MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

ISSN 1175-1584

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New Zealand Fisheries Assessment Report 2003/13
March 2003

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New Zealand Fisheries Assessment Report 2003/13
March 2003

**Published by Ministry of Fisheries**
**Wellington**
**2003**

**ISSN 1175-1584**



Citation:
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.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

## EXECUTIVE SUMMARY

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Catch per unit effort (CPUE) series for ling were developed from commercial fishing return data reported from various line and trawl fisheries in LIN 1 and LIN 2. The trawl fisheries were those targeting scampi in the Bay of Plenty and hoki in Cook Strait (both of which take a substantial bycatch of ling). The line fisheries were those targeting ling and other middle depth species off Northland, in the Bay of Plenty, off east coast North Island (i.e., most of LIN 2), and in Cook Strait. For each of the line fisheries, CPUE series were calculated for target ling operations only, and for all lining operations combined targeting ling, bluenose, ribaldo, hapuku, and bass. The all-targets analyses were conducted to maximise the amount of ling catch data, because some of the areas were deemed to have insufficient ling target data for a comprehensive analysis in some years.

Data from each fishery were groomed to remove as many errors as possible, and selected to ensure that the analysed data related to vessels that had consistently targeted or caught significant landings of ling (and so were likely to truly represent experienced fishers in the various fisheries). The units of effort were catch per day (for the line fisheries) and catch per tow (for the trawl fisheries). Data were modelled using a lognormal linear analysis to produce a set of standardised indices for each stock. Full interaction effects were allowed. However, any selected implausible or poorly defined interaction variables were removed from the final models. Coefficients of selected variables were examined to ensure that they had a plausible range.

Variables entering the models for the line fisheries tended to be vessel, month, and number of hooks set, with target species also an important variable in the all-targets analyses. Vessel was the variable that explained most of the variance in the trawl fishery analyses. Total variance explained by the models was from 3 to 68%.

The data inputs and model outputs for each fishery were examined in an attempt to validate the data selection, model method, and results. Each series was evaluated to determine whether it was likely to be a reliable index of ling abundance.

Both Northland line series, the Bay of Plenty target ling line series, and the Bay of Plenty scampi trawl fishery were believed to provide unreliable indices of ling abundance. The Bay of Plenty all-targets line series may be reliable. All the line series from east coast North Island and Cook Strait were considered to provide reliable indices of ling abundance (at least in years when the number of records exceeds 100). However, the series from the target ling line fisheries would be preferred as inputs in any stock modelling. The series from the Cook Strait hoki trawl fishery was believed to be a good index of ling abundance.

# 1. INTRODUCTION

CPUE from the target ling longline fisheries around the South Island have provided indices of relative abundance (Horn 2002a) that have been incorporated in stock assessments (Horn 2002b). In a descriptive analysis of New Zealand's ling fisheries (Horn 2001), target longline fisheries off Northland (LIN 1) and the east coast of the North Island (LIN 2) were identified as being potentially suitable for CPUE analysis. Analyses of target longline CPUE from fisheries off east Northland and in Bay of Plenty, and trawl CPUE from the scampi target fishery in Bay of Plenty, have been completed previously, but are not available in the public literature. These analyses will be updated and extended here.

Objective 4 of Project LIN2001/01 includes an assessment of ling in Cook Strait. No indices of relative abundance are available for this stock. In an attempt to create such indices, analyses of ling CPUE will be completed for two fisheries in Cook Strait catching significant quantities of the species (i.e., the target ling line fishery and the trawl fishery targeting hoki but taking a significant bycatch of ling).

Throughout the 1990s, line fishing has accounted for about 54% of ling landings from LIN 1, 67% of landings from the east coast North Island portion of LIN 2, and 20% of landings from Cook Strait (Horn 2001). Most ling landings taken by line are from target fisheries for that species. Trawling accounts for about 44% of ling landings from LIN 1, and about 70% of those landings are taken in the scampi target fishery. In Cook Strait, about 79% of ling are trawl caught, and these landings are almost exclusively a bycatch of the target fishery for hoki (Horn 2001).

The ling CPUE analysis reported by Horn (2002a) showed that the longline CPUE series appeared to perform well in relation to the four discussion points raised by Dunn et al. (2000). It was concluded that for each of the stocks around the South Island there is a good likelihood that CPUE is an index of abundance (for that part of the population targeted by the line fishery), that the data are comprehensive and accurate, and that the modelling method was valid. Fishery-independent data from two of the stocks support the CPUE trends. The analyses presented below will also be considered in the light of these four discussion points.

Only two CPUE analyses of ling catch from trawl fisheries have been reported previously. In an analysis of the Puysegur fishery targeting ling and other species it was concluded that the resulting CPUE series was probably meaningless because fishing patterns had changed markedly over the period examined and there was doubt as to the accuracy of the reported target species (Ballara 1997). An analysis of the trawl fishery (primarily for scampi) in the Bay of Plenty is updated below.

This document reports the results of Project LIN2001/01, Objective 3, to evaluate the use of catch per unit of effort (CPUE) as indices of abundance for ling fisheries in LIN 1 and LIN 2.

# 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 catch effort landing return (CELR) and trawl, catch, effort and processing return (TCEPR) records where ling were targeted or caught from anywhere in the NZ EEZ were extracted and groomed to rectify as many errors as possible. The kinds of errors included:

- missing values (which could be imputed based on preceding and following sets),
- data entry errors owing to unclear writing (e.g., several consecutive days of fishing in area 33 were punctuated by a single set recorded from area 23, target species recorded as "LIM"),

- incorrect set 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 2001 calendar year) are stored in two relational database tables (t_lin_celr and t_lin_tcepr) administered by NIWA for MFish. Data from the 2001 calendar year were obtained from MFish in April 2002.

## 2.2 Variables

Variables used in the analysis are described in Table 1. For analyses of line fisheries, CPUE was defined as catch per day, i.e., daily estimated catch in kilograms on that day by that vessel in a particular statistical area. For analyses of trawl fisheries, CPUE was defined as estimated catch (kg) per tow. The season variable was taken as the *day of year*. 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).

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 (see Figure 1) were selected from the database as follows:

LIN 1 (Northland) — 001–005, 045–048, 102–106
LIN 1 (Bay of Plenty) — 008–010, 107
LIN 2 — 011–015
Cook Strait — 016–017

LIN 1 was analysed in two parts because the longline fishery in this area comprises an established ling target fishery in the Bay of Plenty area and a recently developed exploratory fishery off Northland.

Data were available from calendar years 1990 to 2001. Calendar year (rather than fishing year) was used because of a seasonal trend 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.

### 2.3.1 Longline fisheries

Some longline 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 several records per day fishing. Consequently, all data were condensed (catches and hooks summed over vessel, day, and statistical area) to ensure that all the records represented total catch and effort per statistical area per day.

To ensure that the 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 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 less than 35 000 kg per day,
- number of hooks was greater than 50 per day,
- number of records for a vessel was greater than either 30 in 5 years or 15 in 1 year.

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). After this removal, zero catches made up less than 0.5% of the data in any of the fisheries. Consequently, as in previous analyses of ling longline CPUE (e.g., Horn et al. 2000, Horn 2002a, 2002c), all zero observations were removed.

Some years in some fisheries were deemed to have insufficient records to be included in the analyses. A threshold level was set at about 55 records per year. In a fishery where any years had to be excluded because of insufficient data, an additional analysis was conducted incorporating ling catch data from line fisheries where ling was not the target. The additional target species were restricted to those likely to significantly overlap the depth distribution of ling (i.e., the middle depth species ribaldo, hapuku, bass, and bluenose). In these analyses, target species was offered as a predictor variable.

### 2.3.2 Trawl fisheries

The two trawl fisheries chosen to be analysed for ling CPUE are responsible for a large proportion of the ling trawl catch in Cook Strait and the Bay of Plenty. 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 Bay of Plenty scampi fishery, over 99% of records reporting a ling catch were on the TCEPR database. In the Cook Strait hoki target fishery from 1990 to 2001 there were about 15 000 records of ling landings on the TCEPR database and about 2000 records on the CELR database. Consequently, for both fisheries, only TCEPR data were used in the CPUE analyses as this data source enabled a greater variety of predictor variables to be offered.

To ensure that the data to be analysed were within plausible ranges and related to vessels that had consistently fished in the respective fisheries, data were accepted if all the following constraints were met:

- target species was either hoki (in Cook Strait) or scampi (in Bay of Plenty),
- ling catch was greater than 1 kg and less than 15 000 kg per tow,
- tow duration was between 0.2 and 12 hours,
- number of tows for a vessel was greater than either 80 in 5 years or 30 in 1 year.

It would have been desirable to have gear width as one of the predictor variables offered in the models. However, it was apparent that this field in the TCEPR returns variously contained wingspread and doorspread measurements. Consequently, headline height was the only gear dimension variable that could be offered.

All scampi trawling was by bottom trawl, but trawling for hoki used both bottom and midwater gear. Consequently, method was offered as a predictor variable in the analysis of all the data from the Cook Strait hoki fishery, and separate analyses for each method were also completed.

## 2.4 The model

The lognormal linear model was used for all analyses. A forward stepwise multiple regression fitting algorithm 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.

Unstandardised CPUE was also derived for each fishery each year from the available data sets. The annual indices were calculated as the mean of the individual daily catches, scaled to give a value of 1 for the base year for that particular stock.

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 allowed.

Horn (2002a) discussed the problems that the inclusion of interaction effects can have on standardisation analyses, i.e., the data available are 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 subsequent runs.
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.

In this report, 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). If different fixed values were chosen, the values (scale) on the *y*-axis would change but the appearance of the plots would be unchanged.

# 3. RESULTS

## 3.1 Northland line fishery

The target ling line fishery off Northland had insufficient records to allow analysis of any years before 1993 or after 1999 (Table 2). Effort in the fishery peaked in 1993, but landings peaked in 1999, and the unstandardised indices of catch per day exhibited a marked increasing trend from 1993 to 1999. Most fishing occurs in statistical areas 001 and 002; there has been a gradual transfer of effort from area 001 to area 002 over the period analysed. The fishery uses the bottom longline method exclusively.

The model run without interactions indicated that *statarea* explained some of the variance, although it was the last variable to be selected into the model. However, because of the few records available for this analysis, data from all the statistical areas were retained (Table 2). [It was found that running the model without the data from statistical areas 003, 004, and 047 resulted in only minor changes to the standardised indices.] In the model run with full interactions, interactions between *vessel*, *month*, and *statarea* were selected. However, the retention of any of these interaction effects in the final model resulted in implausible ranges in the coefficients for these variables, so they were all excluded. Again it was apparent that the standardised indices derived from the model runs with and without interactions were similar.

Of the variables entering the model in the final analysis, *year* was very dominant as it explained 38% of the total variance (Table 3). *Vessel*, *month*, and *hookno* were also important, and the full list of accepted variables explained 68.6% of the total variance. Diagnostics showed no evidence of poor fit (Figure 2).

The effects of the selected variables are shown in Figure 3. Catch rates by vessels in the model varied markedly, but an examination of the raw data provided no reasons to exclude the vessels with very high or very low daily catches. Highest catch rates tend to occur in August and September (possibly the spawning season); monthly catch rate varies by a factor of 5. Expected catch increases with increasing hook number over most of the hook number range. Expected catches in statistical area 002 are almost double those in area 001, which helps explain the shift in effort over time to area 002.

The standardised year effects (Table 2, Figure 3) show a widely fluctuating index with no apparent increasing or decreasing trend. Confidence bounds around the indices are very wide.

The line fisheries targeting middle depth species and catching ling provided a dataset with about three times as many records as the ling target fishery alone (see Table 2), but there were still insufficient data from years before 1993. Target fishing for bluenose had been relatively constant throughout 1993 to 2001, targeting for hapuku/bass fishing increased, and targeting for ling had decreased. Effort in the ribaldo fishery fluctuated widely with no apparent trend. Most effort occurred in statistical areas 001 and 002, although fisheries in area 003 developed about 1996. Systematic areal changes in effort are apparent; fishing has declined markedly in area 001, and become more frequent in area 003. Bottom longline was the dominant method, although dahn and trot lining combined produced about 20% of the records.

The model run without interactions indicated that *statarea* explained little of the variance, so data from all the statistical areas were retained (see Table 2). In the model run with full interactions, interactions between *vessel*, *month*, and *targetsp* were selected. The retention of any of these interaction effects in the final model resulted in implausible ranges in the coefficients for these variables, so they were all excluded. However, it was apparent that the standardised indices derived from the model runs with and without interactions were similar.

Of the variables entering the model in the final analysis, *vessel* was very dominant as it explained 44% of the total variance (Table 3). *Targetsp* was also important, and the full list of accepted variables explained 65% of the total variance. Diagnostics showed no evidence of poor fit (Figure 2).

The effects of the selected variables are shown in Figure 4. Catch rates by all but one vessel varied by less than a factor of 7. Expected catches of ling were lowest in fisheries targeting bluenose, hapuku, and bass. Highest catch rates tended to occur in August and September, but the difference between the best and worst months was only a factor of 2. Expected catch increases with increasing hook number over most of the hook number range.

The standardised year effects (see Table 2, Figure 3) show an index with no clear trend. Confidence bounds around the indices are wide.

## 3.2 Bay of Plenty line fishery

The target ling line fishery in the Bay of Plenty had fewer than the threshold 55 records in years 1990 and 1996 to 2001. However, data from 1997 were included in the analysis (Table 4). Effort and landings in the fishery peaked in 1992; the unstandardised indices of catch per day were relatively trendless from 1991 to 1995. Most fishing occurs in statistical areas 009 and 010; there are no apparent changes in effort by area over the period analysed. The fishery uses the bottom longline method exclusively.

The model run without interactions indicated that *statarea* explained none of the variance, so data from all the statistical areas were retained (Table 4). In the model run with full interactions, *vessel:month* was selected. Of the variables entering the model in the final analysis, *month* was dominant. *Month*, *vessel*, and *hookno* were the selected variables, explaining 54% of the total variance (see Table 3). The model fitted relatively well, but there was evidence of slight non-normality in the residuals, indicating imperfect model fit to the very low catch rates (Figure 5).

The effects of the selected variables are shown in Figure 6. Highest catch rates tend to occur in August to October (possibly the spawning season), though differences between most months is less than a factor of 3. Catch rates by vessels in the model varied by a factor of 9. Expected catch increases steadily with increasing hook number up to about 3000 hooks, then increases markedly. The rapid increase is owing to two vessels obtaining high catch rates from relatively large numbers of hooks.

The standardised year effects (Table 4, Figure 6) show a relatively flat index except for a peak in 1992. Confidence bounds around the indices are very wide.

The line fisheries targeting middle depth species and catching ling provided a substantially larger dataset in terms of days fishing and ling catch, relative to the target ling fishery alone (Table 4). Days of target fishing for bluenose exhibited an increasing trend from 1992 to 2001, while there was a decreasing trend in ling targeting over the same time period. Effort in the ribaldo fishery was essentially confined to 1992–96. Most effort occurred in statistical areas 009 and 010. Bottom longline was the dominant method (it produced more than 98% of the landings), and the only method used in the analysis. Trot lining occurred in most years, but was responsible for a significant proportion of the catch (30%) only in 1991.

The model run without interactions indicated that *statarea* explained little of the variance, so data from all the statistical areas were retained (Table 4). In the model run with full interactions, none were selected. Of the variables entering the model in the final analysis, *targetsp* was very dominant as it explained 33% of the total variance (see Table 3). *Vessel* was also important, and the full list of accepted variables explained 62% of the total variance. Diagnostics showed no evidence of poor model fit (see Figure 5).

The effects of the selected variables are shown in Figure 7. Expected catches of ling were much lower in fisheries targeting bluenose, ribaldo, hapuku, and bass than in the ling target fishery. Catch rates by vessel varied by less than a factor of 7. Highest catch rates tended to occur in August and September, but the difference between the best and worst months was less than a factor of 3. Expected catch increases with increasing hook number.

The standardised year effects (Table 4, Figure 7) show an index with a clearly declining trend throughout the entire time series. Confidence bounds around the indices are relatively narrow.

## 3.3 East coast North Island line fishery

The target ling line fishery off the lower east coast of the North Island produced between 137 and 367 records per year from 1990 to 2001 (Table 5). The unstandardised indices of catch per day were not highly variable, although a slight decreasing trend throughout the time period was apparent. Most fishing occurs in statistical areas 013 and 014, but all five areas were consistently fished. There are no apparent consistent changes in effort by area over the period analysed. The fishery is dominated by the bottom longline method (Table 5), but data from all three methods were included in the model.

The model run without interactions indicated that *statarea* explained none of the variance, so data from all the statistical areas were retained (Table 5). In the model run with full interactions, *month:hookno* was selected. Of the variables entering the model in the final analysis, *vessel* was dominant. *Month*, *vessel*, and *hookno* were the selected variables, explaining 40% of the total variance (see Table 3). The model fitted relatively well, but there was evidence of non-normality in the residuals, indicating poor model fit to the very low catch rates (Figure 8).

The effects of the selected variables are shown in Figure 9. Catch rates by most vessels in the model varied by less than a factor of 4. Highest catch rates tend to occur in August to October (possibly the spawning season), though differences between most months is less than a factor of 3. Expected catch increases steadily with increasing hook number.

The standardised year effects (Table 5, Figure 9) show an index that declines markedly between 1990 and 1992, and then continues to decline gradually throughout the rest of the period. Confidence bounds around the indices are relatively narrow.

Although the target ling line fishery alone provided sufficient records each year to enable a confident analysis, an additional analysis using data from all line fisheries targeting middle depth species was completed to allow a comparison of the results from the two data sources. The addition of data from fisheries targeting species other than ling provided a substantially larger dataset in terms of days fishing and ling catch (Table 5). Days of target fishing for bluenose declined slightly from 1991 to 2001, while ling targeting was relatively constant over the same time period. Effort in the hapuku/bass fishery was low and sporadic, and there was no target fishing for ribaldo. Bottom longline was the dominant method; a few days fishing with dahn or trot line occurred in the first half of the series.

The model run without interactions indicated that *statarea* explained little of the variance, so data from all the statistical areas were retained (Table 5). In the model run with full interactions, interactions between *vessel*, *targetsp*, *month*, and *hookno* were selected. However, the retention of the *vessel* interaction effects was found to produce implausible ranges in coefficients for several of the variables. Interaction terms between *targetsp*, *month*, and *hookno* were retained in the final model. Of the variables entering the model in the final analysis, *targetsp* was very dominant as it explained 48% of the total variance (see Table 3). *Vessel* was also important, and the full list of accepted variables explained 68% of the total variance. Diagnostics showed no evidence of poor model fit (see Figure 8).

The effects of the selected variables are shown in Figure 10. Expected catches of ling were much lower in fisheries targeting bluenose, hapuku, and bass than in the ling target fishery. Catch rates by most vessels in the model varied by less than a factor of 4. Highest catch rates tend to occur in August to October, and the difference between the best and worst month is less than a factor of 3. Expected catch tends to increase with increasing hook number, though the relationship was not linear.

The standardised year effects (Table 5, Figure 10) show an index with a clearly declining trend throughout the entire time series. Confidence bounds around the indices are narrow.

### 3.4 Cook Strait line fishery

The target ling line fishery in Cook Strait had fewer than the threshold 55 records in years 1997, and 1999 to 2001 (Table 6). The unstandardised indices of catch per day declined slightly throughout the period analysed. Over 90% of days fishing occurred in statistical area 016. Bottom longline and dahn line are both used, with bottom longline being more dominant (Table 6). Large auto-longline vessels fished in this area in 1999–2001. However, the data produced by these vessels were still insufficient to meet the year threshold in 1999 and 2000. With the auto-longline records, more than 55 records were available for 2001. However, the inclusion of high daily catches from vessels using large numbers of hooks markedly changed the relationship between hook number and catch, and the coefficients of other variables selected into the model. Consequently, auto-longline data were excluded from the model.

