each model run, as did a range of vessel characteristics, 'Vessel Power' being the most important of these. Higher catch rates were seen from April to June in a few years, and higher catch rates were also seen in statistical area 016. Again for the "All CELR" data run, 'Target species' was the most important variable, with the higher catch rates when the target species was ling. The 'SOI', or 'Season' variables also entered each run. The overall model explained about 36% and 31% of the variance for the "All CELR" data LNL and GLL runs, respectively.

The relative year effects for each analysis are given in Table 11, and plotted in Figures 5 and 6. The WCSI indices show a slight decline in CPUE over most years (Figure 5), with a larger decrease in 1996 in the data sets comprising only CELR data. The "All data" set has no trend between 1983 and 1990, and then stabilises to a decline from 1991. Both the LNL and GLL indices show similar trends for all three data sets, although the LNL indices are slightly higher than the GLL indices in most years. Running the LNL model without zeros does not change the LNL indices much. For the LNL indices, the "All CELR" series generally had slightly higher indices than the "CELR target ling only" series, but there was not much difference between the GLL indices for these two runs.

The Cook Strait "All data" set relative year effects exhibit no real trend for most years (Figure 6). The "All CELR" data set shows no trend from 1990 to 1995, although there is a slight decrease between 1992 and 1993, and an increase from 1995 to 1997, particularly between 1996 and 1997. The LNL and GLL indices show similar trends.

For both areas, it is considered unwise to use the data series incorporating the FSU data because of the relatively few data points in some years, the unavailability of target species data (which was the most important variable in the "All CELR" data runs), and the unknown quantity of sets with a "zero" catch.

For the WCSI, there is little to pick between either of the WCSI "All CELR" and "CELR target longline" series. Both show quite similar trends. Therefore, the "All CELR" series was chosen as it makes use of more data. The choice between the LNL and GLL models for this series is also not straightforward. An increased number of zero shots apparent in the last two years indicated that the GLL model might be the most applicable model. However, running the LNL model without zeros does not produce a marked change in the relative year effects (*see* Figure 5, "All CELR" data, no zeros), which may be explained by the very few zero tows in the data set. Fits to the residuals for the two models show some trend still apparent through the bulk of the data (Figure 7) in both, and poor correlation for zero catches for the LNL model. The plots of observed CPUE values against fitted values show some correlation between observed CPUE and fitted values for both models. The LNL indices were chosen, as the LNL is the simpler model.

The WCSI CPUE data set for LIN 7 is considered useful as an abundance index for stock assessment as it shows a consistent trend, and for each data set and model yearly indices were very similar. There were also enough data to perform the analysis. [It is suggested that future analyses use only the "CELR target ling BLL" data, and exclude data from auto-longliners (unless this fishing method substantially increases in importance off WCSI). However, it is considered that the current assessment would have changed only slightly if such a data set had been used here.]

The Cook Strait "All CELR" data set may not be useful as an abundance index for stock assessment, and was therefore not used in the modelling. There were not enough data points in the data set to be considered useful for a CPUE analysis, and the relative year effects exhibited no real trend for most years, and were not similar to the trends seen for the WCSI indices. Cook Strait may be also be affected by avoidance behaviours of longliners to other fish species and fisheries, such as bluenose longlining, or the hoki fleet, and catch rates may also be greatly affected by seasonal effects and weather. The stock affinities of Cook Strait ling to LIN 7 are unknown, and although statistical area 016 was included in the analysis, as a logical part of "Cook Strait", this statistical area is not part of LIN 7. Statistical area 016 is from LIN 2, but would be the same biological stock as statistical areas 017 and 039, the other statistical areas used for Cook Strait.

7. STOCK ASSESSMENT

7.1 Model inputs

The LIN 7 stock was modelled using the least squares and single-stock MIAEL estimation techniques of Cordue (1995, 1998).

The model year was set to begin at 1 February, with a pre-spawning season from February to the end of September. Ling were assumed to increase in age on 1 October, and have a 4-month spawning season from October to January. Catch data were available for each year from 1973, with zero landings assumed for all previous years. Because of the uncertain stock affinity of Cook Strait ling, only landings from the WCSI section of LIN 7 were included in this analysis. Since about 1989, 60–90% of the WCSI ling catch was taken by bottom and mid-water trawl, with most of those landings being from the hoki spawning fishery (i.e., June to September in the ling pre-spawning period). The remaining longline and setnet landings were taken throughout the year, but with a weighting towards the summer months (i.e., the ling spawning period). Based on these trends, landings from the spawning and pre-spawning periods were assumed to make up 25% and 75%, respectively, of annual landings (Table 12).

The only relative abundance indices available were CPUE data from the longline fishery in the WCSI section of LIN 7 (*see* Section 6). The series chosen for the base case was the "All CELR" data, LNL model (Table 11a). Because of the possible incomplete nature of the 1997 data, a sensitivity test excluding this point was run. Another sensitivity test using the "All CELR" data, GLL model was also conducted. Although the data used in the CPUE analyses were derived from the whole year, longline catches off WCSI peak from August to October, so the CPUE series was applied to the model at this time, i.e., the second half of the pre-spawning season. CPUE indices were assigned a *c.v.* of 0.35.

Estimates of biological parameters and of model parameters used in the assessments are given in Tables 3 and 7 respectively. The steepness parameter is from the Beverton and Holt stock-recruitment relationship. The proportion spawning is assumed to be 0.9 in the absence of data to fix a figure. Sensitivity tests using values of M of 0.10 and 0.22 were conducted. The selectivity of all fish is assumed to equal 1 on the spawning ground.

The home ground selectivity curve is based on a catch curve analysis of the WCSI trawl samples. Catch at age data were available from 1991, 1997, and 1998 for ling caught as bycatch in the hoki target trawl fishery off WCSI. A sensitivity test assuming constant recruitment each year was conducted to measure the impact of the three years of catch at age data.

In preliminary runs of the model, year class strengths were estimated for the years 1968 to 1990 (Table 13). They were re-estimated for each sensitivity run of the model. These values were used as input data for the estimation of biomass.

The maximum exploitation rate was taken as 0.5 on the home ground (r_{hm_max}) and on the spawning ground (r_{sp_max}). Although ling are likely to be more aggregated and easier to target in the spawning season, it has been concluded above that the bulk of the landings derive from the pre-spawning season. Hence, a greater exploitation rate in the spawning season was not considered in the model base case, although values of 0.7 for both parameters were tested in a sensitivity run. The values of r_{hm_max} and r_{sp_max} determine B_{min}, the lowest value of B_0 that is consistent with the catch history.

The minimum exploitation rates (r_{hm_mmx} and r_{sp_mmx}) are the lowest values that the exploitation rates are believed to have been in the year that the exploitation was highest. A value of 0.01 was used for the spawning and pre-spawning seasons in the base case. Assumptions about r_{hm_mmx} and r_{sp_mmx} determine the value of B_{max}, the highest level that is believed to be feasible for B_0. The values of B_{min} and B_{max} are used as bounds for estimates of B_0.

7.2 Biomass estimation

Estimates of mid-spawning season virgin biomass (B_0), mid-spawning season mature biomass for 1997–98 (B_{mid98}), and 1998–99 (B_{mid99}), and estimates of 1999 beginning of year total biomass (B_{beg99}) were obtained (Table 14).

The best estimate of B_0 (39 310 t) is lower than estimates from previous assessments (Horn 1993a, Horn & Cordue 1996). However, it represents only ling off the west coast of the South Island. The estimate has wide bounds and a low information index, so should be considered as highly uncertain.

Current biomass (B_{mid98}) is estimated to be only 22% of B_0. Even though the information index is reasonable (40%), the bounds around the estimated biomass are very wide (range 6–93%), so the uncertainty associated with this assessment is high. The biomass trajectory is shown in Figure 8.

The base case model fit to the CPUE indices is shown in Figure 9. The model has difficulty fitting to the last three points because of the wide variation between them. The base case fits to the catch at age data (Figure 10) are good when the data for both sexes are combined. However, the goodness of fit by sex is variable, although trends in comparable sets of observed and expected data are similar. Differences are caused by the model predicting that about 45% of the catch will be male fish, compared with an observed level of about 60% of male fish taken in the trawl fishery. This suggests that the time lag between the male and female home selectivity ogives should be even more pronounced than the 1 year used in this assessment.

All the sensitivity tests, except for the CPUE series excluding the 1997 point, had little influence on the estimate of B_0. Information indices ranged between 11 and 17%, indicating that the point estimates of biomass are poorly known. The modified CPUE series resulted in a higher estimate of B_0 and a lower information index. The model fit to this CPUE series is shown in Figure 9.

Estimates of B_{mid98} were also relatively insensitive to changes in *M* and r_{max}, and the GLL CPUE series. However, the tests involving constant year class strengths, and excluding the 1997 point from the CPUE series, markedly increased the estimated current biomass. The information indices for B_{mid98} (7–47%) are better than those for B_0, but the point estimates are still not well known because of the relatively wide bounds. Only one of the estimates of B_{mid98} was above B_{MAY} (28% B_0).

