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EXECUTIVE SUMMARY

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Series of CPUE for commercial line fisheries targeting ling on the Chatham Rise (LIN 3&4, 1990–2007), the Campbell Plateau (LIN 5&6, 1991–2007), the Bounty Plateau (LIN 6B, 1992–2007), the west coast of the South Island (WCSI) (LIN 7WC, 1990–2007), and Cook Strait (LIN 7CK, 1990–2007) were updated to include CELR (catch, effort, and landing return), LCER (lining catch and effort return), and LTCER (lining trip catch effort return) data to the end of the 2007 calendar year. Series have also been derived for sub-areas within the Chatham Rise and Campbell Plateau stocks. The Puysegur section of the Campbell Plateau fishery was analysed separately, and three series were produced for the Chatham Rise (i.e., South-east coast, Chatham Rise, and Chatham Islands). Existing series of CPUE for the ling bycatch from the trawl fisheries targeting hoki in Cook Strait and WCSI since 1990 were also updated with the addition of 2007 TCEPR (trawl catch, effort, and processing return) data, and a new series was created for the WCSI trawl fishery incorporating zero, as well as positive, ling catches.

Data used in the CPUE analyses were groomed to remove as many errors as possible. Data for the longline analyses were selected to ensure that they related to vessels that had consistently targeted and caught significant landings of ling (and so were likely to truly represent experienced and competent ling fishers). For the trawl fishery analyses, only data from vessels that had consistently reported ling bycatch from the chosen years were included. The catch data were modelled using a lognormal linear analysis to produce a set of standardised indices for each stock. Coefficients of selected variables were examined to ensure that they had a plausible range. Any selected interaction variables causing implausible ranges in the coefficients of the main variables were removed from the final models.

The standardised indices indicated that, since the early 1990s, ling stocks targeted by line fisheries had declined by about 20% on the Campbell Plateau, and about 55% on the Chatham Rise and Bounty Plateau. The series for the WCSI line fishery exhibited a flat, but very variable, trend. The Cook Strait index declined slightly throughout the early 1990s, increased from 1995 to 2002, and then declined steadily again to 2007.

The standardised indices derived from the trawl fishery in Cook Strait indicated that the ling stock had declined steadily throughout the early 1990s, exhibited some recovery up to 2003, but is again declining. However, the 1990–93 part of this series may be unreliable; it is possible that some change in reporting behaviour by fishers has biased the input data. The index from the trawl fishery off WCSI based on ‘accurate’ TCEPR data was very variable, but indicated an overall decline from 1996 to 2007. The new WCSI combined model, calculated from 1999 to 2007, indicated a decline to 2002, followed by a relatively constant index to 2007.

The line and trawl CPUE series derived for each of the Cook Strait and WCSI stocks are compared. The two series from Cook Strait exhibit some similar trends, particularly since 1994 (where the trawl series is believed to be most reliable). Differences in the latter parts of the series from the two WCSI fisheries cannot be reconciled. Hence, a reliable relative abundance series for the LIN 7WC stock has still not been identified.

A descriptive analysis of ling fisheries showed a slight reversal of the recent declining trend in landings, largely a result of more deepwater bottom trawl catches off the east and south of the South Island. Line fishery catches were about 10% higher than in the previous year, but still much lower than in all other years since 1991–92. Reduced hoki trawling off WCSI affected the ling catch from this area and method, but some of the LIN 7 quota normally taken by trawlers was caught as a result of increased lining and setnetting effort.

1. INTRODUCTION

This document reports the results of Project LIN2007/01, Objectives 1 and 2, i.e.,

- To carry out a descriptive analysis of the commercial catch and effort data for ling from LIN 2, 3 & 4, 5 & 6, 6B (Bounties) and 7,
- To update the standardised catch and effort analyses from the ling longline and trawl bycatch fisheries in LIN 3 & 4, 5 & 6 and 7 with the addition of data up to the end of the 2006/07 fishing year.

A descriptive analysis of commercial catch and effort data for all New Zealand's ling fisheries from fishing years 1989–90 to 1998–99 was completed by Horn (2001), and this analysis was recently updated to include data to 2004–05 from Fishstocks LIN 2–7 (Horn 2007a). Because a comprehensive analysis has recently been completed, the work reported here simply updates tables 2 and 4 of Horn (2007a), i.e., catch by area, by method. This will indicate whether any marked changes have occurred in the fisheries since 2004–05. The descriptive analysis is presented in Appendix A.

The updated commercial line fishery CPUE series are for ling on the Chatham Rise, the west coast South Island (WCSI), and in Cook Strait from 1990 to 2007, the Campbell Plateau from 1991 to 2007, and the Bounty Plateau from 1992 to 2007. These five fisheries account for over 95% of the line-caught ling (Horn 2007a). The principal lining method in all areas is bottom longline, although dahn lining is also used. CPUE analyses of these fisheries were most recently reported by Horn (2008a). However, the analyses presented below for the Chatham Rise and Campbell Plateau fisheries differ from those in previous years as additional CPUE series have been derived for sub-areas within both stocks. In particular, the Puysegur fishery was analysed separately, and three series were produced for the Chatham Rise (i.e., South-east coast, Chatham Rise, and Chatham Islands).

Series of ling CPUE indices derived from trawl fisheries targeting species other than ling were also reported by Horn (2008a). The series from the trawl fishery targeting hoki in Cook Strait was believed to be a reliable index of abundance of ling vulnerable to that fishery from 1994 to 2006, but its reliability as an index from 1990 to 1993 was dubious. There was a major change in fleet composition in 1994, and the accuracy of estimated ling catch per tow before 1994 was questionable (Horn 2008a). For the trawl fishery targeting spawning hoki off WCSI, a CPUE series using TCEPR data reported by vessels believed to have recorded their ling bycatch relatively accurately was developed in 2005 (Horn 2006a) and has been updated annually since then (Horn 2008a). This series was believed by the Middle Depth Species Fisheries Assessment Working Group to be more likely to index ling abundance than an unmodified TCEPR series or a series based on the relatively data-poor observer database. The Cook Strait TCEPR and WCSI 'accurate' TCEPR trawl series are updated here using 2007 data.

Dunn et al. (2000) proposed four points that should be considered as part of the process to determine whether a CPUE series accurately mirrored fish abundance.

- Is there a good likelihood that CPUE provides an index of abundance (for that part of the population targeted by the fishery)?
- Are the data used in the analyses comprehensive and accurate?
- Was the modelling method valid for the available data?
- Do fishery-independent data support the CPUE trends?

Horn (2002) showed that the CPUE series from the Chatham Rise and Campbell Plateau longline fisheries met all these criteria, and that the Bounty Plateau and WCSI series met the first three. The Cook Strait longline series probably did not index ling abundance well (Horn 2008a). The series derived from the Cook Strait trawl bycatch fishery probably met the first three criteria since 1994 (Horn 2008a). The WCSI 'accurate' TCEPR trawl series is believed to be the best currently available for that fishery, but there is still considerable doubt about its reliability (Horn 2008a).

Series of longline CPUE indices have been used as inputs into population models for ling since 1996. These are the only indices of relative abundance available from the commercial fisheries on the Chatham Rise, Campbell Plateau, and Bounty Plateau. A trawl CPUE series was incorporated into the Cook Strait assessment in 2006 (Horn 2007b), and into the WCSI assessment in 2005 (Horn 2006b). However, the WCSI assessment was complicated because the trawl and longline CPUE series exhibited opposing trends over much of their ranges, and no other relative abundance series were available for that stock.

The updated longline and trawl series will be incorporated into future ling assessments. The stock units used in the stock modelling (and hence, in the CPUE analyses) are denoted as follows:

- Chatham Rise: QMAs 3 & 4 (LIN 3&4)
- Campbell Plateau: QMA 5, and QMA 6 west of 176° E (LIN 5&6)
- Bounty Plateau: QMA 6 east of 176° E (LIN 6B)
- WCSI: QMA 7 west of Cape Farewell (LIN 7WC)
- Cook Strait: statistical areas 16 and 17 (LIN 7CK)

2. METHODS

2.1 Data grooming

Catch and effort data, extracted from the fishery statistics database managed by the Ministry of Fisheries (MFish), were used in these analyses. All CELR, LCER, LTCER, NCELR and TCEPR records where ling were targeted or caught from anywhere in the New Zealand EEZ were extracted and groomed to rectify as many errors as possible. The kinds of errors included:

- missing values (which could be filled based on preceding and following records);
- data entry errors owing to unclear writing (e.g., several consecutive days of fishing in Statistical Area 33 was punctuated by a single set recorded from Area 23, target species recorded as “LIM”);
- incorrect positions, owing either to incorrect recording of east or west for longitudes, or to errors of 1° in latitude or longitude (often obvious based on preceding and following sets);
- transposition of some data (e.g., transposition of number of hooks and number of sets);
- recording QMA number as statistical area.

The groomed data (from the 1989–90 fishing year to the end of the 2007 calendar year) are stored in two relational database tables (t_lin_celr, and t_lin_tcepr) administered by NIWA for MFish. Data from the 2007 calendar year were obtained from MFish in June 2008.

2.2 Variables

Variables used in the analysis are described in Table 1 and are generally similar to those used in previous analyses (e.g., Horn 2008a). Longline CPUE was defined as catch per day (i.e., daily estimated catch in kilograms by a vessel in a particular statistical area), and number of hooks set per day was offered as an explanatory variable. Catch per day (rather than catch per hook) was used as the unit of CPUE because it has been shown previously (Horn 2002) that the relationship between catch per hook and the number of hooks set per day is non-linear. Hook number per day was offered both as an untransformed number and as log-transformed data. Trawl CPUE was defined as catch per tow, with tow duration offered as an explanatory variable.

It would have been desirable to have gear width as one of the explanatory variables offered in the trawl models. However, it was apparent that this field in the TCEPR returns variously contained wingspread and doorspread measurements. Consequently, headline height was the only trawl gear dimension variable that could be offered. Trawling for hoki uses both bottom and midwater gear, so method was offered as an explanatory variable in the trawl analyses. Because midwater trawls are sometimes fished on the bottom, this method was split into two categories (i.e., midwater trawl fished in midwater, and midwater trawl fished on the bottom) based on the reported difference between bottom depth and depth of ground rope.

Season variables of both month and day of year were offered. The Southern Oscillation Index (SOI) was included as a 3-monthly running mean (using the SOI from the month in which fishing occurred, and the two preceding months).

In all the analyses, variables describing vessels were offered to the model both as a categorical vessel identifier and as a series of continuous vessel parameters (i.e., length, breadth, draught, power, tonnage). Any vessel effect is explained either by the categorical variable, or by some of the vessel parameters, but not a combination of both categorical and continuous variables. Offering both variable types allowed the model to select the type that best described any vessel effect.

2.3 Data selection

Data from various groups of statistical areas (Figure 1) were selected as follows:

Chatham Rise (LIN 3&4) — 018–024, 049–052, 401–412, 301
Campbell Plateau (LIN 5&6) — 025–031, 302, 303, 501–504, 601–606, 610–612, 616–620, 623–625
Bounty Plateau (LIN 6B) — 607–609, 613–615, 621, 622
West coast South Island (LIN 7WC) — 032–036, 701–706
Cook Strait (LIN 7CK) — 016–017

Note that these analyses were conducted on the basis of presumed biological stocks, rather than administrative (QMA) stocks. Consequently, the grouping of some statistical areas may appear erroneous, but has been done in a way which best approximates biological stocks. For example, Statistical Areas 302, 303, and most of 026 are in LIN 3, but they have been included in the Campbell Plateau analysis, as ling in these areas probably derive from the Campbell stock because the Campbell Plateau is the closest submarine shelf to these statistical areas.

Data were available from 1 October 1989, but were analysed by calendar year rather than fishing year because of a seasonal trend of higher catch rates in most ling line fisheries running from about June to December (see Horn 2007a). This ensured that all catches in a particular season peak were included in a single year, rather than being spread between two (fishing) years.

Some line vessels had been recording individual set data on CELR forms (whereas for most vessels, a single record constitutes a day’s fishing). If uncorrected, this would cause bias in CPUE analyses as those vessels would contribute about four times as many records per day fishing as other vessels. Consequently, all longline data were condensed (catches and hooks summed over vessel, day, and statistical area) to ensure that each record represented total catch and effort per statistical area per day.

To ensure that the longline data to be analysed were within plausible ranges and related to vessels that had consistently targeted and caught significant landings of ling (and so were likely to truly represent experienced and competent ling fishers), data were accepted if all the following constraints were met:

- catch was by line (i.e., bottom longline, trot line, dahn line),
- catch was between 1 and 35 000 kg per day,
- number of hooks was between 50 and 50 000 per day,

- number of records for a vessel was: greater than 100 in 5 years for LIN 3&4; greater than 50 in 5 years for LIN 5&6 and LIN 7WC; greater than 30 in 5 years for LIN 6B and LIN 7CK; and all vessels included in any particular stock analysis had fished in more than 1 year,
- target species was reported as ling.

Examination of the zero catch records indicated that most represented either duplicated records (two records for a particular day, one with and one without catches) or obvious mistakes (two or three days fishing with no ling catch). Exceptions to this were data recorded by two vessels fishing around the Chatham Islands (in Statistical Areas 049–052), and consistently recording ling as their target species but recording zero or small landings of that species. It is suspected that these vessels were actually targeting species other than ling, so their data were removed from the Chatham Rise analysis. After this removal, zero catches made up less than 0.3% of the data. Because of the relatively high number of hooks fished in any set, a zero catch of ling in any set that is genuinely targeting ling is likely to result either from some gear malfunction or from exploratory fishing. The removal of such data points from the analysis will not bias the index of relative abundance of ling on known fishing grounds. Consequently, as in previous analyses, all zero observations were removed.

This year additional line fishery CPUE series were derived for sub-areas within the Chatham Rise and Campbell Plateau stocks using all the data records that were accepted into the 'whole stock' analyses described above. Three series were produced for the Chatham stock, with data allocated to the sub-areas as follows: South-east coast (Statistical Areas 18, 19, 20, 22, and 24), Chatham Rise (Areas 21, 23, 301, 401–404, and 407–410), and Chatham Islands (Areas 49–52, 405, 406, 411, and 412). For the Campbell Plateau stock, the data were split into Puysegur (Statistical Area 30) and non-Puysegur (all other statistical areas) sets.

Trawl data can be recorded on TCEPR, TCER, or CELR forms. TCEPR and TCER returns contain tow-by-tow data. CELR returns often amalgamate a day's fishing into a single line of data, so some of the data on individual tows may be lost (e.g., duration, towing speed, bottom depth, gear dimensions). In the Cook Strait hoki target fishery about 85% of the records of ling landings are on the TCEPR database; the comparable value for the WCSI fishery is 95%. Consequently, only TCEPR data were used in the CPUE analyses of the trawl fisheries as this data source enabled a greater variety of explanatory variables to be offered. (TCER forms were introduced on 1 October 2007, and there were no records targeting hoki in either the Cook Strait or WCSI fisheries in late 2007. However, data from this form type should be considered for inclusion in future CPUE analyses of these fisheries.)

For the Cook Strait analysis, all available TCEPR data were initially included. For the WCSI fishery the 'accurate' TCEPR series developed by Horn (2006a) was updated. That series assumes that the percentage of hoki target tows reporting a ling bycatch provides some indication of reporting accuracy. From the observer database, 90% of trips using the bottom trawl method had at least 72% of tows reporting a ling bycatch, and 90% of trips using midwater trawl had at least 50% of tows reporting a ling bycatch. These values were used as thresholds to identify vessels in the TCEPR database that were likely to have comprehensively reported their ling bycatch, e.g., if a vessel in a particular year had reported some ling bycatch in 72% or more of their bottom trawl tows, then all the TCEPR data from that vessel in that year were included in the 'accurate' TCEPR data set. In addition, a 'combined model' TCEPR series (after Vignaux 1994) was developed for the WCSI trawl fishery using data from all hoki target tows (i.e., zero and positive ling catches) made by vessels deemed to have accurately reported their ling catch. This series used data from 1999 to 2007. The same thresholds as described above were used to determine if a vessel had reported accurately, but this time data from an individual vessel were combined over all years before being accepted or rejected, rather than being examined on a year-by-year basis.

To ensure that the TCEPR trawl data to be analysed were within plausible ranges and related to vessels that had consistently caught and recorded ling landings, data were accepted if all the following constraints were met:

- target species was hoki,
- ling catch was greater than 5 kg and less than 15 000 kg per tow (except in the WCSI combined model, where ling catch could be zero),
- tow duration was 0.2–7 hours (Cook Strait), or 0.2–10 hours (WCSI),
- number of tows for a vessel was more than 100 in 5 years in Cook Strait, or 80 in 5 years off WCSI, and all vessels had fished in more than one year.

2.4 The model

The lognormal linear model was used for all but the combined model WCSI trawl analysis. A forward stepwise multiple regression fitting algorithm (step.glm) was employed using the statistical package S-PLUS (Chambers & Hastie 1991, Venables & Ripley 1994). *Year* was forced into the model as the first term, and the algorithm added variables based on changes in residual deviance. The explanatory power of a particular model was described by the reduction in residual deviance relative to the null deviance defined by a simple intercept model. Variables were added to the model until an improvement of less than 0.5 in the percentage of residual deviance explained was seen following inclusion of an additional variable. The standardised indices were calculated using GLM, with associated standard errors. Indices are presented using the canonical form (Francis 1999) so that the year effects for a particular stock were standardised to have a geometric mean of 1. The c.v.s represent the ratio of the standard error to the index. The 95% confidence intervals are also calculated for each index.

For the new series estimated for the WCSI trawl fishery a combined lognormal and binomial model was used (Vignaux 1994). This model fits the data as two parts. The lognormal component is used to fit log-transformed non-zero catch data, while the binomial component models the proportion of non-zero tows. Combined CPUE indices are then calculated from the lognormal and binomial indices (Vignaux 1994).

For the longline CPUE series estimated for sub-areas within the Chatham Rise and Campbell Plateau stocks a *year:sub-area* interaction effect was forced into the model. This produced a CPUE series for each sub-area within a stock, but with all other expected variable effects being the same over sub-areas.

Unstandardised CPUE was also derived for each year and Fishstock from the available data sets. The annual indices were calculated as the mean of the individual daily catch (kg) for longline or catch per tow (kg) for trawl.

Variables were either categorical or continuous (Table 1). Model fits to continuous variables were made as third-order polynomials.

Interaction terms allow for the relationship between CPUE and a particular explanatory variable to vary with another explanatory variable (e.g., an interaction between *month* and *statarea* indicates that the relationship between CPUE and *month* differs with *statarea*). Since the primary interest is in relative year effects, possible interactions with *year* were not considered, but interactions between all other principal variables were initially allowed. In the trawl fishery analyses, nested effects between method and both headline height and duration were allowed.

Horn (2002) discussed the problems that the inclusion of interaction effects can have on standardisation analyses, i.e., the amount of data available is insufficient to justify the number of parameters fitted, coefficients for a particular variable can have an implausible range or pattern, and selected interaction variables may be meaningless. In an attempt to overcome these problems and produce the most valid model possible, the following analyses were conducted for each stock.

a) The lognormal linear model was run using all data, but allowing no interaction effects. If *statarea* was selected into the model, then the number of records derived from each statistical area was calculated. Data from areas contributing very few records were removed from future analyses. Although there was no set threshold below which data would be removed, the amount of data deleted was generally negligible and was never more than 3% of the total available.
b) The model was re-run, this time allowing interactions between all variables. The variable coefficient ranges were then examined, and if a range was considered implausible, the model was re-run with one or more of the least significant variables deleted until the resulting coefficient ranges of the more significant variables were considered plausible.

Model predictions for all variables selected into the final model are plotted against a vertical axis representing the expected (non-zero) catch. To calculate the *y*-values for a particular variable, all other model predictors must be fixed. These fixed values were chosen to be 'typical' values (see Francis (2001) for further discussion of this method). Note that if different fixed values were chosen, the values on the *y*-axis would change but the appearance of the plots would be unchanged.

3. RESULTS

3.1 Ling target longline fishery series

For each of the five stocks, the number of records of days fished in each statistical area included in the final analysis is listed in Table 2. Total numbers of days fished, the estimated catch of ling from those fishing operations, and the number of vessels involved, by year, for data used in the final standardised analysis are given in Table 3.

3.1.1 Chatham Rise (LIN 3&4)

The Chatham Rise final analysis comprises almost 15 000 records of days fished throughout the 18 years analysed (Table 3). The estimated landings from this effort represent more than 90% of the total estimated landings by line fishing for this stock. Line fishing accounted for about 55% of the LIN 3&4 landings throughout the 1990s (Horn 2001), but line-caught landings have declined steadily since about 1996 (see Appendix A, Table A3b). Data from bottom longline, trot line, and dahn line operations were included in this analysis, and fishing method was offered as an explanatory variable. None of the 35 vessels included in this analysis had fished in every year, but 16 vessels had fished in six or more years (Figure 2).

The model run without interactions indicated that *statarea* explained an insignificant amount of the variance. Consequently, data from all but four of the statistical areas were retained in the final analysis. The areas that were deleted (301, 406, 411, 412) contributed only 20 observations over the 18 years of the analysis (i.e., less than 0.2% of the data), and these are probably attributable to reporting errors or exploratory fishing. In the model run with full interactions, two interactions (*vessel:log(hookno)* and *vessel:month*) entered the model. However, their inclusion resulted in some implausible *vessel* coefficients, so they were excluded. This exclusion changed the final standardised series only slightly.

Of the variables entering the model in the final analysis, *log(hookno)* was very dominant as it explained about 66% of the total variance (Table 4). The accepted variables explained 81% of the total variance. The model assumptions are mainly satisfied, and there are no marked patterns in the residuals (Figure 3). The poorly estimated points (i.e., those with residuals less than –3) make up a very small fraction of the total data set.