The model run without interactions indicated that *statarea* explained none of the variance, so data from both statistical areas were retained (Table 6). In the model run with full interactions, *month:hookno* was selected. Of the variables entering the model in the final analysis, *vessel* was dominant and explained about 39% of the variance. *Vessel, log(hookno)* and *month* were the selected variables, explaining 54% of the total variance (see Table 3). The model fitted relatively well, but there was some non-normality in the residuals, indicating poor model fit to the very low catch rates (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 a factor of 7. Expected catch rate and hook number are approximately linearly related. Highest catch rates tend to occur throughout winter and spring, although the difference between the best and worst month is less than a factor of 2.

The standardised year effects (Table 6, Figure 12) show a relatively flat index, though with some indication of a slight decline throughout the period analysed. Confidence bounds around the indices are wide.

The line fisheries targeting middle depth species and catching ling provided sufficient data to enable an analysis of all years from 1990 to 2001 (Table 6). Days of target fishing for bluenose and hapuku/bass were relatively consistent, while there was a decreasing trend in ling targeting from 1993 to 2001. There was no target fishing for ribaldo. Most effort occurred in statistical area 16. Dahn line was the dominant method, but both bottom longline and dahn line data were included in the analysis.

The model run without interactions indicated that *statarea* explained little of the variance, so data from all the statistical areas were retained (Table 6). In the model run with full interactions, *month:hookno* was selected. Of the variables entering the model in the final analysis, *vessel* was dominant. *Vessel, targetsp, hookno* and *month* were the selected variables, explaining 54% of the total variance (see Table 3). The model fitted reasonably well, but there was some non-normality in the residuals, indicating poor model fit to the very low catch rates (Figure 11).

The effects of the selected variables are shown in Figure 13. Catch rates by all but one of the vessels in the model varied by a factor of 7. Expected catches of ling were about four times higher in the ling target fishery than in those targeting bluenose, hapuku, and bass. As in the ling target fishery analysis, expected catch increases steadily with increasing hook number up to about 4000 hooks, then increases markedly. The rapid increase is owing to a single vessel obtaining high catch rates from relatively large numbers of hooks. Highest catch rates tend to occur from April to October, although the difference between the best and worst month is less than a factor of 2.

The standardised year effects (Table 6, Figure 13) show a relatively constant index from 1990 to 1998, followed by two markedly higher years. However, the confidence bounds around the indices are relatively wide.

### 3.5 Cook Strait trawl fishery

The trawl fishery targeting hoki in Cook Strait produced a minimum of 656 tows per year, and over 14 000 tows from 1990 to 2001 (Table 7). The unstandardised indices of catch per tow exhibited a clear declining trend. Fishing occurs in statistical areas 016 and 017, but area 016 is the more heavily fished. There are no apparent consistent changes in effort by area over the period analysed. The fishery is dominated by the midwater trawl method (Table 7); little bottom trawling for hoki was conducted in this area before 1994.

Using midwater and bottom trawl data combined, the model run without interactions indicated that *statarea* explained none of the variance, so data from both statistical areas were retained (Table 7). In the run with full interactions, interactions between month, tow duration, and trawl headline height entered the model. Of the variables entering the model in the final analysis, *vessel* was dominant. The final model explained 31% of the total variance (Table 8). The model fitted relatively well, but there was evidence of non-normality in the residuals, indicating poor model fit to the extreme catch rates (Figure 14).

The effects of the selected variables are shown in Figure 15. Catch rates by most vessels in the model varied by less than a factor of 6. Ling catch increases with tow duration up to about 7 hours, then declines. The headline height relationship indicates that expected catches of ling are greater in bottom trawls (i.e., low headline height) than midwater trawls (i.e., greater headline heights). Highest catch rates tend to occur from June to October, though differences between any months are less than a factor of 2. The interactions between month, tow duration, and trawl headline height stem from a preference to use shorter tows in midwater to catch aggregated hoki during their spawning season from June to September.

The standardised year effects (Table 7, Figure 15) show an index that declines markedly between 1990 and 1994, and then is relatively constant until a slight increase in 2001. Confidence bounds around the indices are narrow.

Because there was little bottom trawling in this fishery from 1990 to 1993, it was considered desirable to run separate analyses for the midwater and bottom trawl fisheries. Model fits to both data series were good (Figure 16). All but one of the variables selected into the midwater trawl model are the same as for the "all data" model (Table 8), and the effects are also generally similar (Figure 17). The standardised year effects (Table 7, Figure 17) show an index that declines between 1990 and 1999 (initially quite rapidly), then increases slightly to 2001.

The bottom trawl indices could be calculated only from 1994 to 2001 (see Table 7). Tow duration was the dominant variable, although *vessel* also explained much of the variance (Table 8). The effects of the selected variables are shown in Figure 18. Ling catch increases with tow duration up to about 5 hours, then declines. Catch rates by most vessels in the model varied by less than a factor of 2. Catch rate declines markedly in depths greater than 700 m. The standardised year effects (Table 7, Figure 18) show a relatively flat index, but with an indication of a slight increase since 1997.

The standardised index series from the three analyses of the Cook Strait trawl data are compared in Figure 19. All series exhibit similar trends.

### 3.6 Bay of Plenty trawl fishery

The trawl fishery targeting scampi in the Bay of Plenty produced a minimum of 224 tows per year from 1990 to 2001, with over 6000 tows in total (see Table 7). The unstandardised indices of catch per tow exhibited an overall increasing trend throughout the time period. Fishing occurs primarily in statistical areas 008 and 009, with occasional targeting for scampi in area 010. There are no apparent consistent changes in effort by area over the period analysed. The fishery is exclusively bottom trawl.

In the model run without interactions, *statarea* was selected. However, model runs with and without the data from statistical area 010 produced virtually identical series of indices, so data from all three areas were retained (see Table 7). In the model run with full interactions, *month:midtime* and *month:depbttm* were selected. Of the variables entering the model in the final analysis, *year* was dominant. The final model explained 50% of the total variance (Table 8). Diagnostics showed no evidence of poor model fit (see Figure 14).

The effects of the selected variables are shown in Figure 20. Catch rates by vessel varied by less than a factor of 4. Highest catch rates tend to occur from June to September, though differences between any months are less than a factor of 2. Catch rates of ling were relatively constant between depths of 200 to 350 m, then tended to increase with increasing depth. Catch rate was highest at midday and lowest at midnight. Ling catch increased with tow duration.

The standardised year effects (Table 7, Figure 20) show an index that is relatively constant from 1990 to 1998, and then increases markedly. Confidence bounds around the indices are relatively narrow.

### 3.7 Within-area series comparisons

Each of the four areas investigated (i.e., Northland, Bay of Plenty, east coast North Island, and Cook Strait) had two or three CPUE series calculated for fisheries occurring in them. The series, with their 95% confidence bounds, are plotted in Figures 21 and 22.

There is little correlation between the two line fishery series from Northland (Figure 21), although none of the pairing of indices from any particular year where the series overlap is significantly different. There have been systematic areal changes in the fisheries targeting ling and other middle depth species over the period examined. The inclusion of non-ling target data from 1993 to 1999 (the period of the target fishery indices) more than doubled the numbers of days fished, but increased the ling landings by only about 20%.

The two Bay of Plenty line series (Figure 21) are difficult to compare because there are only 6 years of overlapping data, and only the 1992 to 1995 ling target indices are based on reasonable volumes of data (see Table 4). Those four points indicate a decline in ling abundance during that period. The series derived from target lining for middle depth species declines steadily from 1990 to 1996 (when effort targeting ling declined markedly, Table 4), and then remained relatively constant to 2001. The inclusion of non-ling target data from 1991 to 1995 and 1997 (the period of the target fishery indices) more than doubled the numbers of days fished, and increased the ling landings by about 33%. [An analysis using all available ling target line data with no yearly thresholds produced a CPUE series markedly different in shape to that of the all-targets series (author's unpublished data).] The scampi trawl fishery series is very different to the all-targets line series, primarily owing to the marked increase in the trawl indices after 1998. A biological justification for this increase is considered unlikely. However, it is apparent that the shapes of the two series were similar from 1993 to 1998.

The two east coast North Island line series are similar (Figure 22). The only significant difference between the two series occurs in 1991 when the target ling index is higher than the all data index. Confidence intervals around most of the indices are narrow. The inclusion of non-ling target data increased the numbers of days fished by about 35%, but increased the ling landings by only about 5%. Because line fishing for middle depth species in this area is dominated by ling targeting, and because there has been little change in targeting trends for any of the species throughout the period analysed, it would be expected that the two analyses would produce relatively similar sets of indices.

The two Cook Strait line series are very similar in the eight years for which there are comparable data (Figure 22); none of the pairings between years are significantly different. The inclusion of non-ling target data from 1990 to 1996 and 1998 (the period of the target fishery indices) increased the numbers of days fished by about 45%, and increased the ling landings by about 18%. The last three points of the non-target series are based on relatively low numbers of days fished (see Table 6) and have broad confidence intervals. [An analysis using all available ling target line data with no yearly thresholds produced a CPUE series similar in shape to that of the all-targets series (author's unpublished data).] The hoki trawl fishery series has some similarities to the line series in that it indicates a decline in ling abundance from 1990 to 1995, followed by four years with relatively constant indices, and then an increase in the indices at the end of the series. The all-targets line series indicated a decline followed by a subsequent recovery.

## 4. DISCUSSION

In recent assessments of ling stocks around the South Island, series of CPUE indices derived from commercial line fisheries have been used as indices of abundance (e.g., Horn 2002b). They are the only relative abundance series available for some stocks.

### 4.1 Model validation

In a review of the calculation and interpretation of CPUE indices, Dunn et al. (2000) recommended that CPUE analyses include discussion of the following four components, in an attempt to validate the data selection, model method, and results.

a) Definition of the relationship between CPUE and fish abundance
b) Assessment of data adequacy
c) Methods of model fitting and model validation
d) Evaluation of the CPUE index

Horn (2002a) showed that the longline CPUE series from the four major ling stocks around the South Island appeared to perform well in relation to these four points. It was concluded that for each of the stocks there is a good likelihood that CPUE is an index of abundance (for that part of the population targeted by the line fishery), that the data are comprehensive and accurate, and that the modelling method was valid. Fishery-independent data from two of the stocks support the CPUE trends.

The analyses presented here differ from those of Horn (2002a, 2002c) in that they are of relatively small target fisheries, or that they included data from fisheries targeting species other than ling. The discussion below examines how well each of the analysed datasets meets the requirements recommended by Dunn et al. (2000).

#### Is there a reasonable expectation that changes in catch per effort reflect changes in abundance?

It is generally assumed that CPUE for a fishstock is proportional to fish abundance. However, behaviour by fish or fishers can bias this proportionality.

For ling, hyperstability of CPUE could result from hook saturation or a strong clumped distribution of the population. [Hyperstability is when CPUE remains artificially high when the population is actually declining.] It is unlikely that hook saturation has ever occurred in any of the target ling fisheries examined here as mean annual catch rates for these fisheries are all less than 0.6 kg per hook, and catch rate in any day fished is seldom higher than 3 kg per hook. Most ling caught by line are likely to be larger than 3 kg (Horn 2002b). The proportion of unbaited hooks set is likely to be very low as they will generally be hand baited. No data are available on the proportion of hooks taken by other species, but given the information above on catch rates per hook and likely minimum ling weights, large numbers of bycatch fish would be needed to significantly depress CPUE indices.

It is apparent in the three target ling fisheries examined that maximum catch rates occur around August to October. This is probably related to spawning aggregations, as other ling stocks in New Zealand waters appear to spawn around this time (Horn 2002a). However, as noted above, the maximum catch rates are not indicative of any hook saturation, so it is considered unlikely that this factor has held line CPUE at artificially high levels. Hyperstability could still occur in the absence of hook saturation, but when the population becomes strongly clumped. However, the relatively lengthy spawning seasons for ling, and the geographically large areas where spawning occurs, suggests that while some aggregating will occur, it is unlikely to result in a strongly clumped population. The variable *month* was selected into all the models, and this is likely to correct for gross differences in catch rates between spawning and non-spawning seasons.

Changes in gear technology or configuration through the 1990s are not believed to have influenced the likely catch per hook in the fisheries targeting ling or other middle depth species. Set duration would ideally be a variable offered in the line fishery CPUE models, but this parameter is only sporadically recorded. However, an examination of mean set duration by year for the four ling target fisheries analysed indicated no apparent trend in any area. Consequently, it is considered unlikely that the analyses are biased owing to the lack of data on set duration.

Aspects of fishing behaviour most likely to bias line CPUE are learning by fishers, changes in the distribution of fishing effort over time, and any changing trend in hook soak time. Learning by fishers can probably not be indexed. It cannot even be assumed that learning for a particular vessel increases with time, as vessel skippers can change. However, there is a clear indication that the distribution of fishing effort has changed systematically over time in the Northland line fishery. In this locality, effort in statistical area 001 steadily declined, while effort in area 002 increased. This change was accompanied by a steady increase in catch per day fished. These patterns of change in fishing location and catch might be expected in an exploratory fishery where fishers are prospecting widely, but eventually concentrating effort in the more productive areas. It is therefore considered unlikely that changes in catch per effort in the Northland line fishery reflect changes in ling abundance. No similar patterns of change are apparent for any of the other line fisheries analysed here.

If CPUE is a valid index of abundance it would be expected that the two line fishery series from an individual area would exhibit similar trends. This certainly occurs in the east coast North Island and Cook Strait fisheries (Figure 22). However, it is not the case off Northland or in the Bay of Plenty (see Figure 21), suggesting that at least one of the series in both these areas is unreliable as an abundance index.

The two trawl fisheries analysed here both take ling as a significant (and often the most abundant) bycatch species, so it is expected that ling would be consistently reported on the TCEPR forms from these fisheries. In the Cook Strait hoki fishery, reported ling catch tends to be about 50–200 kg per tow, and has averaged about 6% of the total wetfish landings over the years analysed (but with a steadily declining trend throughout this period). Catches of this magnitude are unlikely to cause vessel skippers to attempt to either avoid or target ling, and so CPUE based on these catches might provide a very reliable index of abundance of ling vulnerable to trawl in this area. Although the small catches of ling in relatively large catches of hoki may make it difficult for skippers to estimate the ling weight, most of the vessels involved in this fishery bin the catch up at sea and use bin counts per species to derive the estimated green weight per tow. It is therefore considered likely that, unless there have been consistent changes over time in the way skippers estimate or report the ling bycatch, changes in ling CPUE in the hoki trawl fishery reflect changes in ling abundance.

In the Bay of Plenty scampi fishery, reported ling catch tends to be about 30–100 kg per tow. From 1990 to 1998, ling averaged about 17% of the total reported catch in the tows analysed, but in 1999 to 2001 it jumped to 24%. Catches of this magnitude may cause vessel skippers to attempt to avoid ling (as large catches of finfish can damage the desired scampi catch), or to not report it (if they have insufficient ling quota to cover the catch). So CPUE based on these catches may produce an unreliable index of abundance of ling vulnerable to scampi trawls in this area. This scepticism is enhanced by the large increase in the standardised indices after 1998 (see Figure 20); it is difficult to imagine that recruitment could double available biomass in a year. It is believed, therefore, that this CPUE series has probably been influenced by some changes in fishing and/or reporting behaviour by fishers, and is not a good index of ling abundance in the Bay of Plenty.

Ideally, line and trawl CPUE series from an individual area should exhibit somewhat similar trends if CPUE from both these fisheries is a valid index of abundance. However, it is known that trawl and line methods can select markedly different sections of a population (see Horn 2002b), so some differences in CPUE trends between fisheries would not necessarily invalidate one or both of the series. The trawl and line series from the Bay of Plenty are markedly different, but, as noted above, there a serious doubts about the trawl series (particularly its last three points). The trawl and line series from Cook Strait show some similarities, but unfortunately the last three points of the all-targets line series are poorly defined.

In summary, although it cannot be concluded that ling CPUE from line fisheries is directly proportional to fish abundance, there are no apparent sources of bias likely to strongly perturb this relationship in any of the fisheries analysed, except that off Northland. CPUE for ling in the Cook Strait hoki trawl fishery is probably a good index of abundance for ling in that area, but there are doubts as to the relationship between CPUE and ling abundance from the Bay of Plenty scampi fishery.

### Is there an adequate data volume free of major error?

The fisheries analysed here each accounted for between 20% and 79% of the total ling landings in the respective areas. The included data provide a good temporal and spatial coverage of the effort in each fishery (although in some years, levels of effort in particular fisheries were low). The data used have been groomed to remove as many errors as possible. In each analysis, vessels with an infrequent history in the fishery have been removed (based on a threshold of a particular number of days or tows fished in one year or in five years). Data from statistical areas infrequently fished were also removed if the *statarea* variable entered the model. This ensured that the analysed data represented the main areas of each fishery. Erroneous data can occur when the processed weight (instead of greenweight) is recorded as the estimated weight on the fishing return forms. Horn (2002c) described how this source of error was checked for and corrected in the CELR data from line fisheries targeting ling.

A possible complication with the data relates to the stated target species. It is known that some fishers record a target species after examination of the catch (i.e., the most abundant species in the catch is listed as the target). In an analysis using target ling data only, from a ling stock where abundance is declining, such behaviour would tend to bias CPUE up from its true level, as a number of small target ling catches would be recorded with a different target species. Where an analysis incorporates data from fisheries with various stated targets (like some of those presented above), the effect on the ling CPUE of post-fishing determination of the target species is uncertain.

The number of records from any one year that are required before validly including that year in the analysis is open to conjecture. A threshold of 55 records (i.e., days fished) per year was set for the analyses described above. This resulted in some years having to be deleted from the analyses of the target ling line fisheries off Northland, and in the Bay of Plenty and Cook Strait. A threshold of about 15 records per year would be necessary to include most of the excluded years; 15 days of fishing effort is unlikely to adequately describe the abundance of ling in any particular year. Even 55–100 records can produce an index with wide confidence bounds (but this is also influenced by variance within the data set). The accepted years in the Northland, Bay of Plenty, and Cook Strait target ling line fisheries are generally represented by between 55 and 200 records. The CPUE series from these fisheries are characterised by missing years and wide confidence bounds, hence these series probably poorly index the relative abundance of ling. The ling target fishery off east coast North Island is generally represented by more than 200 records per year, and the resulting CPUE indices have narrow bounds. The volume of data from this fishery is probably sufficient to provide a good index of relative ling abundance. Both the analysed trawl fisheries are represented by large volumes of data, i.e., about 1200 tows per year in the Cook Strait hoki fishery, and 500 tows per year for Bay of Plenty scampi.

In summary, the data are believed to provide a relatively accurate and comprehensive reflection of the catch and effort in the target ling line fisheries and in the two trawl fisheries producing ling bycatch, and to contain no significant errors. Volumes of data are certainly adequate from the two trawl fisheries, and from the east coast North Island target line fishery. However, the three remaining line fisheries suffer from low volumes of data, resulting in index series from a restricted number of years and with wide confidence bounds. A threshold closer to 100 records per year is probably necessary to produce indices with sufficiently narrow confidence bounds.

**Did the model provide an adequate and valid method of explaining data variance?**
The standardised analyses presented here aim to correct for variance between variables (i.e., those relating to fishing gear, season, and area), and, hence, determine an overall year effect for relative catch rates.

The extent of the residual variance explained by the finally accepted models varied from 31% in the Cook Strait target hoki trawl fishery to 68% in the Northland target ling line fishery (see Tables 3 and 8). For most analyses, it was possible to increase the $R^2$ value by allowing a completely automatic variable selection process and the selection of any interaction effects. However, some selected interaction terms were excluded from the final model because their inclusion caused an implausibly wide range in some of the variable coefficients. Hence, the final models for most of the fisheries contained fewer variables than were chosen in the automatic variable selection process. However, although this reduced the $R^2$ values, the resulting models were believed to provide the most valid explanation of residual variance.