7.3 Yield estimates

MCY was estimated from MCY = $p.B_0$, where p is determined for each stock using the method of Francis (1992) such that the biomass does not drop below 20% B_0 more than 10% of the time. CAY was estimated from the MIAEL estimates of current projected total biomass (B_{beg99}) using the method of Francis (1992). Estimates of MCY and CAY are given in Table 15. In all but one of the years since 1988–89, reported landings have been higher than the estimate of MCY (2 400 t).

7.4 Management implications

The LIN 7 stock appears to be much smaller than either the Chatham Rise or Sub-Antarctic stocks, a conclusion also drawn by Horn & Cordue (1996). However, the current assessment indicates an even lower level of virgin biomass than that reported in 1996 (39 310 t, relative to 52 300 t), although this assessment relates only to the WCSI section of LIN 7. The assessment presented here is largely driven by the longline CPUE indices, which constitute the only estimates of abundance for this stock. The deletion of the last point in the CPUE series (because it may be based on incomplete data) markedly changes the assessment. The catch-at-age data also contribute significantly to the assessment; incorporating estimated year class strengths instead of assuming mean annual recruitment increases the information index for current biomass from 26 to 40%. Estimated year class strengths appear to have been relatively constant over the period 1968 to 1990, with extreme values generally varying by only one order of magnitude. However, year class strengths since 1990 cannot be estimated.

Model results suggest that the LIN 7 stock may be below the level that would support the MSY, and could decline further at the current catch level or at a catch level equal to the current TAC. However, the wide bounds around the estimates, and subsequent high levels of uncertainty about the assessment, have been stressed above.

8. ACKNOWLEDGMENTS

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9. REFERENCES

Ballara, S.L. 1997: Catch per unit effort (CPUE) analysis of ling (*Genypterus blacodes*): Chatham Rise bottom longline and Puysegur trawl fisheries. *N.Z. Fisheries Assessment Research Document 97/17.* 35 p.

Cordue, P.L. 1995: MIAEL estimation of biomass and fishery indicators for the 1995 assessment of hoki stocks. *N.Z. Fisheries Assessment Research Document 95/13.* 38 p.

Cordue, P.L. 1996: A model based method for bounding virgin biomass using a catch history, relative biomass indices, and ancillary information. *N.Z. Fisheries Assessment Research Document 96/8*. 48 p.

Cordue, P.L. 1998: An evaluation of alternative stock reduction estimators of year class strength and an assessment of the frequency of Chatham Rise trawl surveys of juvenile hoki required for stock assessment. *N.Z. Fisheries Assessment Research Document 98/12*. 44 p.

Francis, R.I.C.C. 1992: Recommendations concerning the calculation of Maximum Constant Yield (MCY) and Current Annual Yield (CAY). *N.Z. Fisheries Assessment Research Document 92/8*. 23 p.

Horn, P.L. 1993a: Assessment of ling (*Genypterus blacodes*) stocks (LIN 3, 4, 5, 6 and 7) off the South Island, New Zealand. *N.Z. Fisheries Assessment Research Document 93/9*. 29 p.

Horn, P.L. 1993b: Growth, age structure, and productivity of ling, *Genypterus blacodes* (Ophidiidae), in New Zealand waters. *N.Z. Journal of Marine and Freshwater Research 27*: 385–397.

Horn, P.L. & Cordue, P.L. 1996: MIAEL estimates of virgin biomass and MCY, and an update of stock assessmnet for ling (*Genypterus blacodes*) for the 1996–97 fishing year. *N.Z. Fisheries Assessment Research Document 96/9*. 15 p.

SAS Institute 1988: SAS/STAT User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc. 1028 p.

Vignaux, M. 1993: Catch per unit effort (CPUE) analysis of the hoki fishery 1987–92. *N.Z. Fisheries Assessment Research Document 93/14*. 23 p.

Vignaux, M. 1994: Catch per unit of effort (cpue) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987–93. *N.Z. Fisheries Assessment Research Document 94/11*. 29 p.

Table 1: Estimated and reported catches (t) of ling from LIN 7 from 1973 to 1997–98, and actual TACCs for 1986–87 to 1997–98. Data from 1973 to 1983 from MAF; data from 1983–84 to 1985–86 from FSU; data from 1986–87 to 1997–98 from QMS. See text for method of calculating estimated landings from 1987–88 to 1992–93

Year	Landings	Year [4]	Reported landings	Estimated landings	TACC
1973 [1]	150	1983–84	1 552	–	–
1974 [1]	229	1984–85	1 705	–	–
1975 [1]	1 246	1985–86	1 458	–	–
1976 [1]	2 710	1986–87	1 851	–	1 960
1977 [1]	5 060	1987–88	1 853	1 777	2 008
1978–79 [2]	677	1988–89	2 956	2 844	2 150
1979–80 [2]	954	1989–90	2 452	3 171	2 176
1980–81 [2]	900	1990–91	2 531	3 149	2 192
1981–82 [2]	857	1991–92	2 251	2 728	2 192
1982–83 [2]	1 140	1992–93	2 475	2 817	2 212
1983 [3]	1 775	1993–94	2 142	–	2 213
		1994–95	2 946	–	2 225
		1995–96	3 102	–	2 225
		1996–97	3 024	–	2 225
		1997–98	2 980	–	2 225

[1] Calendar year
[2] April 1 – March 31
[3] April 1 – Sept 30
[4] Oct 1 – Sept 30

Table 2: Reported estimated landings (t) of ling for fishing years 1989–90 to 1996–97 from all LIN 7, WCSI (statistical areas 33–36 and 701–706), the Cook Strait (CKST) section of LIN 7 (statistical areas 38, 39, 17, and 25% of 18), and the Cook Strait section of LIN 2 (statistical areas 15, 16, and 50% of 19). Reported estimated landings of ling taken by line fishing, and the proportions of the total WCSI catch they make up (% line), are also presented

		Fishing year							
Area	Method	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97
All LIN 7	All	2 527	2 146	1 915	2 032	1 892	2 704	2 448	2 446
LIN 7: WCSI	All	2 470	1 877	1 764	1 862	1 695	2 498	2 230	2 189
	Line	184	364	636	689	680	783	670	740
	% line	7.4	19.4	36.1	37.0	40.1	31.3	30.0	33.8
LIN 7: CKST	All	217	267	143	161	181	213	194	267
LIN 2: CKST	All	266	441	248	286	266	301	354	279

Table 3: Biological parameters used in the LIN 7 assessment (*from* Horn 1993a, 1993b)

Fishstock	Estimate					
1. Natural mortality (M)						
All	0.18					
2. Weight = a (length)b (Weight in g, length in cm total length)						
	a	*b*				
LIN 3 and 4	0.00126	3.296				
3. von Bertalanffy growth parameters						
	Females			Males		
	k	t_0	L_∞	k	t_0	L_∞
LIN 7	0.090	0.22	165.9	0.087	-0.13	146.1

Table 4: Catch-at-age data, by sex, for ling sampled from the commercial trawl fishery for hoki off WCSI during the period June–September 1991. Numbers (*N*) represent the estimated total catch by the trawl fishery

	Males			Females		
Age	*N*	%	*c.v.*	*N*	%	*c.v.*
4	179	0.06	1.000	187	0.06	2.922
5	1 159	0.40	1.031	2 174	0.74	0.783
6	4 507	1.54	0.585	4 230	1.44	0.431
7	4 916	1.68	0.327	3 903	1.33	0.466
8	8 197	2.80	0.300	9 213	3.15	0.238
9	9 768	3.33	0.248	4 464	1.52	0.396
10	12 460	4.25	0.244	9 841	3.36	0.266
11	13 913	4.75	0.220	6 166	2.11	0.332
12	23 777	8.12	0.192	15 800	5.39	0.209
13	30 460	10.40	0.173	21 845	7.46	0.163
14	12 352	4.22	0.317	8 463	2.89	0.267
15	9 096	3.11	0.235	8 080	2.76	0.195
16	8 085	2.76	0.405	13 211	4.51	0.156
17	8 525	2.91	0.296	5 936	2.03	0.320
18	4 405	1.50	0.277	3 116	1.06	0.485
19	1 214	0.41	0.732	1 809	0.62	0.273
20	873	0.30	0.746	2 061	0.70	0.255
21	512	0.17	0.497	1 845	0.63	0.436
22	305	0.10	3.063	1 178	0.40	0.443
23	2 997	1.02	0.406	563	0.19	0.527
24	1 037	0.35	0.706	2 157	0.74	0.390
25	1 747	0.60	0.553	1 448	0.49	0.317
26	886	0.30	0.463	361	0.12	0.771
27	60	0.02	4.429	2 695	0.92	0.142
28	0	0.00	0.000	154	0.05	1.517
29	0	0.00	0.000	134	0.05	0.000
30	0	0.00	0.000	274	0.09	0.834
31	0	0.00	0.000	0	0.00	0.000
32	0	0.00	0.000	0	0.00	0.000
33	0	0.00	0.000	0	0.00	0.000
34	92	0.03	4.566	0	0.00	0.000
35	0	0.00	0.000	0	0.00	0.000
36	60	0.02	4.429	0	0.00	0.000