The effects of the selected variables are shown in Figure 4. The relationship between number of hooks set and daily catch is approximately linear. Data from 35 vessels are incorporated in the model; the difference between the best and worst of all but one of these vessels is less than a factor of 5. This level of between-vessel difference is not great given the inclusion in the analysis of auto-longliners and smaller hand-baiting inshore vessels. One vessel, number 24, has an expected catch rate about double that of all the others. However, there are no obvious abnormalities in its data suggesting it should be removed from the analysis, and even if it is removed the series changes negligibly. Highest catch rates tend to occur from August to December (the probable spawning season), but the best monthly catch rate is less than double the worst.

The standardised year effects (Table 5, Figure 4) show a steady decline from 1990 to 1997, followed by a relatively constant signal since then.

To examine whether similar trends in abundance were apparent over the entire area making up the Chatham Rise stock, three sub-areas were defined, and CPUE series were produced for each by forcing a *year:sub-area* interaction into the model. The sub-areas were essentially: 1) coastal South Island waters (i.e., west of the Mernoo gap), 2) the waters around the Chatham Islands (i.e., east of 178° W), and 3) the Chatham Rise between the other two areas. The volumes of data included in each analysis are shown in Table 6; in most years and sub-areas the data are quite evenly spread. The South-east coast and Chatham Rise sub-areas are data rich, with more than 200 fishing days each year (except 1990 on the Chatham Rise), and data were spread quite evenly throughout the years. The Chatham Islands sub-area is relatively data poor, with most years having fewer than 100 days fished, and 1991 being very poorly represented.

The variables selected into the sub-area model where the same as for the single area model; *log(hookno)* was the most influential (Table 7). With the *year* variable included, 81% of total variance was explained. The model assumptions are mainly satisfied, and there are no marked patterns in the residuals (Figure 5). The effects of the selected variables are shown in Figure 6. The relationship between number of hooks set and daily catch is approximately linear. Expected catch rates for all but one of the vessels varied by a factor of 5. This level of between-vessel difference is not great given the inclusion in the analysis of auto-longliners and smaller hand-baiting inshore vessels. One vessel had expected catch rates about double that of the others. However, there are no obvious abnormalities in the data suggesting they should be removed from the analysis, and even if the data are removed the series changes negligibly. Highest catch rates tend to occur from August to December (the probable spawning season), but the best monthly catch rate is only about double the worst. For the south-east coast, the standardised year effects (Table 6, Figure 6) show a steady decline from 1990 to about 1999, followed by a slower decline since then. On the Chatham Rise there is a steady decline from 1992 to 1997, followed by a relatively constant signal since then. Around the Chatham Islands there is a steady decline from 1991 to about 1997, followed by a relatively constant signal since then.

The CPUE series from the three sub-areas can be compared in Figure 7. All have very similar trends from 1993 to 2007. There is some divergence before 1993, but mainly by the Chatham Island series, which is data poor resulting in very wide confidence intervals around the estimated annual indices. The single area series (also shown in Figure 7) appears to reasonably well describe the trends in all three sub-areas.

3.1.2 Campbell Plateau (LIN 5&6)

Line fishing has accounted for 12–40% annually of the LIN 5&6 (excluding the Bounty Plateau) landings since the auto-longline fishery developed in 1991 (Horn 2007a). In recent years the line-caught fraction has been at the lower end of this range (see Appendix A).

The Campbell Plateau final analysis includes almost 5800 days of data from fishing operations responsible for almost 90% of the line landings from 1991 to 2007. This fishery is almost exclusively bottom longline (99.5% of sets), so only data from this method were included in the analysis. Data from 14 vessels were included in the final analysis (see Figure 2). No vessel had fished the entire series, but seven had fished in six or more years.

The model run without interactions indicated that *statarea* was a variable with considerable explanatory power (it explained about 7% of the variance). However, 13 statistical areas each had records of 35 or fewer days fished throughout the 17-year series. Their removal involved less than 2.5% of the data, but reduced the number of included statistical areas to 11 (each with over 40 days fished). It is believed that the remaining subset of data would provide a more accurate representation of any *statarea* effect.

In the model run with full interactions, five interaction variables were selected, *vessel:month*, *vessel:statarea*, *vessel:log(hookno)*, *month:statarea*, and *month:log(hookno)*. However, the inclusion of these resulted in ranges of more than two magnitudes in the coefficients of the *vessel* and *month* variables. The model was re-run restricting *vessel*, or *month*, or *statarea*, or *log(hookno)* from entering any interaction. It was apparent from these runs that all the interacting variables were causing implausible coefficient ranges. Consequently, the final model was derived from a run allowing no interactions between these variables. This reduced the total explained variance by about 7%, but the final series of year effects obtained with and without interactions were virtually identical.

The variables entering the final model were *vessel*, *log(hookno)*, *statarea*, and *month*. About 50% of the variance was explained by the *log(hookno)* variable, and total explained variance was 64% (see Table 4). The model assumptions were mainly satisfied, there being only limited deviations from normality (Figure 8).

The effects of the selected variables are shown in Figure 9. The relationship between the number of hooks set and daily catch is approximately linear. Overall catch by *statarea* varied by a factor of less than 2, and as in previous analyses the highest catch rates occur in Statistical Area 30. Daily catch rate by vessel varied by a factor of less than 3. The low expected catch rate in August may be due to a lull in fishing between the non-spawning fishery on the Campbell Plateau and the spawning fishery near Puysegur, and, hence, little concerted targeting at this time. The standardised year effects (Table 5, Figure 9) indicate a variable series with no clear trend.

To examine whether similar trends in abundance were apparent over the entire area making up the Campbell Plateau stock, two sub-areas were defined, and CPUE series were produced for each by forcing a *year:sub-area* interaction into the model. The sub-areas were the Puysegur Bank and Solander Corridor (i.e., Statistical Area 30), and all other areas normally included in the Campbell Plateau analysis. The volumes of data included in each analysis are shown in Table 8. The Puysegur analysis has more than 100 days fished in most years. The non-Puysegur analysis included more data, particularly through the middle part of the series. The model assumptions were mainly satisfied, there being only limited deviations from normality (Figure 10).

The variables selected into the sub-area model, and the order in which they were selected, were the same as for the single area model, except that *month* was not selected. The variable *log(hookno)* explained most of the variance (46%), and with *vessel*, and *year* included, 65% of total variance was explained (Table 7). The effects of the selected variables are shown in Figure 11. The relationship between number of hooks set and daily catch is approximately linear. Expected catch rates for all vessels varied by less than a factor of 3. Overall catch by *statarea* varied by a factor of less than 2. For the Puysegur region, the standardised year effects (Table 8, Figure 11) exhibit a relatively constant, but jittery, trend over time. For the non-Puysegur region of the Campbell Plateau stock, the standardised year effects (Table 8, Figure 11) show a relatively constant, but possibly slightly declining, trend from 1991 to 2006. The 2007 index is higher than all others, but is based on only 8 days fishing and has very wide confidence bounds.

The CPUE series from the two sub-areas can be compared in Figure 12. The two series exhibit some similar trends, but both are best interpreted as being variable but with no overall trend. CPUE at

Puysegur is markedly higher than in the non-Puysegur area. The Puysegur fishery generally targets aggregations of spawning fish, while the remainder of the Campbell Plateau fishery would be on more disaggregated stocks.

3.1.3 Bounty Plateau (LIN 6B)

Line fishing accounts for virtually all the Bounty Plateau ling landings since 1992 (see Appendix A, Table A3b), and the final analysis presented here includes data from fishing operations responsible for over 98% of those line-caught ling. However, no data from 2005 or 2007 were able to be incorporated in the analysis. Only one vessel fished the Bounty Plateau in 2005 (for 12 days), and although this vessel had also fished here in 2004 (for 4 days) it did not meet the necessary threshold of 30 records. Again in 2007 only one vessel fished the Bounty Plateau and it had not previously fished there (although it had targeted ling in other stocks in previous years). Consequently, the analysis presented here is identical to that reported previously up to 2006 (Horn 2008a). Over 1600 vessel days have been incorporated in the 16 years analysed, although two years provided no data, four years were represented by just over 60 days each, and 2006 contributed only 14 days (see Table 3). Bottom longline is the only method used in this fishery (Horn 2007a). Data from eight vessels were incorporated in the final analysis; one of these vessels had fished in all years from 1992 to 2004, but only one other vessel had fished in six or more years (see Figure 2).

The model run without interactions did not select *statarea*. However, as Statistical Areas 607 and 608 accounted for 99% of the records, data from other statistical areas (i.e., 613 and 614) were deleted as they were probably reporting errors or exploratory fishing. In the model run with full interactions, *month:log(hookno)* and *vessel:log(hookno)* were selected. The inclusion of the *vessel* interaction effect was found to adversely affect the vessel coefficients, so it was excluded.

The variables selected into the final model explained 52% of the total variance (see Table 4). The model assumptions were mainly satisfied, there being only slight deviations from normality (Figure 13).

The effects of the selected variables are shown in Figure 14. The relationship between the number of hooks set and daily catch is approximately linear. Overall catch rates for the included vessels vary by a factor of less than 3. Catch rates tended to be higher from August to October, but the difference between the best and worst month is less than a factor of 5.

The standardised year effects (Table 5, Figure 14) indicate a relatively rapid decline from 1992 to 1994, followed by a slight declining trend to 2004. The 2006 index is indicative of a slight recovery, but has very wide confidence intervals owing to the small volume of data from that year.

3.1.4 West coast South Island (LIN 7WC)

About 30% of the landings of ling from the WCSI section of LIN 7 were taken by line fishing throughout the 1990s, and this level of catch has been maintained since then (Horn 2007a). The final analysis below includes data from fishing operations responsible for over 95% of the line landings (see Table 3). This target fishery for ling is conducted primarily by smaller inshore vessels using the bottom longline and trot line methods. Fishing method was offered as an explanatory variable in this analysis. The final analysis included data from 22 vessels (see Figure 2). Three of these had fished in all 17 years of the series, and 13 vessels had fished in six or more years.

The model run without interactions indicated that *statarea* was a variable with some explanatory power. Consequently, data from only three statistical areas (032, 033, 034) were retained in the analysis (Areas 035, 036, and 703 contributed only 1% of the available observations). In the model run with full interactions, interactions between *month*, *log(hookno)*, and *vessel* were selected.

However, the inclusion of any of these interaction effects produced implausible ranges of variable coefficients, so none were retained. The variables entering the model (*vessel*, *month*, and *log(hookno)*) explained 34% of total variance (see Table 4).

The model assumptions were mainly satisfied, but there was evidence of non-normality in the pattern of the residuals (Figure 15). However, the poorly estimated points (i.e., those with residuals smaller than –3) are a very small fraction of the total data set.

The effects of the selected variables are shown in Figure 16. The vessel coefficients were in a relatively narrow range, with the best and worst vessels varying by a factor of about 4. Catch rates were high from August to October (the spawning season), and low from January to June. Catch per hook increased over the entire range, but at a decreasing rate with increasing hook number.

The standardised year effects (Table 5, Figure 16) indicate a variable series with no clear trends.

3.1.5 Cook Strait (LIN 7CK)

The line fishery in Cook Strait took about 20% of the ling landings from this area throughout the early to mid 1990s, but this proportion has increased to about 40% in recent years (Horn 2007a). The ling target line fishery had relatively few records from 1997 to 2001 (see Table 3), but data from all years were included in the analysis. Over 95% of days fishing occurred in Statistical Area 016 (see Table 2). Bottom longline and dahn line are both used, with bottom longline being dominant. Three large auto-longline vessels have fished in this area since 1998. The total number of days fished by one of these vessels met the 5-year threshold (see Section 2.3), so it was included in the model. Data from 16 vessels were incorporated in the final analysis, and one of these had fished in all but the two most recent years of the series (see Figure 2). Seven vessels had fished in six or more years.

The model run without interactions indicated that *statarea* explained none of the variance, so data from both statistical areas were retained. Interactions between *vessel*, *month*, and *log(hookno)* all entered the full interaction model. However, the interactions with *vessel* gave rise to unrealistic vessel coefficients, so they were excluded. Their exclusion caused very minor changes to the standardised series. Of the variables entering the model in the final analysis, *vessel* was dominant and explained 34% of the variance. *Vessel, log(hookno)* and *month* were the selected variables, explaining 70% of the total variance (see Table 4). The model assumptions were mainly satisfied, there being no marked patterns in the residuals and limited deviations from normality (Figure 17).

The effects of the selected variables are shown in Figure 18. Catch rates by all but one of the vessels in the model varied by less than a factor of 4. Catch per hook increased over the entire range, but at a decreasing rate with increasing hook number. Highest catch rates tended to occur from April to August, although the difference between the best and worst month was less than a factor of 2.

The standardised year effects are quite variable (Table 5, Figure 18) but could be interpreted as showing a slight decline throughout the early 1990s, followed by a steady increase from 1995 to 2002, and then another decline to 2007. An approximate doubling of biomass from 1998 to 2002 is indicated. However, confidence bounds around many of the indices are wide, particularly those from 1999 to 2003 (i.e., most of the higher indices).

3.2 Trawl fishery ling bycatch series

CPUE series for the ling bycatch in two target trawl fisheries for hoki (Cook Strait and WCSI) are presented below. For the analyses of TCEPR data from both fisheries, total numbers of days fished (by trawl method), the estimated catch of ling from those fishing operations, and the number of vessels involved, by year, for data used in the final standardised analysis (i.e., following initial grooming and removal of seldom-fished areas) are given in Table 9. The numbers of records of days fished in each statistical area (following initial grooming and removal of seldom-fished areas) are listed in Table 10.

3.2.1 Cook Strait (LIN 7CK)

The trawl fishery targeting hoki in Cook Strait produced a minimum of 529 tows per year, and about 19 000 tows from 1990 to 2007 (see Table 9). The unstandardised indices of catch per tow exhibited a clear declining trend to the late 1990s, and have since been relatively constant. Fishing occurs in Statistical Areas 016 and 017, but Area 016 is the more heavily fished (Table 10). There are no apparent consistent changes in effort by area over the period analysed. The fishery is dominated by the midwater trawl method (see Table 9); little bottom trawling for hoki was conducted in this area before 1994. Horn (2003) showed that the CPUE derived from bottom trawl data only, midwater trawl data only, and both methods combined, produced series with virtually identical trends. Consequently, both methods have been included in subsequent analyses, but with the midwater trawl category split into two, i.e., fishing on the bottom, and fishing in midwater. Of the 31 vessels included in the final analysis, two had fished in all but the most recent year (Figure 19), and three other vessels produced about 50% of the data. Twenty-two of the vessels had fished in six or more years.

The only interaction to enter the model was between *month* and *method*, but a nested effect of duration by method was also included. Of the variables entering the model in the final analysis, *vessel* was dominant, but explained only 10% of the variance. The final model explained 28% of the total variance (Table 11). The model assumptions were well satisfied, there being no marked patterns in the residuals and limited deviations from normality (Figure 20).

The effects of the selected variables are shown in Figure 21. Catch rates by most vessels in the model varied by a factor of less than 4. Highest catch rates tended to occur from May to October, though differences between any months are just greater than a factor of 2. Ling catch is much higher when using bottom trawl rather than midwater trawl, and bottom trawl catch tends to increase with tow duration up to about 4.5 hours and then declines slightly. Peak ling catch tends to occur over bottom depths of about 350 m.

The standardised year effects (Table 9, Figure 21) indicate a steady decline from 1990 to 1997, followed by a slight increase to 2003, and a subsequent slight decline to 2007. The individual indices have narrow confidence bounds.

3.2.2 WCSI (LIN 7WC)

Available TCEPR data from vessels believed to be accurately reporting their ling bycatch in the trawl fishery targeting spawning hoki off WCSI are summarised in Table 9. After data grooming and selection the number of tows per year ranged from 55 to 2562, with over 18 000 tows in the data set. The years 1991–1997 and 2007 are relatively data poor. The unstandardised indices of catch per tow had no clear trend. The data set is dominated by the midwater trawl method, but there are bottom and midwater trawl shots in each year (see Table 9). Just less than half the midwater tows were reportedly fished on the bottom. Data from the three method categories were included in the model, and *method* was offered as an explanatory variable. Of the 43 vessels included in the final analysis, none had fished in all years, but 16 had fished in six or more years (see Figure19).

In the run with full interactions, an interaction between *latitude* and *method* entered the model and was retained. A nested effect of duration by method was also included. Of the variables entering the model in the final analysis, *vessel* was dominant, but still explained only 10% of the variance. The final model explained 23% of the total variance (Table 11). The model assumptions were well satisfied, with very balanced residuals and no deviations from normality (Figure 22).

The effects of the selected variables are shown in Figure 23. Catch rates by all vessels in the model varied by less than a factor of 5, although most varied by a factor of less than 3. Expected catches of ling are greater in bottom trawls than midwater trawls, and increase with tow duration for all methods. Ling catch peaks at a depth of about 400 m. The categorical variable *latitude* enters the model; the best and worst areas vary by a factor of 5, with catch rates being greatest around the Hokitika Trench. Catch rates vary slightly over time, being lowest in August. Higher catches tend to occur in tows centred on midday.

The standardised year effects (Table 9, Figure 23) produce a series that could be interpreted as relatively flat over much of its range. However, a slight but steady decline since the late 1990s is indicated and most of these indices have narrow confidence bounds. The adjacent points from 1995 and 1996 are relatively low and relatively high, respectively. This is indicative of poor indexing of reality in these years at least.

TCEPR data from vessels believed to have accurately reported their ling bycatch in the WCSI hoki target fishery between 1999 and 2007, and used in the combined model analysis, are summarised in Table 12. There were almost 21 000 tows in the data set, of which over 6000 (30%) reported no ling catch. The data set is dominated by the midwater trawl method, but there are never fewer than 215 bottom trawl shots in any year. Just less than half the midwater tows were reportedly fished on the bottom. Data from the three method categories were included in the model, and *method* was offered as an explanatory variable. Of the 23 vessels included in the final analysis, seven had fished in all years, and 16 had fished in six or more years (see Figure 19).

In the lognormal model (i.e, using all non-zero catches), *vessel* was dominant, but still explained only 10% of the variance. (The variables entering the model are the same as those selected into the 'accurate' TCEPR analysis.) The final model explained 21% of the total variance (Table 11). The effects of the selected variables are shown in Figure 24. Catch rates by all vessels in the model varied by less than a factor of 6, although most varied by a factor of less than 3. Expected catches of ling increase with tow duration and are greater in bottom trawls than midwater trawls. Ling catch peaks at a depth of about 400 m. The categorical variable *latitude* enters the model; the best and worst areas vary by less than a factor of 2. Catch rates vary slightly over time, being lowest in August. Higher catches tend to occur in tows centred on midday.

In the binomial model, *depgndrope*, *vessel*, and *method* each explained about 3% of the variance. The final model explained only 13% of the total variance (Table 11). The effects of the selected variables are shown in Figure 25. The probability of a non-zero ling catch peaks at a depth of about 500 m, and varies between vessels by less than a factor of 3. Bottom trawls are about 75% more likely to catch ling than midwater trawls. The categorical variable *latitude* and *duration* also enter the model, but both have relatively weak effects.

The standardised year effects from the combined model (Table 12, Figure 26) produce a series that declines slightly from 1999 to 2002, and then is relatively flat, or perhaps even increasing, to 2007.

4. DISCUSSION

4.1 LIN 3, 4, 5, 6, and 7 target longline fishery series

In recent assessments of ling stocks around the South Island, series of CPUE indices derived from commercial fisheries have been used as indices of abundance (e.g., Horn 2006b, 2007b, 2008b). CPUE has been the only relative abundance series available for LIN 6B, LIN 7WC, and LIN 7CK, but is used in conjunction with indices from trawl survey series for LIN 3&4 and LIN 5&6. Horn (2002) showed that most of the ling line CPUE series appeared to perform well in relation to the four criteria raised by Dunn et al. (2000), and so were probably reasonable indices of abundance (for that part of the population targeted by the line fishery). The exception was the Cook Strait longline series.

As would be expected, the trends in the indices for the various stocks, and the variables selected into the models, have not changed markedly between the previous (Horn 2008a) and current analyses. Because the five longline fisheries examined here target a single species using similar methods, the sets of variables selected into the model for each stock might be expected to have some similarities. In all the analyses, *log(hookno)*, *vessel*, and *month* were selected into the model. With the CPUE unit being 'kg per day', it would be expected that the number of hooks set per day would be a very influential variable. This is certainly the case for LIN 3&4, LIN 5&6, and LIN 6B, where *log(hookno)* is the most influential variable, accounting for the largest proportion of the explained variance. Skill levels and/or gear efficiency will vary between vessels so the selection of a *vessel* variable in each model would be expected, although vessel catch rates seldom differed by more than a factor of 4 in each stock. Clearly, catch rates in all areas vary throughout the year, probably in relation to the spawning season for ling. Hence, *month* becomes an important explanatory variable.

It is apparent from Figure 2 that the fleet dynamics in some of the line fisheries have changed quite considerably, with periods when several vessels ceased to operate and new ones entered the fishery. However, Horn (2004a) completed separate analyses for shorter time series of data and compared the results with the "all years" indices to show that the change in fleet dynamics has not biased the CPUE. It is also considered unlikely that CPUE series have been biased by any changes in fishing practice over the durations of the fisheries (Horn 2004b), although data on some potentially influential factors are either unavailable before 2004 (e.g., hook spacing) or would be difficult to incorporate into analyses (e.g., learning by fishers).

One clearly apparent change in recent fishing seasons is the reduction in effort, particularly on the Campbell and Bounty Plateaus and in Cook Strait (see Table 3). This reduction is attributable in part to the diversion of autoline vessels to the Ross Sea toothfish fishery, but also to the premanent removal from the New Zealand fleet of some large line vessels. However, it was apparent that a few new line vessels had entered some of the fisheries in 2004–2006, and some of these have built up sufficient history in the fisheries to meet the data thresholds and be included in the analyses reported above.

The sub-area CPUE series for the Chatham Rise and Campbell Plateau stocks were derived to see whether there were any apparent differences in relative ling abundance (as indexed by line catch rates) within what are assumed to be unit stocks. The trends (and catch rates) for the three Chatham Rise sub-areas were very similar. Trends were also relatively similar in the two Campbell Plateau sub-areas, although catch rates are markedly higher in the Puysegur region. However, this is almost certainly a function of the Puysegur fishery targeting spawning aggregations, whereas the fishery in the other sub-area is targeting more disaggregated (generally non-spawning) fish. In summary, there is no information in the sub-area CPUE analyses that indicates a stock structure different to that currently assumed for assessment purposes.

