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EXECUTIVE SUMMARY

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Existing series of CPUE for commercial line fisheries targeting ling on the Chatham Rise (LIN 3&4), the Campbell Plateau (LIN 5&6), the Bounty Plateau (LIN 6B), the west coast of the South Island (WCSI) (LIN 7WC), and Cook Strait (LIN 7CK) were updated to include CELR (Catch, effort and landing return) and LCER (Lining catch and effort return) data to the end of the 2005 calendar year. Series are available for Chatham Rise, WCSI, and Cook Strait from 1990 to 2005, for the Campbell Plateau from 1991 to 2005, and for the Bounty Plateau from 1992 to 2004. (Although there was some fishing on the Bounty Plateau in 2005, the single vessel involved did not meet the data thresholds required for it to be included in the analysis.) 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 2005 TCEPR (Trawl catch, effort and processing return) data.

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. Full interaction effects were allowed. 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 stock off WCSI had declined but then recovered (although the trend was weak). The Cook Strait stock appeared to have declined slightly throughout the early 1990s, increased from 1995 to 2002, and then declined again; however, there are doubts about the reliability of this series.

The standardised indices derived from the trawl fishery in Cook Strait indicated ling stocks had declined steadily throughout the early 1990s, exhibited some recovery up to 2003, but are again declining. The index from the trawl fishery off WCSI based on 'accurate' TCEPR data generally increased from 1990 to 1996, but then declined.

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, but with the trawl series lagged behind the line series. However, the line series indicates an overall increase in biomass, in contrast to an overall decrease indicated by the trawl series. Differences in the latter parts of the series from the two WCSI fisheries cannot be reconciled; the trawl index decreases while the line index increases. Hence, a reliable relative abundance series for the LIN 7WC stock has still not been identified.

1. INTRODUCTION

This document reports the results of Project LIN2005/01, Objective 2, 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 2004–05 fishing year.

The updated commercial line fishery series are for ling on the Chatham Rise, the west coast South Island (WCSI), and in Cook Strait from 1990 to 2004, and the Campbell Plateau from 1991 to 2005. CPUE from the Bounty Plateau longline fishery could not be updated because only one vessel operated there in 2005 and it did not meet the required data thresholds. These five fisheries account for about 96% of the line-caught ling (Horn 2001). 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 (2006a).

Series of ling CPUE indices derived from trawl fisheries targeting species other than ling were also reported by Horn (2006a). The series from the trawl fishery targeting hoki in Cook Strait from 1990 to 2004 was believed to be a reliable index of abundance of ling vulnerable to that fishery because there had probably been no changes in fishing or reporting practice that would have biased the data, and there was no incentive to either target or avoid ling. Horn (2006a) also derived a series for the trawl fishery targeting spawning hoki off WCSI using TCEPR data from 1990 to 2004 reported by vessels believed to have recorded their ling bycatch relatively accurately. 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 2005 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 2006a). The series derived from the Cook Strait trawl bycatch fishery probably met the first three criteria (Horn 2006a), but there was doubt about the WCSI trawl series (Horn 2006a).

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 2002 (Horn & Dunn 2003), and into the WCSI assessment in 2003 (Horn 2004a). 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, 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 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 2005 calendar year) are stored in two relational database tables (t_lin_celr, and t_lin_tcepr) administered by NIWA for MFish. Data from the 2005 calendar year were obtained from MFish in April 2006.

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 2006a). 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 categorical and continuous vessel variables 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 (i.e., 1990 to 2005). Calendar year (rather than fishing year) was used because of a seasonal trend of higher catch rates in most ling line fisheries running from about June to December (see Horn 2001). This ensured that all catches in a particular season peak were included in a single year, rather than being spread between two 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 30 in 5 years for LIN 7CK; greater than 50 in 5 years for all other Fishstocks; 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.

Trawl data can be recorded on either TCEPR or CELR forms. TCEPR 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.

For the Cook Strait analysis, all available TCEPR data were initially included. In the WCSI fishery there is strong evidence to suggest that many vessels have under-reported their ling bycatch, particularly in the 1990s. However, the percentage of hoki target tows reporting a ling bycatch was believed to provide some indication of reporting accuracy (Horn 2006a). 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.

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,
- tow duration was between 0.2 and 8 hours,
- 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 1 year.

2.4 The model

The lognormal linear model was used for all analyses. 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.

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 (following initial grooming and removal of seldom-fished areas) 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 over 13 000 records of days fished throughout the 16 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 (Horn 2006b). 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 33 vessels included in this analysis had fished in every year, but 15 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 18 observations over the 16 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 33 vessels are incorporated in the model; the difference between the best and worst of all but two 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. 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.

3.1.2 Campbell Plateau (LIN 5&6)

Line fishing has accounted for 15–40% annually of the LIN 5&6 (excluding the Bounty Plateau) landings since the auto-longline fishery developed in 1991 (Horn 2001). In recent years the line-caught fraction has been at the lower end of this range (Horn 2006b).

The Campbell Plateau final analysis includes data from fishing operations responsible for almost 90% of the line landings from 1991 to 2005. This fishery is almost exclusively bottom longline (99.4% 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 six 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 6% of the variance). However, 14 statistical areas each had records of 27 or fewer days fished throughout the 15-year series. Their removal involved less than 3% 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 6%, 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*. More than 51% 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 5).

The effects of the selected variables are shown in Figure 6. 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. Daily catch rate by vessel varied by a factor of less than 3. The low expected catch rate in September 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 6) indicate a slight declining trend throughout the series.

3.1.3 Bounty Plateau (LIN 6B)

Line fishing accounts for virtually all the Bounty Plateau ling landings since 1992 (Horn 2006b), 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 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 50 records. Hence, the analysis presented here is identical to that reported by Horn (2006a) using data up to the end of 2004. In 14 years of fishing, over 1600 vessel days have been incorporated in the analysis, although three of the years were represented by just over 60 days each (see Table 3). Bottom longline is the only method used in this fishery (Horn 2001). Data from seven vessels were incorporated in the final analysis; one of these vessels had fished in all years except 2005, 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 51% of the total variance (see Table 4). The model assumptions were mainly satisfied, there being only slight deviations from normality (Figure 7).

The effects of the selected variables are shown in Figure 8. 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 July to October, but the difference between the best and worst month is only about a factor of 4.

The standardised year effects (Table 5, Figure 8) indicate a relatively rapid decline from 1992 to 1994, followed by a slight declining trend since then. The lowest equal indices occurred in 2002 and 2004.

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 (Horn 2001), and this level of catch has been maintained since then (Horn 2006b). 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 20 vessels (see Figure 2). Three of these had fished in all 16 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 33% 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 9). 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 10. 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 10) indicate a decline from 1991 to 1996, followed by an increasing trend to 2004. The 2005 index is close to the low levels of the mid 1990s.

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 (Horn 2001), but this proportion has increased to about 40% in recent years (Horn 2006b). 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 15 vessels were incorporated in the final analysis, and one of these had fished in all 15 years of the series (see Figure 2). Six 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 about 35% of the variance. *Vessel*, *log(hookno)* and *month* were the selected variables, explaining 66% 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 11).

The effects of the selected variables are shown in Figure 12. 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 is less than a factor of 2.

The standardised year effects are quite variable (Table 5, Figure 12) 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. 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 (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 6. The numbers of records of days fished in each statistical area (following initial grooming and removal of seldom-fished areas) are listed in Table 7.

3.2.1 Cook Strait (LIN 7CK)

The trawl fishery targeting hoki in Cook Strait produced a minimum of 650 tows per year, and almost 18 000 tows from 1990 to 2006 (see Table 6). The unstandardised indices of catch per tow exhibited a clear declining trend to the late 1990s, followed by a slight increase. Fishing occurs in statistical areas 016 and 017, but area 016 is the more heavily fished (Table 7). 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 6); 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, only the 'both methods combined' analysis is updated here. However, the midwater trawl category has been split into two, i.e., fishing on the bottom, and fishing in midwater. Of the 31 vessels included in the final analysis, only two had fished in all years (Figure 13), 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. The final model explained 27% of the total variance (Table 8). The model assumptions were mainly satisfied, there being no marked patterns in the residuals and limited deviations from normality (Figure 14).

The effects of the selected variables are shown in Figure 15. 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 August, though differences between any months are less 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.

The standardised year effects (Table 6, Figure 15) indicate a steady decline from 1990 to 1995, followed by relatively constant indices to 1999, an increase from 2000 to 2003, and a decline to 2005. 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 6. After data grooming and selection the number of tows per year ranged from 55 to 2484, with over 16 000 tows in the data set. The years 1991–1997 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 6). 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.

Initially, an analysis using data from 39 vessels was completed. The variables entering this model run were the same as those entering the final model run (see below). However, the standardised index for 1996 was 1.8, and appeared to be incongruously high relative to the other points in the series. An examination of the data showed that this high point was driven by data from a single vessel that had fished only in 1996 and 2002 (vessel 21 in Figure 13). Subsequently, data from this vessel were deleted from the final analysis. Of the 38 vessels included in the final analysis, none had fished in all years, but 12 had fished in six or more years (Figure 13).