It is concluded that the model type and methods of standardisation are believed to be suitable for the fisheries analysed, and the diagnostic analysis of variable coefficients and residuals indicate a reasonable and logical fit of the data to the models presented.

**Can the assumed relationship between CPUE and abundance be validated?**
No fishery-independent measures of relative abundance are available for ling from any of the stocks analysed here, so it is not possible to validate the relationship between CPUE and abundance.

## 4.2 Trends in variable selection

Because the four ling target line 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, *vessel, month* and *hookno* (or *log(hookno)*) were selected as the first three variables (though not necessarily in that order). Clearly, catch rates in all areas vary throughout the year, probably in relation to the spawning season for ling. Skill levels and/or gear efficiency vary between vessels, although in each area vessel catch rates seldom differed by more than a factor of 5. A significant areal effect on catch rates occurred only in the Northland fishery, where statistical area was selected.

When data from other middle depth species target line fisheries were added to the analyses, *targetsp* was always selected as either the first or second variable. As expected, the coefficient for ling as the target species was always markedly higher than coefficients for other target species. Although fishing in all areas was conducted using different lining methods, the *method* variable was not selected into any of the models.

In both the trawl fishery analyses, *vessel* was the most influential variable (although *duration* was the first variable selected in the Cook Strait bottom trawl analysis), and *month* also explained a reasonable portion of the total variance. Other selected sets of variables were quite different between the two fisheries. In the hoki fishery, tow duration and trawl headline height (which relates primarily to a differentiation between bottom and midwater trawling operations) were selected. The scampi fishery was more influenced by bottom depth and the time the tow occurred (with maximum catch rates of ling being at midday).

## 4.3 Evaluation of the series

The objective of this work was to evaluate the use of CPUE as indices of abundance for ling fisheries in LIN 1 and LIN 2. Each analysed fishery is evaluated below.

- **Northland line fishery** — The ling target fishery is based on a relatively low number of records, has experienced marked areal changes in effort, and has widely variant indices, so the resulting series is considered unreliable as an index of abundance. The all-targets line fishery will be similarly confounded in terms of areal changes, and although it is a relatively smooth series it probably does not reliably index ling abundance.

- **Bay of Plenty line fishery** — The ling target fishery series is probably a reliable abundance index, but only for the years 1992 to 1995 (owing to low numbers of records from other years). The CPUE trends for the all-targets line fishery match those of the ling target fishery from 1992 to 1995, and the scampi trawl fishery from 1993 to 1998. The series fluctuates little and has narrow confidence bounds, but is based primarily on bycatch from the bluenose fishery since 1997. It may provide a reliable index of ling abundance.

- **Bay of Plenty scampi trawl fishery** — The trawl series is believable from 1990 to 1998 (and matches the all-targets line fishery from 1993 to 1998). However, the changes after 1998 are considered unlikely to represent a biological change, but are suggestive of some major change in fishing or reporting practice. The overall series does not reliably index ling abundance.

- **East coast North Island line fishery** — The ling target fishery series is probably a reliable abundance index. It is based on a good number of records from a relatively productive fishery. The all-targets series also appears to be a good index, but the ling target fishery series would be preferred in any stock assessment modelling.

- **Cook Strait line fishery** — The ling target fishery series is probably a reliable abundance index for the years 1990 to 1996 (owing to low numbers of records from other years). The CPUE trends for the all-targets line fishery match those of the ling target fishery in all comparable years, so it may also be a reliable index of ling abundance. However, the last three points in the series are less reliable, being based on relatively few records.

- **Cook Strait hoki trawl fishery** — This series is smooth, based on large volumes of data, and exhibits very low confidence bounds. There are no reasons to believe that there have been any changes in fishing or reporting practice that would have biased the series. Trends in separate analyses of midwater trawl data only and bottom trawl data only were similar to those in the "all data" analysis. The "all data" series is therefore considered to be a reliable index of abundance of ling vulnerable to the hoki trawl fishery.

## 5. ACKNOWLEDGMENTS

I thank Alistair Dunn for assistance with this analysis and for useful comments on a draft of this manuscript. This research was funded by the Ministry of Fisheries under Project LIN2001/01.

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**Table 1: Summary of the variables used in the CPUE models.**

| Variable | Type | Description |
|---|---|---|
| **Both fisheries** | | |
| Year | Categorical | Calendar year |
| Month | Categorical | Month of year |
| Statistical area | Categorical | Statistical area for the set |
| Vessel | Categorical | Unique vessel identifier |
| Day of year | 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 |
| CPUE | Continuous | Ling catch (kg) per day in a statistical area |
| **Trawl fisheries** | | |
| Method | Categorical | Trawl method (bottom trawl, midwater trawl) [for Cook Strait only] |
| 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) [for Cook Strait only] |
| Speed | Continuous | Towing speed (kts) |
| Totalcatch | Continuous | Total catch of all commercial species reported from the tow |
| CPUE | Continuous | Ling catch (kg) per tow |

**Table 2: Summary of data used in the final standardised CPUE analysis of the Northland line fishery, and the standardised (Std, with 95% confidence intervals) and unstandardised (Unstd) year effects for that fishery. Days, number of individual records of days fished; Catch, estimated catch (t) from the accepted records; Vessel nos., number of vessels contributing to the accepted records. The total in the "Vessel" column indicates the number of unique vessels contributing to the accepted records throughout the time series. Target species: BNS, bluenose; HPB, hapuku and bass; LIN, ling; RIB, ribaldo. Method: BLL, bottom longline; DL, dahn line; TL, trot line.**

**Target ling line fishery**

| *Year* | *Days* | *Catch* | *Vessel* | *Statistical area* | | | | | *Unstd* | *Std* | *95% CI* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (t) | nos. | 1 | 2 | 3 | 4 | 47 | | | |
| 1993 | 155 | 33 | 3 | 139 | 16 | 0 | 0 | 0 | 1.00 | 1.00 | – |
| 1994 | 64 | 11 | 2 | 58 | 6 | 0 | 0 | 0 | 0.64 | 1.37 | 0.90–2.09 |
| 1995 | 57 | 38 | 6 | 20 | 29 | 5 | 3 | 0 | 2.28 | 1.06 | 0.62–1.84 |
| 1996 | 67 | 67 | 4 | 29 | 25 | 0 | 0 | 13 | 4.33 | 1.60 | 0.85–3.02 |
| 1997 | 89 | 57 | 5 | 34 | 48 | 6 | 0 | 1 | 4.13 | 1.12 | 0.74–1.71 |
| 1998 | 81 | 78 | 4 | 23 | 48 | 9 | 1 | 0 | 6.49 | 1.71 | 0.93–3.15 |
| 1999 | 68 | 122 | 2 | 0 | 62 | 3 | 3 | 0 | 13.27 | 0.58 | 0.27–1.23 |
| Total | 581 | 406 | 8 | | | | | | | | |

**Line fishery all targets**

| Year | Days | Catch | Vessel | Statistical area | | | | | | Target species | | | | Method | | | Unstd | Std | 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (t) | nos. | 1 | 2 | 3 | 4 | 46 | 47 | BNS | HPB | LIN | RIB | BLL | DL | TL | | | |
| 1993 | 196 | 39 | 7 | 159 | 37 | 0 | 0 | 0 | 0 | 13 | 28 | 155 | 0 | 190 | 0 | 6 | 1.00 | 1.00 | – |
| 1994 | 118 | 14 | 7 | 95 | 23 | 0 | 0 | 0 | 0 | 40 | 14 | 64 | 0 | 108 | 0 | 10 | 0.54 | 1.11 | 0.81–1.52 |
| 1995 | 127 | 49 | 9 | 43 | 58 | 6 | 3 | 0 | 17 | 34 | 31 | 62 | 0 | 112 | 1 | 14 | 1.12 | 1.35 | 1.02–1.81 |
| 1996 | 181 | 78 | 10 | 72 | 59 | 24 | 0 | 0 | 26 | 34 | 49 | 74 | 24 | 141 | 2 | 38 | 1.06 | 1.18 | 0.89–1.58 |
| 1997 | 298 | 72 | 12 | 94 | 107 | 76 | 3 | 13 | 5 | 76 | 76 | 92 | 54 | 239 | 4 | 55 | 0.92 | 1.32 | 0.99–1.75 |
| 1998 | 226 | 94 | 14 | 78 | 76 | 54 | 1 | 4 | 13 | 48 | 79 | 82 | 17 | 164 | 28 | 34 | 1.18 | 1.32 | 0.98–1.77 |
| 1999 | 239 | 145 | 11 | 48 | 108 | 72 | 3 | 0 | 8 | 70 | 84 | 83 | 2 | 172 | 42 | 25 | 1.11 | 1.13 | 0.82–1.57 |
| 2000 | 114 | 15 | 10 | 31 | 35 | 32 | 7 | 0 | 9 | 21 | 79 | 0 | 14 | 92 | 4 | 18 | 0.40 | 1.15 | 0.80–1.64 |
| 2001 | 147 | 11 | 10 | 28 | 46 | 45 | 11 | 2 | 15 | 47 | 95 | 5 | 0 | 134 | 5 | 8 | 0.27 | 0.91 | 0.64–1.30 |
| Total | 1 646 | 517 | 21 | | | | | | | | | | | | | | | | |

Table 3: **Standardised CPUE models for the line fisheries from the four areas, showing the change in residual deviance (%) as each new variable was added.**

| | Target LIN only | | | All target species | |
|---|---|---|---|---|---|
| Step | Variable | % deviance | Step | Variable | % deviance |
| **Northland** | | | | | |
| | Year | 38.5 | | Year | 7.0 |
| 1 | Vessel | 54.1 | 1 | Vessel | 51.0 |
| 2 | Month | 61.5 | 2 | Targetsp | 62.0 |
| 3 | log(Hookno) | 66.6 | 3 | Month | 64.1 |
| 4 | SOI | 67.9 | 4 | log(Hookno) | 65.5 |
| 5 | Statarea | 68.6 | | | |
| **Bay of Plenty** | | | | | |
| | Year | 2.4 | | Year | 15.3 |
| 1 | Month | 27.4 | 1 | Targetsp | 48.2 |
| 2 | Vessel | 39.9 | 2 | Vessel | 56.4 |
| 3 | Month:Vessel | 51.4 | 3 | Month | 59.9 |
| 4 | Hookno | 54.5 | 4 | Hookno | 61.9 |
| **East coast North Island** | | | | | |
| | Year | 3.6 | | Year | 2.4 |
| 1 | Vessel | 28.3 | 1 | Targetsp | 50.6 |
| 2 | Month | 35.1 | 2 | Vessel | 61.6 |
| 3 | Hookno | 38.3 | 3 | Month | 64.7 |
| 4 | Month:Hookno | 40.5 | 4 | log(Hookno) | 66.0 |
| | | | 5 | log(Hookno):Targetsp | 66.8 |
| | | | 6 | Month:Targetsp | 67.3 |
| | | | 7 | Month:log(Hookno) | 67.8 |
| **Cook Strait** | | | | | |
| | Year | 6.3 | | Year | 5.5 |
| 1 | Vessel | 45.3 | 1 | Vessel | 34.0 |
| 2 | log(Hookno) | 50.4 | 2 | Targetsp | 49.9 |
| 3 | Month | 51.7 | 3 | Hookno | 52.0 |
| 4 | Month:log(Hookno) | 54.2 | 4 | Month | 53.2 |
| | | | 5 | Month:Hookno | 54.1 |

**Table 4: Summary of data used in the final standardised CPUE analysis of the Bay of Plenty line fishery, and the standardised (Std, with 95% confidence intervals) and unstandardised (Unstd) year effects for that fishery. Days, number of individual records of days fished; Catch, estimated catch (t) from the accepted records; Vessel nos., number of vessels contributing to the accepted records. The total in the "Vessel" column indicates the number of unique vessels contributing to the accepted records throughout the time series. The total in the "Vessel" column indicates the number of unique vessels contributing to the accepted records throughout the time series. Target species: BNS, bluenose; HPB, hapuku and bass; LIN, ling; RIB, ribaldo.**

**Target ling line fishery**

| Year | Days | Catch | Vessel | Statistical area | | | Unstd | Std | 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| | | (t) | nos. | 8 | 9 | 10 | | | |
| 1991 | 57 | 21 | 6 | 22 | 19 | 16 | 1.00 | 1.00 | – |
| 1992 | 203 | 80 | 9 | 6 | 76 | 121 | 1.29 | 1.79 | 1.13–2.83 |
| 1993 | 104 | 33 | 8 | 1 | 16 | 87 | 0.82 | 0.95 | 0.58–1.56 |
| 1994 | 182 | 61 | 8 | 28 | 58 | 96 | 0.89 | 1.15 | 0.72–1.83 |
| 1995 | 135 | 53 | 10 | 5 | 80 | 50 | 0.98 | 0.95 | 0.59–1.52 |
| 1997 | 48 | 25 | 4 | 0 | 23 | 25 | 1.47 | 0.98 | 0.57–1.69 |
| Total | 729 | 273 | 13 | | | | | | |

**Line fishery all targets**

| Year | Days | Catch | Vessel | Statistical area | | | Target species | | | | Unstd | Std | 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (t) | nos. | 8 | 9 | 10 | BNS | HPB | LIN | RIB | | | |
| 1990 | 153 | 14 | 9 | 0 | 76 | 77 | 141 | 2 | 6 | 4 | 1.00 | 1.00 | – |
| 1991 | 165 | 32 | 11 | 28 | 82 | 55 | 77 | 7 | 74 | 7 | 1.56 | 0.81 | 0.63–1.04 |
| 1992 | 364 | 101 | 13 | 11 | 167 | 186 | 53 | 10 | 203 | 98 | 2.82 | 0.91 | 0.71–1.15 |
| 1993 | 192 | 43 | 11 | 3 | 43 | 146 | 51 | 19 | 107 | 15 | 1.76 | 0.66 | 0.50–0.87 |
| 1994 | 358 | 79 | 14 | 35 | 110 | 213 | 109 | 22 | 193 | 34 | 1.87 | 0.64 | 0.50–0.83 |
| 1995 | 270 | 68 | 18 | 7 | 146 | 117 | 71 | 10 | 148 | 41 | 1.80 | 0.56 | 0.43–0.72 |
| 1996 | 176 | 32 | 12 | 3 | 113 | 60 | 38 | 5 | 41 | 92 | 1.79 | 0.44 | 0.33–0.58 |
| 1997 | 253 | 40 | 10 | 5 | 100 | 148 | 179 | 12 | 61 | 1 | 0.77 | 0.40 | 0.31–0.52 |
| 1998 | 135 | 15 | 10 | 3 | 35 | 97 | 114 | 5 | 16 | 0 | 0.52 | 0.45 | 0.34–0.59 |
| 1999 | 162 | 14 | 9 | 5 | 28 | 129 | 143 | 3 | 16 | 0 | 0.49 | 0.43 | 0.33–0.57 |
| 2000 | 141 | 17 | 7 | 2 | 18 | 121 | 108 | 0 | 33 | 0 | 0.66 | 0.40 | 0.31–0.53 |
| 2001 | 219 | 28 | 11 | 1 | 108 | 110 | 193 | 1 | 24 | 1 | 0.49 | 0.37 | 0.28–0.49 |
| Total | 2 588 | 483 | 29 | | | | | | | | | | |

**Table 5: Summary of data used in the final standardised CPUE analysis of the East Coast North Island line fishery, and the standardised (Std, with 95% confidence intervals) and unstandardised (Unstd) year effects for that fishery. Days, number of individual records of days fished; Catch, estimated catch (t) from the accepted records; Vessel nos., number of vessels contributing to the accepted records. The total in the "Vessel" column indicates the number of unique vessels contributing to the accepted records throughout the time series. Method: BLL, bottom longline; DL, dahn line; TL, trot line.**

**Target ling line fishery**

| Year | Days | Catch (t) | Vessel nos. | Statistical area | | | | | Method | | | Unstd | Std | 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 11 | 12 | 13 | 14 | 15 | BLL | DL | TL | | | |
| 1990 | 138 | 112 | 4 | 0 | 4 | 49 | 85 | 0 | 133 | 0 | 5 | 1.00 | 1.00 | – |
| 1991 | 137 | 176 | 9 | 4 | 5 | 50 | 51 | 27 | 103 | 10 | 24 | 1.54 | 1.13 | 0.90–1.42 |
| 1992 | 293 | 343 | 15 | 6 | 10 | 99 | 104 | 74 | 280 | 11 | 2 | 1.15 | 0.62 | 0.49–0.78 |
| 1993 | 290 | 320 | 13 | 10 | 7 | 67 | 145 | 61 | 283 | 7 | 0 | 1.23 | 0.52 | 0.41–0.66 |
| 1994 | 279 | 305 | 15 | 10 | 10 | 103 | 69 | 87 | 258 | 9 | 12 | 1.12 | 0.51 | 0.40–0.65 |
| 1995 | 367 | 424 | 18 | 30 | 51 | 128 | 83 | 75 | 364 | 3 | 0 | 1.43 | 0.58 | 0.45–0.73 |
| 1996 | 261 | 297 | 14 | 23 | 45 | 85 | 60 | 48 | 260 | 1 | 0 | 1.40 | 0.49 | 0.38–0.63 |
| 1997 | 296 | 283 | 12 | 33 | 57 | 113 | 23 | 70 | 296 | 0 | 0 | 1.17 | 0.51 | 0.39–0.65 |
| 1998 | 227 | 231 | 9 | 4 | 15 | 141 | 50 | 17 | 227 | 0 | 0 | 1.29 | 0.48 | 0.37–0.62 |
| 1999 | 275 | 193 | 10 | 6 | 24 | 125 | 60 | 60 | 275 | 0 | 0 | 0.86 | 0.44 | 0.34–0.56 |
| 2000 | 219 | 186 | 11 | 25 | 53 | 78 | 49 | 14 | 219 | 0 | 0 | 0.99 | 0.31 | 0.24–0.40 |
| 2001 | 251 | 168 | 7 | 7 | 32 | 61 | 130 | 21 | 251 | 0 | 0 | 0.73 | 0.35 | 0.27–0.45 |
| Total | 3 033 | 3 038 | 24 | | | | | | | | | | | |

**Line fishery all targets**

| Year | Days | Catch (t) | Vessel nos. | Statistical area | | | | | Method | | | Target species | | | Unstd | Std | 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 11 | 12 | 13 | 14 | 15 | BLL | DL | TL | BNS | HPB | LIN | | | |
| 1990 | 231 | 137 | 9 | 6 | 18 | 98 | 96 | 13 | 211 | 0 | 20 | 36 | 46 | 149 | 1.00 | 1.00 | – |
| 1991 | 283 | 192 | 15 | 9 | 25 | 102 | 100 | 47 | 226 | 18 | 39 | 125 | 16 | 142 | 0.53 | 0.70 | 0.58–0.85 |
| 1992 | 389 | 355 | 17 | 21 | 21 | 146 | 118 | 83 | 371 | 16 | 2 | 85 | 8 | 296 | 1.10 | 0.57 | 0.47–0.69 |
| 1993 | 367 | 330 | 16 | 17 | 17 | 97 | 159 | 77 | 349 | 10 | 8 | 62 | 14 | 291 | 1.34 | 0.52 | 0.42–0.63 |
| 1994 | 377 | 329 | 18 | 11 | 28 | 160 | 76 | 102 | 346 | 19 | 12 | 83 | 12 | 282 | 1.22 | 0.56 | 0.46–0.69 |
| 1995 | 514 | 462 | 22 | 38 | 70 | 209 | 86 | 111 | 483 | 21 | 10 | 81 | 32 | 401 | 1.34 | 0.52 | 0.42–0.63 |
| 1996 | 336 | 306 | 17 | 30 | 69 | 122 | 64 | 51 | 334 | 2 | 0 | 60 | 9 | 267 | 1.36 | 0.43 | 0.34–0.53 |
| 1997 | 391 | 294 | 15 | 49 | 87 | 160 | 25 | 70 | 391 | 0 | 0 | 70 | 14 | 307 | 1.10 | 0.42 | 0.34–0.52 |
| 1998 | 293 | 239 | 15 | 7 | 36 | 174 | 55 | 21 | 293 | 0 | 0 | 56 | 10 | 227 | 1.24 | 0.39 | 0.32–0.49 |
| 1999 | 325 | 197 | 15 | 10 | 55 | 132 | 64 | 64 | 325 | 0 | 0 | 46 | 4 | 275 | 0.99 | 0.37 | 0.30–0.46 |
| 2000 | 276 | 189 | 14 | 37 | 78 | 91 | 56 | 14 | 276 | 0 | 0 | 42 | 15 | 219 | 0.90 | 0.22 | 0.18–0.28 |
| 2001 | 322 | 173 | 13 | 21 | 53 | 69 | 137 | 42 | 322 | 0 | 0 | 42 | 16 | 264 | 0.73 | 0.25 | 0.20–0.31 |
| Total | 4 104 | 3 203 | 29 | | | | | | | | | | | | | | |