The CPUE from the Cook Strait ling line fishery is considered to be the least reliable of all the five major line series. The reduced precision in the indices from 1997 to 2003 is reflected in the relatively high c.v.s for these points (see Figure 18). This series may be biased owing to the existence of target line fisheries for bluenose and hapuku. Ling is often taken as a bycatch in these fisheries, and the distributions of the three species overlap in depth and area. The CPUE analysis uses only data where ling was the stated target species. If it is general practice to define the reported target species as the most abundant species once the catch is onboard, then any real decline in ling abundance would be underestimated in the CPUE series (because only sets where ling was the most abundant species would be included in the analysis). However, fishing practices and areas differ when targeting each of the three species, so the reported target is often likely to be the true target. The approximate doubling of biomass between 1998 and 2002 indicated by the CPUE series could have been achieved through growth and recruitment, but if so, it does represent an exceptional increase for a fished population.

The possibility of population enhancement by migration from other areas cannot be ruled out. Hence, although the reliability of this CPUE series is questionable, there are no factors that have obviously biased this series.

The line fishery CPUE analyses presented here for all stocks (with the possible exception of Cook Strait) provide sets of indices that are probably valid as relative abundance series (for that section of the population exploited by the fisheries) in stock assessment models for ling. Since the early 1990s, ling stocks targeted by line fisheries declined by about 20% on the Campbell Plateau, and about 55% on the Chatham Rise and Bounty Plateau. The stock off WCSI has fluctuated, but there is no strong indication that stock size in 2007 differs markedly from that in the early 1990s.

4.2 Trawl fishery ling bycatch series

This document updates CPUE series for ling bycatch in the target trawl fisheries for hoki in Cook Strait and off WCSI, using TCEPR data. Horn (2004a) discussed in detail the likely reliability of the catch and effort data available from these fisheries, and concluded that ling in Cook Strait hoki catches would be sufficiently abundant to be consistently reported on the TCEPR forms and that any changes in fishing practice have probably been accounted for by the variables accepted into the CPUE models. A subsequent analysis of "rolled-up" Cook Strait trawl CPUE data (Horn 2008a) supported the conclusion that the TCEPR series probably provided a reasonable abundance index, at least from 1994 to 2006. However, the "roll-up" process produced few data before 1994 (the reason for this was not apparent), giving rise to doubts about the accuracy of estimated ling catch before that date. For that reason, and because there were marked changes in fleet structure that occurred around 1994, it was considered desirable to at least place much lower weighting on the CPUE series before then, and rely on the series starting in 1994.

Horn (2008a) also tried excluding data from vessels that had dropped out of the fishery by 1995 or had recorded more than half their fishing effort in 1993 or earlier to determine whether the high CPUE indices from 1990 to 1993 were driven by vessels that participated minimally in the fishery after 1993. The resulting series was little different to the original analysis. A further analysis using a fine scale area variable was run to test whether there was a subtle change around 1994 in the areas fished for hoki, with the more recent effort occurring in areas of relatively low ling abundance (Horn 2008a). Again, the resulting series was little different from the original. Consequently it was concluded that either ling were markedly more abundant in the early 1990s, or some as yet unidentified change in reporting behaviour by fishers has biased the series.

The Cook Strait series is indicative of a steady decline in abundance from 1990 to 1994, but this part of the series may be unreliable. From 1994 to 2007 biomass is reasonably reliably believed to have declined initially, then increased to a peak about 2003, and subsequently declined again. The 2007 index is the lowest of the entire series.

Horn (2006a) noted that since about 2000 in the WCSI fishery there had been more active avoidance of ling, but that there are still incentives to dump or under-report ling (as is strongly believed to have occurred regularly before 1994). This situation has not changed. Consequently, the 'accurate' TCEPR series was developed by using observer data to identify years when particular vessels were likely to have comprehensively reported their ling bycatch (Horn 2006a). This exercise confirmed that ling bycatch had been frequently not reported on the 'estimated catch' section of the TCEPRs from 1990 until at least 1997, and that there are still vessels appearing to consistently under-report ling. This CPUE series was updated above. However, it was noted that this analysis did not include any tows where hoki were caught, but ling were not. Consequently, a combined lognormal/binomial CPUE model (after Vignaux 1994) was run to produce a new CPUE series from 1999 to 2007 for vessels targeting WCSI hoki and believed to have been accurately reporting their ling bycatch. This analysis incorporated zero ling catches. Also in this analysis, vessels that had used the 'twin rig' bottom trawl method were identified, and these tows were excluded from the analysis.

The new combined model series was quite similar to that part of the 'accurate' TCEPR series over the same time period (see Figure 27). They differed only in the two most recent years; the 'accurate' series declined while the combined series was flat. The incorporation of the reported zero tows in the combined model has the effect of flattening the series (see Figure 26). It is clear that the proportions of zero tows each year for the three methods are very variable (see Table 12). While some of this variation will be genuine (i.e., because the probability of a zero ling catch varies between different areas and depths), it is also likely that inaccurate reporting will have had some influence. A relatively small number of ling caught in a large bag of hoki could easily be interpreted (and reported) as a zero ling catch. Also, if several small ling catches were taken concurrently with large hoki catches then it is likely that processing summaries from the factory would lump the ling together, resulting in a QMS report that has several hoki target tows with zero ling catch (even though some ling was caught), and one tow with a positive ling catch (but including ling from several tows). So while the combined lognormal and binomial model does take some account of zero ling catches, and so is probably a better index than the 'accurate' TCEPR series, it will certainly be including some tows where an actual small catch of ling was reported as a zero catch. There is no way to overcome this problem and maintain a tow-by-tow data series. It would be possible to use the processed summary part of the TCEPR form associated with effort from the tows reported on the same form (the 'roll-up' method of Starr (2007)). However, this results in the loss or blurring of some of the explanatory variables (e.g., depth of groundrope, midtime of tow). Also, if bottom and midwater trawls are operated on the same day then this results in the loss of the particularly influential variable "*method*". In addition, it is likely that some of the processed catch reported on a particular day was actually caught the day before, so the effort associated with a particular catch may not be properly reconciled.

In summary, the combined model CPUE series is probably better than the 'accurate' TCEPR series, but we can still not be confident that it is a reliable index of ling abundance available to the trawl fishery.

4.3 Comparison of relative abundance series

CPUE series from both the line and trawl fisheries are available for the Cook Strait and WCSI stocks (Figure 27); in both areas there are some marked differences in the trends from the two fishing methods. However, pairs of indices from an individual stock would not necessarily be expected to exhibit similar trends, owing to different fishing selectivities in the trawl and longline fisheries.

Both Cook Strait CPUE series exhibit some similar trends, i.e., a decline followed by a recovery, and then another decline in the last 5–6 years (Figure 27). However, an overall decline is apparent in the trawl series, while a strong recovery followed by an equally strong decline dominates the line series. The trawl series has the appearance of being lagged 1–2 years behind the line series. The line series is disadvantaged by having few participants, low data volumes in some years, and the potential for some bias as a result of being able to determine the target species after the catch is landed. However, the trend in the line series is similar to the trend estimated from data produced by the one vessel that had fished with the same skipper and gear in all years from 1990 to 2005 (Horn 2008a). The trawl series is based on extensive data, but relies on consistent and relatively accurate estimation of ling bycatch per tow — a comparison of series using estimated and "rolled up" data suggests that the estimation is accurate from 1994 (Horn 2008a). If only the 1994 to 2006 parts of the two series are compared, marked similarities are apparent, i.e., a general increase from the mid-late 1990s to a peak about 2002–03, followed by another decline. There are no fishery-independent data available to validate either of the Cook Strait CPUE series. However, both may be reliable; stock modelling (Horn 2007b) showed that the catch-at-age data from the trawl fishery also contained a signal for a biomass decline to 1998, an increase to 2003, and a subsequent decline.

The WCSI line CPUE series exhibits an opposing trend to the 'accurate' TCEPR trawl series over much of its range. The line series steadily increases from 1996 to 2004, while the trawl series has an overall decline over the same period (Figure 27). Both series exhibit a reasonable match from 1990 to 1995. The new combined model trawl series is also markedly different from the line series. There has always been, and still is, some incentive for the trawl bycatch of ling to be actively avoided or under-reported; the use of the 'accurate' TCEPR data in both trawl CPUE series has hopefully removed much of the bias that misreporting would introduce. For the line fishery, it is suggested that the hoki trawlers sometimes direct the line vessels to areas with apparently high ling abundance, as indicated by the trawl bycatch, thereby increasing fishing pressure on a species the trawlers are trying to avoid. This behaviour would enable line fishers to reduce their search time and/or fish in areas that are likely to produce relatively high ling catch rates, hence biasing the recent line CPUE upwards. There are also reports of trawlers directly transferring some of their ling catch (presumably for which they have no quota) to line or setnet boats; this behaviour would bias both trawl and line CPUE. However, catch-at-age data from the trawl fishery are not consistent with a fishing down of the larger older fish; fish aged 15 and over are still as abundant in the catch now as they were in the early 1990s (author's unpublished data). Also, there is no perception by the line fishers that the WCSI ling stock has declined in recent years. There is also an indication of some relatively strong recent recruitment resulting in recent biomass increases. Recent stock modelling has indicated that the combined model trawl CPUE exhibits a trend comparable to that derived from an extensive series of trawl catch-at-age data, while the line fishery has probably maintained hyper-stable catch rates in the face of an actual stock decline (author's unpublished data). However, there are no fishery-independent data available to validate any of the WCSI CPUE series, so it is clear that a relative abundance index that can confidently be used in stock assessments of LIN 7WC has still not been identified.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Anderson, O.F.; Bagley, N.W.; Hurst, R.J.; Francis, M.P.; Clark, M.R.; McMillan, P.J. (1998). Atlas of New Zealand fish and squid distributions from research bottom trawls. *NIWA Technical Report 42*. 303 p.

Chambers, J.M.; Hastie, T.J. (1991). Statistical models in S. Wadsworth & Brooks/Cole, Pacific Grove, CA. 608 p.

Dunn, A.; Harley, S.J.; Doonan, I.J.; Bull, B. (2000). Calculation and interpretation of catch-per-unit-effort (CPUE) indices. *New Zealand Fisheries Assessment Report 2000/1*. 44 p.

Francis, R.I.C.C. (1999). The impact of correlations in standardised CPUE indices. New Zealand Fisheries Assessment Research Document 99/42. 30 p. (Unpublished report held in NIWA library, Wellington.)

Francis, R.I.C.C. (2001). Orange roughy CPUE on the South and East Chatham Rise. *New Zealand Fisheries Assessment Report 2001/26*. 30 p.

Horn, P.L. (2001). A descriptive analysis of commercial catch and effort data for ling from New Zealand waters. *New Zealand Fisheries Assessment Report 2001/2*. 64 p.

Horn, P.L. (2002). CPUE from commercial line fisheries for ling (*Genypterus blacodes*) around the South Island (Fishstocks LIN 3, 4, 5, 6, and 7). *New Zealand Fisheries Assessment Report 2001/17*. 32 p.

Horn, P.L. (2003). CPUE from commercial fisheries for ling (*Genypterus blacodes*) around the North Island, New Zealand: an evaluation of series for LIN 1, LIN 2, and Cook Strait. *New Zealand Fisheries Assessment Report 2003/13*. 49 p.

Horn, P.L. (2004a). CPUE from commercial fisheries for ling (*Genypterus blacodes*) in Fishstocks LIN 3, 4, 5, 6, and 7 from 1990 to 2002. *New Zealand Fisheries Assessment Report 2004/12*. 41 p.

Horn, P.L. (2004b). A review of the auto-longline fishery for ling (*Genypterus blacodes*) based on data collected by observers from 1993 to 2003. *New Zealand Fisheries Assessment Report 2004/47*. 28 p.

Horn, P.L. (2005). A review of the stock structure of ling (*Genypterus blacodes*) in New Zealand waters. *New Zealand Fisheries Assessment Report 2005/59*. 41 p.

Horn, P.L. (2006a). CPUE from commercial fisheries for ling (*Genypterus blacodes*) in Fishstocks LIN 1, 2, 3, 4, 5, 6, and 7 from 1990 to 2004. *New Zealand Fisheries Assessment Report 2006/12*. 49 p.
Horn, P.L. (2006b). Stock assessment of ling (*Genypterus blacodes*) off the west coast of the South Island (LIN 7) for the 2005–06 fishing year. *New Zealand Fisheries Assessment Report 2006/24*. 47 p.
Horn, P.L. (2007a). A descriptive analysis of commercial catch and effort data for ling from New Zealand waters in Fishstocks LIN 2, 3, 4, 5, 6, and 7. *New Zealand Fisheries Assessment Report 2007/22*. 71 p.
Horn, P.L. (2007b). Stock assessment of ling (*Genypterus blacodes*) on the Bounty Plateau and in Cook Strait for the 2006–07 fishing year. Final Research Report for Ministry of Fisheries Research Project LIN2005/01, Objective 3. 52 p. (Unpublished report held by Ministry of Fisheries, Wellington.)
Horn, P.L. (2008a). CPUE from commercial fisheries for ling (*Genypterus blacodes*) in Fishstocks LIN 3, 4, 5, 6, and 7 from 1990 to 2006, and a descriptive analysis update. *New Zealand Fisheries Assessment Report 2008/2*. 43 p.
Horn, P.L. (2008b). Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise, Campbell Plateau, and in Cook Strait for the 2007–08 fishing year. *New Zealand Fisheries Assessment Report 2008/24*. 76 p.
Starr, P. (2007). Procedure for merging MFish landing and effort data, version 2.0. Report to the Adaptive Management Programme Fishery Assessment Working Group: Document 2007/04, 17 p. (Unpublished report held by Ministry of Fisheries, Wellington.)
Venables, W.N.; Ripley, B.D. (1994). Modern applied statistics with S-PLUS. 2nd edition. Springer-Verlag, New York. 462 p.
Vignaux, M. (1994). Catch per unit effort (CPUE) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987–93. New Zealand Fisheries Assessment Research Document 94/11. 29 p. (Unpublished report held in NIWA library, Wellington.)

Table 1: Summary of the variables offered in the CPUE models for the trawl and line fisheries.

Variable	Type	Description
Year	Categorical	Calendar year
Month	Categorical	Month of year
Statistical area	Categorical	Statistical area for the set or tow
Vessel	Categorical	Unique vessel identifier
Day of year (doy)	Continuous	Julian day, starting at 1 on 1 January
SOI	Continuous	Southern Oscillation Index, 3-month running mean
Length	Continuous	Overall length of the vessel, in metres
Breadth	Continuous	Breadth of the vessel, in metres
Draught	Continuous	Draught of the vessel, in metres
LBD	Continuous	Vessel length × breadth × draft
Power	Continuous	Power of the vessel engine, in kilowatts
Tonnage	Continuous	Gross registered tonnage of the vessel, in tonnes
Line fisheries		
Method	Categorical	Fishing method (bottom longline, trot line, dahn line)
Hookno	Continuous	Number of hooks set per day in a statistical area
Log(hookno)	Continuous	Logarithm of variable Hookno
CPUE	Continuous	Ling catch (kg) per day in a statistical area
Subarea	Categorical	Subareas within a biological stock
Trawl fisheries		
Method	Categorical	Trawl method (bottom trawl, midwater trawl on bottom, midwater trawl)
Headlineht	Continuous	Distance between trawl headline and groundrope (m)
Duration	Continuous	Tow duration, in hours
Starttime	Continuous	Start time of tow, 24-hour clock
Midtime	Continuous	Time at the midpoint of the tow, 24-hour clock
Depbttm	Continuous	Bottom depth (m)
Depgndrp	Continuous	Depth of groundrope (m)
Speed	Continuous	Towing speed (kts)
Latitude	Categorical	Latitude in 0.25° or 0.5° bins (WCSI fishery only)
CPUE	Continuous	Ling catch (kg) per tow

Table 2: Summary of records of days fished (Days) by statistical area (Statarea) used in the analyses of the target ling longline fisheries in each ling stock.

Chatham 1990–2007		Campbell 1991–2007		Bounty 1992–2007		WCSI 1990–2007		Cook Strait 1990–2007	
Statarea	Days	Statarea	Days	Statarea	Days	Statarea	Days	Statarea	Days
018	2 466	030	1 825	607	657	032	1 243	016	1 620
019	70	602	384	608	1 007	033	3 971	017	57
020	2 574	603	331			034	4 205		
021	589	604	458						
022	65	605	244						
023	311	610	834						
024	175	611	164						
401	1 360	612	40						
402	1 154	618	841						
403	627	619	606						
404	1 439	625	45						
405	97								
407	406								
408	394								
409	235								
410	1 492								
049	530								
050	92								
051	114								
052	594								

Table 3: Summary of data (by calendar year) used in the final standardised longline CPUE analysis for each stock. Days, number of individual records of days fished; Catch, estimated catch (t) from the accepted records; Vessels, number of vessels contributing to the accepted records. The total in the "Vessels" column indicates the number of unique vessels contributing to the accepted records throughout the time series.

	Chatham Rise (LIN 3&4)			Campbell Plateau (LIN 5&6)			Bounty Plateau (LIN 6B)			WCSI (LIN 7WC)			Cook Strait (LIN 7CK)		
Year	Days	Catch	Vessels	Days	Catch	Vessels	Days	Catch	Vessels	Days	Catch	Vessels	Days	Catch	Vessels
1990	271	205	5	–	–	–	–	–	–	293	240	9	97	40	7
1991	763	1 735	12	116	465	2	–	–	–	438	450	12	91	36	9
1992	691	2 932	11	245	1 077	3	171	1 035	4	655	769	13	125	53	9
1993	810	3 250	13	280	1 162	5	221	1 231	5	446	616	10	168	71	10
1994	1 010	3 853	13	344	1 418	5	137	661	4	534	799	11	165	34	9
1995	991	4 493	10	349	1 853	5	62	343	3	550	786	11	94	28	7
1996	916	3 915	12	372	1 922	6	91	458	2	667	871	12	70	28	5
1997	1 140	3 275	11	654	3 208	6	62	256	3	679	991	11	32	12	4
1998	742	2 409	11	695	3 021	7	68	465	1	616	997	9	55	20	2
1999	920	2 379	13	674	2 754	6	99	669	3	529	780	10	32	89	3
2000	766	2 318	12	469	2 211	4	171	1 131	3	514	693	10	30	61	3
2001	685	2 416	9	326	1 764	6	192	975	3	525	779	10	31	90	3
2002	920	2 098	11	227	1 288	6	156	799	3	450	607	9	96	107	4
2003	673	1 837	10	162	638	5	157	858	4	524	693	9	152	119	6
2004	798	1 576	10	426	1 635	4	63	341	2	395	525	10	177	187	8
2005	1 078	2 012	11	180	941	2	0	0	0	602	639	10	124	158	6
2006	829	1 412	9	142	817	3	14	58	1	453	542	8	49	180	4
2007	781	1 370	9	111	812	3	0	0	0	549	864	9	89	142	5
Total	14 784	43 485	35	5 772	25 351	14	1 664	9 280	8	9 419	12 641	22	1 648	1 455	16

Table 4: Standardised CPUE models for the target ling line fisheries from the five stocks, showing the percentages of residual deviance explained as each new variable was added.

Step	Variable	% deviance
Chatham Rise (LIN 3&4)		
	Year	10.1
1	log(hookno)	75.7
2	Vessel	79.4
3	Month	80.8
Campbell Plateau (LIN 5&6)		
	Year	4.2
1	log(hookno)	54.6
2	Statarea	61.5
3	Vessel	63.5
4	Month	64.1
Bounty Plateau (LIN 6B)		
	Year	3.9
1	log(hookno)	36.8
2	Vessel	44.4
3	Month	48.4
4	log(hookno):Month	52.3
West Coast South Island (LIN 7WC)		
	Year	2.9
1	Vessel	17.4
2	Month	28.9
3	log(hookno)	33.8
Cook Strait (LIN 7CK)		
	Year	29.5
1	Vessel	63.3
2	log(hookno)	67.6
3	Month	68.7
4	log(hookno):Month	70.2

Table 5: Unstandardised (Unstd) and standardised (Std, with 95% confidence intervals and c.v.s) year effects for the target ling line fisheries in five areas.