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. The final model explained 21% of the total variance (Table 8). The model assumptions were well satisfied, with very balanced residuals and no deviations from normality (Figure 16).

The effects of the selected variables are shown in Figure 17. 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.

The standardised year effects (Table 6, Figure 17) produce a relatively flat series. Indices generally increased towards the mid-late 1990s, and then declined slightly to 2005. Most of the indices have narrow confidence bounds.

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 2005, 2006b). 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 discussion points 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 2006a) 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 (2004b) 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 2004c), 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 between the most recent and previous fishing seasons is the reduction in effort in the Campbell Plateau and Bounty Plateau fisheries (see Table 3). The reduction may be attributable in part to the diversion of autoline vessels to the Ross Sea toothfish fishery. However, it was also apparent that some new line vessels had entered some of the fisheries in 2004 and 2005, and it will be another year before some of these build up sufficient history in the fisheries to meet the data thresholds and be included in the analyses.

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 the latter half of the series is reflected in the relatively high c.v.s for these points (see Figure 12). 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 under-estimated 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 except 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. The Cook Strait CPUE is questionable, but cannot be ruled out as a reliable relative abundance series. 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 declined but then recovered (although the trend was weak).

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 (2004b) discussed in detail the likely reliability of the catch and effort data available from these fisheries, and concluded that ling 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. Consequently, it was concluded (and is still believed) that the Cook Strait trawl CPUE series provides a reasonable index of ling available to that fishery. However, it should be noted that both these trawl CPUE analyses did not include any tows where hoki were caught, but ling were not. Nor was it possible to incorporate variables identifying tows in the WCSI fishery that used the 'twin-rigging' method.

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. The resulting CPUE series, while being relatively data poor from 1990 to 1997, is believed to be the best currently available for that fishery, and was updated above.

The Cook Strait series is indicative of a steady decline from 1990 to the mid 1990s, but with relatively constant abundance since then. The abundance indices for the WCSI series are certainly less reliable before 1998 (owing to paucity of data), but there is a probably more reliable indication of a slight decline since the late 1990s.

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. A detailed comparison of these series was completed by Horn (2004d); in both areas there were some marked differences in the trends from the two fishing methods. However, it was noted that the 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 2–3 years (Figure 18). However, an overall decline is apparent in the trawl series, while a recovery 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. The trawl series is based on extensive data from a fishery that is believed to have changed little throughout the time series, but is reliant on consistent and relatively accurate reporting of a bycatch species. There are no fishery-independent data available to validate either of the Cook Strait CPUE series, but the trawl series is believed to be the more reliable of the two. The compatibility of the two series in a stock modelling exercise has yet to be tested.

The WCSI line CPUE series exhibits an opposing trend to the trawl series over much of its range. The line series steadily increases from 1996 to 2004, while the trawl series has an overall decline from 1996 to 2005 (Figure 18). Both series exhibit a reasonable match from 1990 to 1995, and both have declined between 2004 and 2005. 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 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. Catch-at-age data from the trawl fishery are consistent with a fishing down of the larger older fish (Horn 2006b), and line fishers also perceive that the mean size of ling has decreased since the mid 1990s. However, there was no perception by the line fishers that the WCSI ling stock had declined in recent years. This is indicative of some relatively strong recent recruitment compensating for the fishing down of older biomass, and is supported by recent assessments (Horn 2006b). However, there are no fishery-independent data available to validate either of the WCSI CPUE series.

The WCSI line and observer trawl series were not compatible in stock assessment models (Horn 2006b). The current analysis updated the WCSI line and trawl series, but there is still a clear conflict between them. Hence, 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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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
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 1990–2005		Campbell 1991–2005		Bounty 1992–2005		WCSI 1990–2005		Cook Strait 1990–2005	
Statarea	Days	Statarea	Days	Statarea	Days	Statarea	Days	Statarea	Days
018	2 132	030	1 634	607	624	032	1 062	016	1 457
019	56	602	384	608	1 002	033	3 415	017	53
020	2 302	603	331			034	3 814		
021	516	604	439						
022	65	605	243						
023	283	610	804						
024	121	611	164						
401	1 210	612	40						
402	1 019	618	829						
403	576	619	609						
404	1 289	625	45						
405	85								
407	359								
408	381								
409	226								
410	1 325								
049	472								
050	76								
051	66								
052	559								

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	765	2 311	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	139	796	3	524	693	9	149	116	5
2004	795	1 575	10	426	1 635	4	57	329	1	391	524	9	160	153	7
2005	1 026	1 974	11	180	941	2	0	0	0	480	557	8	115	149	5
Total	13 118	40 657	33	5 519	23 722	14	1 626	9 148	7	8 291	11 152	20	1 481	1 087	15

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	9.5
1	log(hookno)	75.3
2	Vessel	79.1
3	Month	80.5
Campbell Plateau (LIN 5&6)		
	Year	3.1
1	log(hookno)	54.2
2	Statarea	61.1
3	Vessel	63.0
4	Month	63.6
Bounty Plateau (LIN 6B)		
	Year	3.9
1	log(hookno)	36.0
2	Vessel	42.9
3	Month	47.1
4	log(hookno):Month	50.8
West Coast South Island (LIN 7WC)		
	Year	2.6
1	Vessel	18.1
2	Month	28.5
3	log(hookno)	32.9
Cook Strait (LIN 7CK)		
	Year	24.0
1	Vessel	59.1
2	log(hookno)	63.2
3	Month	64.6
4	log(hookno):Month	66.1

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	0.23	1.92	1.66–2.22	0.07	–	–	–	–
1991	0.47	1.45	1.32–1.58	0.04	0.86	0.90	0.74–1.10	0.10
1992	1.63	1.91	1.75–2.09	0.05	0.91	1.21	1.05–1.41	0.08
1993	1.43	1.40	1.29–1.51	0.04	0.81	1.30	1.12–1.50	0.07
1994	1.36	1.35	1.25–1.45	0.04	0.78	0.95	0.84–1.08	0.06
1995	2.04	1.35	1.25–1.45	0.04	1.21	1.29	1.13–1.46	0.06
1996	1.73	1.14	1.06–1.22	0.04	1.14	1.04	0.92–1.18	0.06
1997	1.01	0.80	0.75–0.85	0.03	1.13	1.19	1.08–1.32	0.05
1998	1.06	0.78	0.72–0.84	0.04	0.98	0.99	0.90–1.09	0.05
1999	0.77	0.67	0.62–0.72	0.04	0.91	0.83	0.75–0.91	0.05
2000	1.07	0.79	0.72–0.85	0.04	1.09	0.97	0.86–1.09	0.06
2001	1.65	0.78	0.71–0.85	0.04	1.28	1.09	0.95–1.25	0.07
2002	0.95	0.65	0.60–0.70	0.04	1.29	1.08	0.93–1.25	0.07
2003	1.13	0.80	0.73–0.87	0.05	0.83	0.80	0.67–0.96	0.09
2004	0.89	0.67	0.61–0.73	0.04	0.82	0.74	0.63–0.86	0.08
2005	0.59	0.74	0.68–0.80	0.04	1.17	0.85	0.69–1.04	0.10
	Bounty Plateau (LIN 6B)				WCSI (LIN 7WC)			
1990	–	–	–	–	0.63	0.88	0.78–1.00	0.06
1991	–	–	–	–	0.79	1.13	1.02–1.26	0.05
1992	1.00	1.79	1.39–2.29	0.12	0.90	1.13	1.03–1.23	0.05
1993	0.92	1.57	1.28–1.92	0.10	1.03	0.90	0.81–0.99	0.05
1994	0.81	1.06	0.82–1.38	0.13	1.06	0.93	0.86–1.02	0.04
1995	1.06	1.12	0.87–1.45	0.13	1.06	0.96	0.88–1.05	0.04
1996	0.85	1.04	0.83–1.30	0.11	0.93	0.80	0.73–0.86	0.04
1997	0.76	0.84	0.65–1.09	0.13	1.03	0.87	0.80–0.95	0.04
1998	1.35	1.03	0.81–1.29	0.12	1.29	0.98	0.90–1.07	0.04
1999	1.27	1.04	0.84–1.27	0.11	1.14	1.04	0.95–1.14	0.04
2000	1.17	0.95	0.79–1.15	0.09	1.10	1.01	0.93–1.11	0.04
2001	0.91	0.81	0.67–0.98	0.10	1.19	1.16	1.06–1.27	0.04
2002	0.90	0.73	0.60–0.88	0.09	1.02	1.12	1.02–1.23	0.05
2003	1.09	0.78	0.65–0.94	0.09	1.01	1.15	1.06–1.26	0.04
2004	1.10	0.73	0.55–0.98	0.15	1.04	1.15	1.03–1.27	0.05
2005	–	–	–	–	0.99	0.89	0.81–0.97	0.05
	Cook Strait (LIN 7CK)							
1990	0.82	0.72	0.53–0.98	0.16				
1991	0.56	1.06	0.82–1.37	0.13				
1992	0.66	1.05	0.84–1.31	0.11				
1993	0.51	0.76	0.61–0.95	0.11				
1994	0.33	0.67	0.55–0.82	0.10				
1995	0.40	0.61	0.49–0.77	0.11				
1996	0.58	0.74	0.58–0.96	0.13				
1997	0.77	0.96	0.67–1.37	0.18				
1998	0.57	0.67	0.50–0.90	0.15				
1999	4.06	1.24	0.84–1.83	0.20				
2000	2.07	1.41	0.97–2.06	0.19				
2001	3.22	1.31	0.87–1.99	0.21				
2002	2.00	1.77	1.41–2.23	0.12				
2003	1.55	1.50	1.19–1.88	0.11				
2004	1.48	1.27	1.02–1.58	0.11				
2005	1.63	1.08	0.85–1.38	0.12				

