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Descriptive analysis of the fishery for hake (*Merluccius australis*) in HAK 1, 4 and 7 from 1989–90 to 2010–11, and a catch-per-unit-effort (CPUE) analysis for Chatham Rise and WCSI hake

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EXECUTIVE SUMMARY

Ballara, S.L. (2013). Descriptive analysis of the fishery for hake (*Merluccius australis*) in HAK 1, 4 and 7 from 1989–90 to 2010–11, and a catch-per-unit-effort (CPUE) analysis for Chatham Rise and WCSI hake.

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This report provides a descriptive analysis of the catch and effort data for hake from the WCSI (HAK 7), Chatham Rise (HAK 4), and Sub-Antarctic (HAK 1) stocks for 1989–90 to 2010–11. Updated CPUE series for Chatham Rise and WCSI hake are also presented.

Commercial catch and effort data were groomed to correct errors and misreported data. Tow-by-tow data were combined into vessel-day summary records. Vessel-days that targeted either hake or hoki on any tow but did not process any hake were considered to be a zero catch day. A complete extract of data was undertaken, so this analysis captures the latest data available, and all variables were error groomed and interpreted in a similar manner.

The WCSI fishery peaks during June–September, mainly as a bycatch of the hoki fishery, but with some targeting before or after the main hoki season. The Chatham Rise fishery is concentrated on the northern and western Rise, mainly from September to February, with targeting mainly on spawning aggregations. The Sub-Antarctic fishery is concentrated off the south and east of the Snares shelf, also with targeting mainly on spawning aggregations. The timing of the peak Sub-Antarctic fishery has shifted from September–November in the early 1990s to December–February since the mid 2000s.

In CPUE analyses, estimates of relative year effects were obtained from a forward stepwise multiple regression method, where the data were fitted using lognormal models. The data used for each analysis consisted of all records from core vessels that targeted hoki or hake; core vessels were those that reported 80% of the hake catch and were involved in the fishery for a varying number of years.

The r^2 values for the Chatham Rise East CPUE models were very high (72–77%), with *vessel* and *statistical area* accounting for most of the deviance explained, while the r^2 values for the Chatham Rise West and WCSI CPUE models were relatively high (35–49%), with *vessel* and *target species* generally accounting for most of the deviance explained. The variables included appeared logical, and were generally consistent between the models and were similar to those previously calculated. However, much of the underlying variability was not explained in most models.

The relationship between the survey biomass indices from the eastern Chatham Rise and the CPUE indices for that area were strong, suggesting that those CPUE indices were reasonably reliable as an index of relative abundance. The Chatham Rise western CPUE index does appear to track the survey biomass index. However, the Chatham Rise West CPUE index was not used in the hake assessment model as years with big catches where spawning aggregations were targeted had a large effect on CPUE indices, suggesting that this CPUE series is not useful as an index of relative abundance.

For WCSI, there are currently no reliable fishery-independent indices of abundance. The CPUE indices from various sources (i.e., daily processed catch, tow-by-tow estimated catch, and observer data) all showed similar trends. The tow-by-tow estimated index from 2001 to 2011 was used in hake assessment modelling as this part of the series was considered most likely to be accurate. Data before 2001 were believed to be influenced by changes in fishing behaviour and reporting.

1. INTRODUCTION

Hake are widely distributed throughout the middle depths, mainly from 250 to 800 m and primarily south of latitude 40° S (Colman 1995). Adults have been found as deep as 1200 m and juveniles (0+) are often found in shallower inshore regions (less than 250 m depth) (Hurst et al. 2000). Hake within the New Zealand Exclusive Economic Zone (EEZ) are managed as three separate Fishstocks: the Challenger Plateau and west coast of the South Island (HAK 7), the eastern Chatham Rise (HAK 4), and the remainder of the EEZ (HAK 1), which includes waters around the North Island, east coast of the South Island and Sub-Antarctic, and excludes the Kermadec area (Figure 1). A comprehensive descriptive analysis of New Zealand hake fisheries was produced by Devine (2009).

Hake are currently believed to consist of three biological stocks (Colman 1998), i.e., West coast South Island (WCSI, HAK 7), Sub-Antarctic (the area of HAK 1 encompassing the Sub-Antarctic), and Chatham Rise (HAK 4 and the area of HAK 1 on the western Chatham Rise and east coast of the North Island) (Figure 1). Differences in growth parameters, size frequencies, and morphometrics were shown to exist between hake from the three areas (Horn 1997, 1998). In addition, there are three areas where spawning is known to occur consistently: the west coast of the South Island (WCSI), north-west of the Chatham Islands, and on the Campbell Plateau south of the Snares shelf (Dunn 1998).

Commercial catch and effort data were analysed to produce catch-per-unit-effort (CPUE) indices for HAK 1 and 4 in 1998 (Kendrick 1998), and were updated, using the methodology of Gavaris (1980) and Vignaux (1994) in 1999 (Dunn et al. 2000b), 2001 (Phillips & Livingston 2004), 2003 (Phillips 2005), 2005 (Dunn & Phillips 2006), 2007 (Devine & Dunn 2008), 2009 (Devine 2010), 2011 (Ballara & Horn, 2011), and 2012 (Ballara, 2012). Evidence of misreporting of catch by a small number of vessels was detected during the 2001 update. Hake caught in HAK 7 were misreported as catch on the Chatham Rise and Sub-Antarctic in HAK 4 and HAK 1 (Dunn 2003).

In 2002, the misreported catch-effort data were corrected (Dunn 2003) and data were used to estimate CPUE indices using mixed effect models. Concerns that hoki and hake target tows, where no hake were recorded (zero tows), were not adequately modelled led to a re-analysis that included zero tows. Changes in the proportion of zero tows between years were believed to be partially explained by changes in behaviour of fishers in the recording of very low or zero hake catches, probably as a consequence of the relationship of hake catch to the catch of other species when recording the top five species on the Trawl Catch Effort Processing Returns (TCEPR). Hence, an update by Phillips (2005) for the 2002–03 fishing year used daily processed catch from the processing summaries (from the bottom half of the TCEPR forms) to estimate CPUE indices for the Chatham Rise. All catch processed on each day is recorded on the daily processed summaries, and these data are believed to provide a more accurate account of low and zero catch observations.

This report includes a descriptive summary of catch and effort data, recorded on Trawl Catch Effort Processing Returns (TCEPRs) since 1989–90 and on TCERs since 2007–08, for HAK 1, 4, and 7. This fulfils Milestones 2 and 3 of Project DEE201002HAKB — “To carry out a descriptive analysis of the commercial catch and effort data for hake from HAK 1, 4, and 7”.

An analysis of the catch and effort data for hake from the Chatham Rise and WCSI stocks (HAK 4 and 7, respectively) for the years 1989–90 to 2010–11 is also presented, and it fulfils Milestones 3 and 8 of Project DEE201002HAKB — “To update the standardised analysis of the commercial catch and effort data for HAK 4 and 7”. This milestone requires that CPUE be updated only for the stock(s) to be fully investigated using a stock assessment model, i.e., the Chatham Rise and WCSI stocks.

2. METHODS

2.1 Data selection and variable description

Catch and effort data were requested from the Ministry for Primary Industries catch-effort database “warehou” as extract 8262 which consisted of all fishing and landing events associated with a set of fishing trips that reported a positive catch or landing of hake, hoki, or ling between 1 October 1989 and 30 December 2011. Catch and effort data forms included the total estimated catch from the catch effort and landing return (CELR), lining catch effort return (LCER), netting catch effort and landing return (NCELR), trawl catch effort return (TCER), lining trip catch effort return (LTCER), tuna longlining catch effort return (TLCER), and trawl catch effort and processing return (TCEPR) forms.

The MPI observer sampling programme catch effort data for hake (held by NIWA) was also extracted.

Hake trawl data can be recorded on TCEPR, TCER, or CELR forms. TCEPR and TCER returns contain tow-by-tow data. CELR returns often amalgamate a day's fishing into a single line of data, so some of the data on individual tows may be lost (e.g., duration, towing speed, bottom depth, gear dimensions). Only TCEPR data was used in the analyses as there was found to be little difference between CPUE indices including or excluding TCER data (Ballara & Horn 2011).

The estimated hake catch associated with the fishing events were mainly reported on TCEPR and CELR forms. TCEPR forms record tow-by-tow data and summarise the estimated catch for the top five species (by weight) for individual tows. The daily processed part of the TCEPR form contains information regarding the catch that was processed that day. The processed fish are weighed and a conversion factor (depending on processing type) allows the weight of the fish before processing (i.e., green weight) to be estimated. CELR forms summarise daily catches, which are further stratified by statistical area, method of capture, and target species. Trawl vessels less than 28 m long used to use either CELR or TCEPR forms; trawl vessels over 28 m used TCEPR forms. However, from 1 October 2007, TCER forms replaced CELR forms for trawl vessels less than 28 m, and enabled the recording of estimated catches of up to the top eight species by tow. The green weight for landing events for catch associated with the TCEPR or TCER form is reported on the associated Catch Landing Return (CLR), and for catch reported on the CELR the landing events are reported on the bottom part of the CELR form.

Analyses by Phillips (2005) for the 1989–90 to 2002–03 fishing years found that changes in behaviour of fishers in the recording of very low or zero hake catches could partially explain changes in the ratio of zero tows. The most likely explanation for this was that a change in the recording of the top five species on the top of the TCEPR form changed the relationship between hake catch and catch of other species, which could be due to regulation changes. Hence, Phillips (2005) used the daily processed catch from the TCEPR processing summaries to estimate catch and derive CPUE indices for the Chatham Rise.

The same approach was used by Dunn & Phillips (2006), Devine & Dunn (2008), and Devine (2010) to update the CPUE indices for the Chatham Rise and Sub-Antarctic hake stocks. Tow-by-tow data were combined into vessel-day summary records. The location and depth of fishing were defined as the median value of these variables for the day's fishing for a particular vessel from all of its individual tows. Total daily processed catch was calculated from the daily processing summaries of the TCEPR forms and merged with the combined tow-by-tow data. The variable *vessel-day* from the combined tow-by-tow data and the daily processing summary was used to link the data.

Target species associated with the daily processed catch data is not reported, hence target species was defined as the most common target species specified in the tow-by-tow data. Vessel-days that targeted either hake or hoki on any tow but did not process any hake were considered to be a zero day. Both hake and hoki target tows were selected, as hake form a significant and important bycatch of the more dominant hoki fishery.

The tow-by-tow commercial and observed catches of hake were corrected for possible misreporting, using the method of Dunn (2003). Catch data from the daily processing summaries for a vessel-day were excluded from further analyses if the vessel-day was identified as having a misreported catch in any of its associated tow-by-tow data.

Most of the variables extracted from the catch-effort database are self-explanatory and are summarised in Table 1. Those that require further explanation are described below, but in general, most variables were defined as the median of the equivalent variable from the tow-by-tow records that were made on the same day as the daily processing summary record.

Commercial and observer catch-effort data often contain significant errors, most commonly invalid codes and missing or implausible values. Data were checked for errors, using simple checking and imputation algorithms described below and similar to those used by Dunn & Phillips (2006), Devine & Dunn (2008), Devine (2010), Ballara & Horn (2011), and Ballara (2012).

Individual tow locations were investigated and, where possible, errors were corrected using median imputation; that is, all tows for each vessel on each fishing day where the start/finish latitude was more than one degree different from the median start/finish latitude were replaced with the median start/finish latitude. This error check was then repeated for longitude. If the median value could not be determined or the tow locations appeared invalid, the tow record was excluded from any further analysis. Tow speed, net depth, bottom depth, duration, wingspread, and headline height were also corrected by method subsets using median imputation. If the median values could not be determined for these variables or appeared invalid, the tow record was excluded from the analysis. Range checks were defined for the remaining attributes to identify outliers in the data. The outliers were checked and corrected if possible, or the record was removed from the data set. Individual vessel details were checked for consistency each year as it was apparent that more than one vessel can have the same vessel identification number. Where there was more than one set of values for an individual vessel, the data were examined and corrected. Tow records with no vessel identification data were excluded from further analyses.

Fishing method was bottom trawl, midwater trawl, or midwater trawl fished on the bottom; midwater gear was classified as fishing on the bottom if reported net depth was within 5 m of bottom depth. Year was a categorical variable covering differing months for different areas: for the Chatham Rise and Sub-Antarctic, year was September–August, and for WCSI it was May–October.

Sub-areas on the Chatham Rise, WCSI, and Sub-Antarctic were based on tree regression analyses of mean fish length (by sex) in the catches sampled by MFish (now Ministry for Primary Industries) observers (Horn & Dunn 2007, Horn 2008, Horn & Sutton 2010).

Chatham Rise sub-areas were defined as: Area 404 (Statistical Area 404); East Chatham Rise (east of 178.1° E and excluding Statistical Area 404); West Chatham Rise deep (west of 178.1° E and greater than 530 m depth); and West Chatham Rise shallow (west of 178.1° E and less than 530 m depth) (Figure 2a). However, for this analysis sub-areas were combined to West (West Chatham Rise deep and West Chatham Rise shallow) and East (East Chatham Rise and Area 404) Chatham Rise as used in the last stock assessment (Horn & Francis 2010).

WCSI sub-areas included North shallow (north of 42.55° S and less than 629 m depth); South shallow (south of 42.55° S and less than 629 m depth); and Deep (greater than 629 m depth) (Figure 2b).

Sub-Antarctic sub-areas were defined as Puysegur, Snares-Pukaki, Auckland Islands, and Campbell Island (Figure 2c). Data from areas on the Sub-Antarctic that were outside these sub-areas were excluded from the CPUE analyses.

The data used for each CPUE analysis consisted of all records from core vessels that targeted hoki or hake. To ensure that the data was in plausible ranges and related to vessels that had consistently targeted and caught significant landings of hake, data were accepted if all the constraints were met (Table 2). Catches believed to be misreported were excluded. Core vessel analyses were run for the Chatham Rise (West and East) and WCSI areas for both tow-by-tow data and daily processed data. For the WCSI area, an observer data tow-by-tow analysis was also carried out.

Sensitivity analyses were carried out on the Chatham Rise data sets. For Chatham Rise West, the first three years were removed, or the aggregate fishing (Statistical Area 020 for Oct 2004 and Oct/Nov 2008; Statistical Area 018 for Oct/Nov 2010) were removed for both the tow-by-tow and daily processed analyses. For Chatham Rise East, the first two years were removed from the daily processed data set. The WCSI was investigated by target species (hoki or hake), and by fishing method (midwater or bottom tows).

2.2 Catch per unit effort analysis

The analysis of CPUE for the Chatham Rise and WCSI hake fisheries is updated here. Annual unstandardised (raw) CPUE indices were calculated as the mean of the catch per tow (in kilograms) for tow by tow data, or catch per vessel-day for daily processed data. 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 2012) 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. Interaction terms with method were ignored for the Chatham Rise as all data were for bottom tows, however, these were included for the WCSI as both midwater and bottom trawling occurs there. A stopping rule of 1% change in residual deviance was used as it 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. Hence, it represents a possible index of abundance. Year indices were standardised to the mean and were presented in canonical form (Francis 1999).

Categorical and continuous variables offered to the model are listed in Table 1. Fits to continuous variables were modelled as third-order polynomials, although a fourth-order polynomial was also offered to the models for duration. In each analysis statistical area and start latitude or start longitude were not allowed to enter the same model at the same time as they were correlated. For the estimated catch runs, all variables were included. For the processed catch runs, date, start time, and time mid were not included because they were unavailable. Date was included in the processed catch runs as year and month, or day of year. Of course, the potential exists that factors that drive hake CPUE are not available in the processed catch models.

A vessel variable was incorporated into the CPUE standardisation to allow for differences in fishing power between vessels. Vessels not involved in the fishery for a certain number of years were excluded because they provided little information for the standardisations, which could result in model over-fitting (Francis 2001). Data was investigated for level of catch and effort for different years of vessel participation in the fishery, and thus CPUE analyses were undertaken for "core" vessels only, which together reported approximately 80% of positive hake catches in the defined fishery and were each involved in the fishery for a significant number of years and for a significant number of tows or vessel-days in a year.

The influence of each variable accepted into the lognormal models was described using influence plots (Bentley et al. 2012). These 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 which is accounted for by the standardisation.

Fits to the 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 Descriptive analyses

Estimated catches, reported landings, and TACC by stock from 1989–90 to 2010–11 are shown in Table 3 and Figure 3 for the main hake stocks. Most hake catches since 1989–90 have been reported on the TCEPR form (Table 4). New reporting forms have been introduced in several years since 2003–04, but in 2010–11 most hake catch (98.2%) is still reported in TCEPRs, with TCERs (53 t, 0.9%) accounting for the second highest proportion. The distribution and density of the catch recorded on these two form types in 2010–11 (Figure 4) shows that TCEPR hake is mainly caught on the Chatham Rise, WCSI, and Sub-Antarctic, whereas the TCER caught hake is mainly on the WCSI.

3.1.1 Chatham Rise

On the Chatham Rise, hake have been caught mainly by bottom trawlers targeting hake or hoki (Table 5, Figure 5a). Generally, hake are caught on the northern edge of the Chatham Rise and in the deep channel along the western part of the Chatham Rise, but with most of the catch taken from Statistical Area 404 (Figure 6a) where vessels target the hake spawning aggregation (Devine 2010). However, catches from Area 404 since 2006 have been low relative to the previous 14 years (Figure 6a). The proportion of hake caught in hoki target tows has been slowly decreasing since the late 1990s (Table 5, Figure 6a). More than 99% of the Chatham Rise catch is reported on the TCEPR form.

Hake are caught on the Chatham Rise all year around, but more commonly between September and February (Figure 7a, Table 6). In October 2004, a large aggregation of possibly mature or maturing hake was fished on the western Chatham Rise, west of the Mernoo Bank in Statistical Area 020; approximately 2000 t of hake were caught over a four week period (Table 6, Figure 6a) (Devine 2010). The reasons for the presence of this aggregation are not known, although periodic and minor aggregations of pre-mature and mature hake have been found in that area in previous years and also in October–November 2008, and in Statistical Area 018 in October–November 2010 (Figure 6a).

In 2006, very little catch was taken from any area. In 2007 and 2008, most of the catch was taken in January–February from the Eastern Chatham Rise and Statistical Area 404 subareas. In 2009, most of the catch was taken between October 2008 and February 2009 in Statistical Area 404 and west of the Mernoo Bank (Table 6, Figure 6a). The catch in 2010 at 391 t was lower than all years since 1990, and in 2011 at 951 t the catch was still relatively low.

For target hoki and hake vessels, bottom tows have shown an overall slight increase in mean duration to 2009, and a decrease in speed since 2002, followed by an increase in both in 2010 and 2011 (Figure 8a), which can be attributed in part to the increased bottom tow catches from 2002 by smaller Korean vessels. Mean hoki catch per tow has increased since 2004.

3.1.2 WCSI

The WCSI hake fishery is mainly bycatch of the much larger hoki fishery (Table 7), but has undergone a number of changes during the last decade (Devine 2010). These include changes in TACCs for both hake and hoki, and changes in fishing practices such as the gear used, tow duration, and strategies to limit hake bycatch. Most of the hake catches are from hake or hoki target tows, although the hake caught in hoki target tows has decreased steadily since 2005 (Figure 6b, Table 7).

The timing of the catch on the WCSI has varied slightly between years, but most catch has been taken between June and September (Figure 6b, Table 8). Targeted catches of hake were relatively high early in the fishing season in 1995, 1996, 1999, 2001, 2004 and 2005 (Figure 6b). In some years there has been a hake target fishery in September after the peak of the hoki fishery is over, particularly in 1992, 1993, 2006, and 2009 (Table 7, Figure 7b). More than 2000 t of hake was taken during September 1993 and 2006. In 2010, catches were the lowest in any year since 1990 (Table 8) and were taken mainly from July to September by mid-sized Korean vessels targeting hake with bottom trawl. In 2011, catches were higher and were taken mainly from July to September. Catches are taken mainly in Statistical Areas 034 and 035, and in the last three years mainly from sub-area North shallow (Figure 6b). In 2011, most of the catch was taken immediately north of the Hokitika Canyon in the North shallow sub-area (Figures 5b and 6b).

Mean duration, distance, and depth per tow increased, and speed decreased in the last few years (Figure 8b), which can be attributed in part to the increased bottom tow catches since 2002 by smaller Korean vessels, and changes in midwater and bottom tow vessels. In 2011 there was little midwater catch, an increase in mean duration, and an increase in mean hoki catch (Figure 8b). For hake target vessels, there were very low hoki catches, increases in duration per tow for bottom tows in recent years, and an overall decrease in fishing speed (Figure 8c). Target hake catches also show distinct fishing by timing and location, especially in earlier years compared to hoki target fishing (Figure 9).

3.1.3 Sub-Antarctic

Sub-Antarctic hake are caught mainly by bottom trawlers targeting hoki or hake (Table 9, Figure 5c). Significant targeting for hake occurs around the Norwegian Hole and at the southern end of the Snares shelf (Devine 2010). The majority of the catch is taken from the Snares-Pukaki sub-area (Figures 5c and 6c). Since 2000, 1000–2000 t of targeted hake have been caught annually, but since 2005 hake caught in hoki target tows has been decreasing (Table 9, Figure 6c). More than 99% of the hake catch in the Sub-Antarctic is reported on the TCEPR form.

The timing of the catch in the Sub-Antarctic shifted over the years (Figure 7c, Table 10). Most catch was taken from September to November in the early 1990s, October to December in the late 1990s, November to January during the early 2000s, and December to February from 2006. In December 2005, 2000 t of hake was taken (Figure 7c) in an area of rough ground on the Stewart-Snares shelf where commercial fishing vessels reported an aggregation of spawning hake (O’Driscoll & Bagley 2006). In 2011, most of the catch was taken from December to February on the southern Snares shelf (Figures 5c and 6c). In general, hake were caught mostly along the edge of the Stewart-Snares shelf, in the Norwegian Hole, and, in smaller amounts, on the northern Campbell Plateau, southern Auckland Island shelf, and Puysegur Bank (Figure 5c).

For vessels targeting hoki or hake, bottom tows showed a decrease in mean distance, speed, and depth of net and bottom since 2002 (Figure 8d), which can be attributed in part to the increased bottom tow catches from 2002 by smaller Korean vessels. Mean hoki catches decreased from 2001 to 2006 but have since increased.