Year	Unstd	Std	95% CI	c.v.	Unstd	Std	95% CI	c.v.
	Chatham Rise (LIN 3&4)				Campbell Plateau (LIN 5&6)			
1990	0.24	2.11	1.83–2.44	0.07	–	–	–	–
1991	0.49	1.54	1.41–1.68	0.04	0.82	0.90	0.73–1.11	0.10
1992	1.74	2.01	1.83–2.20	0.05	0.86	1.22	1.04–1.42	0.08
1993	1.52	1.48	1.36–1.60	0.04	0.77	1.30	1.12–1.51	0.08
1994	1.45	1.42	1.32–1.53	0.04	0.74	0.95	0.84–1.09	0.07
1995	2.17	1.41	1.31–1.53	0.04	1.15	1.29	1.13–1.48	0.07
1996	1.85	1.18	1.10–1.28	0.04	1.08	1.04	0.91–1.19	0.07
1997	1.08	0.83	0.77–0.89	0.03	1.07	1.20	1.08–1.33	0.05
1998	1.13	0.80	0.74–0.87	0.04	0.93	0.99	0.90–1.10	0.05
1999	0.82	0.70	0.65–0.75	0.04	0.86	0.83	0.75–0.92	0.05
2000	1.14	0.81	0.75–0.88	0.04	1.04	0.97	0.86–1.09	0.06
2001	1.76	0.80	0.74–0.87	0.04	1.21	1.09	0.96–1.24	0.07
2002	1.01	0.69	0.64–0.74	0.04	1.22	1.07	0.93–1.24	0.07
2003	1.21	0.85	0.78–0.93	0.04	0.79	0.81	0.68–0.96	0.09
2004	0.94	0.70	0.65–0.76	0.04	0.78	0.73	0.63–0.85	0.07
2005	0.61	0.77	0.72–0.84	0.04	1.11	0.84	0.69–1.01	0.10
2006	0.60	0.64	0.59–0.70	0.04	1.27	0.89	0.74–1.07	0.09
2007	0.61	0.71	0.65–0.78	0.04	1.73	1.10	0.89–1.36	0.11
	Bounty Plateau (LIN 6B)				WCSI (LIN 7WC)			
1990	–	–	–	–	0.63	0.90	0.80–1.03	0.06
1991	–	–	–	–	0.79	1.16	1.05–1.29	0.05
1992	1.05	1.80	1.40–2.32	0.13	0.90	1.15	1.05–1.26	0.05
1993	0.97	1.58	1.28–1.96	0.11	1.03	0.92	0.84–1.02	0.04
1994	0.85	1.07	0.82–1.41	0.13	1.06	0.93	0.85–1.02	0.04
1995	1.11	1.13	0.87–1.47	0.13	1.06	0.96	0.88–1.04	0.04
1996	0.90	1.05	0.83–1.33	0.12	0.93	0.79	0.73–0.86	0.04
1997	0.81	0.85	0.66–1.11	0.13	1.03	0.87	0.80–0.94	0.04
1998	1.42	1.03	0.80–1.32	0.12	1.29	0.97	0.89–1.05	0.04
1999	1.33	1.04	0.84–1.30	0.11	1.14	1.04	0.96–1.14	0.04
2000	1.23	0.95	0.79–1.16	0.10	1.10	1.00	0.91–1.09	0.04
2001	0.96	0.81	0.67–0.99	0.10	1.19	1.14	1.05–1.25	0.04
2002	0.94	0.72	0.60–0.88	0.10	1.02	1.10	1.00–1.21	0.05
2003	1.05	0.78	0.66–0.94	0.09	1.01	1.14	1.04–1.25	0.04
2004	1.05	0.71	0.54–0.94	0.14	1.03	1.13	1.02–1.25	0.05
2005	–	–	–	–	0.88	0.86	0.79–0.94	0.04
2006	0.61	0.97	0.48–1.94	0.36	0.90	0.89	0.81–0.99	0.05
2007	–	–	–	–	1.26	1.15	1.05–1.26	0.04
	Cook Strait (LIN 7CK)							
1990	0.69	0.71	0.52–0.97	0.15				
1991	0.47	1.07	0.82–1.38	0.13				
1992	0.56	1.09	0.87–1.36	0.11				
1993	0.43	0.78	0.63–0.98	0.11				
1994	0.28	0.69	0.56–0.85	0.10				
1995	0.34	0.64	0.51–0.81	0.12				
1996	0.49	0.76	0.59–0.99	0.13				
1997	0.60	1.01	0.70–1.45	0.18				
1998	0.48	0.69	0.52–0.94	0.15				
1999	3.43	1.23	0.85–1.79	0.19				
2000	1.75	1.41	0.98–2.05	0.19				
2001	2.72	1.27	0.85–1.90	0.20				
2002	1.69	1.85	1.48–2.32	0.11				
2003	1.33	1.63	1.32–2.03	0.11				
2004	1.39	1.35	1.10–1.66	0.10				
2005	1.42	1.14	0.91–1.42	0.11				
2006	5.60	0.92	0.66–1.28	0.17				
2007	2.28	0.69	0.53–0.90	0.13				

Table 6: Summary of data used in the final standardised longline CPUE analysis for the three Chatham Rise sub-areas, and the unstandardised (Unstd) and standardised (Std, with 95% confidence intervals and c.v.s) year effects for those fisheries. Days, number of individual records of days fished; Catch, estimated catch (t) from the records; Vessels, number of vessels contributing to the records.

Year	Days	Catch (t)	Vessel nos.	CPUE indices Unstd	Std	95% CI	c.v.
South-east coast							
1990	250	130	4	0.18	2.11	1.77–2.51	0.09
1991	456	258	11	0.15	1.52	1.33–1.75	0.07
1992	244	404	10	0.45	1.47	1.25–1.70	0.08
1993	233	212	12	0.29	1.26	1.08–1.48	0.08
1994	293	283	9	0.30	1.33	1.15–1.54	0.07
1995	220	442	9	0.79	1.78	1.53–2.07	0.08
1996	187	278	8	0.31	1.28	1.08–1.53	0.09
1997	368	345	8	0.26	1.06	0.92–1.22	0.07
1998	265	177	6	0.20	0.86	0.74–1.01	0.08
1999	370	296	11	0.19	0.65	0.58–0.74	0.06
2000	337	468	10	0.38	0.82	0.73–0.93	0.06
2001	211	319	7	0.59	0.75	0.64–0.87	0.08
2002	323	290	9	0.31	0.81	0.70–0.93	0.07
2003	274	276	7	0.40	0.92	0.79–1.07	0.08
2004	209	243	7	0.40	0.78	0.66–0.93	0.09
2005	437	223	9	0.17	0.82	0.71–0.94	0.07
2006	397	314	9	0.24	0.66	0.58–0.75	0.07
2007	276	140	7	0.17	0.72	0.62–0.84	0.08
Chatham Rise							
1990	21	75	1	2.24	1.46	0.94–2.28	0.22
1991	297	1 459	4	2.30	1.60	1.40–1.83	0.07
1992	360	1 955	5	2.79	2.48	2.17–2.83	0.07
1993	494	2 735	6	2.62	1.65	1.48–1.84	0.05
1994	601	3 303	8	2.63	1.61	1.46–1.78	0.05
1995	673	3 327	7	2.34	1.38	1.25–1.52	0.05
1996	633	3 137	8	2.51	1.24	1.13–1.36	0.05
1997	670	2 485	7	1.76	0.82	0.75–0.89	0.04
1998	428	1 974	7	2.42	0.87	0.78–0.97	0.05
1999	523	1 904	7	1.68	0.79	0.71–0.87	0.05
2000	396	1 643	6	2.05	0.87	0.77–0.97	0.06
2001	389	1 640	6	2.27	0.88	0.78–0.98	0.06
2002	470	1 458	6	1.72	0.72	0.65–0.80	0.05
2003	311	1 133	4	2.06	0.96	0.84–1.09	0.07
2004	396	927	7	1.17	0.75	0.67–0.84	0.06
2005	572	1 508	5	1.22	0.82	0.74–0.91	0.05
2006	380	895	4	1.10	0.71	0.63–0.80	0.06
2007	393	983	5	1.18	0.81	0.71–0.91	0.06
Chatham Islands							
1991	10	18	1	1.08	0.81	0.44–1.54	0.32
1992	87	573	2	3.99	2.78	2.22–3.47	0.11
1993	83	303	5	1.94	1.62	1.29–2.03	0.11
1994	116	267	5	1.14	1.06	0.87–1.29	0.10
1995	98	724	5	3.62	1.40	1.14–1.73	0.11
1996	96	500	4	2.35	1.06	0.86–1.31	0.11
1997	102	445	5	2.01	0.79	0.64–0.97	0.10
1998	49	258	4	2.83	0.73	0.54–0.97	0.15
1999	27	179	2	3.77	0.81	0.55–1.19	0.20
2000	33	207	2	3.80	0.94	0.66–1.34	0.18
2001	85	457	3	2.96	0.94	0.75–1.17	0.11
2002	127	350	5	1.16	0.65	0.54–0.78	0.09
2003	88	428	5	2.27	0.78	0.63–0.97	0.11
2004	193	406	7	0.92	0.71	0.61–0.82	0.08
2005	69	281	5	1.16	0.70	0.55–0.89	0.12
2006	52	203	5	1.12	0.66	0.50–0.88	0.14
2007	112	247	4	0.64	0.62	0.50–0.77	0.11

Table 7: Standardised CPUE models for the target ling line fisheries in the Chatham Rise and Campbell Plateau stocks, where a *year:sub-area* interaction had been forced into the model, showing the percentages of residual deviance explained as each new variable was added.

		Chatham Rise			Campbell Plateau
Step	Variable	% deviance	Step	Variable	% deviance
	Year	47.1		Year	16.0
1	log(hookno)	76.6	1	log(hookno)	61.8
2	Vessel	79.8	2	Vessel	63.8
3	Month	81.2	3	Statarea	64.5

Table 8: Summary of data used in the final standardised longline CPUE analysis for the two Campbell Plateau sub-areas, and the unstandardised (Unstd) and standardised (Std, with 95% confidence intervals and c.v.s) year effects for those fisheries. Days, number of individual records of days fished; Catch, estimated catch (t) from the records; Vessels, number of vessels contributing to the records.

Year	Days	Catch (t)	Vessel nos.	CPUE indices Unstd	Std	95% CI	c.v.
Puysegur							
1991	35	195	2	1.22	1.34	0.92–1.94	0.19
1992	89	462	3	0.92	1.42	1.08–1.87	0.14
1993	142	715	3	0.76	1.77	1.37–2.28	0.13
1994	130	717	4	0.83	1.23	0.96–1.58	0.13
1995	41	248	3	0.94	1.26	0.89–1.79	0.18
1996	101	748	3	1.61	1.34	1.03–1.75	0.13
1997	154	946	3	1.19	1.35	1.06–1.73	0.12
1998	154	846	3	0.97	1.00	0.78–1.28	0.12
1999	112	848	3	1.77	1.31	1.01–1.68	0.13
2000	117	913	3	1.91	1.40	1.09–1.81	0.13
2001	133	988	4	1.71	1.43	1.12–1.82	0.12
2002	106	858	4	1.83	1.64	1.27–2.11	0.13
2003	75	444	3	1.41	1.19	0.89–1.59	0.15
2004	165	978	3	1.33	1.01	0.80–1.28	0.12
2005	80	668	2	2.07	1.52	1.13–2.03	0.15
2006	88	665	3	1.68	1.33	1.00–1.76	0.14
2007	103	773	3	1.68	1.51	1.15–1.98	0.14
Non-Puysegur							
1991	81	269	1	0.64	0.64	0.47–0.85	0.15
1992	156	614	2	0.76	0.97	0.76–1.24	0.12
1993	138	447	3	0.70	0.83	0.64–1.08	0.13
1994	214	701	3	0.64	0.72	0.58–0.90	0.11
1995	308	1 605	4	1.11	1.00	0.82–1.23	0.10
1996	271	1 175	5	0.86	0.77	0.63–0.95	0.10
1997	500	2 261	5	0.97	0.92	0.76–1.11	0.10
1998	541	2 176	6	0.86	0.78	0.65–0.94	0.09
1999	562	1 905	6	0.70	0.63	0.53–0.76	0.09
2000	352	1 298	4	0.79	0.77	0.63–0.93	0.10
2001	193	775	5	0.87	0.92	0.73–1.16	0.12
2002	121	4431	6	0.78	0.79	0.61–1.01	0.12
2003	87	194	4	0.43	0.61	0.46–0.80	0.14
2004	261	657	3	0.51	0.55	0.43–0.70	0.12
2005	100	274	1	0.61	0.48	0.35–0.65	0.15
2006	54	172	1	0.70	0.57	0.41–0.79	0.16
2007	8	39	1	1.16	1.02	0.50–2.08	0.37

Table 9: Summary of TCEPR data used in the final CPUE analyses of ling catch in the target trawl fisheries for hoki, and the unstandardised (Unstd) and standardised (Std, with 95% confidence intervals and c.v.s) year effects for those fisheries. Tows, number of individual tows recorded; Catch, estimated catch (t) from the accepted records; Vessel nos., number of vessels contributing to the accepted records. The total in the "Vessel nos." column indicates the number of unique vessels contributing to the accepted records throughout the time series. Method: BT, bottom trawl; MWB, midwater trawl on the bottom; MWM, midwater trawl in midwater.

Year	Tows	Catch	Vessel		Method				CPUE indices	
		(t)	nos.	BT	MWB	MWM	Unstd	Std	95% CI	c.v.
Cook Strait hoki trawl fishery										
1990	650	212	14	11	125	514	2.06	2.11	1.91–2.34	0.05
1991	1 102	302	18	9	293	800	1.51	1.75	1.62–1.89	0.04
1992	744	178	16	6	220	518	1.36	1.53	1.40–1.67	0.04
1993	705	183	13	16	432	257	1.51	1.62	1.48–1.75	0.04
1994	788	132	15	209	212	367	1.14	1.04	0.96–1.11	0.04
1995	1 393	186	19	546	325	522	0.98	0.87	0.82–0.93	0.03
1996	1 379	178	21	637	375	367	0.98	0.87	0.82–0.92	0.03
1997	1 569	202	22	621	282	666	0.84	0.75	0.71–0.79	0.03
1998	1 448	176	17	425	373	650	0.82	0.78	0.73–0.82	0.03
1999	1 639	190	18	580	338	721	0.74	0.77	0.73–0.81	0.03
2000	1 414	161	17	410	308	696	0.75	0.86	0.82–0.91	0.03
2001	1 252	158	18	181	391	680	0.80	0.98	0.92–1.04	0.03
2002	853	120	15	174	267	412	0.97	1.01	0.94–1.08	0.04
2003	1 039	154	15	139	396	504	0.99	1.05	0.99–1.12	0.03
2004	986	139	14	157	443	386	0.89	0.84	0.79–0.90	0.03
2005	891	120	12	172	466	253	0.85	0.80	0.74–0.85	0.03
2006	650	80	10	98	299	253	0.85	0.79	0.73–0.85	0.04
2007	529	56	7	55	254	220	0.76	0.65	0.60–0.71	0.04
Total	19 031	2 928	31							
WCSI hoki trawl fishery ('accurate' TCEPR)										
1990	658	180	6	109	265	284	0.72	0.90	0.80–1.01	0.06
1991	479	289	9	112	54	313	1.33	1.07	0.96–1.21	0.06
1992	277	162	5	61	80	136	1.58	1.19	1.03–1.38	0.07
1993	179	106	6	45	105	29	1.59	1.18	1.00–1.39	0.08
1994	302	140	7	106	67	129	1.21	1.09	0.96–1.24	0.06
1995	55	19	2	40	4	11	0.82	0.87	0.65–1.15	0.14
1996	330	166	6	110	104	116	1.18	1.58	1.39–1.79	0.06
1997	242	65	6	38	65	139	0.76	1.17	1.02–1.34	0.07
1998	871	344	13	151	336	384	0.83	1.11	1.03–1.21	0.04
1999	1 336	559	17	363	513	460	1.02	1.26	1.17–1.35	0.04
2000	1 540	604	15	496	364	680	0.91	1.09	1.02–1.17	0.03
2001	2 553	921	26	876	826	851	0.87	0.98	0.92–1.03	0.03
2002	2 349	802	20	793	606	950	0.76	0.86	0.81–0.92	0.03
2003	2 562	864	21	1 180	653	729	0.90	0.84	0.79–0.89	0.03
2004	2 046	804	19	752	616	678	1.02	0.92	0.87–0.98	0.03
2005	1 111	462	12	439	351	321	1.01	0.79	0.73–0.85	0.04
2006	953	378	15	412	250	291	0.97	0.71	0.66–0.77	0.04
2007	326	160	8	125	95	106	1.02	0.76	0.67–0.85	0.06
Total	18 169	7 027	43							

Table 10: Summary of records of days fished (Days) by statistical area (Statarea) used in the analyses of the ling bycatch from TCEPR data in the target hoki trawl fisheries.

Cook Strait 1990–2007		WCSI 1990–2007	
Statarea	Days	Statarea	Days
16	12 763	33	124
17	6 268	34	14 626
		35	3 029
		36	352
		703	38

Table 11: Standardised CPUE models for the two trawl fisheries, showing the percentages of residual deviance explained as each new variable was added.

Step	Variable	% deviance
Cook Strait (LIN 7CK)		
	Year	5.7
1	Vessel	15.8
2	Month	19.4
3	Method	22.1
4	Duration by Method	26.6
5	Month:Method	27.2
6	Depbottom	27.7
WCSI (LIN 7WC) — 'accurate' TCEPR data		
	Year	2.1
1	Vessel	11.6
2	Method	14.7
3	Duration by Method	17.2
4	Depgndrope	18.5
5	Latitude	19.9
6	Day of year	21.0
7	Latitude:Method	22.0
8	Midtime	22.6
WCSI (LIN 7WC) — combined model lognormal		
	Year	1.2
1	Vessel	11.4
2	Duration	14.5
3	Method	16.7
4	Depgndrope	18.2
5	Latitude	19.5
6	Day of year	20.5
7	Midtime	21.1
binomial		
	Year	0.8
1	Depgndrope	3.8
2	Vessel	6.7
3	Method	10.9
4	Latitude	12.4
5	Duration	13.2

Table 12: Summary of TCEPR data used in the combined model CPUE analysis of ling catch in the WCSI target trawl fishery for hoki, and the standardised (Index, with c.v.s) year effects. Tows, number of individual tows recorded; Catch, estimated catch (t) from the accepted records; Vessel nos., number of vessels contributing to the accepted records. The total in the "Vessel nos." column indicates the number of unique vessels contributing to the accepted records throughout the time series. Method: BT, bottom trawl; MWB, midwater trawl on the bottom; MWM, midwater trawl in midwater.

Year	Catch	Vessel	Non-zero tows			Zero tows			Lognormal		Binomial		Combined	
	(t)	nos.	BT	MWB	MWM	BT	MWB	MWM	Index	c.v.	Index	c.v.	Index	c.v.
1999	647	17	291	375	493	103	269	210	1.43	0.03	1.21	0.06	1.26	0.10
2000	682	18	390	477	801	79	451	365	1.23	0.02	1.04	0.05	1.20	0.09
2001	839	20	718	710	857	172	442	447	1.09	0.02	1.00	0.04	1.08	0.07
2002	890	22	812	609	1 042	164	411	404	0.97	0.02	1.27	0.04	0.83	0.06
2003	825	20	930	639	736	226	325	377	0.93	0.02	0.99	0.04	0.93	0.06
2004	827	18	723	601	711	111	144	334	1.03	0.02	1.29	0.05	0.87	0.07
2005	529	15	462	376	447	90	125	262	0.90	0.03	0.91	0.05	0.94	0.07
2006	318	13	320	233	302	119	92	189	0.82	0.03	0.77	0.06	0.95	0.07
2007	153	12	149	131	152	66	126	155	0.76	0.05	0.69	0.08	0.93	0.08
Total	5 710	23	4 795	4 151	5 541	1 130	2 385	2 743						

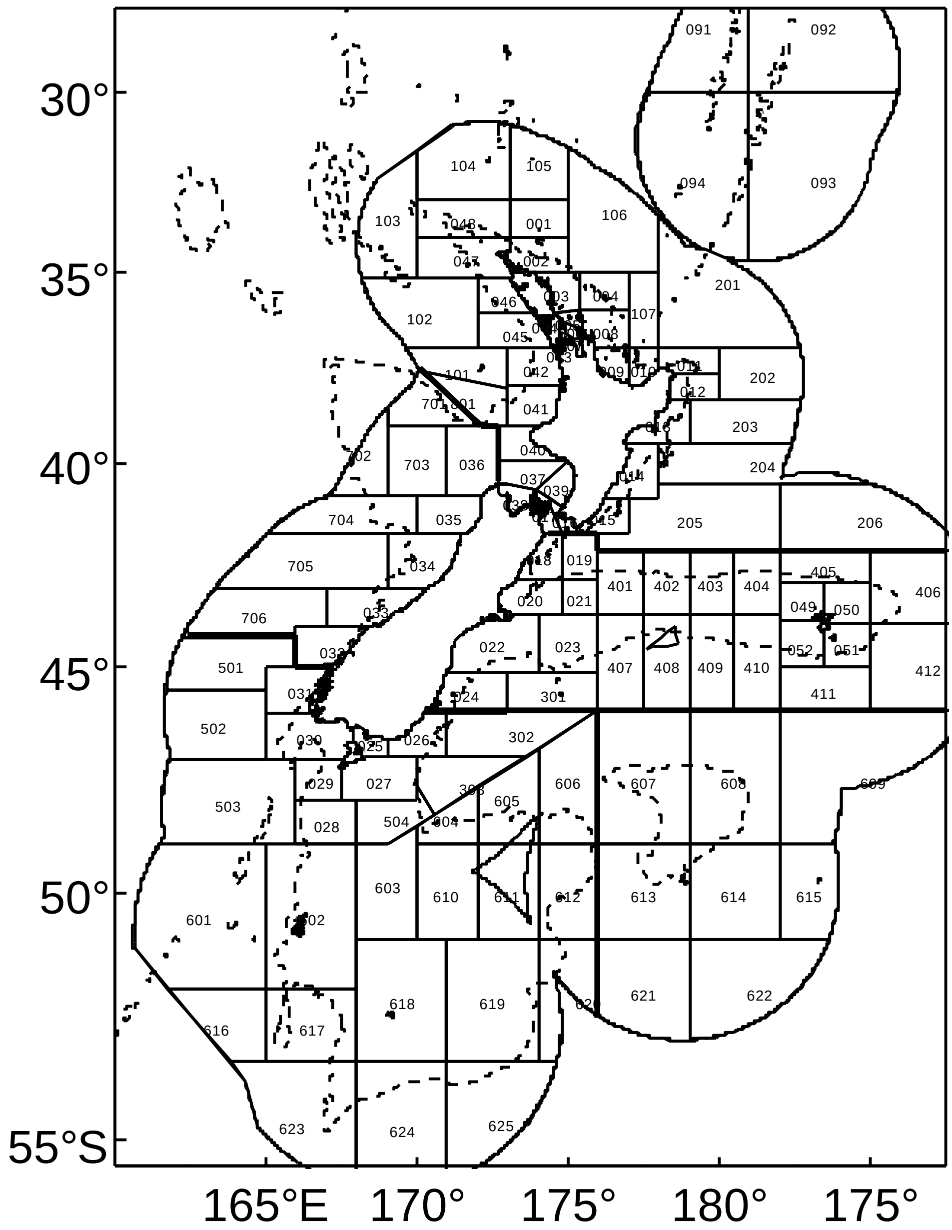

Figure 1: Map of the New Zealand EEZ with statistical areas (numbers from 001 to 801), showing how they were grouped (thick lines) to construct the stock areas used in this analysis. The 1000 m isobath is plotted as a broken line.