Table 6: 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 (t)	Vessel nos.	Method			CPUE indices			
				BT	MWB	MWM	Unstd	Std	95% CI	c.v.
Cook Strait hoki trawl fishery										
1990	650	212	14	11	125	514	2.01	2.02	1.83–2.24	0.05
1991	1 102	302	18	9	293	800	1.47	1.66	1.55–1.79	0.04
1992	744	178	16	6	220	518	1.32	1.46	1.34–1.59	0.04
1993	705	183	13	16	432	257	1.47	1.52	1.40–1.66	0.04
1994	788	132	15	209	212	367	1.11	0.99	0.92–1.07	0.04
1995	1 393	186	19	546	325	522	0.95	0.86	0.80–0.91	0.03
1996	1 379	178	21	637	375	367	0.96	0.84	0.79–0.89	0.03
1997	1 569	202	22	621	282	666	0.82	0.72	0.68–0.76	0.03
1998	1 448	176	17	425	373	650	0.80	0.74	0.70–0.78	0.03
1999	1 639	190	18	580	338	721	0.72	0.73	0.69–0.77	0.03
2000	1 414	161	17	410	308	696	0.73	0.83	0.78–0.88	0.03
2001	1 252	158	18	181	391	680	0.78	0.93	0.88–0.99	0.03
2002	853	120	15	174	267	412	0.95	0.97	0.90–1.04	0.04
2003	1 039	154	15	139	396	504	0.96	1.02	0.95–1.09	0.03
2004	986	139	14	157	443	386	0.87	0.81	0.75–0.86	0.03
2005	891	120	12	172	466	253	0.83	0.77	0.72–0.83	0.04
Total	17 852	2 792	31							
WCSI hoki trawl fishery										
1990	648	177	6	108	265	275	0.73	0.85	0.75–0.96	0.06
1991	356	212	6	31	54	271	1.32	1.04	0.90–1.20	0.07
1992	238	114	4	31	80	127	1.35	1.03	0.88–1.22	0.08
1993	169	95	6	44	98	27	1.60	1.10	0.92–1.31	0.09
1994	298	139	7	106	67	125	1.24	1.01	0.88–1.15	0.07
1995	55	19	2	40	4	11	0.84	0.79	0.59–1.05	0.14
1996	280	125	5	105	77	98	1.11	1.34	1.17–1.54	0.07
1997	233	61	6	37	65	113	0.76	1.09	0.94–1.25	0.07
1998	838	317	13	148	322	368	0.83	1.11	1.01–1.21	0.04
1999	1 299	547	17	361	503	435	1.05	1.27	1.18–1.38	0.04
2000	1 530	594	15	494	362	674	0.93	1.07	1.00–1.16	0.04
2001	2 482	896	25	863	802	817	0.90	0.99	0.92–1.06	0.03
2002	2 291	772	20	765	597	929	0.76	0.87	0.81–0.93	0.04
2003	2 484	842	21	1 159	628	697	0.93	0.86	0.80–0.92	0.04
2004	1 972	774	19	710	603	659	1.05	0.95	0.88–1.02	0.04
2005	1 037	420	11	409	325	303	1.00	0.81	0.75–0.88	0.04
Total	16 200	6 284	38							

Table 7: 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 1990–2005		WCSI 1994–2005	
Statarea	Days	Statarea	Days
16	11 953	33	96
17	5 899	34	13 524
		35	2 559
		36	252
		703	34

Table 8: 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	5.8
1	Vessel	16.0
2	Month	19.3
3	Method	22.0
4	Duration by Method	26.5
5	Month:Method	27.1
WCSI (LIN 7WC) — 'accurate' TCEPR data		
	Year	1.9
1	Vessel	11.5
2	Method	14.1
3	Duration by Method	16.5
4	Depgndrope	17.8
5	Latitude	19.1
6	Day of year	20.2
7	Latitude:Method	21.2

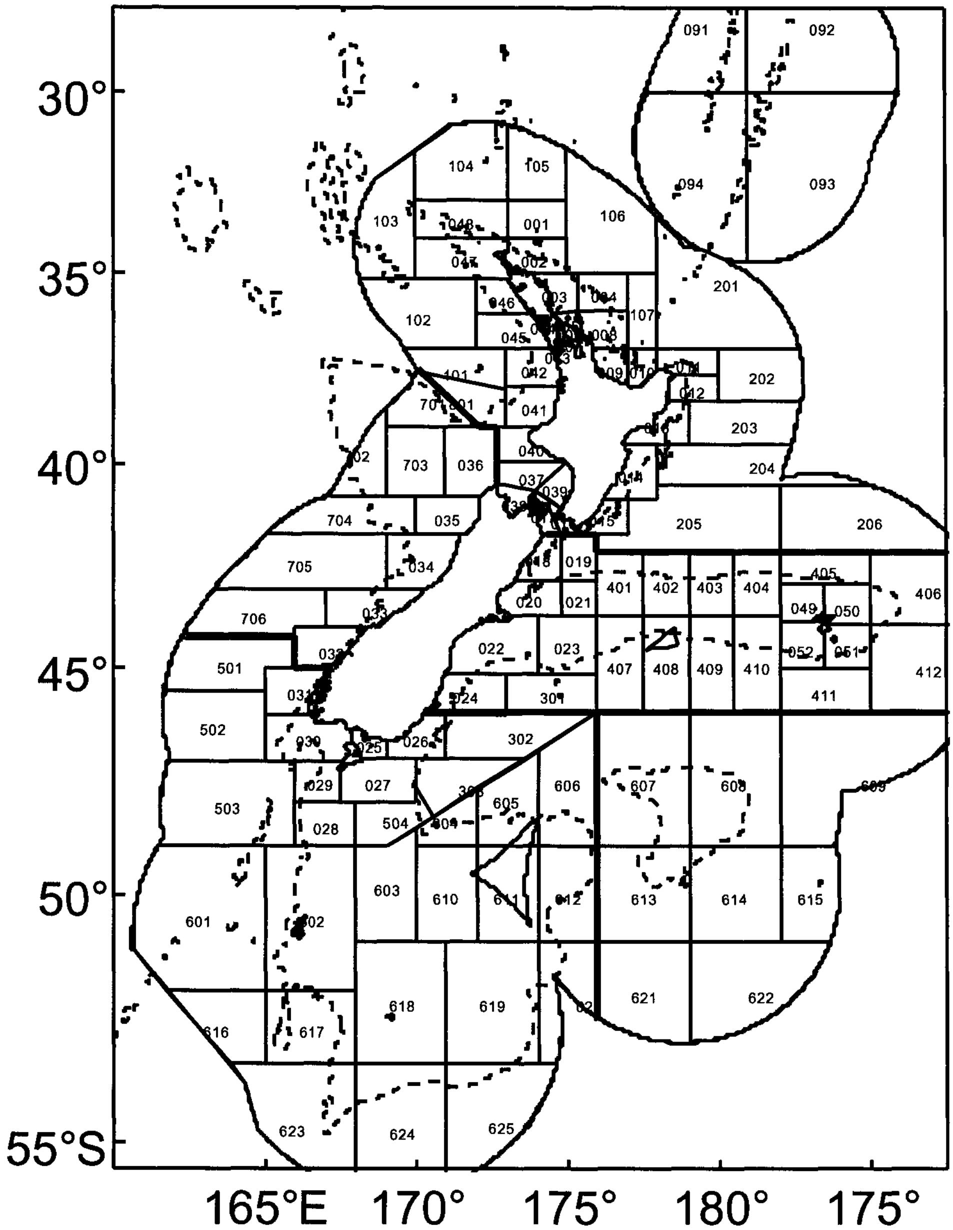

Figure 1: Map of the New Zealand EEZ with statistical areas (numbers from 001 to 801), showing how they were grouped (thick lines) to construct the stock areas used in this analysis. The 1000 m isobath is plotted as a broken line.