3.2 CPUE indices

3.2.1 Chatham Rise West

A total of 198 unique vessels (range 21–82 vessels each year) targeting hake or hoki caught an estimated 15 300 t of hake since 1990, from 122 794 tows (Table 11a). Core vessels for the tow-by-tow index were selected using the criteria described in Section 2.2 and were defined as those taking in total approximately 80% of the catch and each with participation in the fishery for five or more years (Table 2, Figure 10). Fifty-seven core vessels (range 5–44 per year) caught an estimated 13 000 t of hake, representing 84% of the total catch. Estimated hake catches for core vessels targeting hake and hoki ranged from 98–1250 t annually (Table 11a). The proportion of zero tows for all vessels ranged between 0.45 and 0.82, and showed an increasing trend for both core and all vessels (Table 11a, Figure 11).

Vessels targeting hake or hoki fished in total 31 636 vessel-days, averaging 1428 days per year since 1990 (Table 11b). The 48 core vessels producing data for the daily processed index were defined as those taking in total approximately 80% of the catch and each with participation in the fishery for six or more years (Table 2, Figure 10). The selected vessels fished in total 28 822 vessel-days averaging 1128 vessel-days per year. The proportion of zero days (i.e., days fished where either hoki or hake was targeted, but no hake was processed) for all vessels fishing ranged between 0.07 and 0.48, and was higher in earlier years of the fishery. The proportion of zero days was much lower than for tow-by-tow data (Table 11b, Figure 11). The proportion of total estimated data was 0.9 of the total processed catch (Table 11, Figure 12).

The number of core vessels in the fishery increased from 5 in 1990 to a peak of 44 in 1998, and then declined to 19 vessels by 2011. Hake catch by core vessels also increased from about 98 t in 1990 to about 1000 t from 1997 to 2001, but has been generally low (about 200 t) since 2006 (Table 11a, Figure 13). High catches in Statistical Area 020 in October 2004 and in October–November 2009 were seen for most vessels.

For the tow-by-tow estimated core data analysis, three variables were selected into the lognormal model, resulting in a total r^2 of 39%, with *vessel* explaining 27% of the residual deviance (Table 12). The other variables selected were *target* and *start latitude*. *Statistical area* and *vessel* were selected for the binomial model and *statistical area* explained 11% of the total 16% residual deviance. For the processed core data analysis, the same four variables as in the estimated core analysis were selected into the lognormal model, along with *start longitude* and *fishing duration*, resulting in 35% of the residual deviance being explained. With the exception of *duration*, the variables were the same for the binomial model with *vessel* explaining 14% of the total 22% residual deviance (Table 12).

CPUE series are presented in Table 13 and Figures 14 and 15. The tow-by-tow estimated catch index increased to 2004 and 2005, and decreased to 2011. The binomial index increased from 1990 to 2011, and the combined index was similar in trend to the lognormal index, although the binomial had some effect on the lognormal by increasing the lognormal slightly until 1999 and decreasing it from 2004 to 2011, implying that the trend in zero tows had some influence on the combined index. The daily processed catch index increased from 1991 to about 1996, decreased to 1999, and was then stable with minor fluctuations to 2007, followed by a slight increase to 2009, and a subsequent decrease to 2011. The daily processed binomial index decreased from 1994 to 2011, and the combined index was similar in trend to the lognormal index, implying that the trend in zero tows had little influence on the combined index. Unstandardised and standardised indices in the tow-by-tow estimated and daily processed data did not follow the same trend in earlier years, and can be attributed mainly to the influence of the variable *vessel* (Figures 14 and 16). When plotted together, the two series look similar until 2003, and from 2007, but diverge between 2004 and 2006 (Figure 17). There was little difference in indices if the first three years were removed (Figure 17), however when aggregated fishing (Statistical Area 020 for Oct 2004 and Oct/Nov 2008; Statistical Area 018 for Oct/Nov 2010) was removed the 2005 index was lowered a lot, especially for the tow-by-tow data, although the 2009 index was lowered only a little. Both CPUE indices differ from the research survey biomass indices from the January trawl survey series (Figure 18) for the western Chatham Rise.

Influence plots (Figures 19a) for the lognormal tow-by-tow model showed that for vessels there is a large positive influence on CPUE in the first three years, suggesting a possible change in fleet dynamics. Influence of target species shows that there is a positive influence on CPUE when hake are targeted, especially in 2009 when an aggregation in October 2008 in Statistical Area 020 was targeted (Figure 19a). The influence of latitude on CPUE moved from negative to positive between 1990 and 2006, and then shifted back to negative by 2011, showing that there was a change in fishing area; however this had little overall influence on CPUE as the influence values are mostly between 0.9 and 1.1. Expected catch rates are higher for target hake catches, and for catches to the north (Figure 19a). Influence plots for the daily processed lognormal model similarly showed a large positive influence on vessel in the first three years and a positive influence when hake was targeted, with little influence from other variables as most values were between 0.9 and 1.1 (Figure 19b).

The models showed that the probability of a zero catch was higher for tow-by-tow data where vessels fished in Statistical Areas 022, 407 and 408, and that vessels accounting for less catch of hake had lower catch rates and a higher probability of a zero catch (Figure 20).

The diagnostics for both models were poor and the quantile-quantile plots indicated a 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 (Figures 21). The diagnostics for the binomial model indicated a reasonable pattern in the residuals and the quantile-quantile plot appeared adequate (Figure 22).

3.2.2 Chatham Rise East

On the Eastern Chatham Rise, 121 unique vessels (range 13–45 vessels each year) targeting hake or hoki caught an estimated 29 300 t of hake since 1990, from 42 862 tows (Table 11c). Core vessels for the tow-by-tow index were defined as those taking in total approximately 80% of the catch, and each with participation in the fishery for three or more years, and with 20 or more tows in each year (Table 2, Figure 10). Thirty-eight core vessels (range 5–17 per year) caught an estimated 23 403 t of hake, representing 80% of the total catch. Estimated hake catches for core vessels targeting hake and hoki ranged from 94–2457 t annually (Table 11c). The proportion of zero tows for all vessels ranged between 0.29 and 0.70, and showed an increasing trend for both core and all vessels (Table 11c, Figure 11).

Vessels targeting hake or hoki fished in total 11 567 vessel-days, averaging 526 days per year since 1990 (Table 11d). The 38 core vessels producing data for the daily processed index were defined as those taking in total approximately 80% of the catch and each participating in the fishery for five or more years (Table 2, Figure 10). The selected vessels fished in total 10 149 vessel-days, averaging 461 vessel-days per year. Hake catches by core vessels were the lowest on record in 2011 at 117 t (Table 11d). The proportion of zero days (i.e., days fished where either hoki or hake was targeted, but no hake was processed) for all vessels fishing was higher in the late 1990s (0.10–0.17), but has been low (0.01–0.06) since then, and the proportion overall was much lower than for tow-by-tow data (Table 11d, Figure 11). The total estimated catch was about 90% of the total processed catch (Table 11, Figure 12).

The number of core vessels increased from 4 in 1990 to 17 in 1995, and then declined to 5 vessels again in 2005 vessels with hake catch by core vessels generally higher (750–2380 t) during that period. From 2007, two or three vessels took most of the catch with relatively low effort and in 2011 core vessels took 94 t (Table 11c, Figure 13).

For the tow-by-tow estimated core data analysis, four variables were selected into the lognormal model, with a total r^2 of 77%, with *statistical area* explaining most of the residual variance (Table 12). The other variables selected were *vessel*, *target* and *duration*. Three variables were selected in the binomial model giving a total r^2 of 42%; *statistical area* again explained the greatest reduction in residual variance. For the processed core data analysis, three of the same variables as in the estimated core analysis were selected into the lognormal model, although *distance2* replaced *duration*, resulting in 72% of the residual deviance explained. With the exception of the addition of *duration*, the variables were the same for the tow-by-tow binomial model with *vessel* explaining 15% of the total 22% residual deviance (Table 12).

CPUE series are presented in Table 13 and Figures 14 and 15. The tow-by-tow lognormal CPUE indices showed a variable but overall decreasing trend, the binomial index showed a slight increasing trend, and the combined index was similar in trend to the lognormal index, implying that the trend in zero tows had no influence on the combined index. The daily processed catch index also showed a variable but overall decreasing trend, the binomial index showed no trend, and the combined index was again similar to the lognormal index.

Unstandardised and standardised indices in the tow-by-tow estimated catch analysis did not follow the same trend in the first two years, or from 2004, which is due to the addition of the variables *vessel* and *statistical area* (Figures 14 and 16). The standardised indices track the raw indices reasonably well for the daily processed data, except for the first two years, which can be attributed mainly to the addition of the variable *vessel* (Figures 14 and 16). When plotted together, the two series look similar until 2010 (Figure 17). There was little difference in indices if the first two years were removed (Figure 17). The East Chatham Rise index showed a steeper declining trend than the All Chatham Rise index, with the All Chatham Rise index having an averaging effect on the East and West indices, and an All Chatham Rise two-area model showed similar results (Figure 17).

There was a strong correlation between the survey biomass indices for the eastern Chatham Rise (i.e., all strata completely or partially east of 176° E) and the CPUE indices for the eastern Chatham Rise (Figure 18), although there are some slight differences between series. For example, the Eastern Chatham Rise CPUE index increased in 1996 and in 2000, but the biomass index declined in both those years. Again, the differences may be due to stratum placement, as the trawl biomass index includes the area from 176° E to 178.1° E.

Influence plots (Figures 19c) for the lognormal tow-by-tow model showed that the vessel variable had a large positive influence on CPUE in the first two years, suggesting a possible change in fleet dynamics. Influence of duration shows a positive influence on CPUE when durations are longer, especially from 2004 to 2009, although there is no difference in indices when catch/km rather than catch/tow is used (Figure 18). For target species and statistical area, there is a positive influence on CPUE when hake are targeted especially in Statistical Area 404 in 1990, 2005, and 2009. Influence plots for the daily processed lognormal model similarly showed a large positive influence on vessel in the first two years and a positive influence when hake was targeted (Figure 19d).

The probability of a zero catch was higher for statistical areas on the far east of the Chatham Rise, and for statistical areas on the south Chatham Rise, and the probability of a zero catch was lower at depths between 350 and 700 m (Figure 20).

For both models the quantile-quantile plots indicated a deviation from the normal distribution of the residuals at both the lower and upper ends, suggesting that very small and very large catch rates were not well modelled (Figures 21). The diagnostics for the binomial model showed a reasonable pattern in the residuals, and the quantile-quantile plot appeared adequate (Figure 22).

3.2.3 WCSI

Since 1990, 242 unique vessels (range 24–75 vessels each year) targeting hake or hoki caught an estimated 117 632 t of hake, from 130 446 tows (Table 11e). Core vessels for the tow-by-tow index were defined as those taking in total approximately 80% of the catch, and each participating in the fishery for five or more years, and reporting 20 or more tows in each year (Table 2, Figure 10). Fifty-eight core vessels (range 12–42 per year) caught an estimated 96 328 t of hake, representing 82% of the total catch. Estimated hake catches for core vessels targeting hake and hoki ranged from 1070–6848 t annually (Table 11e). The proportion of zero tows ranged between 0.34 and 0.76 for all vessels, and showed a slight decreasing trend for both core and all vessels, with the proportion of zeros above 0.5 from 1991 to 1995 (Table 11e, Figure 11).

Vessels targeting hake or hoki fished 38 706 vessel-days, averaging 1760 days per year since 1990 (Table 11d). Core vessels producing data for the daily processed index were defined as those taking in total approximately 80% of the catch, and each participating in the fishery for three or more years, and reporting 20 or more vessel-days in each year (Table 2, Figure 10). The 72 core vessels fished over 25 890 vessel-days averaging 1177 vessel-days per year. The proportion of zero days (i.e., days fished where either hoki or hake was targeted, but no hake was processed) for all vessels fishing on the WCSI fluctuated between 0.07 and 0.60 with a decreasing trend over time (Table 11d, Figure 12). The proportion of zero days was much lower than for tow-by-tow data especially from 1996 (Table 11b, Figure 11). Total estimated catch was 114% of total processed catch (Table 11, Figure 12).

The number of core vessels increased from 10 in 1990 to a peak of 42 in 1998, and then declined to 16 vessels by 2010, although there were 25 in 2011. Estimated hake catches for core vessels targeting either hake or hoki in the WCSI fishery ranged from about 1100 t to 3600 t from 1990 to 1994 (Table 11e). After 1994, core estimated catches ranged from 3900 to 6900 t in most years. Catches since 2009 have all been less than 3900 t (Table 11e, Figure 13). For the core vessel daily processed data set, there were fewer than 1000 vessel-days per year until 1995, followed by a period of more vessel-days per year from 1996 to 2006 (1202 to 1928 vessel-days), and then a steady decline to 486 vessel-days in 2010, although there was an increase in vessel-days to 897 in 2011 (Table 11e).

For the tow-by-tow estimated core data analysis, six variables were selected into the lognormal model, resulting in a total r^2 of 46%, with *target* explaining 24% of the residual deviance (Table 12). Four variables were selected for the binomial model and *depth of bottom* explained 24% of the total 32% residual deviance. For the processed core catch by vessel-day, five variables were selected for the lognormal model with an r^2 of 48%, and *start longitude* explaining 29% of the residual deviance. Four variables were selected into the binomial model resulting in an r^2 of 25%, and with *depth of bottom* explaining the greatest reduction in residual deviance (11%) (Table 12).

CPUE series are presented in Table 13 and Figures 14 and 15. The tow-by-tow estimated catch index increased to 1996, followed by a decrease to 2008, and a subsequent increase to 2011. The binomial index was almost flat with a very gradual decline from 1990 to 2011, and the combined index was similar in trend to the lognormal index, implying that the trend in zero tows has little influence on the combined index. For the processed core catch by vessel-day and observer catch by tow, the lognormal indices show similar results with an increase to 1996, then an overall but spiky decrease to 2008, and again a subsequent increase to 2011. The binomial indices showed a slight decline, and the combined indices were similar in trend to the lognormal indices.

Standardised CPUE do not track the trends in the raw indices in the tow-by-tow estimated and daily processed data especially in later years, and this can be attributed mainly to the addition of the variables *target species* and *vessel* (Figures 14 and 16). When plotted together, the three series look similar (Figure 17). For the daily processed data, there was little difference in indices for target hoki, however the target hake index shows no trend from 1994 to 2006, after which a decline is seen to 2008, with an increase to 2011 (Figure 17). For the tow-by-tow data, midwater and bottom tow indices look similar to the overall analysis (Figure 17).

Influence plots (Figures 19e) for the lognormal tow-by-tow model showed that the vessel variable has a large positive influence on CPUE in the first two years, a negative influence from 1993 to 2003, with a shift back to positive influence from 2004 to 2011, suggesting a possible change in fleet dynamics. Vessels with more overall catch tended to have higher expected catches and lower variability. There is a positive influence on CPUE when hake are targeted, especially in 1993, and from 2005 to 2011, and expected catch rates were higher for target hake catches. Influence of depth of bottom on CPUE also showed a positive shift in 1993, and from 2005 to 2009, showing that there has been a change in fishing patterns. Expected catch rates of hake were higher in deeper tows. Latitude and mid time of tow showed shifts in influence on CPUE from positive to negative from 1990 to 2011, however with little influence as most values were between 0.9 and 1.1. Expected catch rates of hake were higher to the south and from tows around midday (Figure 19e). Influence plots for the daily processed lognormal model similarly showed a large positive influence on vessel in the first four years and a positive influence when hake was targeted (Figure 19f). Influence plots for the observer lognormal model similarly showed a large positive influence on vessel in the first two years and a positive influence in depth of tow in 1993 and 2007 when there were deeper tows (Figure 19g).

The models showed that the probability of a zero catch was higher for tow-by-tow data where tows were of shorter duration, were particularly shallow or deep, or were to the west of the main fishing area (Figure 20). The predicted values for vessel followed a consistent pattern and, in general, indicated that vessels accounting for a lower catch of hake had lower catch rates and a higher probability of a zero catch (Figure 20). Analyses of the daily processed data and observer data showed similar variable effects to the tow-by-tow analysis (Figure 20).

The diagnostics for all WCSI models were poor and the quantile-quantile plots indicated a 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 (Figures 21). 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 diagnostics for the binomial model indicated a reasonable pattern in the residuals and the quantile-quantile plot appeared adequate (Figure 22).

4. SUMMARY

The data used in the analyses were groomed to correct errors where catch may have been misreported, and where incorrect data was recorded or punched. Although some errors may still be present, they would have had only a negligible effect on the CPUE analysis due to the large size of the data sets used (e.g., Dunn & Harley 1999). A complete extract of data was undertaken, so all variables in all years were error groomed and interpreted in a similar manner.

The hake catches from fisheries in all three areas are a consequence of direct targeting for the species and a bycatch of targeting for hoki. The WCSI fishery is of short duration (June–September), with hake mainly a bycatch of hoki, but with some targeting occurring generally before or after the main hoki season. The Chatham Rise fishery is concentrated on the northern and western Rise, mainly from September to February, with targeting for hake concentrating on spawning aggregations. The Sub-Antarctic fishery is concentrated off the south and east of the Snares shelf out to the Pukaki Rise; target fishing here also concentrates on spawning aggregations. The timing of the peak Sub-Antarctic fishery has shifted over time, from September–November in the early 1990s to December–February since the mid 2000s.

The CPUE analysis by Phillips (2005) indicated that low or zero catches may have been inconsistently recorded over time, and there may have also been some problems due to hake not being one of the top five species recorded on the TCEPR tow by tow data. However, the Chatham Rise and WCSI analyses presented above using the daily processed summaries for hake may not be superior to a tow-by-tow analysis (even though they account for those days when catches were not recorded on the tow-by-tow summaries), as estimated and processed indices generally showed similar trends, and estimated and processed catches are of a similar order. However, this may not be true for species that are rarely recorded as one of the top five on the TCEPR form. Ballara & Horn (2011) showed strong similarities between daily processed and tow-by-tow CPUE for WCSI hake, and also found that trends in the combined and lognormal indices were similar, implying that little was gained by adding data from zero catches into that analysis.

The relationship of western Chatham Rise hake to those on the rest of the Chatham Rise is not well understood. Fish have tended to be shorter and younger in the west relative to the east (Horn & Dunn 2007), and have previously been thought to be pre-mature or sub-adult fish. The highly concentrated aggregation fished in October 2004 suggests that some of these fish may have been either a spawning or a pre-spawning aggregation. Fishing on aggregated schools in the same area also occurred during October-November 2008 and 2010. Also, the trawl survey took high catches of young, mature fish in this area in January 2009. It is possible that young, mature hake spawn on the western Chatham Rise, and slowly move east, towards the main spawning area, as they age.

It is assumed there is a proportional relationship between CPUE and abundance. However, there are specific areas and times (e.g., Statistical Area 404 on the Chatham Rise during the spawning season) when hake were more available and hence targeted, and therefore the indices from this area may have a hyperstable CPUE/abundance relationship (Dunn et al. 2000a).

The relationships between the survey biomass indices from the eastern Chatham Rise and the CPUE series for that area were strong, suggesting that these CPUE indices were indexing relative abundance. Consequently, the Chatham East daily processed CPUE series was used in subsequent assessment modelling.

The Chatham Rise western CPUE series did not track the survey biomass index. Also, there was a marked difference between the tow-by-tow and daily processed series around the mid 2000s. Some of this difference is clearly related to years with big catches where spawning aggregations were targeted. Consequently, neither of the Chatham West CPUE series was used in subsequent assessment modelling.

For the WCSI, there are no extended fishery independent indices (a pair of comparable survey indices is available from 2000 and 2012). There were no strong trends in the processed or estimated WCSI CPUE indices, although credence may be given to these indices as they are very similar to the WCSI observed data series. However, it is known that fishing (particularly target fishing) and reporting practices for hake off WCSI have varied markedly over time, and this could easily have biased the data, producing CPUE series that do not track abundance. A series using tow-by-tow estimated landings from 2001 to 2011 was used in assessment modelling of the WCSI hake stock. This part of the longer series was considered likely to be reasonably accurate as it followed the implementation of the deemed value scheme. Data before 2001 were considered more likely to be influenced by changes in fishing behaviour and reporting.

The r^2 values for the Chatham Rise East CPUE models were very high (72–77%), with *vessel* and *statistical area* accounting for most of the deviance explained, while the r^2 values for the Chatham Rise West and WCSI CPUE models were relatively high (35–49%), with *vessel* and *target species* generally accounting for most of the deviance explained. The residual deviance explained by the binomial models was generally lower (ranging from 16–42%), with the main predictors being *depth of bottom* and *vessel* on the WCSI, and *statistical area* and *vessel* for the Chatham Rise. Most of the explanatory power was from the first two or three variables, with subsequent variables having a lesser impact. However, a large proportion of the underlying variability was not explained. While this is not unusual for CPUE analyses (e.g., Vignaux 1994, Punt et al. 2000), it may be a reflection of a lack of explanatory information available to the models to explain catch rates. For example, individual skippers' experience was not available, even though the number of years the vessel has been in the fishery was included as a variable. There were almost certainly different skippers over the time period. Other effects on catching ability, such as improvements or changes in net and bottom rig design and electronic equipment could not be quantified but might have resulted in an increase in the overall deviance explained.

The diagnostic plots for the CPUE analyses show that the lognormal model was unable to capture the extremes in catch rates observed in the fishery and tended to underestimate the lower catch rates. Clumping of residuals is also apparent, probably due to the different catch rates for each target species and subarea. 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). Other models may need investigating. Diagnostics for the binomial models were good; however, there is little published documentation on the success of using randomised quantile residuals as diagnostics for discrete response variable models, so the interpretation of diagnostics should be treated with caution.

In all cases the combined index was similar in trend to the lognormal index, implying that the trend in zero tows had relatively little influence on the combined index. The value of adding zero data into the CPUE models was therefore low.

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Table 1: Description of variables and their type used in the CPUE analysis for the estimated tow-by-tow dataset and the daily processed dataset. Continuous variables were fitted as third order polynomials except for tow duration which was offered as both third and fourth order polynomials.