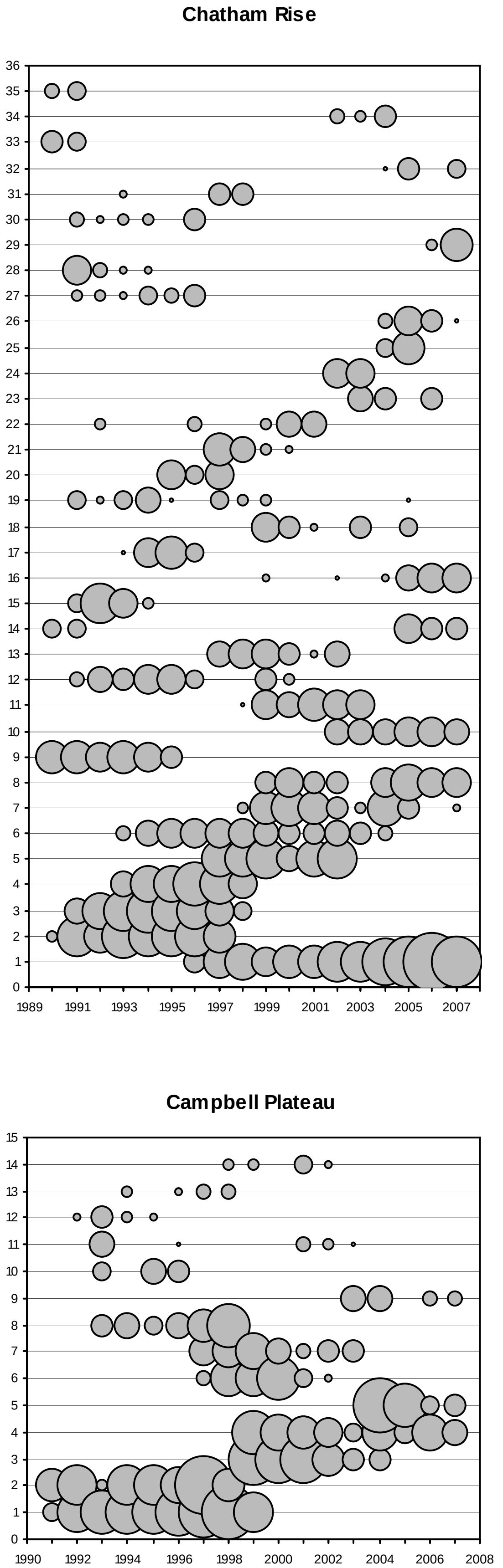

Figure 2: Fishing effort (where circle area is proportional to number of days fished) by year for individual vessels (denoted anonymously by number on the *y*-axis) included in the final longline CPUE analyses for the five main stocks.

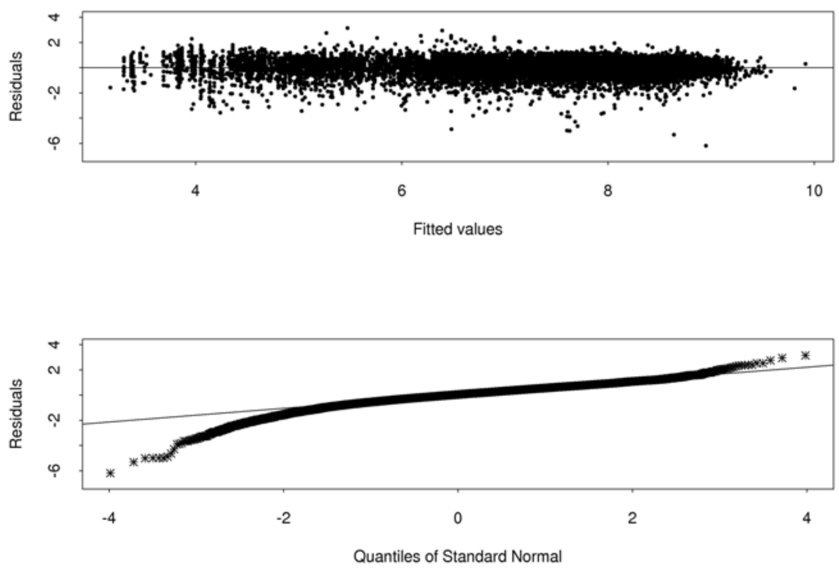

Figure 3: Diagnostic plots for the CPUE model of the Chatham Rise (LIN 3&4) ling line fishery.

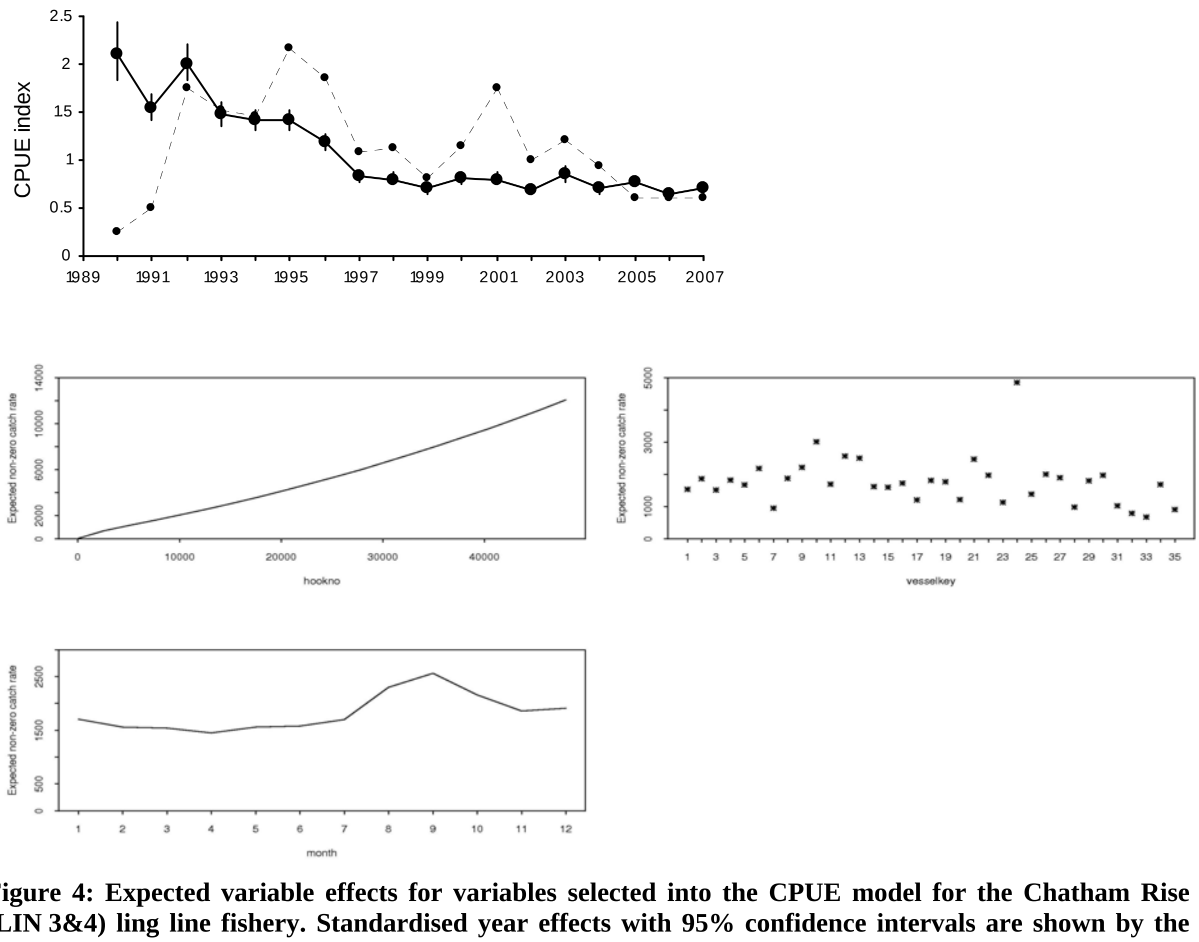

Figure 4: Expected variable effects for variables selected into the CPUE model for the Chatham Rise (LIN 3&4) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero catch rate" is kg per day in this fishery.

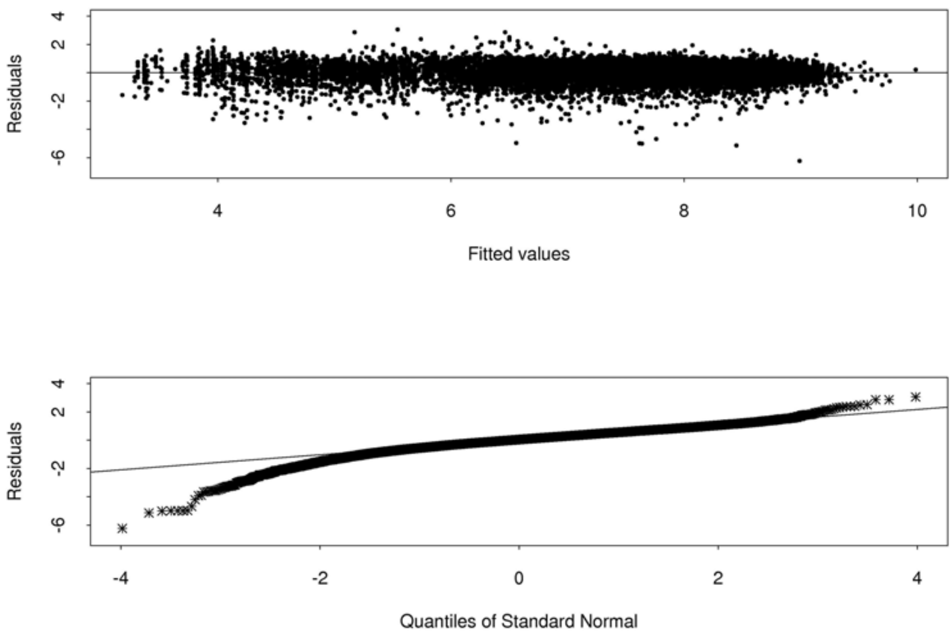

Figure 5: Diagnostic plots for the CPUE model of the three sub-area fisheries in the Chatham Rise (LIN 3&4) ling line fishery.

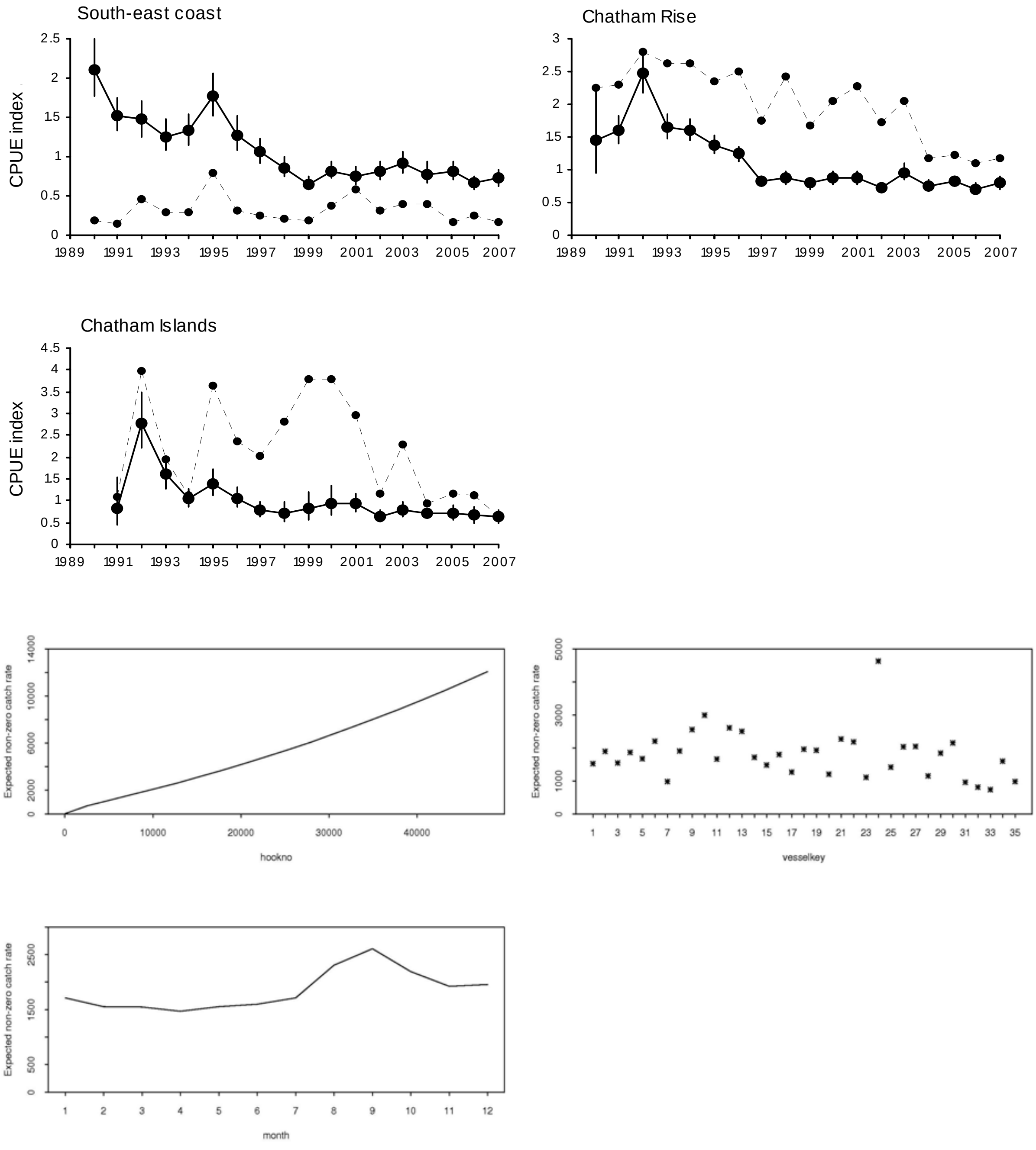

Figure 6: Expected variable effects for variables selected into the CPUE model for the three sub-area fisheries of the Chatham Rise ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid lines in the top three plots; unstandardised data are shown as broken lines. "Expected non-zero catch rate" is kg per day in this fishery.

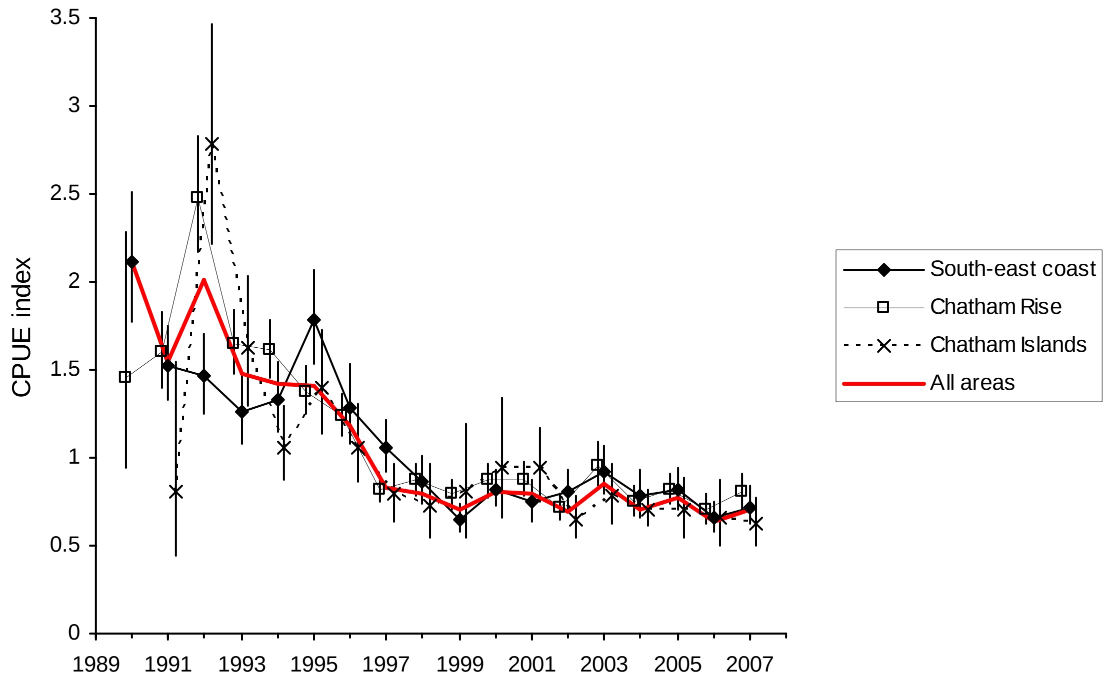

Figure 7: CPUE indices (with 95% confidence intervals) for the line fisheries in the three sub-areas of the Chatham Rise stock, and for all areas combined.

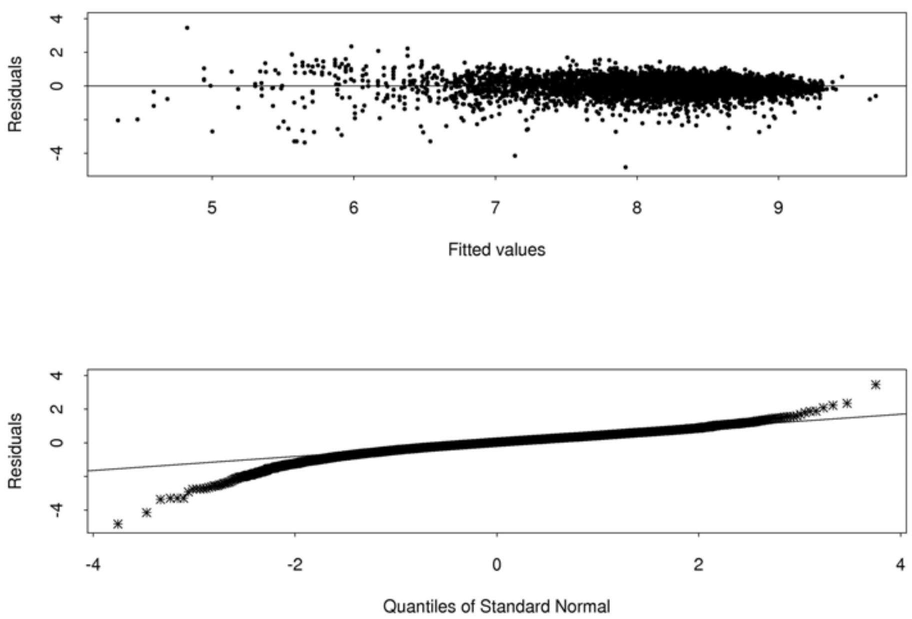

Figure 8: Diagnostic plots for the CPUE model of the Campbell Plateau (LIN 5&6) ling line fishery.

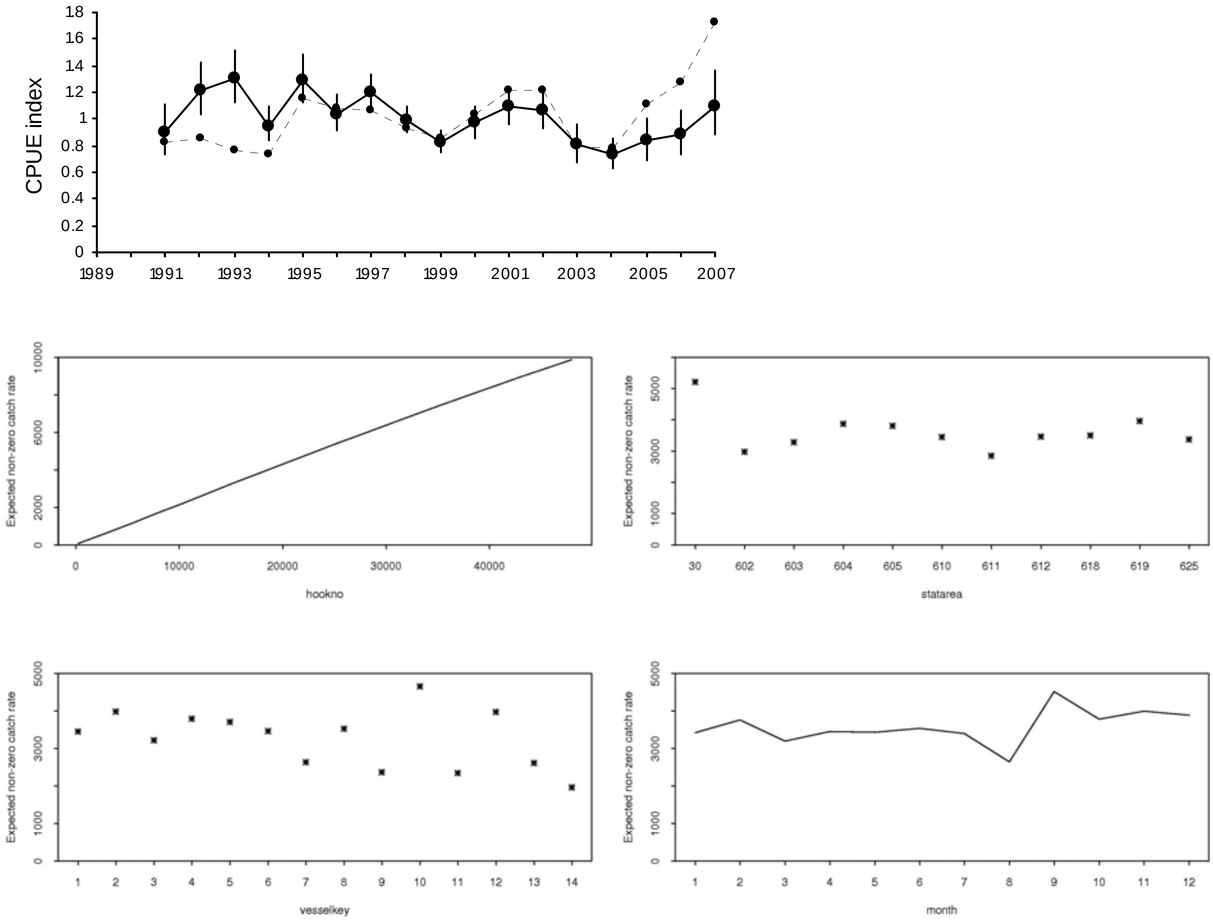

Figure 9: Expected variable effects for variables selected into the CPUE model for the Campbell Plateau (LIN 5&6) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero catch rate" is kg per day in this fishery.

