



**A descriptive analysis of all ling (*Genypterus blacodes*) fisheries, and CPUE for ling longline fisheries in LIN 3&4 and LIN 5&6, from 1990 to 2013**

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## EXECUTIVE SUMMARY

**Ballara, S.L.; Horn, P.L. (2015). A descriptive analysis of all ling (*Genypterus blacodes*) fisheries, and CPUE for ling longline fisheries for LIN 3&4 and LIN 5&6, from 1990 to 2013. *New Zealand Fisheries Assessment Report 2015/11*. 55 p.**

Updated descriptive analyses for all New Zealand ling fisheries are presented incorporating data up to the 2012–13 fishing year. The overall 2012–13 ling catch from the EEZ is higher than the previous year and catches have increased from the lowest levels in 2008–09 to 2011–12, although the last five years are all below the landings from the 1991–92 to 2007–08 fishing years. The Southland fishery had the highest overall catches in 2012–13. The distribution and size of trawl fishery landings changed little in the last year, with the main changes being a decrease on the Chatham Rise, and a relatively marked increase in the Sub-Antarctic. Overall trawl landings were higher than those taken in 2011–12 but lower than those taken by this method during the early to mid-2000s.

The overall line fishery catch distribution was also quite similar to the previous year, although catches increased in West South Island, East South Island, and Cook Strait, decreased in Southland and North North Island, and decreased markedly to be negligible in the Sub-Antarctic. The 2012–13 catch is markedly lower than in the most productive years (i.e., 1992–2002), but relatively consistent with the pattern of landings since 2003.

Series of CPUE for commercial line fisheries targeting ling on the Chatham Rise (LIN 3&4, 1990–2013), the Sub-Antarctic (LIN 5&6, 1991–2012), and the Bounty Plateau (LIN 6B, 1992–2012) were updated.

Since the early 1990s the standardised indices for line fisheries had declined by about 55% on the Chatham Rise and Bounty Plateau, but remained relatively constant in the Sub-Antarctic. The overall trends for all indices are similar to previous analyses.

## 1. INTRODUCTION

This document reports the results of the first of two objectives of Ministry for Primary Industries Project DEE2010-02LIND. The specific objectives were to carry out a descriptive analysis of the commercial catch and effort data for ling from LIN 2, 3 & 4, 5 & 6, 6B (Bounty Plateau) and 7, and to update the standardised catch-per-unit-effort (CPUE) analyses from the ling longline fisheries for LIN 3&4 (Chatham Rise) and LIN 5&6 (Sub-Antarctic) with the addition of data up to the end of the 2012–13 fishing year.

Previous descriptive analyses of commercial catch and effort data for ling were completed for the fishing years 1989–90 to 1998–99 (Horn 2001) and 1989–90 to 2004–05 (Horn 2007a). These were both comprehensive reports showing how the ling fisheries in the New Zealand EEZ had evolved and operated. They also aimed to define seasonal and areal patterns of fish distribution. The work presented here updates an analysis by Dunn et al. (2013) for fishing years 1989–90 to 2011–12, i.e., catch by area by method, to indicate whether any marked changes have occurred in the fisheries in the last year.

An analysis updating series of CPUE indices from target line fisheries for ling on the Chatham Rise (LIN 3&4) and Sub-Antarctic (LIN 5&6) is also presented here. CPUE analyses of these fisheries were most recently reported by Horn et al. (2013). These fisheries, along with the WCSI, Cook Strait and the Bounty Plateau line fisheries, account for over 95% of the line-caught ling. The principal lining method in all areas is bottom longline. These CPUE series are used as inputs into stock assessments.

This report also provides an update of the the standardised CPUE series for the line fishery on the Bounty Plateau (LIN 6B). This work was initially part of project DEE2010-02LINC (to conduct a stock assessment of LIN 6B), but the assessment was not completed as no new data inputs were available since the previous assessment of that stock (Horn 2007b).

## 2. METHODS

### 2.1 Data

Catch-effort, daily processed, and landed data were extracted from the MPI catch-effort database “warehouse” as extract 9171 and consist of all fishing and landing events associated with a set of fishing trips that reported a positive catch or landing of hoki, hake, or ling from fishing years 1989–90 to 2012–13. This included all fishing recorded on Trawl Catch, Effort and Processing Returns (TCEPRs); Trawl Catch Effort returns (TCERs); Catch, Effort and Landing Returns (CELRs); LCER (Lining Catch Effort Return); LTCER (Lining Trip Catch Effort Return); NCELR (Netting Catch Effort Landing Return); and included high seas versions of these forms.

Data were checked for errors, using simple checking and imputation algorithms similar to those used by Ballara & O’Driscoll (2014). Data were also groomed for errors using simple checking and imputation algorithms developed in the statistical software package ‘R.0.1’ (R Development Core Team 2013). Individual tow or set locations were investigated and errors were corrected using median imputation for start/finish latitude or longitude, fishing method, target species, tow speed, net depth, bottom depth, wingspread, duration, and headline height for each fishing day for a vessel. Range checks were defined for the remaining attributes to identify outliers in the data. The outliers were checked and corrected if possible with mean imputation on larger ranges of data such as vessel, target species and fishing method for a year or month, or the record was removed from the data set. Statistical areas were calculated from positions where these were available. Transposition of some data was carried out (e.g., bottom depth and depth of net, or number of hooks and number of sets).

The fishing methods examined were: deepwater bottom trawl, deepwater midwater trawl, inshore bottom trawl, inshore midwater trawl, line, setnet, and fish pots. The distinction between deepwater

and inshore trawls is not based on depth or position, but rather on the form type that the catch is reported on. TCEPR records are classified as deepwater; CELR and TCER records are classified as inshore.

The catch data from the statistical areas were combined so that the groupings generally approximated the various administrative ling stocks, with two major exceptions. The Bounty Plateau section of LIN 6 was examined separately as it is believed to contain a distinct biological stock (Horn 2005), and a Cook Strait area comprising parts of LIN 2 and LIN 7 was created. The areas are: North North Island (North NI), East North Island (East NI), East South Island (East SI), Chatham, Southland, Sub-Antarctic, Bounty, West South Island (West SI), and Cook Strait (Table 1, Figure 1).

## 2.2 CPUE analysis

### Variables

Variables used in the CPUE analysis are described in Table 2 and are generally similar to those used in previous analyses (e.g., Horn et al. 2013). Longline CPUE was defined as catch per day per statistical area (i.e., daily estimated catch in kilograms by a vessel in a particular statistical area), and number of hooks set per day was offered as an explanatory variable. Catch per day (rather than catch per hook) was used as the unit of CPUE because it has been shown (Horn 2002) that the relationship between catch per hook and the number of hooks set per day is non-linear. *Total hooks* per day and *number of sets* per day were offered as an untransformed number and as log-transformed data. *Year* was a categorical variable and was defined as the calendar year. Season variables of both *month* and *day of year*, and statistical area (*statarea*) variables were offered to the model. Records with no vessel identification data were excluded from analyses. *Vessel* was incorporated into the CPUE standardisation to allow for possible differences in fishing ability between vessels.

### Data selection

Data for the Chatham Rise and Sub-Antarctic were grouped by statistical area as follows: Chatham Rise (LIN 3&4): 018–024, 049–052, 301, 401–412, and Sub-Antarctic (LIN 5&6): 025–031, 302, 303, 501–504, 601–606, 610–612, 616–620, 623–625. Note that these analyses were carried out on the basis of presumed biological stocks, rather than administrative (QMA) stocks. Consequently, the grouping of some statistical areas may appear erroneous, but has been done in a way that best approximates biological stocks. For example, Statistical Areas 302, 303, and most of 026 are in LIN 3, but they have been included in the Sub-Antarctic analysis, as ling in these areas probably derive from the Sub-Antarctic stock because the Stewart-Snares shelf and Campbell Plateau are the closest submarine shelves to these statistical areas.

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

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

The estimated catch of the top five species is reported on the CELR form whereas the estimated catch of the top eight species are reported on the LCER and LTCER forms per set. If there is more than one set recorded in a day the estimated catch of up to 20–30 species may be reported for a day of fishing on LCER and LTCER forms. Therefore the daily aggregate estimated catch of ling was only associated with the LCER or LTCER daily aggregate effort record if the catch of that species was



ranked amongst the five largest species catches (by weight) for the vessel fishing day and statistical area. Consequently there were 838 and 18 vessel-day-statistical area aggregate data removed from the Chatham Rise and Sub-Antarctic datasets respectively.

To ensure that the longline data to be analysed were within plausible ranges and related to vessels that had consistently targeted and caught significant landings of ling (and so were likely to truly represent experienced and competent ling fishers), data were accepted if all constraints in Table 3 were met.

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). Because of the relatively high number of hooks fished in any set, a zero catch of ling in any set that is genuinely targeting ling is likely to result either from some gear malfunction or from exploratory fishing. The removal of such data points from the analysis will not bias the index of relative abundance of ling on known fishing grounds. Consequently, as in previous analyses, all zero observations were removed. There were 487 and 52 records of zero ling catch from the Chatham Rise and Sub-Antarctic respectively, making up 2.5% and 0.8% of the data.

The Sub-Antarctic line fishery data were also analysed as two fisheries within the Sub-Antarctic stock using all the data records that were accepted into the ‘whole stock’ analysis. The two fisheries were: spawning (Statistical Area 030 for the months of September to December), and non-spawning (all other statistical areas and all months). This is consistent with the assessment model structure for this stock which incorporates a spawning fishery at Puysegur and a non-spawning fishery in other areas (Horn et al. 2013).

### The model

Estimates of relative year effects were obtained from a stepwise multiple regression method, where the data were fitted using a lognormal model using log transformed non-zero catch-effort data. A forward stepwise multiple-regression fitting algorithm (Chambers & Hastie 1991) implemented in the R statistical programming language (R Development Core Team 2013) was used to fit all models. The algorithm generates a final regression model iteratively and used the year term as the initial or base model in all cases. The reduction in residual deviance (denoted  $R^2$ ) was calculated for each single term added to the base model. The term that resulted in the greatest reduction in the residual deviance was then added to the base model, where the change was at least 1%. The algorithm was then repeated, updating the base model, until no more terms were added. A stopping rule of 1% change in residual deviance was used because this results in a relatively parsimonious model with moderate explanatory power. Alternative stopping rules or error structures were not investigated.

The variable *year* was treated as a categorical value so that the regression coefficients of each year could vary independently within the model. The relative year effects calculated from the regression coefficients represent the change in CPUE through time, all other effects having been taken into account, and represents a possible index of abundance. *Year* was standardised to the first year of the data series. Year indices were standardised to the mean and were presented in canonical form (Francis 1999). Variables are either categorical or continuous, with model fits to continuous variables being made as third-order polynomials. The CVs represent the ratio of the standard error to the index. The 95% confidence intervals are also calculated for each index. Date was included in the processed catch runs as *year* and *month*, or *day of year*. Interaction terms and nested terms were not used, as in the past their inclusion resulted in some implausible *vessel* coefficients (Horn & Ballara 2012).

*Vessel* was incorporated into the CPUE standardisation to allow for differences in fishing ability between vessels. Vessels not involved in the fishery for at least three consecutive years were excluded because they provided little information for the standardisations, which could result in model over-fitting (Francis 2001). Thus, CPUE analyses were undertaken for “core” vessels that were determined for each area analysis using area-specific criteria based on approximately 80% of ling catch, the number of years of vessel participation, and the number of vessel-days per vessel-year.



The primary Chatham Rise model used the data from the bottom longline target ling fishery during 1991–2013 for core vessels. Another model run investigated previous vessel selection criteria, (i.e., number of records for a vessel was greater than 100 and all vessels included had fished for at least two years). Because the last assessment of LIN 3&4 (Horn et al. 2013) had found that the two available relative abundance series (i.e., trawl survey biomass, longline CPUE) exhibited markedly different trends that could not be fitted satisfactorily in the model, the following additional CPUE analyses were completed to investigate the cause of the initial steep decline in CPUE series.

- year as July–November for core vessels
- number of hooks less than 10 000 for core vessels
- subsets of core vessels (vessels 1–10; 9–17; 6–17; and 1, 4, 6–17)

The primary Sub-Antarctic analysis used data from the bottom longline target ling fishery during 1991–2013 for core vessels run both as a single fishery and as separate spawning and non-spawning fisheries. Other model runs used the previous vessel selection criteria (i.e., number of records for a vessel was greater than 500 and all vessels included in any particular stock analysis had fished for at least two years). For the longline CPUE series estimated for separate fisheries within the Sub-Antarctic stock, a *year:fishery* interaction effect was forced into the model. This produced a CPUE series for each of the two fisheries within the stock, but with all other expected variable effects being the same over the fisheries.

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

The influence of each variable accepted into the lognormal models was described by coefficient–distribution–influence (CDI) plots (Bentley et al. 2012). These plots show the combined effect of (a) the expected log catch for each level of the variable (model coefficients) and (b) the distribution of the levels of the variable in each year, and therefore describe the influence that the variable has on the unstandardised CPUE and that is accounted for by the standardisation.

Model fits to the lognormal component of the combined model were investigated using standard residual diagnostics. For each model, a plot of residuals against fitted values and a plot of residuals against quantiles of the standard normal distribution were produced to check for departures from the regression assumptions of homoscedasticity and normality of errors in log-space (i.e., log-normal errors).

### 3. RESULTS

#### 3.1 All catch data

Annual estimated catches by area, from all methods combined, are listed in Table 4, and shown in Figure 2. The estimated totals for each year ranged between 85 and 101% of the MHR landings. Significant catches have been taken in all areas. Most catches are taken in five areas around the South Island: East SI, Chatham, Southland, Sub-Antarctic, and West SI. This pattern of catches is consistent with ling distributions derived from research trawls (Anderson et al. 1998). There are some changes in the proportions of catches contributed by some areas before and after 2000. Catches from the Sub-Antarctic increased in the latter period (although have been lower from 2008–09 to 2011–12), while those from Chatham declined. The largest overall fishery in 2012–13 was the Southland fishery.

Relative to the previous fishing year, 2012–13 trawl fishery catches in East SI, Southland and the West SI were similar, Chatham trawl catches decreased, and Sub-Antarctic and Cook Strait trawl catches increased (Table 5, Figure 3). The 2012–13 line fishery catches from Sub-Antarctic and the Bounty Plateau were negligible, and Cook Strait line-caught catches were low, as in previous years. Relative to the previous fishing year, 2012–13 line catches on the Chatham Rise changed little, but

they were lower in Southland and North NI, and higher in West SI and East SI (Table 5, Figure 4). Total landings from the EEZ increased by nearly 1900 t in 2012–13 compared with 2011–12, an increase from the lowest levels in 2008–09 to 2011–12. Catches from the last five years are all below the higher total landings of the 1991–92 to 2007–08 fishing years (Table 4).

### 3.2 Catch summaries by fishing method and area

Ling were taken by a variety of fishing methods in each of the areas. Summaries of catch by fishing method, by area and fishing year, are presented in Tables 5a–g. For the inshore bottom trawl fishery (Table 5a) there were low levels of landings (i.e., generally less than 100 t annually) in all areas except for Sub-Antarctic, Chatham, and Bounty, where catches were negligible or zero. There are increased catches in Southland and West SI by this method from about 2008–09. Landings from the inshore midwater trawl fishery (Table 5b) are negligible in all areas except West SI and Cook Strait; catches in 2012–13 in both those areas are low.

The deepwater bottom trawl fishery (Table 5c) is still important in the Southland and Sub-Antarctic areas with annual landings generally greater than 2000 t. Landings in the Sub-Antarctic increased from the late 1990s to peak at more than 4900 t in 2003–04. Only 750–1500 t was reported from 2009–10 to 2011–12, but there was a large increase to 3390 t taken in 2012–13. Southland catches have ranged from 1900 to 3300 t, with 3036 t taken in 2012–13. West SI catches have been greater than 500 t since 1996–97, and in 2012–13 increased slightly to 811 t. Chatham catches decreased and the East SI catch was similar in 2012–13. Total landings from the deepwater midwater trawl fishery (Table 5d) have been relatively low since 2006–07, ranging between 125 and 472 t.

The line fishery (Table 5e) is significant in all areas, but landings by area can vary markedly between years. The total catch in 2012–13 was slightly lower than in recent years, primarily a consequence of the Sub-Antarctic catch being negligible for the first time since 2006–07. The Chatham area is still the most productive, but its recent landings are only about a third of those taken at its peak in the mid 1990s.

Setnet fishery landings (Table 5f) have always been negligible in all areas except East SI and West SI. The 2012–13 landings in these two areas were low and similar to 2011–12. Landings from fish pots (Table 5g) are generally recorded only from East SI and Southland, and average about 20–50 t annually. The 2012–13 landings are moderately low (3 and 26 t in East SI and Southland respectively).

### 3.3 Estimation of CPUE from line fisheries

The number of vessels, amount of effort, and amount of ling catch, and the unstandardised CPUE are listed in Tables 6a–e, for all vessels and for core vessels, where appropriate. The variables retained in each model are listed in Table 7 and the CPUE indices by fishing year are given for each model in Table 8a–b.

#### 3.3.1 Chatham Rise (LIN 3&4)

Chatham Rise line fisheries catch ling throughout the year, but most catch is taken from July to November (Figure 5a). Over 99% of the catch is taken by the bottom longline method and from target ling fishing. Most of the line catch is taken in Statistical Areas 020–021, 049, 052, 401–404, and 410. Statistical Areas 301, 406, 411, and 412 had an insignificant number of sets (0.1% of days over 23 years), and these were probably attributable to reporting errors or exploratory fishing so were removed from the final analysis. The Chatham Rise bottom longline ling target fishery model used data from calendar years 1991 to 2013 where catch per vessel-day ranged from 1–30 000 kg and hooks set per vessel-day ranged from 50–50 000. A total of 113 unique vessels (range 9–23 vessels per year) targeting ling using bottom longline caught 54 233 t of ling since 1991, from 19 570 vessel

days (Table 6a). The estimated landings from this effort represented more than 90% of the total estimated landings by line fishing for this stock. Line fishing has accounted for about half of the LIN 3&4 landings since 1990, although the line fishery produced 59–72% of the catch annually from 1993 to 1997 (Tables 4 and 5). Core vessels for the bottom longline index were defined as those participating in the fishery for five or more years, and reporting 20 or more vessel-days per year (Table 6a, Figures 6 (upper plot) and 7a). Seventeen core vessels (range 4–7 per year) caught 46 063 t of ling, representing 85% of the total line catch during 1991–2013, and catches ranged from 664 to 4128 t annually (Table 4).

Four variables were selected into the lognormal model, resulting in a total  $R^2$  of 73%, with *vessel* explaining 54.7% of the residual deviance (Table 7). Other variables selected were *total hooks* and *month*.

Indices from the models are presented in Table 8a and Figures 8a and 9a. The standardised year effects show a steady decline from 1991 to 1997, followed by a relatively constant signal since then. The decline in the standardised index in the early 1990s does not match the raw index (which increases), but does follow the trend in the raw index from 1995 to 2010. The overall trend is similar to the previous analysis of Horn et al. (2013) where vessels were chosen when they had at least 2 years participation with 100 vessel-days overall, rather than the core vessels chosen for the current analysis. An analysis using the previous vessel selection criteria but with the latest data also produces similar results (Figure 9a).

Investigations were conducted to attempt to determine what factors produced the marked initial decline in the CPUE series. Data for core vessels for a restricted month range of July–November, or for less than 10 000 hooks, did not change the indices (Figure 9a). Removing core vessels 2, 3, and 5 flattened out the indices (Figure 9a) but also removed 55% of the catch (Table 6b).

The effects of the selected variables on the expected catch rates of ling in the lognormal longline catch models are shown in influence plots (Figures 10a and 10b). Generally, the changes in the influence of the main variables was small. For *vessel*, changes are related to the movement of vessels out of the fishery, and the positive influence for 1991–1995 derived from five vessels that fished early on in the fishery. Vessels catching the most ling had relatively high expected catches (but not the highest expected catches) and had lower variability. Data from core vessels are incorporated in the model; the difference between the best and worst of all but one of these is less than a factor of 6. This level of between-vessel difference is not great given the inclusion in the analysis of auto-longliners and smaller hand-baiting inshore vessels.

The positive influence on *total hooks* is high from 1997–2001 when there was less effort for lower total hook number, and the predicted values indicated higher expected catch rates with increased total hooks, and there is a strong negative influence from 1991 to 1994 again suggesting that changes are related to movement of vessels out of the fishery.

The overall influence of month was not very strong on the model. Higher coefficients were estimated when the effort was in August–October, the probable peak spawning season, but the best monthly catch rate is less than twice that of the worst.

The diagnostics were poor and the quantile–quantile plot for the lognormal model indicated a large deviation from the normal distribution of the residuals at both the lower and upper ends i.e., very small and very large catch rates were not well modelled (Figure 11). This suggests that the lognormal models can be improved, and there may be violations of model assumptions (i.e., the assumption of normally distributed constant variance residual errors). The poorly estimated points (i.e., those with residuals less than  $-2$  or greater than  $2$ ) made up a small fraction (1.6%) of the total data set.

### 3.3.2 Sub-Antarctic (LIN 5&6)

Sub-Antarctic line fisheries catch ling throughout the year, although very little catch is taken in August and September (Figure 5b). Most of the Sub-Antarctic line catch is taken by bottom longline (99.9% of vessel-days), and ling targeting (99.7% of vessel-days), so only data from this method and target were included in the analysis. Most of the line catch was taken in Statistical Areas 030, 602–605, 610–611, 618, and 619. Most Puysegur (Statistical Area 030) catch was taken from October to December, and most non-Puysegur catch from January to July, and in December (Figure 5c). Statistical Areas 025–029, 031, 302–303, 502, 504, 601, 606, 612, 616–617 and 624 all had few days fished (i.e., less than 50) throughout the 23 years (overall 3.7% of vessel-days), and these were probably attributable to reporting errors or exploratory fishing, so were removed from the final analysis.

The Sub-Antarctic bottom longline ling target fishery model used data from calendar years 1991 to 2012 only as there were only 23 data points available from one vessel for the 2013 calendar year to 30 September. Further Sub-Antarctic data constraints included catches of 1–35 000 kg and number of hooks at 50–50 000 per vessel-day. The Sub-Antarctic analysis included a catch of 29 875 t with 6439 records of vessel-days fished throughout the 22 years analysed: 1867 from the spawning fishery, and 4692 from the non-spawning fishery (Tables 6c–e). The spawning fishery had 36–151 days fished in each year; the non-spawning fishery had 27–564 days per year. Data were more abundant through the middle part of the series. From 1993 to 2002 when the auto-longline fishery was at its peak, line fishing accounted for about 17–37% of the LIN 5&6 landings (excluding the Bounty Plateau) (Table 5). The percentage of line catch was lower from 2003 to 2009 (8–14% of the landings), but was again relatively high (21%) in 2012, although very low in 2013 (5%) (Tables 4 and 5). Core vessels for the bottom longline index were defined as those participating in the fishery for four or more years (Table 5e, Figures 6 (bottom plot) and 7b). Vessels with five or six years participation in the fishery could have been chosen to get approximately 80% of the catch, but this resulted in in some years with only one vessel in the data. Consequently, 14 core vessels (range 2–6 per year) were selected; they caught 29 266 t of ling, representing 97% of the total catch during 1991–2012, with catches ranging from 514 to 2981 t annually (Table 6c–e).

Five variables were selected into the single fishery lognormal model, resulting in a total  $R^2$  of 63%, with  $\log(\text{total hooks})$  explaining 53.4% of the residual deviance (Table 7). Other variables selected were *statarea*, *vessel*, and *number of sets*.

Indices from the models are presented in Table 8b and Figures 8b and 9b. The standardised year effects show a variable series with a slightly declining trend. The trend in the standardised index follows the trend in the raw index. The overall trend is similar to the previous analysis of Horn et al. (2013) where chosen vessels had at least 2 years participation with 50 vessel-days overall, rather than the core vessels chosen for the current analysis. A repeat of this vessel selection, but with the latest data, also produces similar results (Figure 9b).