Number males measured	1 211
Number females measured	1 019
Number males aged	190
Number females aged	231
Number shots sampled	186
Mean weighted *c.v.*	28.1

Table 5: Catch-at-age data, by sex, for ling sampled from the commercial trawl fishery for hoki off WCSI during the period June–September 1997. Numbers (*N*) represent the estimated total catch by the trawl fishery

	Males			Females		
Age	*N*	%	*c.v.*	*N*	%	*c.v.*
4	247	0.06	1.118	96	0.02	4.376
5	1 378	0.36	1.752	3 093	0.80	0.398
6	8 960	2.33	0.328	3 394	0.88	0.284
7	11 494	2.99	0.249	5 891	1.53	0.274
8	13 668	3.55	0.223	7 574	1.97	0.249
9	29 697	7.71	0.151	6 442	1.67	0.249
10	36 113	9.38	0.138	8 177	2.12	0.246
11	32 286	8.39	0.150	12 287	3.19	0.175
12	39 984	10.39	0.130	15 042	3.91	0.167
13	32 477	8.44	0.146	15 121	3.93	0.156
14	22 642	5.88	0.185	8 735	2.27	0.184
15	13 235	3.44	0.253	7 569	1.97	0.227
16	8 620	2.24	0.273	4 832	1.26	0.289
17	4 661	1.21	0.547	3 421	0.89	0.268
18	3 912	1.02	0.479	3 811	0.99	0.266
19	5 524	1.43	0.363	2 559	0.66	0.398
20	2 900	0.75	0.657	1 714	0.45	0.370
21	3 235	0.84	0.681	736	0.19	0.634
22	74	0.02	1.410	460	0.12	0.492
23	68	0.02	2.954	144	0.04	0.830
24	68	0.02	2.954	188	0.05	1.045
25	0	0.00	0.000	480	0.12	0.784
26	0	0.00	0.000	321	0.08	1.052
27	0	0.00	0.000	666	0.17	0.618
28	478	0.12	1.807	427	0.11	0.735
29	21	0.01	55.004	0	0.00	0.000
30	0	0.00	0.000	0	0.00	0.000
31	0	0.00	0.000	0	0.00	0.000
32	25	0.01	4.079	0	0.00	0.000
33	0	0.00	0.000	37	0.01	7.131

Number males measured	1 630
Number females measured	995
Number males aged	449
Number females aged	401
Number shots sampled	263
Mean weighted *c.v.*	22.5

Table 6: Catch-at-age data, by sex, for ling sampled from the commercial trawl fishery for hoki off WCSI during the period June–September 1998. Numbers (*N*) represent the estimated total catch by the trawl fishery

	Males			Females		
Age	*N*	%	*c.v.*	*N*	%	*c.v.*
4	0	0.00	0.000	735	0.17	0.546
5	4 240	0.97	0.745	4 129	0.95	0.537
6	8 070	1.85	0.318	5 440	1.25	0.366
7	6 607	1.52	0.388	17 667	4.06	0.136
8	31 664	7.27	0.166	7 833	1.80	0.292
9	50 183	11.53	0.133	25 818	5.93	0.141
10	45 219	10.39	0.141	23 707	5.45	0.163
11	42 614	9.79	0.142	15 076	3.46	0.189
12	31 528	7.24	0.172	16 547	3.80	0.194
13	14 384	3.30	0.250	17 560	4.03	0.182
14	19 212	4.41	0.222	4 437	1.02	0.383
15	3 671	0.84	0.469	3 720	0.85	0.387
16	2 414	0.55	0.533	3 098	0.71	0.435
17	2 695	0.62	0.755	5 714	1.31	0.320
18	1 250	0.29	0.683	1 750	0.40	0.570
19	1 539	0.35	0.739	6 778	1.56	0.209
20	3 702	0.85	0.318	2 710	0.62	0.467
21	548	0.13	2.434	744	0.17	0.977
22	464	0.11	1.368	52	0.01	0.707
23	0	0.00	0.000	130	0.03	1.629
24	0	0.00	0.000	0	0.00	0.000
25	476	0.11	1.372	0	0.00	0.000
26	0	0.00	0.000	478	0.11	1.482
27	405	0.09	2.047	0	0.00	0.000
28	0	0.00	0.000	50	0.01	4.474
29	0	0.00	0.000	34	0.01	2.649
30	71	0.02	4.699	78	0.02	2.681
31	121	0.03	1.646	0	0.00	0.000
32	0	0.00	0.000	0	0.00	0.000
33	0	0.00	0.000	0	0.00	0.000
34	0	0.00	0.000	0	0.00	0.000
35	0	0.00	0.000	0	0.00	0.000
36	19	0.00	0.000	0	0.00	0.000

Number males measured	1 150
Number females measured	776
Number males aged	346
Number females aged	275
Number shots sampled	213
Mean weighted *c.v.*	22.1

Table 7: Model input parameters for the LIN 7 assessment

Parameter	Estimate
Steepness	0.9
Recruitment variability	0.6
Proportion spawning	0.9
Spawning season length	0.33
M	0.18
Maximum exploitation on home ground ($r_{hm\text{-}max}$)	0.5
Maximum exploitation on spawning ground ($r_{sp\text{-}max}$)	0.5
Minimum exploitation at highest catch on home ground ($r_{hm\text{-}mmx}$)	0.01
Minimum exploitation at highest catch on spawning ground ($r_{hm\text{-}mmx}$)	0.01
Ageing error	± 15% for ages ≥ 3
Model *c.v.* for CPUE indices	0.35

Maturity ogive	Age	5	6	7	8	9	10				
	Male	0.10	0.11	0.19	0.23	0.60	1.00				
	Female	0.001	0.10	0.11	0.19	0.23	1.00				
Home ground selectivity	Age	4	5	6	7	8	9	10	11	12	13
	Male	0.001	0.004	0.013	0.033	0.076	0.16	0.30	0.54	0.93	1.00
	Female	0.004	0.012	0.029	0.063	0.12	0.22	0.37	0.60	0.93	1.00

Table 8: Number of data rows, and the catch (t) and number of vessels associated with them, after data grooming from (a) WCSI, and (b) Cook Strait. Source: FSU domestic data (1983–1989) and CELR data (1989–1997). BLL, bottom longline

a) WCSI

	All data				All CELR data		CELR target ling BLL			
Year	No. of sets	No. of zeros	Catch (t)	No. of vessels	No. of sets	No. of zeros	No. of sets	No. of zeros	Catch (t)	No. of vessels
1983	394	0	483	17	-	-	-	-	-	-
1984	283	0	242	19	-	-	-	-	-	-
1985	297	0	384	15	-	-	-	-	-	-
1986	168	0	133	12	-	-	-	-	-	-
1987	19	0	27	5	-	-	-	-	-	-
1988	6	0	1	3	-	-	-	-	-	-
1989	117	1	135	7	117	1	23	1	-	-
1990	354	5	244	14	354	5	294	5	216	11
1991	546	5	500	17	546	5	421	5	412	14
1992	777	3	822	21	777	3	623	3	735	14
1993	630	4	694	18	630	4	481	4	625	13
1994	726	2	853	21	726	2	581	2	779	16
1995	698	2	804	23	698	2	533	2	710	17
1996	745	25	758	22	745	25	612	25	733	16
1997	627	21	666	20	627	21	506	21	639	14

b) Cook Strait

	All data				All CELR data		CELR target ling BLL	
Year	No. of sets	No. of zeros	Catch (t)	No. of vessels	No. of sets	No. of zeros	No. of sets	No. of zeros
1983	200	0	67	12	-	-	-	-
1984	192	0	57	12	-	-	-	-
1985	211	0	58	15	-	-	-	-
1986	115	0	25	18	-	-	-	-
1987	126	0	57	13	-	-	-	-
1988	185	0	87	13	-	-	-	-
1989	196	0	41	11	60	0	10	0
1990	196	3	57	17	196	3	19	1
1991	192	4	52	18	192	4	23	2
1992	192	1	78	17	192	1	45	0
1993	253	6	84	16	253	6	40	0
1994	315	7	65	18	315	7	62	3
1995	247	3	38	16	247	3	72	1
1996	130	2	33	8	130	2	53	1
1997	78	0	15	5	78	0	19	0