Variable	Type	Estimated catch dataset	Processed catch dataset
Year	Categorical	Fishing year Sep–Aug (Chatham Rise), and Jun–Sep (WCSI).	Fishing year as Sep–Aug (Chatham Rise), and Jun–Sep (WCSI).
Vessel	Categorical	Unique (encrypted) vessel identification number	Unique (encrypted) vessel identification number
Statarea	Continuous	Statistical area	Statistical area
Subarea	Categorical	Defined by fishing effort distribution and depth for a tow	Defined by fishing effort distribution and depth for a given day
Effort	Continuous	–	Number of tows for a given day
Primary method	Categorical	Fishing method for a tow	Fishing method for a given day
Tow duration	Continuous	Duration of tow (hrs)	Duration of all tows (hrs) on a given day
Tow distance	Continuous	Distance of tow	Distance of all tows on a given day
Distance2	Continuous	Distance of tow (speed in knots* duration)	Distance (as speed * duration) of all tows on a given day
Headline height	Continuous	Headline height (m) of the net for a tow	Median headline height (m) of the net on a given day
Bottom depth	Continuous	Seabed depth (m) for a tow	Median seabed depth (m) on a given day
Speed	Continuous	Vessel speed (knots) for a tow	Median vessel speed (knots) on a given day
Wingspread	Continuous	Wingspread (m) of the net for a tow	Median wingspread (m) of the net on a given day
Vessel experience	Continuous	Number of years the vessel has been involved in the fishery	Number of years the vessel has been involved in the fishery
Twin trawl vessel	Categorical	T/F variable for a vessel that has used a twin trawl	T/F variable for a vessel that has used a twin trawl
Catch	Continuous	Estimated green weight of hake (t) caught from a tow	Estimated green weight of hake (t) caught on a given day
Longitude	Continuous	Longitude of the vessel for a tow	Median longitude of the vessel on a given day
Latitude	Continuous	Latitude of the vessel for a tow	Median latitude of the vessel on a given day
Target species	Categorical	Target species of tow	Main target species on a given day
Date	Continuous	Date of the tow	Date the fish were processed
Month	Categorical	Month of the year	Month of the year
Fday	Continuous	Day of the year	Day of the year
Time start	Continuous	Start time of tow	–
Time mid	Continuous	Mid time of tow	–

Table 2: CPUE data constraints by area for core vessels that targeted hoki or hake.

(a) Chatham Rise West

Data source	TCEPR tow-by-tow	TCEPR daily processed
Year range	1990–2011	1990–2011
Year definition	September–August	September–August
Fisheries	West Chatham Rise (West shallow, West deep)	West Chatham Rise (West shallow, West deep)
Statistical areas	At least 50 tows: 018, 019, 020, 021, 022, 023, 401, 402, 407, 408	> 50 vessel-days: 018, 019, 020, 021, 022, 023, 401, 402, 407, 408
Method	MW, MB, BT	MW, MB, BT
Target	HOK, HAK	HOK, HAK
Core vessel selection	80% of catch, ≥ 5 years vessel participation	80% of catch, ≥ 6 years vessel participation
Catch	< 50 t	< 80 t
Other	300–900 m 0.2–15 hours Exclude misreported tows One vessel removed (odd catch values) Latitude < 46°, Longitude > 172°	300–900 m 0.2–24 hours Exclude days with misreported tows One vessel removed (odd catch values) Latitude < 46°, Longitude > 172°

(b) Chatham Rise East

Data source	TCEPR tow-by-tow	TCEPR daily processed
Year range	1990–2011	1990–2011
Year definition	September–August	September–August
Fisheries	East Chatham Rise (Stat. Area 404, East Chat)	East Chatham Rise (Stat. Area 404, East Chat)
Statistical areas	At least 50 tows: 051 ,052 ,402, 403, 404, 408, 409, 410, 411	> 50 vessel-days: 049, 050, 051 ,052 ,402, 403, 404, 408, 409, 410
Method	MW, MB, BT	MW, MB, BT
Target	HOK, HAK	HOK, HAK
Core vessel selection	80% of catch, ≥ 3 years vessel participation, ≥ 20 tows per vessel-year	80% of catch, ≥ 5 years vessel participation
Catch	< 50 t	< 80 t
Other	300–900 m 0.2–15 hours Exclude misreported tows One vessel removed (odd catch values) Latitude < 46°	300–900 m 0.2–24 hours Exclude days with misreported tows One vessel removed (odd catch values) Latitude < 46°

(c) WCSI

Data source	TCEPR tow-by-tow	TCEPR daily processed	Observer data
Year range	1990–2011	1990–2011	1986–2011
Year definition	June–September	June–September	June–September
Fisheries	Deep; North shallow; South shallow	Deep; North shallow; South shallow	
Statistical Areas	033, 034, 035, 036, 703	033, 034, 035, 036, 703	034,035
Method	MW, MB, BT	MW, MB, BT	MW, MB, BT
Target	HOK, HAK	HOK, HAK	HOK, HAK
Vessel selection	80% of catch, ≥ 5 years vessel participation, ≥ 20 tows per vessel-year	80% of catch, ≥ 3 years vessel participation, ≥ 20 days per vessel-year	≥ 1 year vessel participation, ≥ 35 tows per vessel
Catch	< 50 t	< 80 t	< 50 t
Other	300–900 m 0.2–15 hours Exclude misreported tows One vessel removed (odd catch values)	300–900 m 0.2–24 hours Exclude misreported tows One vessel removed (odd catch values) Longitude < 171.5°	300–900 m 0.2–15 hours Latitude 40–43° Longitude 169.5– 171°

Table 3: Estimated hake catch (t) (TCEPR and CELR were scaled to reported QMR or MHR catch totals and adjusted for misreporting), reported landings (t) from QMR records, and TACC (t) by QMA from 1989–90 to 2010–11. Estimated data also includes LCER (from 2003–04), and NCELR estimated data (from 2006–07), TCER and LTCER data (from 2007–08), and TLCER data. All catches have been rounded to the nearest tonne.

	Estimated catch			Reported landings			TACC		
Year	HAK1	HAK4	HAK7	HAK1	HAK4	HAK7	HAK1	HAK4	HAK7
1989–90	2 115	763	4 903	2 115	763	4 903	2 610	1 000	3 310
1990–91	2 592	726	6 175	2 603	743	6 148	2 610	1 000	3 310
1991–92	3 141	2 007	3 048	3 156	2 013	3 027	3 500	3 500	6 770
1992–93	3 522	2 546	7 157	3 525	2 546	7 154	3 501	3 500	6 835
1993–94	1 787	2 587	2 990	1 803	2 587	2 974	3 501	3 500	6 835
1994–95	2 263	2 855	9 659	2 572	3 369	8 841	3 632	3 500	6 835
1995–96	3 805	3 028	9 153	3 956	3 466	8 678	3 632	3 500	6 835
1996–97	3 285	2 865	6 950	3 534	3 524	6 118	3 632	3 500	6 835
1997–98	3 659	3 237	7 686	3 809	3 523	7 416	3 632	3 500	6 835
1998–99	3 702	2 882	8 929	3 845	3 324	8 165	3 632	3 500	6 835
1999–00	3 747	2 447	7 086	3 899	2 803	6 898	3 632	3 500	6 835
2000–01	3 429	2 321	8 351	3 429	2 321	8 360	3 632	3 500	6 835
2001–02	2 865	1 420	7 499	2 870	1 424	7 519	3 701	3 500	6 835
2002–03	3 334	805	7 406	3 336	811	7 433	3 701	3 500	6 835
2003–04	3 455	2 254	7 943	3 466	2 275	7 945	3 701	3 500	6 835
2004–05	4 795	1 260	7 302	4 795	1 264	7 317	3 701	1 800	6 835
2005–06	2 742	305	6 897	2 743	305	6 906	3 701	1 800	7 700
2006–07	2 006	900	7 660	2 025	900	7 668	3 701	1 800	7 700
2007–08	2 442	865	2 615	2 445	865	2 620	3 701	1 800	7 700
2008–09	3 409	854	5 945	3 415	856	5 954	3 701	1 800	7 700
2009–10	2 156	208	2 340	2 156	208	2 352	3 701	1 800	7 700
2010–11	1 904	179	3 716	1 904	179	3 754	3 701	1 800	7 700

Table 4: Hake estimated catches by form type and fishing year.

							Catches (t)
Year	TCEPR	TCER	CELR	LCER	NCELR	LTCER	Total
1989–90	7 780.1	–	1.0	–	–	–	7 781.1
1990–91	9 474.1	–	19.7	–	–	–	9 493.9
1991–92	8 187.3	–	8.1	–	–	–	8 195.4
1992–93	13 188.4	–	36.1	–	–	–	13 224.5
1993–94	7 358.9	–	4.7	–	–	–	7 363.6
1994–95	14 772.6	–	5.2	–	–	–	14 777.9
1995–96	15 980.5	–	4.6	–	–	–	15 985.1
1996–97	13 097.3	–	2.4	–	–	–	13 099.7
1997–98	14 577.9	–	3.9	–	–	–	14 581.8
1998–99	15 505.2	–	8.4	–	–	–	15 513.6
1999–00	13 271.5	–	9.2	–	–	–	13 280.7
2000–01	14 098.5	–	3.0	–	–	–	14 101.5
2001–02	11 778.3	–	5.3	–	–	–	11 783.6
2002–03	11 543.2	–	1.8	–	–	–	11 545.0
2003–04	13 648.3	–	1.8	1.1	–	–	13 651.1
2004–05	13 355.0	–	0.5	1.9	–	–	13 357.4
2005–06	9 938.0	–	5.2	0.8	–	–	9 944.0
2006–07	10 560.3	–	1.3	3.7	0.9	–	10 566.1
2007–08	5 880.4	19.6	5.8	3.4	1.8	11.5	5 922.5
2008–09	10 164.5	20.8	0.0	6.4	2.3	14.0	10 208.0
2009–10	4 631.0	36.4	0.0	9.6	1.9	25.1	4 703.9
2010–11	5 700.2	53.2	0.0	10.2	1.1	34.2	5 798.8
Total	244 491.6	130.0	127.9	37.0	8.0	84.8	244 879.3

Table 5: Chatham Rise hake TCEPR catch by target species and fishing method, 1989–90 to 2010–11. Values have been rounded to the nearest tonne unless catch was less than 1 t, so '0' denotes catches from 1 to 499 kg, and '–' denotes zero catch.

Method	Bottom trawl			Midwater trawl			Midwater, on bottom		
Target species	Hake	Hoki	Other	Hake	Hoki	Other	Hake	Hoki	Other
1989–90	531	381	39	–	0	0	–	0	0
1990–91	109	556	82	0	21	0	–	162	0
1991–92	1 514	756	72	6	15	0	20	12	0
1992–93	1 629	829	53	4	9	0	237	35	1
1993–94	856	365	65	23	43	0	1 501	78	1
1994–95	807	686	55	237	29	0	1 241	208	1
1995–96	2 640	944	84	7	40	0	72	170	0
1996–97	2 064	1 400	78	–	65	0	75	209	0
1997–98	2 138	1 180	255	0	64	0	360	250	0
1998–99	2 412	1 007	152	–	25	0	46	166	0
1999–00	1 274	904	243	382	32	0	234	102	0
2000–01	1 787	901	69	38	15	0	120	32	0
2001–02	1 111	515	36	0	44	0	2	61	0
2002–03	532	671	43	0	91	0	1	63	0
2003–04	1 782	542	59	–	12	0	–	70	0
2004–05	1 376	436	15	1 110	291	0	158	140	0
2005–06	173	243	29	0	5	0	–	39	0
2006–07	695	294	84	0	2	0	–	7	0
2007–08	657	356	73	–	3	0	–	6	0
2008–09	1 412	349	61	0	1	0	0	1	1
2009–10	86	226	63	0	3	0	–	12	0
2010–11	36	263	10	610	25	0	5	1	0

Table 6: Chatham Rise estimated hake TCEPR catch (t) by month from 1989–90 to 2010–11. Values have been rounded to the nearest tonne unless catch was less than 1 t, so '0' denotes catches from 1 to 499 kg, and '–' denotes zero catch.

	Month												
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989–90	82	30	304	167	15	50	144	88	24	17	3	26	950
1990–91	7	37	268	99	48	177	114	63	62	14	29	14	931
1991–92	78	59	520	572	146	99	83	48	32	54	119	587	2 396
1992–93	1 194	132	87	219	90	87	59	24	90	62	12	742	2 798
1993–94	219	2 086	64	39	26	8	11	32	43	25	6	374	2 934
1994–95	948	1 110	656	64	41	14	14	52	107	42	28	189	3 264
1995–96	242	1 079	997	669	59	23	45	96	151	75	95	329	3 961
1996–97	628	267	1 484	133	72	112	82	100	83	57	4	570	3 893
1997–98	302	469	284	95	65	173	107	112	174	86	1	2 081	4 250
1998–99	327	610	623	349	73	278	46	37	490	10	1	765	3 810
1999–00	878	373	299	107	71	122	57	28	575	31	1	531	3 174
2000–01	138	493	772	385	51	143	70	149	625	16	0	119	2 962
2001–02	108	396	385	255	24	53	36	59	36	14	18	385	1 770
2002–03	236	185	91	41	24	45	71	85	30	31	2	561	1 401
2003–04	197	446	694	421	44	68	65	70	53	14	7	384	2 465
2004–05	2 401	91	552	281	18	13	15	17	15	3	15	105	3 526
2005–06	68	61	203	15	10	8	20	14	40	7	4	39	489
2006–07	98	51	46	133	330	76	73	75	24	8	8	160	1 081
2007–08	37	40	47	418	248	58	27	63	24	19	20	94	1 096
2008–09	467	417	107	492	249	19	12	13	17	10	6	17	1 825
2009–10	99	21	85	29	30	18	6	41	30	13	12	7	391
2010–11	113	605	25	26	26	32	61	15	10	13	0	24	951

Table 7: WCSI hake TCEPR catch (t) by target species and fishing method, 1989–90 to 2010–11. Values have been rounded to the nearest tonne unless catch was less than 1 t, so '0' denotes catches from 1 to 499 kg, and '–' denotes zero catch.

Method	Bottom trawl			Midwater trawl			Midwater, on bottom		
Target species	Hake	Hoki	Other	Hake	Hoki	Other	Hake	Hoki	Other
1989–90	4	614	4	2	3 392	0	1	885	0
1990–91	-	247	3	0	4 627	2	5	1 246	44
1991–92	1 223	360	74	45	853	1	249	232	2
1992–93	536	607	21	962	1 024	0	2 548	1 409	15
1993–94	53	639	20	173	934	2	761	386	3
1994–95	0	631	96	851	4 410	20	1 870	1 763	14
1995–96	221	1 235	98	1 198	4 348	25	217	1 751	48
1996–97	57	1 078	45	511	3 192	48	281	1 590	71
1997–98	58	791	5	213	4 273	20	297	2 007	1
1998–99	370	1 430	40	1 114	3 267	7	1 204	1 297	47
1999–00	286	1 905	51	400	2 316	2	587	1 501	15
2000–01	333	1 547	15	2 164	1 578	0	1 172	1 536	0
2001–02	427	2 886	20	234	1 810	0	143	1 978	1
2002–03	2 158	1 984	7	434	996	0	528	1 296	1
2003–04	2 706	1 564	2	224	584	2	1 274	1 581	2
2004–05	2 675	743	3	842	454	1	2 123	457	0
2005–06	2 576	674	15	701	410	0	1 940	576	1
2006–07	1 591	373	10	4 266	438	0	915	60	7
2007–08	2 322	127	3	2	7	0	70	50	0
2008–09	2 504	122	4	1 206	6	0	2 002	69	0
2009–10	1 948	159	9	10	11	0	67	78	0
2010–11	2 811	499	14	1	36	0	12	90	0

Table 8: WCSI estimated hake TCEPR catch (t) by month from 1989–90 to 2010–11. Values have been rounded to the nearest tonne unless catch was less than 1 t, so '0' denotes catches from 1 to 499 kg, and '–' denotes zero catch.

												Month	
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989–90	0	0	0	–	0	0	0	0	1 107	3 075	696	25	4 903
1990–91	0	–	0	0	0	0	0	0	758	5 065	327	22	6 173
1991–92	0	0	–	0	0	0	0	0	213	771	172	1 884	3 040
1992–93	3	0	0	0	0	4	0	1	556	1 383	1 832	3 343	7 122
1993–94	0	0	0	0	0	1	0	0	885	1 234	381	470	2 971
1994–95	14	0	2	0	0	3	1	24	3 237	2 365	3 672	338	9 656
1995–96	85	0	0	0	0	1	0	1	2 530	2 625	2 794	1 107	9 143
1996–97	56	0	0	0	0	0	0	0	1 012	2 484	2 033	1 357	6 942
1997–98	64	31	0	0	0	0	2	15	1 589	3 328	2 156	492	7 677
1998–99	48	32	15	0	0	4	1	31	3 191	3 475	1 153	641	8 890
1999–00	195	0	–	–	0	2	1	44	1 776	3 586	835	637	7 076
2000–01	71	0	0	–	0	–	3	17	3 607	2 308	1 675	665	8 346
2001–02	0	2	0	0	–	0	0	0	824	3 471	2 920	281	7 498
2002–03	92	0	2	0	0	–	2	109	1 119	3 416	1 001	1 664	7 404
2003–04	280	0	0	0	–	0	–	39	2 850	1 548	2 249	972	7 939
2004–05	192	64	0	–	0	0	0	4	3 373	2 014	1 031	620	7 298
2005–06	275	19	0	0	0	0	0	0	774	1 092	2 185	2 547	6 892
2006–07	61	0	0	0	0	0	0	73	1 919	4 602	637	367	7 660
2007–08	65	0	–	0	–	–	–	59	510	578	772	598	2 583
2008–09	11	0	–	–	–	0	–	168	448	709	2 655	1 922	5 912
2009–10	13	0	–	–	–	–	–	15	209	517	716	813	2 282
2010–11	131	0	0	–	–	0	–	0	494	836	1 395	605	3 462

Table 9: Sub-Antarctic hake TCEPR catch (t) by target species and fishing method, 1989–90 to 2010–11. Values have been rounded to the nearest tonne unless catch was less than 1 t, so '0' denotes catches from 1 to 499 kg, and '–' denotes zero catch.

Method	Bottom trawl			Midwater trawl			Midwater, on bottom		
Target species	Hake	Hoki	Other	Hake	Hoki	Other	Hake	Hoki	Other
1989–90	610	724	477	–	5	44	–	5	61
1990–91	241	1 477	603	–	7	18	–	3	22
1991–92	544	1 610	549	3	18	12	0	4	10
1992–93	76	2 212	278	–	418	6	–	276	3
1993–94	148	547	317	43	368	3	9	10	7
1994–95	885	444	301	–	160	8	–	54	1
1995–96	1 251	440	1 077	–	68	0	–	37	0
1996–97	555	953	590	–	155	6	–	0	1
1997–98	738	1 197	658	–	7	3	–	0	2
1998–99	946	1 141	644	0	36	3	0	22	2
1999–00	906	1 460	252	0	357	2	–	32	10
2000–01	1 157	1 273	200	1	71	5	0	41	43
2001–02	1 039	1 238	154	–	6	4	–	8	63
2002–03	1 498	1 015	152	–	16	8	–	11	39
2003–04	1 224	1 537	426	–	8	15	–	12	23
2004–05	1 074	449	903	41	1	5	12	13	34
2005–06	2 078	112	336	2	6	6	0	2	17
2006–07	1 029	277	480	0	0	10	0	3	18
2007–08	1 558	188	436	–	0	6	–	–	13
2008–09	1 918	147	355	–	0	4	0	0	3
2009–10	1 493	245	206	–	1	2	–	0	10
2010–11	1 005	148	106	–	0	10	–	1	18

Table 10: Sub-Antarctic estimated hake TCEPR catch (t) recorded by month, 1989–90 to 2010–11. Values have been rounded to the nearest tonne, so '0' denotes catches from 1 to 499 kg.

	Month												
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989–90	222	11	18	22	26	45	79	156	107	8	64	1 169	1 927
1990–91	230	82	57	16	91	84	106	167	187	25	166	1 159	2 370
1991–92	272	92	78	75	106	127	200	139	171	125	265	1 100	2 750
1992–93	1 515	570	103	89	72	95	112	118	39	9	120	427	3 269
1993–94	648	126	53	78	66	48	45	23	78	1	3	284	1 453
1994–95	611	535	27	40	37	132	56	77	35	0	161	141	1 852
1995–96	1 147	705	219	24	15	152	62	54	36	145	78	236	2 873
1996–97	294	791	120	66	50	19	50	71	158	46	16	582	2 262
1997–98	554	1 024	83	44	122	136	88	195	101	21	7	230	2 606
1998–99	478	427	305	35	339	196	174	149	320	163	37	172	2 796
1999–00	295	851	435	253	322	120	142	194	307	14	4	84	3 020
2000–01	413	825	343	190	147	60	100	207	378	39	33	55	2 790
2001–02	177	1 007	391	191	106	124	96	97	120	28	54	121	2 510
2002–03	210	1 190	804	135	10	54	84	57	111	0	0	82	2 738
2003–04	432	1 246	862	254	39	6	12	137	143	4	5	105	3 245
2004–05	445	976	880	83	26	2	30	14	19	8	3	44	2 531
2005–06	163	189	2 083	1	1	11	22	15	8	1	4	60	2 557
2006–07	268	194	536	164	343	9	13	36	21	10	57	167	1 818
2007–08	227	609	509	214	560	11	8	3	2	3	14	40	2 202
2008–09	72	294	727	876	345	49	23	5	5	7	2	22	2 427
2009–10	109	84	586	619	303	41	32	93	33	3	3	53	1 958
2010–11	77	58	357	441	246	19	19	24	10	2	12	22	1 288

Table 11: Summary of data for all vessels and for core vessels included in the final datasets, by year. Data include: number of unique vessels fishing (Vessels), number of tow records for non-zero and zero hake catches for trawl data (Tows), number of vessel-days overall for non-zero and zero hake catches for daily processed data (Days), proportion of tows (trawl data) or vessel-days (daily processed data) that caught zero catch (Zeros), estimated catch, and unstandardised CPUE from non-zero catches from the tow-by-tow data.

(a) Chatham Rise West estimated data targeting hake and hoki for September–August.