**Table 6: Summary of data used in the final standardised CPUE analysis of the Cook Strait line fishery, and the standardised (Std, with 95% confidence intervals) and unstandardised (Unstd) year effects for that fishery. Days, number of individual records of days fished; Catch, estimated catch (t) from the accepted records; Vessel nos., number of vessels contributing to the accepted records. The total in the "Vessel" column indicates the number of unique vessels contributing to the accepted records throughout the time series. Target species: BNS, bluenose; HPB, hapuku and bass; LIN, ling; RIB, ribaldo. Method: BLL, bottom longline; DL, dahn line.**

**Target ling line fishery**

| Year | Days | Catch (t) | Vessel nos. | Statistical area 16 | 17 | Method BLL | DL | Unstd | Std | 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 111 | 49 | 9 | 104 | 7 | 11 | 100 | 1.00 | 1.00 | – |
| 1991 | 95 | 41 | 10 | 89 | 6 | 9 | 86 | 0.69 | 1.43 | 1.03–1.98 |
| 1992 | 142 | 76 | 10 | 122 | 20 | 43 | 99 | 0.91 | 1.37 | 0.98–1.90 |
| 1993 | 169 | 66 | 11 | 164 | 5 | 36 | 133 | 0.57 | 1.04 | 0.76–1.44 |
| 1994 | 185 | 52 | 11 | 160 | 25 | 46 | 139 | 0.42 | 0.92 | 0.67–1.28 |
| 1995 | 110 | 29 | 10 | 103 | 7 | 68 | 42 | 0.42 | 0.92 | 0.64–1.33 |
| 1996 | 83 | 31 | 7 | 81 | 2 | 52 | 31 | 0.63 | 1.07 | 0.73–1.60 |
| 1998 | 55 | 20 | 2 | 53 | 2 | 28 | 27 | 0.65 | 0.98 | 0.63–1.50 |
| Total | 950 | 364 | 18 | | | | | | | |

**Line fishery all targets**

| Year | Days | Catch (t) | Vessel nos. | Statistical area 16 | 17 | Method BLL | DL | Target species BNS | HPB | LIN | Unstd | Std | 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 153 | 53 | 11 | 146 | 7 | 24 | 129 | 9 | 31 | 113 | 1.00 | 1.00 | – |
| 1991 | 138 | 47 | 11 | 132 | 6 | 25 | 113 | 8 | 31 | 99 | 0.77 | 1.21 | 0.92–1.58 |
| 1992 | 173 | 80 | 11 | 153 | 20 | 52 | 121 | 3 | 23 | 147 | 1.11 | 1.17 | 0.88–1.56 |
| 1993 | 220 | 75 | 13 | 214 | 6 | 54 | 166 | 4 | 45 | 171 | 0.67 | 0.93 | 0.71–1.23 |
| 1994 | 263 | 63 | 13 | 229 | 34 | 74 | 189 | 7 | 61 | 195 | 0.53 | 0.90 | 0.68–1.18 |
| 1995 | 206 | 39 | 12 | 177 | 29 | 96 | 110 | 30 | 58 | 118 | 0.41 | 0.82 | 0.60–1.11 |
| 1996 | 130 | 34 | 9 | 119 | 11 | 55 | 75 | 7 | 40 | 83 | 0.53 | 0.91 | 0.66–1.26 |
| 1997 | 98 | 16 | 6 | 92 | 6 | 19 | 79 | 4 | 60 | 34 | 0.38 | 1.05 | 0.75–1.48 |
| 1998 | 104 | 26 | 4 | 98 | 6 | 31 | 73 | 32 | 17 | 55 | 0.61 | 1.13 | 0.80–1.60 |
| 1999 | 71 | 22 | 4 | 56 | 15 | 21 | 50 | 5 | 47 | 19 | 0.62 | 1.91 | 1.33–2.75 |
| 2000 | 85 | 30 | 5 | 81 | 4 | 33 | 52 | 5 | 47 | 33 | 0.63 | 1.75 | 1.22–2.52 |
| 2001 | 59 | 9 | 5 | 57 | 2 | 27 | 32 | 3 | 28 | 28 | 0.37 | 1.25 | 0.83–1.90 |
| Total | 1 700 | 494 | 21 | | | | | | | | | | |

**Table 7: Summary of data used in the final standardised CPUE analyses of target trawl fisheries for hoki in Cook Strait and scampi in the Bay of Plenty, and the standardised (Std, with 95% confidence intervals) and unstandardised (Unstd) 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" column indicates the number of unique vessels contributing to the accepted records throughout the time series. Method: BT, bottom trawl; MW, midwater trawl.**

**Cook Strait target hoki trawl fishery**

| Year | Tows | Catch (t) | Vessel nos. | Statistical area 16 | Statistical area 17 | Method BT | Method MW | Both methods Unstd | Both methods Std | Both methods 95% CI | Midwater trawl only Unstd | Midwater trawl only Std | Midwater trawl only 95% CI | Bottom trawl only Unstd | Bottom trawl only Std | Bottom trawl only 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 656 | 219 | 14 | 367 | 289 | 11 | 645 | 1.00 | 1.00 | – | 1.00 | 1.00 | – | | | |
| 1991 | 1 164 | 324 | 20 | 719 | 445 | 10 | 1 154 | 0.72 | 0.82 | 0.74–0.91 | 0.73 | 0.85 | 0.76–0.94 | | | |
| 1992 | 788 | 194 | 17 | 520 | 268 | 6 | 782 | 0.63 | 0.77 | 0.69–0.86 | 0.64 | 0.79 | 0.70–0.88 | | | |
| 1993 | 726 | 183 | 13 | 471 | 255 | 16 | 710 | 0.67 | 0.78 | 0.70–0.88 | 0.66 | 0.82 | 0.72–0.93 | | | |
| 1994 | 803 | 136 | 15 | 531 | 272 | 209 | 594 | 0.53 | 0.55 | 0.48–0.62 | 0.45 | 0.61 | 0.53–0.70 | 1.00 | 1.00 | – |
| 1995 | 1 407 | 188 | 19 | 944 | 463 | 554 | 853 | 0.48 | 0.47 | 0.42–0.53 | 0.46 | 0.54 | 0.47–0.62 | 0.59 | 0.79 | 0.68–0.91 |
| 1996 | 1 436 | 188 | 22 | 960 | 476 | 653 | 783 | 0.48 | 0.46 | 0.41–0.52 | 0.45 | 0.56 | 0.48–0.64 | 0.62 | 0.77 | 0.67–0.90 |
| 1997 | 1 726 | 234 | 25 | 1 098 | 627 | 690 | 1 035 | 0.41 | 0.44 | 0.39–0.50 | 0.37 | 0.47 | 0.41–0.54 | 0.58 | 0.75 | 0.65–0.87 |
| 1998 | 1 491 | 180 | 19 | 947 | 544 | 435 | 1 056 | 0.39 | 0.47 | 0.41–0.53 | 0.33 | 0.48 | 0.42–0.55 | 0.72 | 0.97 | 0.82–1.14 |
| 1999 | 1 678 | 191 | 18 | 1 017 | 661 | 585 | 1 093 | 0.34 | 0.45 | 0.40–0.51 | 0.26 | 0.43 | 0.39–0.50 | 0.70 | 1.11 | 0.95–1.30 |
| 2000 | 1 449 | 163 | 17 | 1 078 | 371 | 413 | 1 036 | 0.34 | 0.50 | 0.44–0.56 | 0.29 | 0.50 | 0.44–0.57 | 0.65 | 1.00 | 0.84–1.18 |
| 2001 | 1 319 | 196 | 19 | 1 064 | 255 | 192 | 1 127 | 0.37 | 0.60 | 0.53–0.68 | 0.35 | 0.62 | 0.54–0.71 | 0.75 | 1.14 | 0.94–1.38 |
| Total | 14 643 | | 37 | | | | | | | | | | | | | |

**Bay of Plenty target scampi trawl fishery**

| Year | Tows | Catch (t) | Vessel nos. | Statistical area 8 | Statistical area 9 | Statistical area 10 | Unstd | Std | 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 671 | 28 | 5 | 170 | 473 | 28 | 1.00 | 1.00 | – |
| 1991 | 1 403 | 75 | 9 | 837 | 534 | 31 | 1.07 | 0.84 | 0.78–0.92 |
| 1992 | 540 | 45 | 8 | 339 | 201 | 0 | 1.40 | 1.04 | 0.95–1.15 |
| 1993 | 355 | 31 | 4 | 198 | 157 | 0 | 1.92 | 1.29 | 1.16–1.44 |
| 1994 | 280 | 38 | 5 | 143 | 108 | 29 | 1.96 | 1.23 | 1.10–1.39 |
| 1995 | 226 | 21 | 5 | 195 | 26 | 5 | 1.00 | 1.07 | 0.95–1.21 |
| 1996 | 228 | 16 | 6 | 143 | 85 | 0 | 1.19 | 0.84 | 0.74–0.95 |
| 1997 | 356 | 15 | 3 | 265 | 90 | 1 | 0.85 | 0.85 | 0.76–0.95 |
| 1998 | 224 | 11 | 6 | 130 | 95 | 0 | 0.96 | 0.93 | 0.82–1.04 |
| 1999 | 234 | 22 | 6 | 122 | 109 | 3 | 2.10 | 1.91 | 1.69–2.16 |
| 2000 | 742 | 75 | 7 | 518 | 220 | 4 | 2.45 | 2.53 | 2.30–2.80 |
| 2001 | 1 000 | 104 | 8 | 662 | 337 | 1 | 2.29 | 2.25 | 2.03–2.49 |
| Total | 6 259 | | 11 | | | | | | |

**Table 8: Standardised CPUE models from the two analysed trawl fisheries, showing the change in residual deviance (%) as each new variable was added.**

| Step | Variable | % deviance |
|---|---|---|
| **Cook Strait hoki target** | | |
| | **Both fishing methods** | |
| | Year | 6.5 |
| 1 | Vessel | 19.9 |
| 2 | Duration | 24.2 |
| 3 | Headlineht | 27.1 |
| 4 | Month | 29.0 |
| 5 | Duration:Height | 29.8 |
| 6 | Month:Duration | 30.4 |
| 7 | Month:Height | 31.0 |
| | **Midwater trawl only** | |
| | Year | 10.6 |
| 1 | Vessel | 24.9 |
| 2 | Month | 27.8 |
| 3 | Duration | 29.8 |
| 4 | Headlineht | 30.7 |
| 5 | Month:Height | 31.5 |
| 6 | Month:Duration | 32.3 |
| 7 | Depbttm | 32.8 |
| | **Bottom trawl only** | |
| | Year | 2.4 |
| 1 | Duration | 14.1 |
| 2 | Vessel | 21.0 |
| 3 | Month | 24.8 |
| 4 | Month:Duration | 26.5 |
| 5 | Depbttm | 27.5 |
| 6 | Totalcatch | 28.0 |
| **Bay of Plenty scampi target** | | |
| | Year | 14.2 |
| 1 | Vessel | 24.2 |
| 2 | Month | 32.5 |
| 3 | Depbttm | 38.7 |
| 4 | Midtime | 42.9 |
| 5 | Statarea | 45.4 |
| 6 | Month:Statarea | 48.3 |
| 7 | Duration | 49.4 |
| 8 | Month:Midtime | 50.1 |
| 9 | Month:Depbttm | 50.8 |