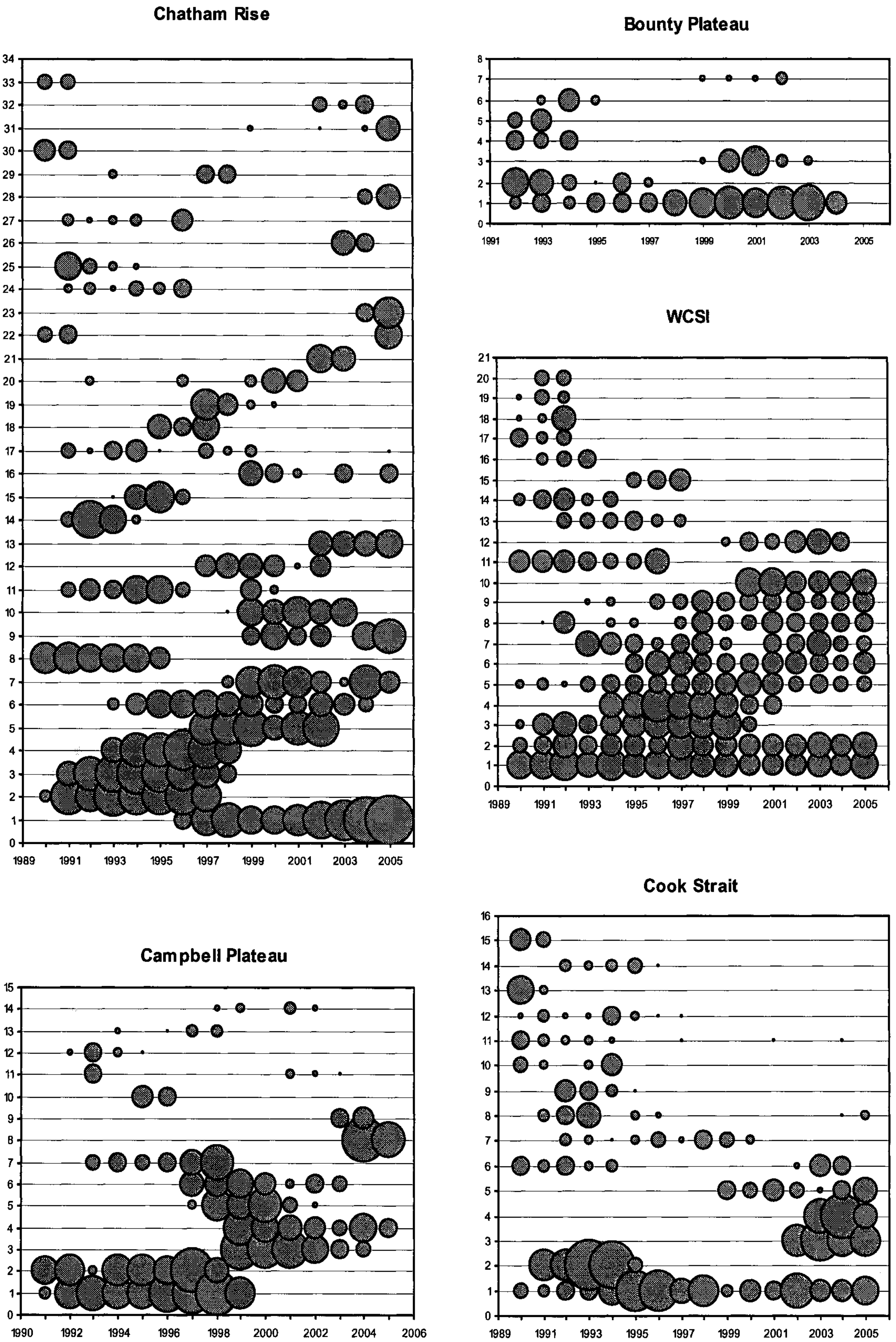

Figure 2: Fishing effort (where circle area is proportional to number of days fished) by year for individual vessels (denoted anonymously by number on the *y*-axis) included in the final longline CPUE analyses for the five main stocks.

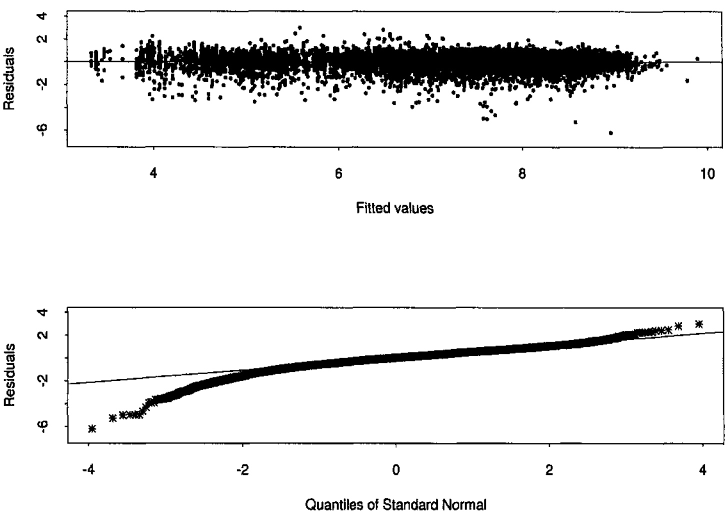

Figure 3: Diagnostic plots for the CPUE model of the Chatham Rise (LIN 3&4) ling line fishery.

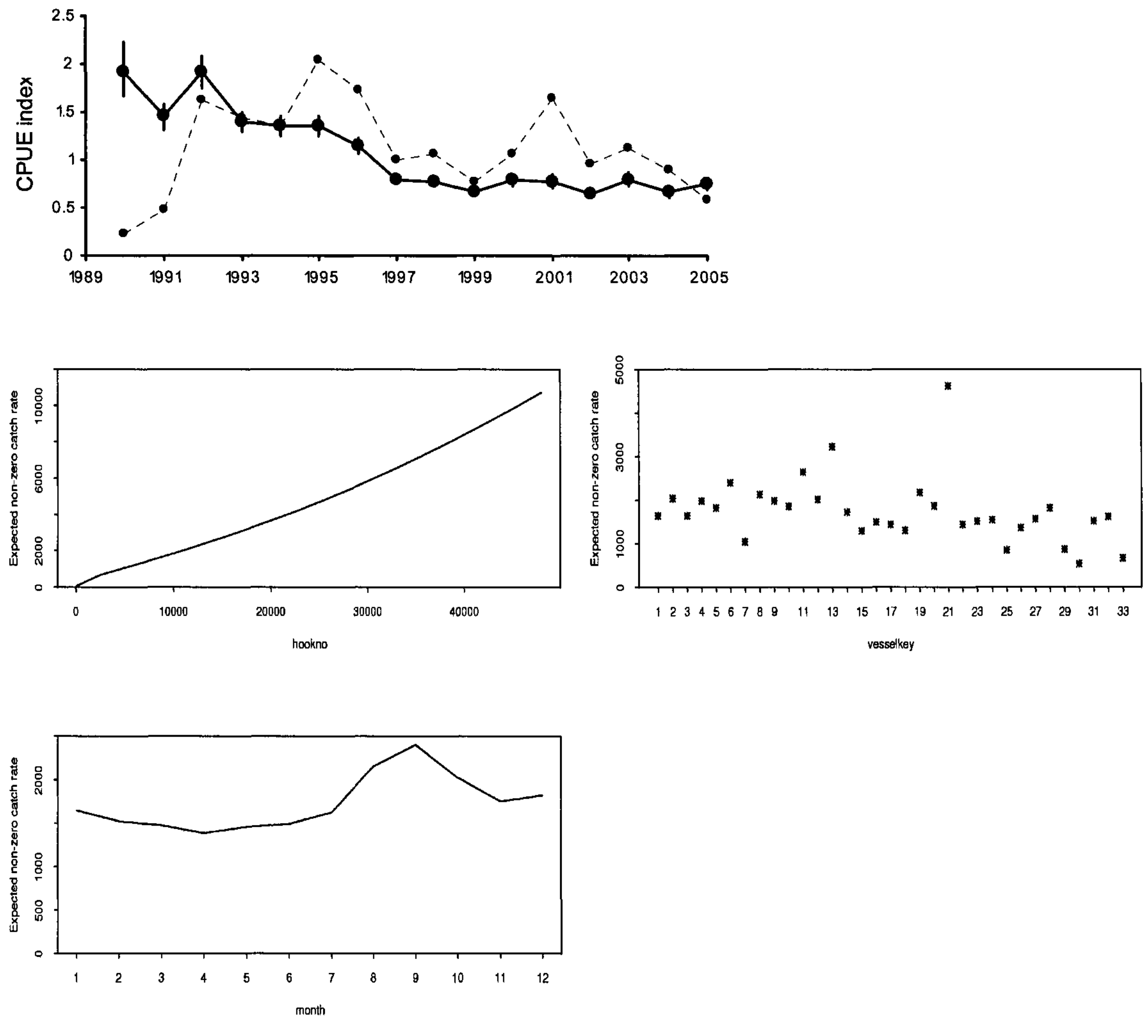

Figure 4: Expected variable effects for variables selected into the CPUE model for the Chatham Rise (LIN 3&4) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero catch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