The effects of the selected variables on the expected catch rates of ling in the lognormal longline catch models are shown in the influence plots in Figures 10c. Generally, the changes in the influence of the main variables were small. For number of hooks there is a positive influence from 1999–2007 when there was less effort for lower total hook number, and the predicted values indicated higher expected catch rates with increased total hooks. For statistical area the highest expected catch rates occurred in Statistical Area 030, but rates varied by a factor of less than 2 over all areas. There was a large influence in 2007 when the effort in Statistical Area 030 was the highest. For vessel, changes are related to the movement of vessels out of the fishery, and to differing levels of effort by individual vessels. Vessels catching the most ling had higher expected catch rates and lower variability, although catch rate by vessel varied by a factor of less than 3. Higher expected catch rates and higher influence were found with more sets per day.

The diagnostics were poor and the quantile–quantile plot for the lognormal model indicated a large deviation from the normal distribution of the residuals at both the lower and upper ends i.e., very

small and very large catch rates were not well modelled (Figure 11b, upper plot). This suggests that the lognormal models can be improved, and there may be violations of model assumptions (i.e., the assumption of normally distributed constant variance residual errors). The poorly estimated points (i.e., those with residuals less than  $-2$  or greater than  $2$ ) made up a small fraction (0.78%) of the total data set.

The variables selected into the two-fishery model were the similar to single fishery model, although *statarea* and *number of sets* were not selected (Table 7). The variable *log(total hooks)* explained most of the variance (61%), and with *vessel* included, 63% of total variance was explained.

For both the spawning and non-spawning fisheries, the standardised indices were variable with a slightly declining trend (Table 8, Figure 9b). There were similar trends between series although the indices in the spawning fishery were higher than in the non-spawning fishery (Figure 9b), and the 2009 index for the spawning fishery shows a large increase (although this was not sustained in subsequent years). The highest indices in each series (2007 for non-spawning and 2009 for spawning), and the low 2010 spawning index, are based on low numbers of days fishing and have very wide confidence bounds. The trend in the standardised indices follows the trend in the raw indices for both fisheries. The overall trend is similar to the previous analysis of Horn et al. (2013), and a repeat of the analysis using the previous vessel selection criteria but with the latest data also produces similar results (Figure 9b, lower plot).

The two-fishery model showed no marked patterns in the residuals (Figure 11b) although the diagnostics were poor with the quantile-quantile plots showing a deviation from the normal distribution of the residuals especially at the lower end.

### 3.3.3 Bounty Plateau (LIN 6B)

The results of the Bounty Plateau longline CPUE analysis are presented in Appendix A.

## 4. DISCUSSION

In summary, the overall 2012–13 ling catch from the EEZ is higher than the previous year and catches have increased from the lowest levels in 2008–09 to 2011–12, although the last five years are all lower than the landings of the 1991–92 to 2007–08 fishing years. The Southland fishery had the largest overall catches of any fishery in 2012–13. The distribution and size of trawl fishery landings changed little in the last year. Overall trawl landings were higher than those taken in 2011–12 but lower than those taken by this method during the early to mid 2000s.

The overall line fishery catch distribution was also quite similar to the previous year, although catches from Sub-Antarctic and the Bounty Plateau were negligible. The total line fishery catch is markedly lower than in the most productive years (i.e., 1992–2002), but relatively consistent with the pattern of landings since 2003.

In recent assessments of ling stocks around the South Island, series of CPUE indices derived from commercial fisheries have been used as indices of abundance (e.g., Dunn et al. 2013, Horn et al. 2013). CPUE is used in conjunction with indices from trawl survey series for LIN 3&4 and LIN 5&6.

As would be expected, the trends in the indices, and the variables selected into the models, have not changed markedly between the previous (Horn et al. 2013) and current analyses. The longline fisheries examined here target a single species using the same method, so the sets of variables selected into the model for each stock might be expected to have some similarities. In all the analyses, *total hooks* or *log(total hooks)* and *vessel* were selected into the model. *Month* was accepted into the Chatham Rise model, and *statistical area* into the single fishery Sub-Antarctic model. With the CPUE unit being ‘kg per day’, it would be expected that the number of hooks set per day would be a very



influential variable. This is certainly the case for LIN 3&4, and LIN 5&6, where *total hooks* or  $\log(\text{total hooks})$  is the most influential variable, accounting for the largest proportion of the explained variance. Skill levels and/or gear efficiency will vary between vessels so the selection of a *vessel* variable in each model would be expected. Clearly, catch rates vary throughout the year, probably in relation to the spawning season for ling. Hence, *month* was an important explanatory variable.

One clearly apparent change in recent fishing seasons is the reduction in effort on the Campbell Plateau (see Table 5). This reduction is attributable in part to the diversion of autoline vessels to the Ross Sea toothfish fishery, but also to the permanent removal from the New Zealand fleet of some large line vessels, and to a recent reduction in overseas demand for New Zealand ling.

## 5. ACKNOWLEDGMENTS

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

Area	Statistical areas	Approximate ling stock
North NI	041–048, 001–010, 101–110, 801	LIN 1
East NI	011–015, 201–206	LIN 2
East SI	018–024, 301	LIN 3
Chatham	049–052, 401–412	LIN 4
Southland	025–031, 302, 303, 501–504	LIN 5
Sub-Antarctic	601–606, 610–612, 616–620, 623–625	Part of LIN 6
Bounty	607–609, 613–615, 621, 622	Part of LIN 6
West SI	032–036, 701–706	Part of LIN 7
Cook Strait	016, 017, 37–40	Parts of LIN 2 & 7

**Table 2: Summary of the variables offered in the CPUE models for the line fisheries.**

Variable	Type	Description
Year	Categorical	Calendar year
Month	Categorical	Month of year
Statistical area	Categorical	Statistical area for the set or tow
Vessel	Categorical	Unique vessel identifier
Day of year	Continuous	Julian day, starting at 1 on 1 January
Total hooks	Continuous	Number of hooks set per day in a statistical area
Log(Total hooks)	Continuous	Logarithm of variable Total hooks
Number of sets	Continuous	Number of set per day in a statistical area
Log(Number of sets)	Continuous	Logarithm of variable Number of sets
CPUE	Continuous	Ling catch (kg) per day in a statistical area

**Table 3: CPUE data constraints by area for vessels that targeted ling.**

	Chatham Rise	Sub-Antarctic
Data source	CELR (all catch) LTCER and LCER (ling catch included only if ling is one of the top 5 species by weight caught in a day's fishing for a vessel/stat area)	CELR (all catch) LTCER and LCER (ling catch included only if ling is one of the top 5 species by weight caught in a day's fishing for a vessel/stat area)
Year range	1991–2013	1991–2012
Year definition	January–December	January–December
Statistical areas	At least 50 sets: 018–024, 049–052, 401–405, 407–410	At least 50 sets: 026, 030, 602–605, 610, 611, 618, 619, 625
Method	BLL	BLL
Target	LIN	LIN
Catch	1–30 000 kg	1–35 000 kg
Total number of hooks	50–50 000	50–50 000
Core vessel selection	Approx. 80% of catch, $\geq 5$ years vessel participation and $\geq 20$ vessel-days per year	Approx. 80% of catch, $\geq 4$ years vessel participation

**Table 4: Total estimated ling landings (t) as reported on TCEPR, TCER, CELR, NCER, and LCER returns, by fishing year and by area. The percentage of total estimated landings (Total) taken from each area is also presented (Percent). Total estimated landings by year (Total by year) can be compared with actual reported landings from Fishstocks LIN 1–7 (MHR total). The MHR total also includes catches from FMA 10 and outside the EEZ.**

Fishing year	Area									Total by year	MHR total	Percent of MHR
	North NI	East NI	East SI	Chatham	Southland	Sub-Antarctic	Bounty	West SI	Cook Strait			
1989–90	83	268	1 221	512	2 116	1 216	12	2 323	414	8 167	9 026	90.5
1990–91	139	437	1 935	2 156	2 093	2 683	33	1 947	527	11 950	13 675	87.4
1991–92	185	450	1 806	4 358	3 832	2 398	908	1 859	314	16 119	17 796	90.6
1992–93	155	526	1 622	3 657	2 685	5 252	969	1 874	323	17 065	19 069	89.5
1993–94	185	508	1 573	3 756	3 248	2 282	1 149	1 763	251	14 722	15 959	92.3
1994–95	219	530	2 139	5 728	3 765	3 683	396	2 875	321	20 027	19 817	101.1
1995–96	165	552	2 420	4 171	4 764	4 077	381	2 622	366	19 575	21 471	91.2
1996–97	254	525	2 068	3 797	4 294	5 009	340	2 497	366	19 285	22 535	85.6
1997–98	220	607	2 086	4 261	4 022	5 345	395	2 766	287	20 150	23 083	87.3
1998–99	178	545	1 981	3 924	3 510	4 336	563	2 927	345	18 334	21 019	87.2
1999–00	297	485	2 148	3 969	3 150	5 072	991	2 697	331	19 146	21 594	88.7
2000–01	236	597	1 743	3 445	3 394	4 641	1 064	3 070	391	18 584	20 551	90.4
2001–02	280	583	1 582	3 217	3 255	5 406	629	2 642	289	17 885	19 563	91.4
2002–03	226	471	1 845	2 719	3 061	5 137	922	2 338	353	17 075	18 908	90.3
2003–04	207	507	1 473	2 385	3 119	5 899	853	2 402	360	17 204	18 758	91.7
2004–05	241	399	1 267	2 927	4 126	5 389	49	2 057	372	16 827	17 186	97.9
2005–06	291	415	1 218	1 729	3 917	3 737	43	2 053	297	13 700	14 178	96.6
2006–07	232	512	1 601	1 943	3 998	4 112	236	1 797	239	14 670	16 099	91.1
2007–08	361	503	1 505	2 307	4 251	3 818	503	1 909	186	15 344	16 263	94.3
2008–09	307	452	1 394	1 815	3 201	2 264	232	1 851	124	11 640	13 137	88.6
2009–10	379	451	1 373	1 844	3 240	2 272	1	1 957	75	11 593	12 609	91.9
2010–11	440	482	1 173	1 398	4 013	1 129	53	2 288	129	11 105	12 337	90.0
2011–12	377	346	815	2 017	3 828	1 885	2	2 142	110	11 522	12 955	88.9
2012–13	378	361	1 031	1 927	3 691	3 396	3	2 436	176	13 399	14 334	93.5
Total	6 036	11 513	39 018	69 961	84 575	90 438	10 728	55 094	6 948	375 089	411 921	–
Percent	1.6	3.1	10.4	18.7	22.5	24.1	2.9	14.7	1.9	–	–	–

**Table 5: Catch of ling (t) by area, by fishing year, for various fishing methods. Values have been rounded to the nearest tonne, so “0” represents estimated landings of less than 0.5 t, and “–” indicates nil reported landings. Total catches also includes catches from FMA 10 and outside the EEZ.**

**(a) Inshore bottom trawl (methods BT and BPT for CELR and TCER forms)**

Fishing year	Area									Total
	North NI	East NI	East SI	Chatham	Southland	Sub-Antarctic	Bounty	West SI	Cook Strait	
1989–90	10	25	148	4	47	–	–	148	4	386
1990–91	18	36	198	5	63	–	–	150	9	480
1991–92	30	21	145	2	53	–	0	192	4	448
1992–93	35	17	110	0	91	0	–	220	14	486
1993–94	29	22	64	1	78	–	–	111	22	326
1994–95	20	18	66	2	83	0	–	106	78	374
1995–96	9	24	50	3	50	0	0	188	82	406
1996–97	19	17	62	0	56	–	–	168	72	394
1997–98	9	7	45	0	30	–	–	104	24	220
1998–99	8	5	51	0	66	0	–	158	26	314
1999–00	57	7	80	0	48	–	–	129	20	340
2000–01	22	6	75	0	99	–	–	55	15	271
2001–02	11	4	99	1	89	–	–	55	17	275
2002–03	9	8	91	1	166	–	–	69	8	352
2003–04	3	3	88	0	137	–	–	54	4	290
2004–05	1	2	99	1	136	–	–	130	7	376
2005–06	6	2	46	10	106	–	–	127	3	299
2006–07	8	15	49	1	98	–	–	101	4	276
2007–08	52	18	72	0	109	–	–	240	6	496
2008–09	62	11	39	–	122	0	–	252	31	517
2009–10	86	14	66	0	180	0	–	277	26	649
2010–11	39	21	62	0	368	–	0	315	68	873
2011–12	25	51	64	13	288	0	0	275	36	753
2012–13	86	36	45	39	248	0	–	270	39	764

**(b) Inshore midwater trawl (methods MW and MPT for CELR and TCER forms)**

Fishing year	Area									Total
	North NI	East NI	East SI	Chatham	Southland	Sub-Antarctic	Bounty	West SI	Cook Strait	
1989–90	1	1	3	–	–	–	–	2	42	49
1990–91	0	0	9	–	–	–	–	–	125	134
1991–92	0	1	6	–	–	–	–	2	36	44
1992–93	0	2	0	–	–	–	–	1	26	30
1993–94	0	0	1	–	–	–	–	3	11	14
1994–95	1	0	0	1	–	–	–	9	6	17
1995–96	1	0	2	–	–	–	–	24	16	43
1996–97	4	0	7	–	–	–	–	21	8	45
1997–98	9	0	4	–	–	–	–	45	13	74
1998–99	1	0	20	–	–	–	–	83	9	113
1999–00	0	0	7	–	–	–	–	206	18	232
2000–01	6	1	7	–	–	–	–	175	29	218
2001–02	0	0	9	–	–	–	–	83	14	106
2002–03	0	0	30	–	0	–	–	113	36	178
2003–04	0	0	13	0	–	–	–	67	29	110
2004–05	0	0	1	0	0	–	–	70	22	93
2005–06	0	0	2	–	–	–	–	63	21	86
2006–07	0	0	0	–	–	–	–	34	18	52
2007–08	0	0	1	–	–	–	–	6	14	20
2008–09	–	–	0	–	–	–	–	33	14	48
2009–10	0	0	1	–	–	–	–	40	8	49
2010–11	0	0	0	0	0	–	–	48	4	53
2011–12	–	–	1	–	0	–	–	71	4	75
2012–13	–	0	3	–	–	–	–	72	5	79

Table 5 continued.

## (c) Deepwater bottom trawl (methods BT and BPT for TCEPR form)

Fishing year	Area									Total
	North NI	East NI	East SI	Chatham	Southland	Sub-Antarctic	Bounty	West SI	Cook Strait	
1989-90	31	59	599	500	1 953	1 174	4	370	7	4 698
1990-91	70	117	817	1 235	1 996	2 457	7	260	13	6 972
1991-92	55	87	933	1 348	3 368	2 053	35	306	4	8 189
1992-93	30	75	807	1 028	1 985	4 308	0	491	4	8 730
1993-94	45	74	727	451	2 038	1 818	4	389	47	5 595
1994-95	44	77	1 016	968	2 557	2 102	0	505	57	7 327
1995-96	73	125	1 081	697	3 945	2 807	1	385	97	9 213
1996-97	141	151	1 017	764	3 254	2 772	0	516	119	8 757
1997-98	136	130	1 174	2 262	2 933	2 970	0	498	78	10 182
1998-99	104	159	973	1 836	2 609	2 389	3	875	111	9 063
1999-00	188	156	871	1 897	2 121	3 850	0	759	90	9 932
2000-01	170	205	971	1 480	1 958	3 684	0	1 019	39	9 527
2001-02	169	207	860	1 216	2 064	4 517	1	1 133	72	10 240
2002-03	121	113	1 131	1 313	1 896	4 707	1	836	35	10 153
2003-04	108	74	811	1 061	2 269	4 936	1	815	38	10 114
2004-05	75	55	641	814	3 042	4 875	8	764	29	10 302
2005-06	124	40	610	595	2 982	3 095	4	994	21	8 465
2006-07	63	71	945	854	3 108	3 920	0	701	19	9 681
2007-08	74	19	828	1 182	3 264	3 469	0	525	41	9 402
2008-09	67	37	699	498	2 674	2 042	8	556	21	6 603
2009-10	39	23	548	539	2 607	1 475	0	603	7	5 842
2010-11	52	28	390	400	3 333	749	0	854	5	5 811
2011-12	86	6	256	731	2 914	1 158	0	761	4	5 916
2012-13	83	7	260	486	3 063	3 390	-	811	9	8 109

## (d) Deepwater midwater trawl (methods MW and MPT for TCEPR form)

Fishing year	Area									Total
	North NI	East NI	East SI	Chatham	Southland	Sub-Antarctic	Bounty	West SI	Cook Strait	
1989-90	0	1	72	0	116	42	8	1 261	260	1 759
1990-91	0	13	57	69	29	9	20	740	325	1 261
1991-92	0	1	61	11	121	19	38	402	201	854
1992-93	0	4	34	24	155	58	4	324	176	780
1993-94	0	1	39	33	268	14	3	348	107	812
1994-95	0	0	38	58	417	14	3	1 260	119	1 909
1995-96	0	2	92	60	463	46	2	863	117	1 646
1996-97	0	1	106	53	133	5	0	723	142	1 166
1997-98	1	12	195	44	79	5	7	985	105	1 433
1998-99	0	7	214	46	62	6	11	772	91	1 209
1999-00	0	4	227	29	114	16	7	726	109	1 232
2000-01	0	5	81	44	351	229	0	855	147	1 712
2001-02	0	1	103	38	131	233	1	651	74	1 233
2002-03	5	4	87	19	135	217	0	585	138	1 190
2003-04	0	4	80	60	130	306	2	759	119	1 460
2004-05	0	1	70	15	98	204	6	335	97	826
2005-06	0	3	25	2	149	470	1	269	65	985
2006-07	0	1	6	1	101	191	2	125	45	472
2007-08	0	2	10	0	84	3	1	87	33	220
2008-09	0	2	4	0	6	6	2	80	25	125
2009-10	0	1	18	0	36	8	0	127	22	213
2010-11	0	3	3	0	50	20	2	141	19	237
2011-12	0	0	6	1	138	3	0	165	31	344
2012-13	0	1	16	2	5	6	3	317	34	384

Table 5 continued.

## (e) Line (methods BLL,TL, and DL for the CELR, LCER, and LTCER forms)

Fishing year	Area									Total
	North NI	East NI	East SI	Chatham	Southland	Sub-Antarctic	Bounty	West SI	Cook Strait	
1989-90	39	134	185	8	0	–	–	197	66	630
1990-91	50	186	613	846	2	217	7	428	55	2 406
1991-92	98	300	478	2 997	288	326	835	691	70	6 090
1992-93	83	401	491	2 605	453	886	965	708	100	6 694
1993-94	108	406	552	3 272	863	449	1 142	761	63	7 619
1994-95	128	432	811	4 697	704	1 567	385	891	59	10 047
1995-96	81	396	1 011	3 412	301	1 224	378	991	53	7 900
1996-97	67	328	634	2 974	847	2 232	340	962	20	8 506
1997-98	60	446	427	1 955	975	2 366	388	1 008	67	7 848
1998-99	39	370	528	2 040	770	1 940	549	972	107	7 339
1999-00	50	317	776	2 043	857	1 206	984	784	94	7 115
2000-01	36	380	473	1 921	961	728	1 063	917	160	6 640
2001-02	100	370	385	1 962	955	657	627	659	111	5 826
2002-03	90	346	401	1 386	850	214	921	686	137	5 032
2003-04	95	425	356	1 264	581	656	850	682	169	5 078
2004-05	166	340	369	2 097	848	310	34	728	215	5 107
2005-06	161	365	434	1 123	676	172	38	562	187	3 718
2006-07	161	425	498	1 087	685	–	234	745	153	3 988
2007-08	235	461	521	1 125	789	345	502	1 010	93	5 081
2008-09	177	397	583	1 314	382	216	222	887	33	4 211
2009-10	252	412	638	1 303	404	789	1	864	11	4 674
2010-11	349	431	629	995	252	360	51	902	33	4 002
2011-12	266	289	446	1 272	483	723	1	848	34	4 362
2012-13	208	317	654	1 401	367	0	–	933	89	3 969

## (f) Setnet (method SN for the CELR and NCELR forms)

Fishing year	Area									Total
	North NI	East NI	East SI	Chatham	Southland	Sub-Antarctic	Bounty	West SI	Cook Strait	
1989-90	2	48	210	0	0	–	–	346	36	642
1990-91	1	85	227	–	2	–	–	368	0	682
1991-92	3	40	144	0	1	–	–	264	1	453
1992-93	6	25	164	–	1	–	–	129	3	327
1993-94	3	4	179	0	0	–	–	151	1	342
1994-95	27	1	199	–	1	–	–	103	1	332
1995-96	1	5	179	–	0	0	–	170	1	357
1996-97	23	28	203	0	2	0	–	108	1	365
1997-98	4	12	201	–	2	–	–	127	0	346
1998-99	23	1	147	–	0	0	–	65	0	237
1999-00	1	1	165	–	0	–	–	94	0	262
2000-01	0	1	131	–	0	–	–	49	2	184
2001-02	1	0	123	–	1	0	–	62	0	187
2002-03	1	0	104	0	0	–	–	50	0	156
2003-04	1	1	120	–	1	–	–	24	0	148
2004-05	0	1	78	0	1	–	–	31	1	112
2005-06	0	5	51	–	1	–	–	39	0	96
2006-07	0	0	47	–	2	0	–	91	0	141
2007-08	1	2	55	0	3	0	0	43	0	104
2008-09	0	5	58	2	6	0	–	43	0	115
2009-10	0	0	62	2	5	0	–	47	0	116
2010-11	0	0	55	2	5	0	–	28	0	90
2011-12	0	0	34	–	4	0	–	22	1	62
2012-13	0	0	27	0	4	0	–	34	0	66



Table 5 continued.