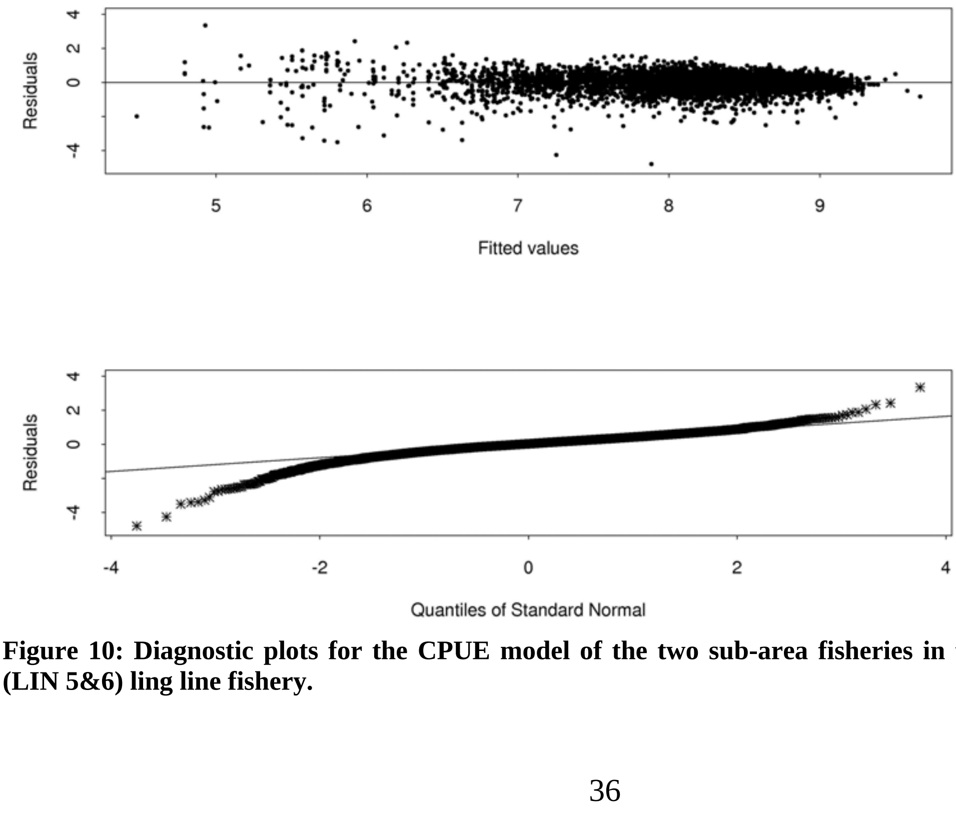

Figure 10: Diagnostic plots for the CPUE model of the two sub-area fisheries in the Campbell Plateau (LIN 5&6) ling line fishery.

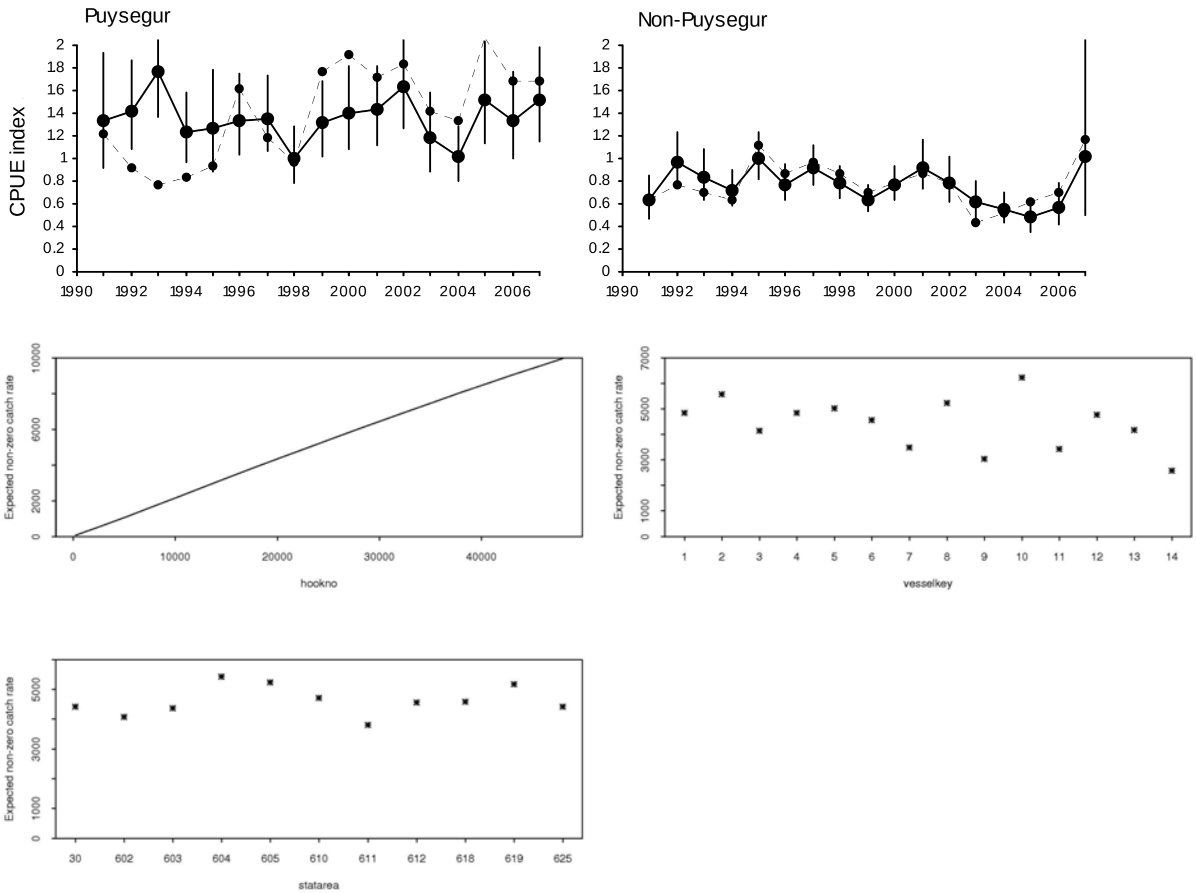

Figure 11: Expected variable effects for variables selected into the CPUE model for the two sub-area fisheries of the Campbell Plateau ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid lines in the top two plots; unstandardised data are shown as broken lines. "Expected non-zero catch rate" is kg per day in this fishery.

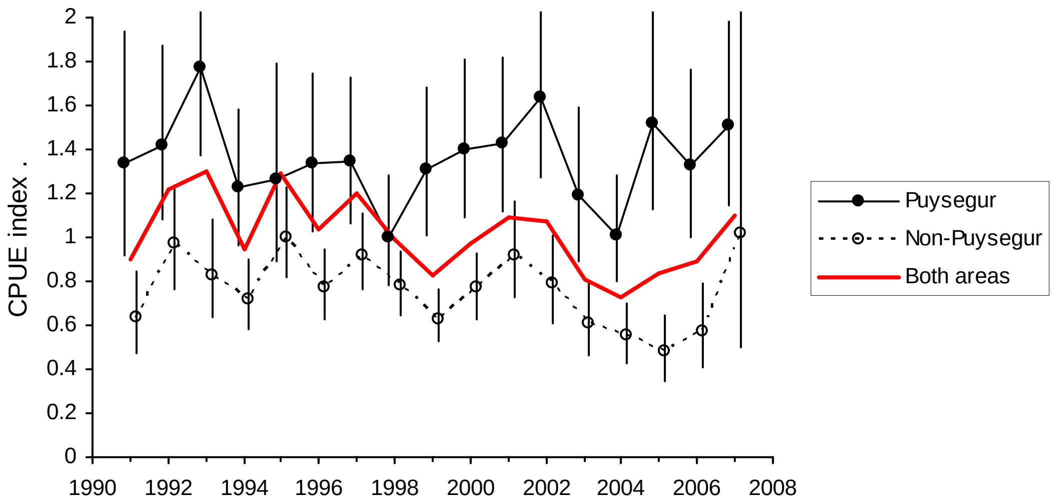

Figure 12: CPUE indices (with 95% confidence intervals) for the line fisheries in the two sub-areas of the Campbell Plateau stock, and for both areas combined.

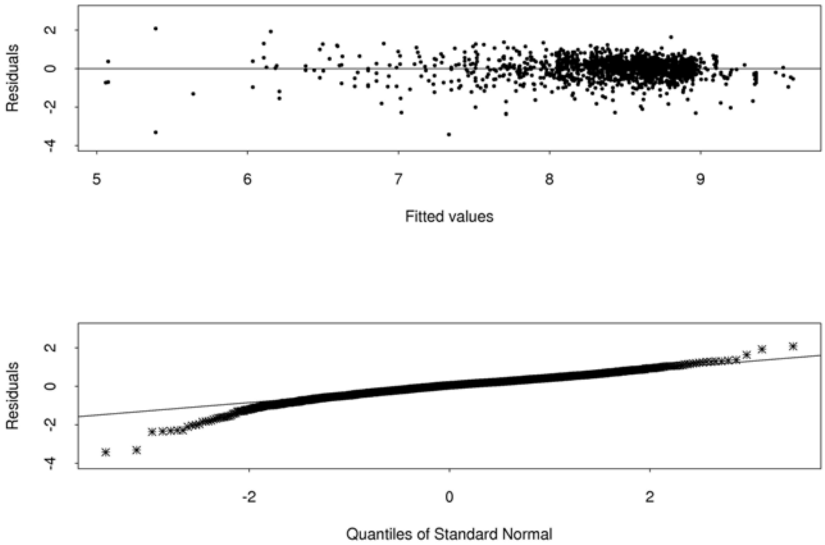

Figure 13: Diagnostic plots for the CPUE model of the Bounty Plateau (LIN 6B) ling line fishery.

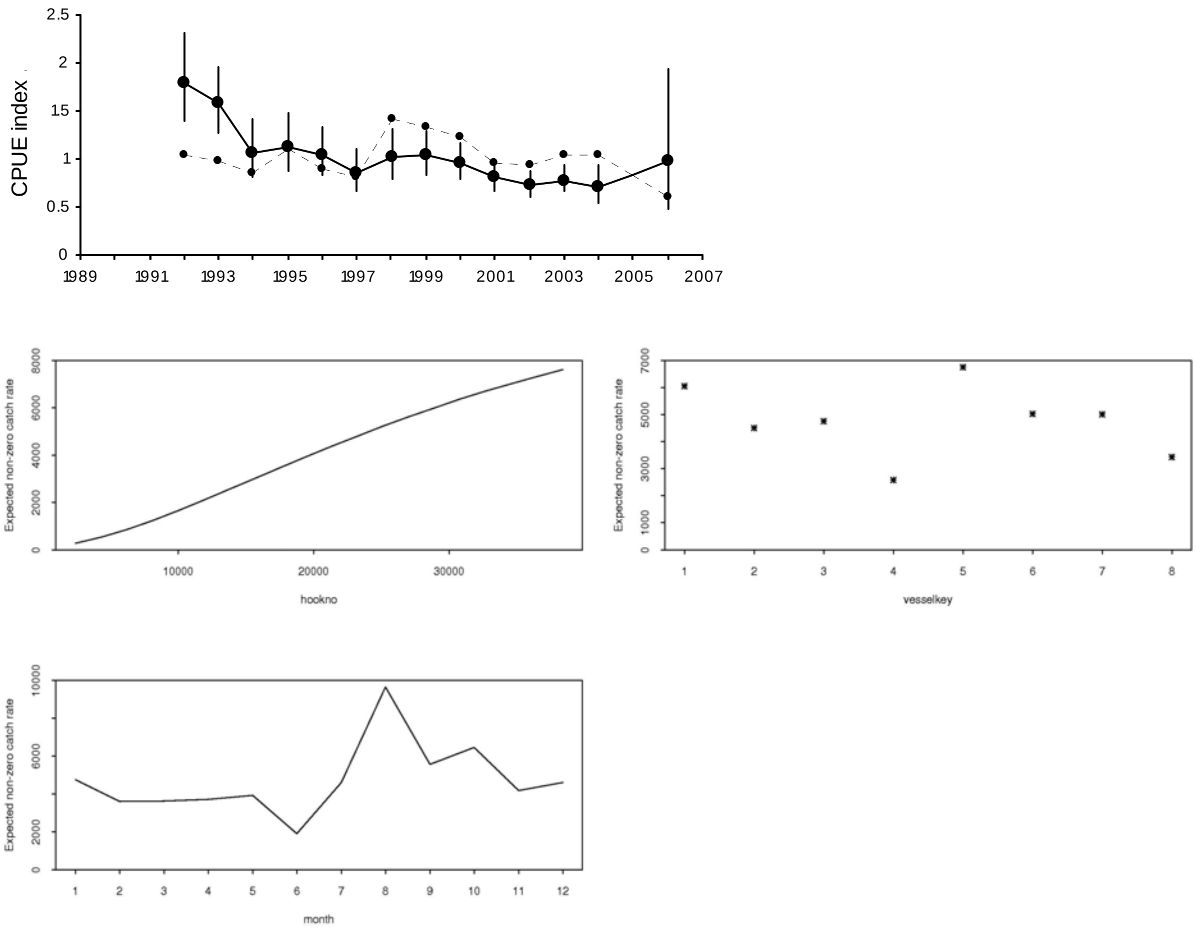

Figure 14: Expected variable effects for variables selected into the CPUE model for the Bounty Plateau (LIN 6B) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. “Expected non-zero catch rate” is kg per day in this fishery. Note that there are no data from 2005.

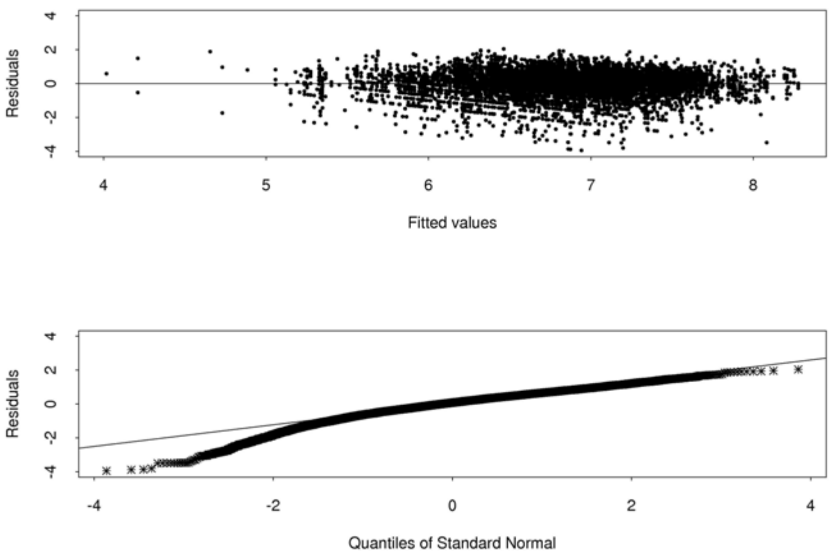

Figure 15: Diagnostic plots for the CPUE model of the WCSI (LIN 7WC) ling line fishery.

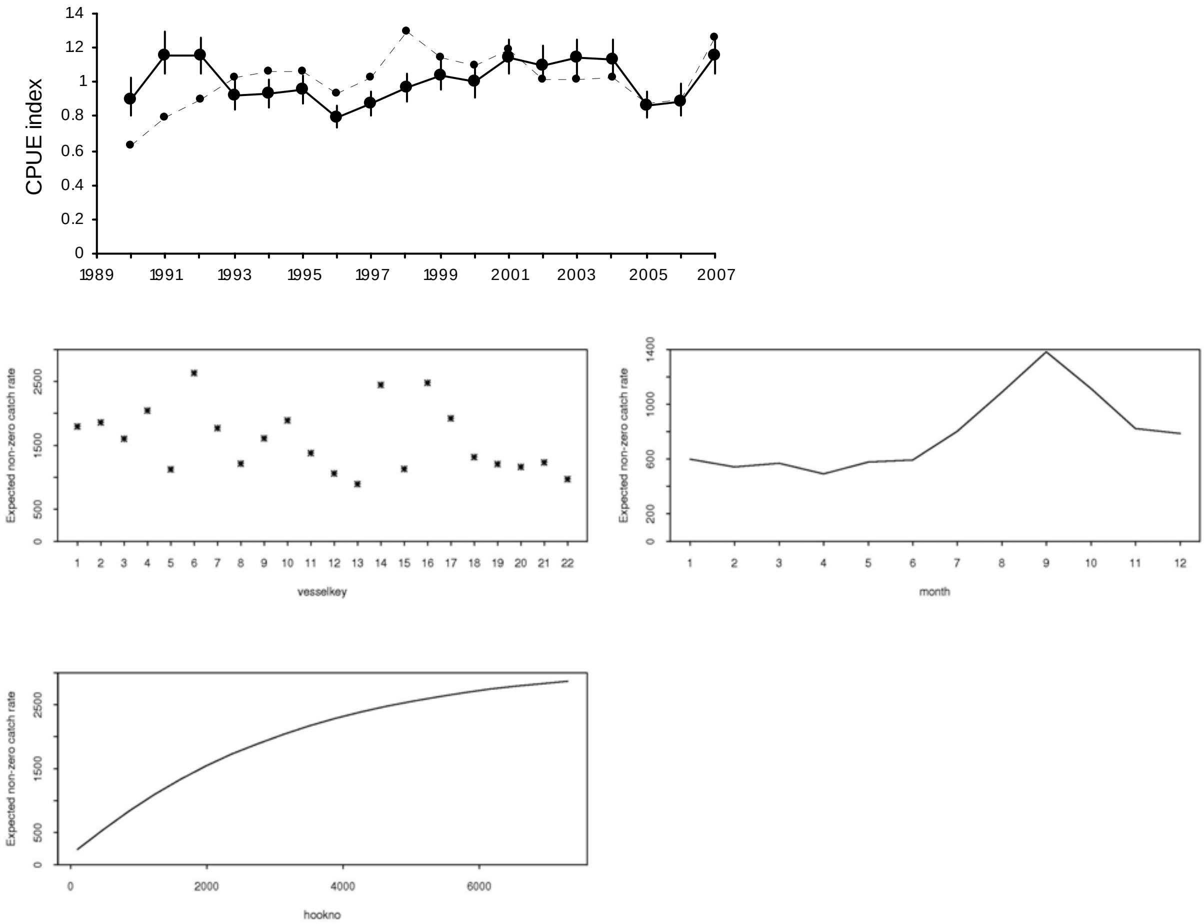

Figure 16: Expected variable effects for variables selected into the CPUE model for the WCSI (LIN 7WC) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero catch rate" is kg per day in this fishery.

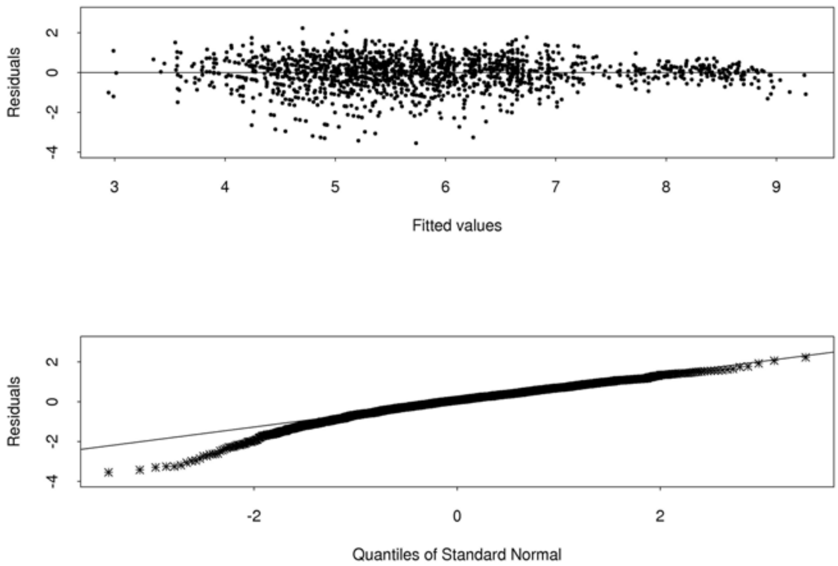

Figure 17: Diagnostic plots for the CPUE model of the Cook Strait (LIN 7CK) ling line fishery.