Table 9: Summary of variables used in LIN 7 CPUE models

Variable	Description
Year	Calendar year
Month	Month of year
Season	Day of year
Statistical area	Statistical area for the longline set
Target species	Target species for that longline
CPUE	Ling catch (kg)/Number of hooks hauled in a day
Number of sets	Total number of sets hauled in a day
SOI	Southern oscillation index, five monthly running mean
Vessel length	Overall length of the vessel, in metres
Vessel tonnage	Gross tonnage of the vessel
Vessel breadth	Breadth of the vessel, in metres
Vessel draft	Draft of vessel, in metres
Vessel LBD	Vessel length * breadth * draft
Year built	Year the vessel was built
Vessel power	Power of vessel engine in kilowatts

Table 10: Variables used in the (a) WCSI, and (b) Cook Strait LNL and GLL models, in the order in which they entered the model

a) WCSI

Variable	All data		All CELR data		CELR target ling BLL	
number	LNL	GLL	LNL	GLL	LNL	GLL
1	Stat area	Month	Target sp	Target sp	Month	Month
2	Month	Stat area	Month	Month	Year	Breadth
3	Year	Year	Year	Breadth	Breadth	Year
4	Draft	Length	Tonnage	Year	Tonnage	Power
5	Length	Draft	Breadth	Tonnage	Stat area	Tonnage
6	Year built	Breadth	Stat area	Stat area	SOI	Stat area
7	-	LBD	Length	Draft	-	Draft
8	-	Tonnage	SOI	Length	-	Year built
9	-	Power	-	Season	-	Season

b) Cook Strait

Variable	All data		All CELR data	
number	LNL	GLL	LNL	GLL
1	Month	Month	Target sp	Target sp
2	Year	Year	Power	Power
3	Stat area	Power	Year	No sets
4	Power	SOI	Month	Month
5	Length	Draft	No sets	Year
6	Year built	Tonnage	Year built	Stat area
7	Tonnage	Stat area	Breadth	Year built
8	SOI	Length	Draft	Tonnage
9	Draft	Season	Tonnage	Draft
10	-	-	-	Breadth
11	-	-	-	Length

Table 11: Relative year effects from the LNL and GLL models for years 1983 to 1997 in the (a) WCSI, and (b) Cook Strait LIN 7 data set. BLL, bottom longline

a) WCSI

	All data		All CELR data		CELR target ling BLL	
Year	LNL	GLL	LNL	GLL	LNL	GLL
1983	1.00	1.00	-	-	-	-
1984	0.88	0.76	-	-	-	-
1985	1.36	1.15	-	-	-	-
1986	0.51	0.53	-	-	-	-
1987	0.68	0.71	-	-	-	-
1988	1.00	0.75	-	-	-	-
1989	1.06	0.63	-	-	-	-
1990	0.88	0.64	1.00	1.00	1.00	1.00
1991	1.19	0.79	1.24	1.17	1.42	1.18
1992	1.04	0.67	1.22	1.06	1.42	1.11
1993	0.88	0.59	1.08	1.01	1.18	0.94
1994	0.92	0.62	1.11	0.99	1.29	0.95
1995	0.87	0.56	1.17	0.95	1.00	0.87
1996	0.66	0.47	0.47	0.66	0.53	0.61
1997	0.77	0.51	0.89	0.75	0.75	0.70

b) Cook Strait

	All data		All CELR data	
Year	LNL	GLL	LNL	GLL
1983	1.00	1.00	-	-
1984	0.70	0.83	-	-
1985	0.88	1.05	-	-
1986	0.51	0.77	-	-
1987	1.62	1.90	-	-
1988	1.35	1.43	-	-
1989	1.38	1.52	-	-
1990	1.11	0.89	1.00	1.00
1991	1.31	1.16	1.14	1.12
1992	2.20	1.79	1.18	0.93
1993	1.00	0.79	0.75	0.69
1994	1.30	0.96	0.72	0.71
1995	1.07	0.77	0.79	0.72
1996	1.81	1.25	0.91	0.77
1997	1.73	1.07	1.41	1.02

Table 12: Catch histories (tonnes per year) for LIN 7 used in the stock assessment. The split between the pre-spawning and spawning seasons was estimated as a ratio of 3:1, and calculated as in the following example. The 1990 catch comprises 75% of the 1989–90 fishing year landings (Pre-spawn) plus 25% of the 1990–91 fishing year landings (Spawning). Catches for 1998 and 1999 were assumed

Year	Pre-spawn	Spawning	Year	Pre-spawn	Spawning
1972	0	0	1986	1 025	444
1973	79	26	1987	1 332	437
1974	138	46	1988	1 310	699
1975	901	300	1989	2 097	739
1976	1 999	666	1990	2 216	721
1977	3 761	1 254	1991	2 162	646
1978	467	156	1992	1 939	664
1979	674	225	1993	1 992	490
1980	634	211	1994	1 471	683
1981	594	198	1995	2 050	727
1982	806	269	1996	2 181	688
1983	1 370	500	1997	2 065	690
1984	1 105	405	1998	2 100	700
1985	1 215	342	1999	2 100	700

Table 13: Estimates of year class strengths from the model base case and the sensitivity runs. Those not estimated were assumed to be 1. Year class strengths from 1968 to 1986 were based on three estimates of catch-at-age; those from 1987 to 1990 were based on two estimates

Year	Base case	$M = 0.10$	$M = 0.22$	$r_{max} = 0.7$	CPUE:ex97	CPUE:GLL
1968	1.99	1.89	2.18	1.99	2.23	1.94
1969	0.44	0.56	0.40	0.44	0.47	0.44
1970	0.89	1.08	0.86	0.89	0.97	0.88
1971	0.63	0.82	0.58	0.63	0.67	0.62
1972	0.80	1.10	0.72	0.80	0.85	0.79
1973	0.36	0.53	0.32	0.36	0.38	0.36
1974	0.41	0.64	0.35	0.41	0.44	0.40
1975	0.94	1.51	0.80	0.94	0.99	0.94
1976	0.87	1.48	0.72	0.87	0.92	0.85
1977	2.46	4.20	2.04	2.46	2.51	2.49
1978	1.49	2.69	1.21	1.49	1.51	1.49
1979	0.38	0.71	0.31	0.38	0.39	0.40
1980	1.51	2.89	1.21	1.51	1.54	1.46
1981	0.74	1.46	0.58	0.74	0.76	0.68
1982	1.16	2.30	0.92	1.16	1.21	1.14
1983	0.95	1.86	0.75	0.95	0.99	0.96
1984	1.66	3.16	1.34	1.66	1.67	1.58
1985	0.52	0.98	0.42	0.52	0.50	0.79
1986	0.75	1.79	0.54	0.75	0.59	0.63
1987	1.16	1.87	0.99	1.16	0.90	1.30
1988	1.67	3.23	1.28	1.67	1.19	1.69
1989	1.00	1.68	0.84	1.00	0.82	1.05
1990	2.11	5.74	1.41	2.11	1.38	2.07

Table 14: Least squares (LSQ) and best k estimates of biomass, and MIAEL estimates of p, biomass (MIAEL) and information indices (Info.), for base case and sensitivity model runs. All biomass estimates are in tonnes. MIAEL estimates of B_{mid98} and B_{mid99} as a percentage of virgin biomass (% B_0) are also presented

Estimate	Model run	Bounds ($B_{min} - B_{max}$)	LSQ	best k	p	MIAEL	Info.	% B_0
B_0	Base case	19 910 – 124 840	24 250	43 490	0.217	39 310	15.0 %	
	$M = 0.10$	20 200 – 128 310	22 000	44 320	0.183	40 240	11.6 %	
	$M = 0.22$	19 910 – 122 240	26 220	43 160	0.234	39 200	16.7 %	
	$r_{max} = 0.7$	19 340 – 124 840	24 250	42 680	0.228	38 480	16.4 %	
	CPUE: excl '97	24 090 – 123 690	24 090	48 940	0.100	46 460	3.7 %	
	CPUE: GLL	19 630 – 124 840	24 810	43 090	0.214	39 180	14.7 %	
	R=1 all years	21 070 – 127 160	24 250	45 400	0.189	41 400	11.9 %	
B_{mid98}	Base case	1 210 – 116 490	6 390	5 580	0.436	5 940	40.1 %	21.6 %
	$M = 0.10$	1 300 – 185 800	5 010	6 500	0.387	5 920	36.6 %	21.7 %
	$M = 0.22$	1 080 – 93 200	7 020	4 870	0.419	5 770	37.3 %	20.2 %
	$r_{max} = 0.7$	590 – 116 490	6 390	3 130	0.461	4 640	45.1 %	18.0 %
	CPUE: excl '97	5 070 – 108 580	5 070	16 300	0.154	14 570	7.0 %	36.7 %
	CPUE: GLL	1 000 – 117 940	7 300	4 810	0.411	5 830	38.0 %	21.4 %
	R=1 all years	2 550 – 119 000	6 390	10 010	0.333	8 810	26.0 %	27.7 %
B_{mid99}	Base case	1 150 – 120 050	6 400	5 400	0.361	5 760	31.7 %	20.4 %
B_{beg99}	Base case	8 570 – 194 000	18 330	27 970	0.224	25 810	21.6 %	

Table 15: MIAEL estimates and information indices (Info.) of B_{MCY} (as % of B_0), MCY (as % of B_0) and MCY (t), and B_{MAY} (as % of B_0), MAY (as % of B_0) and CAY (t), for base case assessments of LIN 7.