## (g) Fishpots (methods RLP, CP, and FP for the CELR form)

Fishing year	Area									Total
	North NI	East NI	East SI	Chatham	Southland	Sub-Antarctic	Bounty	West SI	Cook Strait	
1989-90	0	0	2	0	1	-	-	0	0	3
1990-91	0	0	15	0	1	0	-	-	0	16
1991-92	0	-	39	0	1	-	-	0	0	40
1992-93	0	0	15	0	1	-	-	-	0	16
1993-94	0	0	11	0	1	-	-	0	0	13
1994-95	0	0	8	0	2	-	-	-	0	10
1995-96	0	0	4	0	4	-	-	0	0	8
1996-97	0	0	38	0	2	-	-	0	0	40
1997-98	0	0	40	0	3	-	-	-	0	43
1998-99	-	0	41	0	0	0	-	-	0	42
1999-00	0	0	21	-	10	-	-	-	0	32
2000-01	2	0	4	0	25	-	-	1	0	31
2001-02	0	0	3	-	16	-	-	-	0	19
2002-03	0	-	1	0	13	-	-	0	0	14
2003-04	0	0	4	0	0	-	-	0	1	5
2004-05	0	0	10	0	0	-	-	0	0	10
2005-06	0	0	49	-	3	0	-	0	0	52
2006-07	0	0	56	0	3	-	-	0	0	60
2007-08	0	0	19	0	2	-	-	-	0	21
2008-09	0	0	10	0	11	-	-	0	0	21
2009-10	0	0	41	-	8	-	-	0	0	49
2010-11	0	0	33	-	5	-	-	-	0	39
2011-12	0	0	8	0	1	-	-	0	0	10
2012-13	0	0	26	-	3	-	-	0	0	29

**Table 6: Summary of data for all vessels and for vessels included in the final core datasets, by year. Data include: number of unique vessels fishing (Vessels), estimated catch (Catch), number of vessel-days (Days), and unstandardised CPUE from non-zero catches. All vessel data is defined as data from which core vessels were chosen using constraints defined in Table 3. Note: These numbers differ from table B2 of Horn et al. (2013) as “all vessel” data for Chatham Rise or Sub-Antarctic was defined there as target ling data for BLL, TL, and DL fishing methods without additional constraints.**

**(a) Chatham Rise**

Year	All vessels				Final vessels			
	Vessels	Catch	Days	CPUE	Vessels	Catch	Days	CPUE
1991	19	1 790.0	790	2.27	4	1 526.2	414	3.69
1992	21	2 946.9	792	3.72	4	2 110.4	478	4.42
1993	23	3 340.9	856	3.90	6	2 915.0	638	4.57
1994	21	3 901.8	1 034	3.77	6	3 505.3	779	4.50
1995	22	5 516.5	1 067	5.17	6	4 127.8	689	5.99
1996	23	3 515.6	998	3.52	7	3 101.6	725	4.28
1997	19	3 000.6	1 052	2.85	7	2 726.0	749	3.64
1998	17	2 274.4	606	3.75	6	2 174.8	483	4.50
1999	16	2 206.9	730	3.02	8	2 162.6	651	3.32
2000	15	2 263.0	675	3.35	6	2 194.1	542	4.05
2001	9	2 435.0	678	3.59	6	2 393.5	600	3.99
2002	11	2 089.3	891	2.34	8	2 004.7	759	2.64
2003	13	1 784.8	645	2.77	5	1 348.2	439	3.07
2004	20	1 620.9	834	1.94	5	1 318.8	587	2.25
2005	15	2 421.5	1 002	2.42	5	1 445.8	618	2.34
2006	14	1 415.1	692	2.04	4	1 268.6	544	2.33
2007	18	1 432.5	869	1.65	7	1 363.4	732	1.86
2008	21	1 846.4	810	2.28	8	1 548.5	615	2.52
2009	13	1 824.8	855	2.13	7	1 762.1	776	2.27
2010	13	1 771.6	839	2.11	7	1 692.7	773	2.19
2011	19	1 538.2	898	1.71	5	1 350.9	700	1.93
2012	15	1 681.1	769	2.19	5	1 358.3	567	2.40
2013	17	1 615.0	701	2.30	5	663.5	249	2.66

**(b) Chatham Rise, exclude core vessels 2, 3, and 5**

Year	All vessels				Final vessels			
	Vessels	Catch	Days	CPUE	Vessels	Catch	Days	CPUE
1991	19	1 789.9	787	2.27	2	174.1	150	1.16
1992	21	2 946.9	792	3.72	2	259.2	176	1.47
1993	23	3 305.0	855	3.87	3	378.3	189	2
1994	21	3 900.8	1 031	3.78	3	674.5	258	2.61
1995	22	4 966.8	1 048	4.74	3	903.0	241	3.75
1996	22	3 443.2	994	3.46	4	736.6	235	3.13
1997	18	2 992.5	1 050	2.85	4	1 197.8	350	3.42
1998	16	2 274.4	606	3.75	4	1 571.1	346	4.54
1999	15	2 206.9	730	3.02	8	2 162.6	651	3.32
2000	15	2 259.6	674	3.35	6	2 194.1	542	4.05
2001	9	2 430.7	677	3.59	6	2 393.5	600	3.99
2002	11	2 089.3	891	2.34	8	2 004.7	759	2.64
2003	13	1 777.0	644	2.76	5	1 348.2	439	3.07
2004	19	1 620.9	834	1.94	5	1 318.8	587	2.25
2005	15	1 969.7	976	2.02	5	1 445.8	618	2.34
2006	14	1 415.1	692	2.04	4	1 268.6	544	2.33
2007	18	1 432.5	869	1.65	7	1 363.4	732	1.86
2008	21	1 846.4	810	2.28	8	1 548.5	615	2.52
2009	13	1 824.8	855	2.13	7	1 762.1	776	2.27
2010	13	1 771.6	839	2.11	7	1 692.7	773	2.19
2011	19	1 538.2	898	1.71	5	1 350.9	700	1.93
2012	15	1 681.1	769	2.19	5	1 358.3	567	2.40
2013	17	1 615.0	701	2.30	5	663.5	249	2.66

Table 6 continued.

## (c) Sub-Antarctic, single fishery

Year	All vessels				Final vessels			
	Vessels	Catch	Days	CPUE	Vessels	Catch	Days	CPUE
1991	3	466.4	120	3.89	2	466.2	119	3.92
1992	4	1 077.7	246	4.38	3	1 070.7	244	4.39
1993	7	1 265.3	298	4.25	5	1 157.7	279	4.15
1994	6	1 416.0	346	4.09	5	1 266.8	302	4.19
1995	6	1 824.1	340	5.36	4	1 611.2	285	5.65
1996	7	1 711.7	334	5.12	4	1 533.9	297	5.16
1997	9	3 009.2	631	4.77	6	2 981.0	606	4.92
1998	7	2 678.3	581	4.61	6	2 670.2	572	4.67
1999	6	2 704.7	671	4.03	6	2 700.1	667	4.05
2000	5	2 125.8	434	4.90	5	2 125.8	434	4.90
2001	6	1 670.2	310	5.39	6	1 670.2	310	5.39
2002	6	1 260.3	222	5.68	6	1 260.3	222	5.68
2003	5	620.1	157	3.95	5	620.1	157	3.95
2004	4	1 633.5	411	3.97	4	1 633.5	411	3.97
2005	2	941.5	177	5.32	2	941.5	177	5.32
2006	3	814.5	140	5.82	3	814.5	140	5.82
2007	5	837.8	129	6.49	3	832.8	117	7.12
2008	4	665.1	209	3.18	2	514.4	123	4.18
2009	4	531.4	89	5.97	2	528.8	86	6.15
2010	5	1 003.7	235	4.27	2	961.0	205	4.69
2011	4	797.9	222	3.59	2	795.4	217	3.67
2012	2	1 109.4	257	4.32	2	1 109.4	257	4.32

## (d) Sub-Antarctic, spawning fishery (Puysegur, October–December)

Year	All vessels				Final vessels			
	Vessels	Catch	Days	CPUE	Vessels	Catch	Days	CPUE
1991	3	195.6	36	5.43	2	195.4	35	5.58
1992	4	377.2	64	5.89	3	377.2	63	5.99
1993	4	678.8	100	6.79	3	678.1	99	6.85
1994	4	679.6	104	6.53	4	679.6	104	6.53
1995	3	232.6	37	6.29	2	232.2	36	6.45
1996	3	746.1	101	7.39	3	746.1	101	7.39
1997	3	783.1	124	6.32	3	783.1	124	6.32
1998	3	745.6	139	5.36	3	745.6	139	5.36
1999	3	832.9	107	7.78	3	832.9	107	7.78
2000	3	909.1	117	7.77	3	909.1	117	7.77
2001	4	935.5	125	7.48	4	935.5	125	7.48
2002	3	830.4	100	8.30	3	830.4	100	8.30
2003	3	427.9	73	5.86	3	427.9	73	5.86
2004	3	953.3	151	6.31	3	953.3	151	6.31
2005	2	667.7	80	8.35	2	667.7	80	8.35
2006	3	642.7	88	7.30	3	642.7	88	7.30
2007	3	773.3	102	7.58	3	773.3	102	7.58
2008	2	358.3	66	5.43	1	326.3	54	6.04
2009	2	313.9	29	10.82	1	311.6	27	11.54
2010	1	135.2	30	4.51	1	135.2	30	4.51
2011	1	348.7	50	6.97	1	348.7	50	6.97
2012	1	330.8	44	7.52	1	330.8	44	7.52

Table 6 continued.

## (e) Sub-Antarctic, non-spawning fishery (i.e. non-Puysegur, all year)

Year	All vessels				Final vessels			
	Vessels	Catch	Days	CPUE	Vessels	Catch	Days	CPUE
1991	1	270.8	84	3.22	1	270.8	84	3.22
1992	2	700.5	182	3.85	2	700.5	182	3.85
1993	6	586.5	198	2.96	4	484.0	181	2.67
1994	6	736.4	242	3.04	5	735.2	241	3.05
1995	5	1 591.5	303	5.25	4	1 384.4	250	5.54
1996	6	965.5	233	4.14	4	794.5	201	3.95
1997	9	2 226.0	507	4.39	7	2 223.0	505	4.40
1998	6	1 932.7	442	4.37	5	1 924.6	433	4.44
1999	6	1 871.8	564	3.32	6	1 871.8	564	3.32
2000	5	1 216.7	317	3.84	5	1 216.7	317	3.84
2001	5	734.7	185	3.97	5	734.7	185	3.97
2002	6	429.9	122	3.52	6	429.9	122	3.52
2003	4	192.2	84	2.29	4	192.2	84	2.29
2004	3	680.2	260	2.62	3	680.2	260	2.62
2005	1	273.8	97	2.82	1	273.8	97	2.82
2006	1	171.9	52	3.31	1	171.9	52	3.31
2007	3	64.5	27	2.39	1	59.5	15	3.97
2008	2	306.8	143	2.15	1	188.1	69	2.73
2009	3	217.5	60	3.62	2	217.2	59	3.68
2010	5	868.5	205	4.24	2	825.8	175	4.72
2011	4	449.2	172	2.61	2	446.7	167	2.67
2012	2	778.6	213	3.66	2	778.6	213	3.66

Table 7: Variables retained in order of decreasing explanatory value by each model for each area, with the corresponding total R<sup>2</sup> value.**Chatham Rise**

Variable	R <sup>2</sup>
Year	8.31
Vessel	54.66
Total hooks	70.15
Month	73.16

**Chatham Rise, excluding core vessels 2, 3, and 5**

Variable	R <sup>2</sup>
Year	6.50
Vessel	55.40
Total hooks	69.39
Month	72.03

**Sub-Antarctic, single fishery**

Variable	R <sup>2</sup>
Year	4.30
Log total hooks	53.37
Statistical area	60.51
Vessel	62.28
Number of sets	63.29

**Sub-Antarctic, two fisheries**

Variable	R <sup>2</sup>
Year	22.34
Log total hooks	61.08
Vessel	63.37

**Table 8a: Lognormal CPUE standardised indices (with 95% confidence intervals and CVs) for the target ling line fisheries.**

Chatham Rise core vessels				Chatham Rise excluding core vessels 2, 3, and 5			
Year	Index	CI	CV	Year	Index	CI	CV
1991	1.67	1.48–1.89	0.06	1991	1.12	0.91–1.39	0.10
1992	2.43	2.17–2.73	0.06	1992	1.40	1.16–1.70	0.10
1993	1.73	1.56–1.92	0.05	1993	1.03	0.86–1.23	0.09
1994	1.65	1.50–1.81	0.05	1994	1.20	1.03–1.39	0.08
1995	1.68	1.53–1.86	0.05	1995	1.83	1.58–2.13	0.07
1996	1.31	1.20–1.44	0.05	1996	1.59	1.39–1.82	0.07
1997	0.88	0.81–0.95	0.04	1997	1	0.89–1.12	0.06
1998	0.90	0.82–0.99	0.05	1998	1.03	0.91–1.15	0.06
1999	0.80	0.74–0.87	0.04	1999	0.84	0.77–0.91	0.04
2000	0.93	0.85–1.02	0.05	2000	1	0.91–1.10	0.05
2001	0.93	0.85–1.01	0.04	2001	1	0.91–1.10	0.05
2002	0.77	0.71–0.83	0.04	2002	0.83	0.77–0.91	0.04
2003	0.85	0.77–0.94	0.05	2003	0.92	0.83–1.02	0.05
2004	0.81	0.74–0.88	0.04	2004	0.88	0.80–0.97	0.05
2005	0.85	0.78–0.93	0.04	2005	0.93	0.85–1.02	0.05
2006	0.74	0.68–0.81	0.05	2006	0.81	0.74–0.89	0.05
2007	0.81	0.74–0.88	0.04	2007	0.88	0.81–0.96	0.04
2008	1.04	0.95–1.14	0.04	2008	1.13	1.03–1.24	0.05
2009	0.73	0.67–0.79	0.04	2009	0.80	0.73–0.87	0.04
2010	0.84	0.78–0.91	0.04	2010	0.92	0.84–1	0.04
2011	0.65	0.60–0.71	0.04	2011	0.72	0.65–0.78	0.04
2012	0.79	0.72–0.87	0.05	2012	0.86	0.79–0.95	0.05
2013	0.80	0.70–0.92	0.07	2013	0.89	0.78–1.01	0.07

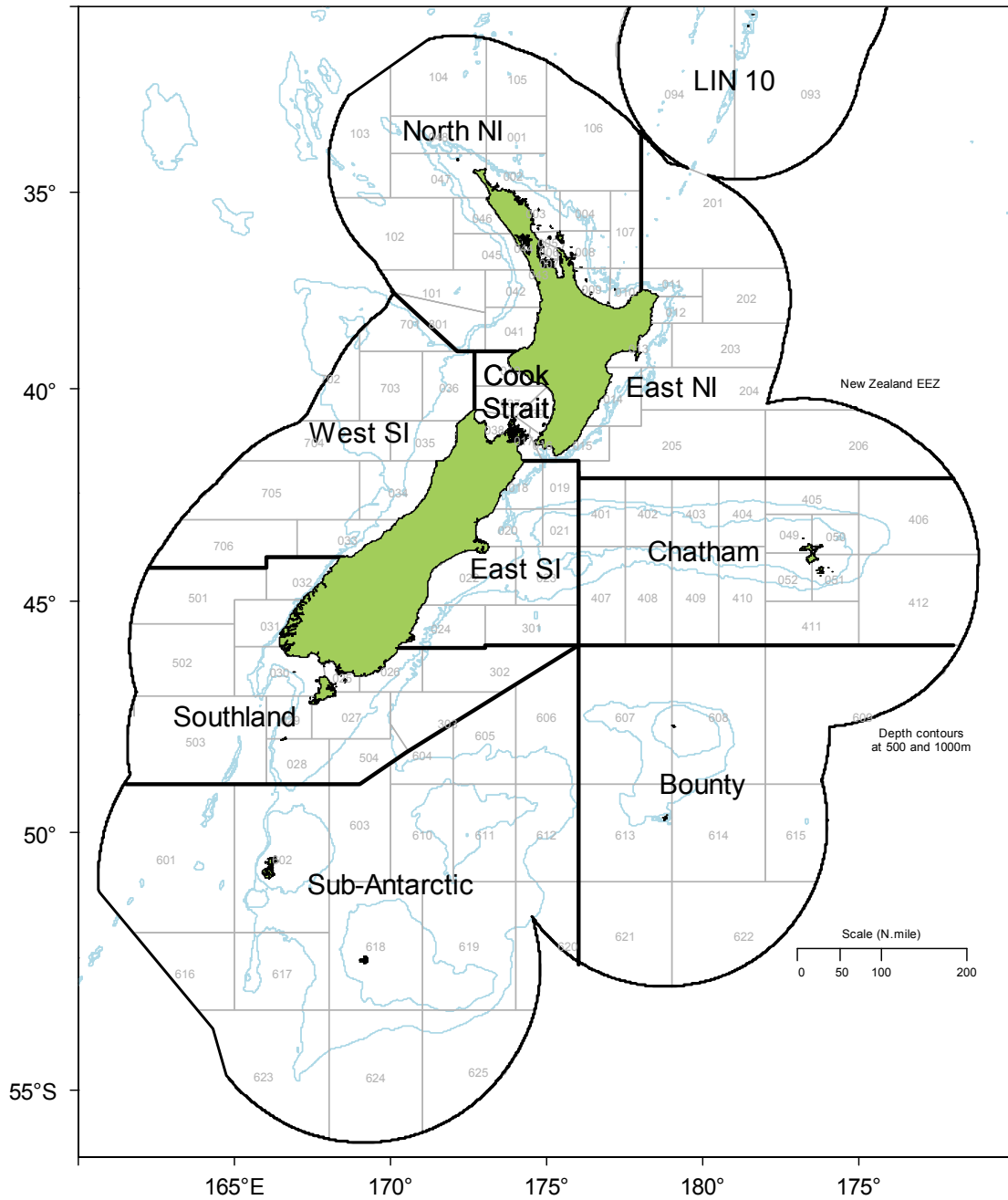
**Table 8b: Lognormal CPUE standardised indices continued.**

<b>Sub-Antarctic single fishery</b>				<b>Sub-Antarctic spawning fishery</b>			
<b>Year</b>	<b>Index</b>	<b>CI</b>	<b>CV</b>	<b>Year</b>	<b>Index</b>	<b>CI</b>	<b>CV</b>
1991	0.82	0.66–1.02	0.11	1991	1.39	0.98–1.96	0.17
1992	1.24	1.04–1.46	0.08	1992	1.81	1.37–2.39	0.14
1993	1.19	1.01–1.41	0.08	1993	1.78	1.42–2.23	0.11
1994	0.95	0.82–1.11	0.08	1994	1.48	1.18–1.85	0.11
1995	1.26	1.08–1.47	0.08	1995	1.48	1.05–2.08	0.17
1996	1.05	0.91–1.22	0.07	1996	1.40	1.12–1.76	0.11
1997	1.19	1.06–1.34	0.06	1997	1.22	0.98–1.52	0.11
1998	1.10	0.97–1.24	0.06	1998	1.10	0.89–1.36	0.11
1999	0.80	0.73–0.88	0.05	1999	1.25	1.02–1.53	0.10
2000	0.96	0.86–1.08	0.06	2000	1.32	1.09–1.61	0.10
2001	1.09	0.96–1.24	0.07	2001	1.27	1.05–1.53	0.09
2002	1.05	0.91–1.21	0.07	2002	1.58	1.28–1.94	0.10
2003	0.80	0.67–0.95	0.09	2003	1.14	0.89–1.46	0.12
2004	0.78	0.68–0.90	0.07	2004	1.04	0.87–1.25	0.09
2005	0.87	0.72–1.05	0.10	2005	1.47	1.15–1.87	0.12
2006	0.89	0.75–1.07	0.09	2006	1.30	1.03–1.64	0.12
2007	1.09	0.90–1.34	0.10	2007	1.39	1.11–1.73	0.11
2008	0.92	0.76–1.11	0.09	2008	1.05	0.79–1.39	0.14
2009	1.18	0.95–1.47	0.11	2009	2.09	1.42–3.08	0.19
2010	1.13	0.96–1.35	0.09	2010	0.69	0.48–1	0.19
2011	0.83	0.70–0.98	0.08	2011	1.04	0.77–1.38	0.15
2012	1.04	0.89–1.22	0.08	2012	1.13	0.83–1.53	0.15

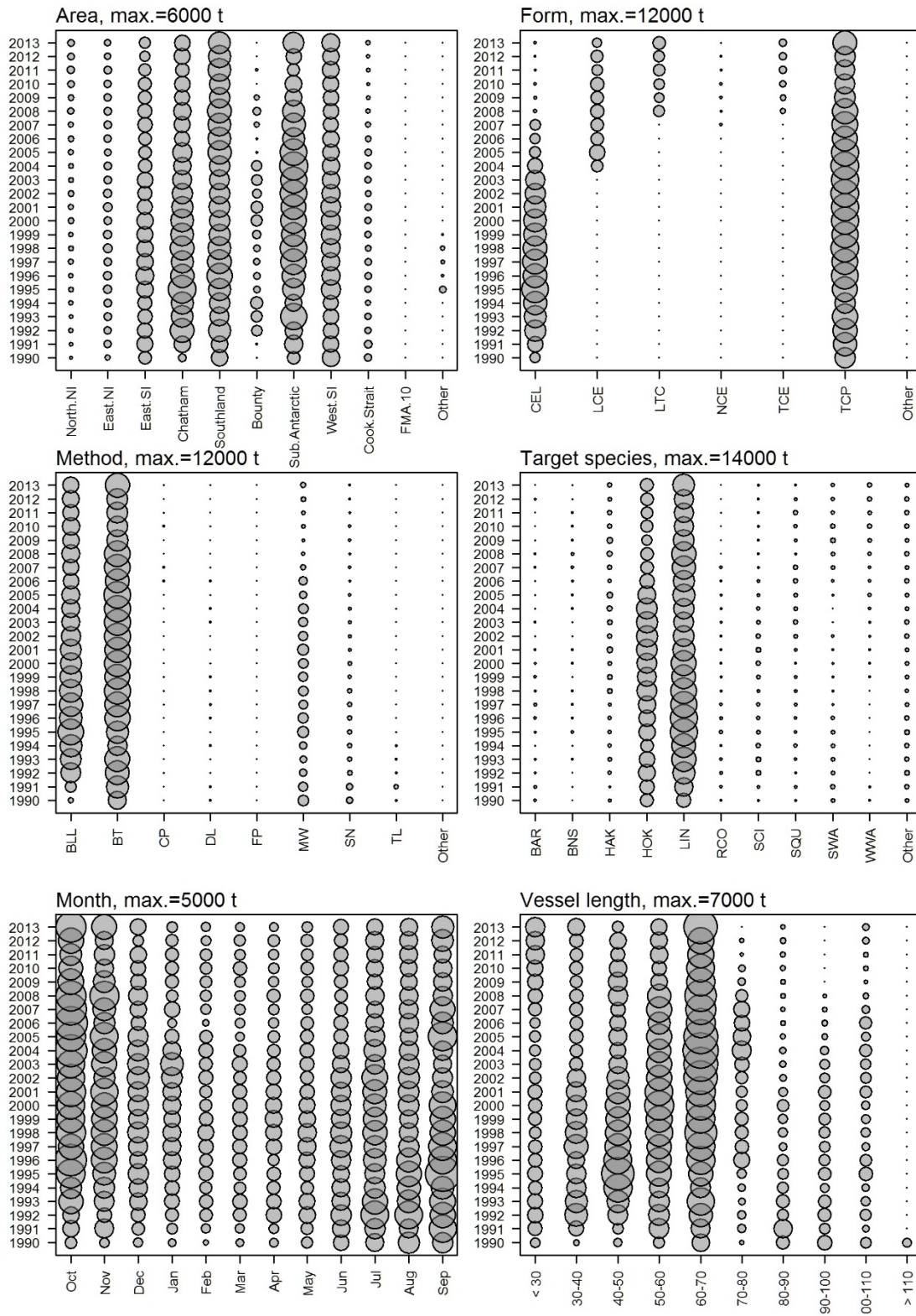
  

<b>Sub-Antarctic non-spawning fishery</b>			
<b>Year</b>	<b>Index</b>	<b>CI</b>	<b>CV</b>
1991	0.67	0.53–0.86	0.12
1992	1.07	0.89–1.28	0.09
1993	1	0.82–1.22	0.10
1994	0.76	0.64–0.91	0.09
1995	1.10	0.93–1.29	0.08
1996	0.85	0.72–1.01	0.09
1997	0.96	0.84–1.09	0.06
1998	0.90	0.79–1.03	0.07
1999	0.64	0.58–0.71	0.05
2000	0.74	0.65–0.85	0.07
2001	0.90	0.76–1.06	0.08
2002	0.77	0.63–0.93	0.10
2003	0.60	0.48–0.76	0.12
2004	0.57	0.47–0.68	0.09
2005	0.52	0.40–0.68	0.13
2006	0.60	0.45–0.79	0.14
2007	0.74	0.45–1.24	0.26
2008	0.87	0.66–1.13	0.13
2009	0.76	0.58–0.99	0.13
2010	0.91	0.76–1.08	0.09
2011	0.58	0.48–0.70	0.09
2012	0.73	0.62–0.86	0.08