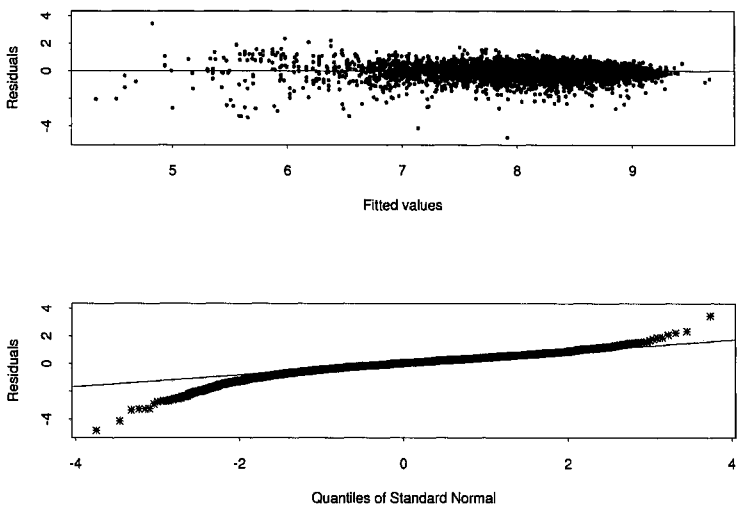

Figure 5: Diagnostic plots for the CPUE model of the Campbell Plateau (LIN 5&6) ling line fishery.

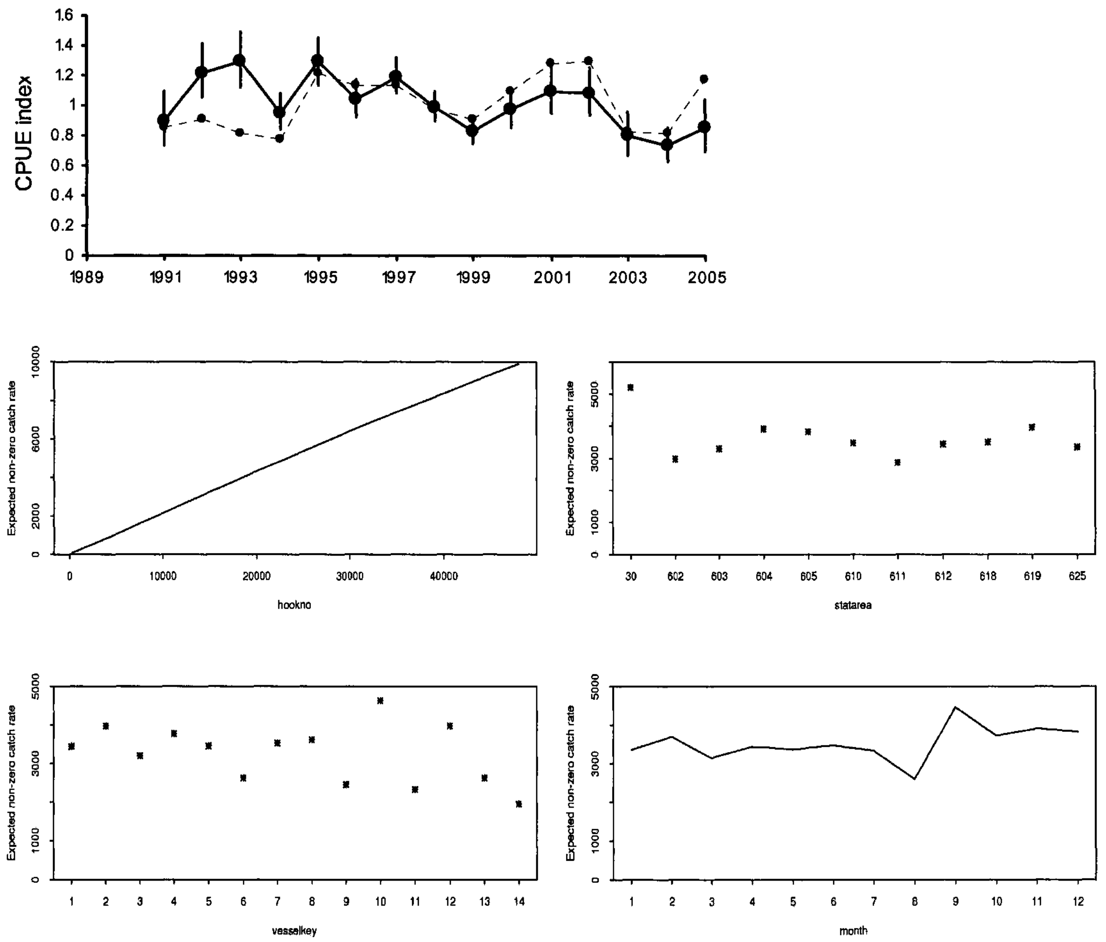

Figure 6: Expected variable effects for variables selected into the CPUE model for the Campbell Plateau (LIN 5&6) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero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

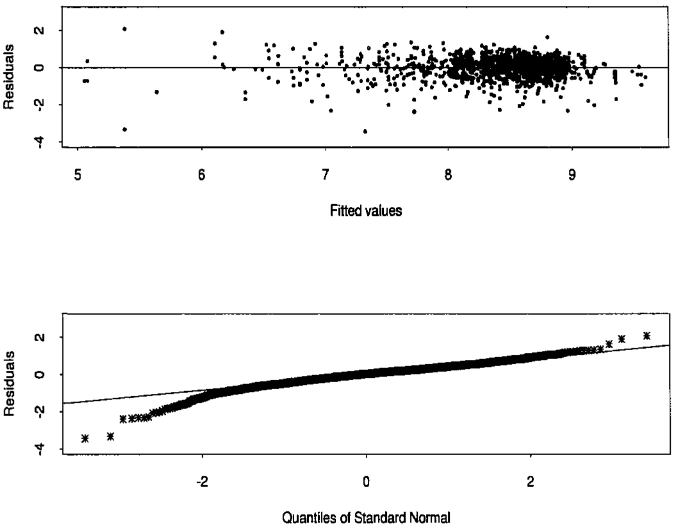

Figure 7: Diagnostic plots for the CPUE model of the Bounty Plateau (LIN 6B) ling line fishery.

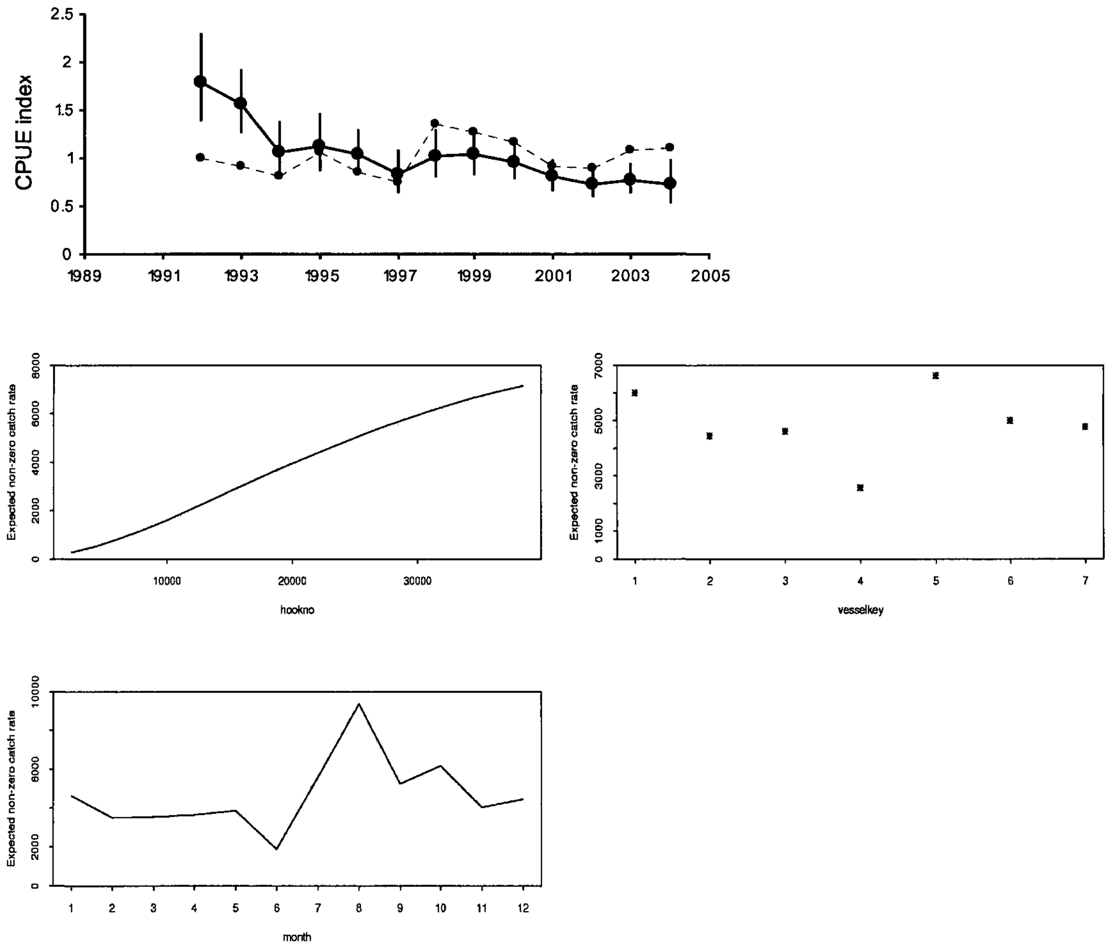

Figure 8: Expected variable effects for variables selected into the CPUE model for the Bounty Plateau (LIN 6B) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero catch rate" is kg per day in this fishery.