	All data					Final CPUE data (Core vessels)				
Year	Vessels	Tows	Zeros	Catch (t)	CPUE	Vessels	Tows	Zeros	Catch (t)	CPUE
1990	29	1 556	0.45	269.6	0.31	5	493	0.28	97.8	0.28
1991	55	3 159	0.55	372.9	0.26	13	1 068	0.48	158.0	0.28
1992	58	4 134	0.51	669.7	0.33	16	1 767	0.44	304.8	0.31
1993	57	4 796	0.63	583.1	0.33	18	3 065	0.66	262.8	0.25
1994	48	3 264	0.74	311.8	0.37	19	2 407	0.78	157.2	0.30
1995	53	4 690	0.66	484.7	0.30	28	3 620	0.66	401.7	0.32
1996	71	8 152	0.65	1 048.9	0.37	30	5 373	0.59	823.8	0.38
1997	82	8 667	0.60	1 472.9	0.42	36	6 683	0.56	1 244.5	0.42
1998	79	11 691	0.63	1 401.4	0.33	44	9 546	0.63	1 115.6	0.32
1999	55	9 981	0.68	1 001.3	0.31	40	9 082	0.67	963.5	0.32
2000	46	9 435	0.70	1 104.0	0.39	37	8 572	0.69	1 073.5	0.40
2001	47	8 239	0.68	1 062.1	0.40	35	7 646	0.67	1 022.7	0.40
2002	35	6 675	0.66	432.1	0.19	26	6 247	0.66	399.2	0.19
2003	31	7 568	0.73	461.7	0.22	25	7 046	0.74	402.1	0.22
2004	32	5 838	0.78	607.5	0.46	25	5 568	0.77	580.8	0.46
2005	31	4 207	0.73	2 155.0	1.91	21	4 148	0.73	2 154.0	1.93
2006	25	4 119	0.82	199.2	0.27	18	4 099	0.82	199.2	0.27
2007	21	3 465	0.82	184.5	0.30	18	3 458	0.82	184.5	0.30
2008	25	3 234	0.75	168.3	0.21	22	3 168	0.75	163.1	0.20
2009	21	3 382	0.66	931.3	0.80	19	3 329	0.66	911.2	0.81
2010	22	3 457	0.79	167.9	0.24	17	3 359	0.80	156.1	0.23
2011	21	3 085	0.80	207.4	0.34	19	3 053	0.80	204.5	0.34
Total	198	122 794		15 297.4		57	102 797		12 980.4	

(b) Chatham Rise West daily processed data targeting hake and hoki for September–August.

	All data					Final CPUE data (Core vessels)				
Year	Vessels	Days	Zeros	Catch (t)	CPUE	Vessels	Days	Zeros	Catch (t)	CPUE
1990	21	375	0.13	273.0	0.84	3	41	0.15	30.1	0.86
1991	41	772	0.30	314.9	0.58	11	207	0.20	86.6	0.52
1992	46	1 043	0.25	617.5	0.79	14	330	0.22	137.1	0.53
1993	43	1 127	0.31	546.7	0.70	18	633	0.36	183.7	0.45
1994	36	772	0.48	301.5	0.75	18	520	0.49	126.0	0.48
1995	46	1 124	0.31	447.8	0.58	23	790	0.30	278.4	0.50
1996	57	1 996	0.28	965.5	0.67	25	1 133	0.20	657.9	0.73
1997	62	2 071	0.25	1 356.7	0.88	30	1 297	0.22	1 064.3	1.05
1998	68	2 899	0.22	1 433.6	0.63	39	2 105	0.21	1 049.4	0.63
1999	50	2 483	0.16	1 045.4	0.50	36	2 049	0.14	940.3	0.53
2000	41	2 405	0.15	1 221.5	0.60	37	2 247	0.15	1 178.7	0.62
2001	40	2 065	0.09	1 196.3	0.63	32	1 929	0.09	1 142.7	0.65
2002	29	1 704	0.08	639.0	0.41	26	1 600	0.07	601.1	0.41
2003	27	1 997	0.09	781.0	0.43	22	1 802	0.08	692.0	0.42
2004	28	1 545	0.08	751.9	0.53	25	1 380	0.07	648.7	0.51
2005	28	1 276	0.07	1 956.7	1.65	21	1 124	0.05	1 760.5	1.65
2006	22	1 182	0.10	485.3	0.46	18	1 097	0.10	467.9	0.48
2007	19	1 016	0.10	301.4	0.33	16	863	0.10	257.2	0.33
2008	25	977	0.10	307.7	0.35	22	957	0.10	302.2	0.35
2009	20	979	0.07	984.1	1.08	18	950	0.07	947.2	1.07
2010	21	946	0.07	289.7	0.33	18	901	0.07	267.5	0.32
2011	21	882	0.08	628.6	0.77	18	867	0.08	624.2	0.78
Total	161	31 636		16 845.6		48	24 822		13 443.6	

Table 11: continued.

(c) Chatham Rise East estimated data targeting hake and hoki for September–August.

	All data					Final CPUE data (Core vessels)				
Year	Vessels	Tows	Zeros	Catch (t)	CPUE	Vessels	Tows	Zeros	Catch (t)	CPUE
1990	13	351	0.29	624.5	2.52	4	157	0.02	481.5	3.13
1991	16	1 126	0.22	467.2	0.53	7	880	0.21	303.8	0.44
1992	23	1 956	0.47	1 068.6	1.03	10	1 373	0.47	299.6	0.42
1993	32	1 971	0.35	1 998.4	1.56	13	1 196	0.29	1 207.1	1.42
1994	29	1 379	0.41	2 843.6	3.52	11	889	0.43	2 019.7	3.95
1995	38	3 223	0.56	2 859.0	2.02	17	2 523	0.55	2 456.9	2.14
1996	38	1 549	0.52	2 373.9	3.20	11	1 114	0.47	2 050.1	3.46
1997	45	2 435	0.51	1 680.9	1.40	14	1 400	0.40	1 513.8	1.79
1998	42	2 941	0.63	1 059.1	0.98	12	1 892	0.59	749.4	0.96
1999	36	4 170	0.67	3 044.7	2.19	15	2 790	0.57	2 373.1	1.98
2000	31	2 183	0.63	1 785.4	2.24	15	1 815	0.61	1 708.7	2.40
2001	35	2 684	0.54	1 756.3	1.41	16	2 209	0.54	1 464.0	1.43
2002	35	2 560	0.64	992.5	1.06	13	1 411	0.50	904.7	1.29
2003	30	2 472	0.70	692.2	0.93	10	1 543	0.63	570.4	1.01
2004	32	2 778	0.57	1 911.5	1.59	12	2 191	0.53	1 709.7	1.66
2005	22	2 100	0.62	1 414.1	1.79	5	970	0.33	1 266.7	1.95
2006	20	1 040	0.75	316.5	1.20	5	371	0.57	106.1	0.66
2007	20	1 419	0.60	614.1	1.08	9	1 188	0.57	562.3	1.10
2008	20	1 446	0.57	728.2	1.18	11	1 294	0.59	676.8	1.28
2009	16	1 073	0.55	800.5	1.65	8	661	0.35	780.5	1.83
2010	17	1 012	0.82	149.4	0.80	4	749	0.84	103.8	0.86
2011	18	994	0.67	117.4	0.36	5	760	0.64	94.4	0.34
Total	121	42 862		29 297.8		38	29 376		23 402.9	

(d) Chatham Rise East daily processed data targeting hake and hoki for September–August.

	All data					Final CPUE data (Core vessels)				
Year	Vessels	Days	Zeros	Catch (t)	CPUE	Vessels	Days	Zeros	Catch (t)	CPUE
1990	11	85	0.11	556.5	7.32	4	47	0.00	427.3	9.09
1991	13	305	0.02	476.2	1.59	5	163	0.01	247.8	1.54
1992	22	463	0.13	1 028.5	2.56	12	185	0.12	426.9	2.64
1993	28	510	0.10	1 863.5	4.04	15	278	0.12	1 122.7	4.58
1994	26	351	0.07	2 507.2	7.69	18	296	0.07	2 071.2	7.50
1995	37	792	0.16	2 427.4	3.63	23	635	0.12	2 081.5	3.74
1996	32	395	0.17	1 970.1	5.99	21	353	0.16	1 850.0	6.23
1997	37	565	0.16	1 520.2	3.21	25	459	0.15	1 439.3	3.71
1998	38	681	0.10	884.6	1.44	28	572	0.09	710.9	1.37
1999	34	1 009	0.08	2 794.1	3.02	30	980	0.08	2 626.9	2.91
2000	27	556	0.06	1 687.6	3.23	23	548	0.05	1 684.8	3.25
2001	34	704	0.03	1 910.1	2.80	29	660	0.03	1 876.1	2.94
2002	33	718	0.03	941.6	1.35	30	674	0.02	929.9	1.41
2003	28	642	0.03	620.4	0.99	27	624	0.03	610.4	1.01
2004	31	838	0.04	1 592.9	1.97	28	823	0.03	1 487.0	1.87
2005	21	675	0.06	1 219.3	1.91	19	666	0.06	1 117.4	1.78
2006	19	339	0.05	268.3	0.83	15	333	0.04	161.9	0.51
2007	19	464	0.03	591.1	1.32	17	439	0.03	534.6	1.26
2008	20	498	0.02	710.0	1.45	17	479	0.02	701.9	1.49
2009	16	379	0.02	672.2	1.80	15	350	0.02	598.5	1.74
2010	16	280	0.01	135.8	0.49	15	279	0.01	135.7	0.49
2011	16	318	0.04	120.7	0.39	14	306	0.04	117.1	0.40
Total	108	11 567		26 498.4		44	10 149		22 959.8	

Table 11: continued.

(e) WCSI estimated data targeting hake and hoki for June–September.

					All data					Final CPUE data (Core vessels)
Year	Vessels	Tows	Zeros	Catch (t)	CPUE	Vessels	Tows	Zeros	Catch (t)	CPUE
1990	75	7 960	0.43	4 628.1	1.03	10	1 445	0.30	1 070.3	1.06
1991	72	8 014	0.60	5 525.5	1.73	15	1 692	0.50	1 914.9	2.26
1992	66	6 166	0.73	2 613.4	1.58	12	1 548	0.58	1 383.0	2.15
1993	60	7 099	0.70	5 933.0	2.80	19	2 848	0.62	3 644.5	3.33
1994	65	8 602	0.76	2 769.4	1.35	22	3 483	0.65	2 103.6	1.75
1995	60	8 021	0.62	6 305.2	2.06	26	4 085	0.54	4 399.6	2.33
1996	59	6 774	0.42	7 975.2	2.04	30	4 587	0.43	6 216.8	2.39
1997	75	7 706	0.50	5 166.1	1.35	37	4 633	0.45	3 884.3	1.52
1998	67	7 473	0.44	6 406.7	1.53	42	5 157	0.40	5 170.2	1.67
1999	57	6 637	0.48	7 052.1	2.03	37	5 127	0.44	6 446.4	2.24
2000	50	7 042	0.47	6 149.0	1.66	39	6 437	0.46	5 958.8	1.71
2001	62	8 124	0.45	7 284.4	1.62	41	6 786	0.43	6 848.1	1.76
2002	55	7 253	0.42	6 958.4	1.66	40	6 274	0.38	6 826.1	1.75
2003	50	7 296	0.44	6 596.8	1.61	37	6 340	0.41	6 018.3	1.60
2004	50	6 283	0.42	6 891.8	1.88	33	5 041	0.33	6 616.5	1.95
2005	36	4 098	0.44	6 623.9	2.91	28	3 326	0.37	5 950.3	2.85
2006	35	4 051	0.37	6 115.6	2.39	29	3 800	0.35	5 955.1	2.43
2007	31	2 548	0.47	4 818.2	3.59	24	2 325	0.44	4 728.4	3.65
2008	25	2 263	0.36	2 388.2	1.64	19	2 031	0.34	2 315.9	1.74
2009	24	1 808	0.34	4 234.8	3.57	16	1 452	0.25	3 895.9	3.59
2010	28	2 283	0.51	2 101.9	1.87	16	1 744	0.43	1 911.2	1.93
2011	27	2 945	0.35	3 083.7	1.61	25	2 783	0.33	3 070.2	1.64
Total	242	130 446		117 621.6		58	82 944		96 328.4	

(f) WCSI daily processed data targeting hake and hoki for June–September.

					All data					Final CPUE data (Core vessels)
Year	Vessels	Days	Zeros	Catch (t)	CPUE	Vessels	Days	Zeros	Catch (t)	CPUE
1990	71	2 430	0.23	5 379.2	2.88	14	699	0.12	1 828.7	2.98
1991	70	2 557	0.41	5 211.3	3.46	18	825	0.28	2 716.4	4.57
1992	64	1 949	0.57	2 332.2	2.77	13	572	0.41	1 449.5	4.29
1993	58	1 812	0.60	3 854.8	5.34	15	747	0.45	2 515.5	6.15
1994	59	2 353	0.54	2 448.7	2.24	17	851	0.31	1 927.0	3.27
1995	58	2 231	0.31	5 813.4	3.76	30	1 362	0.22	4 716.6	4.45
1996	58	1 950	0.17	6 804.2	4.19	30	1 336	0.14	5 484.4	4.78
1997	66	2 300	0.20	4 368.1	2.38	40	1 647	0.15	3 565.3	2.55
1998	62	2 290	0.19	5 330.2	2.86	42	1 804	0.15	4 723.8	3.07
1999	53	2 006	0.24	5 865.6	3.83	39	1 737	0.22	5 554.0	4.10
2000	45	1 903	0.16	4 991.2	3.13	35	1 652	0.14	4 736.4	3.33
2001	53	2 204	0.13	5 795.3	3.02	41	1 928	0.10	5 674.6	3.29
2002	45	1 932	0.13	6 597.6	3.95	39	1 764	0.12	6 292.4	4.06
2003	45	2 077	0.12	5 741.0	3.16	36	1 860	0.09	5 703.7	3.36
2004	46	1 762	0.13	5 739.7	3.73	34	1 544	0.08	5 393.4	3.78
2005	36	1 313	0.16	5 483.6	4.94	27	1 061	0.09	5 134.8	5.31
2006	34	1 367	0.11	5 315.5	4.39	25	1 202	0.08	4 952.0	4.50
2007	31	924	0.24	4 686.1	6.65	18	696	0.16	3 905.7	6.68
2008	25	805	0.07	2 053.4	2.75	12	616	0.02	1 905.4	3.17
2009	24	740	0.08	4 663.6	6.82	14	604	0.05	4 265.5	7.42
2010	28	782	0.18	1 824.9	2.84	12	486	0.09	1 598.6	3.60
2011	27	1 019	0.09	2 658.4	2.86	21	897	0.08	2 521.4	3.05
Total	226	38 706		102 957.9		72	25 890		86 565.2	

Table 11: continued.

(g) WCSI observer data targeting hake and hoki for June–September.

	All data					Final CPUE data (Core vessels)				
Year	Vessels	Tows	Zeros	Catch (t)	CPUE	Vessels	Tows	Zeros	Catch (t)	CPUE
1987	25	2 414	0.22	1 537.0	0.81	13	1 369	0.18	1 090.4	0.97
1988	22	2 490	0.24	2 017.7	1.07	16	2 117	0.22	1 796.8	1.09
1989	14	1 472	0.24	2 380.5	2.13	10	1 053	0.24	1 683.7	2.09
1990	14	1 541	0.12	2 545.9	1.87	8	1 018	0.07	1 627.1	1.71
1991	14	1 255	0.24	1 570.2	1.64	7	618	0.18	920.9	1.81
1992	12	858	0.43	628.0	1.28	9	396	0.27	484.9	1.68
1993	15	1 247	0.46	1 498.1	2.24	14	1 005	0.46	801.0	1.48
1994	15	1 641	0.58	289.7	0.42	11	964	0.52	143.3	0.31
1995	9	845	0.17	1 274.7	1.81	8	643	0.13	1 075.4	1.93
1996	15	1 070	0.15	1 524.6	1.67	10	826	0.13	1 109.0	1.55
1997	12	698	0.18	676.9	1.19	12	675	0.17	540.9	0.97
1998	16	907	0.19	1 067.0	1.45	13	817	0.18	994.4	1.49
1999	14	1 114	0.22	1 225.8	1.42	14	1 103	0.22	1 219.3	1.42
2000	17	1 158	0.19	1 071.6	1.14	16	1 142	0.19	1 060.3	1.15
2001	21	1 018	0.22	509.5	0.64	20	987	0.21	505.3	0.65
2002	16	1 320	0.16	1 463.3	1.31	15	1 224	0.14	1 433.9	1.36
2003	13	958	0.23	903.5	1.23	13	810	0.21	708.5	1.11
2004	16	1 382	0.15	1 331.4	1.14	14	1 180	0.13	1 203.3	1.17
2005	13	1 066	0.12	1 092.8	1.16	12	1 017	0.11	1 080.7	1.19
2006	15	1 124	0.08	2 035.8	1.97	15	1 039	0.05	1 842.4	1.87
2007	16	672	0.41	1 392.1	3.49	16	519	0.33	1 153.6	3.33
2008	14	738	0.27	845.2	1.56	14	627	0.30	525.7	1.20
2009	16	557	0.28	1 441.4	3.60	15	490	0.30	1 052.3	3.09
2010	15	672	0.35	497.6	1.14	14	489	0.26	442.8	1.22
2011	11	629	0.16	593.8	1.12	11	561	0.16	529.5	1.13
Total	135	28 846		31 414.1		77	22 689		25 025.3	

Table 12: Variables retained in order of decreasing explanatory value by each model for each area, with the corresponding total r^2 value.

Lognormal model		Binomial model	
Variable	r^2	Variable	r^2
Chatham Rise West: TCEPR tow-by-tow core vessels			
Year	3.2	Year	3.4
Vessel	26.9	Statistical area	11.4
Target	33.2	Vessel	16.3
Latitude	39.1		
Chatham Rise West: TCEPR daily processed core vessels			
Year	2.0	Year	6.4
Latitude	16.0	Vessel	14.0
Vessel	27.9	Longitude	19.7
Target	32.0	Latitude	21.0
Longitude	34.0	Duration	22.0
Duration	35.4		
Chatham Rise East: TCEPR tow-by-tow core vessels			
Year	11.6	Year	5.8
Statistical area	68.2	Statistical area	36.4
Vessel	73.9	Vessel	40.4
Target	76.0	Depth of bottom	41.5
Duration	77.3		
Chatham Rise East: TCEPR daily processed core vessels			
Year	7.8	Year	3.3
Statistical area	64.7	Vessel	14.6
Vessel	69.1	Statistical area	17.7
Target	70.9	Depth of bottom	21.6
Distance2	72.2	Duration	22.2
WCSI: TCEPR tow-by-tow core vessels			
Year	2.2	Year	3.0
Target	23.9	Depth of bottom	24.3
Vessel	34.5	Vessel	27.1
Depth of bottom	40.4	Longitude	30.5
Latitude	42.3	Method : Duration	31.6
Mid time of tow	42.7		
Method : Duration	46.4		
WCSI: TCEPR daily processed core vessels			
Year	2.5	Year	6.3
Longitude	28.6	Depth of bottom	18.2
Vessel	34.7	Longitude	22.4
Target	40.1	Vessel	24.4
Method : Depth of net	46.4	Distance2	25.4
Method : Duration	48.2		
WCSI: observer core vessels			
Year	4.1	Year	7.1
Depth of bottom	29.8	Depth of bottom	24.6
Vessel	37.5	Longitude	29.8
Latitude	43.5	Vessel	32.2
Method : Duration	47.3	Latitude	33.3
Method : Depth of net	49.3	Method : Duration	35.0
		Method : Headline height	36.2

Table 13: Lognormal CPUE standardised indices, and binomial, and combined CPUE indices (with 95% confidence intervals and c.v.s).

(a) Chatham Rise West: TCEPR tow-by-tow core vessel data

	Lognormal			Binomial			Combined
Year	Index	95% CI	c.v.	Index	95% CI	c.v.	Index
1990	0.67	0.60–0.76	0.06	0.84	0.84–0.76	0.05	0.74
1991	0.62	0.56–0.67	0.04	0.94	0.94–0.88	0.03	0.64
1992	0.79	0.73–0.86	0.04	0.87	0.87–0.83	0.03	0.85
1993	0.77	0.71–0.82	0.04	0.97	0.97–0.93	0.02	0.77
1994	0.83	0.76–0.91	0.04	1.02	1.02–0.98	0.02	0.81
1995	0.89	0.84–0.94	0.03	0.96	0.96–0.92	0.02	0.90
1996	0.96	0.91–1.01	0.02	0.89	0.89–0.86	0.02	1.02
1997	1.09	1.04–1.13	0.02	0.86	0.86–0.84	0.01	1.19
1998	1.06	1.02–1.10	0.02	0.92	0.92–0.90	0.01	1.10
1999	0.91	0.87–0.95	0.02	0.95	0.95–0.93	0.01	0.93
2000	1.11	1.06–1.15	0.02	0.99	0.99–0.97	0.01	1.10
2001	1.00	0.96–1.04	0.02	0.99	0.99–0.97	0.01	0.99
2002	1.01	0.96–1.06	0.02	0.99	0.99–0.96	0.01	1.00
2003	1.09	1.04–1.14	0.02	1.06	1.06–1.03	0.01	1.03
2004	1.51	1.43–1.61	0.03	1.13	1.13–1.10	0.01	1.36
2005	1.55	1.46–1.66	0.03	1.06	1.06–1.03	0.02	1.46
2006	1.29	1.20–1.40	0.04	1.13	1.13–1.10	0.02	1.17
2007	1.23	1.13–1.34	0.04	1.13	1.13–1.09	0.02	1.11
2008	1.06	0.99–1.14	0.04	1.10	1.10–1.06	0.02	0.98
2009	1.06	1.00–1.13	0.03	1.01	1.01–0.98	0.02	1.04
2010	1.06	0.98–1.14	0.04	1.13	1.13–1.09	0.02	0.96
2011	0.98	0.91–1.07	0.04	1.17	1.17–1.12	0.02	0.86

(b) Chatham Rise West: TCEPR daily processed core vessel data

	Lognormal			Binomial			Combined
Year	Index	95% CI	c.v.	Index	95% CI	c.v.	Index
1990	0.88	0.63–1.23	0.17	1.08	0.79–1.48	0.16	0.86
1991	0.77	0.66–0.90	0.08	1.09	0.95–1.26	0.07	0.75
1992	0.83	0.72–0.95	0.07	1.09	0.97–1.23	0.06	0.81
1993	0.89	0.80–0.98	0.05	1.16	1.07–1.26	0.04	0.86
1994	0.97	0.86–1.10	0.06	1.22	1.11–1.33	0.05	0.93
1995	1.01	0.92–1.10	0.04	1.10	1.02–1.19	0.04	0.99
1996	1.31	1.21–1.41	0.04	1.01	0.95–1.08	0.03	1.29
1997	1.34	1.25–1.43	0.03	1.04	0.98–1.10	0.03	1.32
1998	1.24	1.18–1.31	0.03	1.02	0.97–1.07	0.02	1.22
1999	0.99	0.94–1.05	0.03	0.96	0.91–1.01	0.03	0.98
2000	1.07	1.01–1.13	0.03	0.96	0.92–1.01	0.02	1.06
2001	1.07	1.01–1.13	0.03	0.95	0.90–1.00	0.03	1.07
2002	1.05	0.99–1.11	0.03	0.94	0.89–0.99	0.03	1.05
2003	0.97	0.92–1.03	0.03	0.95	0.90–1.00	0.03	0.97
2004	0.96	0.90–1.02	0.03	0.95	0.89–1.00	0.03	0.96
2005	0.92	0.86–0.98	0.03	0.92	0.86–0.98	0.03	0.92
2006	0.94	0.87–1.00	0.03	0.96	0.90–1.03	0.03	0.94
2007	0.96	0.89–1.03	0.04	0.96	0.89–1.03	0.04	0.96
2008	1.06	0.99–1.14	0.04	0.94	0.87–1.00	0.03	1.06
2009	1.21	1.12–1.30	0.04	0.92	0.86–0.99	0.03	1.21
2010	0.94	0.87–1.01	0.04	0.93	0.86–0.99	0.03	0.94
2011	0.86	0.80–0.93	0.04	0.93	0.87–1.00	0.04	0.86

Table 13: continued.