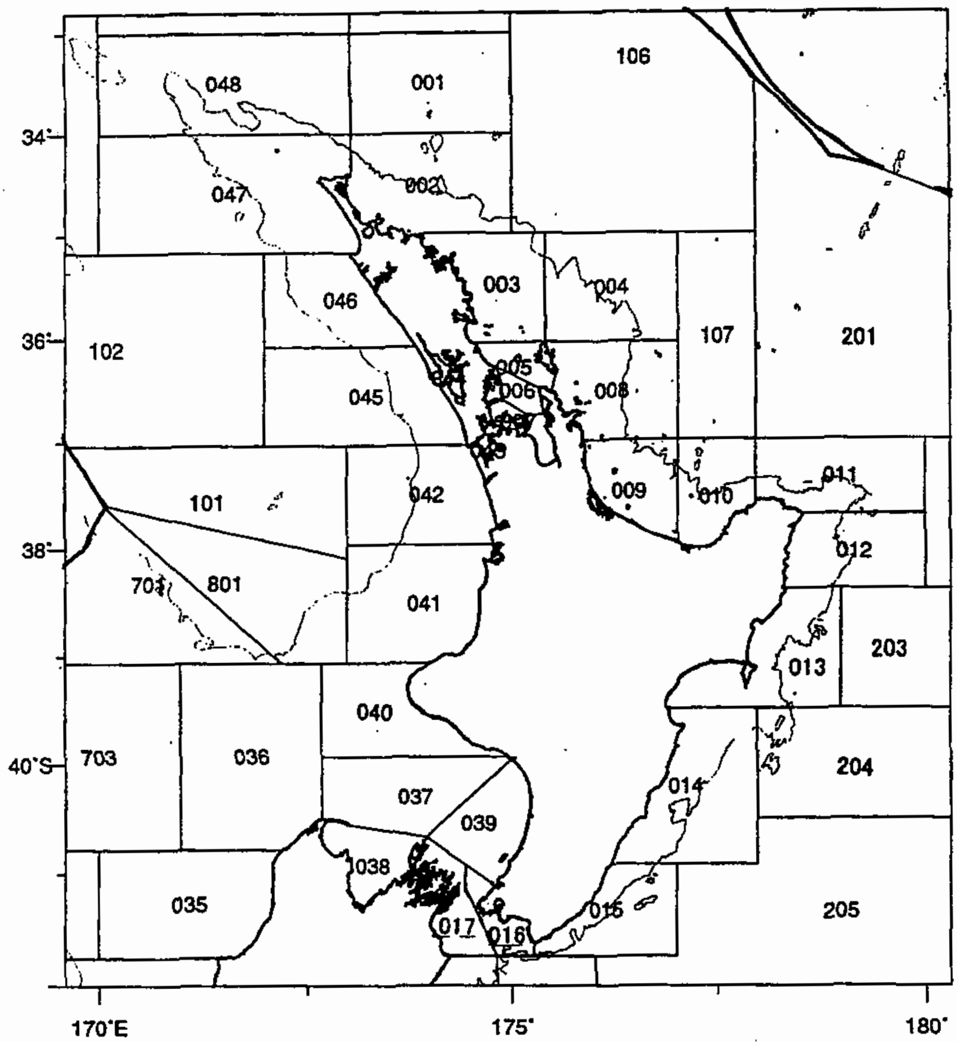



**Figure 1: Map of the waters around northern New Zealand with statistical areas. The 1000 m isobath is also plotted.**

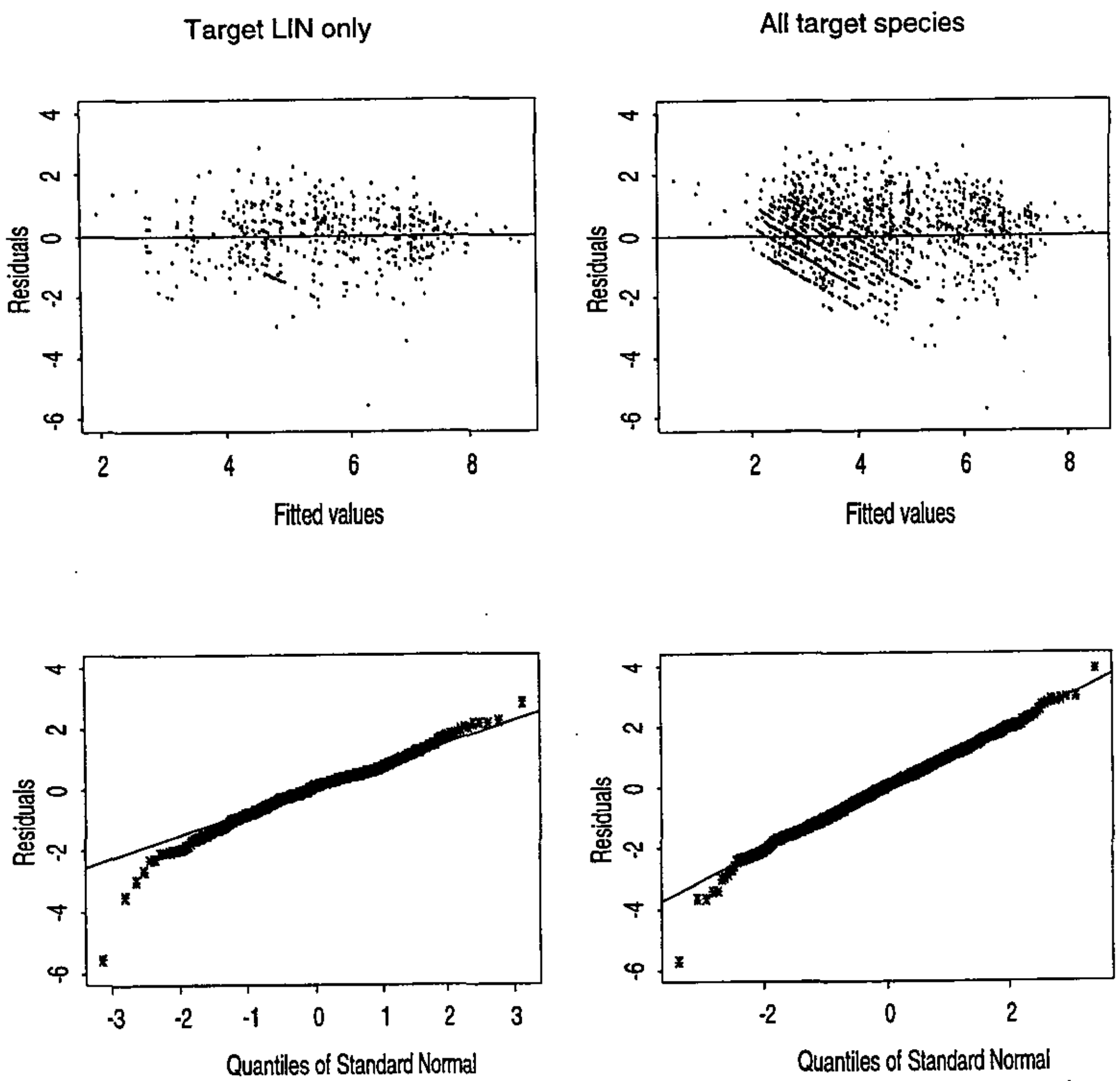



**Figure 2: Diagnostic plots for the CPUE model of the Northland line fishery.**

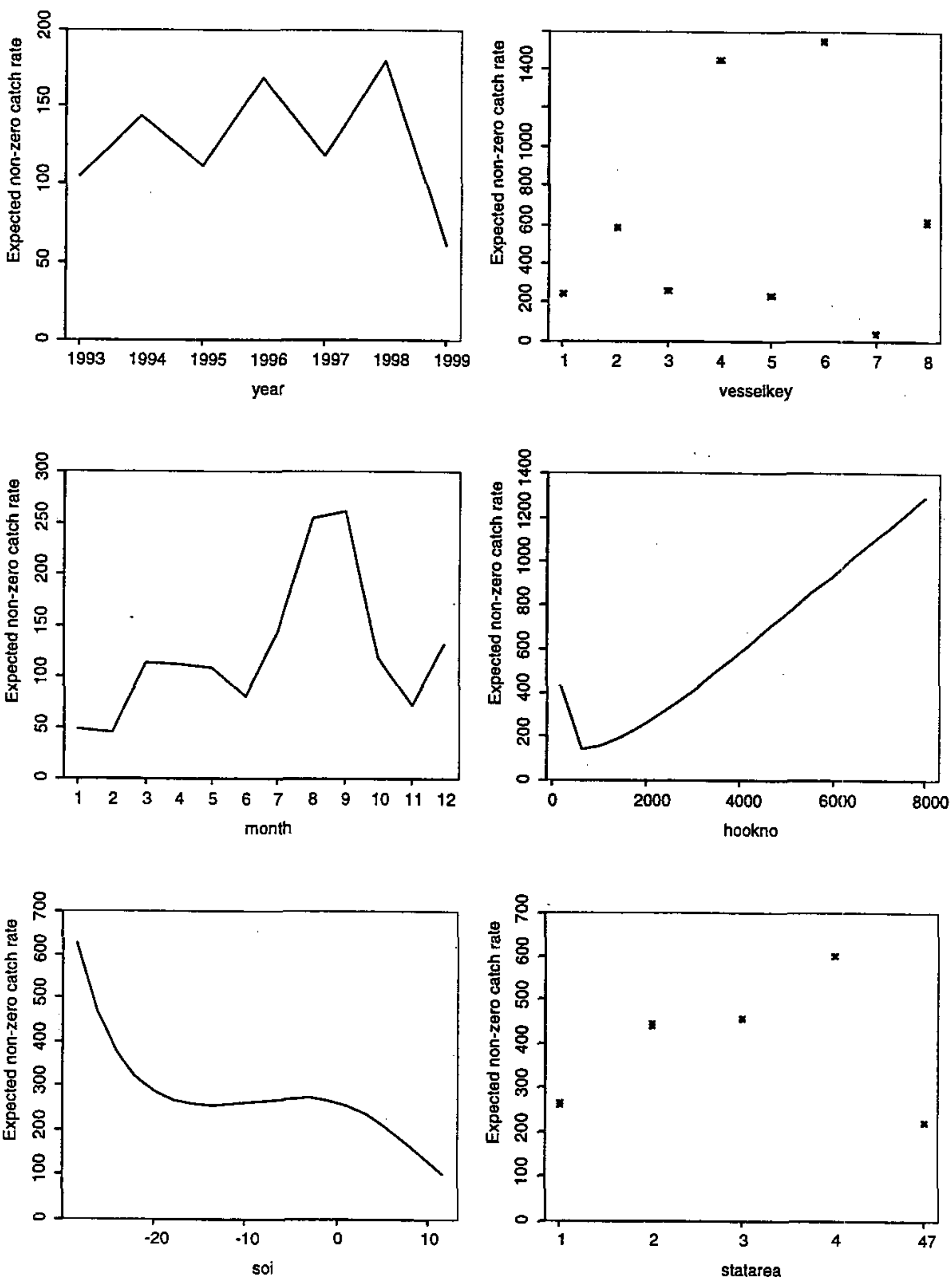



**Figure 3: Expected variable effects for variables selected into the CPUE model for the Northland ling target line fishery. "Expected non-zero catch rate" is kg per day in this fishery. In the "method" plot, the methods are bottom longline (BLL), dahn line (DL), and trot line (TL).**

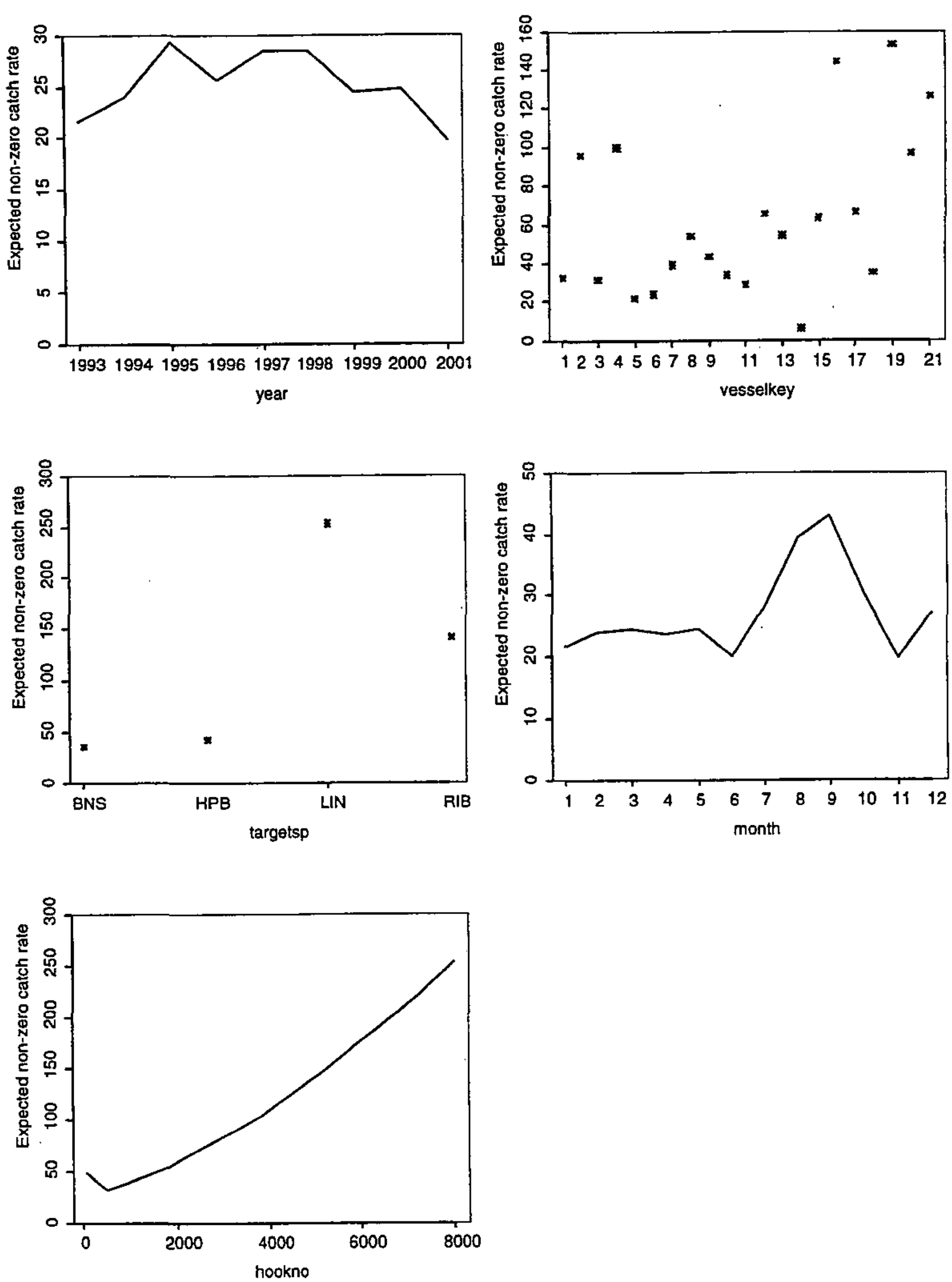



**Figure 4: Expected variable effects for variables selected into the CPUE model for the Northland line fisheries targeting middle depth species. "Expected non-zero catch rate" is kg per day in this fishery. In the "target species" plot, the species are bluenose (BNS), hapuku and bass (HPB), ling (LIN), and ribaldo (RIB).**

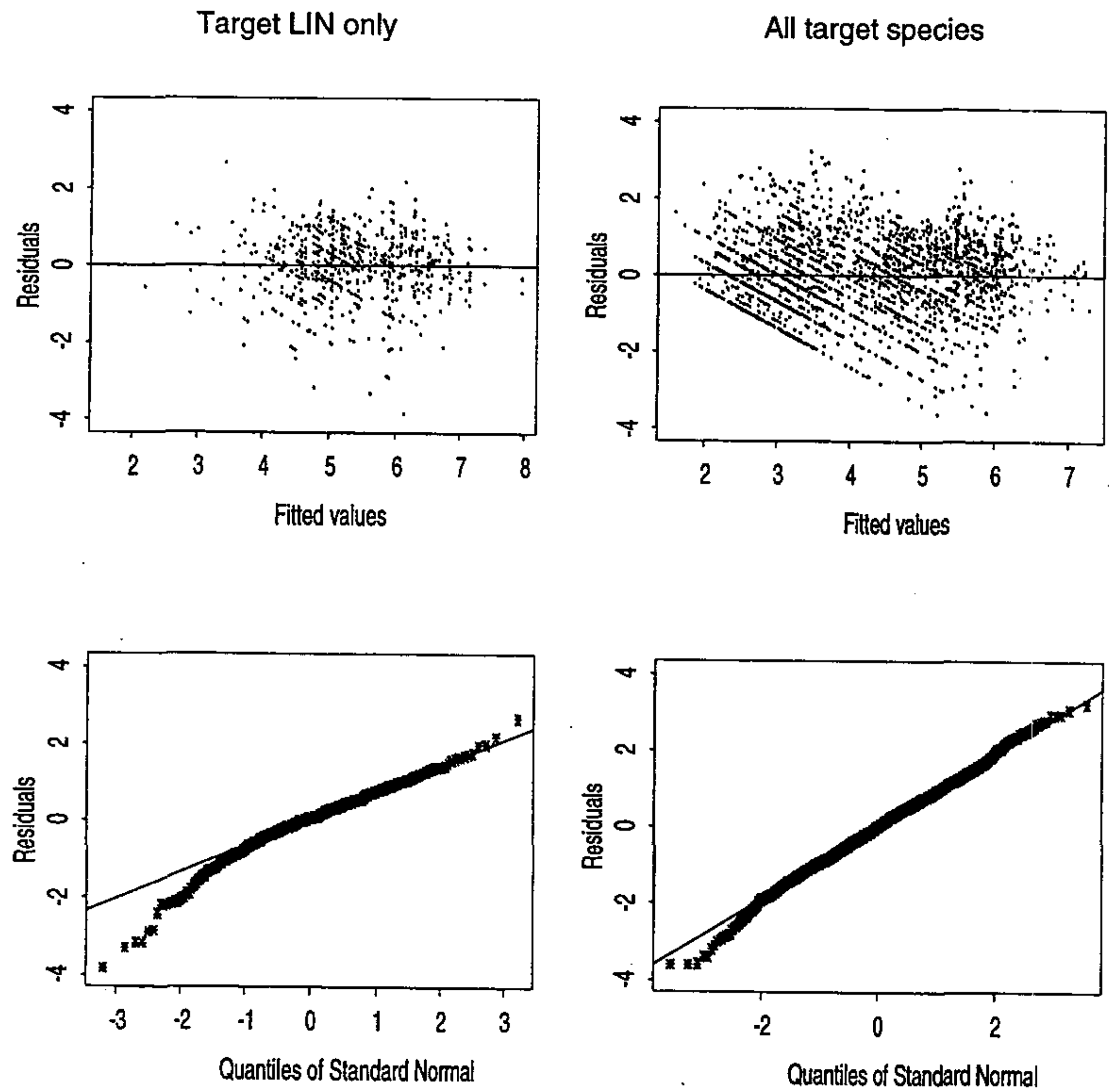



**Figure 5: Diagnostic plots for the CPUE model of the Bay of Plenty line fishery.**

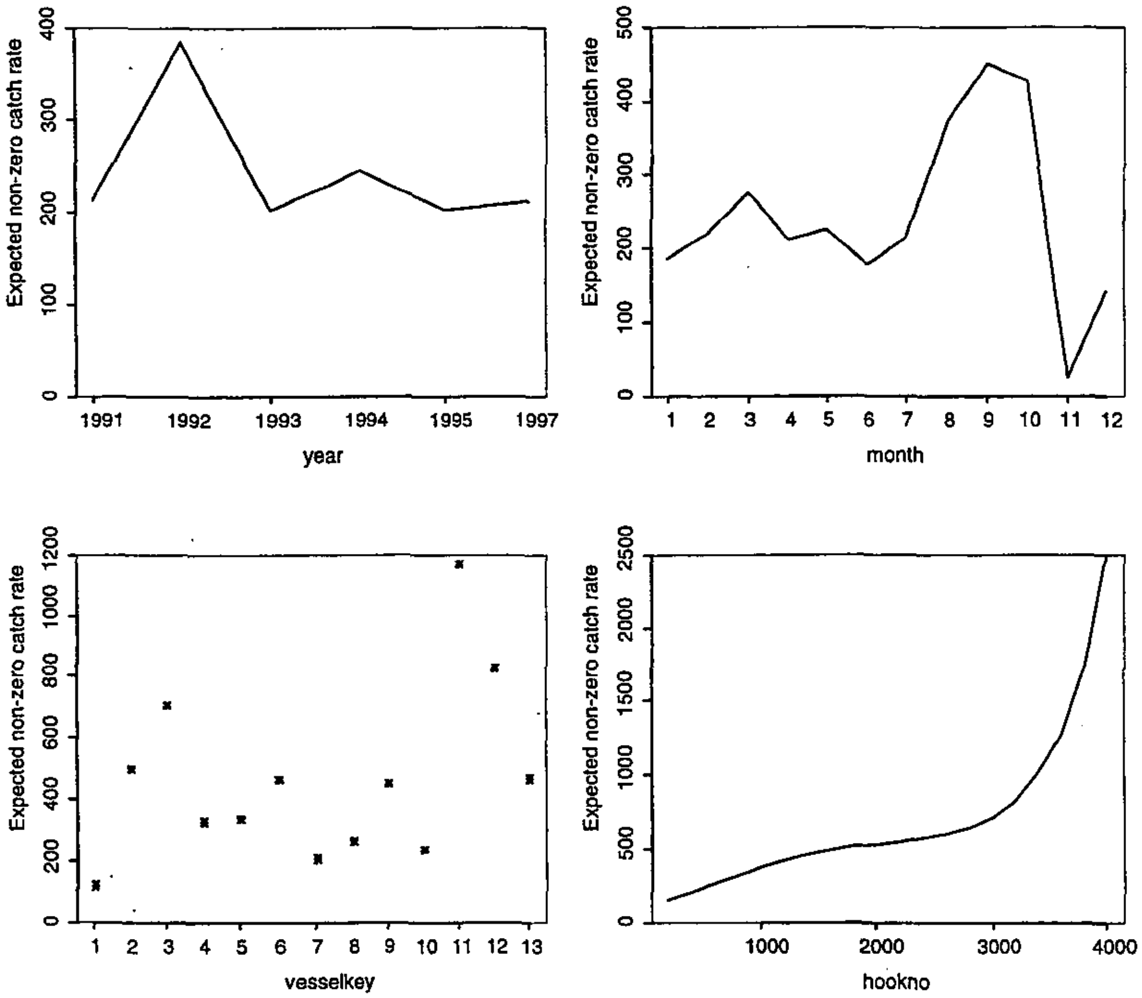



**Figure 6: Expected variable effects for variables selected into the CPUE model for the Bay of Plenty ling target line fishery. "Expected non-zero catch rate" is kg per day in this fishery. Note that there is no data point from 1996 in the year effects.**

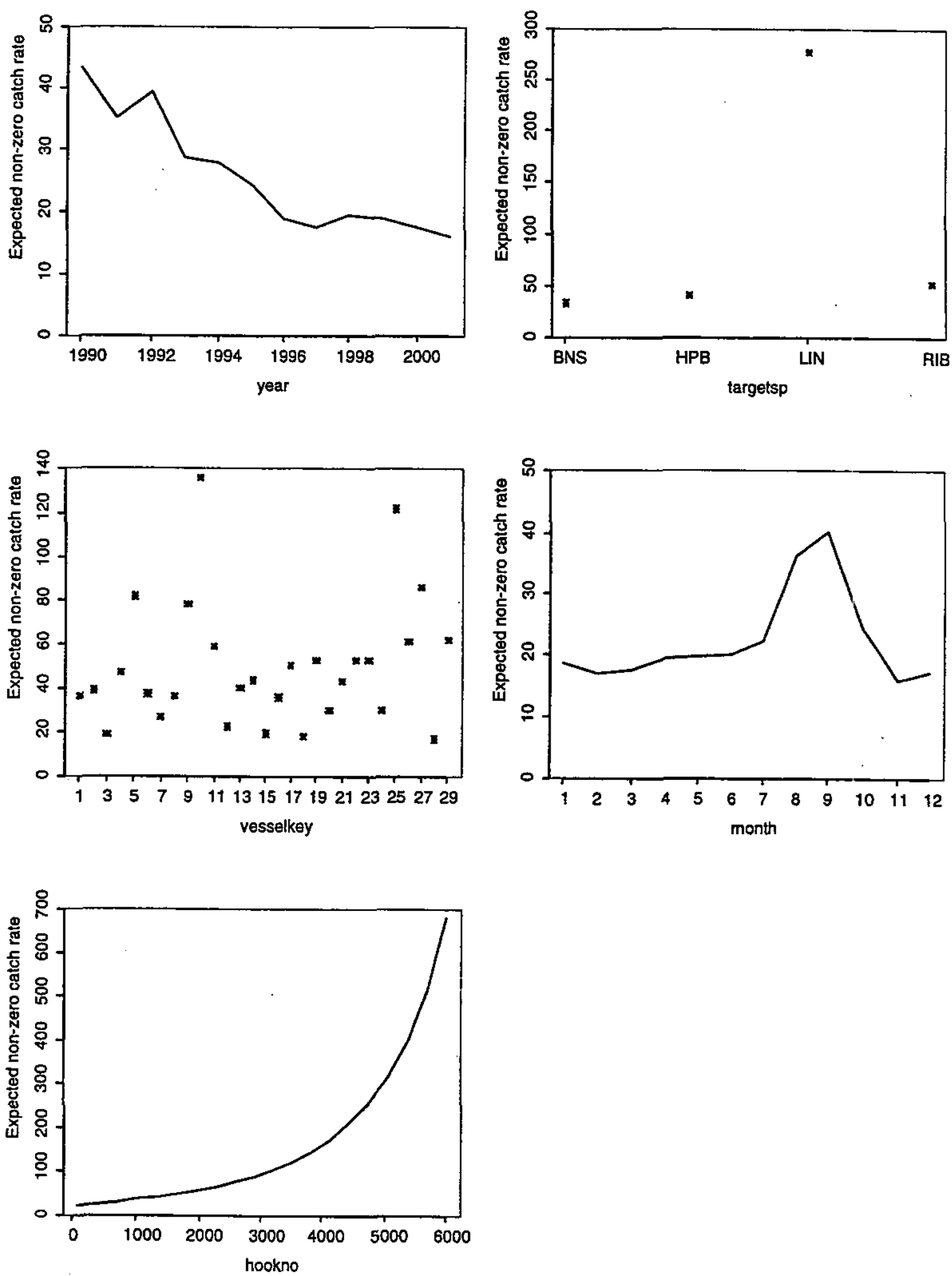



**Figure 7: Expected variable effects for variables selected into the CPUE model for the Bay of Plenty line fisheries targeting middle depth species. "Expected non-zero catch rate" is kg per day in this fishery. In the "target species" plot, the species are bluenose (BNS), hapuku and bass (HPB), ling (LIN), and ribaldo (RIB).**