Fishstock	B_{MCY} (%B_0)	MCY (% B_0)	MCY	Info.	MCY range
LIN 7	41.4	6.1	2 400	15 %	1 210–7 620
Fishstock	B_{MAY} (%B_0)	MAY (% B_0)	CAY	Info.	
LIN 7	27.8	7.2	2 760	22 %	

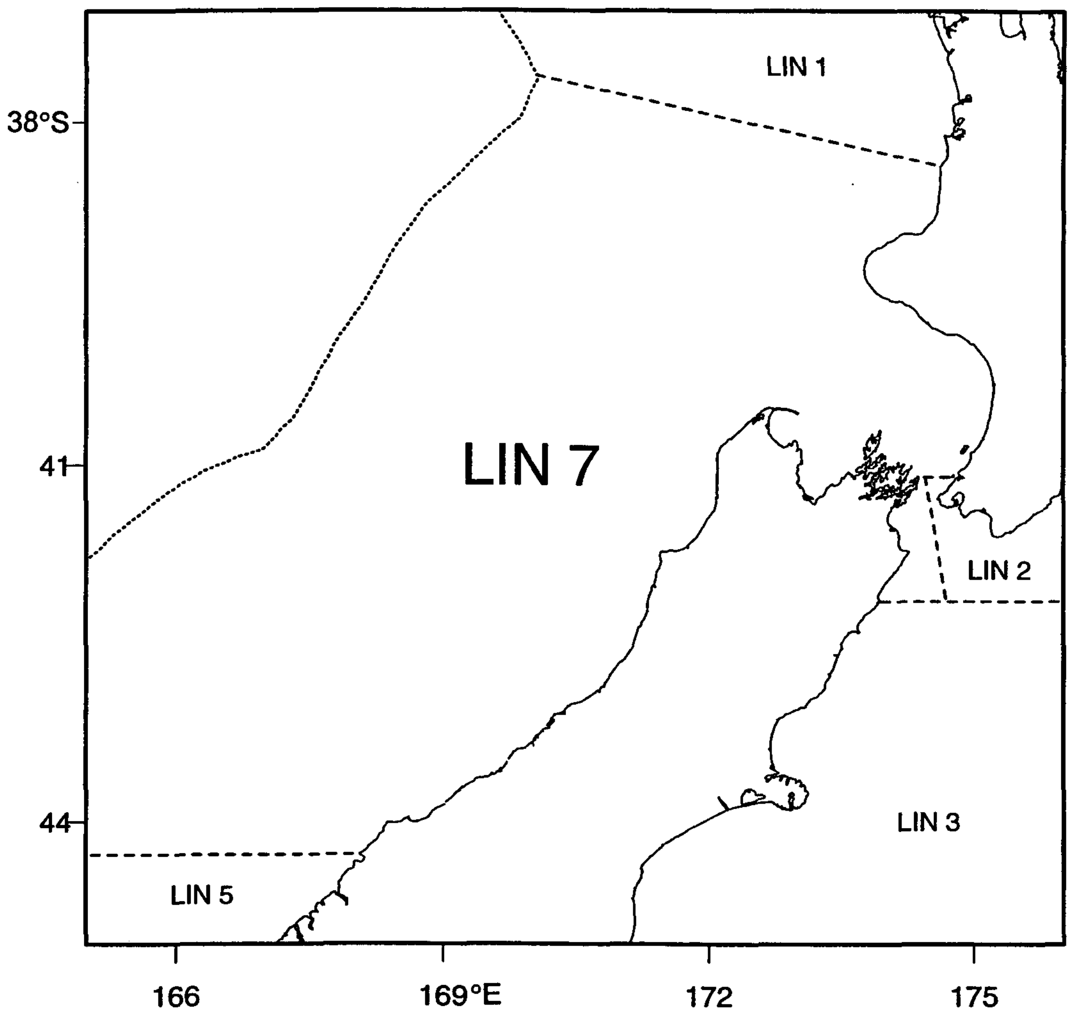

Figure 1: Area of Fishstock LIN 7, comprising QMAs 7 and 8. Adjacent ling fishstock areas are also labelled.

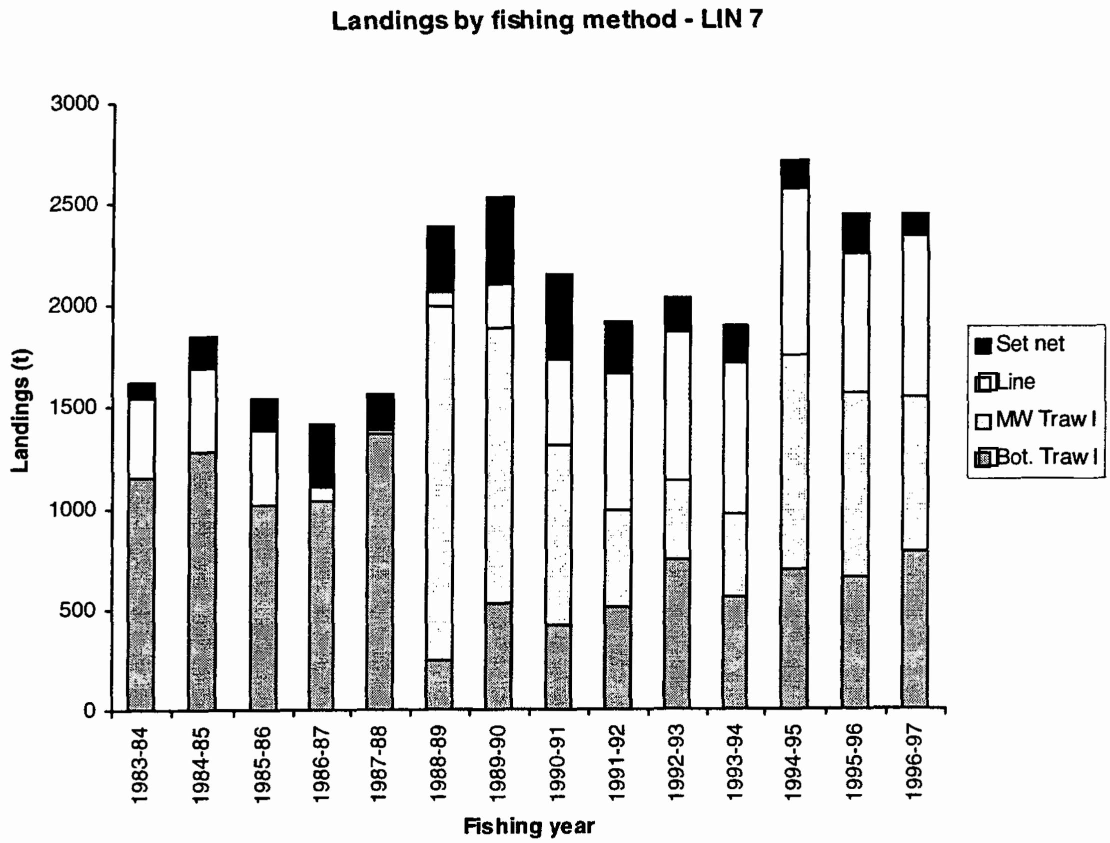

Figure 2: Reported estimated landings of ling in LIN 7, by fishing year and method. (MW, midwater; Bot., bottom)