(c) Chatham Rise East: TCEPR tow-by-tow core vessel data

	Lognormal			Binomial			Combined
Year	Index	95% CI	c.v.	Index	95% CI	c.v.	Index
1990	1.66	1.36–2.02	0.10	0.89	0.74–1.07	0.09	1.66
1991	1.32	1.20–1.45	0.05	0.78	0.72–0.85	0.04	1.41
1992	1.29	1.17–1.42	0.05	0.89	0.83–0.96	0.04	1.29
1993	1.14	1.04–1.23	0.04	0.87	0.81–0.93	0.04	1.15
1994	1.68	1.52–1.85	0.05	0.95	0.88–1.02	0.04	1.63
1995	1.13	1.05–1.21	0.03	0.94	0.90–0.98	0.02	1.10
1996	1.23	1.13–1.35	0.04	0.92	0.86–0.98	0.03	1.21
1997	1.09	1.01–1.18	0.04	0.85	0.80–0.90	0.03	1.12
1998	0.89	0.83–0.97	0.04	0.93	0.89–0.98	0.02	0.87
1999	0.91	0.85–0.97	0.03	0.94	0.90–0.98	0.02	0.89
2000	1.47	1.36–1.60	0.04	1.01	0.96–1.07	0.03	1.38
2001	0.92	0.85–0.98	0.04	1.04	0.99–1.09	0.02	0.85
2002	0.81	0.74–0.88	0.04	1.12	1.05–1.18	0.03	0.72
2003	0.79	0.72–0.86	0.05	1.11	1.05–1.17	0.03	0.71
2004	0.92	0.86–0.99	0.04	1.08	1.03–1.14	0.02	0.83
2005	0.64	0.59–0.70	0.04	1.15	1.07–1.23	0.04	0.56
2006	0.53	0.45–0.62	0.08	1.18	1.06–1.31	0.05	0.46
2007	0.92	0.84–1.02	0.05	1.07	1.01–1.14	0.03	0.84
2008	0.69	0.63–0.76	0.05	1.10	1.03–1.16	0.03	0.62
2009	0.71	0.64–0.79	0.06	1.15	1.06–1.25	0.04	0.62
2010	1.41	1.18–1.69	0.09	1.12	1.04–1.21	0.04	1.25
2011	0.89	0.78–1.01	0.06	1.06	0.99–1.15	0.04	0.82

(d) Chatham Rise East: TCEPR daily processed core vessel data

	Lognormal			Binomial			Combined
Year	Index	95% CI	c.v.	Index	95% CI	c.v.	Index
1990	2.22	1.62–3.05	0.16	1.01	0.73–1.38	0.16	2.07
1991	1.92	1.61–2.27	0.09	0.99	0.84–1.18	0.09	1.79
1992	1.29	1.10–1.52	0.08	1.07	0.92–1.25	0.08	1.20
1993	1.27	1.11–1.44	0.07	1.00	0.88–1.13	0.06	1.18
1994	1.47	1.29–1.67	0.06	0.99	0.88–1.12	0.06	1.37
1995	1.06	0.96–1.16	0.05	1.05	0.96–1.14	0.04	0.98
1996	1.38	1.23–1.55	0.06	1.05	0.94–1.17	0.06	1.28
1997	1.31	1.18–1.45	0.05	1.04	0.94–1.15	0.05	1.22
1998	1.02	0.93–1.12	0.05	1.01	0.93–1.10	0.04	0.95
1999	0.95	0.88–1.02	0.04	1.00	0.93–1.07	0.04	0.89
2000	1.29	1.17–1.41	0.05	0.99	0.91–1.08	0.04	1.20
2001	1.10	1.01–1.19	0.04	0.99	0.91–1.08	0.04	1.03
2002	0.89	0.82–0.97	0.04	0.97	0.89–1.05	0.04	0.83
2003	0.72	0.66–0.79	0.04	0.97	0.89–1.06	0.04	0.67
2004	0.80	0.74–0.87	0.04	0.98	0.91–1.06	0.04	0.75
2005	0.54	0.49–0.59	0.04	1.01	0.93–1.10	0.04	0.50
2006	0.51	0.45–0.57	0.06	0.99	0.88–1.11	0.06	0.48
2007	0.81	0.73–0.89	0.05	0.99	0.89–1.09	0.05	0.76
2008	0.83	0.75–0.91	0.05	0.98	0.89–1.07	0.05	0.77
2009	0.88	0.78–0.98	0.06	0.98	0.88–1.10	0.06	0.82
2010	0.75	0.66–0.84	0.06	0.95	0.84–1.07	0.06	0.70
2011	0.61	0.54–0.69	0.06	1.00	0.73–1.38	0.06	0.57

Table 13: continued.

(c) WCSI: TCEPR tow-by-tow core vessel data

	Lognormal			Binomial			Combined
Year	Index	95% CI	c.v.	Index	95% CI	c.v.	Index
1990	0.58	0.54–0.62	0.04	0.98	0.93–1.04	0.03	0.54
1991	0.92	0.86–0.99	0.04	1.11	1.06–1.17	0.03	0.81
1992	0.75	0.69–0.82	0.04	1.13	1.08–1.20	0.03	0.66
1993	1.19	1.11–1.26	0.03	1.12	1.08–1.17	0.02	1.05
1994	0.98	0.93–1.04	0.03	1.16	1.12–1.20	0.02	0.85
1995	1.36	1.30–1.43	0.02	1.07	1.03–1.10	0.02	1.22
1996	2.15	2.06–2.24	0.02	1.00	0.97–1.03	0.02	1.99
1997	1.69	1.62–1.76	0.02	0.95	0.92–0.98	0.02	1.60
1998	1.50	1.45–1.56	0.02	0.96	0.93–0.99	0.01	1.41
1999	1.48	1.42–1.54	0.02	1.02	0.99–1.05	0.01	1.36
2000	1.48	1.43–1.54	0.02	0.98	0.96–1.01	0.01	1.38
2001	1.17	1.13–1.21	0.02	1.00	0.97–1.02	0.01	1.08
2002	1.56	1.51–1.62	0.02	0.93	0.90–0.95	0.01	1.49
2003	1.11	1.07–1.15	0.02	0.95	0.92–0.97	0.01	1.05
2004	0.95	0.92–0.99	0.02	0.91	0.89–0.94	0.01	0.91
2005	0.86	0.82–0.90	0.02	1.01	0.98–1.05	0.02	0.79
2006	0.80	0.77–0.83	0.02	0.99	0.95–1.02	0.02	0.74
2007	0.64	0.60–0.68	0.03	1.03	0.98–1.07	0.02	0.58
2008	0.43	0.40–0.45	0.03	0.99	0.95–1.04	0.02	0.40
2009	0.61	0.58–0.65	0.03	0.97	0.92–1.02	0.03	0.57
2010	0.67	0.63–0.72	0.03	0.97	0.92–1.01	0.02	0.63
2011	0.88	0.83–0.92	0.02	0.83	0.80–0.87	0.02	0.88

(d) WCSI: TCEPR daily processed core vessel data

	Lognormal			Binomial			Combined
Year	Index	95% CI	c.v.	Index	95% CI	c.v.	Index
1990	0.89	0.81–0.98	0.05	1.05	0.97–1.15	0.04	0.82
1991	1.20	1.09–1.31	0.05	1.16	1.07–1.25	0.04	1.09
1992	0.72	0.64–0.81	0.06	1.26	1.14–1.38	0.05	0.64
1993	0.96	0.87–1.07	0.05	1.25	1.16–1.36	0.04	0.86
1994	0.79	0.72–0.86	0.04	1.14	1.05–1.22	0.04	0.72
1995	1.15	1.07–1.22	0.03	1.04	0.98–1.10	0.03	1.06
1996	2.09	1.96–2.23	0.03	1.00	0.95–1.06	0.03	1.94
1997	1.65	1.56–1.75	0.03	0.95	0.90–1.00	0.03	1.55
1998	1.70	1.61–1.80	0.03	0.98	0.93–1.03	0.02	1.59
1999	1.22	1.15–1.30	0.03	1.04	0.98–1.09	0.03	1.13
2000	1.33	1.25–1.40	0.03	0.97	0.92–1.02	0.03	1.24
2001	0.97	0.92–1.02	0.03	0.95	0.91–1.00	0.02	0.91
2002	1.71	1.61–1.80	0.03	0.94	0.89–0.99	0.03	1.61
2003	1.21	1.15–1.28	0.03	0.91	0.86–0.95	0.02	1.14
2004	1.07	1.01–1.13	0.03	0.91	0.86–0.96	0.03	1.01
2005	0.83	0.78–0.89	0.03	0.93	0.88–0.99	0.03	0.78
2006	0.82	0.76–0.87	0.03	0.94	0.89–1.00	0.03	0.77
2007	0.68	0.62–0.74	0.04	1.00	0.92–1.08	0.04	0.63
2008	0.42	0.38–0.46	0.04	0.94	0.86–1.02	0.04	0.39
2009	0.66	0.60–0.72	0.04	0.97	0.89–1.05	0.04	0.62
2010	0.59	0.53–0.65	0.05	0.92	0.84–1.01	0.05	0.56
2011	0.98	0.91–1.05	0.04	0.87	0.81–0.93	0.03	0.93

Table 13: continued.

(e) WCSI: Observer tow-by-tow core vessel data

	Lognormal			Binomial			Combined
Year	Index	95% CI	c.v.	Index	95% CI	c.v.	Index
1987	0.46	0.41–0.52	0.06	1.10	0.99–1.22	0.05	0.40
1988	0.72	0.66–0.80	0.05	1.09	1.00–1.20	0.05	0.63
1989	0.95	0.84–1.07	0.06	1.22	1.10–1.35	0.05	0.81
1990	1.13	1.02–1.26	0.05	1.03	0.93–1.14	0.05	1.00
1991	0.67	0.60–0.75	0.06	1.04	0.94–1.16	0.05	0.59
1992	0.52	0.45–0.60	0.07	1.16	1.02–1.32	0.06	0.45
1993	0.81	0.72–0.92	0.06	1.15	1.05–1.26	0.05	0.70
1994	0.75	0.67–0.84	0.05	1.05	0.97–1.14	0.04	0.66
1995	1.12	1.00–1.27	0.06	0.90	0.81–1.00	0.05	1.02
1996	2.10	1.91–2.30	0.05	0.93	0.86–1.02	0.04	1.90
1997	2.52	2.29–2.79	0.05	0.89	0.81–0.98	0.05	2.29
1998	1.63	1.49–1.78	0.04	0.95	0.88–1.03	0.04	1.47
1999	1.50	1.38–1.64	0.04	1.00	0.93–1.09	0.04	1.33
2000	2.03	1.88–2.20	0.04	0.93	0.87–1.00	0.04	1.83
2001	0.93	0.85–1.01	0.04	0.92	0.85–0.99	0.04	0.84
2002	2.11	1.95–2.28	0.04	0.94	0.87–1.01	0.04	1.90
2003	0.97	0.88–1.06	0.05	0.98	0.90–1.06	0.04	0.87
2004	1.15	1.06–1.24	0.04	0.94	0.88–1.02	0.04	1.04
2005	0.88	0.82–0.96	0.04	0.94	0.88–1.02	0.04	0.79
2006	1.10	1.02–1.19	0.04	0.92	0.85–0.99	0.04	1.00
2007	0.66	0.59–0.74	0.06	1.03	0.94–1.13	0.05	0.58
2008	0.50	0.45–0.56	0.05	1.06	0.97–1.16	0.05	0.44
2009	0.58	0.52–0.66	0.06	1.06	0.96–1.17	0.05	0.51
2010	0.81	0.72–0.91	0.06	0.96	0.87–1.07	0.05	0.73
2011	1.35	1.22–1.50	0.05	0.89	0.81–0.98	0.05	1.23

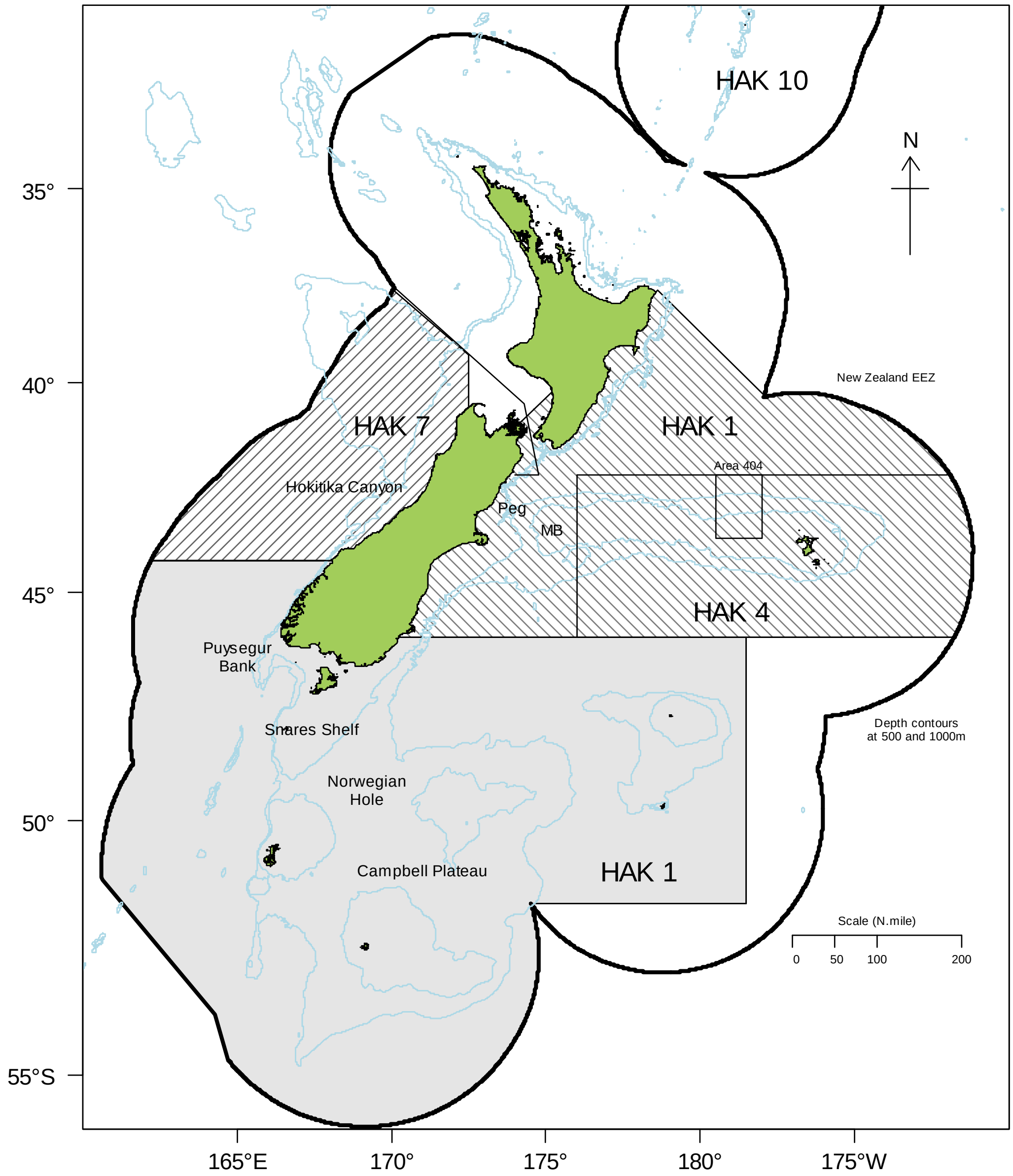


Figure 1: Quota Management Areas (QMAs) HAK 1, 4, 7, and 10, and hake stock boundaries, as assumed in this report: West coast South Island (dark stripes over HAK7), Chatham Rise (light stripes over HAK1 and HAK4), and Sub-Antarctic (grey shading over HAK1). Place names referred to in the text are also noted, including: Peg, Pegasus Bay; MB, Mernoo Bank.

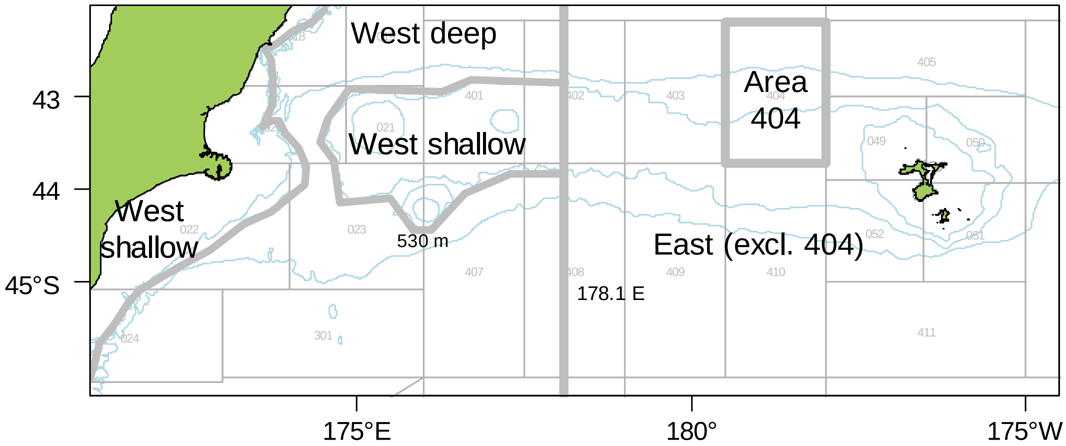


Figure 2a: Location and boundaries of the four Chatham Rise sub-areas used in this analysis: West deep (at least 530 m deep); West shallow (less than 530 m deep); East, excluding Statistical Area 404; and Statistical Area 404.

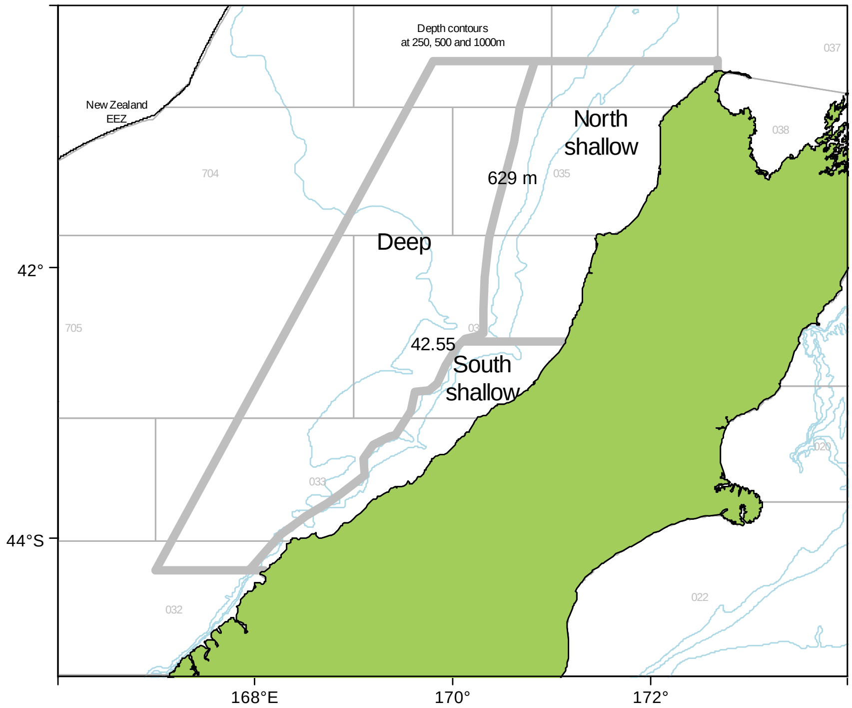


Figure 2b: Location and boundaries of the three WCSI sub-areas used in this analysis: Deep (at least 530 m deep); North shallow (less than 530 m deep, above 42.55° S); South shallow (less than 530 m deep, below 42.55° S).