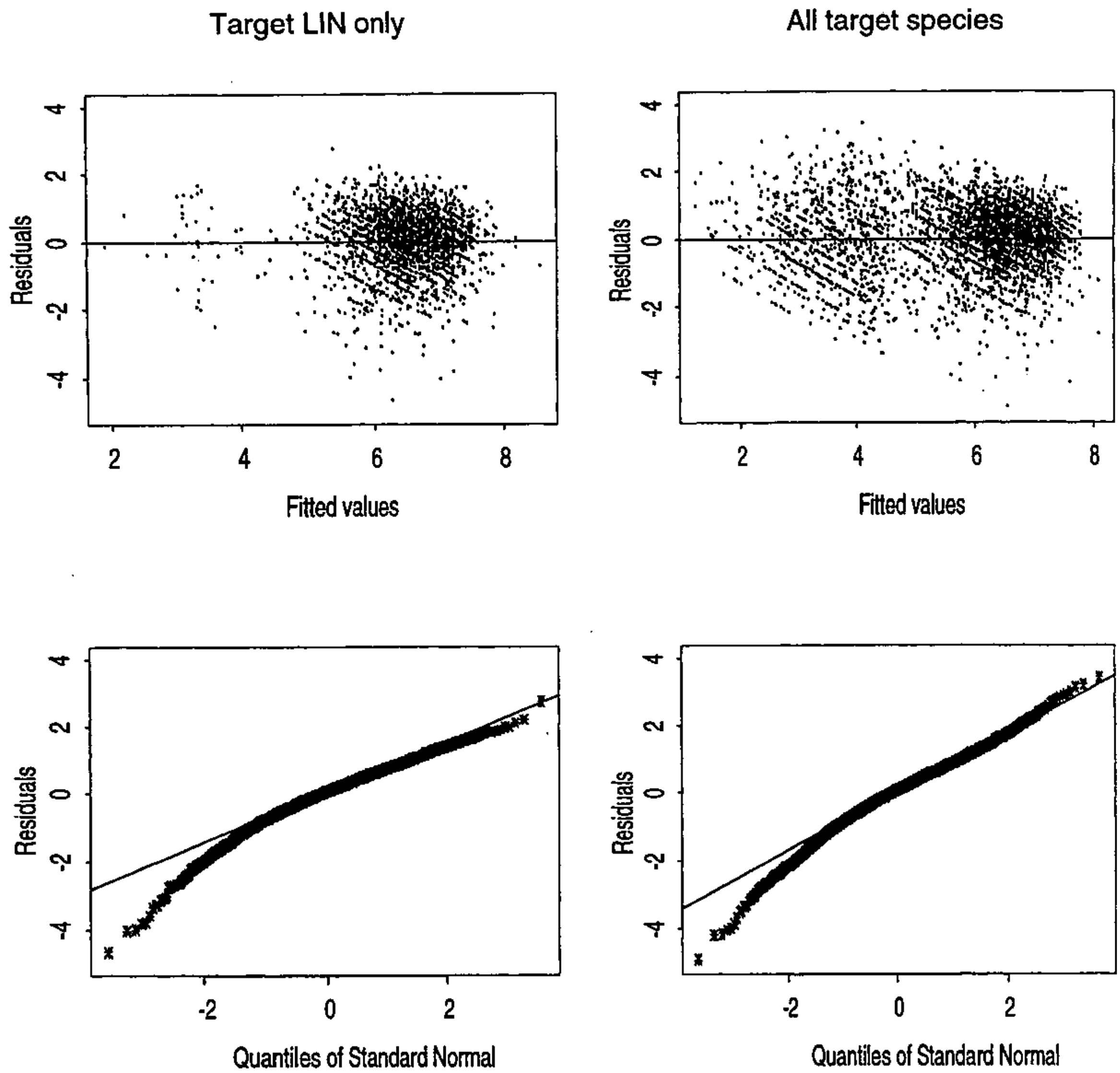



**Figure 8: Diagnostic plots for the CPUE model of the east coast North Island line fishery.**

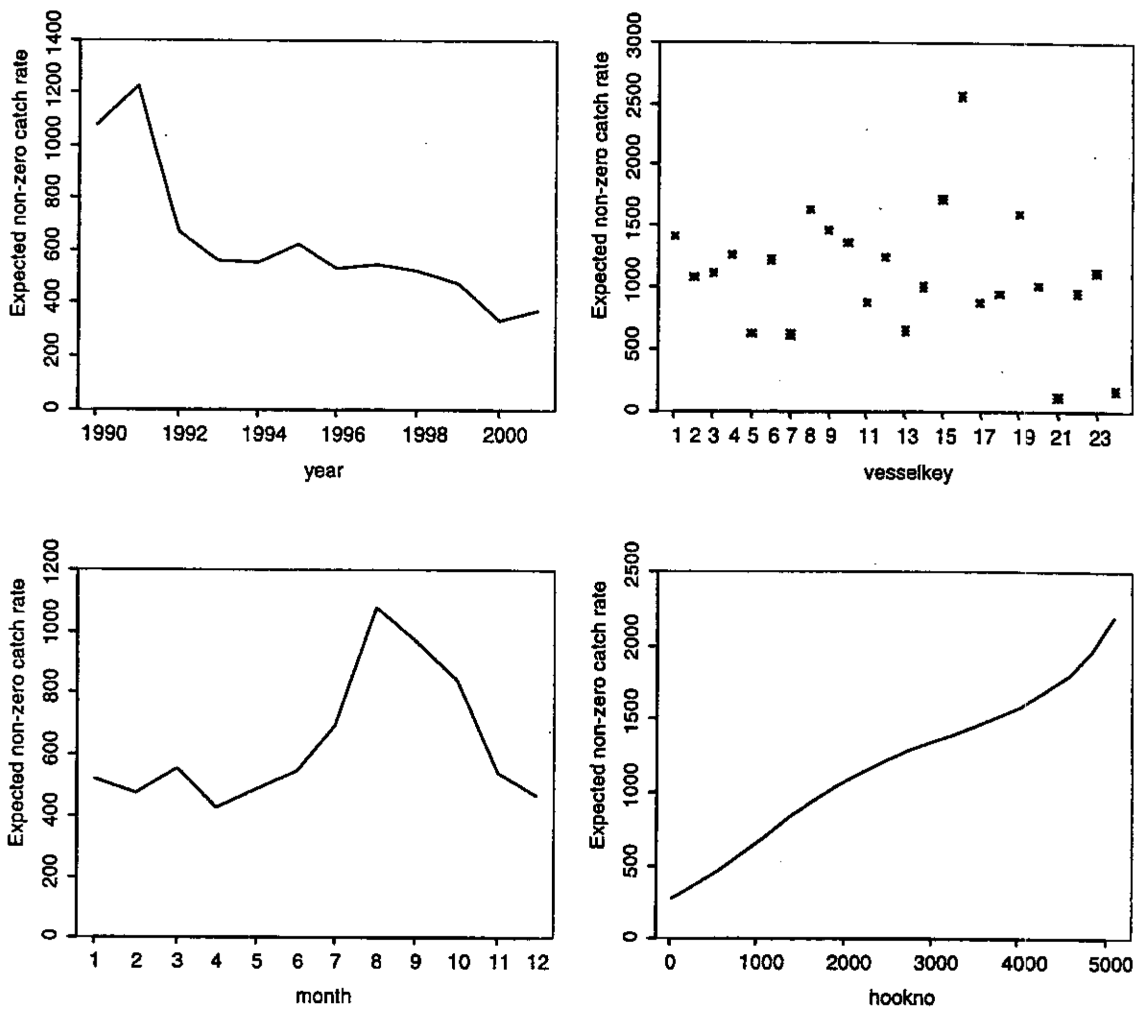



**Figure 9: Expected variable effects for variables selected into the CPUE model for the east coast North Island ling target line fishery. "Expected non-zero catch rate" is kg per day in this fishery.**

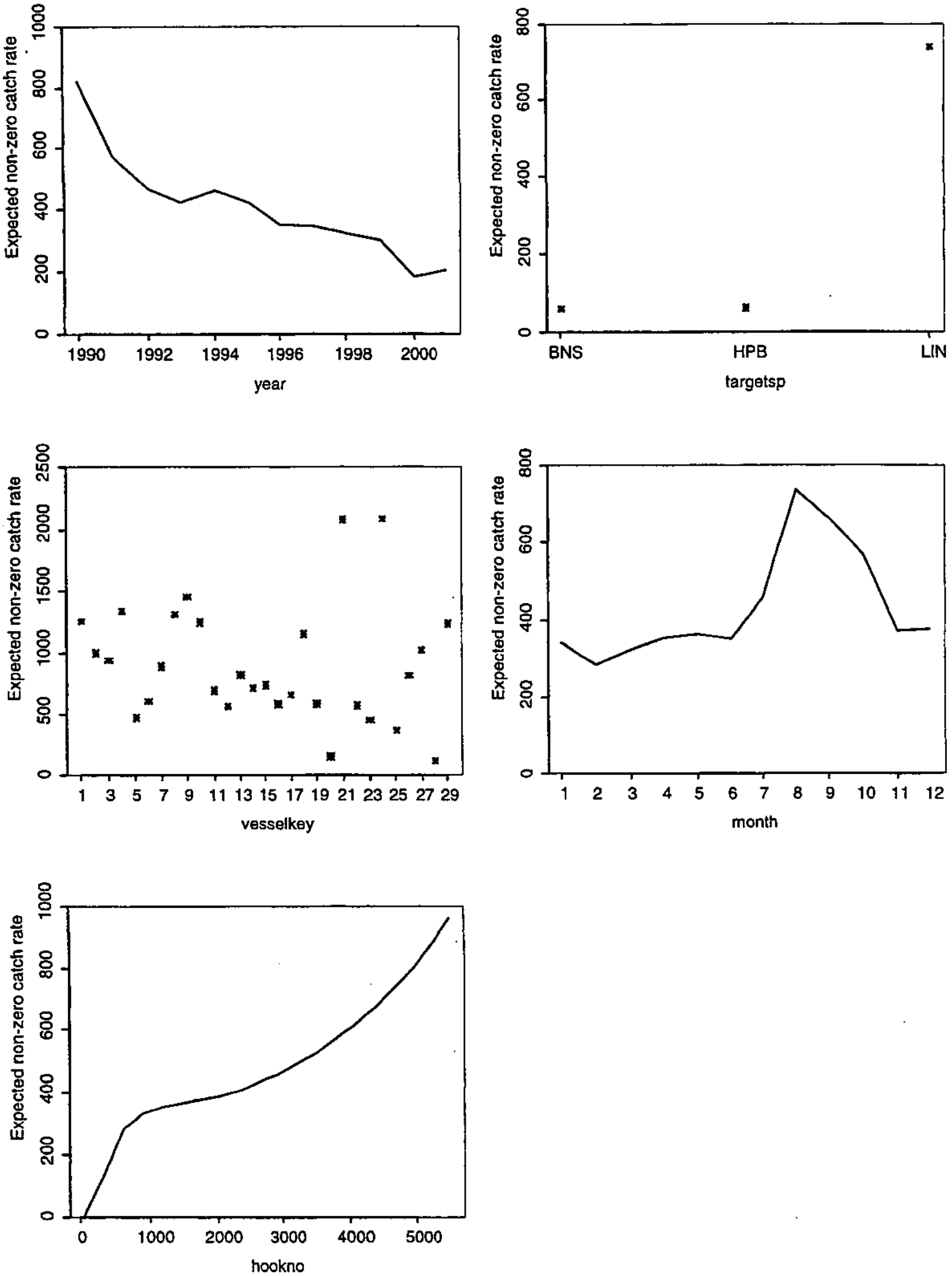



**Figure 10: Expected variable effects for variables selected into the CPUE model for the east coast North Island line fishery targeting middle depth species. "Expected non-zero catch rate" is kg per day in this fishery.**

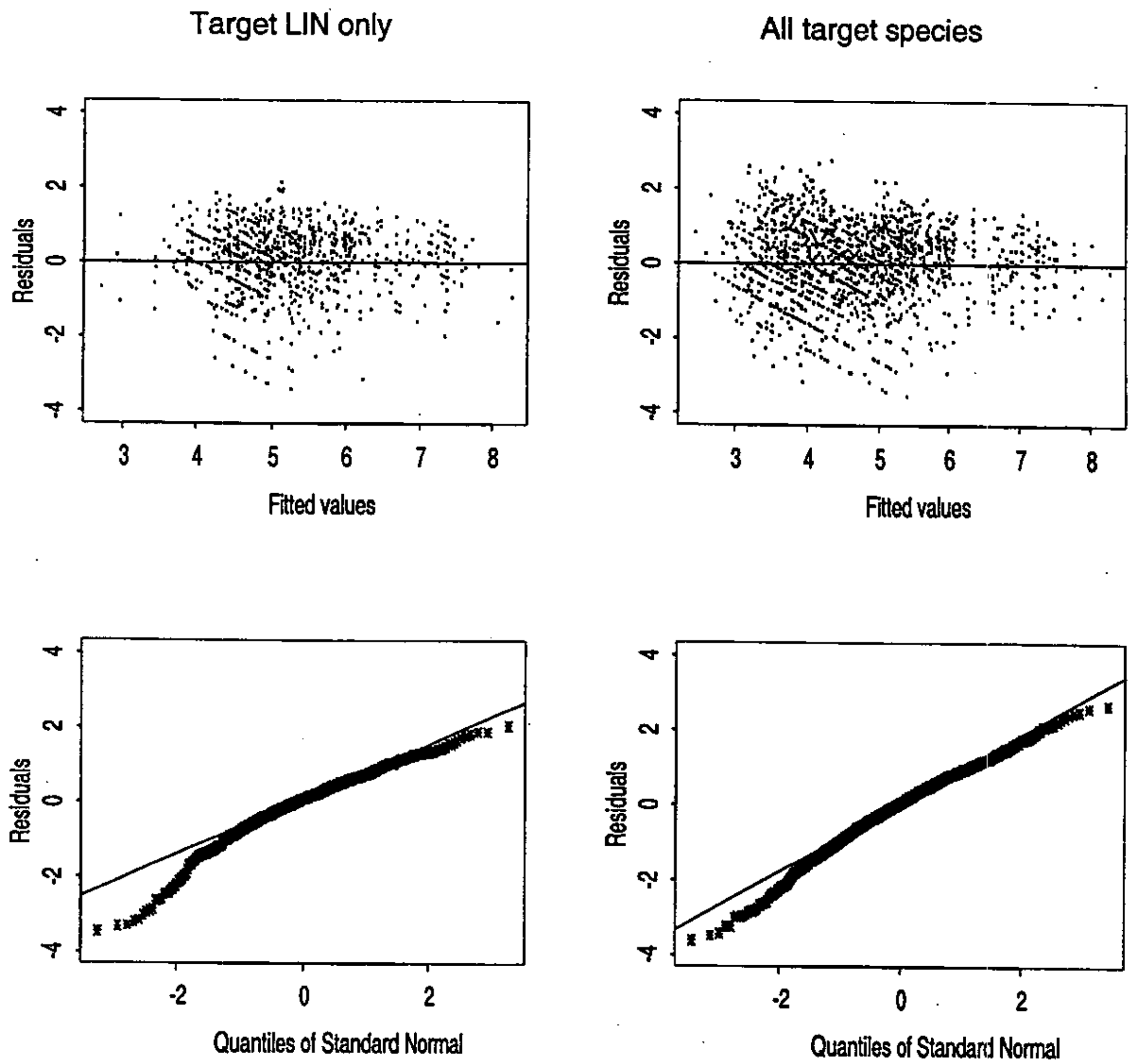



**Figure 11: Diagnostic plots for the CPUE model of the Cook Strait ling line fishery.**

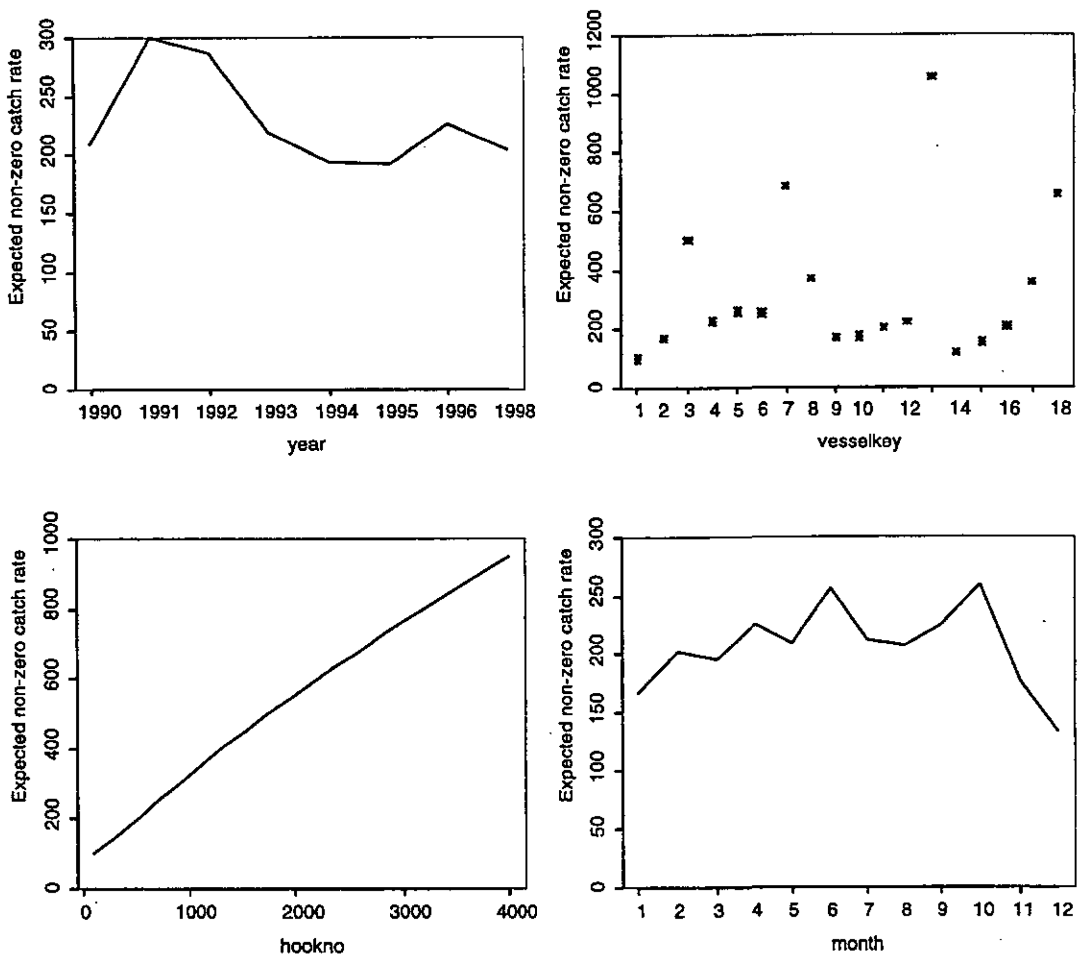



**Figure 12: Expected variable effects for variables selected into the CPUE model for the Cook Strait ling target line fishery. "Expected non-zero catch rate" is kg per day in this fishery. Note that there is no data point from 1997 in the year effects.**