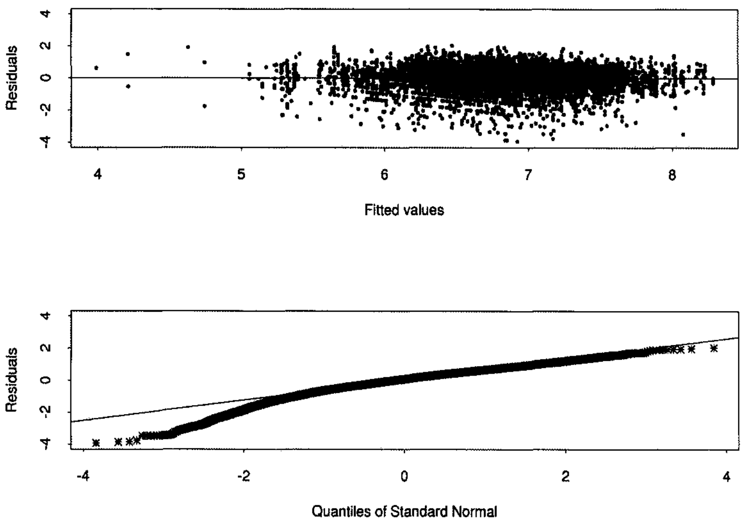

Figure 9: Diagnostic plots for the CPUE model of the WCSI (LIN 7WC) ling line fishery.

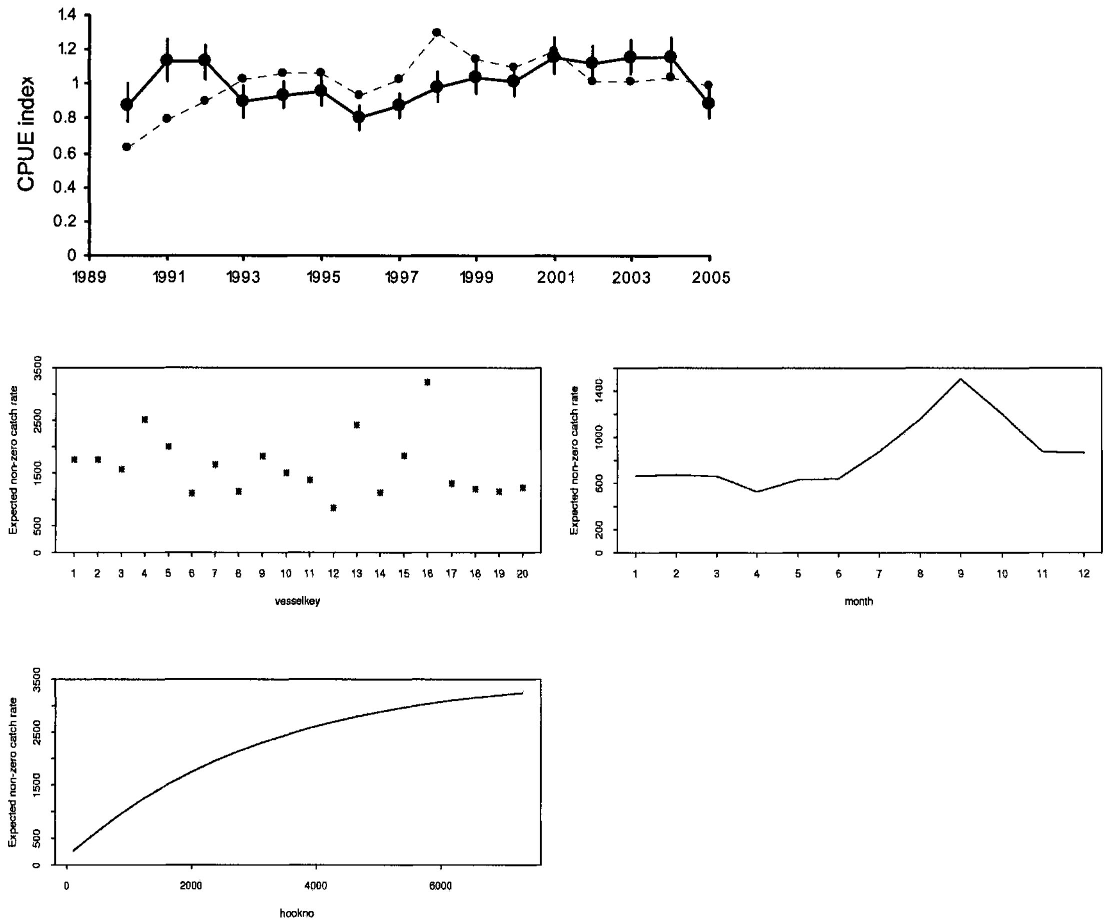

Figure 10: Expected variable effects for variables selected into the CPUE model for the WCSI (LIN 7WC) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero catch rate" is kg per day in this fishery.

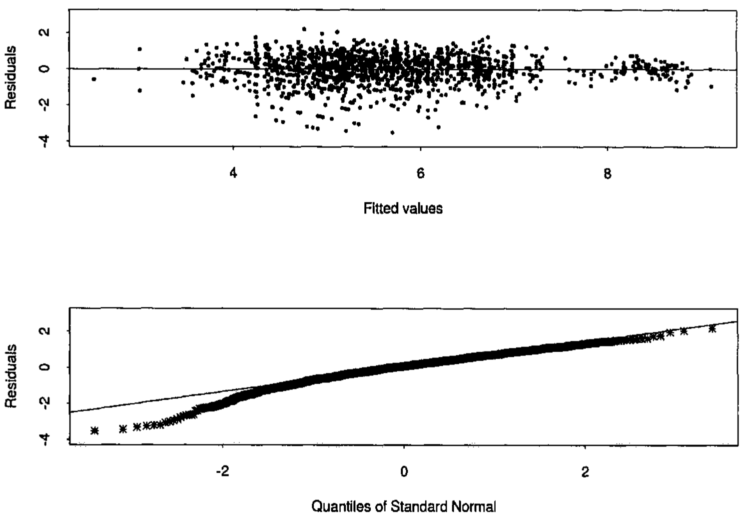

Figure 11: Diagnostic plots for the CPUE model of the Cook Strait (LIN 7CK) ling line fishery.