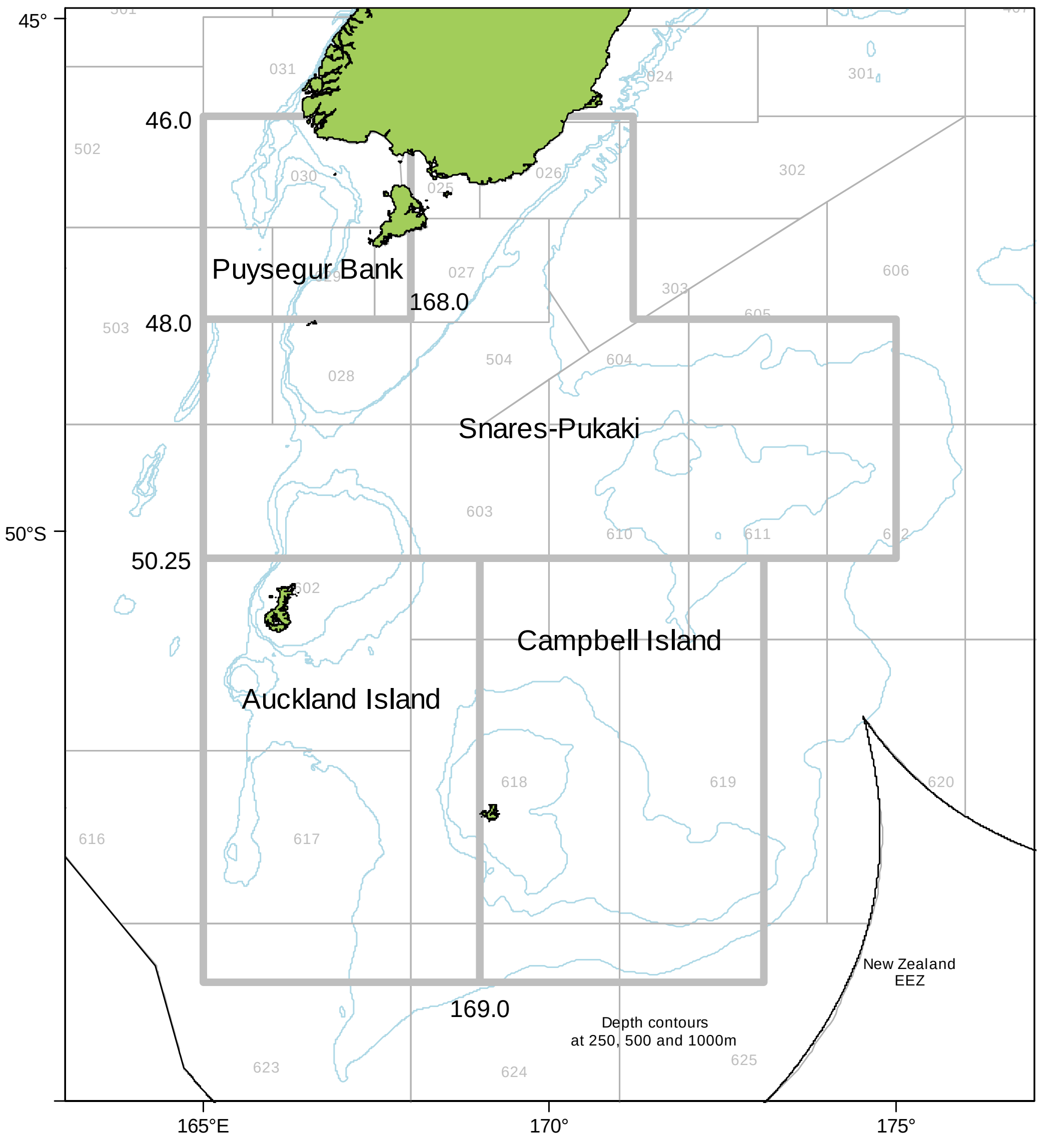


Figure 2c: Location and boundaries of the four Sub-Antarctic sub-areas used in this analysis: Puysegur Bank; Snares-Pukaki; Auckland Island; and Campbell Island.

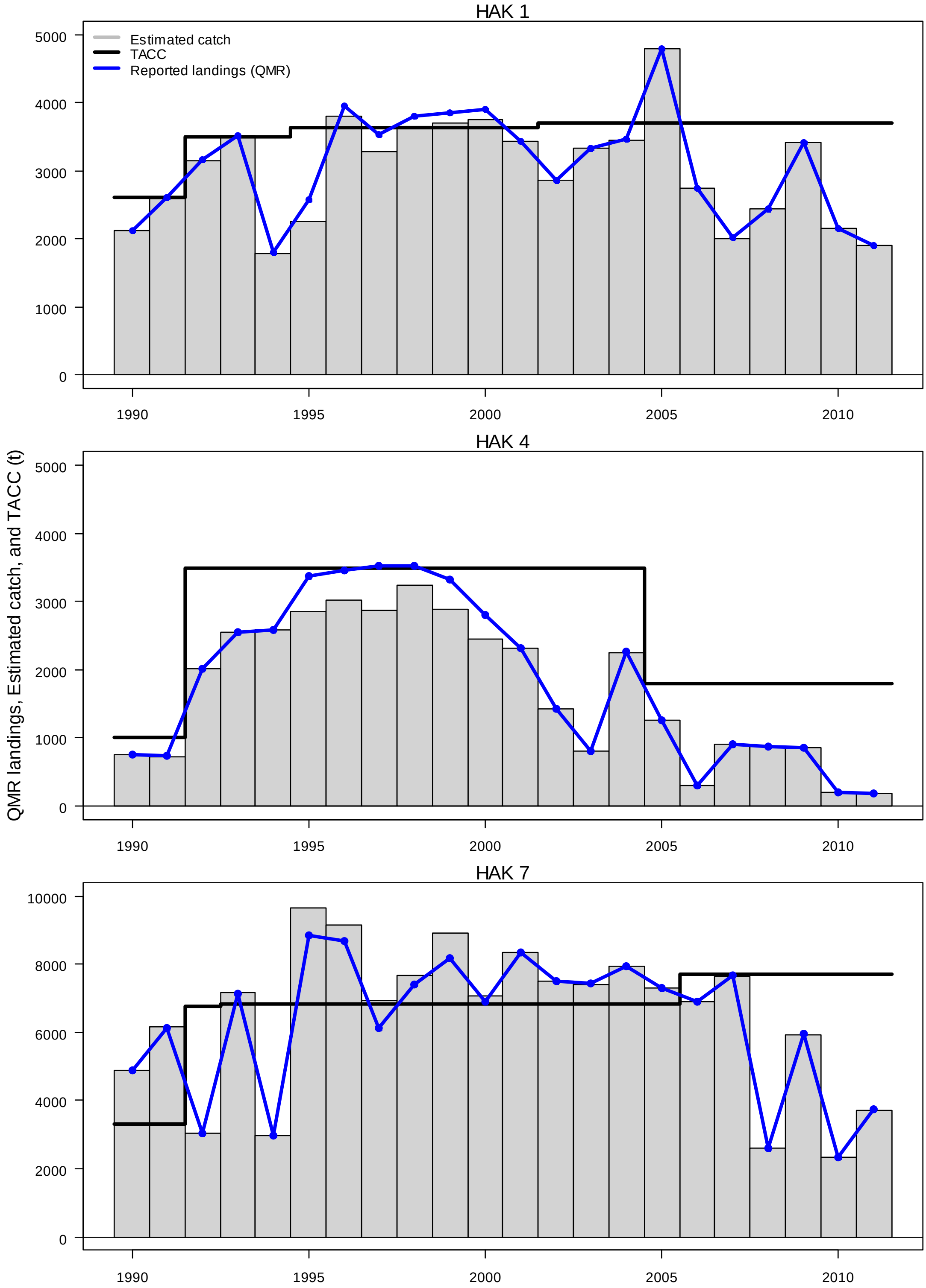
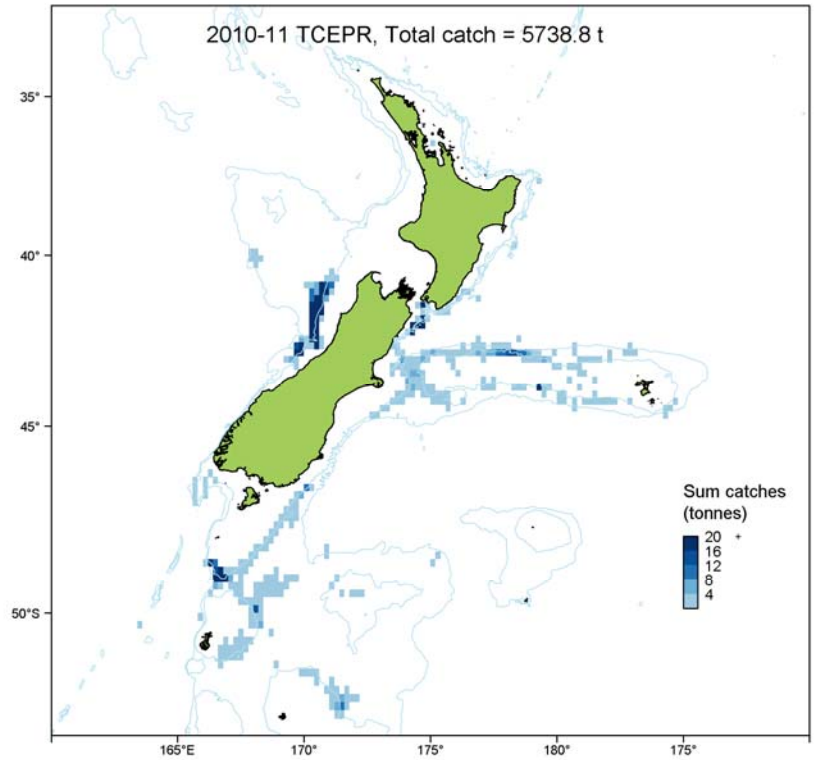


Figure 3: QMR landings (line with dots), scaled estimated catch corrected for misreporting (shaded bars), and TACC (solid line) for HAK1, HAK4, and HAK7, for the fishing years 1989–90 (1990) to 2010–11 (2011).



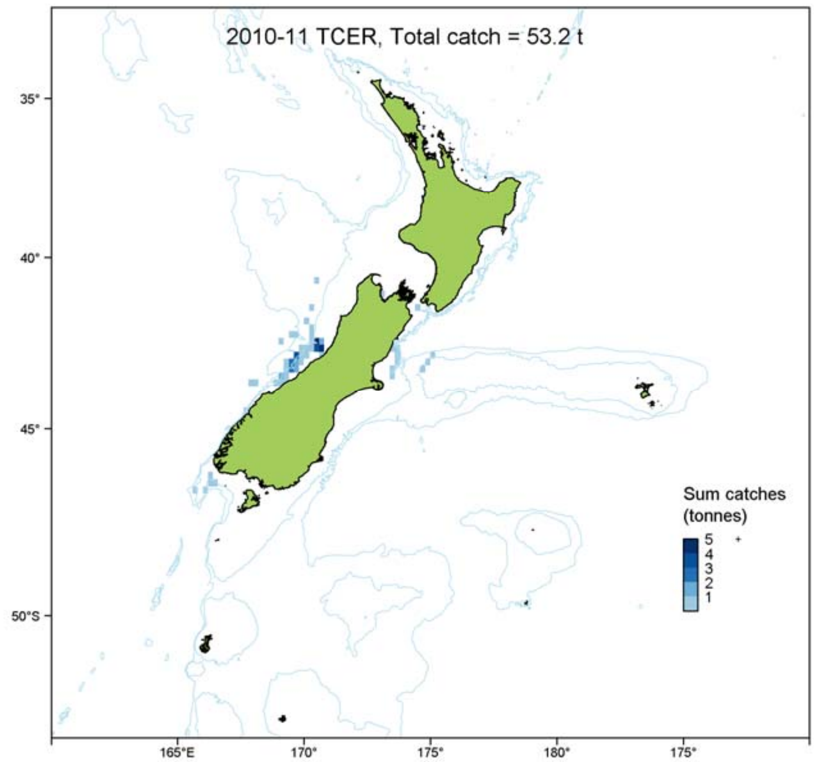


Figure 4: Density plots of all commercial TCEPR and TCER trawls where hake was caught in the 2010–11 fishing year.

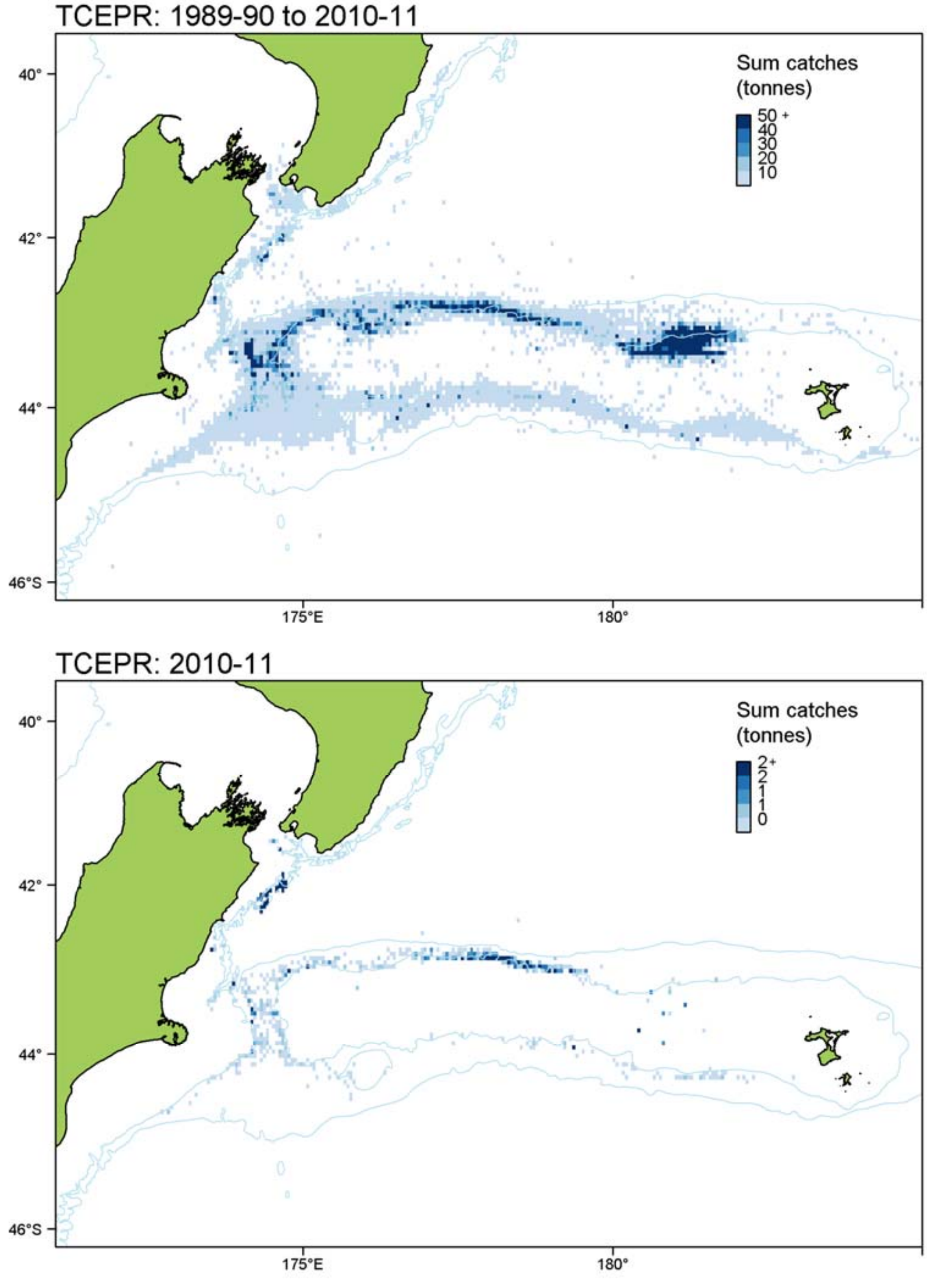


Figure 5a: Density (in tonnes) of Chatham Rise commercial hake catches from TCEPR records by fishing year (1 October to 30 September) for all fishing years combined (1989–90 to 2010–11), and for the 2010–11 fishing year.

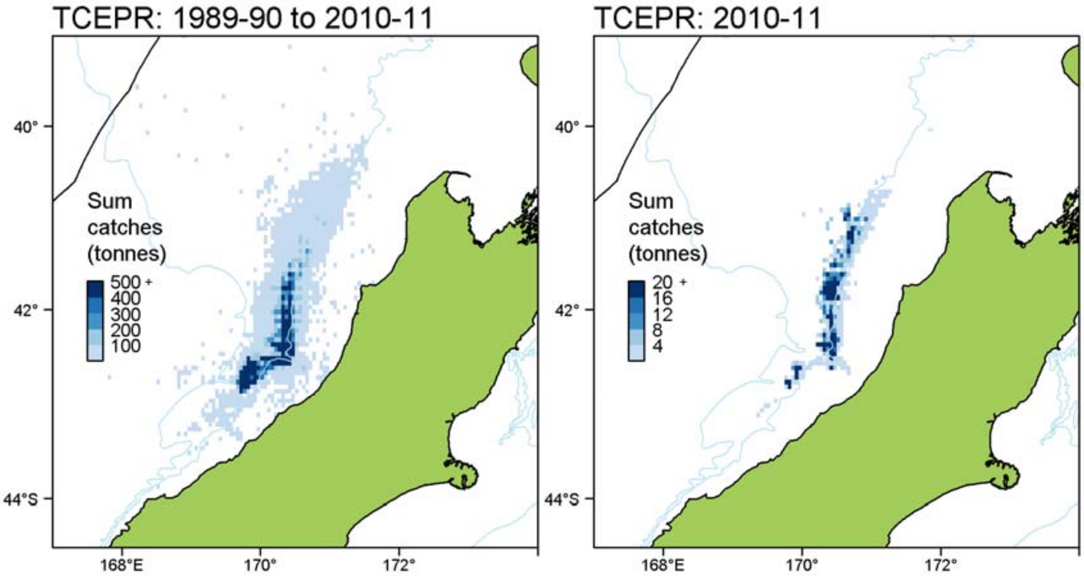


Figure 5b: Density (in tonnes) of WCSI commercial hake catches from TCEPR records by fishing year (1 October to 30 September) for all fishing years combined (1989–90 to 2010–11), and for the 2010–11 fishing year.

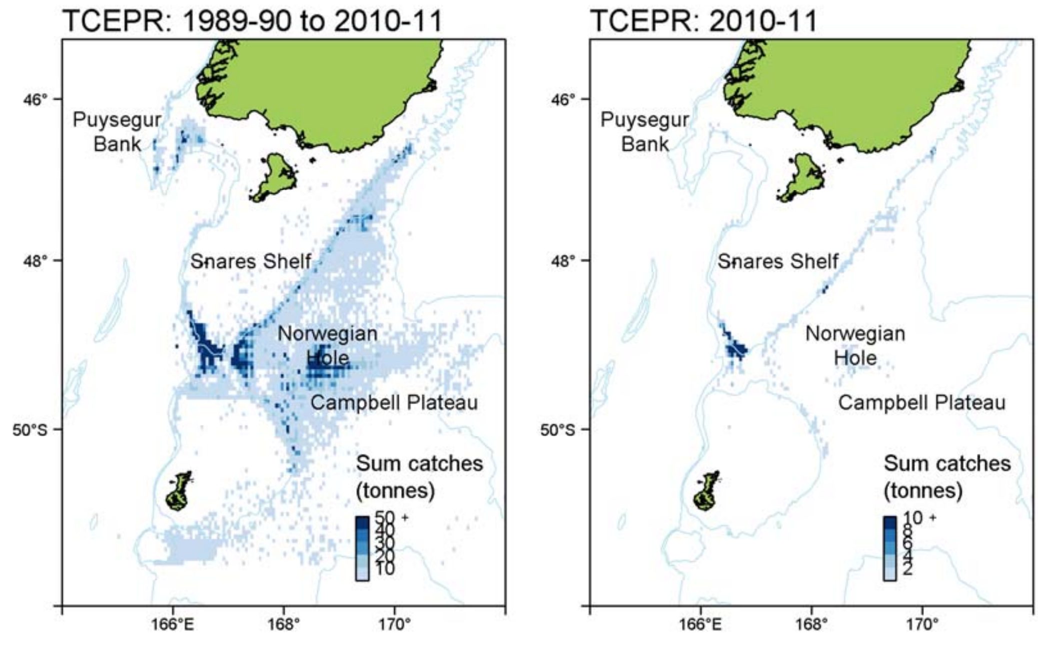


Figure 5c: Density (in tonnes) of Sub-Antarctic commercial hake catches from TCEPR estimated catch records by fishing year (1 October to 30 September) for all fishing years combined (1989–90 to 2010–11), and for the 2010–11 fishing year.

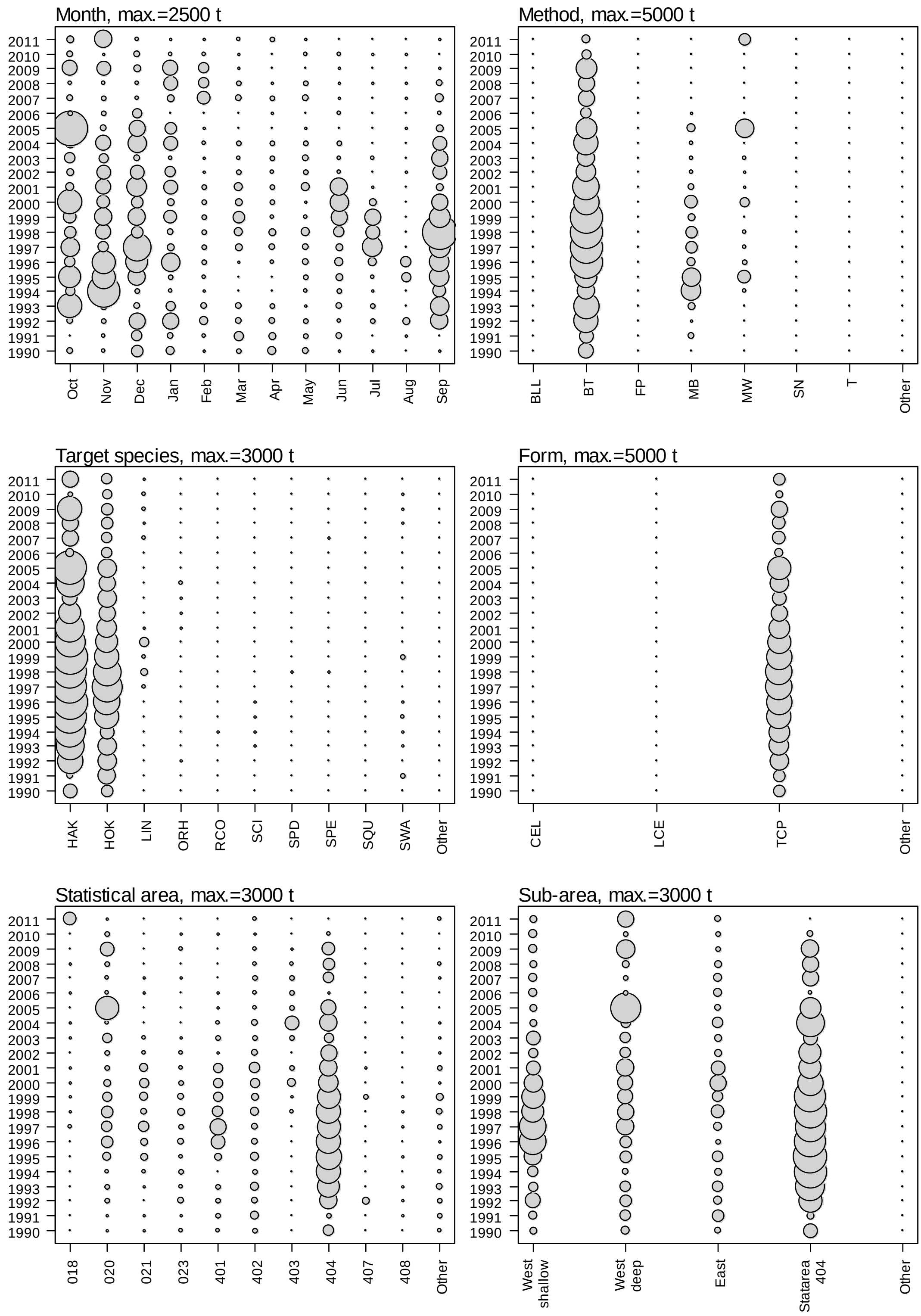


Figure 6a: Distribution of Chatham Rise TCEPR tow-by-tow hake trawl catch by month, statistical area, method, target species, and sub-area for the 1990 to 2011 calendar years. Circle size is proportional to catch; maximum circle size is indicated on the top of each plot. Statistical areas and sub-areas are defined in Figure 2. Form types: CEL is Catch, Effort, Landing Return; LCE is Lining Catch Effort Return; TCP is Trawl, Catch, Effort, and Processing Return. Method definitions: BLL, bottom longlining; BT, bottom trawl; MB, midwater trawl within 5 m of the bottom; FP, fish traps; MW, midwater trawl; SN, set net; T, trolling; Species codes: HAK, hake; HOK, hoki; LIN, ling; ORH: orange roughy; RCO, red cod; SCI, scampi; SPD, spiny dogfish; SPE, sea perch; SQU, arrow squid; SWA, silver warehou.