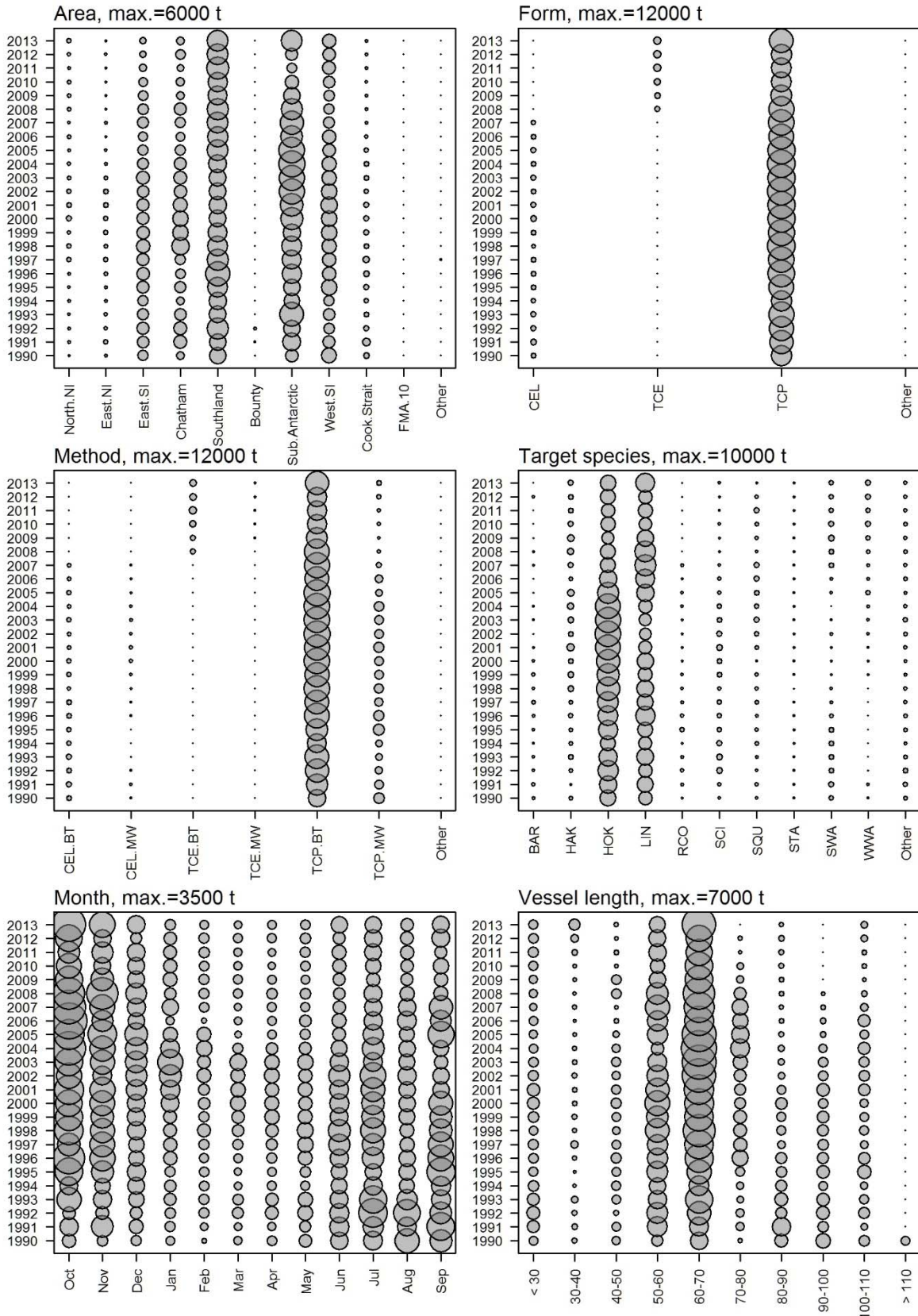




**Figure 1: Definitions of geographical areas used in the analysis (based on statistical areas). See Table 1 for the administrative ling stocks they approximate.**

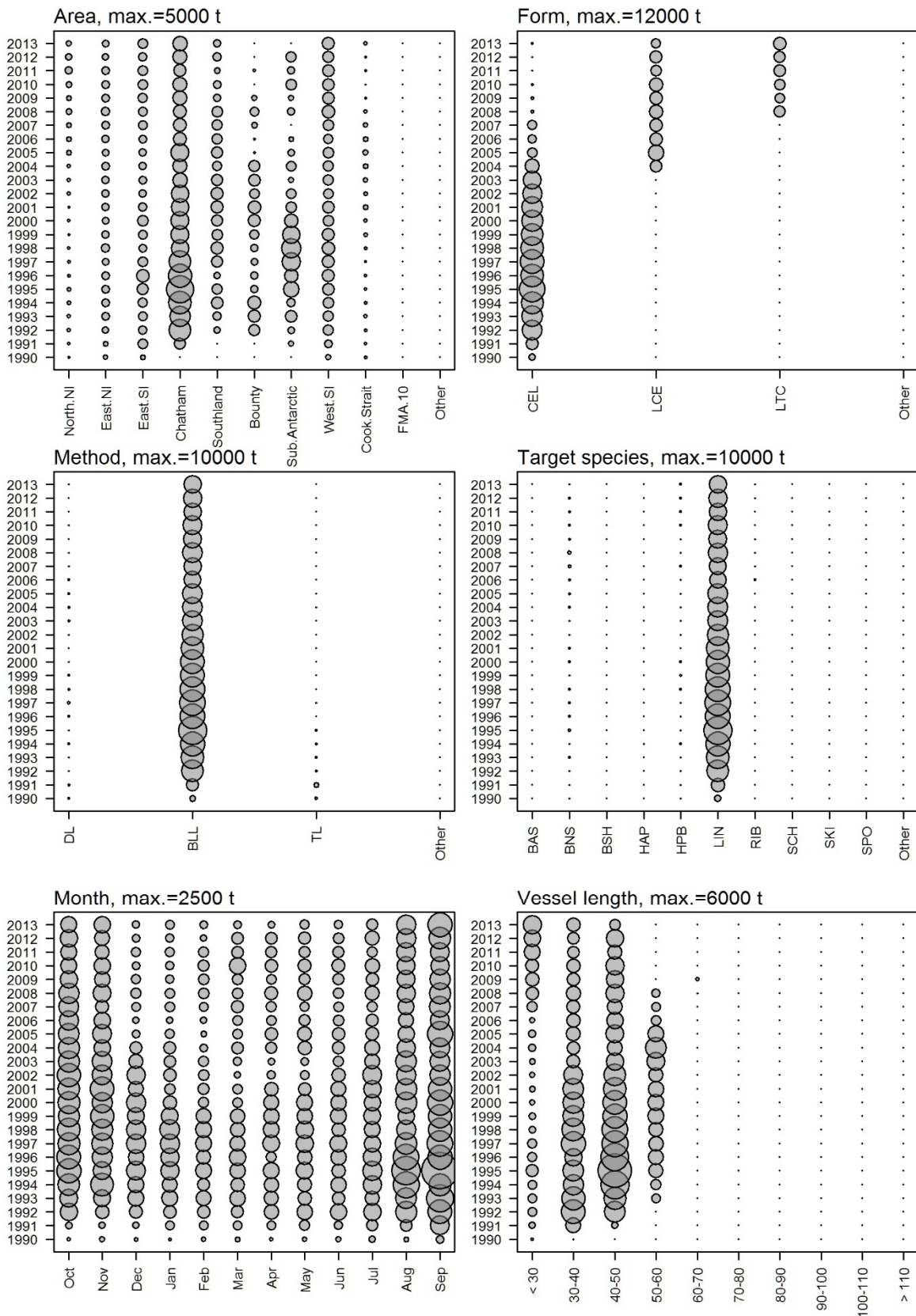


**Figure 2: Distribution of annual catch by area, form type, fishing method, target species, month, and vessel length for all ling catches by all methods. Circle size is proportional to catch; maximum circle size is indicated in the heading of each plot. Form types: CEL is Catch, Effort, Landing Return; LCE is Line Catch Effort return; LTC is Lining Trip Catch, Effort return; NCE is Net Catch Effort Return; TCE is Trawl, Catch, Effort Return; TCP is Trawl, Catch, Effort, and Processing Return. Method definitions: BLL, bottom longlining; BT, bottom trawl; CP, cod potting; DL, dahn lines; MB, midwater trawl within 5 m of the sea bed; MW, midwater trawl; SN, set net; TL, trot line. Species codes: BAR, barracouta; BNS, bluenose; HAK, hake; HOK, hoki; LIN, ling; RCO, red cod; SCI, scampi; SQU, arrow squid; SWA, silver warehou; WWA, white warehou.**

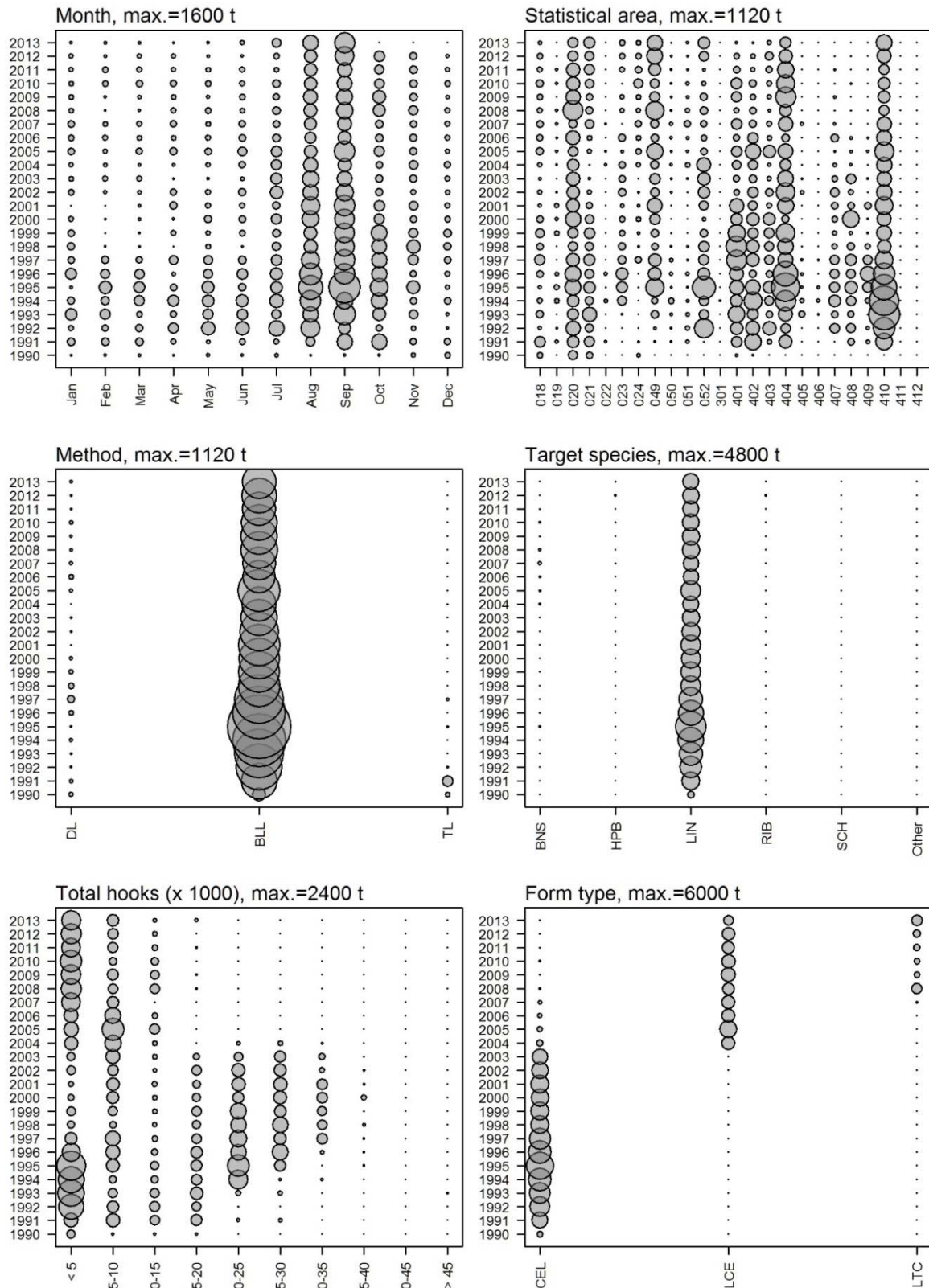


**Figure 3: Distribution of annual catch by area, form type, fishing method (by form type), target species, month, and vessel length for all ling catches by trawl methods. Circle size is proportional to catch; maximum circle size is indicated in the heading of each plot. Form types and method types are defined in Figure 2. Species codes: BAR, barracouta; HAK, hake; HOK, hoki; LIN, ling; RCO, red cod; SCI, scampi; SQU, arrow squid; STA, giant stargazer; SWA, silver warehou; WWA, white warehou.**

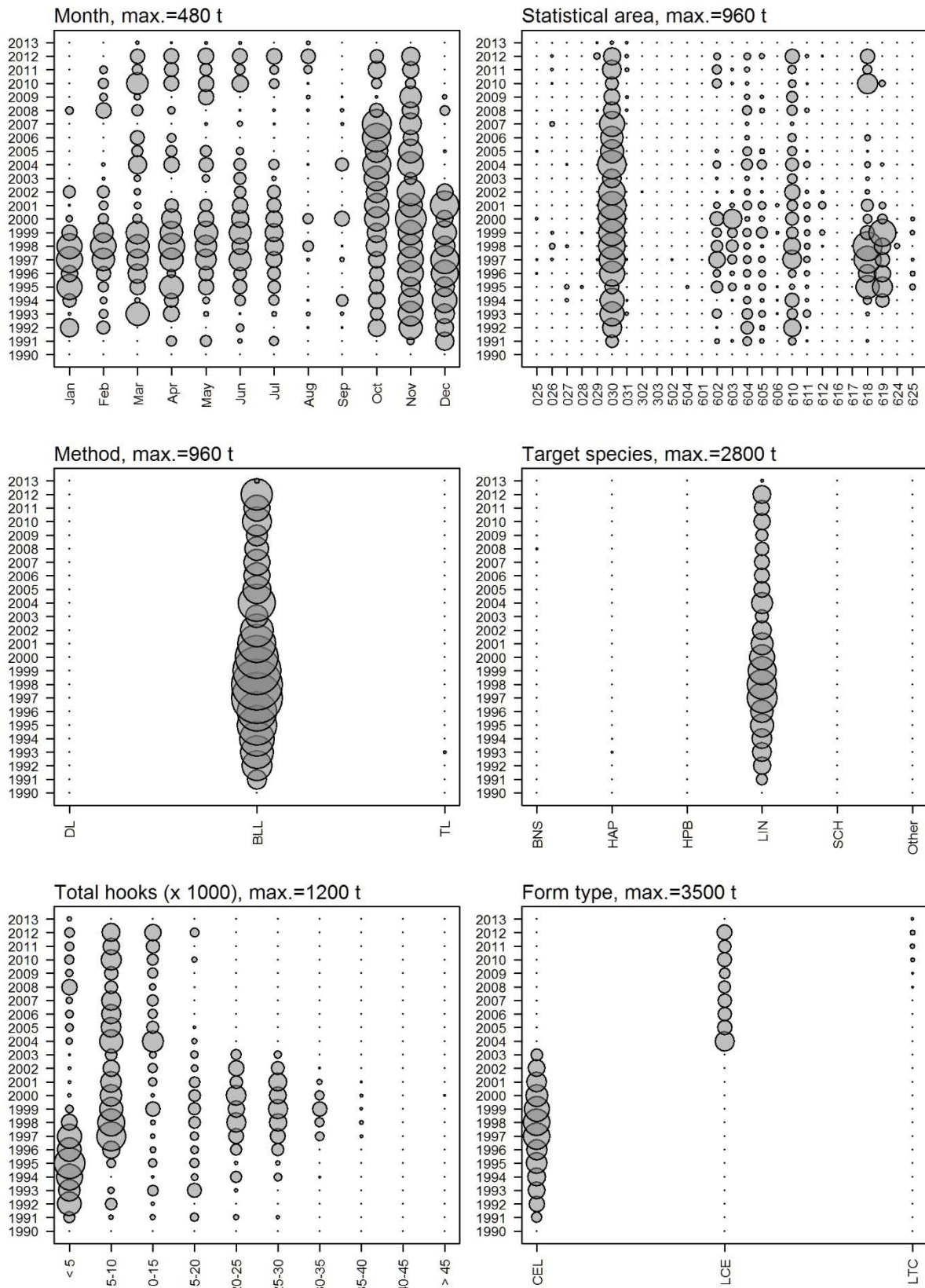




**Figure 4: Distribution of annual catch by area, form type, fishing method (by form type), target species, month, and vessel length for all ling catches by line methods. Circle size is proportional to catch; maximum circle size is indicated in the heading of each plot. Form types and method types are defined in Figure 2. Species codes: BAS, bass; BNS, bluenose; BSH, seal shark; HAP, hapuku; HPB, hapuku and bass; LIN, ling; RIB, ribaldo; SCH, school shark; SKI, gemfish; SPO, rig.**

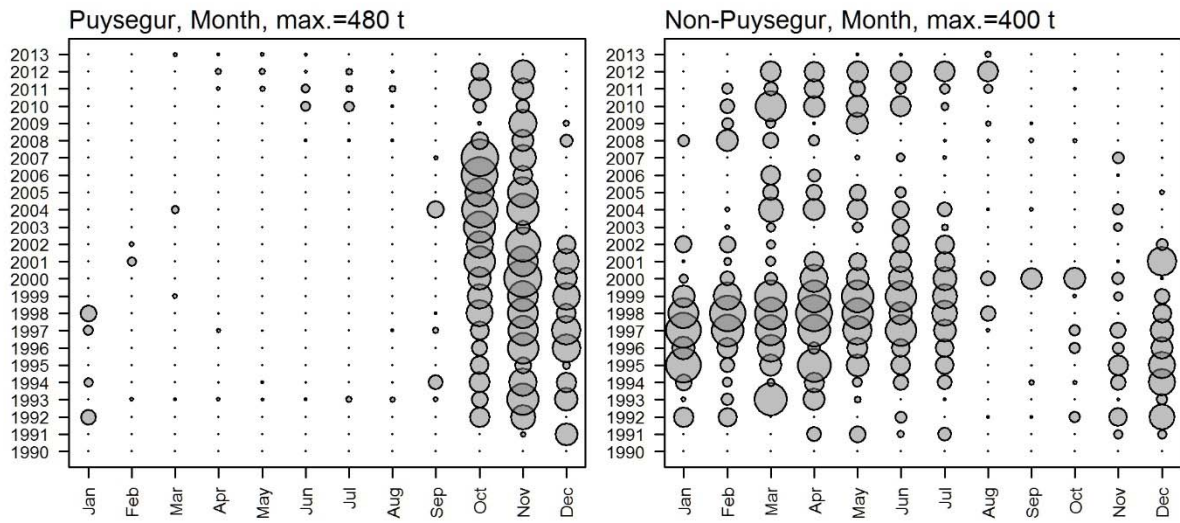


**Figure 5a: Distribution of Chatham Rise ling line catch by month, target species, method, statarea, number of hooks, and form type for 1990 to 2013 calendar years. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Method definitions: BLL, bottom longline; DL, dahn line; TL, trot line. Species codes: BNS, bluenose; HPB, hapuku and bass; LIN, ling; RIB, ribaldo; SCH, school shark. Form types: CEL is Catch, Effort, Landing Return; LCE is Line Catch Effort return; LTC is Lining Trip Catch, Effort return.**

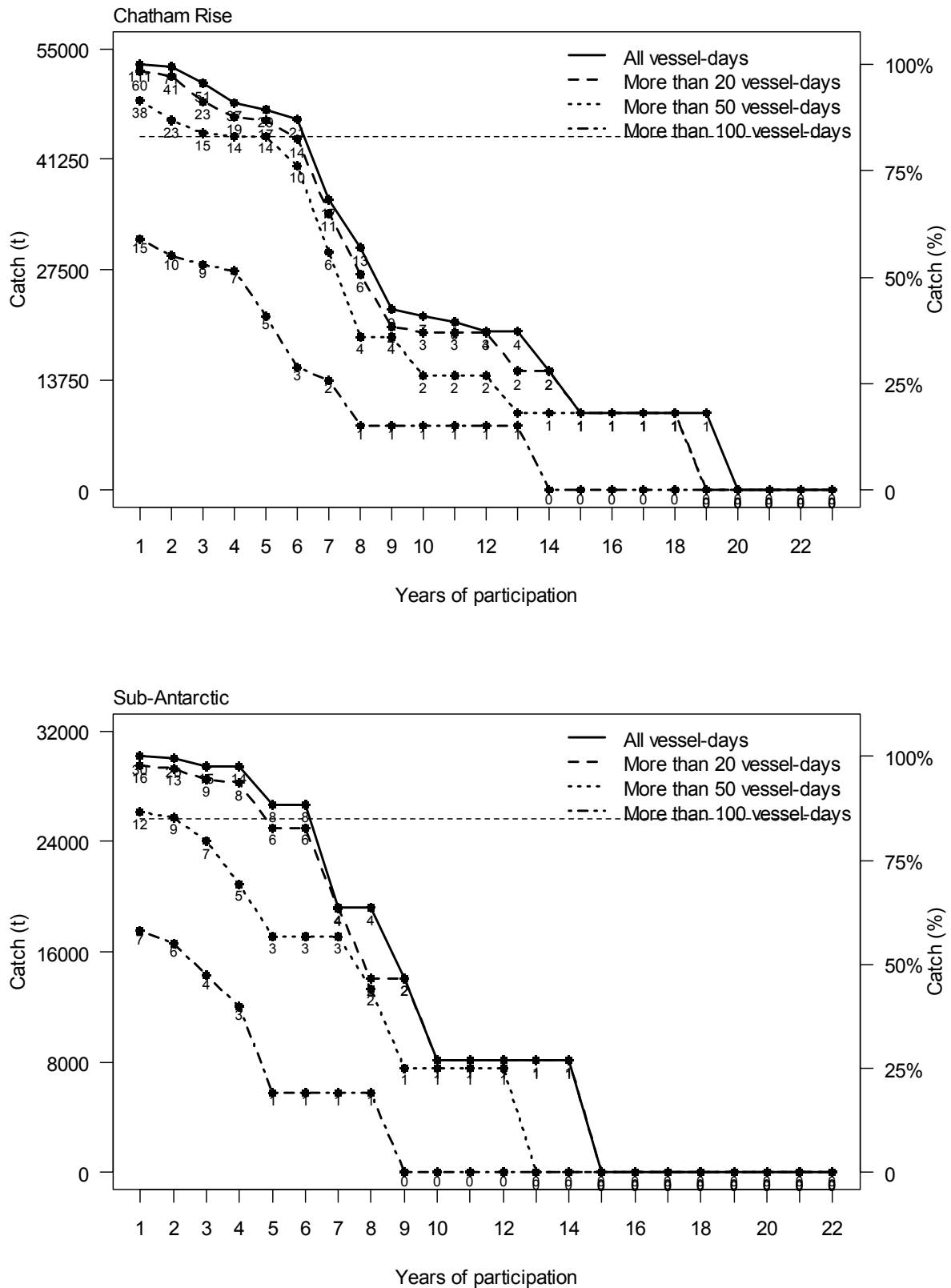


**Figure 5b: Distribution of Sub-Antarctic single fishery ling line catch by month, target species, method, starea, number of hooks, and form type for 1990 to 2013 calendar years. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Method definitions: BLL, bottom longline; DL, dahn line; TL, trot line. Species codes: BNS, bluenose; HAP: hapuku; HPB, hapuku and bass; LIN, ling; SCH, school shark. Form types: CEL is Catch, Effort, Landing Return; LCE is Line Catch Effort return; LTC is Lining Trip Catch, Effort return.**





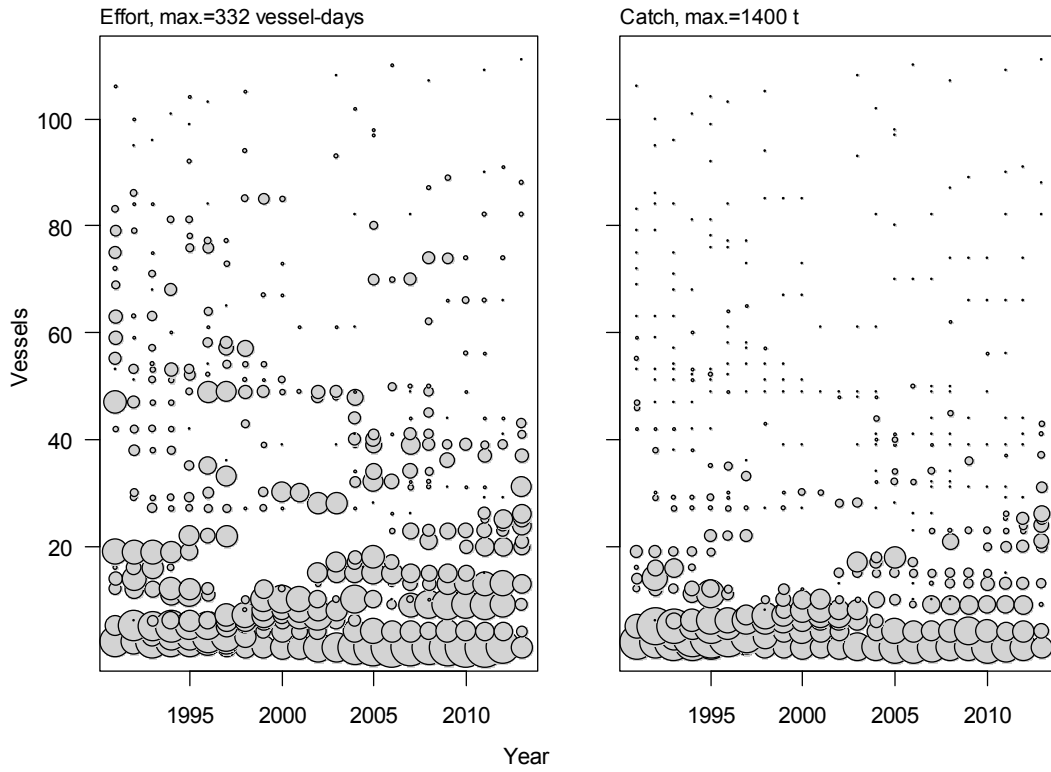
**Figure 5c: Distribution of Sub-Antarctic ling line catch by month for Puysegur (Statistical Area 030) and non-Puysegur for the 1990 to 2013 calendar years. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot.**