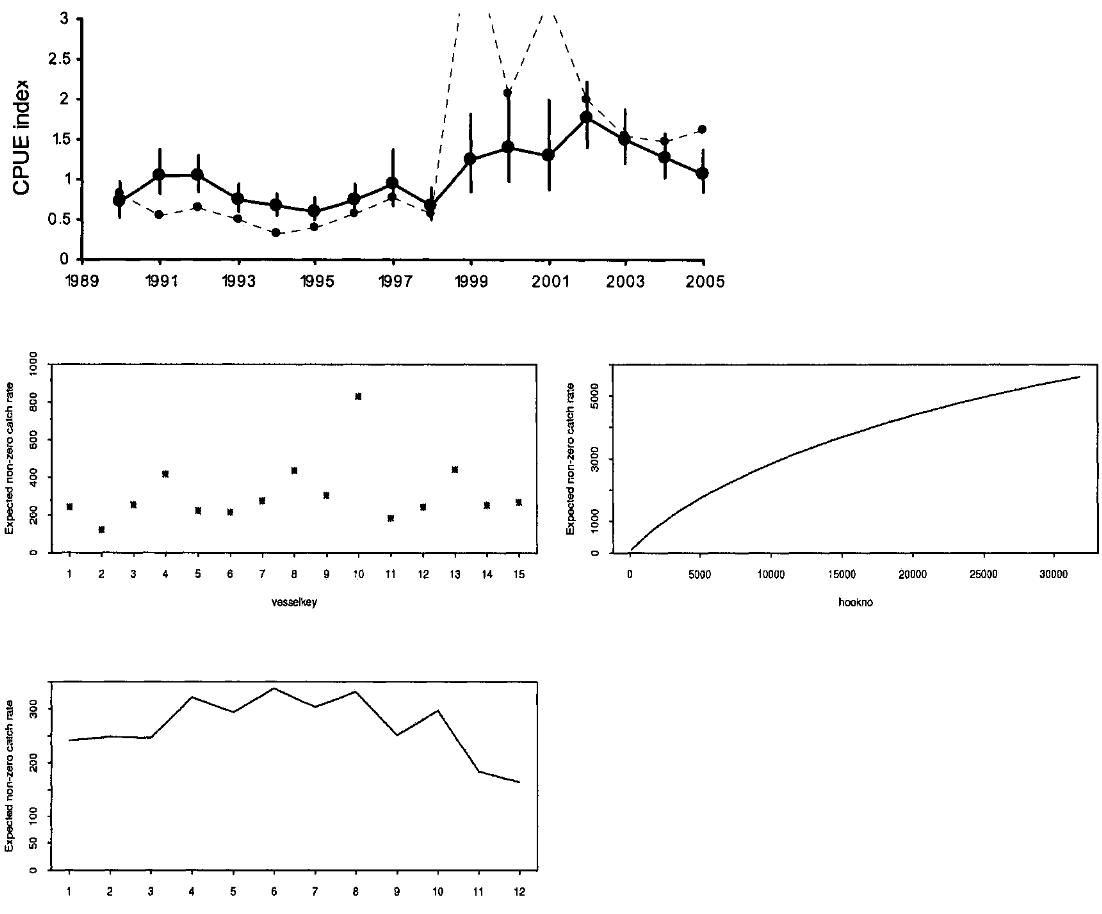

Figure 12: Expected variable effects for variables selected into the CPUE model for the Cook Strait (LIN 7CK) ling line fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero catch rate" is kg per day in this fishery.

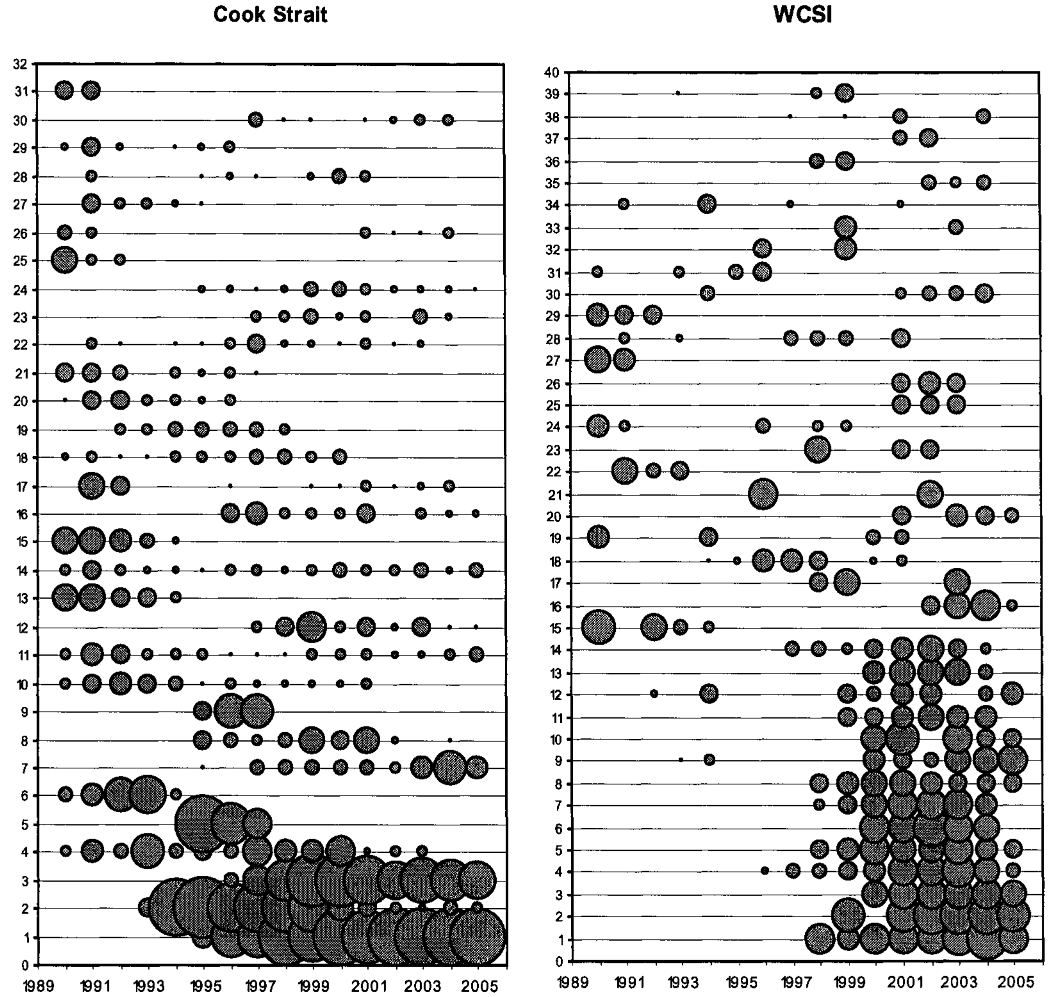

Figure 13: Fishing effort (where circle area is proportional to number of days fished) by year for individual vessels (denoted anonymously by number on the *y*-axis) included in the final trawl CPUE analyses.

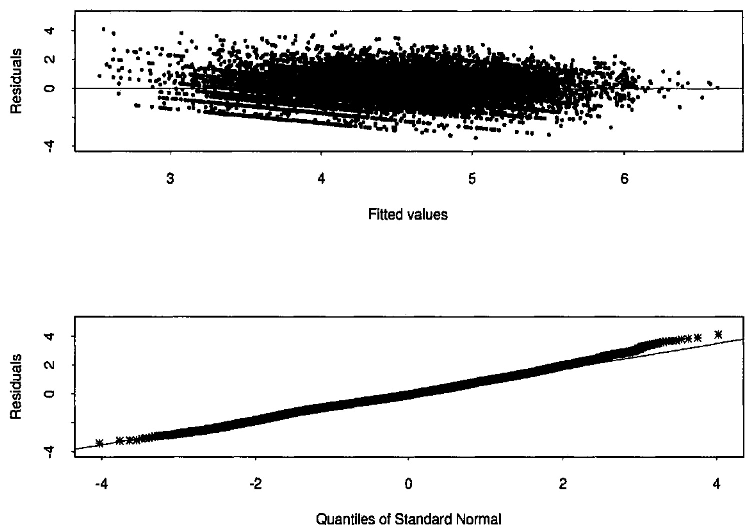

Figure 14: Diagnostic plots for the CPUE model of the Cook Strait (LIN 7CK) hoki trawl fishery.