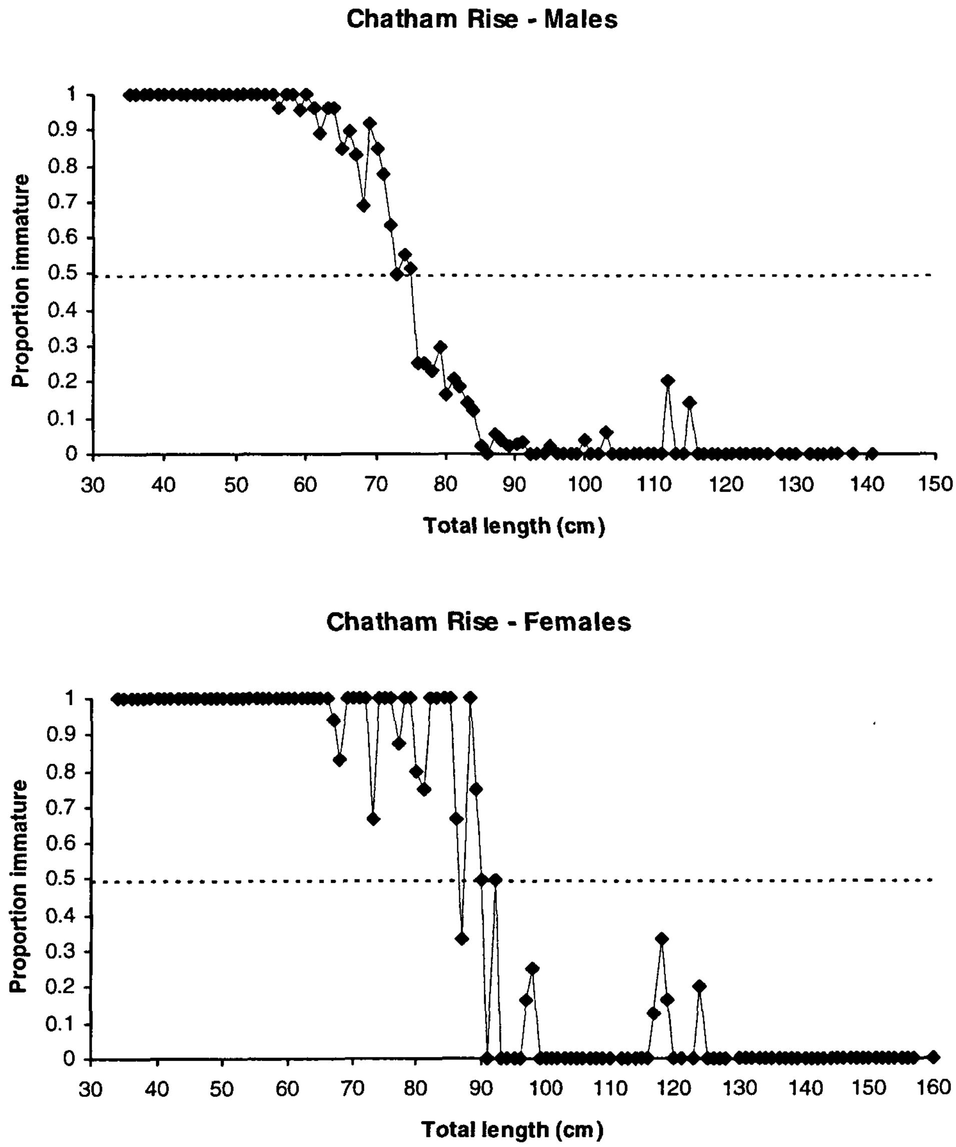

Figure 3: Proportion of immature ling by length class from trawl surveys of the Chatham Rise conducted in January 1992 to 1998.

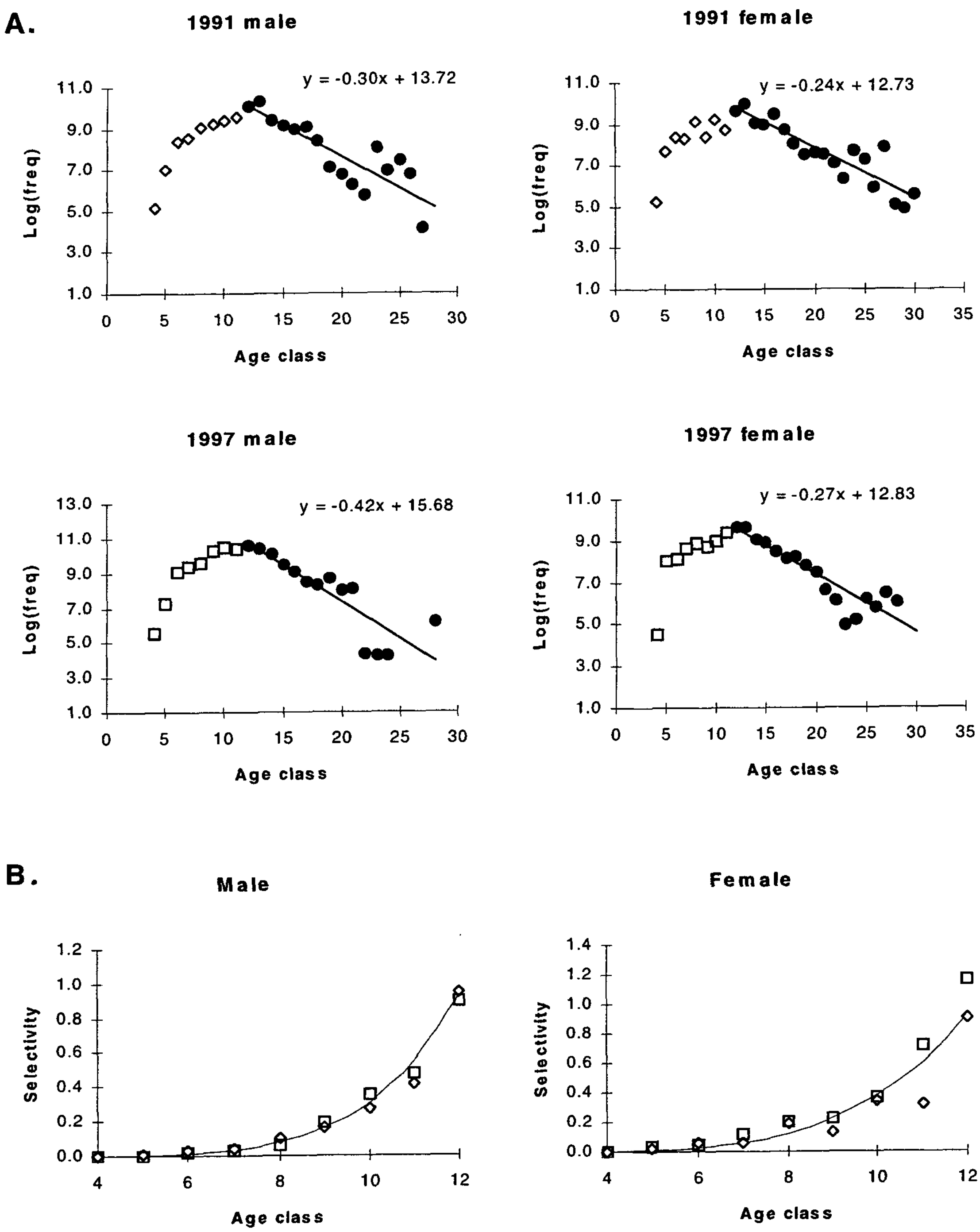

Figure 4: A: Catch curves, by sex, for the 1991 and 1997 aged samples, with regression lines fitted to the right hand limb. B: Plots of the proportions of observed versus expected abundance (i.e., selectivity), by sex, for age classes 4 to 12, and curves fitted to these data.