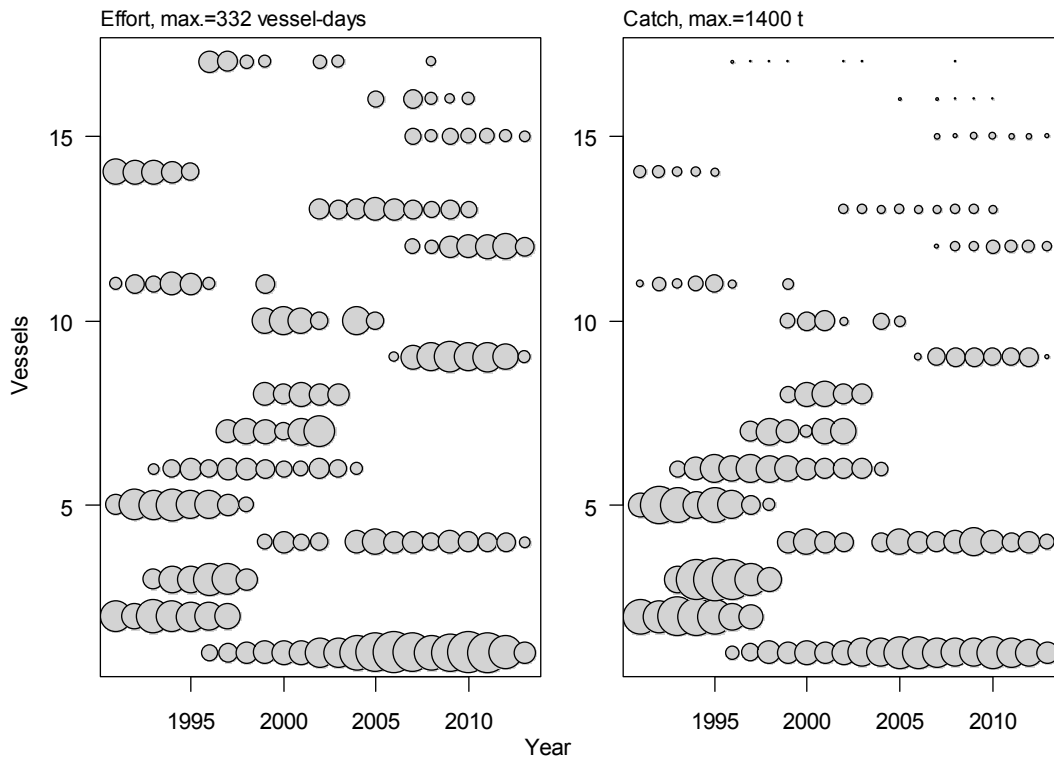
**Figure 6: Relationship between the number of years of vessel participation and total ling catch by those vessels for the bottom longline ling target fisheries by area. The number under each circle indicates the number of vessels with the corresponding number of years of participation. The dotted horizontal line represents 80% of the catch.**



All vessels

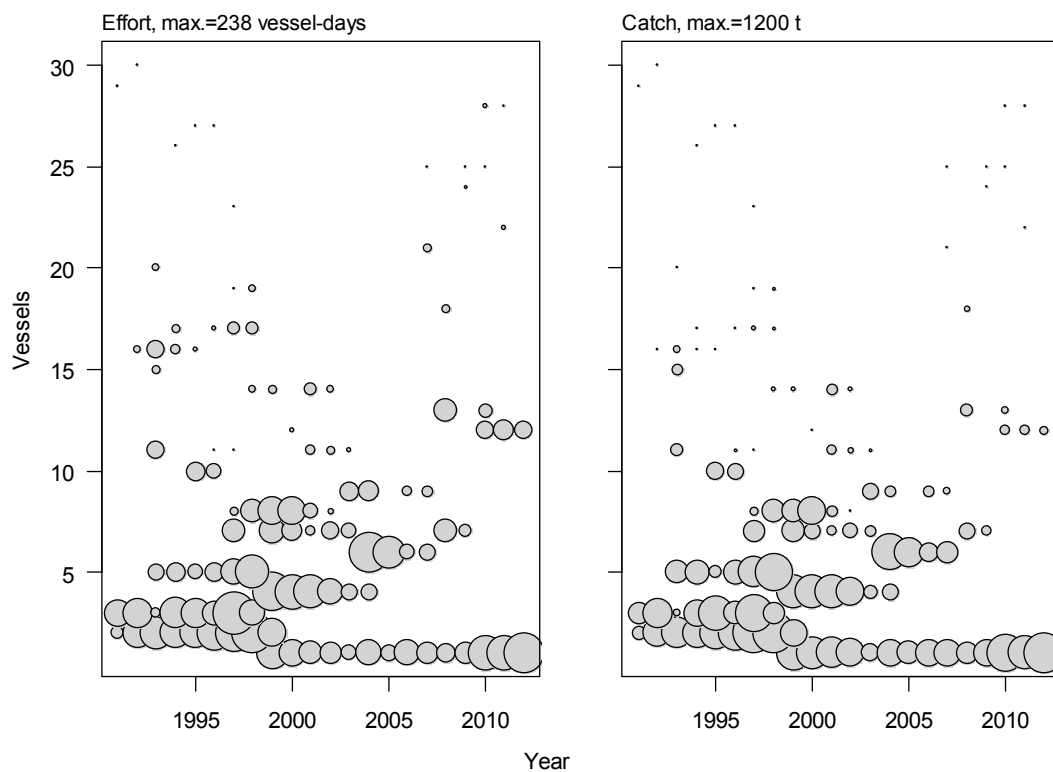


Core vessels

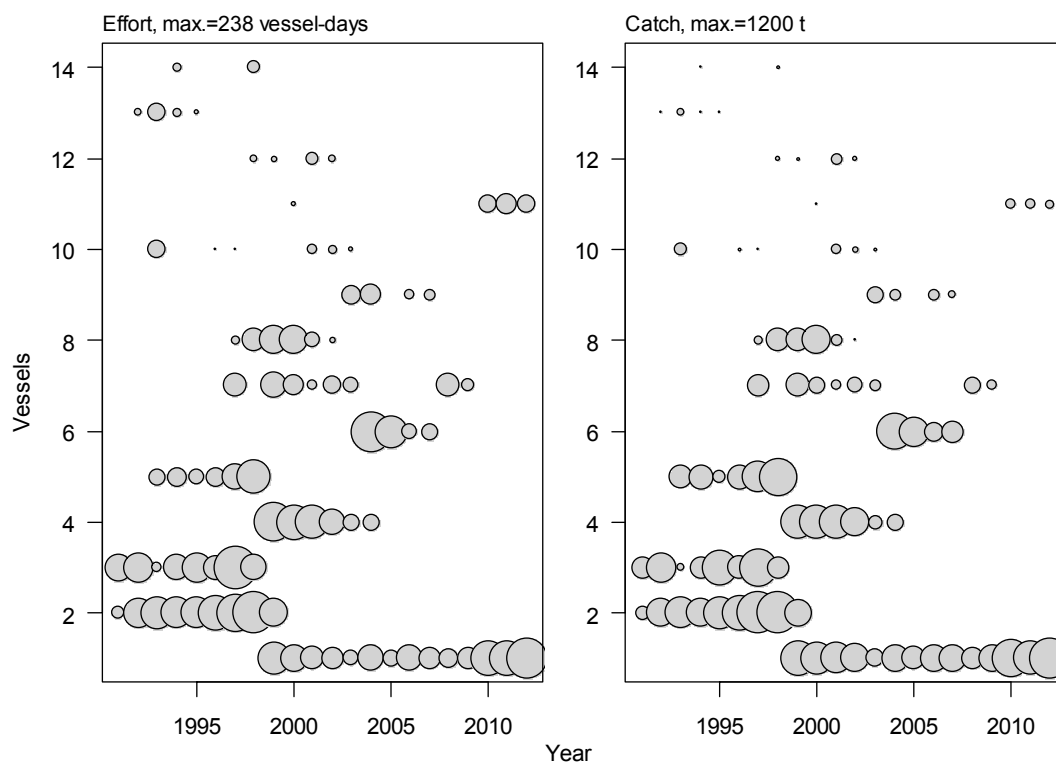


**Figure 7a: Line fishing effort and catches (where circle area is proportional to the effort or catch) by year for individual vessels (denoted anonymously by number on the y-axis), for all vessels, and for the final set of core vessels, for the Chatham Rise.**

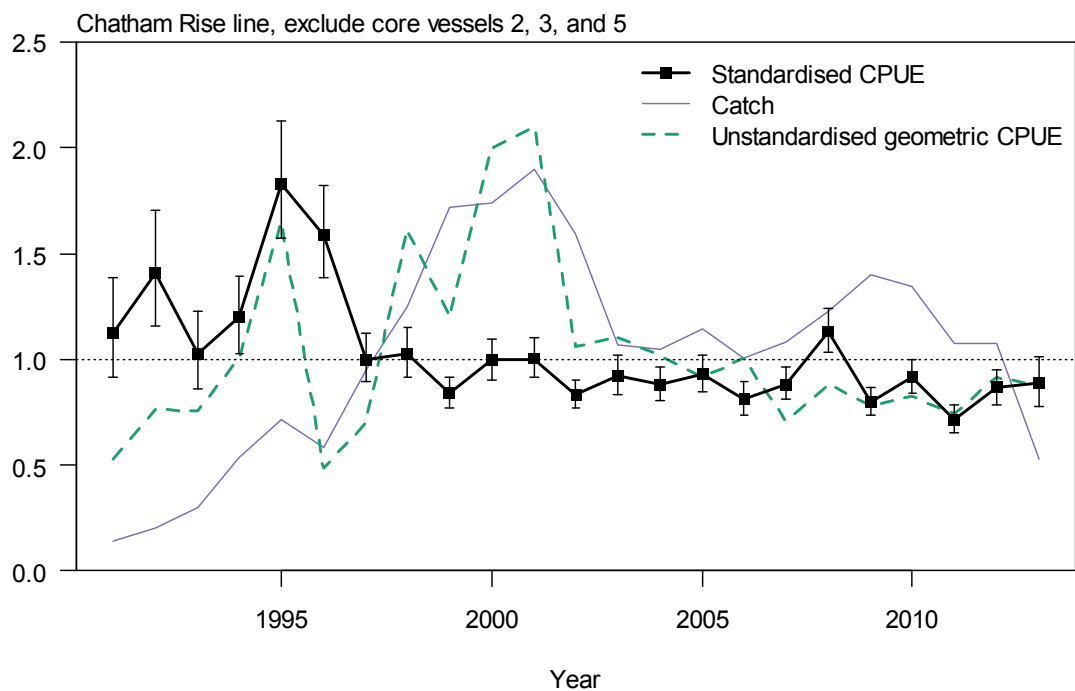
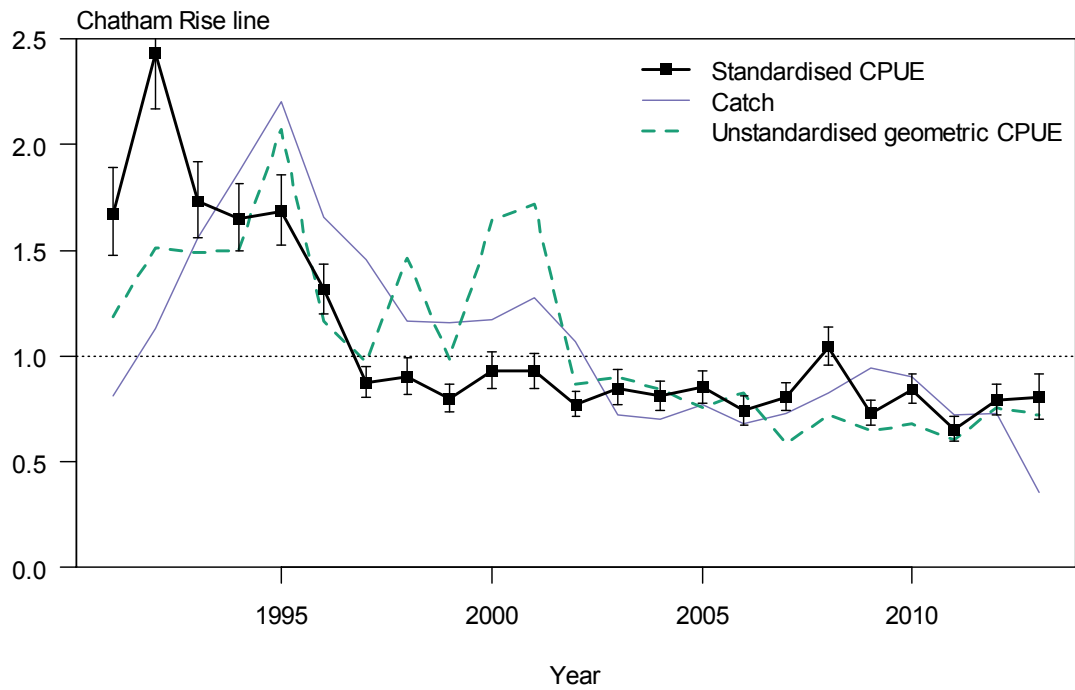
All vessels



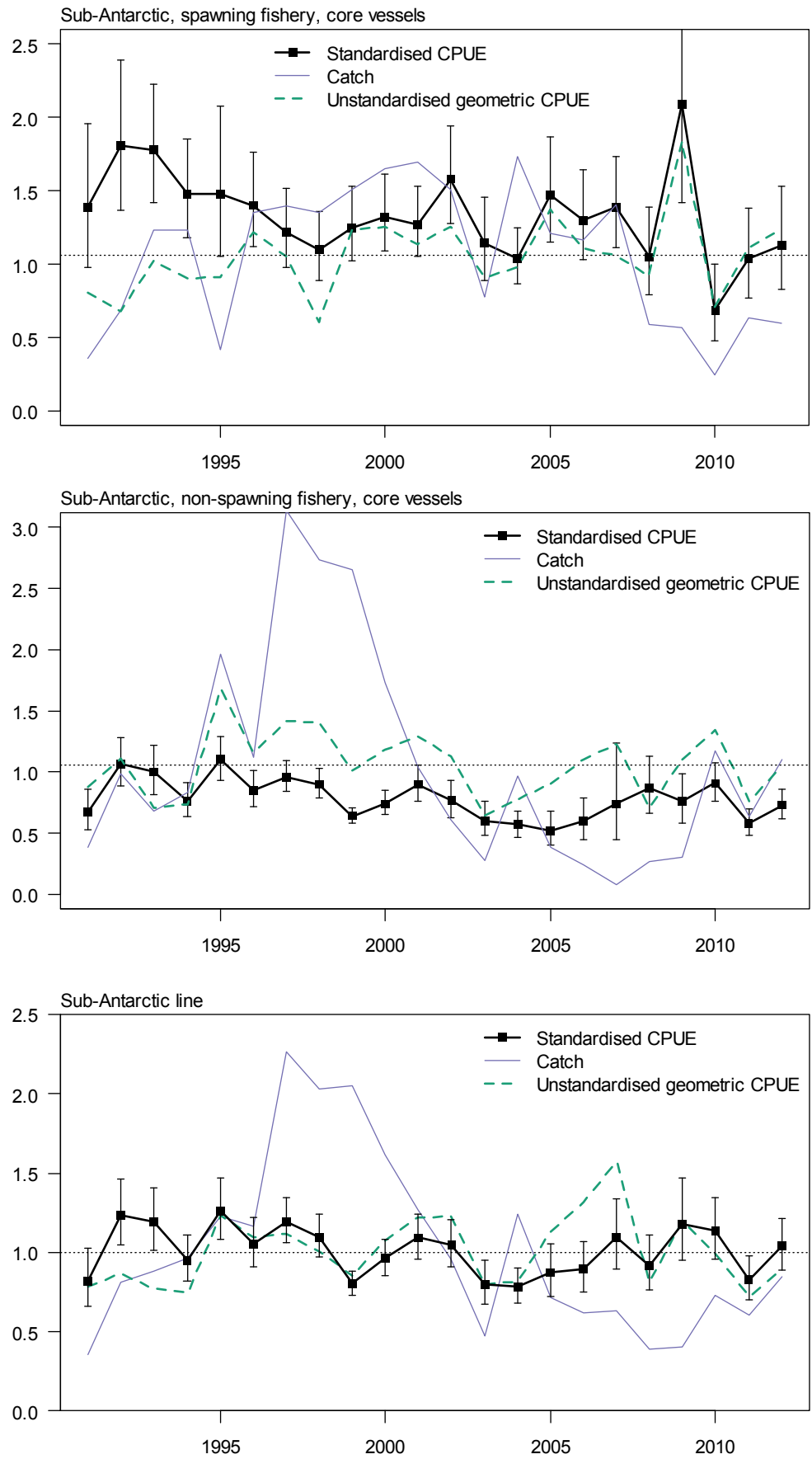
Core vessels



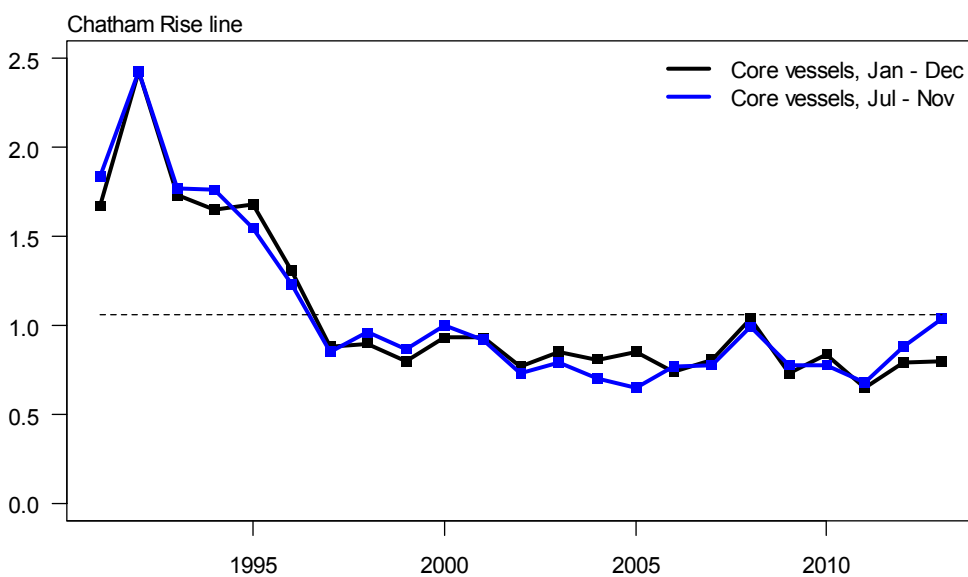
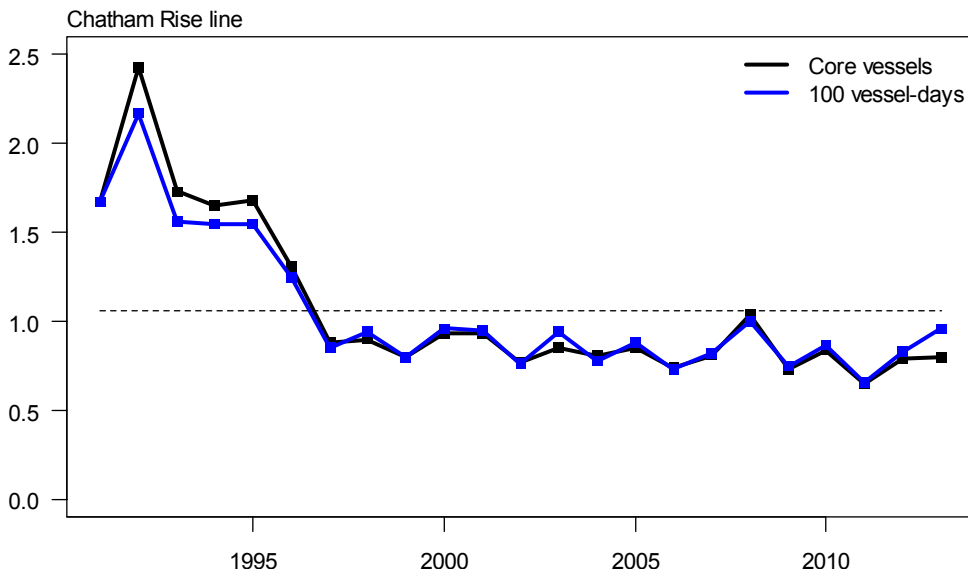
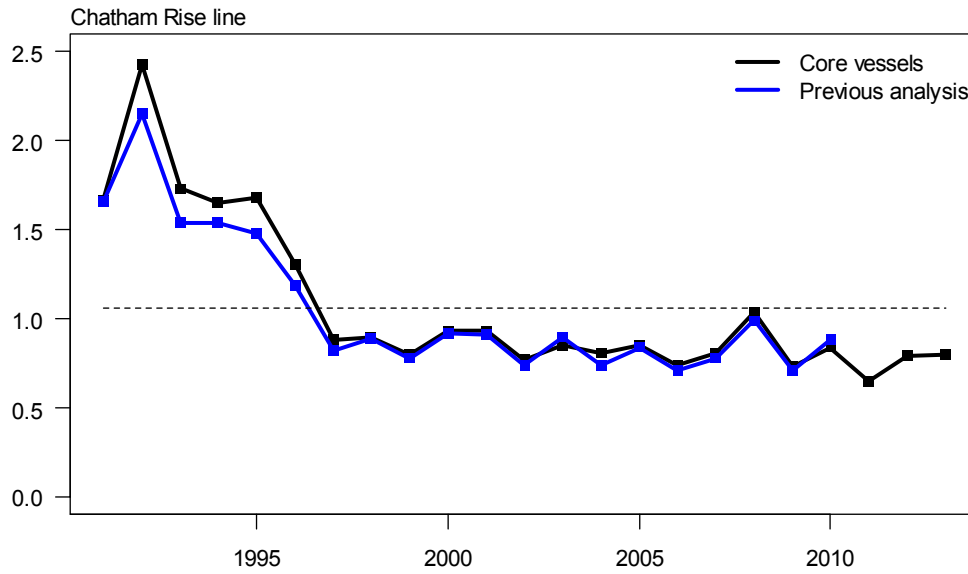
**Figure 7b: Line fishing effort and catches (where circle area is proportional to the effort or catch) by year for individual vessels (denoted anonymously by number on the y-axis), for all vessels, and for the final set of core vessels, for the Sub-Antarctic.**



**Figure 8a:** CPUE from the lognormal models for the Chatham Rise core fishery for all core vessels (upper panel) and core vessels excluding vessels 2, 3, and 5 (lower panel), 1991–2013. Bars indicate 95% confidence intervals.