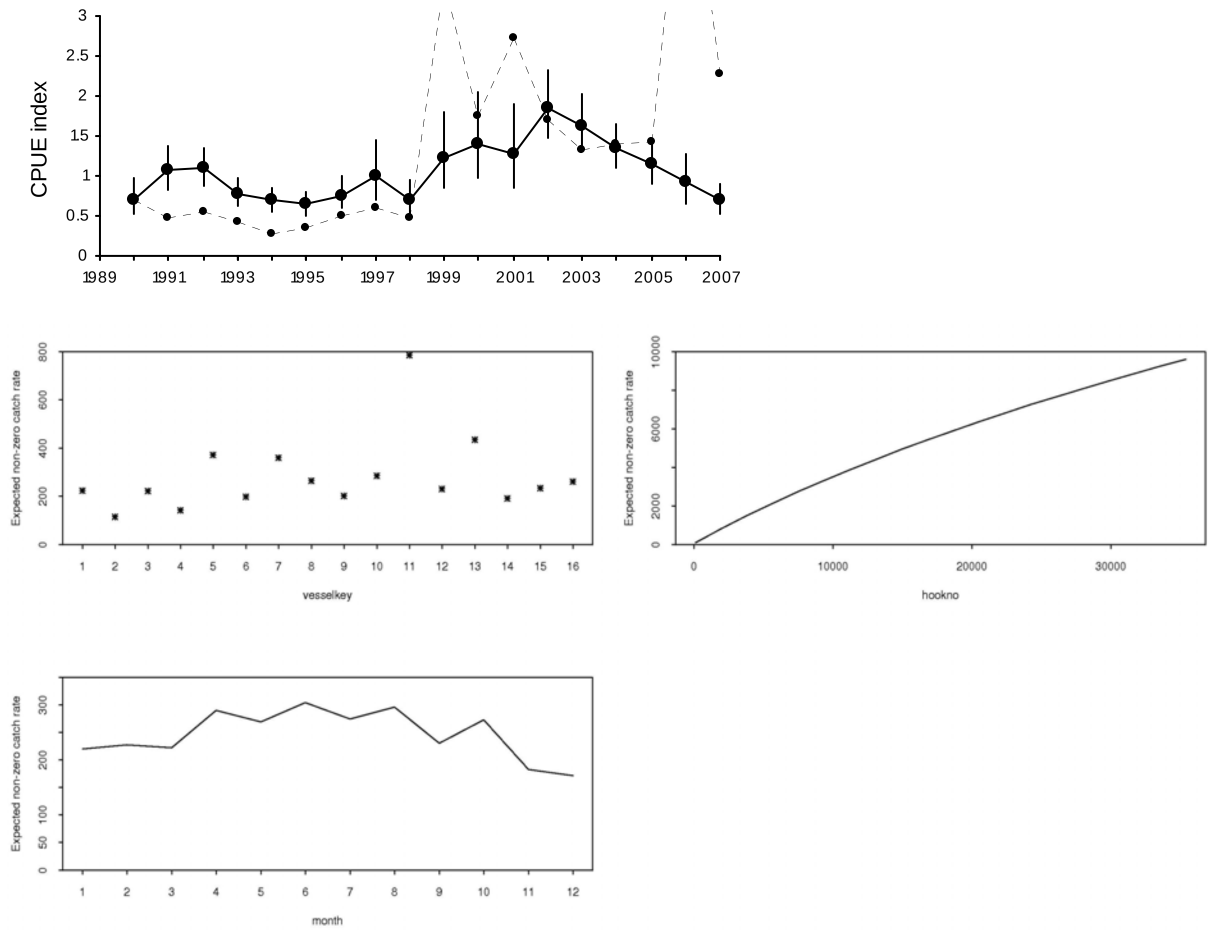

Figure 18: Expected variable effects for variables selected into the CPUE model for the Cook Strait (LIN 7CK) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. “Expected non-zero catch rate” is kg per day in this fishery.

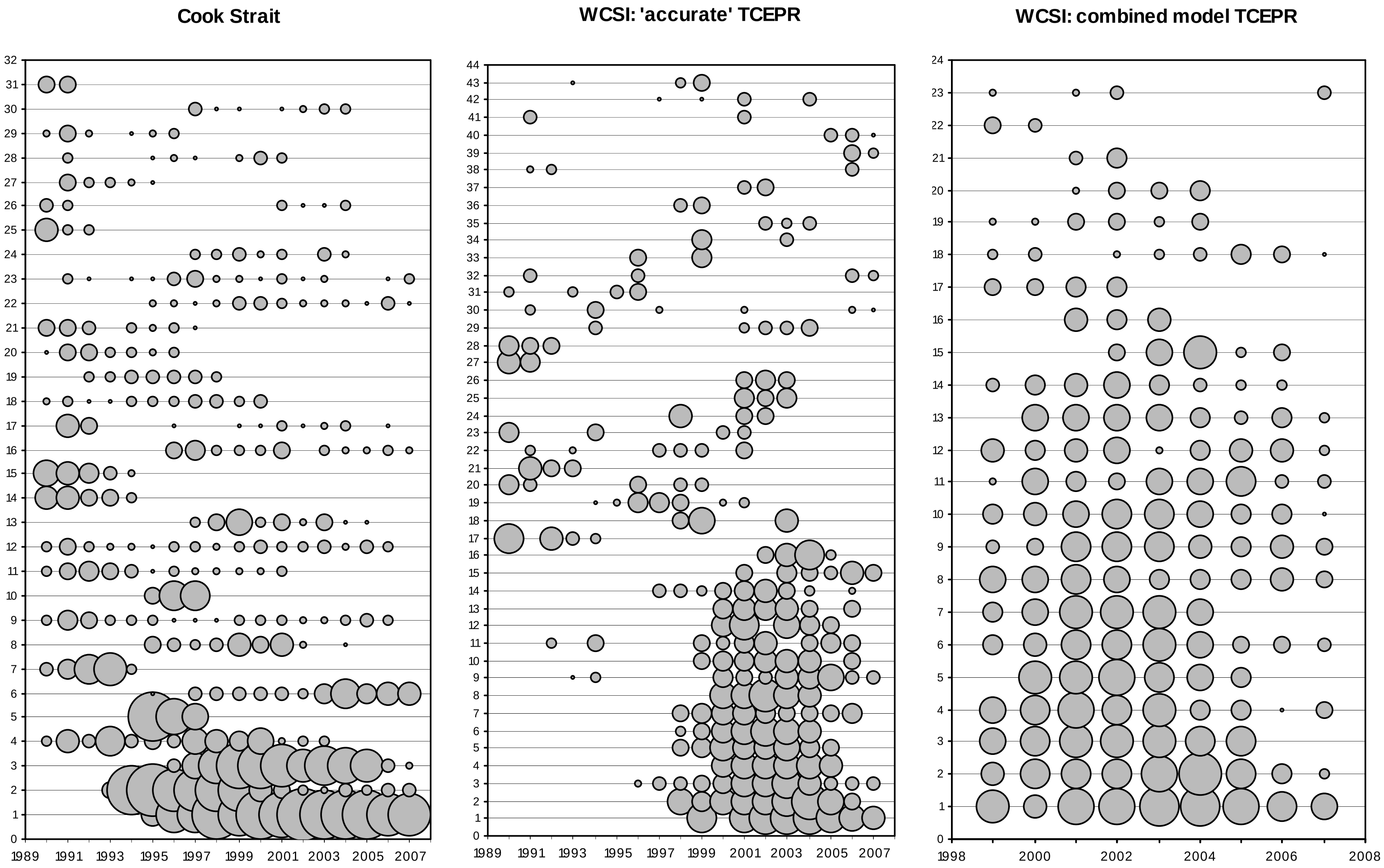

Figure 19: Fishing effort (where circle area is proportional to number of days fished) by year for individual vessels included in the final trawl CPUE analyses.

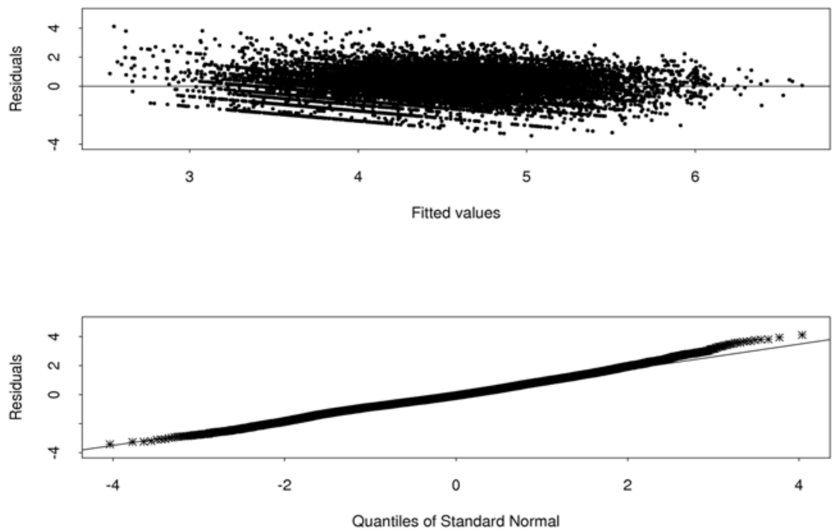

Figure 20: Diagnostic plots for the CPUE model of the Cook Strait (LIN 7CK) hoki trawl fishery.

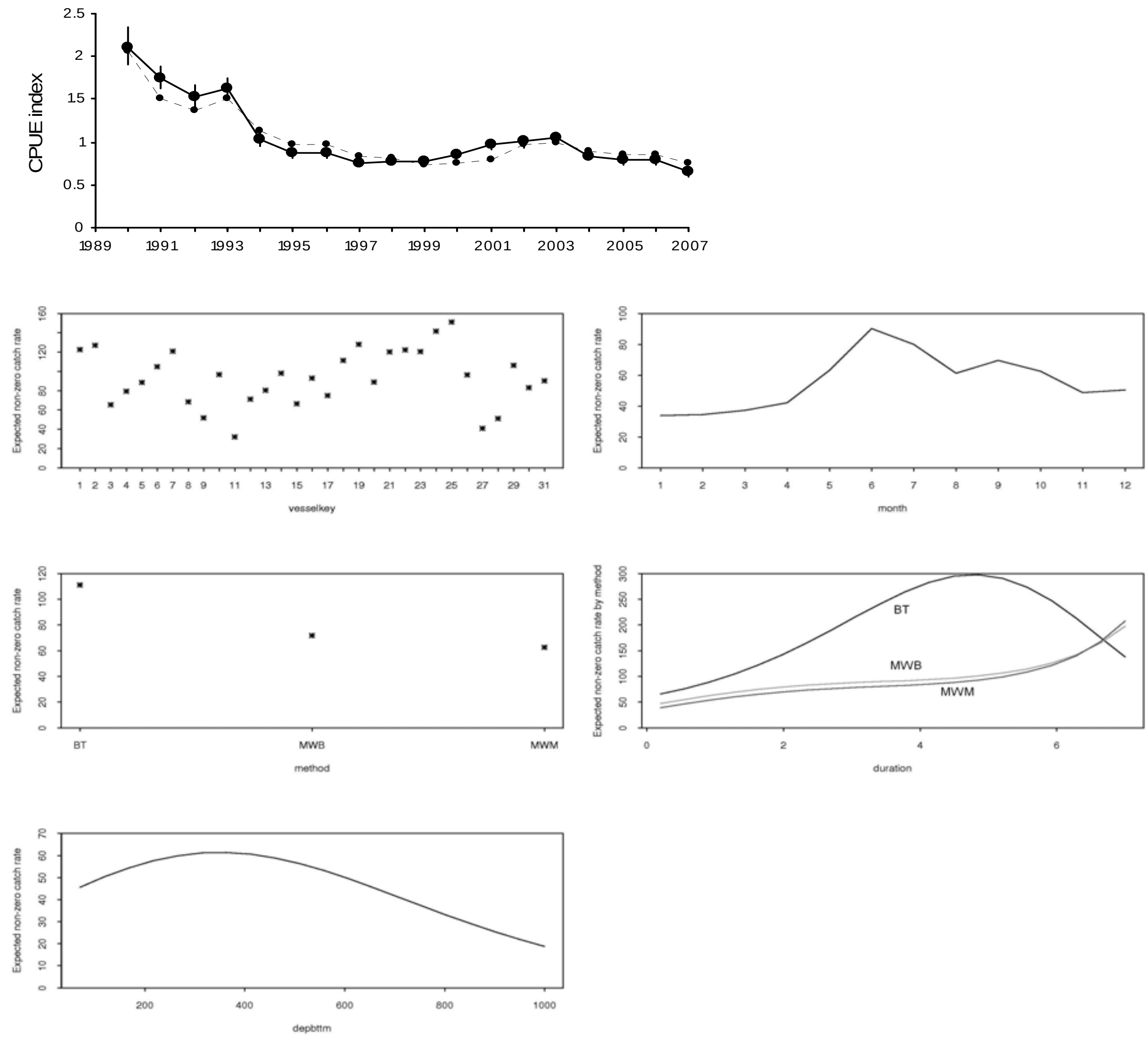

Figure 21: Expected variable effects for variables selected into the CPUE model for the Cook Strait (LIN 7CK) hoki trawl fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. “Expected non-zero catch rate” is kg per tow in this fishery.

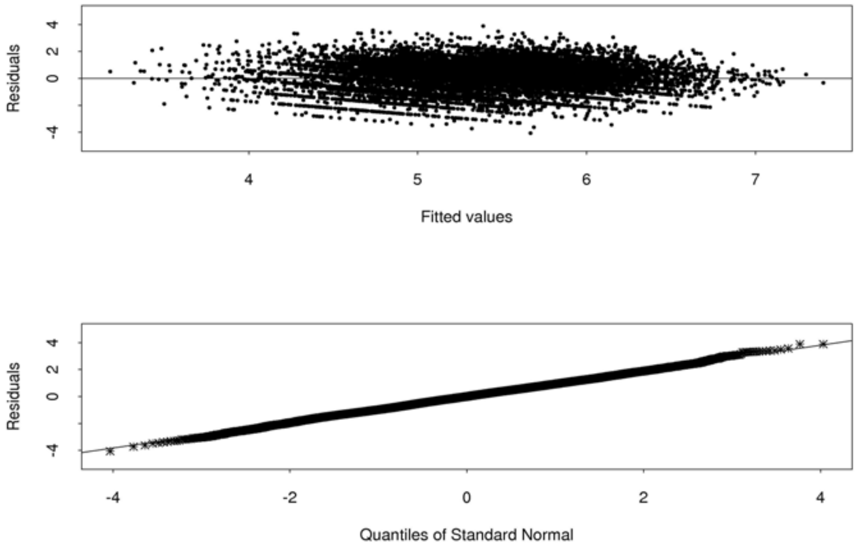

Figure 22: Diagnostic plots for the CPUE model using 'accurate' TCEPR data from the WCSI (LIN 7WC) hoki trawl fishery.

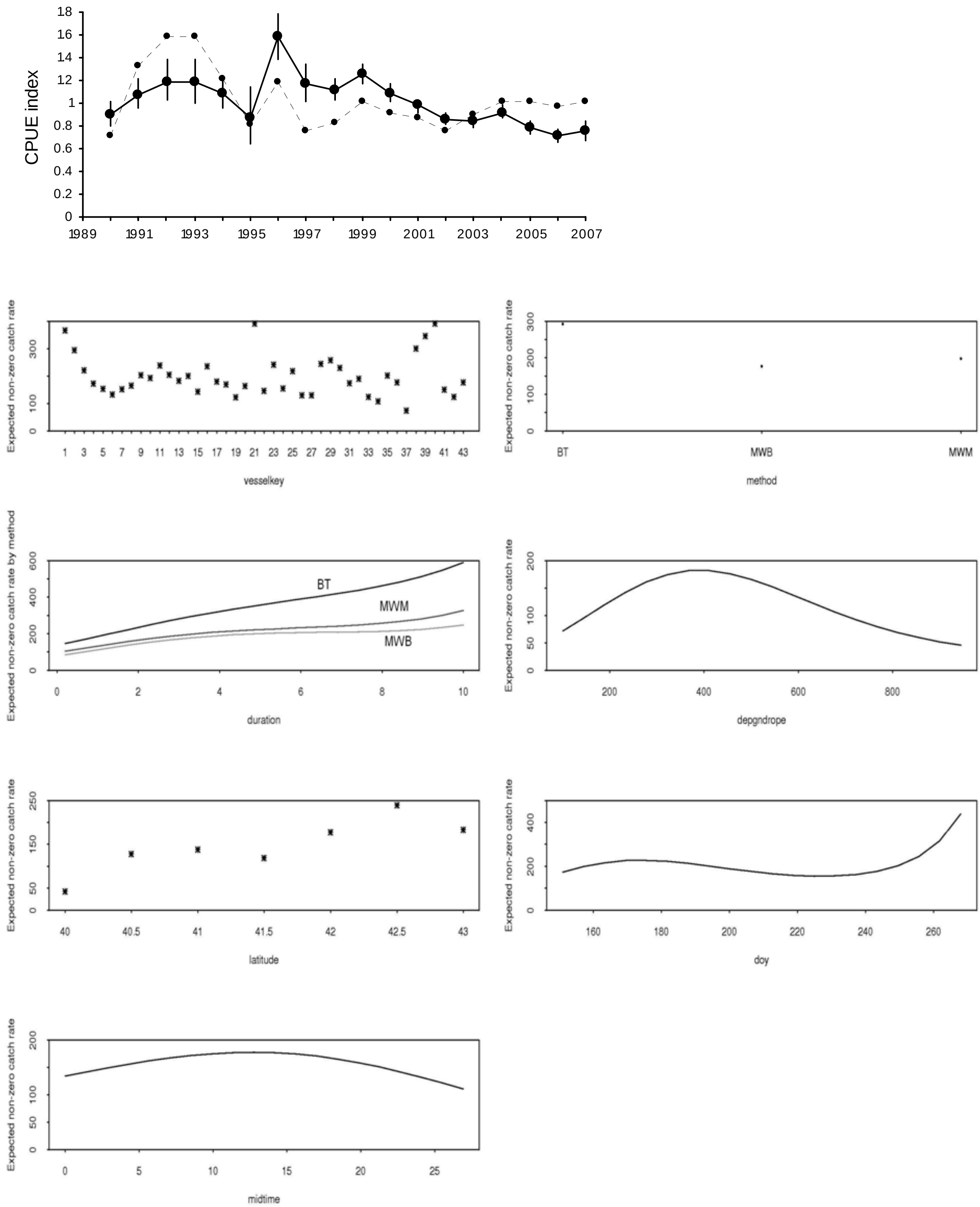

Figure 23: Expected variable effects for variables selected into the ‘accurate’ TCEPR CPUE model for the WCSI (LIN 7WC) hoki trawl fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. “Expected non-zero catch rate” is kg per tow in this fishery.

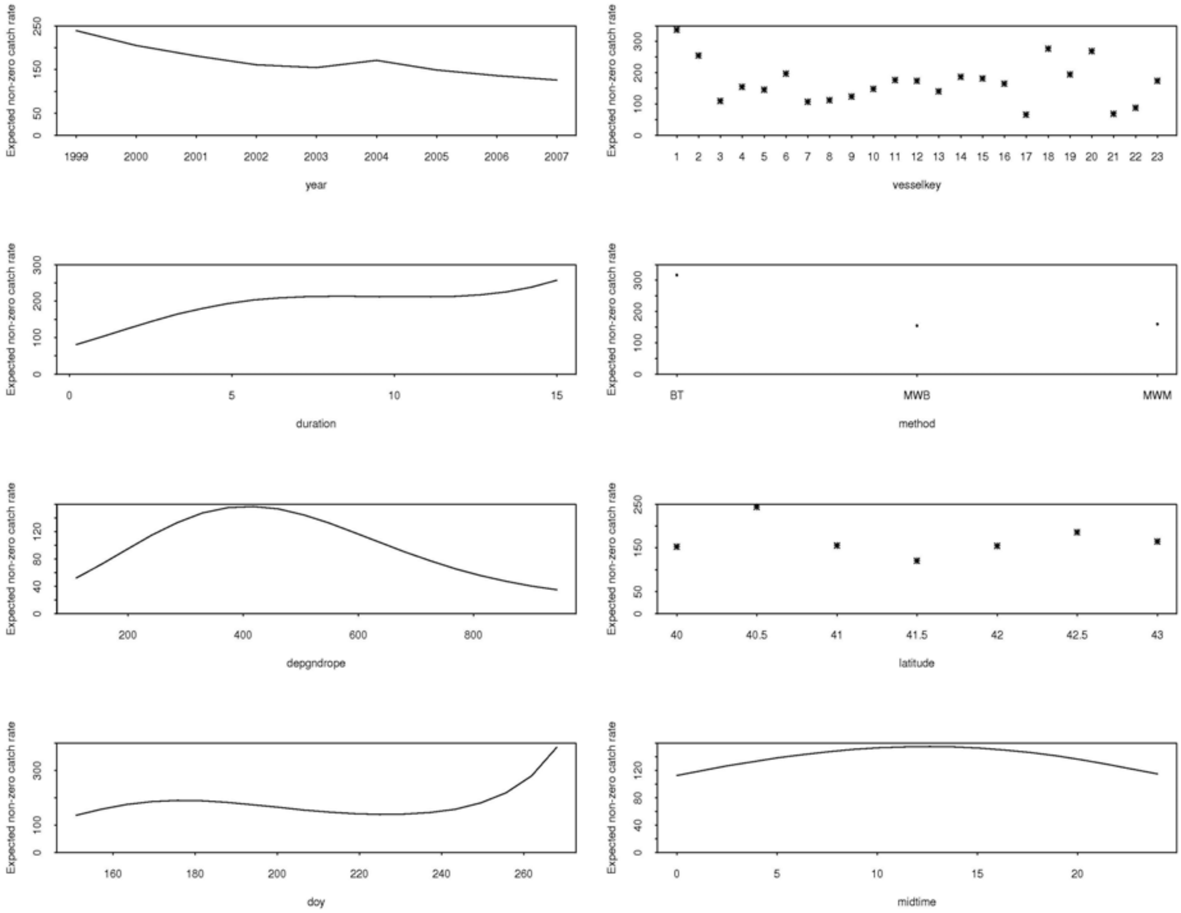

Figure 24: Expected variable effects for variables selected into the lognormal part of the combined CPUE model for the WCSI (LIN 7WC) hoki trawl fishery. “Expected non-zero catch rate” is kg per tow in this fishery.