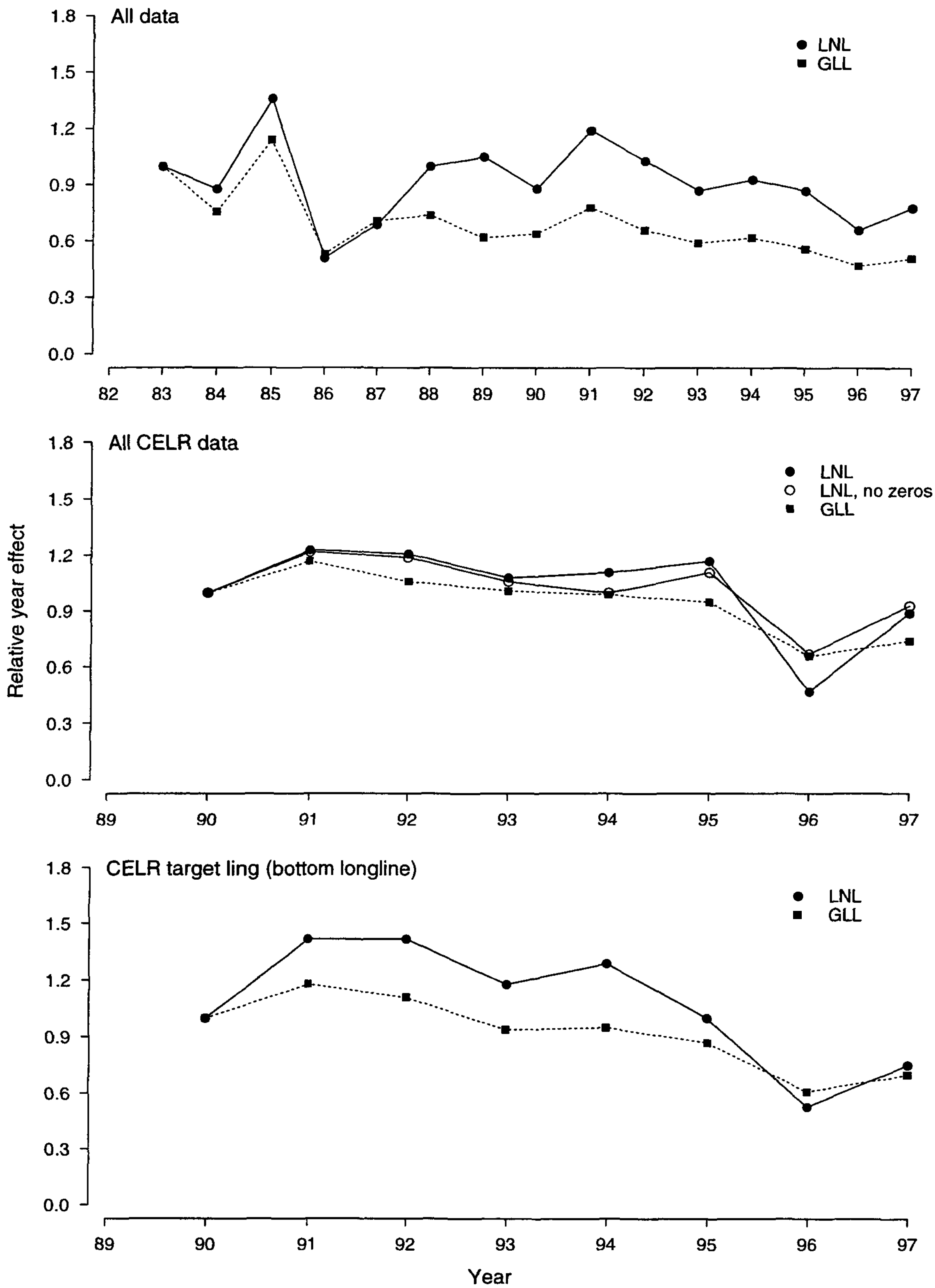

Figure 5: Relative year effects estimated for the lognormal linear (LNL) model, and the gamma, log-link (GLL) model for WCSI ling longline catches.

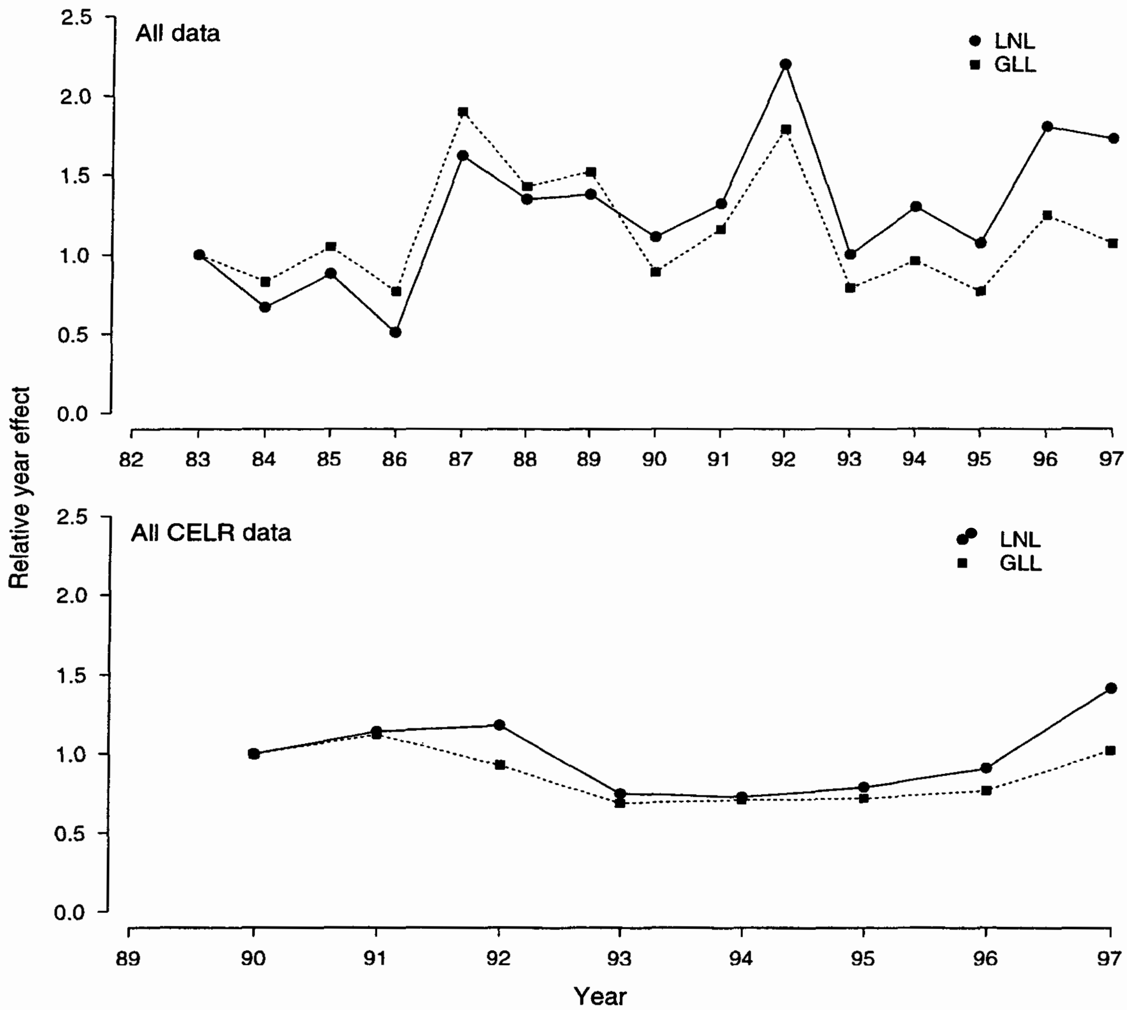

Figure 6: Relative year effects estimated for the lognormal linear (LNL) model, and the gamma, log-link (GLL) model for Cook Strait ling longline catches.

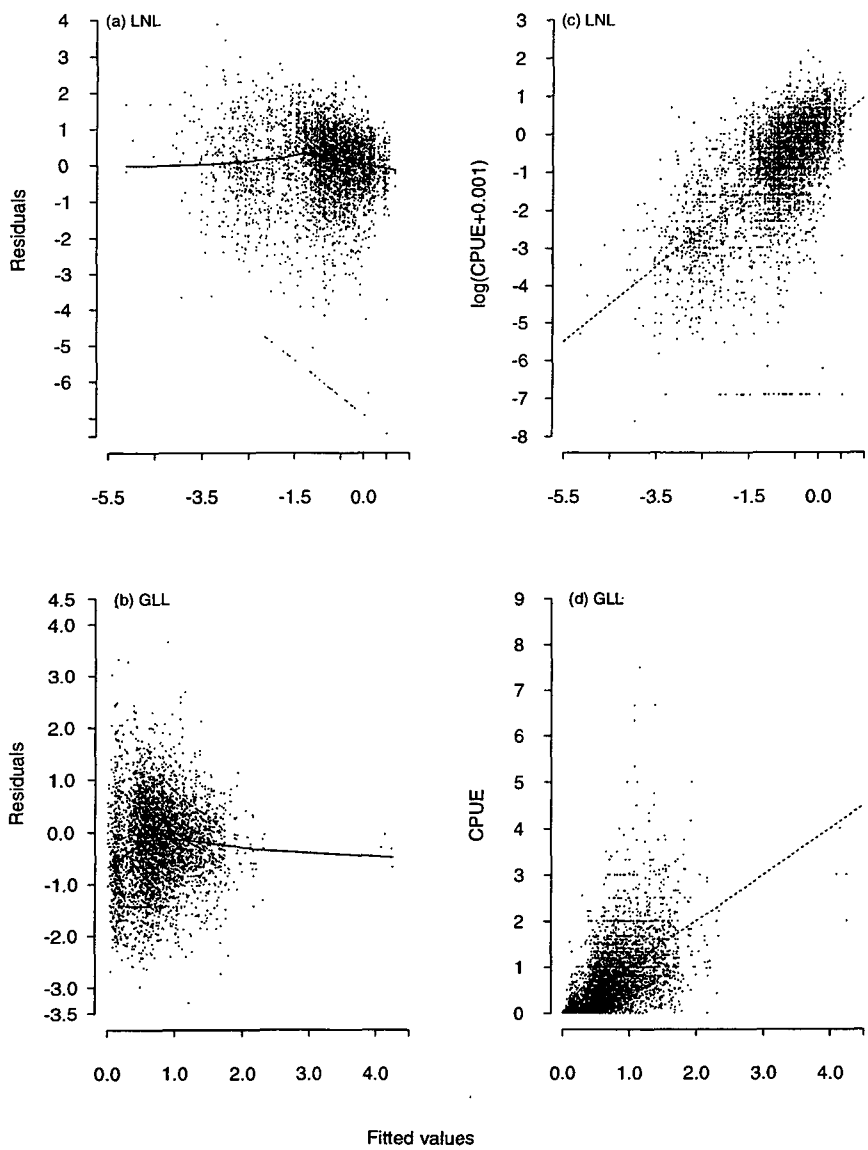

Figure 7: Plots of residuals and observed against expected values for the LIN 7 WCSI "All CELR" data set. (a) plot of residuals from the lognormal linear (LNL) model, with LOWESS curve fitted; (b) plot of residuals from the gamma, log-link (GLL) model, with LOWESS curve fitted; (c) plot of observed CPUE values versus fitted (expected) values for the LNL model with y = x line fitted, and (d) plot of observed CPUE values versus fitted (expected) values for the GLL model with y = x line fitted.