**Figure 8b: CPUE from the lognormal models for the Sub-Antarctic spawning fishery, non-spawning fishery, and single fishery, 1991–2013. Bars indicate 95% confidence intervals.**



**Figure 9a: CPUE indices for the Chatham Rise fishery, comparing the current core vessel analysis with the previous analysis, previous vessel selection criteria, and subsets of months, hook numbers, and core vessels.**

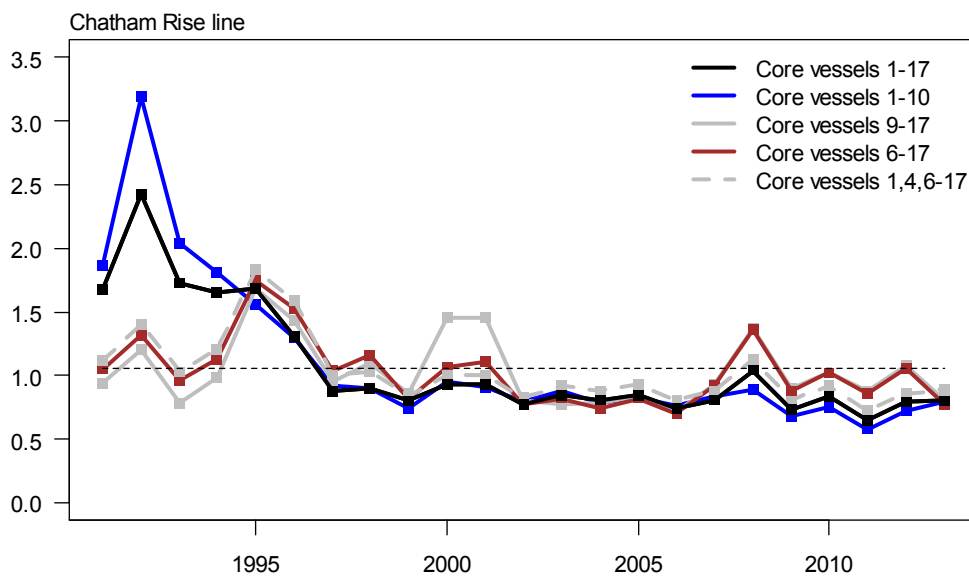
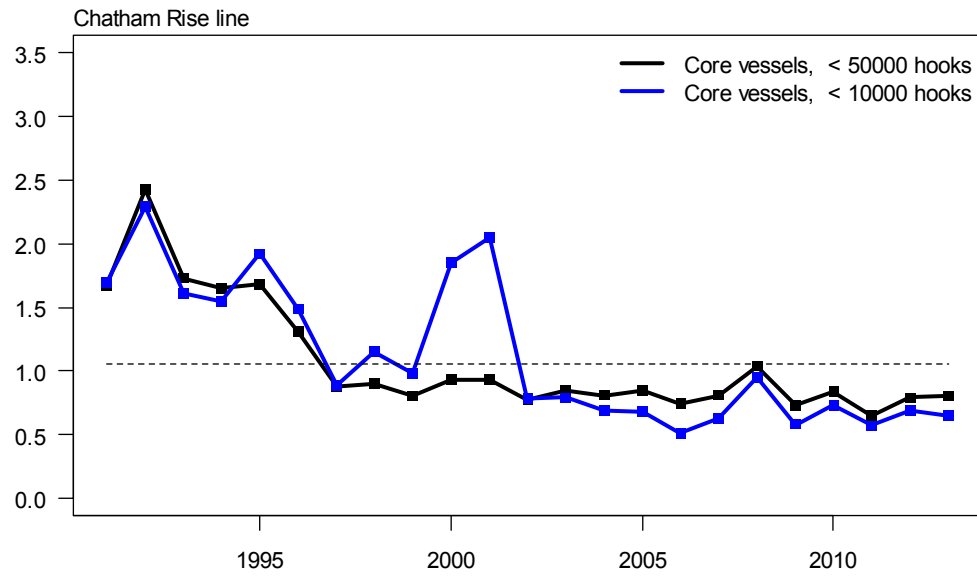
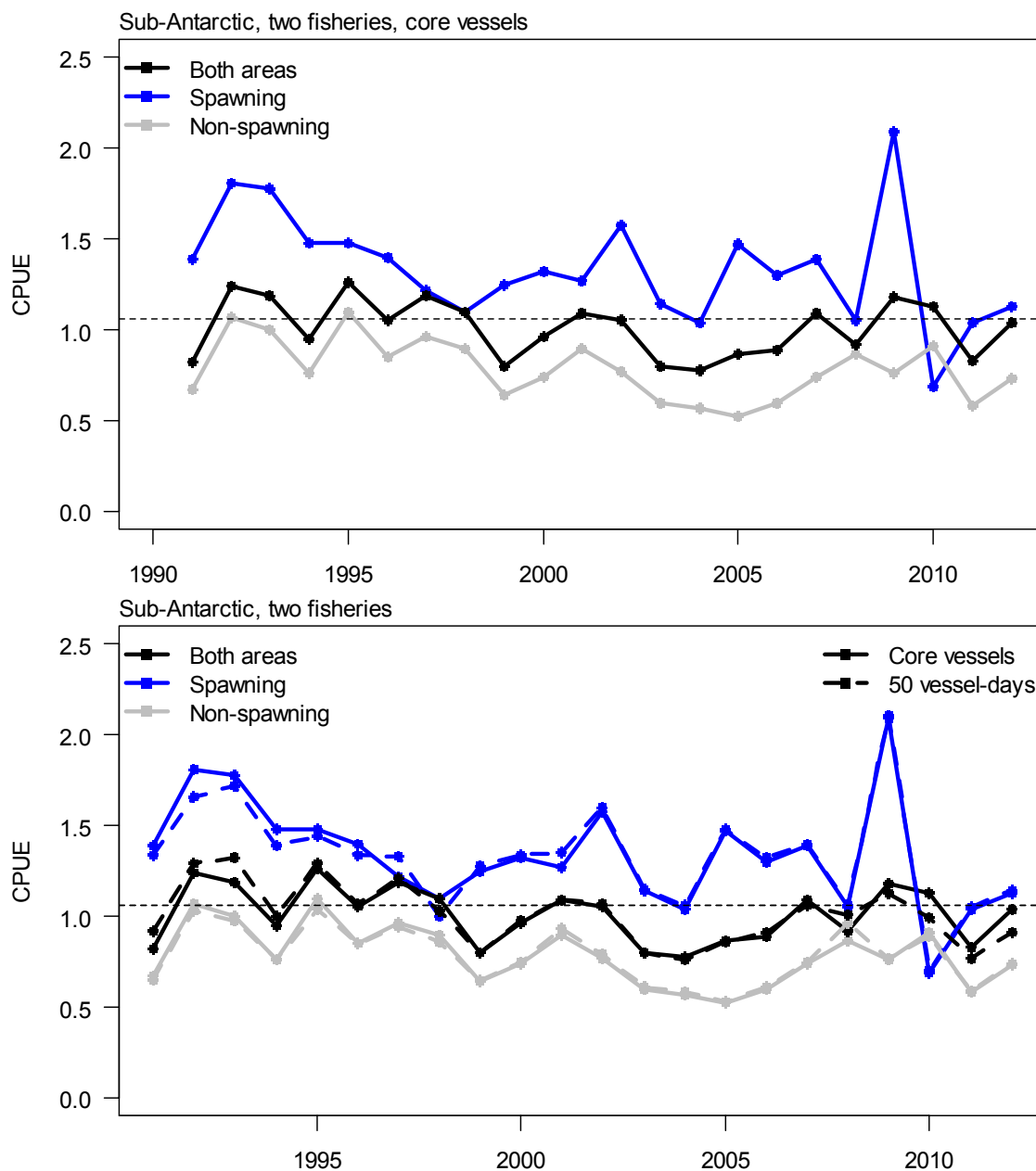


Figure 9a continued.



**Figure 9b: CPUE indices for the lognormal model for the Sub-Antarctic single (both areas) and two fishery (spawning and non-spawning) models, comparing the current core vessel analysis with the previous analysis, and previous vessel selection criteria.**

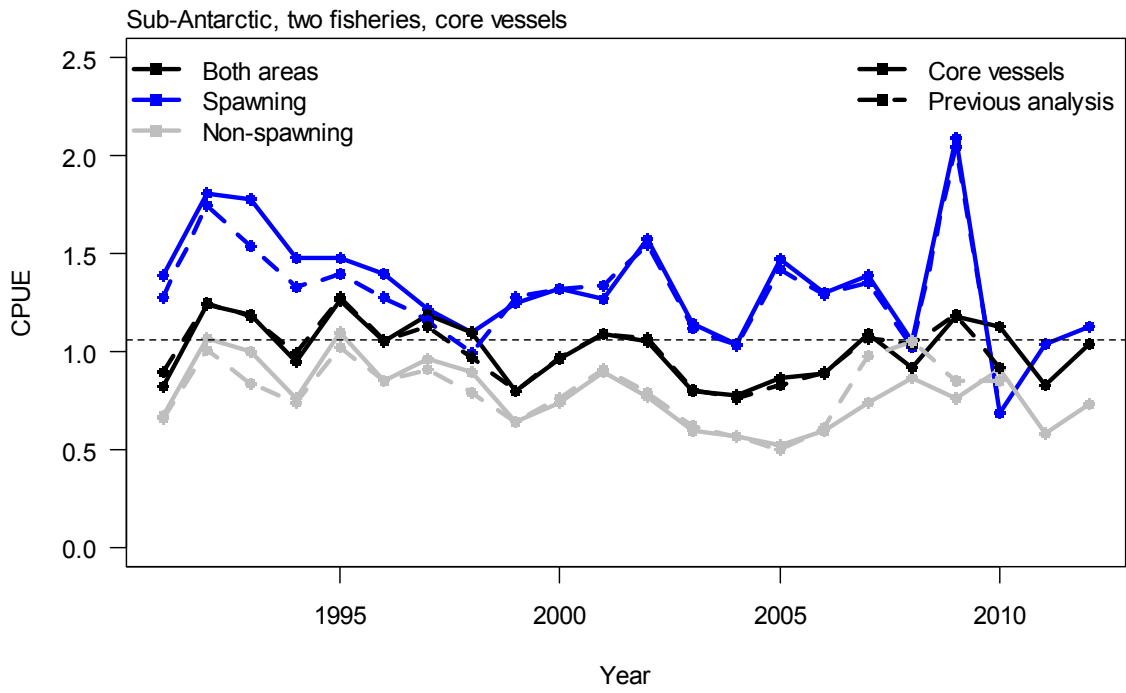
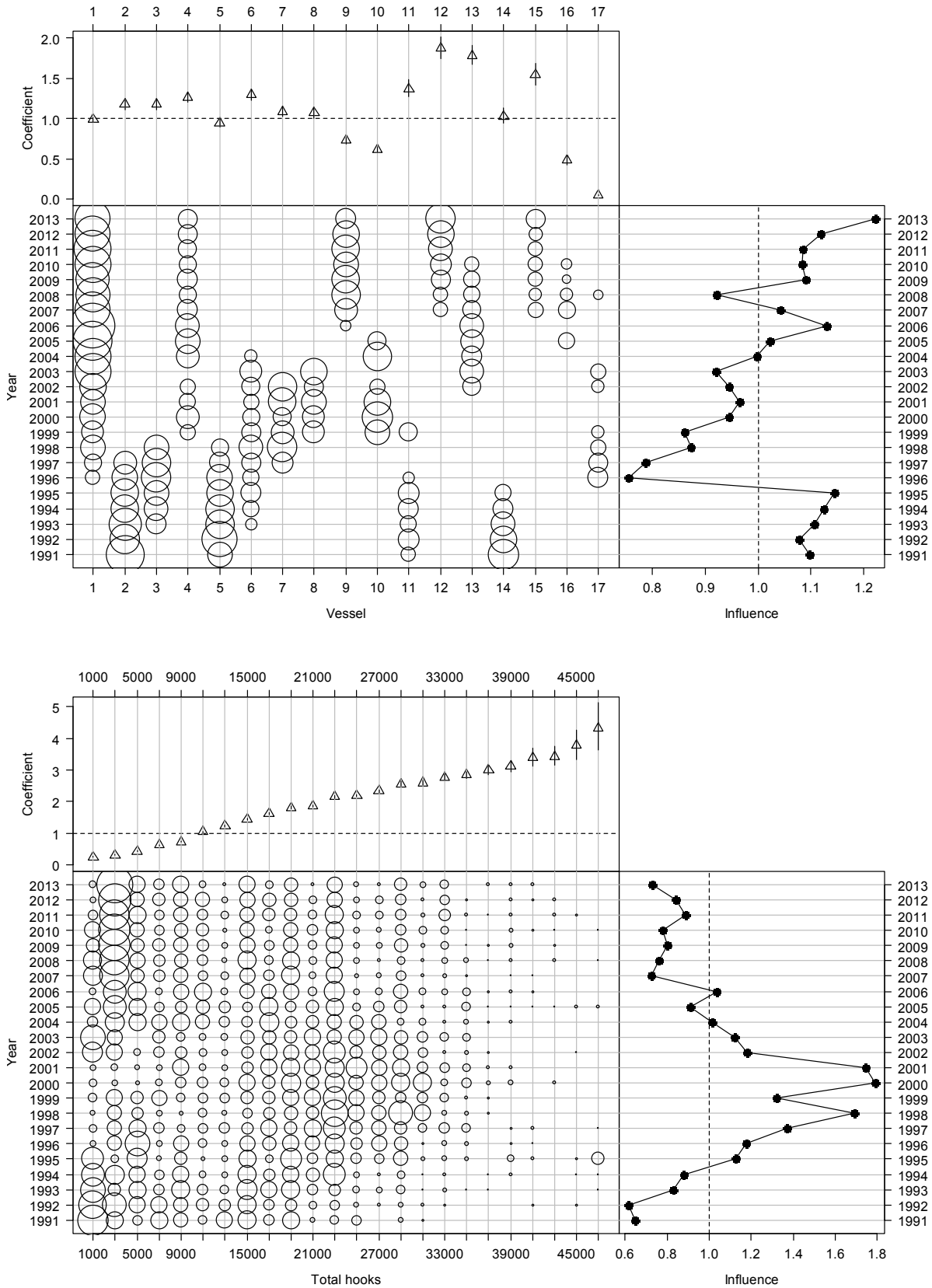
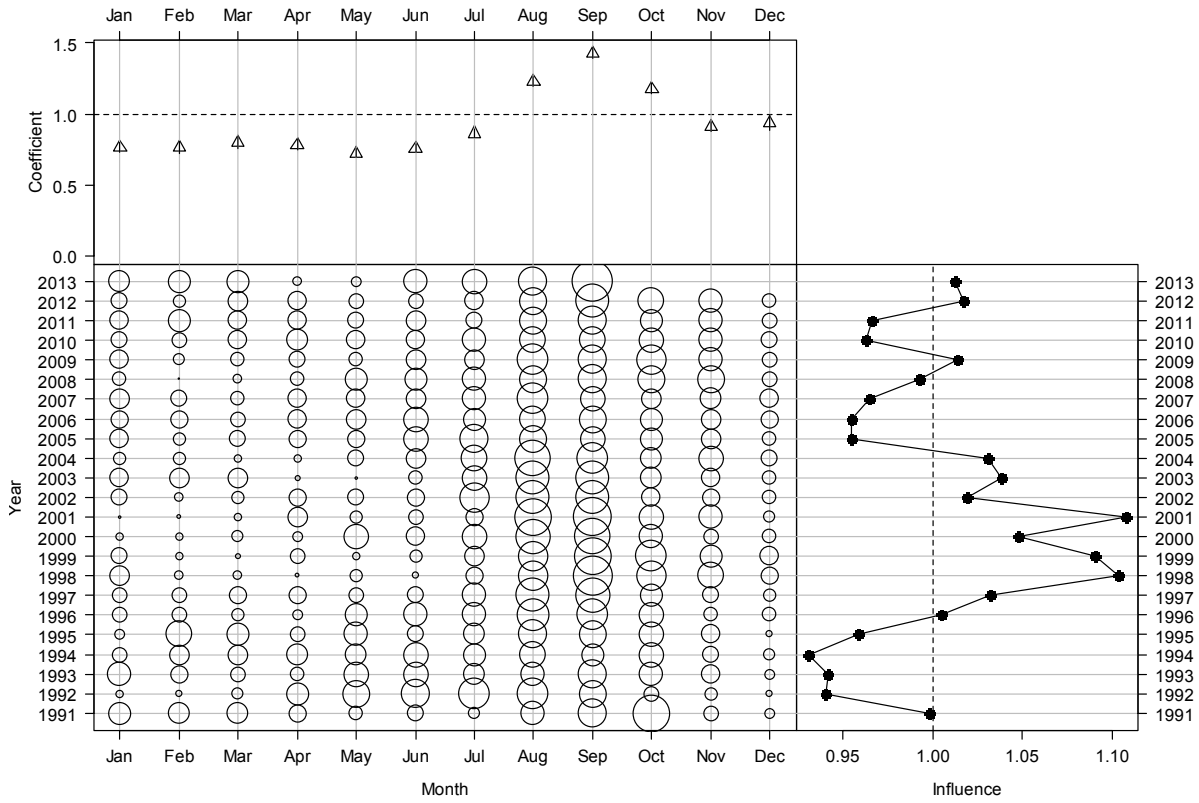


Figure 9b continued.

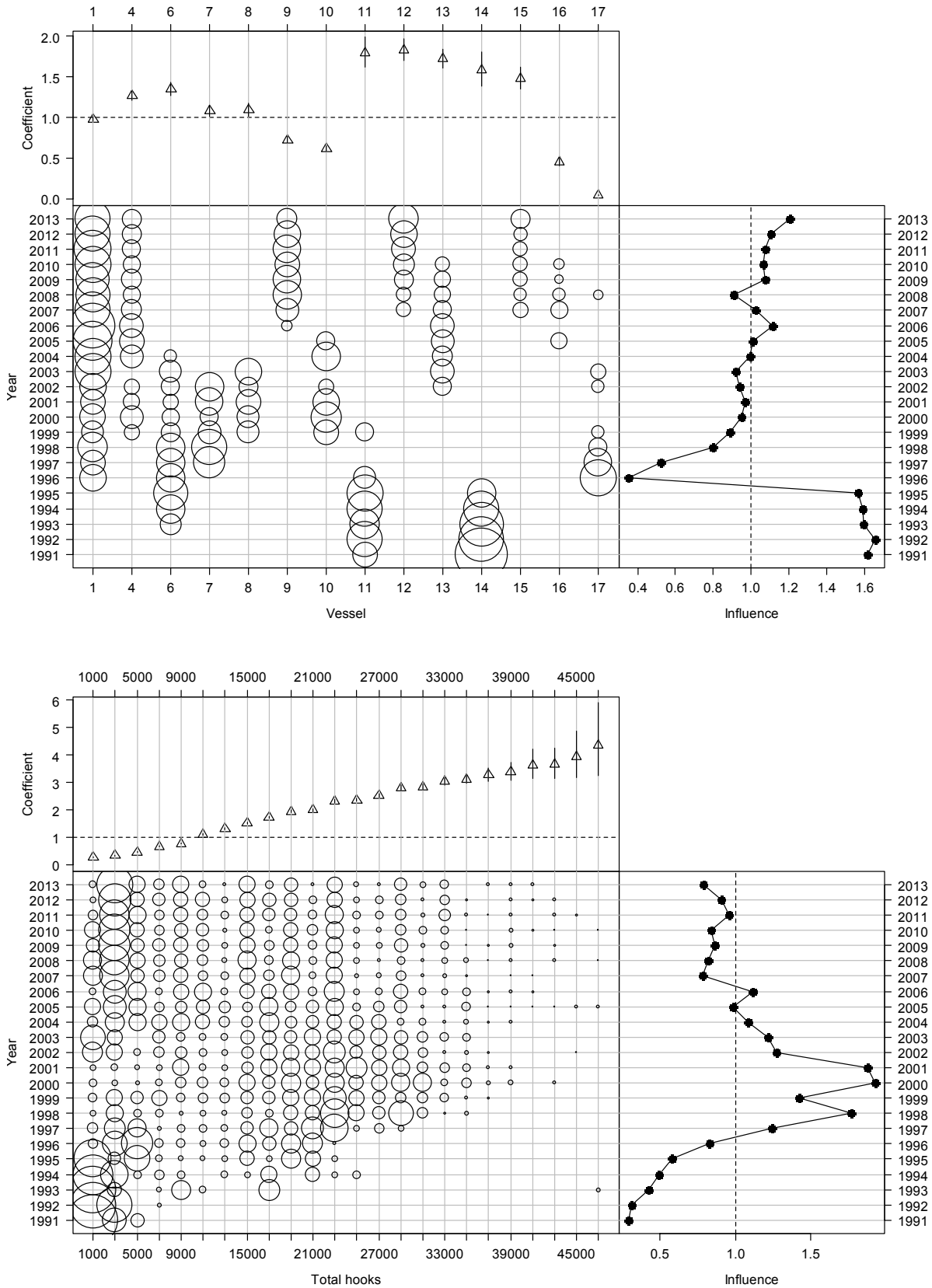




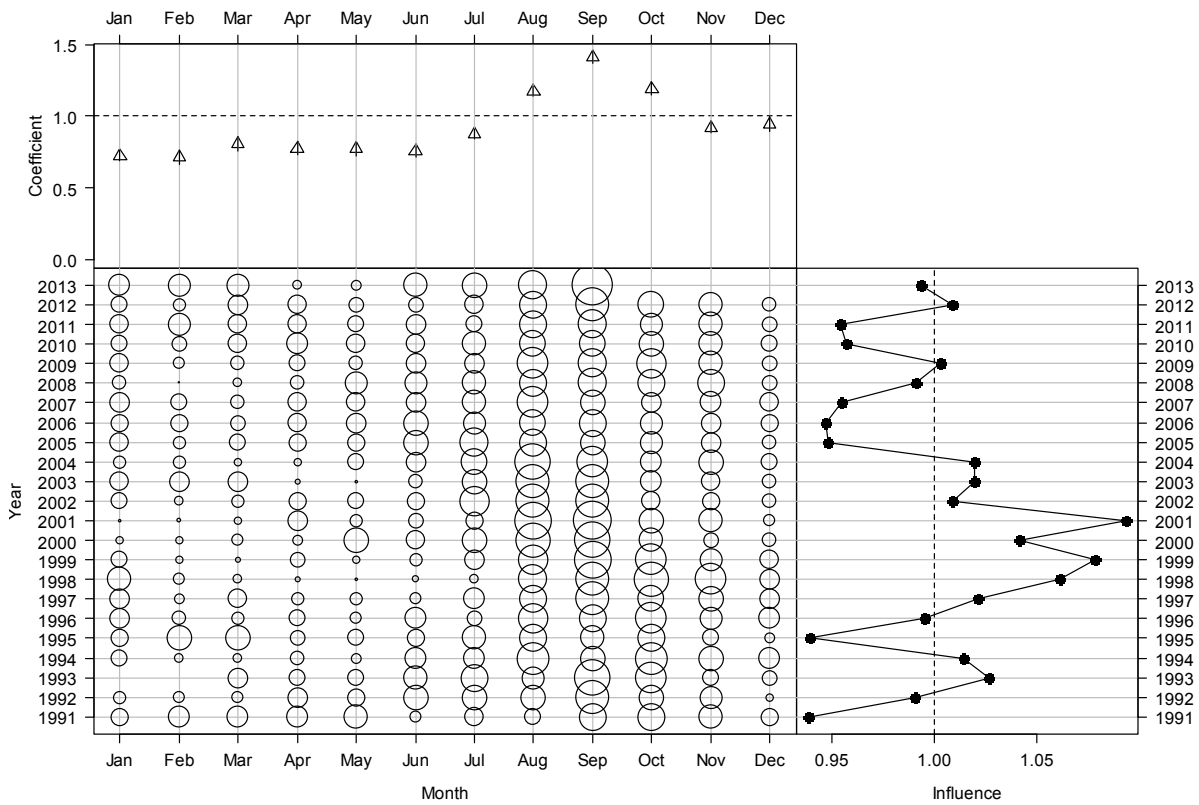
**Figure 10a: Effect and influence of non-interaction term variables (vessel, total number of hooks) in the Chatham Rise longline core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.**