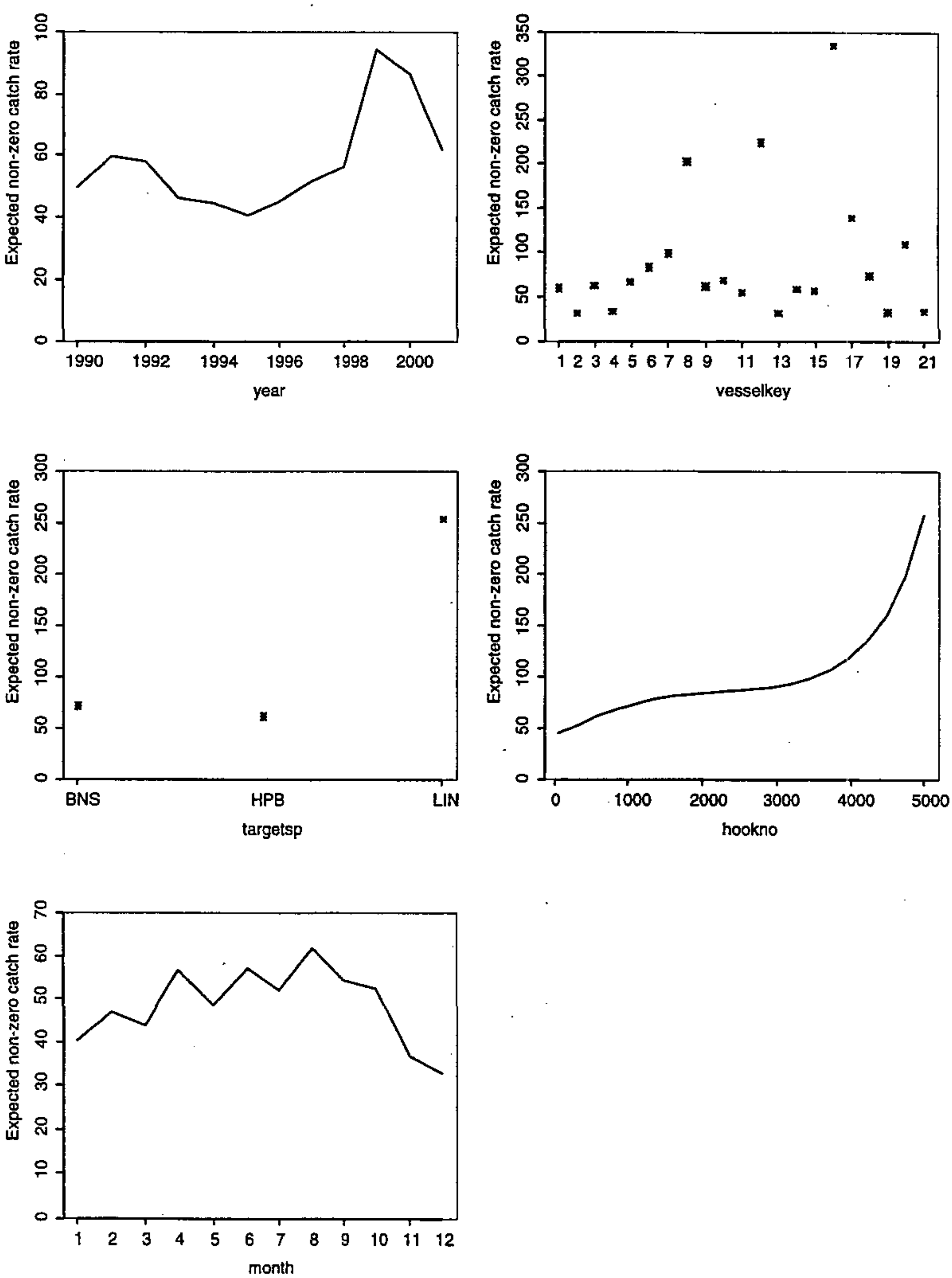



**Figure 13: Expected variable effects for variables selected into the CPUE model for the Cook Strait line fisheries targeting middle depth species. "Expected non-zero catch rate" is kg per day in this fishery.**

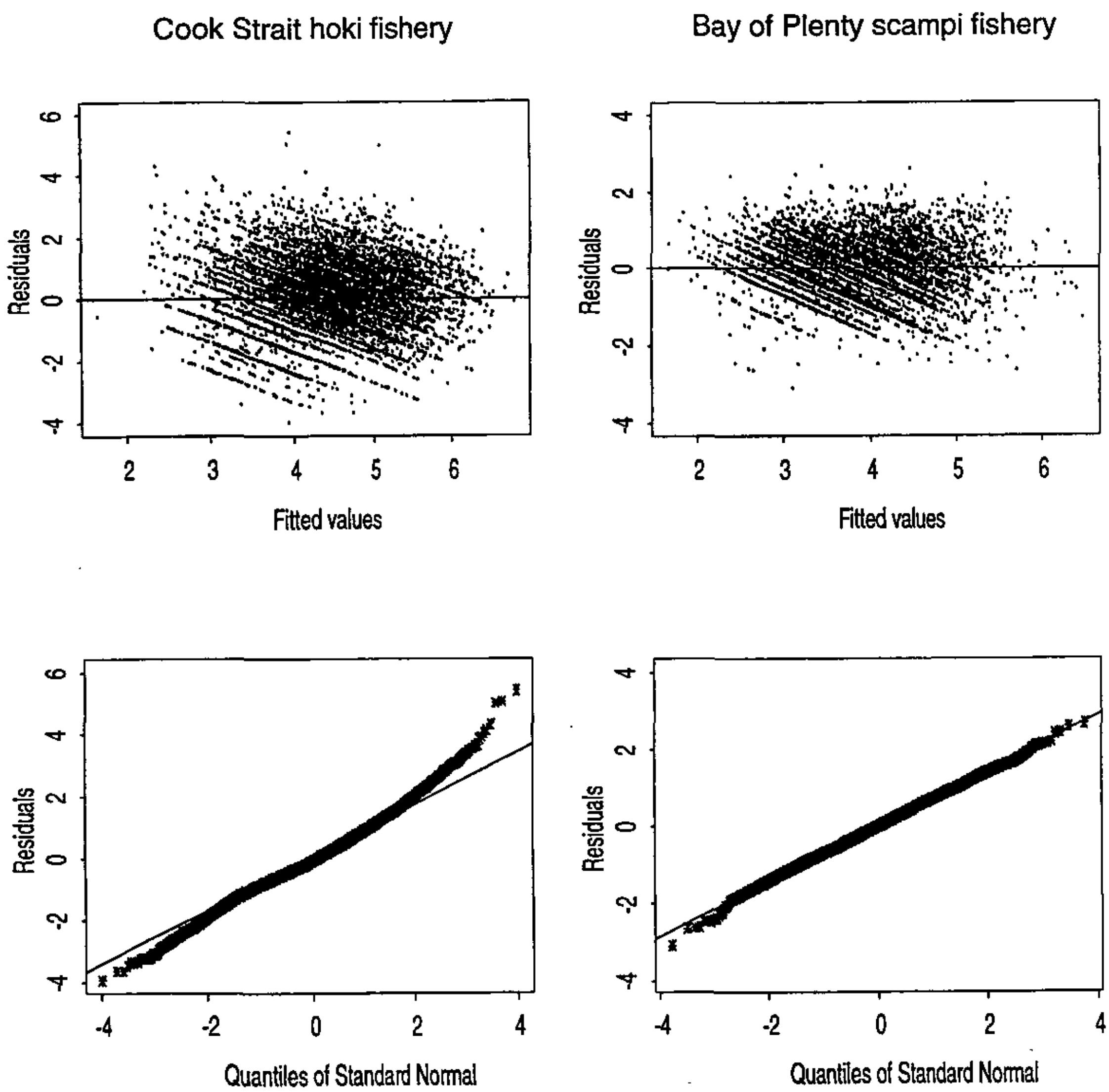



**Figure 14: Diagnostic plots for the CPUE models of the trawl fisheries targeting hoki in Cook Strait (midwater and bottom trawl data combined) or scampi in the Bay of Plenty.**

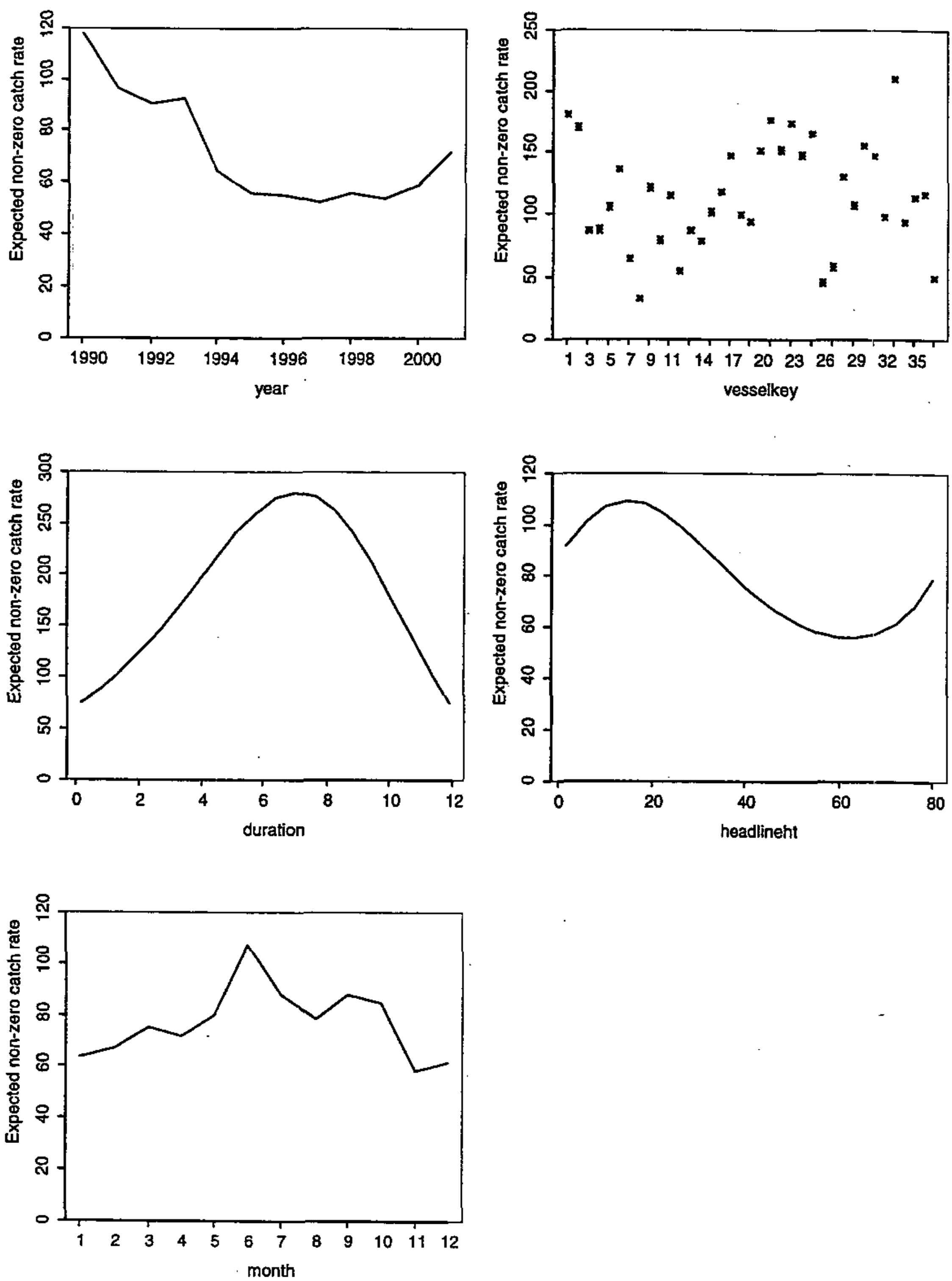



**Figure 15: Expected variable effects for variables selected into the CPUE model for ling catches in the trawl fishery targeting hoki in Cook Strait, using data from midwater and bottom trawl combined. "Expected non-zero catch rate" is kg per tow in this fishery.**

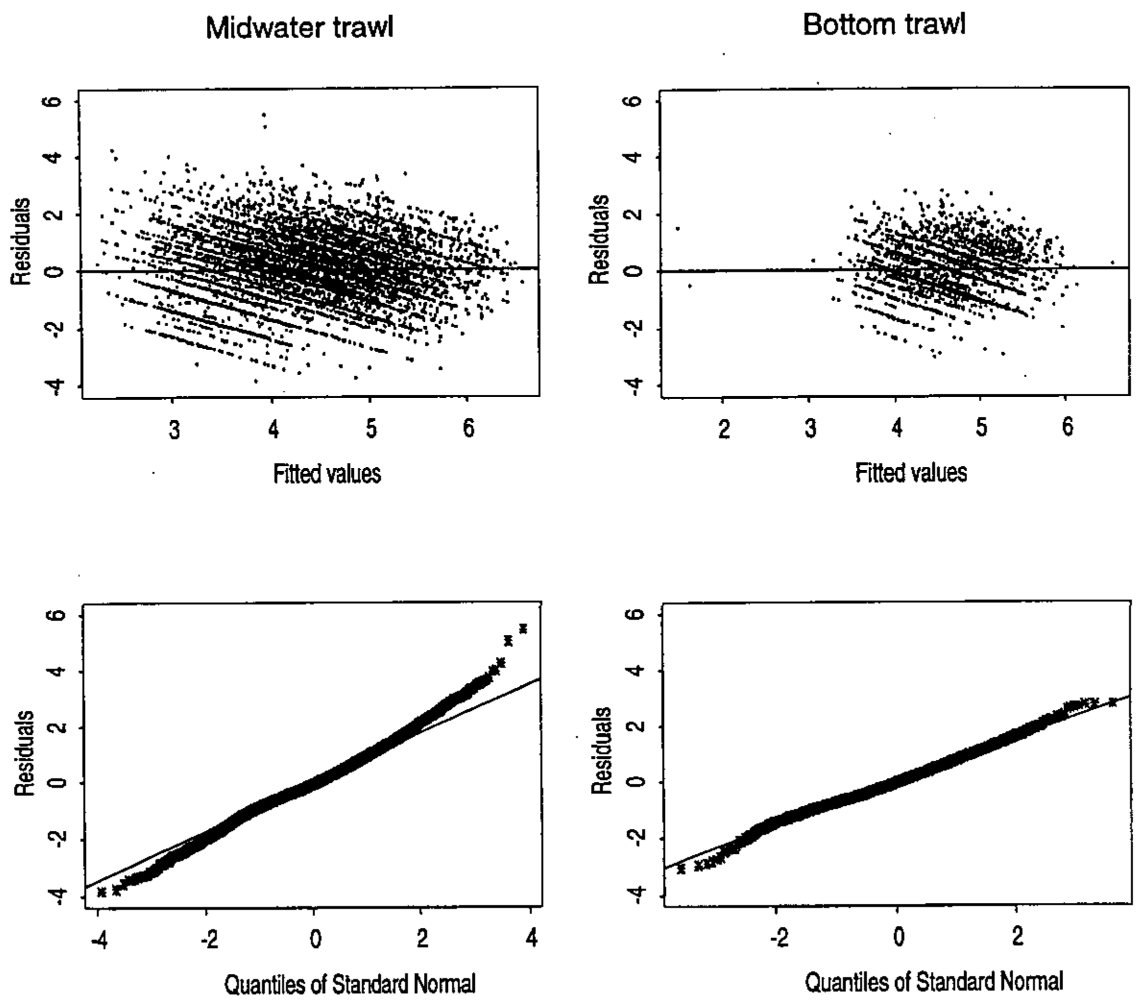



**Figure 16: Diagnostic plots for the CPUE models of the trawl fisheries targeting hoki in Cook Strait, from analyses using midwater trawl data only and bottom trawl data only.**

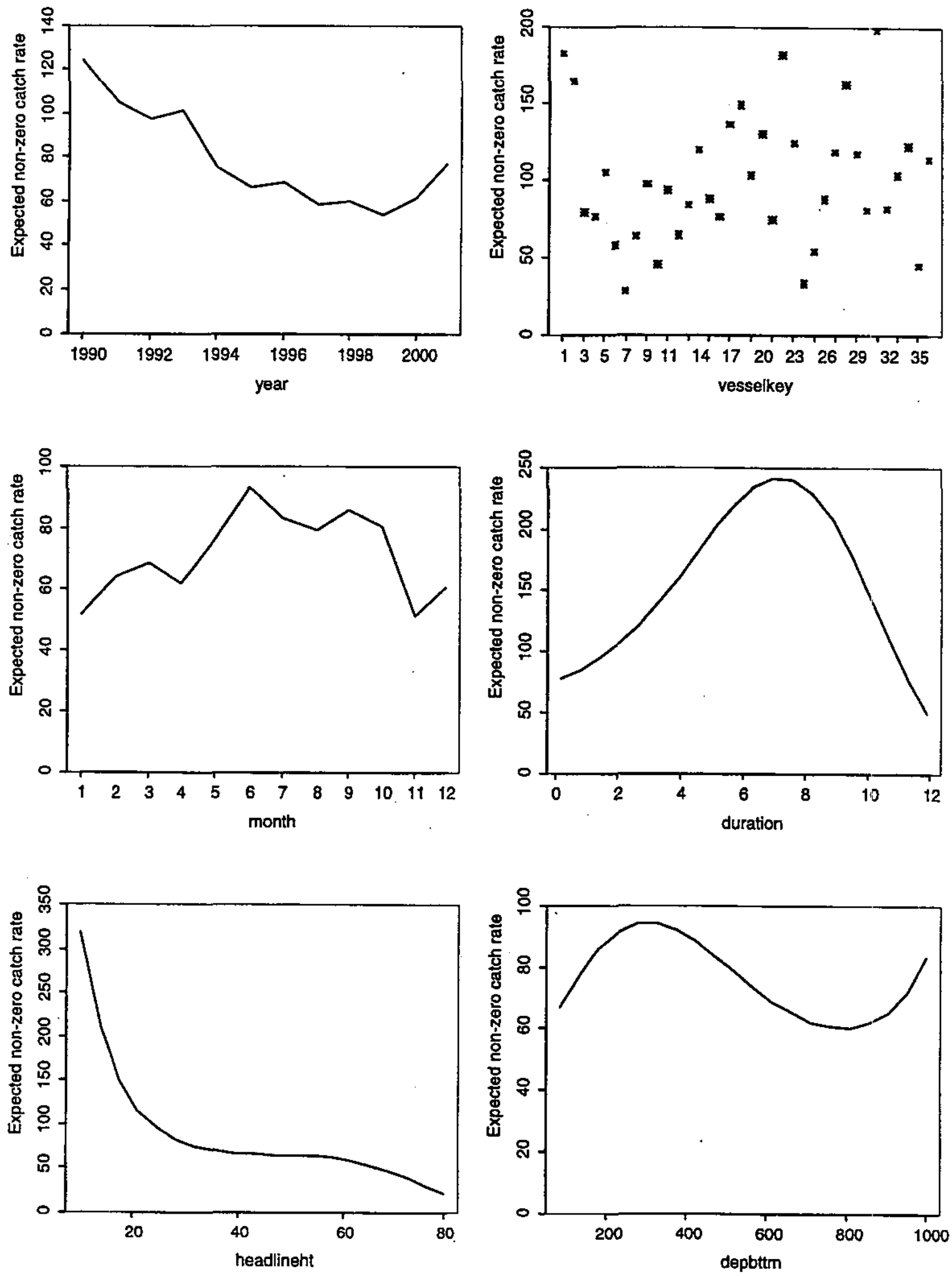



**Figure 17: Expected variable effects for variables selected into the CPUE model for ling catches in the trawl fishery targeting hoki in Cook Strait, using data from midwater trawl only. "Expected non-zero catch rate" is kg per tow in this fishery.**