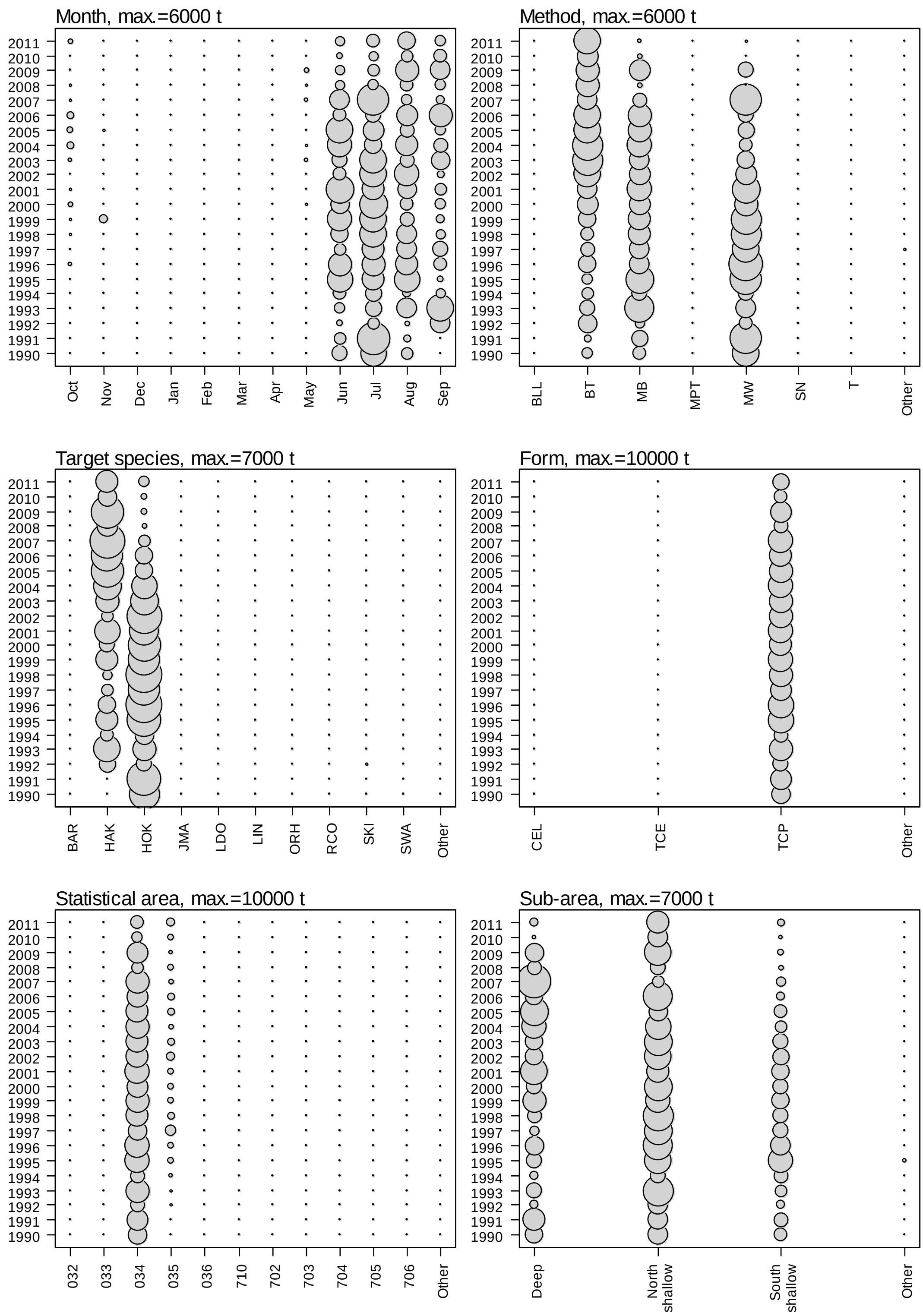


Figure 6b: Distribution of WCSI TCEPR tow-by-tow hake trawl catch by month, statistical area, method, target species, and sub-area for the 1990 to 2011 calendar years. Circle size is proportional to catch; maximum circle size is indicated on the top of each plot. Statistical areas and sub-areas are defined in Figure 2. Form types: CEL is Catch, Effort, Landing Return; TCE is Trawl, Catch, Effort Return; TCP is Trawl, Catch, Effort, and Processing Return. Method definitions: BLL, bottom longlining; BT, bottom trawl; MB, midwater trawl within 5 m of the bottom; MPT: midwater pair trawl; MW, midwater trawl; SN, set net; T, trolling. Species codes: BAR, barracouta; HAK, hake; HOK, hoki; JMA, jack mackerels; LDO: lookdown dory; LIN, ling; ORH, orange roughy; RCO, red cod; SKI, gemfish; SWA, silver warehou.

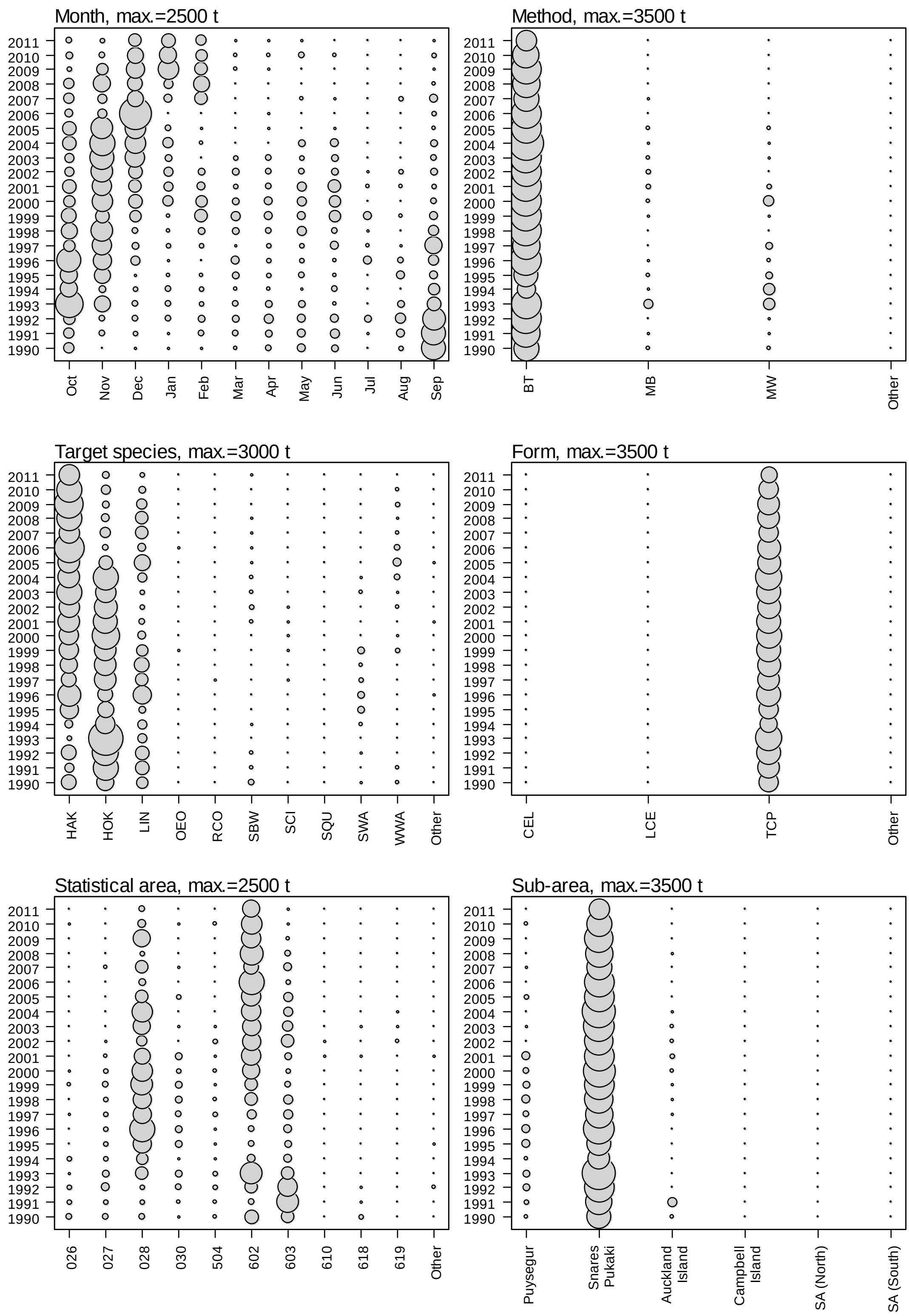


Figure 6c: Distribution of Sub-Antarctic TCEPR tow-by-tow hake trawl catch by month, statistical area, method, target species, and sub-area for the 1990 to 2011 calendar years. Circle size is proportional to catch; maximum circle size is indicated on the top of each plot. Statistical areas and sub-areas are defined in Figure 2. Form types: CEL is Catch, Effort, Landing Return; LCE is Lining Catch Effort Return; TCP is Trawl, Catch, Effort, and Processing Return. Method definitions: BT, bottom trawl; MB, midwater trawl within 5 m of the bottom; MW, midwater trawl. Species codes: HAK, hake; HOK, hoki; LIN, ling; OEO, Oreos (black, smooth, and spiky); RCO, red cod; SBW, southern blue whiting; SCI, scampi; SQU, arrow squid; SWA, silver warehou; WWA, white warehou.

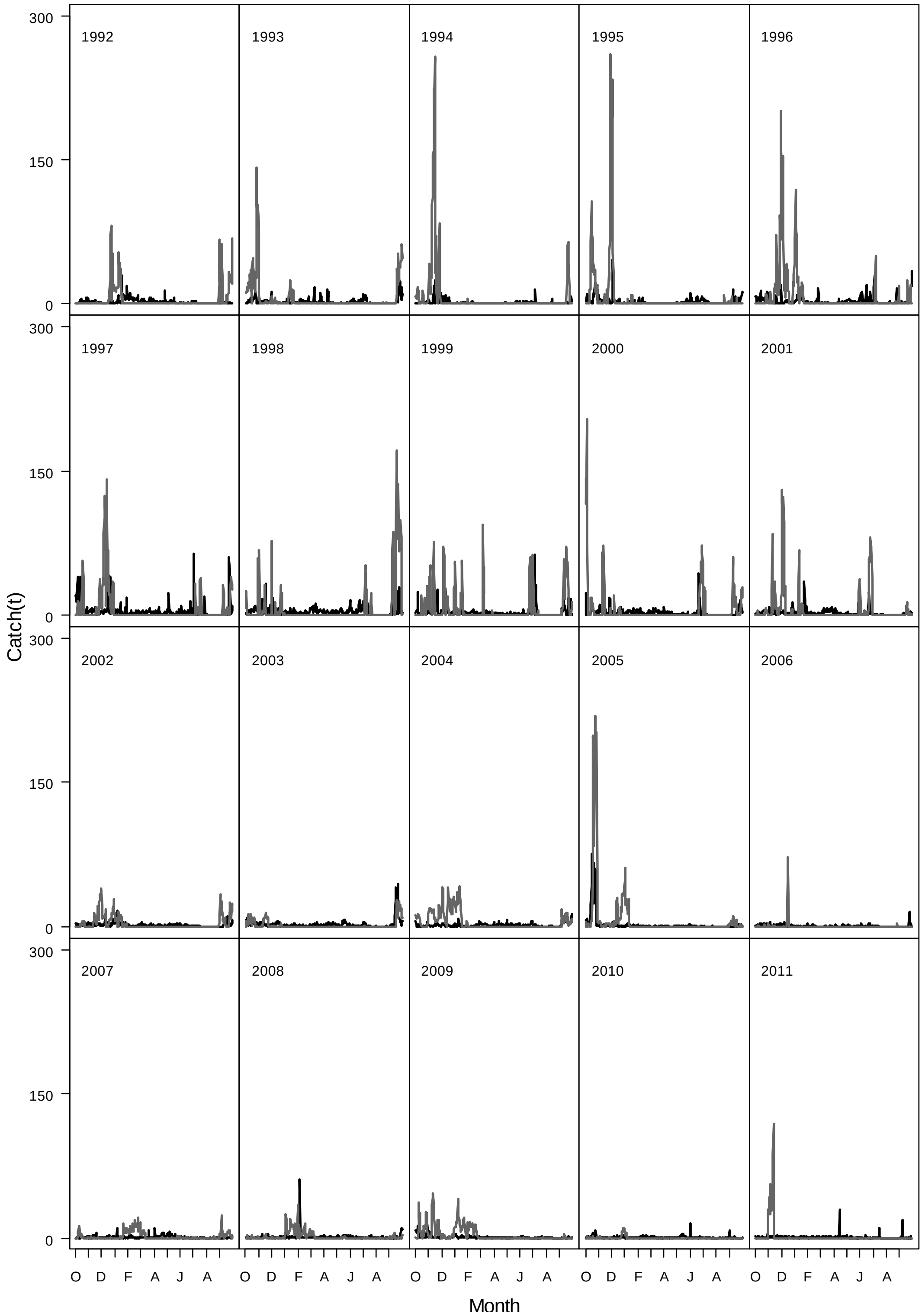


Figure 7a: Chatham Rise daily catch by fishing year 1991–91 (1992) to 2010–11 (2011). Grey lines are hake catches from target hake tows; black lines are hake catches from target hoki tows.

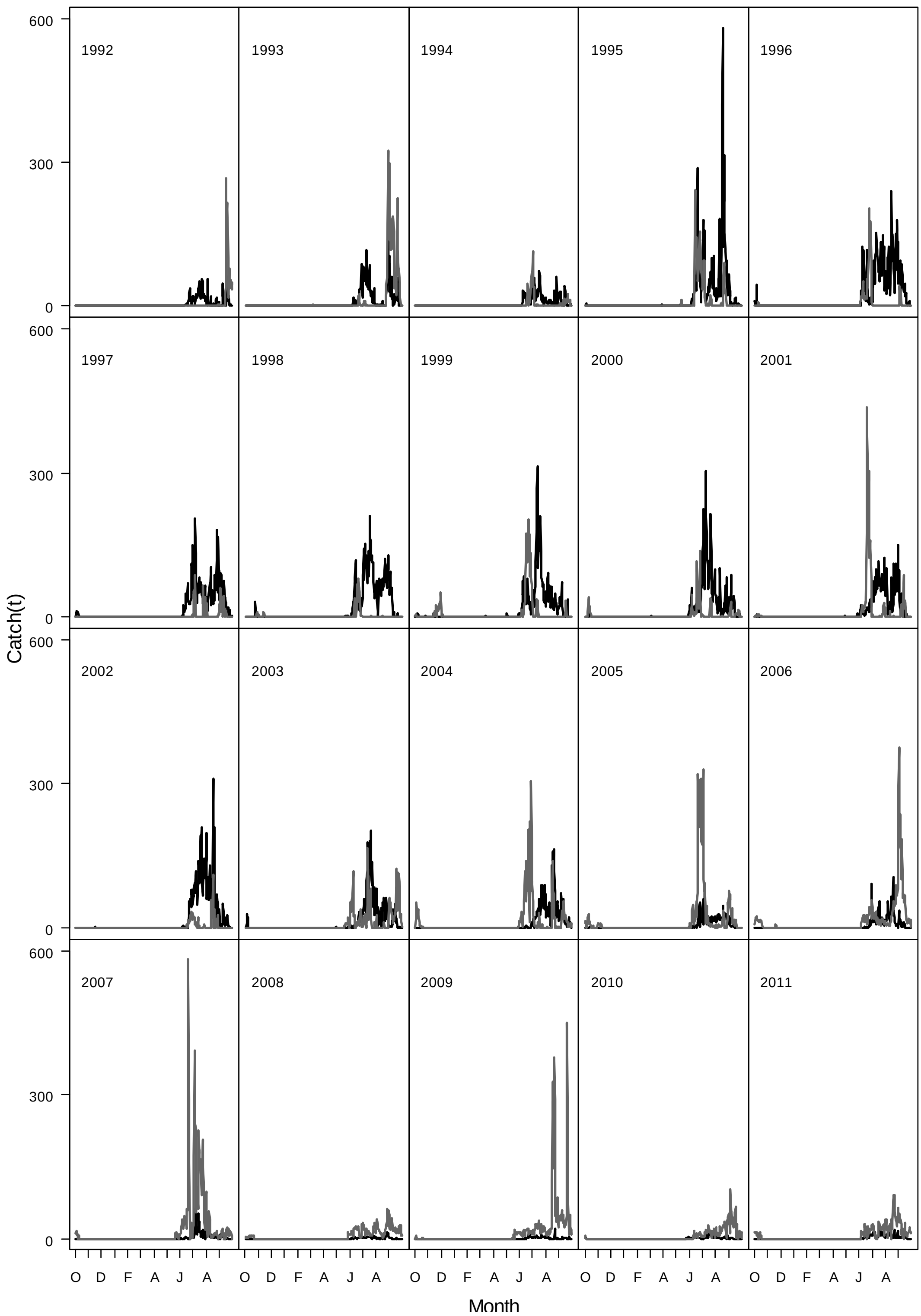


Figure 7b: Daily WCSI hake catch by fishing year 1991–91 (1992) to 2010–11 (2011). Grey lines are hake catches from target hake tows; black lines are hake catches from target hoki tows.

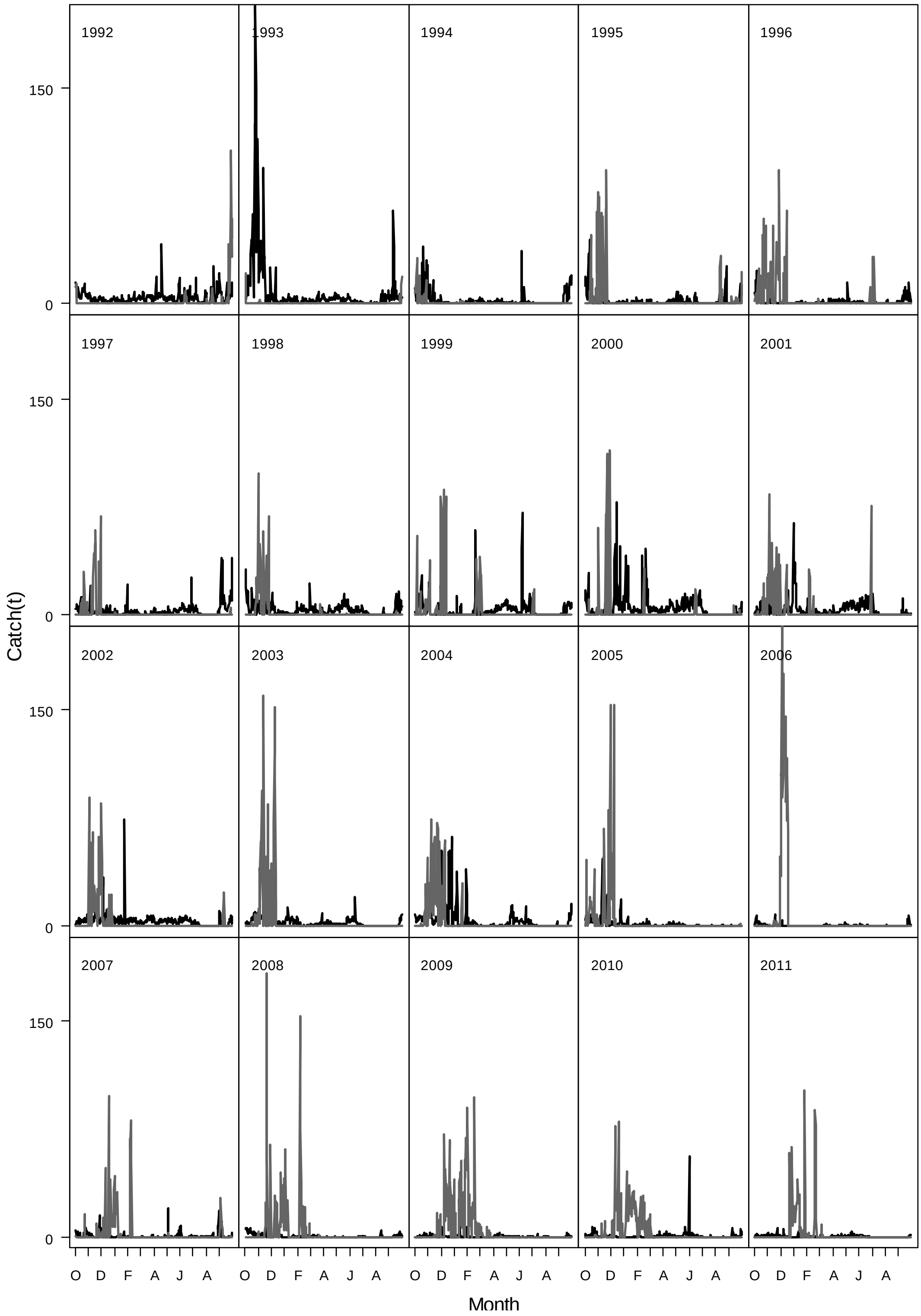


Figure 7c: Daily Sub-Antarctic catch by fishing year 1991–91 (1992) to 2010–11 (2011). Grey lines are hake catches from target hake tows; black lines are hake catches from target hoki tows.