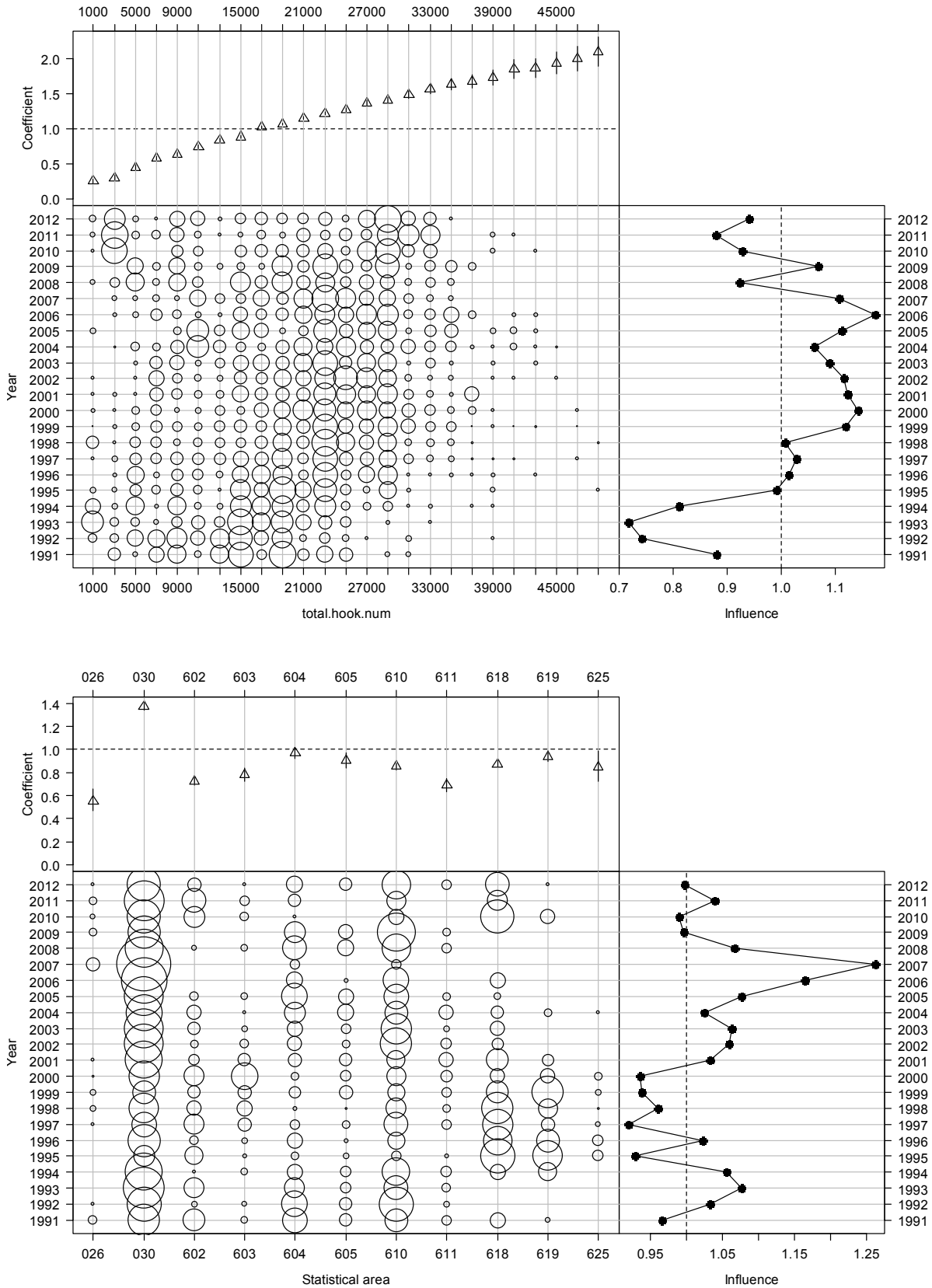
**Figure 10a continued. Effect and influence of non-interaction term variables (month) in the Chatham Rise longline core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.**



**Figure 10b: Effect and influence of non-interaction term variables (vessel, total number of hooks) in the Chatham Rise longline core vessel lognormal model excluding vessels 2, 3, and 5. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.**



**Figure 10b continued. Effect and influence of non-interaction term variables (month) in the Chatham Rise longline core vessel lognormal model excluding vessels 2, 3, and 5. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.**



**Figure 10c: Effect and influence of non-interaction term variables (total number of hooks, statistical area) in the Sub-Antarctic single fishery longline core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.**

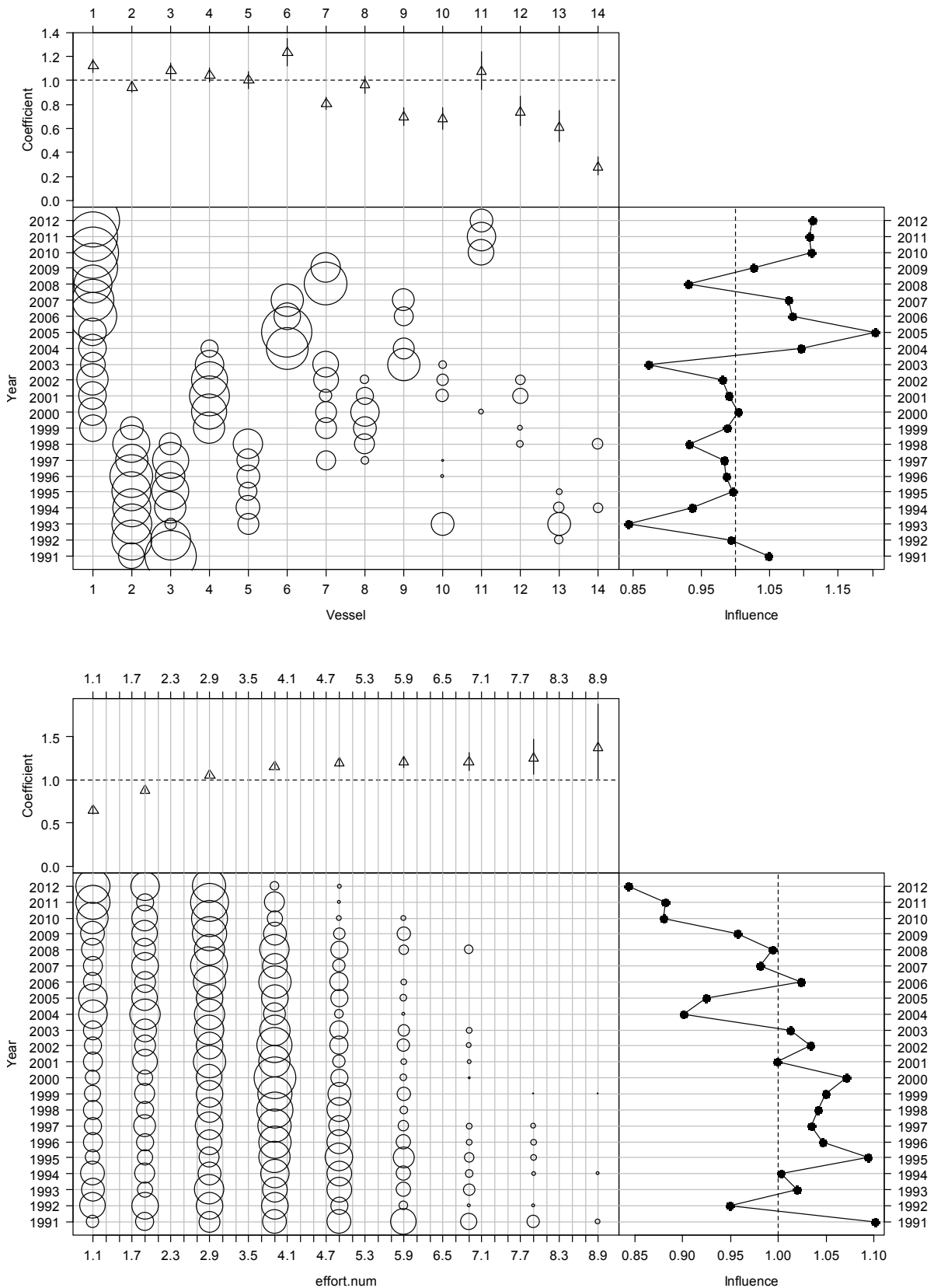
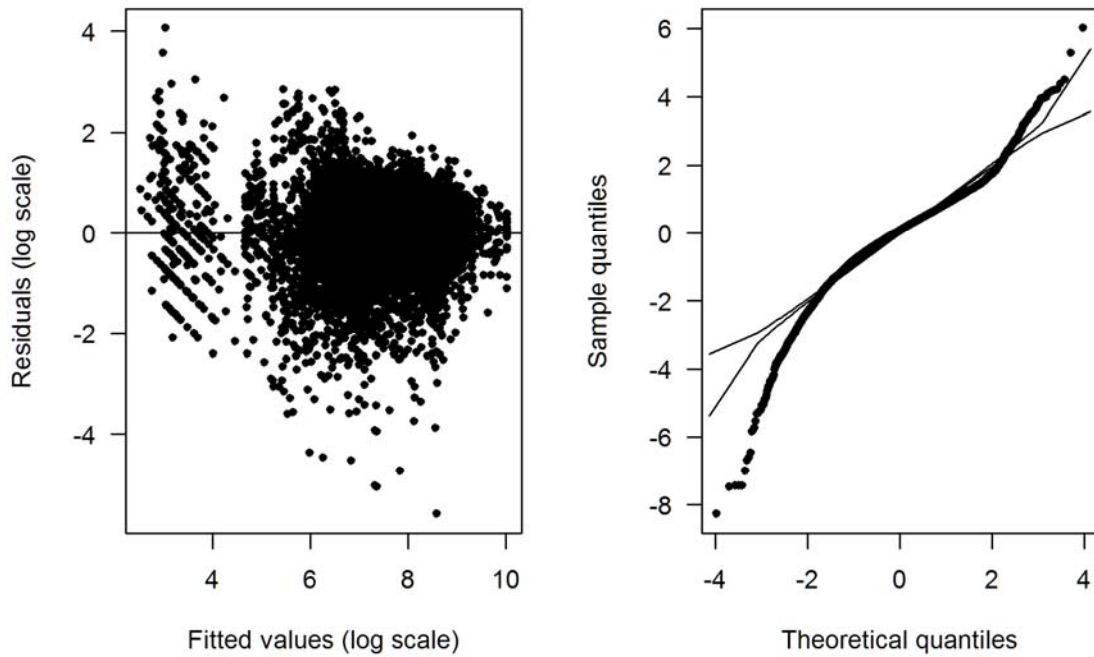
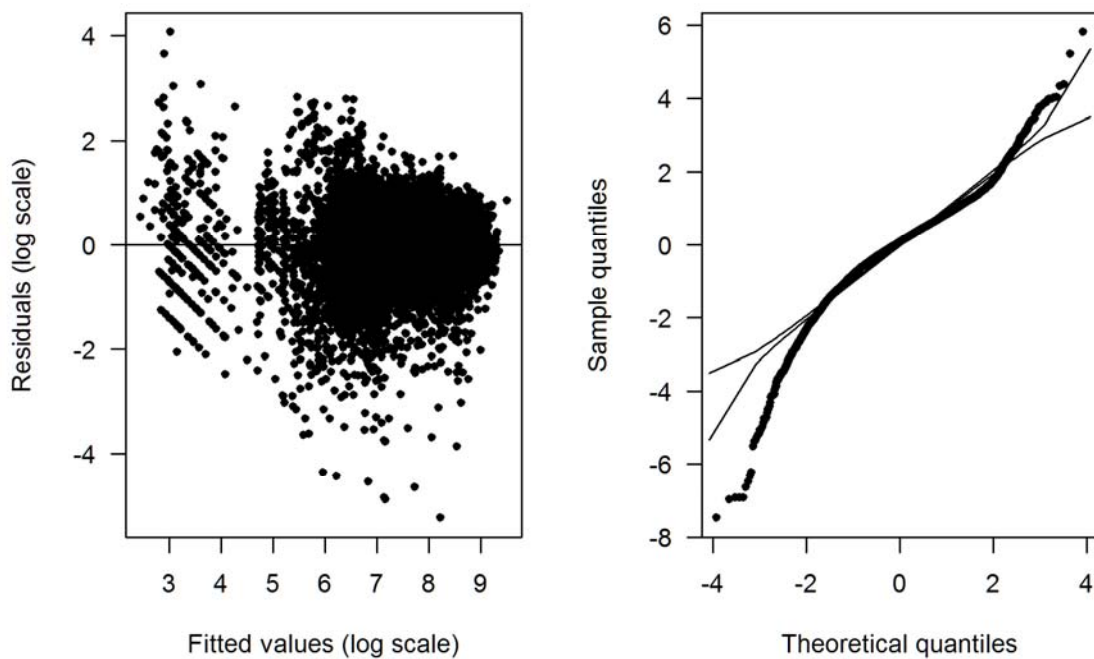


Figure 10c continued. Effect and influence of non-interaction term variables (vessel, number of sets) in the Sub-Antarctic single fishery longline core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.

## Chatham Rise fishery

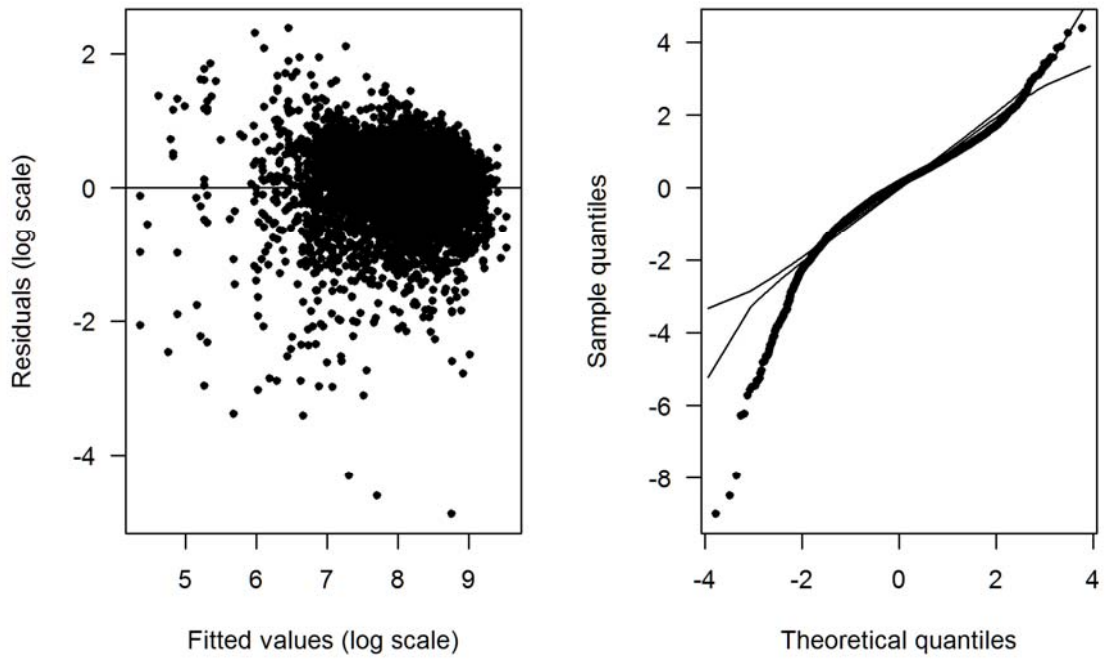


## Chatham Rise fishery excluding core vessels 2, 3, and 5

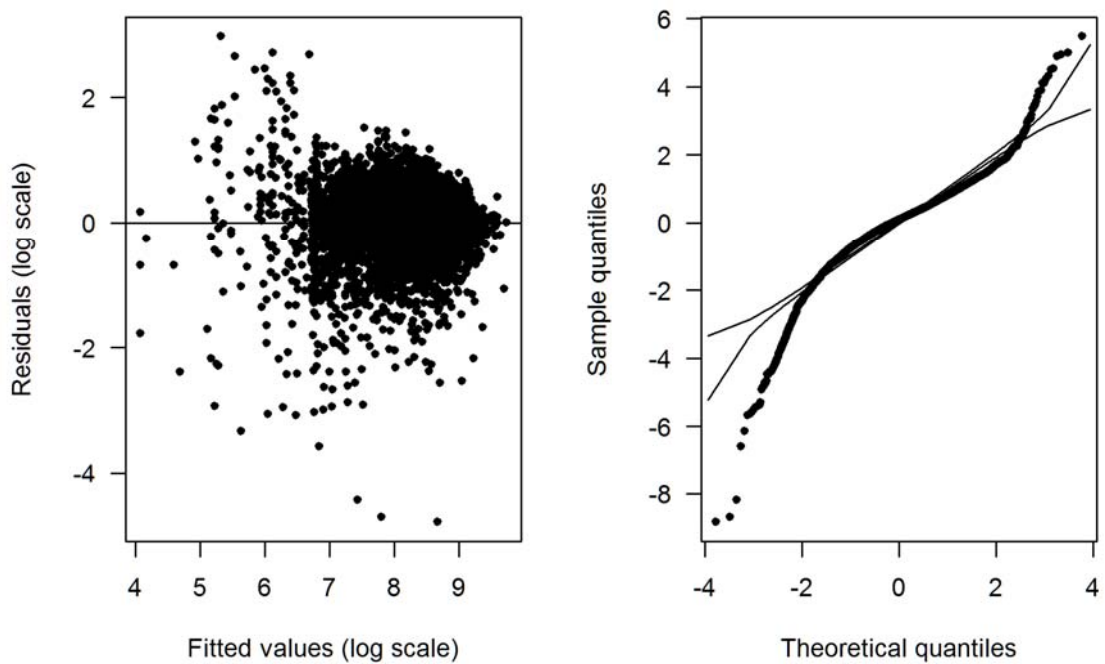


**Figure 11a: Diagnostic plots for the Chatham Rise CPUE models.**

## Sub-Antarctic single fishery



## Sub-Antarctic two fishery model



**Figure 11b: Diagnostic plots for the Sub-Antarctic single and two fishery CPUE models.**



## APPENDIX A. ESTIMATION OF CPUE FROM THE LINE FISHERY IN LIN 6B

This Appendix reports on an analysis to update the series of CPUE indices from the target line fishery for ling in LIN 6B on the Bounty Plateau. CPUE analysis of this fishery was most recently reported by Horn & Ballara (2012). The stock was last assessed by Horn (2007b).

### Methods

Data grooming, variable selection, data selection, and the modelling procedure were completed as described previously in Sections 2.1 and 2.2. Data for the Bounty Plateau was grouped by the following statistical areas: 607–609, 613–615, 621, and 622. This analysis was carried out on the basis of presumed biological stocks, rather than administrative (QMA) stocks.

To ensure that the data were within plausible ranges and related to vessels that had consistently targeted and caught significant landings of ling (and so were likely to truly represent experienced and competent ling fishers), data were accepted if all the following constraints were met: sets where ling was targeted using the BLL (bottom longline) fishing method for statistical areas 607 and 608 for calendar years 1992–2004 and for CELR (Catch Effort Landing Return) and LCER (Line Catch Effort Return) forms. A vessel was selected if it had participated in the fishery for at least 2 years, and there were more than 30 daily records overall for that vessel. Catches were constrained to 1–20 000 kg and number of hooks to 500–50 000, per vessel-day.

### Results

The number of records of days fished, total numbers of days fished, the estimated catch of ling, and the number of vessels involved, by year are presented in Table A1.

The Bounty Plateau line fishing has accounted for almost all of the LIN 6B landings since 1990, with catches throughout the year, but with less catch taken in June to August (Figure A1). Most of the catch is taken by the bottom longline method targeting ling in Statistical Areas 607 and 608 by smaller inshore vessels using 5000–35 000 hooks/day.

The Bounty Plateau final vessel selection included 1906 days fished throughout the 22 years analysed (Table A1), and the estimated catch from this effort was 98% of the total estimated catch by line fishing in this area. However, no data from 2005 were able to be incorporated in the final analysis. Only one vessel fished the Bounty Plateau in 2005 (for 13 days), and although this vessel had also fished here in 2003 and 2004 it did not meet the threshold of 30 records. Only two vessels fished the Bounty Plateau from 2007 to 2012, with one fishing in 2007–2009 and 2011, the other fishing in 2010 and 2012, with neither of these vessels fishing in earlier years. Consequently, the CPUE series are presented for the Bounty Plateau line fishery only for 1991–2004.

The 1992–2004 final analysis incorporated 1636 vessel days from the 13 years of data (Table A1). Data from seven vessels were incorporated in the analysis; one of these vessels had fished in all years, and two other vessels had fished in six years (Figure A2). The model run did not select *statarea*. As statistical areas 607 and 608 accounted for 99% of the records, data from other LIN 6B statistical areas were deleted as they were probably reporting errors or exploratory fishing.

For the lognormal model, six variables were selected with *total hooks* explaining 30% (from a total of 57%) of total variance (Table A2). Other variables selected included *vessel*, *month*, and interaction terms between *vessel & total hooks*, *vessel & month*, and *month & total hooks*. The standardised year effects show an overall decline from 1992 to 2004, but with a relatively rapid decline from 1992 to 1994 (Table A3, Figure A3a). This trend does not match the trend in the raw catch index, as the standardised CPUE indices are higher in early years and lower in later years. The overall trend is similar to the previous analysis (Figure A3b), even though the previous analysis included 2006 data.

Influence plots (Figures A4) show that fleet dynamics may have changed as the vessel influence on CPUE was very negative in 1992 and 1994, and since 1995 has remained positive. Overall catch rates for the included vessels vary by a factor of less than 3. The influence plot of total hooks per day shows a general trend from negative to positive, with influence in most years outside the range 0.9–1.1 showing that the number of hooks had a great influence on CPUE from year to year. Predicted number of hooks indicated higher expected catch rates with increased total hooks. The influence plot for month ranged between 0.9 and 1.1, in all years except 1994, so does not have much influence on the CPUE from year to year, with highest catch rates in June (Figure A4).

The model shows no marked patterns in the residuals (Figure A5), although the diagnostics for the lognormal model were poor; the quantile-quantile plots indicated a deviation from the normal distribution of the residuals at the lower, suggesting that very small catch rates were not well modelled. The poorly estimated points (i.e., those with residuals smaller than  $-3$ ) are a small fraction of the total data set.

## Conclusions

CPUE is the only relative abundance series available for LIN 6B. The trends in the series, and the variables selected into the model, have not changed markedly between the previous (Horn & Ballara 2012) and current analysis. Skill levels and/or gear efficiency vary between vessels, so the selection of a *vessel* variable in each model would be expected. With the CPUE unit being ‘kg per day’, it would be expected that the number of hooks set per day would be influential. Clearly, catch rates vary throughout the year, probably in relation to the spawning season for ling, hence, *month* was an explanatory variable in the Bounty Plateau fishery.

It is apparent from influence plots that the fleet dynamics in the line fisheries have changed, with periods when vessels ceased to operate and new ones entered the fishery, as seen by the negative influence from 1992–1994, moving to a positive influence from 1995–2004 (Figure A4). There has also been a negative to positive shift in influence in number of hooks showing a change in behaviour of the fleet from smaller vessels to larger vessels setting longer lines.

There has been a marked reduction in effort on the Bounty Plateau in recent years. New line vessels entered the fishery after 2006, although only one vessel fished per year and so these vessels cannot be included in the analysis reported above.

Although Horn (2002) concluded that most ling line CPUE series performed well in relation to the four criteria raised by Dunn et al. (2000), and were probably reasonable indices of abundance (for that part of the population targeted by the line fishery), the line fishery CPUE analysis presented here may not provide a useful set of indices that are valid as relative abundance series (for that section of the population exploited by the fisheries) in stock assessment models for LIN 6B. Since the early 1990s, ling stocks targeted by line fisheries have been relatively constant in the Sub-Antarctic, but have declined on the Bounty Plateau. The line series is disadvantaged by having few vessels and low data volumes in most years. This CPUE series may have been biased by changes in fishing practice over the duration of the fishery.