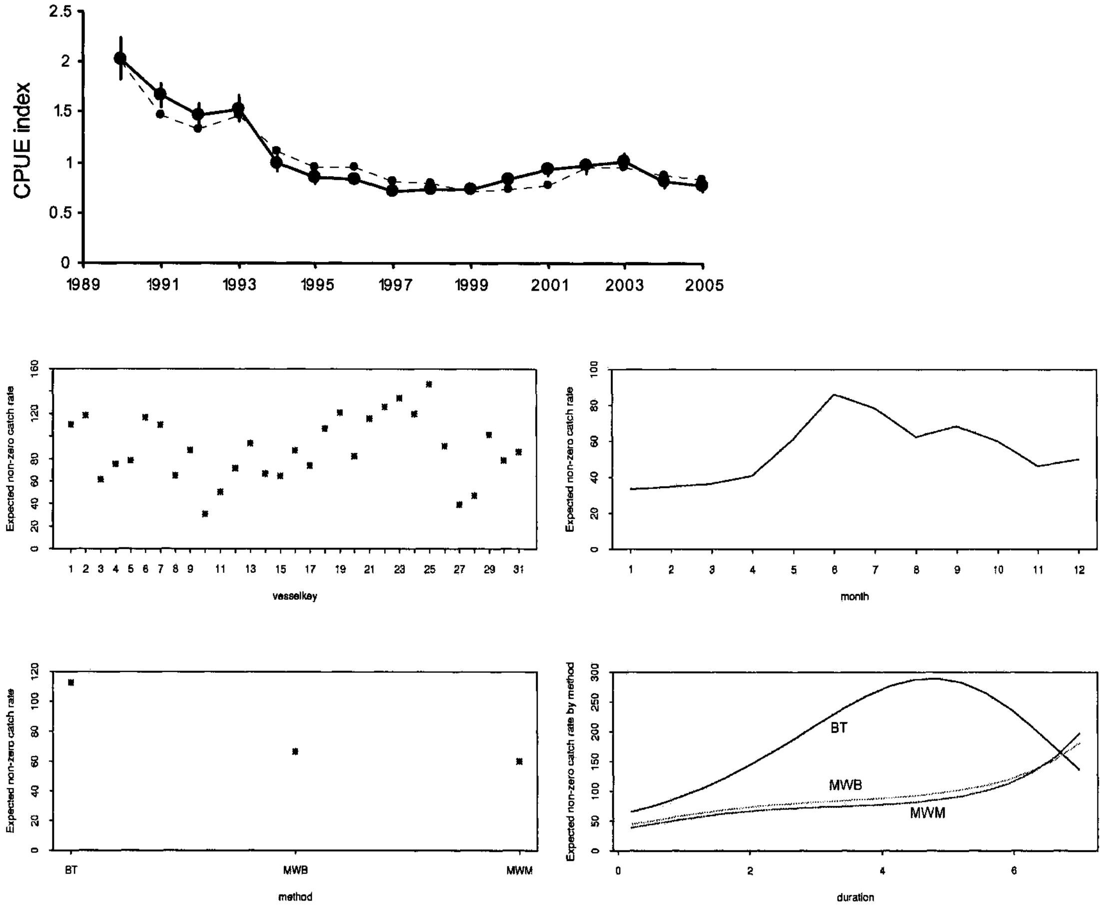

Figure 15: Expected variable effects for variables selected into the CPUE model for the Cook Strait (LIN 7CK) hoki trawl fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero catch rate" is kg per tow in this fishery.

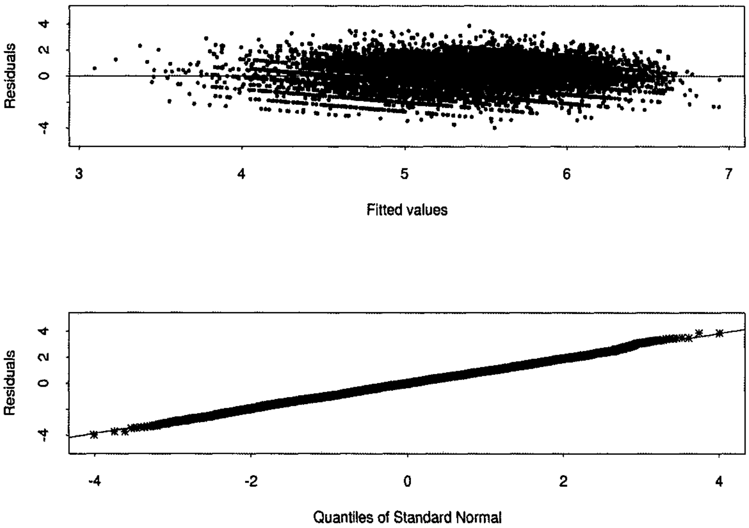

Figure 16: Diagnostic plots for the CPUE model using 'accurate' TCEPR data from the WCSI (LIN 7WC) hoki trawl fishery.

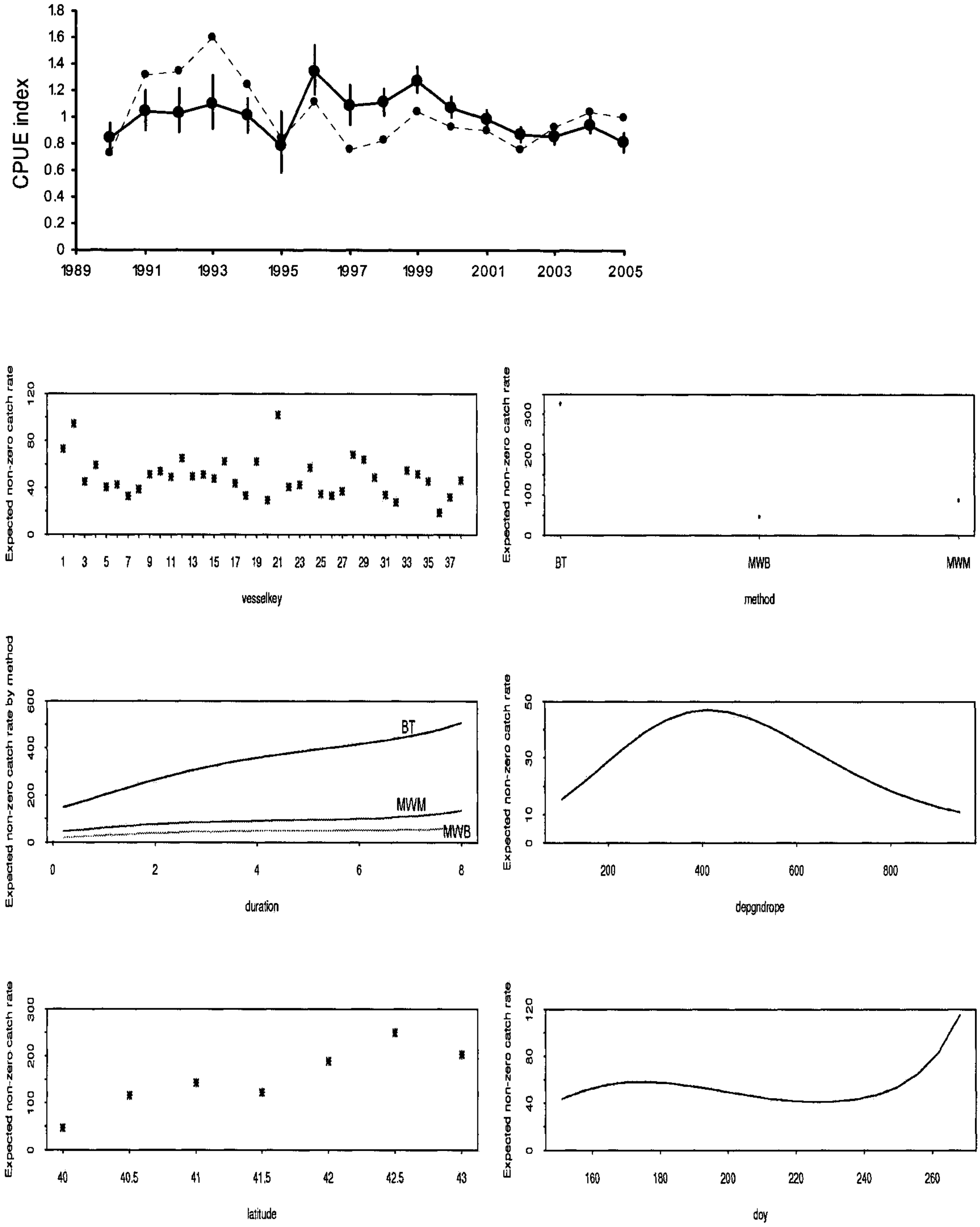

Figure 17: Expected variable effects for variables selected into the CPUE model for the WCSI (LIN 7WC) hoki trawl fishery. Standardised year effects with 95% confidence intervals are shown by the solid line in the top plot; unstandardised data are shown as a broken line. "Expected non-zero catch rate" is kg per tow in this fishery.

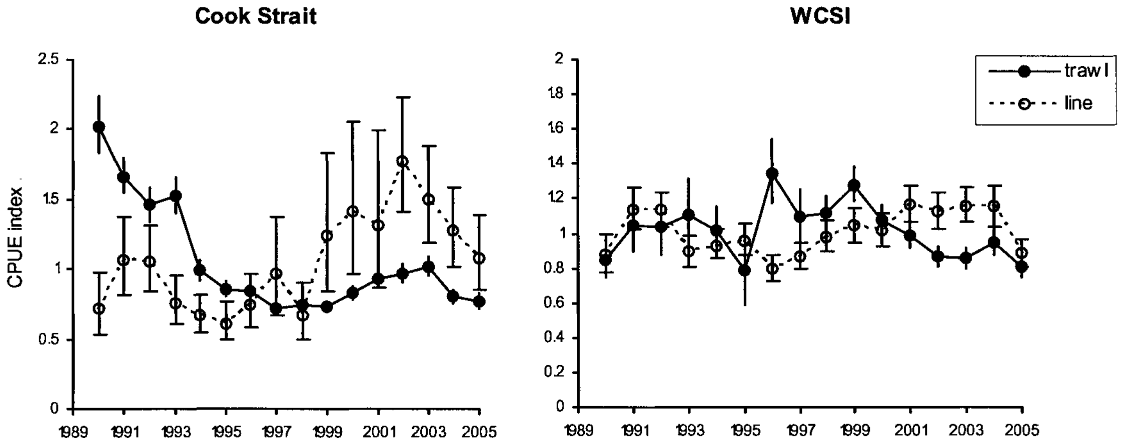

Figure 18: CPUE indices (with 95% confidence intervals) for stocks where both line and trawl series were calculated. The values in each series are scaled to average 1.