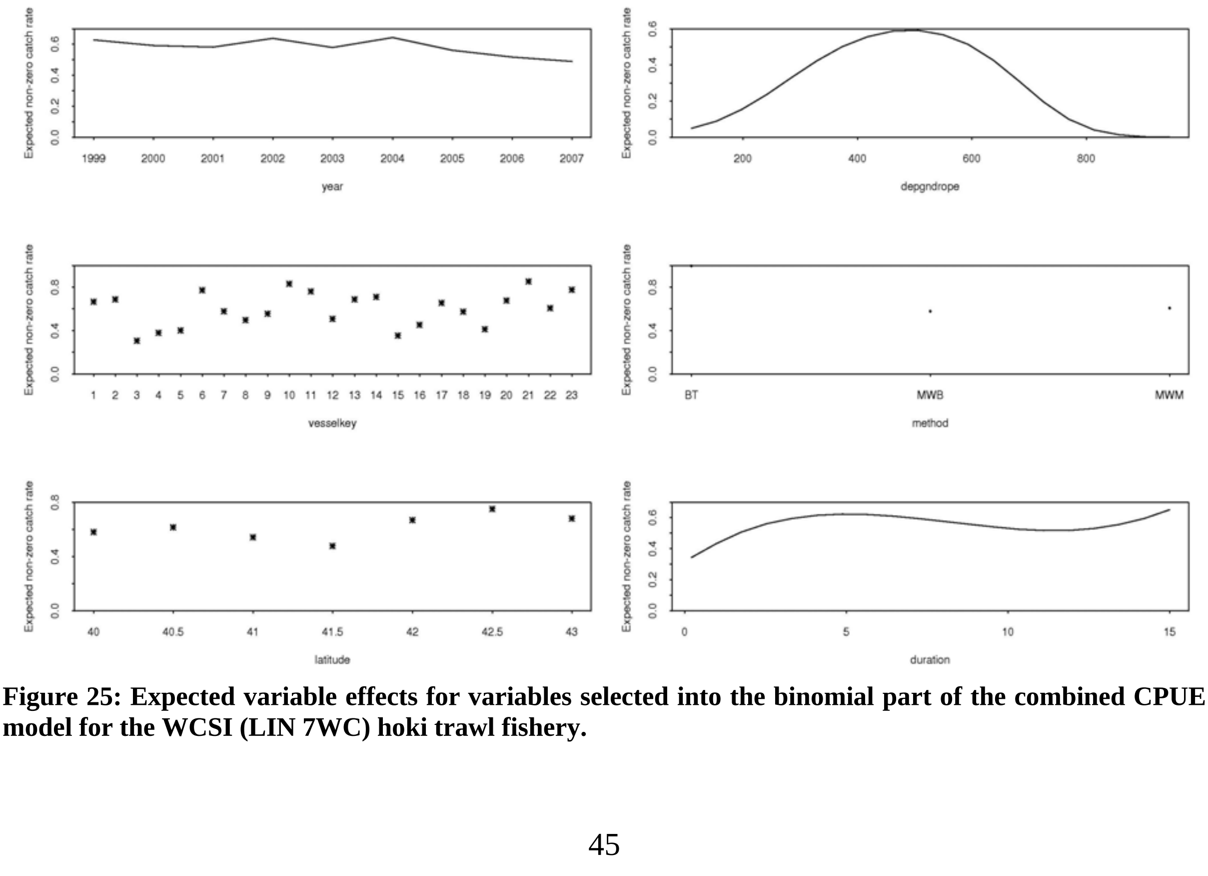

Figure 25: Expected variable effects for variables selected into the binomial part of the combined CPUE model for the WCSI (LIN 7WC) hoki trawl fishery.

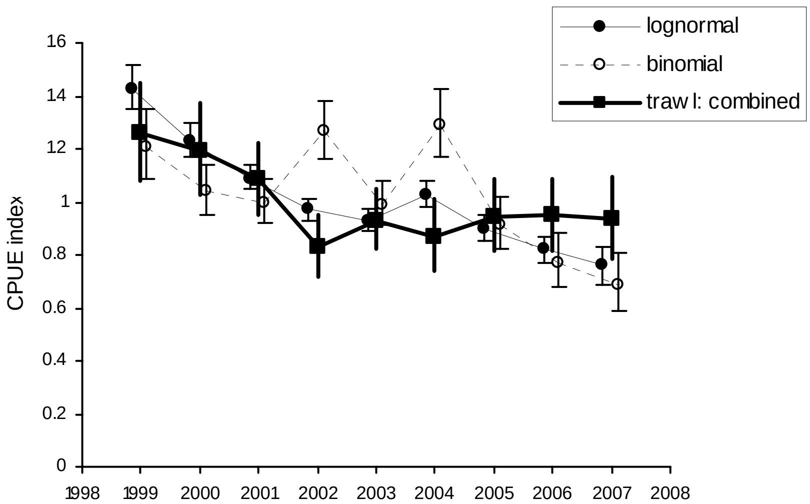

Figure 26: CPUE indices (with 95% confidence intervals) for the lognormal, binomial and combined parts of the combined CPUE model for the WCSI (LIN 7WC) hoki trawl fishery.

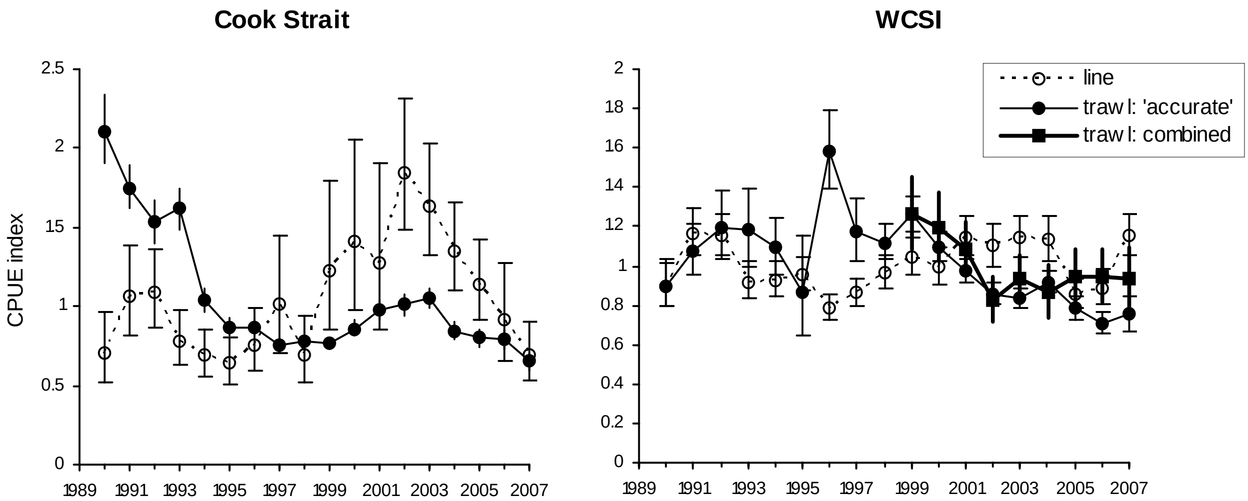

Figure 27: CPUE indices (with 95% confidence intervals) for stocks where both line and trawl series were calculated. The values in each series are scaled to average 1.

APPENDIX A. Updated descriptive analysis

Previous descriptive analyses of commercial catch and effort data for ling were completed for the fishing years 1989–90 to 1998–99 (Horn 2001) and 1989–90 to 2004–05 (Horn 2007a). These were both comprehensive reports showing how the ling fisheries in the New Zealand EEZ had evolved and operated. They also aimed to define seasonal and areal patterns of fish distribution. The work presented here simply updates tables 2 and 4 of Horn (2007a), i.e., catch by area, by method, to indicate whether any marked changes have occurred in the fisheries in the last year.

For a detailed description of the methods used to extract and summarise the landings data, see Horn (2007a). Commercial catch and effort data for all landings of ling from fishing years 1989–90 to 2006–07 had previously been extracted from the MFish catch and effort database, and groomed. The data extracted were reported by fishers on CELR (Catch, Effort, and Landing Return), LCER (Lining Catch Effort Return), LTCER (Lining Trip Catch Effort Return), NCELR (Netting Catch Effort Landing Return), TCER (Trawl Catch Effort Return), or TCEPR (Trawl, Catch, Effort, and Processing Return) forms. The fishing methods examined were: deepwater bottom trawl, deepwater midwater trawl, inshore bottom trawl, inshore midwater trawl, line, setnet, and fish pots. The distinction between deepwater and inshore trawls is not based on depth or position, but rather on the form type that the catch is reported on. TCEPR records are classified as deepwater; CELR and TCER records are classified as inshore.

The catch data from the statistical areas were combined so that the groupings generally approximated the various administrative ling stocks, with two major exceptions. The Bounty Platform section of LIN 6 was examined separately as it is believed to contain a distinct biological stock (Horn 2005), and a Cook Strait area comprising parts of LIN 2 and LIN 7 was created. The areas are: East North Island (East NI), East South Island (East SI), Chatham, Southland, Sub-Antarctic, Bounty, West South Island (West SI), and Cook Strait (Table A1).

All landings data

Annual estimated landings by area, from all methods combined, are listed in Table A2. The estimated totals for each year amount to between 86 and 93% of the actual reported landings. Significant landings have been taken in all areas. Most landings are taken in five areas around the South Island: East SI, Chatham, Southland, Sub-Antarctic, and West SI. This pattern of landings is consistent with ling distributions derived from research trawls (Anderson et al. 1998). There are some changes in the proportions of landings contributed by some areas before and after 2000. Landings from the Sub-Antarctic increased in the latter period, while those from East SI and Chatham declined. There are also some changes between the 2005–06 and 2006–07 fishing years. No line-caught landings from the Sub-Antarctic were reported in 2006-07, continuing a declining trend in this fishery apparent over the last 9 years (Table A3b). The trawl-caught ling catch from West SI was markedly lower than in previous years (particularly landings by the ‘deepwater’ fleet), but some of this reduction was offset by increases in the line and setnet catches (Table A3). Total landings from the EEZ were higher than in the previous year, but are still low relative to annual landings over the last decade (Table A2).

Landings summaries by fishing method and area

Ling are taken by a variety of fishing methods in each of the areas. Summaries of catch by fishing method, by area and fishing year, are presented in Tables A3a–c.

The inshore bottom trawl fishery (Table A3a) produces low levels of landings (i.e., generally less than 100 t annually) in all areas except Sub-Antarctic, Chatham, and Bounty, where catches are negligible or zero. Landings by this method in 2006–07 are similar to those from the previous year, with the most productive areas being West SI and Southland. The deepwater bottom trawl fishery (Table A3a) is particularly important in the Southland and Sub-Antarctic areas, with annual landings generally in excess of 2000 t. Landings in the Sub-Antarctic increased from the late 1990s to peak in 2003–04, dropped markedly in 2005–06, but rebounded slightly in 2006–07. The 2006–07 catches are high (relative to recent previous years) in all areas except West SI.

Landings from the inshore midwater trawl fishery (Table A3a) are negligible in all areas except West SI and Cook Strait. Landings from 2006–07 in both those areas are low relative to previous years. Total landings from the deepwater midwater trawl fishery (Table A3b) in 2006–07 are less than in any year since 1989–90. Landings declined in most areas; only Southland recorded an increase.

The line fishery (Table A3b) is significant in all areas except Sub-Antarctic; zero catch was reported from Sub-Antarctic for the first year since the development of the longline fishery in that area in 1991. At its peak in the late 1990s the Sub-Antarctic fishery produced more than 2000 t annually. Total EEZ catch was slightly higher than last year, but still very low relative to most landings since 1991–92 (i.e., since the development of the autoline fisheries). The Chatham area is particularly productive, but its most recent landings are only about a third of those taken at its peak in the mid 1990s. Landings from the Bounty area were markedly higher than in the two previous years, but still low when compared with catches since 1991–92. Other areas appear to be increasing, or at least maintaining, their recent catch levels.

Setnet fishery landings (Table A3b) are negligible in all areas except East SI and West SI. Landings from West SI steadily declined from 1990–91 to 2004–05, but increased markedly in the most recent year. East SI landings appear to be still declining, and are currently less than 25% of their peak level. Landings from fish pots (Table A3c) are generally recorded only from East SI and Southland, but they average about 20 t annually. However, the 2005–06 and 2006–07 East SI landings are higher than in any other year since 1989–90. There is now a fishery reportedly targeting ling using fish pots in statistical area 24 (i.e., off the Otago coast).

Conclusions

In summary, 2006–07 has seen a slight reversal in the declining trend of overall ling catch from the EEZ, largely a result of increased deepwater bottom trawl catches off the east and south of South Island. The overall line fishery catches were about 10% higher than in the previous year, but still markedly lower than in all other years since 1991–92. The line catch reduction is a consequence of a reduction in the size of the autoline fleet, and some effort from the remaining vessels being transferred to the line fishery for toothfish in the Ross Sea. The reduction in trawling for hoki off West SI also impacted the ling catch from this area and method. However, it appears that some of the LIN 7 quota normally taken by trawlers was caught as a result of increased lining and setnetting effort off West SI.

Table A1: Definitions of geographical areas used in the analysis (based on statistical areas), and the administrative ling stocks they approximate. For a plot of statistical areas, see Figure 1.

Area	Statistical areas	Approximate ling stock
East NI	11–15, 201–206	LIN 2
East SI	18–24, 301	LIN 3
Chatham	49–52, 401–412	LIN 4
Southland	25–31, 302, 303, 501–504	LIN 5
Sub-Antarctic	601–606, 610–612, 616–620, 623–625	Part of LIN 6
Bounty	607–609, 613–615, 621, 622	Part of LIN 6
West SI	32–36, 701–706	Part of LIN 7
Cook Strait	16, 17, 37–40	Parts of LIN 2 & 7

Table A2: Total estimated ling landings (t) as reported on TCEPR, CELR, and LCER returns, by fishing year, by area. Fishing year 1989–90 is denoted as "1990", etc. The percentage of total landings taken over two distinct periods (1990–1999 and 2000–2007) from each area is also presented (Percentage). Total estimated landings by year (Total) can be compared with actual reported landings from Fishstocks LIN 2–7 (Landings).

Area	Fishing year										Percentage
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	1990–99
East NI	268	425	451	512	501	508	509	478	562	423	2.9
East SI	1 220	1 934	1 808	1 612	1 571	1 948	2 320	2 034	2 031	1 939	11.5
Chatham	513	2 157	4 360	3 649	3 755	4 839	4 151	3 814	4 343	3 926	22.2
Southland	2 143	2 105	3 841	2 890	3 259	3 646	4 537	4 445	4 123	3 549	21.6
Sub-Antarctic	1 189	2 673	2 390	5 038	2 270	3 653	3 591	4 951	5 382	4 284	22.1
Bounty	12	32	907	969	1 149	382	387	351	394	563	3.2
West SI	2 322	1 946	1 854	1 864	1 765	2 399	2 595	2 536	2 745	2 975	14.4
Cook Strait	415	527	314	324	252	319	369	381	276	344	2.2
Total	8 083	11 800	15 925	16 859	14 524	17 695	18 459	18 990	19 855	18 004	
Landings	8 907	13 296	17 537	18 812	15 720	19 580	21 183	22 209	22 841	20 811	
% of landings	90.7	88.8	90.8	89.6	92.4	90.4	87.1	85.5	86.9	86.5	

Area	Fishing year								Percentage
	2000	2001	2002	2003	2004	2005	2006	2007	2000–07
East NI	461	557	582	481	507	393	416	512	3.0
East SI	2 098	1 681	1 571	1 842	1 475	1 213	1 202	1 592	9.7
Chatham	3 969	3 412	3 214	2 723	2 379	2 570	1 667	1 947	16.7
Southland	3 423	3 557	3 349	3 143	3 350	4 294	3 918	4 492	22.6
Sub-Antarctic	4 716	4 469	5 326	5 052	5 658	4 678	2 935	3 613	27.8
Bounty	990	1 064	629	922	853	49	43	236	3.7
West SI	2 685	3 068	2 630	2 344	2 406	2 057	2 051	1 797	14.5
Cook Strait	332	395	289	346	360	373	299	241	2.0
Total	18 674	18 203	17 591	16 852	16 990	15 628	12 531	14 430	
Landings	21 300	20 255	19 255	18 654	18 506	16 894	13 814	15 798	
% of landings	87.7	89.9	91.4	90.3	91.8	92.5	90.7	91.3	

Table A3a: Catch of ling (t) by area, by fishing year, for various fishing methods: inshore bottom trawl, deepwater bottom trawl, inshore midwater trawl. Fishing year 1989–90 is denoted as “1990”, etc. Values have been rounded to the nearest tonne, so “0” represents reported landings of less than 0.5 t, and “–” indicates nil reported landings.

Method &																		Fishing year
Area	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Inshore bottom trawl																		
East NI	25	25	21	17	22	18	24	17	7	5	7	6	4	8	3	2	2	15
East SI	148	197	145	109	64	66	50	62	46	51	80	75	106	91	88	99	46	49
Chatham	4	5	2	–	1	2	3	0	0	0	–	0	1	1	0	1	10	1
Southland	47	63	54	94	78	83	50	56	28	66	67	99	89	166	137	136	106	100
West SI	148	150	192	218	111	107	190	166	105	157	129	51	54	69	55	130	127	101
Cook Strait	4	9	3	10	22	78	83	72	25	25	20	15	17	8	4	7	3	4
Total	376	450	418	447	297	354	400	373	211	304	303	245	270	342	287	375	294	269
Deepwater bottom trawl																		
East NI	59	117	88	75	74	79	126	153	131	163	157	206	207	113	74	51	40	71
East SI	599	817	936	802	726	824	1 084	1 019	1 158	972	857	956	855	1 127	810	589	599	944
Chatham	500	1 236	1 344	1 010	443	818	729	771	2 254	1 841	1 889	1 461	1 217	1 317	1 062	798	567	854
Southland	1 980	2 008	3 376	2 182	2 096	2 507	3 929	3 407	2 921	2 650	2 396	2 095	2 133	1 944	2 431	3 157	2 971	3 534
Sub-Antarctic	1 148	2 445	2 045	4 104	1 758	2 013	2 297	2 661	2 990	2 344	3 496	3 540	4 447	4 655	4 764	4 223	2 598	3 495
Bounty	4	7	35	–	4	0	1	–	–	3	1	0	1	1	1	9	4	–
West SI	370	260	306	476	385	486	370	518	496	876	761	1 018	1 133	838	823	763	993	703
Cook Strait	7	13	4	2	48	58	96	126	77	111	88	39	72	35	38	30	21	19
Total	4 666	6 901	8 133	8 650	5 534	6 786	8 632	8 655	10 026	8 961	9 645	9 315	10 063	10 029	10 004	9 620	7 794	9 620
Inshore midwater trawl																		
East NI	1	0	1	2	0	0	0	–	0	–	0	1	–	–	0	0	–	–
East SI	3	9	6	0	1	0	2	7	4	8	7	7	2	30	13	1	2	0
West SI	2	–	2	4	3	10	24	25	57	83	206	180	82	113	67	70	63	34
Cook Strait	42	125	37	30	11	6	16	22	13	9	18	30	14	36	29	23	21	18
Total	48	134	45	35	14	17	43	54	74	100	231	218	98	178	110	93	86	52

Table A3b: Catch of ling (t) by area, by fishing year, for various fishing methods: deepwater midwater trawl, line, setnet. Fishing year 1989–90 is denoted as "1990", etc. Values have been rounded to the nearest tonne, so "0" represents reported landings of less than 0.5 t, and "–" indicates nil reported landings.

Method &																		Fishing year
Area	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Deepwater midwater trawl																		
East NI	0	12	1	4	1	0	2	2	12	7	4	5	1	4	4	1	3	1
East SI	72	57	62	35	39	34	87	111	198	213	213	81	103	88	79	65	24	6
Chatham	–	69	11	44	39	54	59	52	44	45	30	44	38	20	60	15	2	1
Southland	116	29	121	173	271	398	274	133	79	57	100	380	139	169	197	139	161	175
Sub-Antarctic	42	11	19	48	11	11	22	5	5	6	15	200	225	183	239	157	165	118
Bounty	8	19	38	4	3	3	2	–	7	11	7	0	1	–	2	6	1	2
West SI	1 261	740	402	340	353	803	857	725	997	768	713	855	651	587	759	335	268	123
Cook Strait	260	326	200	179	107	117	119	141	105	91	107	147	74	137	119	96	65	45
Total	1 759	1 261	854	828	824	1 421	1 421	1 168	1 446	1 197	1 189	1 713	1 233	1 188	1 460	815	690	471
Line																		
East NI	135	186	300	389	401	409	353	278	401	248	292	339	370	356	425	339	365	425
East SI	185	613	475	488	550	816	913	593	382	512	748	426	379	400	360	370	430	492
Chatham	8	846	3 003	2 595	3 272	3 966	3 360	2 991	2 045	2 039	2 050	1 907	1 958	1 386	1 257	1 757	1 088	1 092
Southland	0	2	288	439	813	653	280	845	1 090	775	850	960	972	850	583	860	676	678
Sub-Antarctic	–	217	326	886	501	1 630	1 273	2 285	2 388	1 934	1 204	728	655	214	655	298	172	–
Bounty	–	7	834	965	1 142	378	384	351	386	549	982	1 063	627	921	850	34	38	234
West SI	197	428	686	698	761	891	983	975	963	990	782	913	648	688	678	729	562	745
Cook Strait	66	56	70	100	63	59	53	20	56	107	98	163	112	130	169	216	189	155
Total	591	2 357	5 982	6 560	7 503	8 801	7 598	8 337	7 710	7 154	7 007	6 499	5 721	4 945	4 976	4 602	3 520	3 820
Setnet																		
East NI	48	85	40	25	4	1	4	27	12	1	1	1	–	0	1	0	5	0
East SI	210	227	145	164	180	199	180	205	201	147	171	132	124	104	120	79	51	47
Chatham	0	–	0	–	–	–	–	–	–	–	–	–	–	0	–	0	–	–
Southland	0	2	1	1	0	1	0	2	2	0	0	0	1	0	1	1	1	2
West SI	345	368	266	129	154	103	170	126	129	103	94	49	62	50	24	31	39	91
Cook Strait	36	0	1	3	1	1	1	1	0	0	0	2	0	0	0	1	0	0
Total	639	681	452	322	339	305	356	361	343	251	266	184	186	155	147	112	96	140

Table A3c: Catch of ling (t) by area, by fishing year, for various fishing methods: fish pots. Fishing year 1989–90 is denoted as "1990", etc. Values have been rounded to the nearest tonne, so "0" represents reported landings of less than 0.5 t, and "–" indicates nil reported landings.

Method &																		Fishing year
Area	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Fish pots																		
East NI	–	–	–	–	–	0	–	0	–	–	–	–	–	–	–	–	0	–
East SI	2	14	39	15	12	8	4	38	41	36	21	4	3	1	4	10	49	53
Chatham	0	0	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–
Southland	1	1	1	1	1	2	4	2	3	0	10	24	16	13	0	0	3	3
West SI	–	–	0	–	–	–	0	0	0	–	–	1	–	–	0	–	–	–
Cook Strait	–	0	0	0	–	–	–	–	–	–	0	–	–	–	1	–	–	–
Total	3	16	40	16	13	10	8	40	44	36	31	29	19	14	5	10	52	57