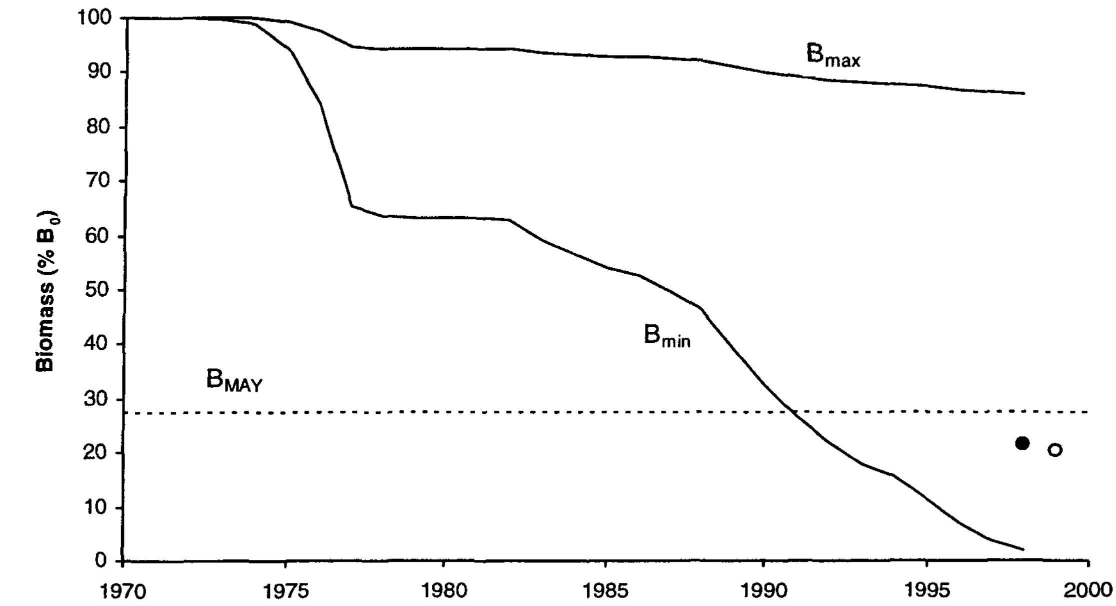

Figure 8: Estimated catch histories for B_0 at B_{max} and B_{min}. The positions of the current biomass (B_{mid98}) and projected biomass (B_{mid99}) as estimated by the MIAEL method are also shown (filled circle and open circle respectively). The horizontal broken line represents B_{MAY}.

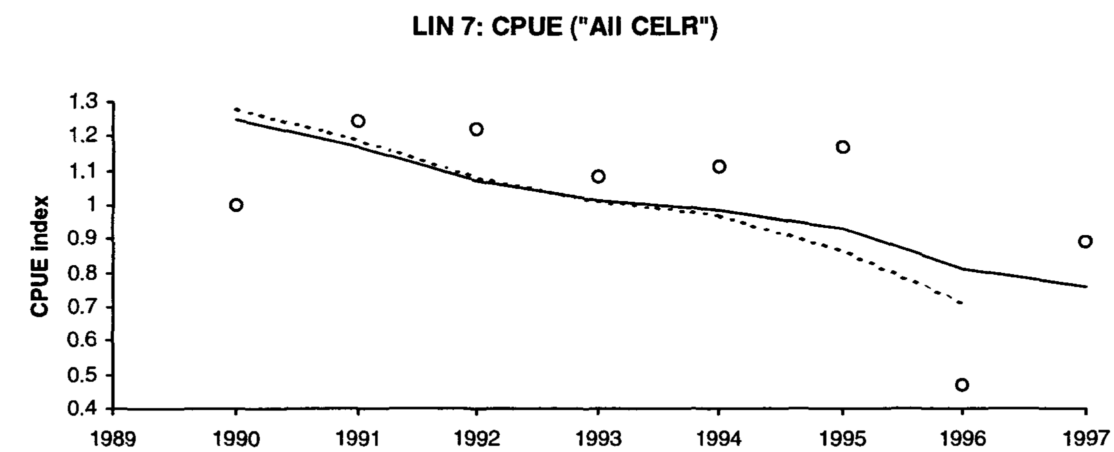

Figure 9: Model fit (solid line) to the series of observed "All CELR" CPUE indices from 1990 to 1997 (open circles). Model estimate of q is 1.03×10^{-4}. Broken line shows the model fit to the same series of data excluding the 1997 point ($q = 1.10 \times 10^{-4}$).

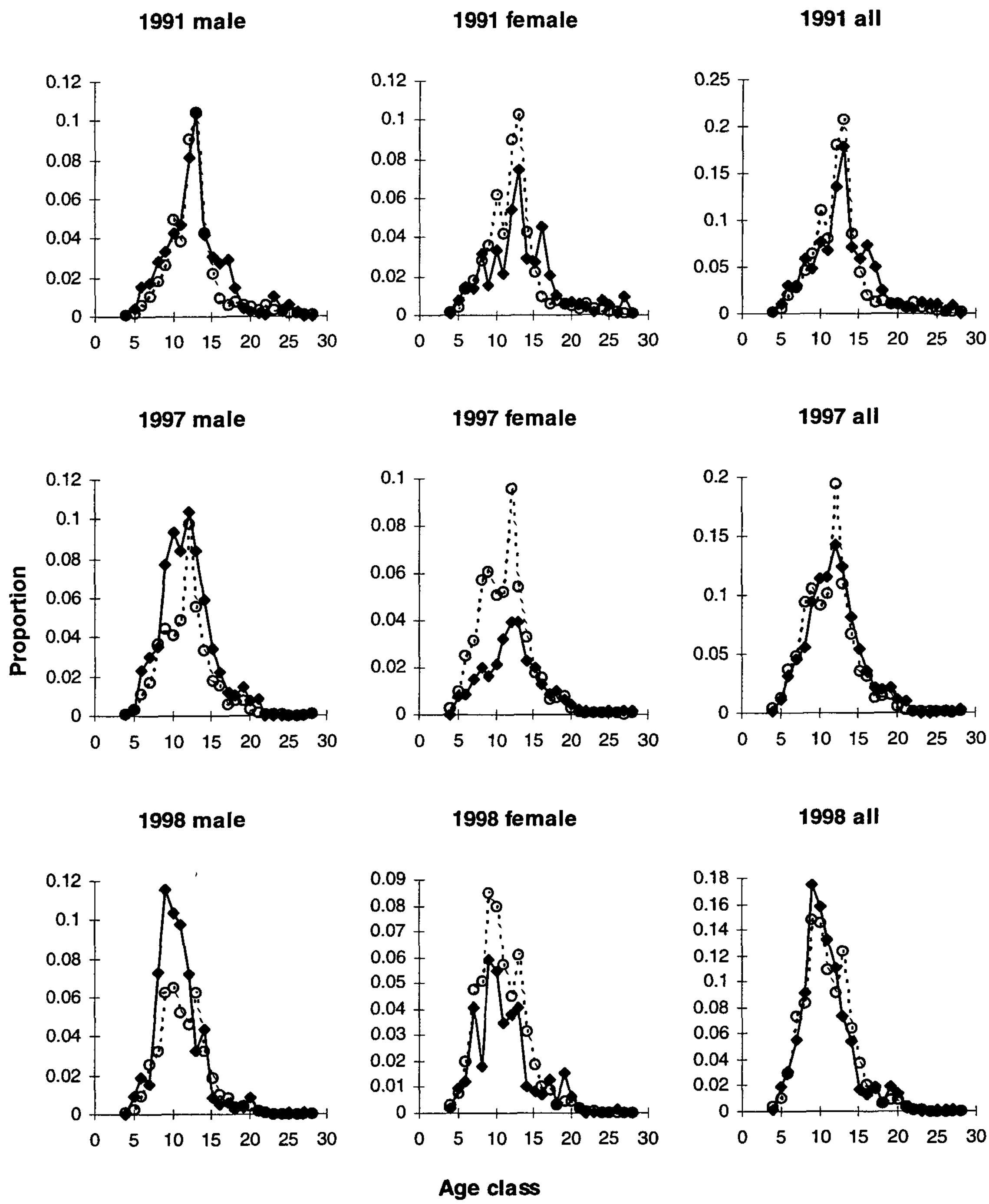

Figure 10: Observed (solid diamonds) proportions at age data, and model fits (open circles) to these data, by sex and year.