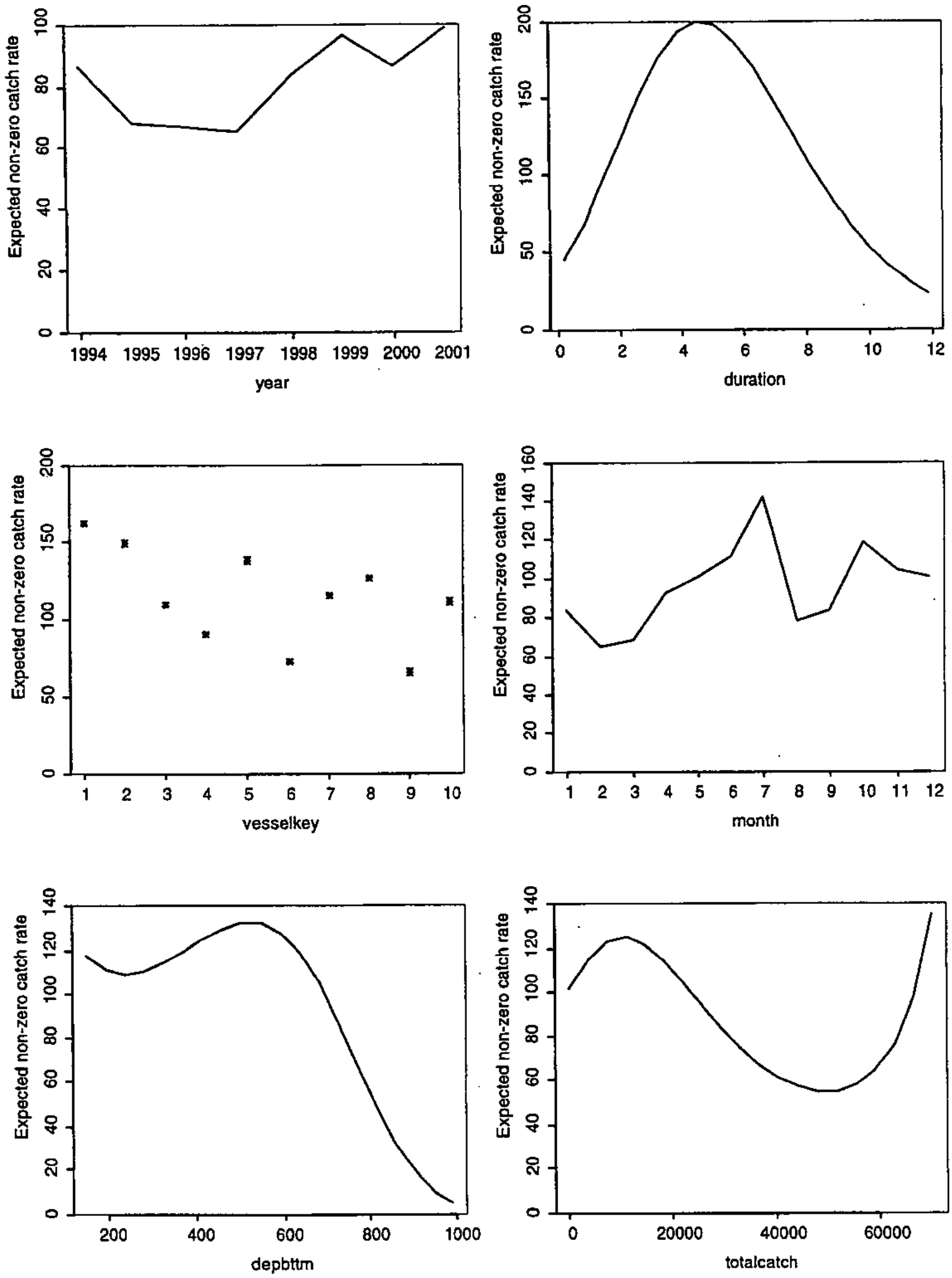



**Figure 18: Expected variable effects for variables selected into the CPUE model for ling catches in the trawl fishery targeting hoki in Cook Strait, using data from bottom trawl only. "Expected non-zero catch rate" is kg per tow in this fishery.**

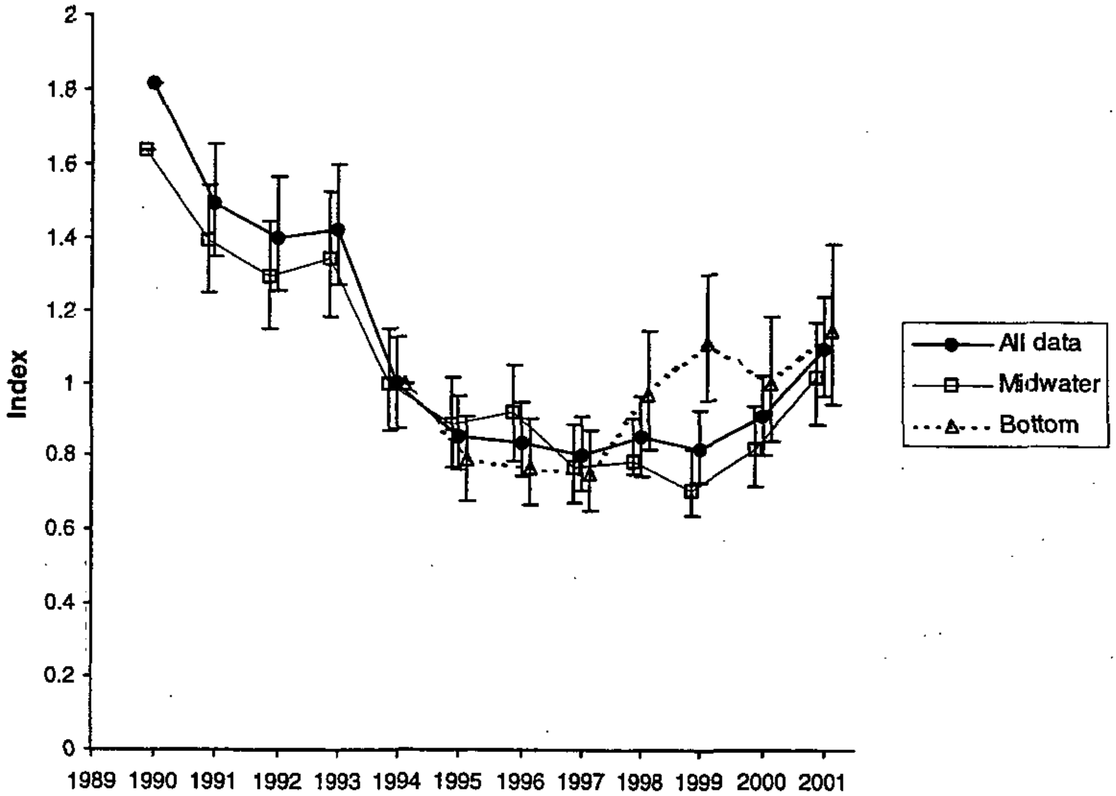



**Figure 19: Comparison of the three standardised series of indices from the Cook Strait hoki target trawl fishery (i.e., all data, midwater trawl only, bottom trawl only). All the series have been standardised to have an index of 1 in 1994. Vertical bars are 95% confidence intervals.**

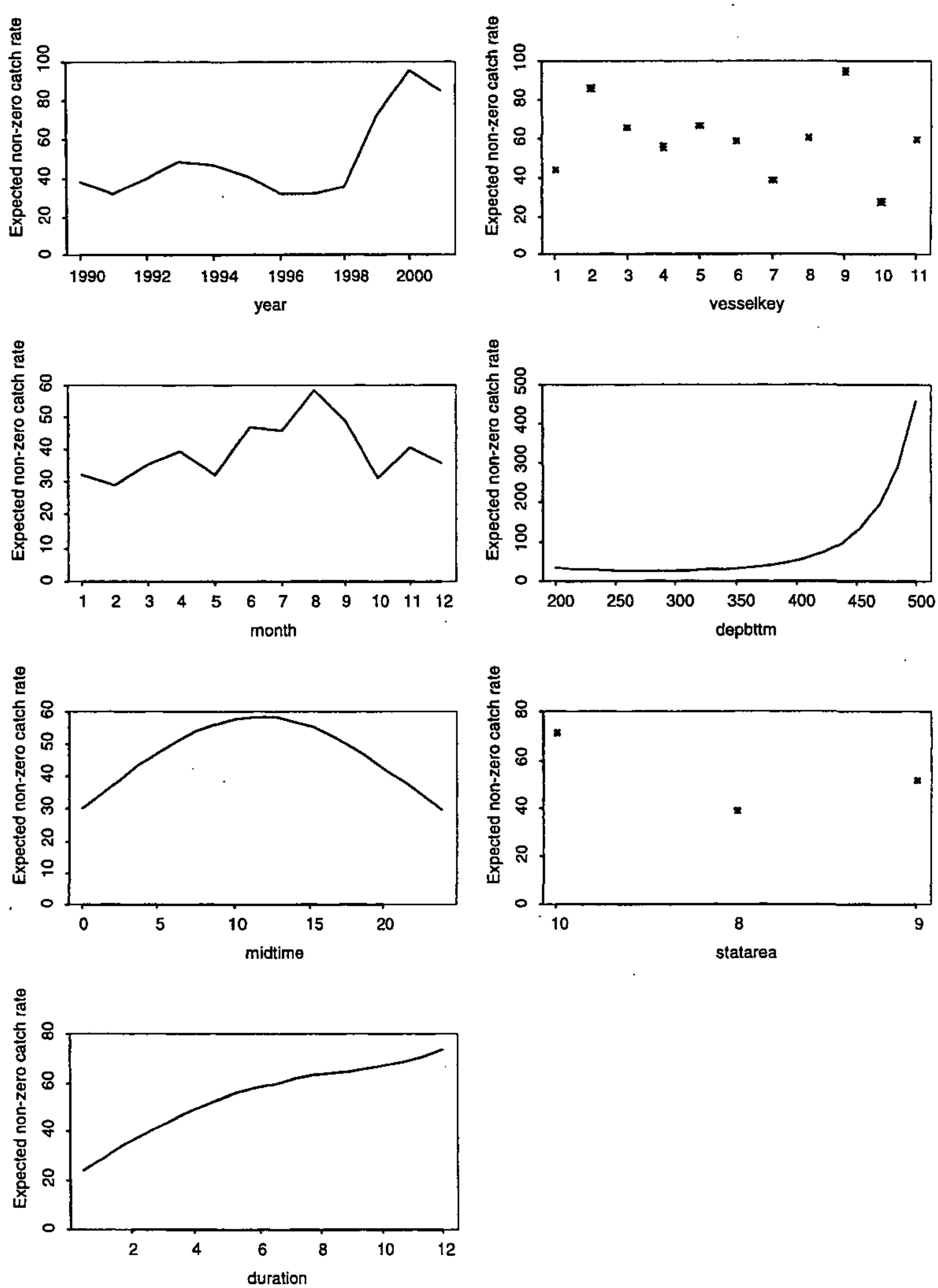



**Figure 20: Expected variable effects for variables selected into the CPUE model for ling catches in the trawl fishery targeting scampi in the Bay of Plenty. "Expected non-zero catch rate" is kg per tow in this fishery.**

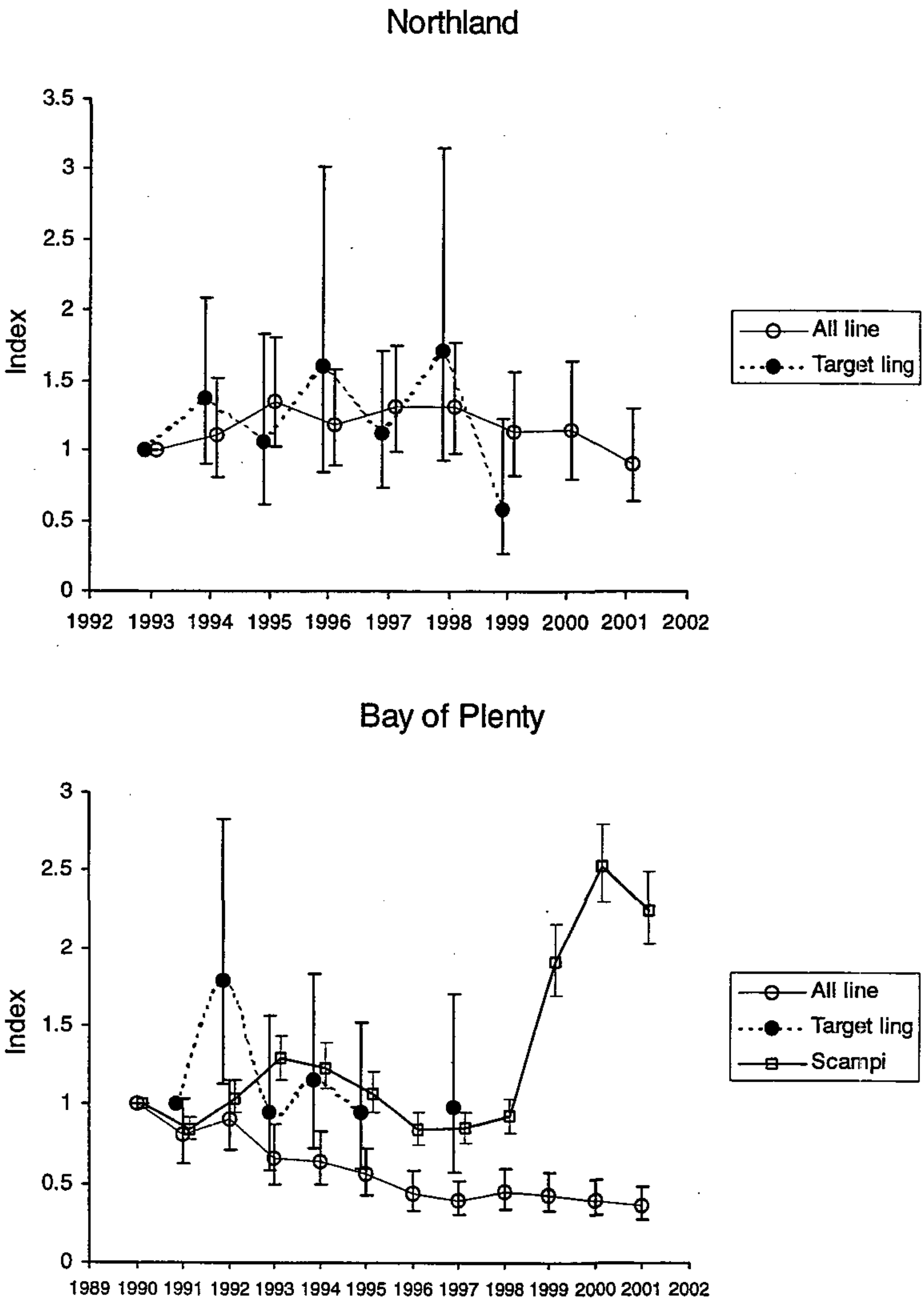
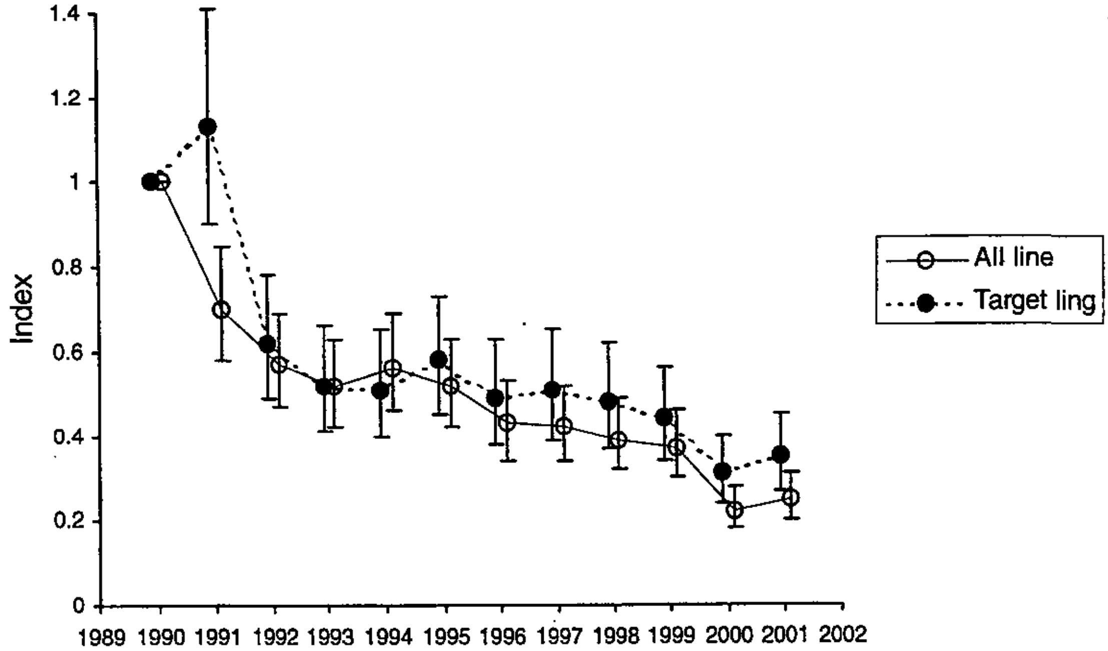



**Figure 21: Plotted comparisons of CPUE series (with 95% confidence intervals for individual points) calculated for fisheries off Northland and in the Bay of Plenty. All line, line fisheries targeting middle depth species; Target ling, ling target line fishery; Scampi, target trawl fishery for scampi.**

## East Coast North Island




## Cook Strait

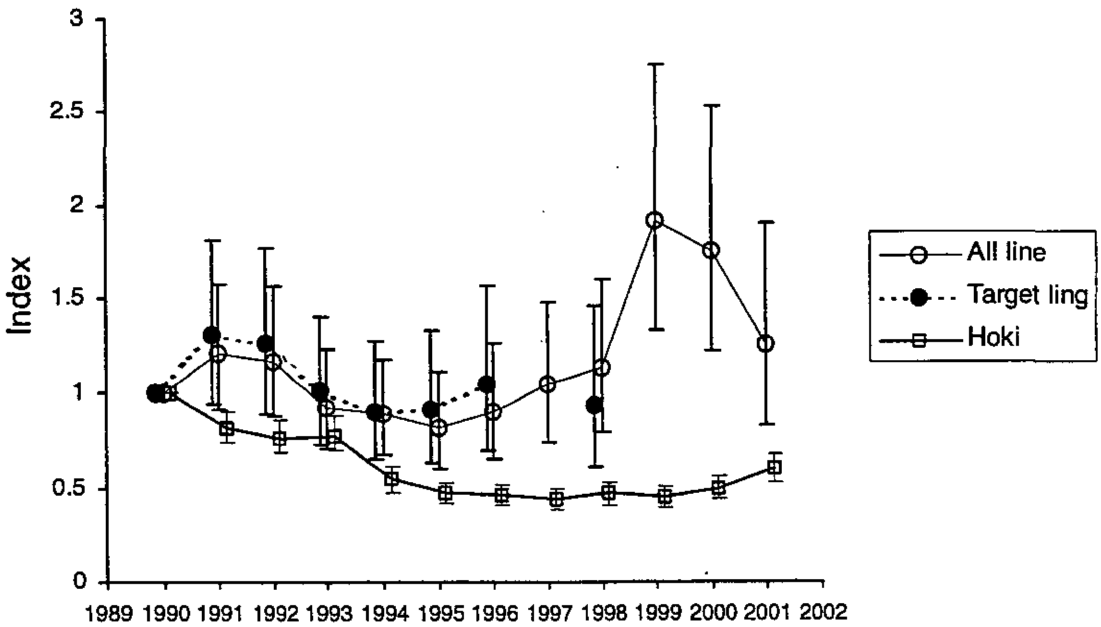



**Figure 22: Plotted comparisons of CPUE series (with 95% confidence intervals for individual points) calculated for fisheries off east coast North Island and in Cook Strait. All line, line fisheries targeting middle depth species; Target ling, ling target line fishery; Hoki, target trawl fishery for hoki.**