**Table A1: Summary of Bounty Plateau line data for all vessels and for vessels included in the final dataset, by year. Data include: number of unique vessels fishing (Vessels), estimated catch (Catch), number of vessel-days overall for non-zero ling catches for line data (Days), and unstandardised CPUE from non-zero catches. \*, one vessel so data not shown.**

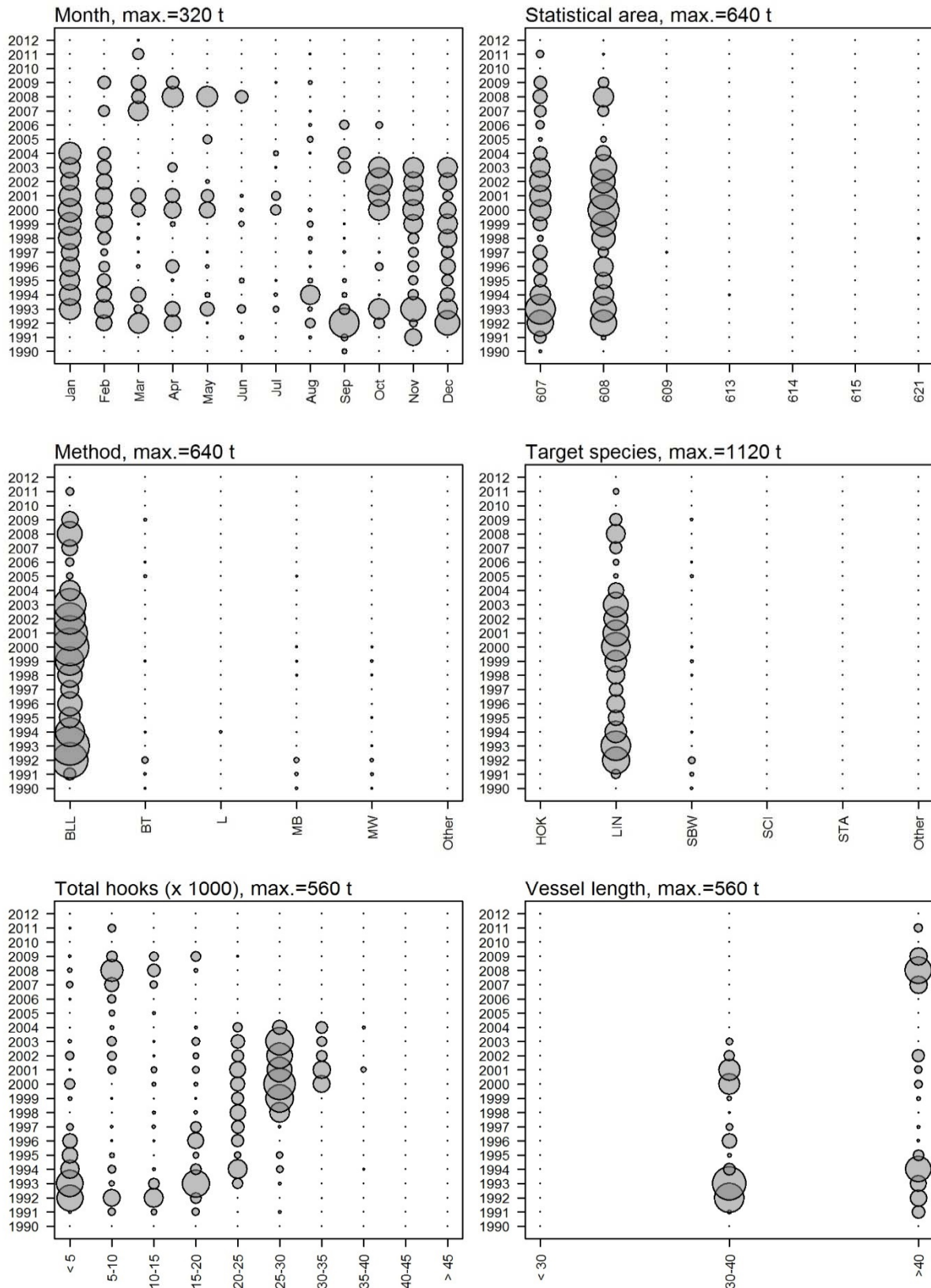
Year	All vessels				Final vessels			
	Vessels	Catch	Days	CPUE	Vessels	Catch	Days	CPUE
1991	2	126.1	23	5.48	2	126.1	23	5.48
1992	5	1 034.8	171	6.05	4	955.2	158	6.05
1993	6	1 234.0	225	5.48	5	1 230.8	221	5.57
1994	5	670.7	143	4.69	4	656.2	136	4.83
1995	5	446.5	78	5.72	4	435.9	74	5.89
1996	4	536.2	109	4.92	2	528.7	105	5.04
1997	3	255.2	61	4.18	3	255.2	61	4.18
1998	3	466.2	70	6.66	2	466.2	69	6.76
1999	3	668.5	99	6.75	3	668.5	99	6.75
2000	4	1 114.5	172	6.48	3	1 097.9	170	6.46
2001	4	983.6	195	5.04	3	975.1	192	5.08
2002	3	798.2	156	5.12	3	798.2	156	5.12
2003	4	858.4	158	5.43	4	858.4	158	5.43
2004	3	339.3	64	5.30	2	336.1	62	5.42
2005	1	*	*	*	0	–	–	–
2006	1	*	*	*	1	*	*	*
2007	1	*	*	*	1	*	*	*
2008	1	*	*	*	1	*	*	*
2009	1	*	*	*	1	*	*	*
2010	1	*	*	*	0	–	–	–
2011	1	*	*	*	1	*	*	*
2012	1	*	*	*	0	–	–	–

**Table A2: Variables retained in the lognormal model in order of decreasing explanatory value, with the corresponding total R<sup>2</sup> value.**

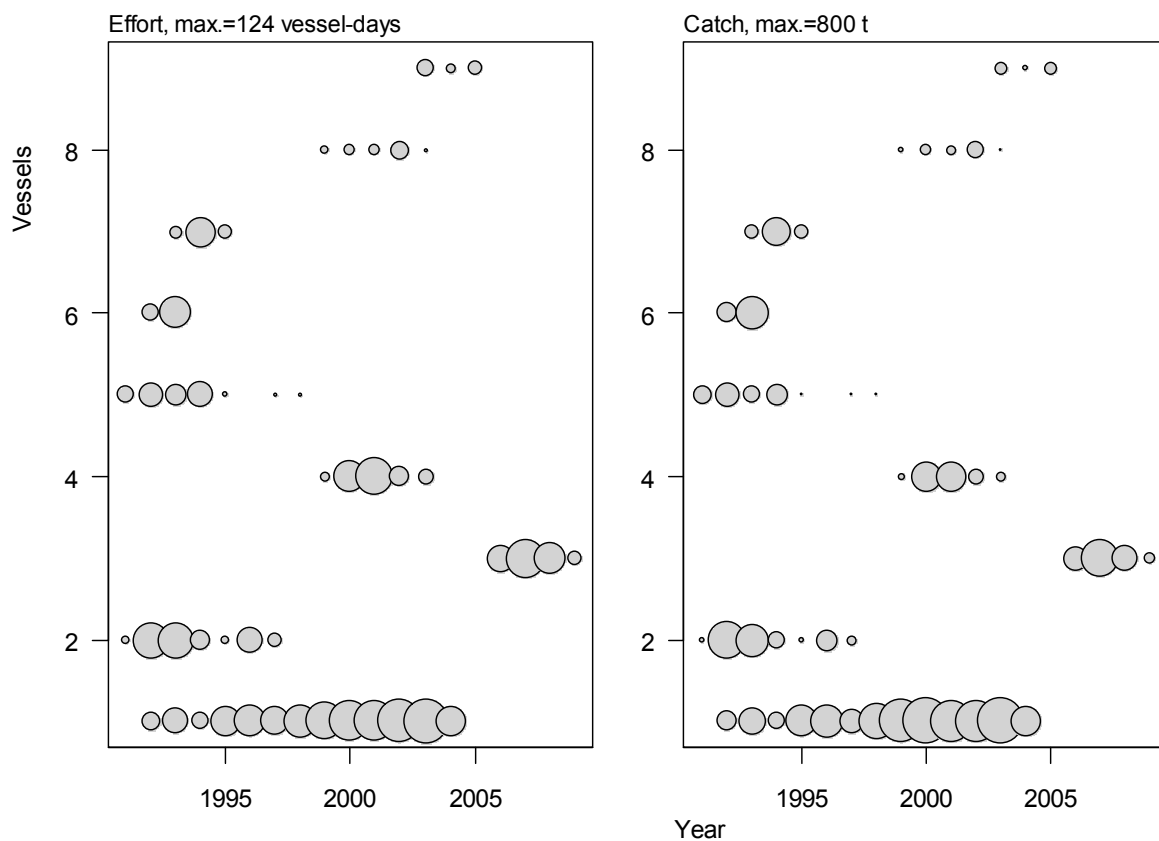
Variable	R <sup>2</sup>
Year	3.5
Total hooks	29.7
Vessel	37.4
Month	42.8
Vessel: Total hooks	48.0
Vessel : Month	54.1
Month: Total hooks	57.3

**Table A3: Lognormal CPUE standardised indices for the Bounty Plateau line fishery (with 95% confidence intervals and CVs).**

<b>Year</b>	<b>Index</b>	<b>CI</b>	<b>CV</b>
1992	1.74	1.29–2.35	0.15
1993	1.41	1.09–1.82	0.13
1994	0.95	0.70–1.30	0.16
1995	1.24	0.96–1.60	0.13
1996	1.15	0.90–1.45	0.12
1997	0.92	0.70–1.22	0.14
1998	1.06	0.83–1.35	0.12
1999	1.07	0.85–1.34	0.11
2000	0.95	0.78–1.17	0.10
2001	0.76	0.61–0.95	0.11
2002	0.69	0.56–0.85	0.11
2003	0.78	0.63–0.95	0.10
2004	0.74	0.54–1.02	0.16

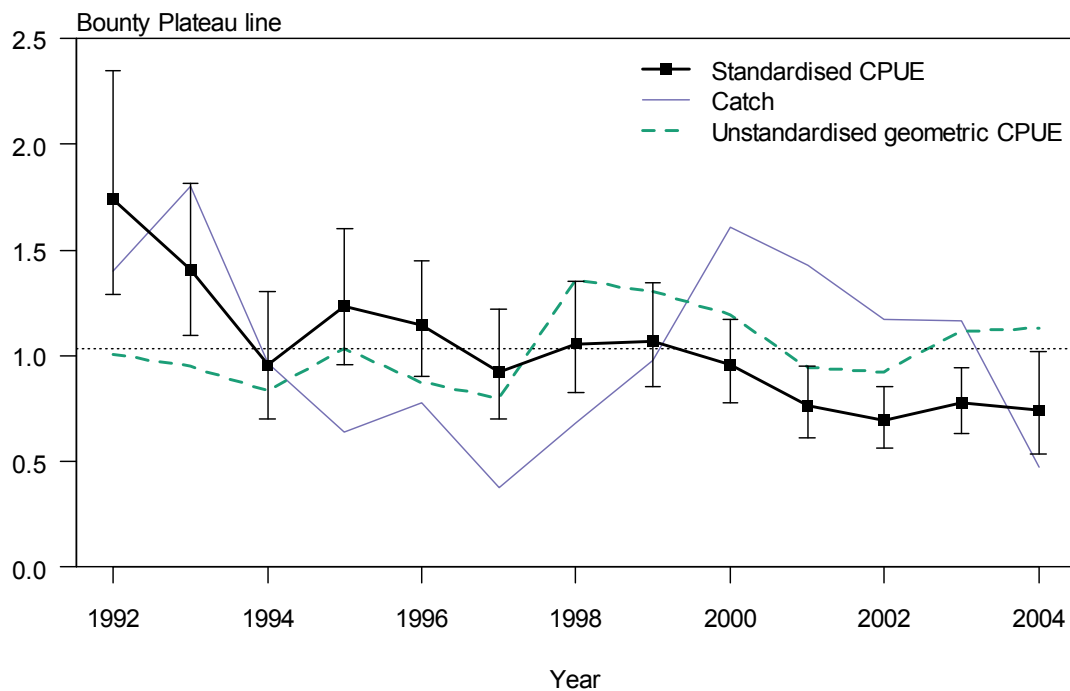


**Figure A1: Distribution of Bounty Plateau ling catch by month, statarea, method, target species, number of hooks, and vessel length for 1991 to 2012 calendar years. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Statistical areas are defined in Figure 1. Methods defined in Figure 2. Species codes: HOK, hoki; LIN, ling; SBW, southern blue whiting; SCI, scampi; STA, giant stargazer.**

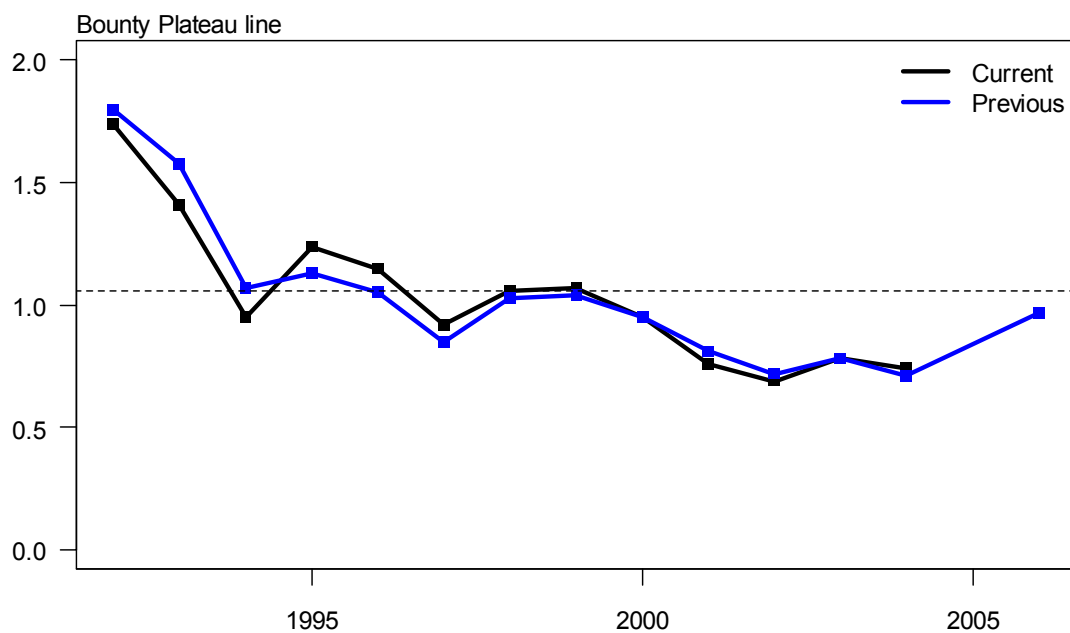


**Figure A2: Line fishing effort and catches (where circle area is proportional to the effort or catch) by year for individual vessels (denoted anonymously by number on the y-axis) in final CPUE analysis for the Bounty Plateau.**

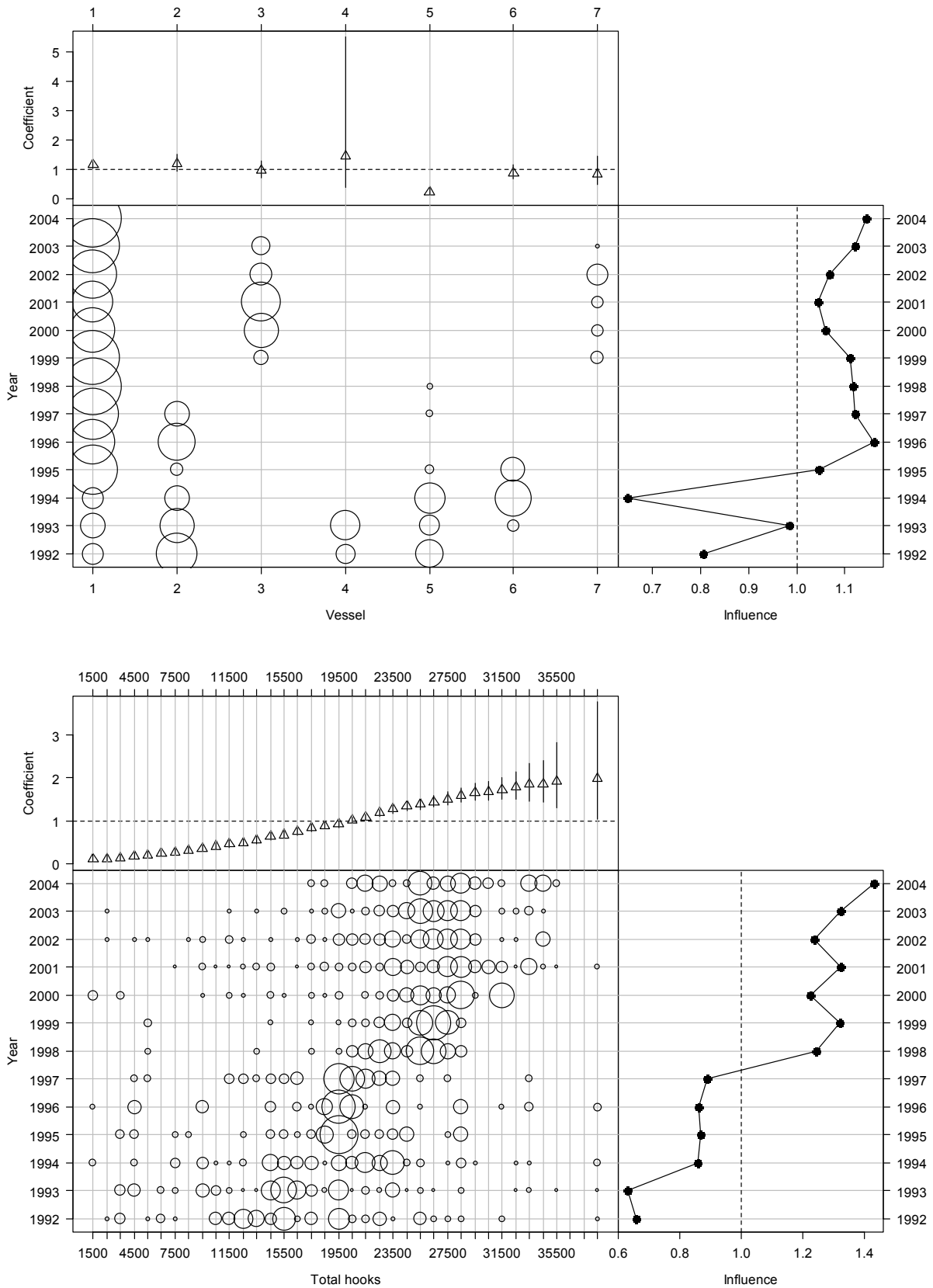
(a)



(b)



**Figure A3: (a) CPUE from the lognormal model for the Bounty Plateau fishery, 1991–2004. Bars indicate 95% confidence intervals. (b) Comparison to previous Bounty Plateau longline fishery model.**



**Figure A4: Effect and influence of non-interaction term variables in the Bounty Plateau longline vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.**



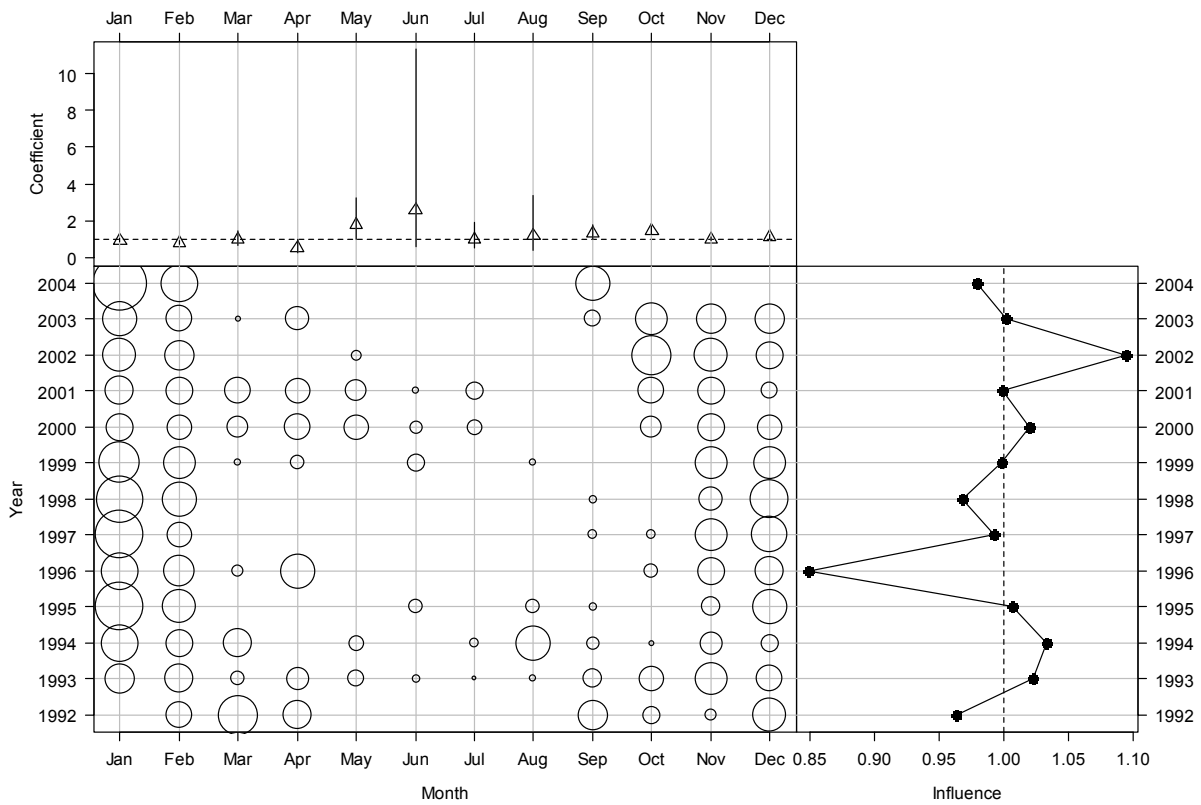


Figure A4 continued.

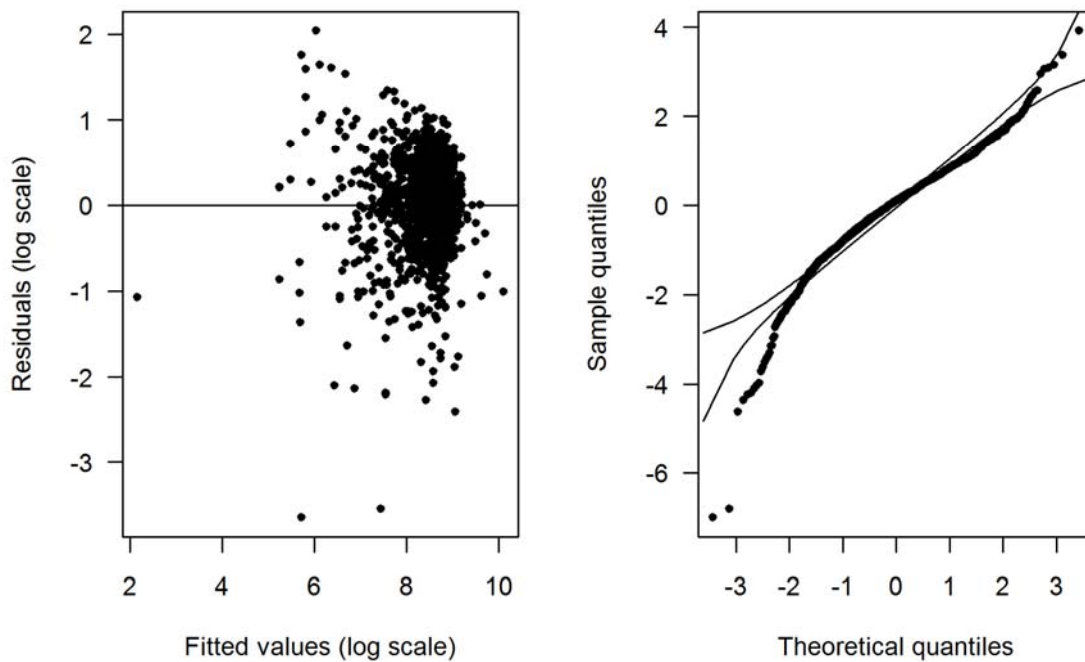


Figure A5: Diagnostic plots for the Bounty Plateau lognormal CPUE models.