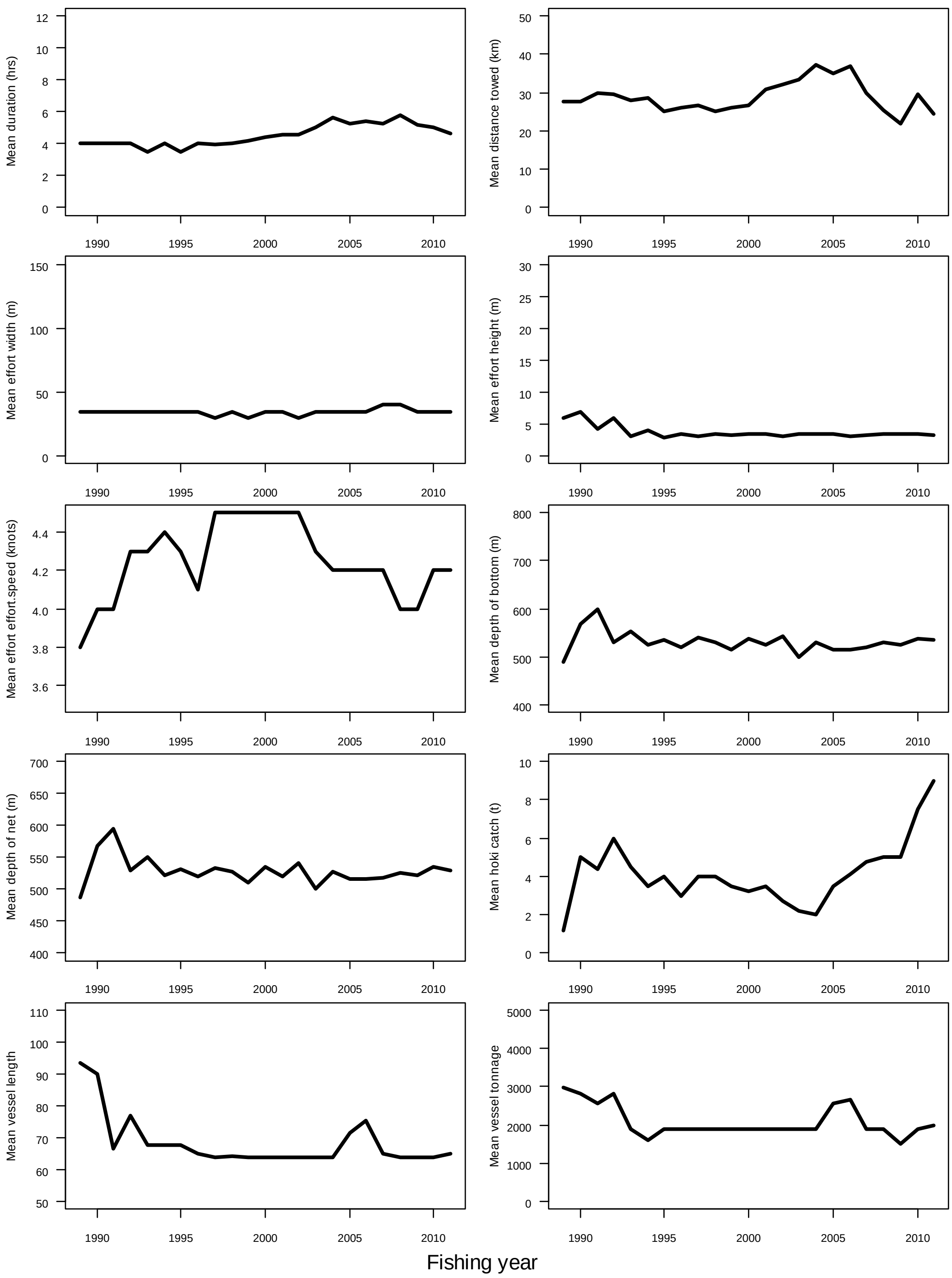


Figure 8a: Means of effort variables by fishing year for Chatham Rise vessels using bottom trawl targeting hake or hoki.

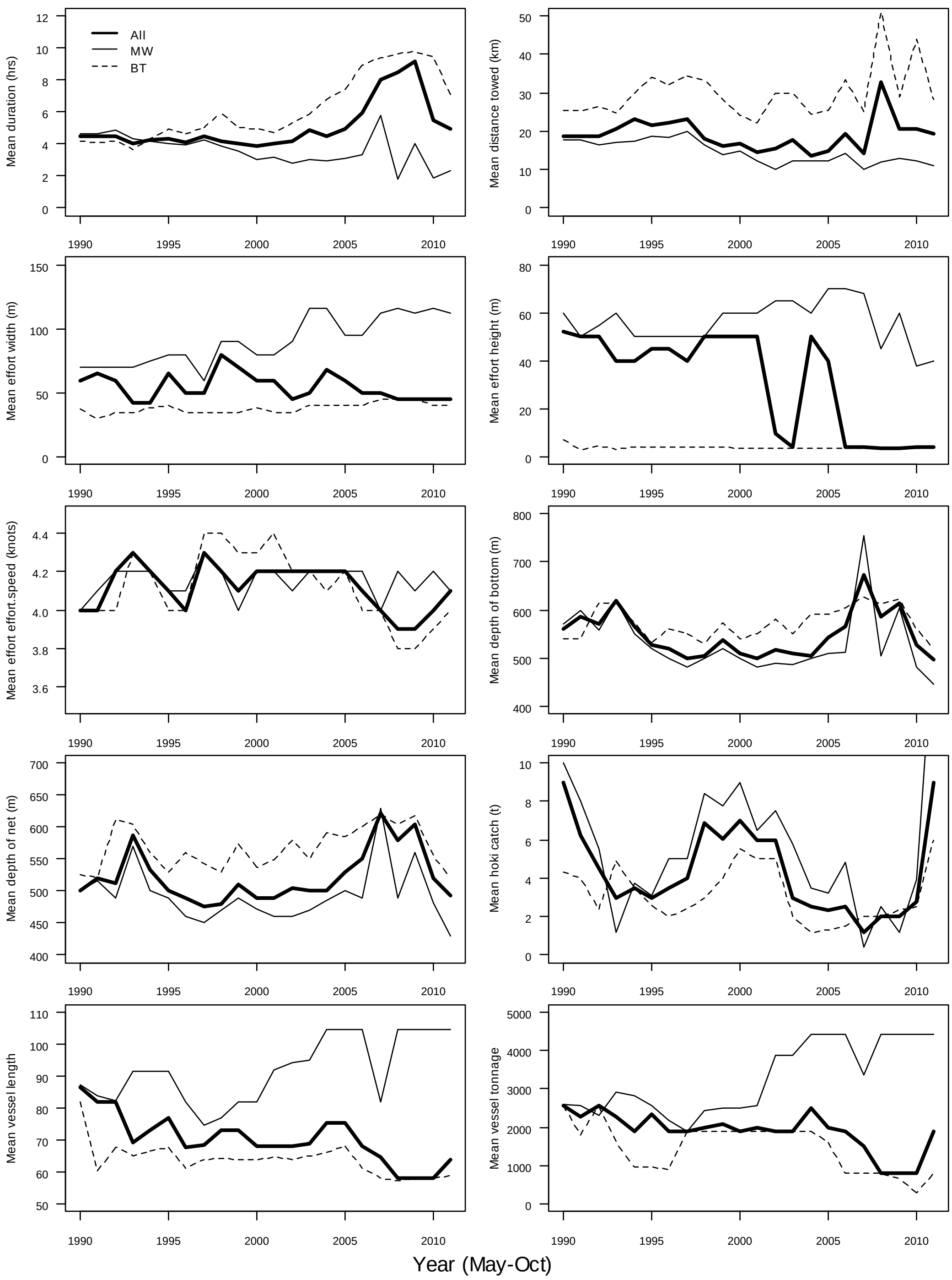


Figure 8b: Means of effort variables by year for WCSI vessels targeting hake or hoki, for all tows (All), bottom tows (BT), and midwater tows (MW).

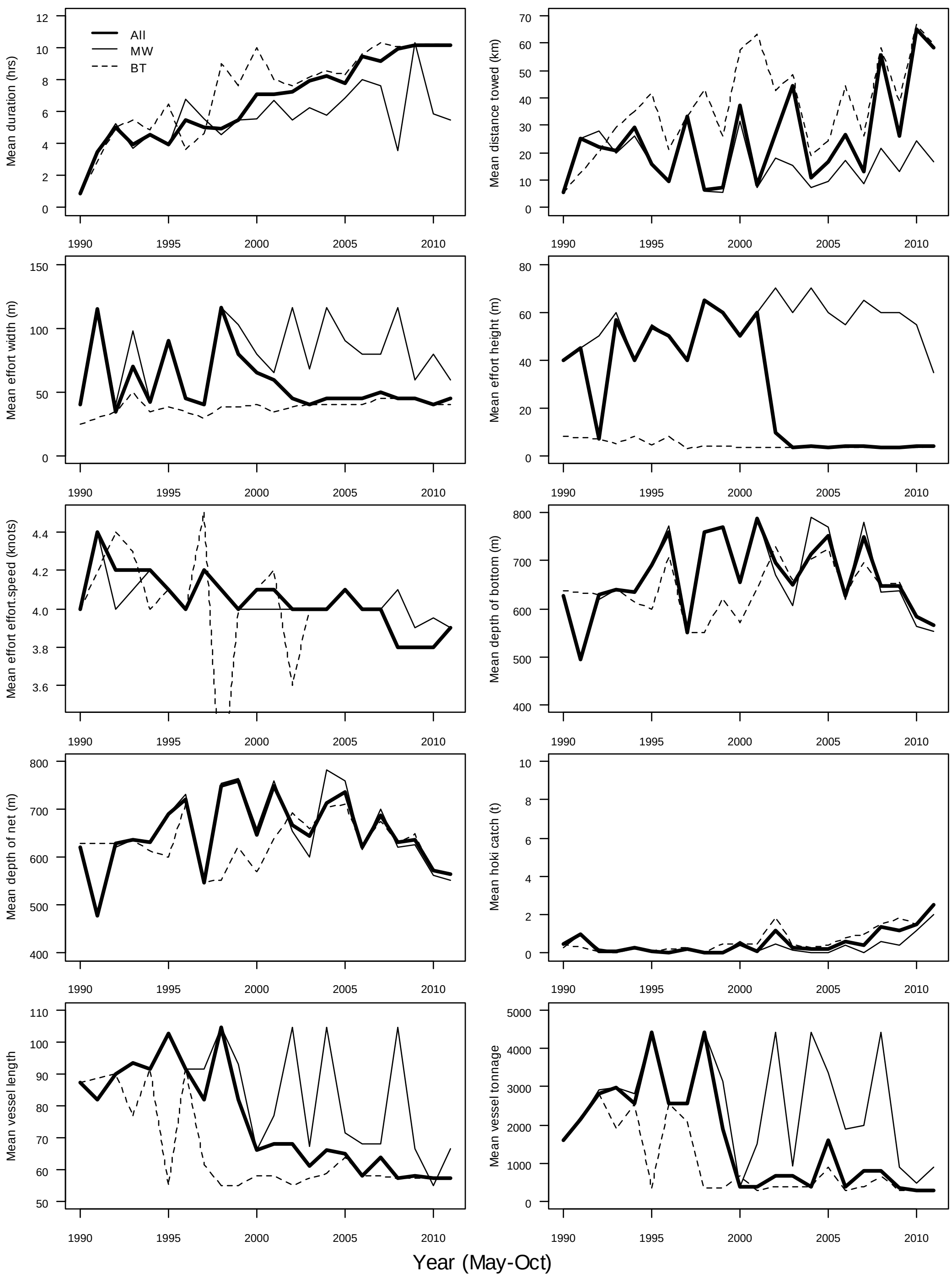


Figure 8c: Means of effort variables by year for WCSI vessels targeting hake, for all tows (All), bottom tows (BT), and midwater tows (MW).

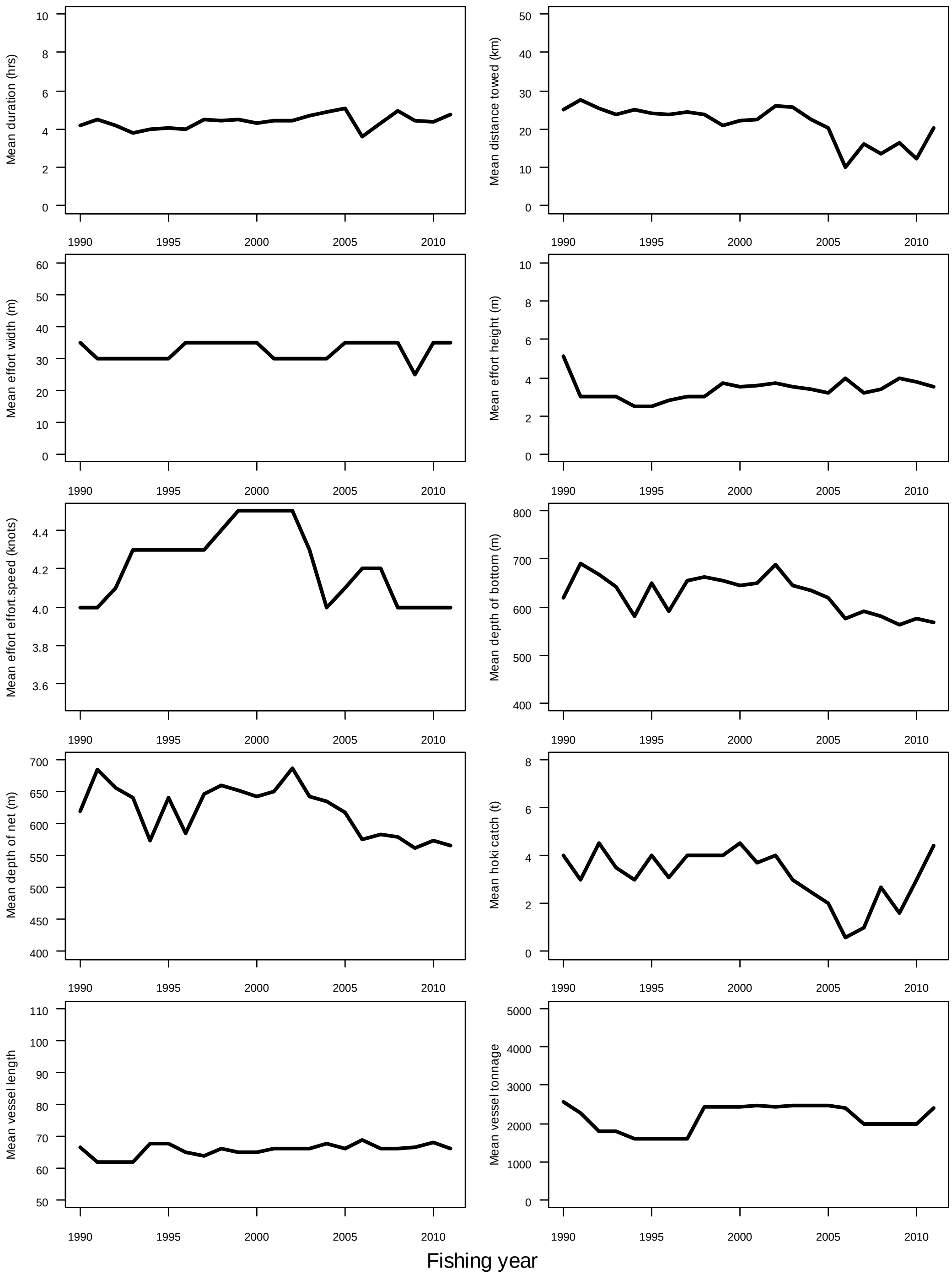


Figure 8d: Means of effort variables by fishing year for Sub-Antarctic vessels using bottom trawl targeting hake or hoki.

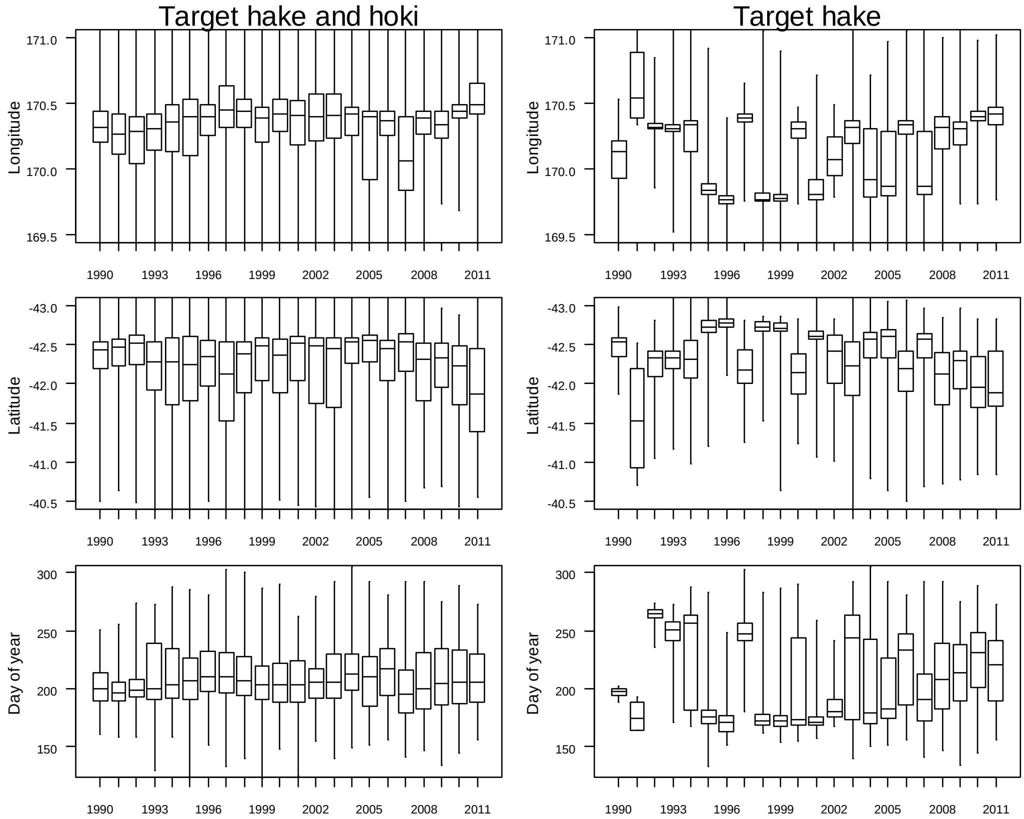


Figure 9: Box and whisker plots of longitude, latitude, and day of year for WCSI vessels targeting hake or hoki, or targeting hake only. The plots show medians and lower and upper quartiles in the box, and whiskers extending up to 1.5 times the interquartile range.

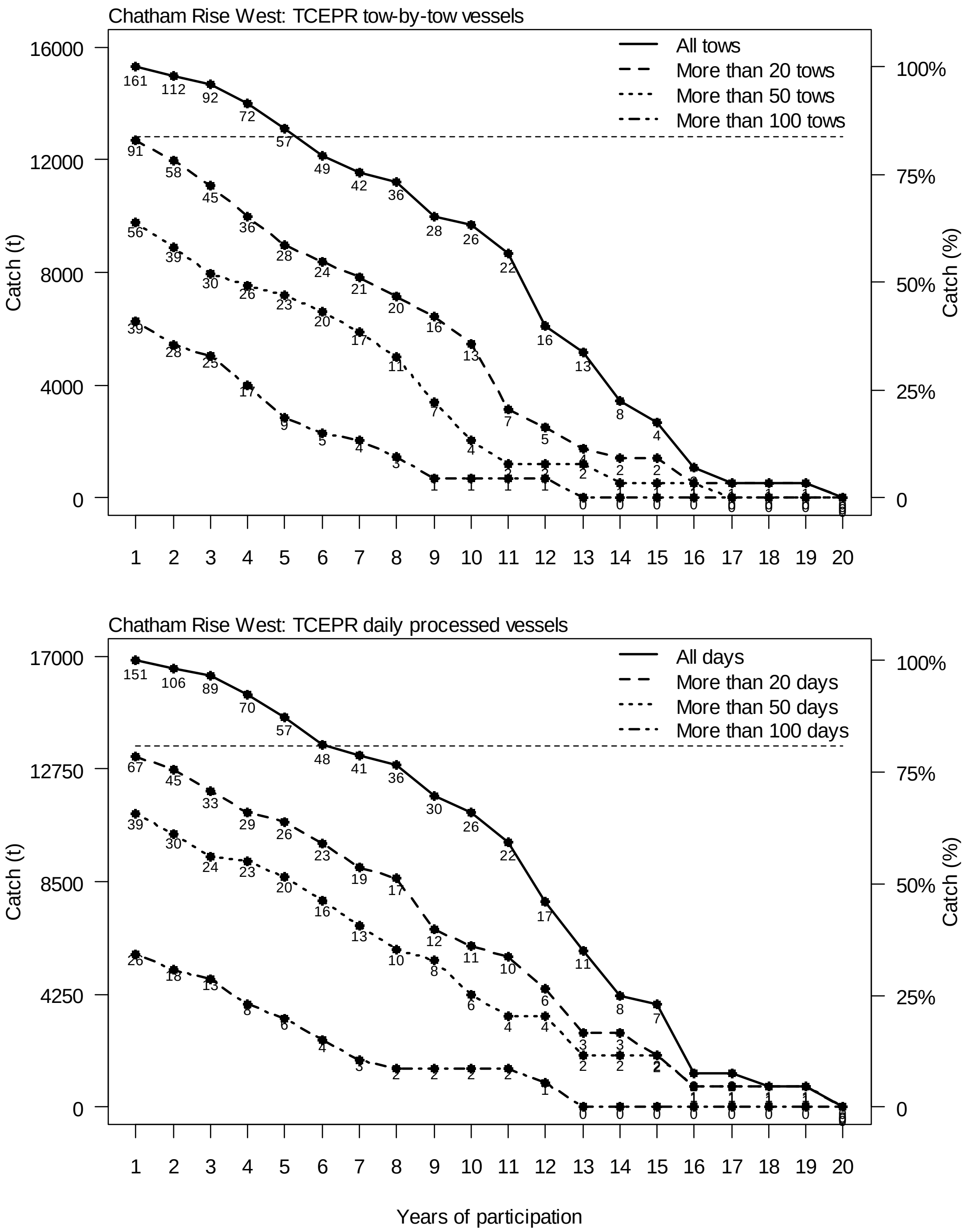


Figure 10: Relationship between the number of years of vessel participation and total hake catch by those vessels for the trawl hoki and hake target fisheries by area. The number under each circle indicates the number of vessels with the corresponding number of years of participation. The dotted horizontal line represents 80% of the catch.

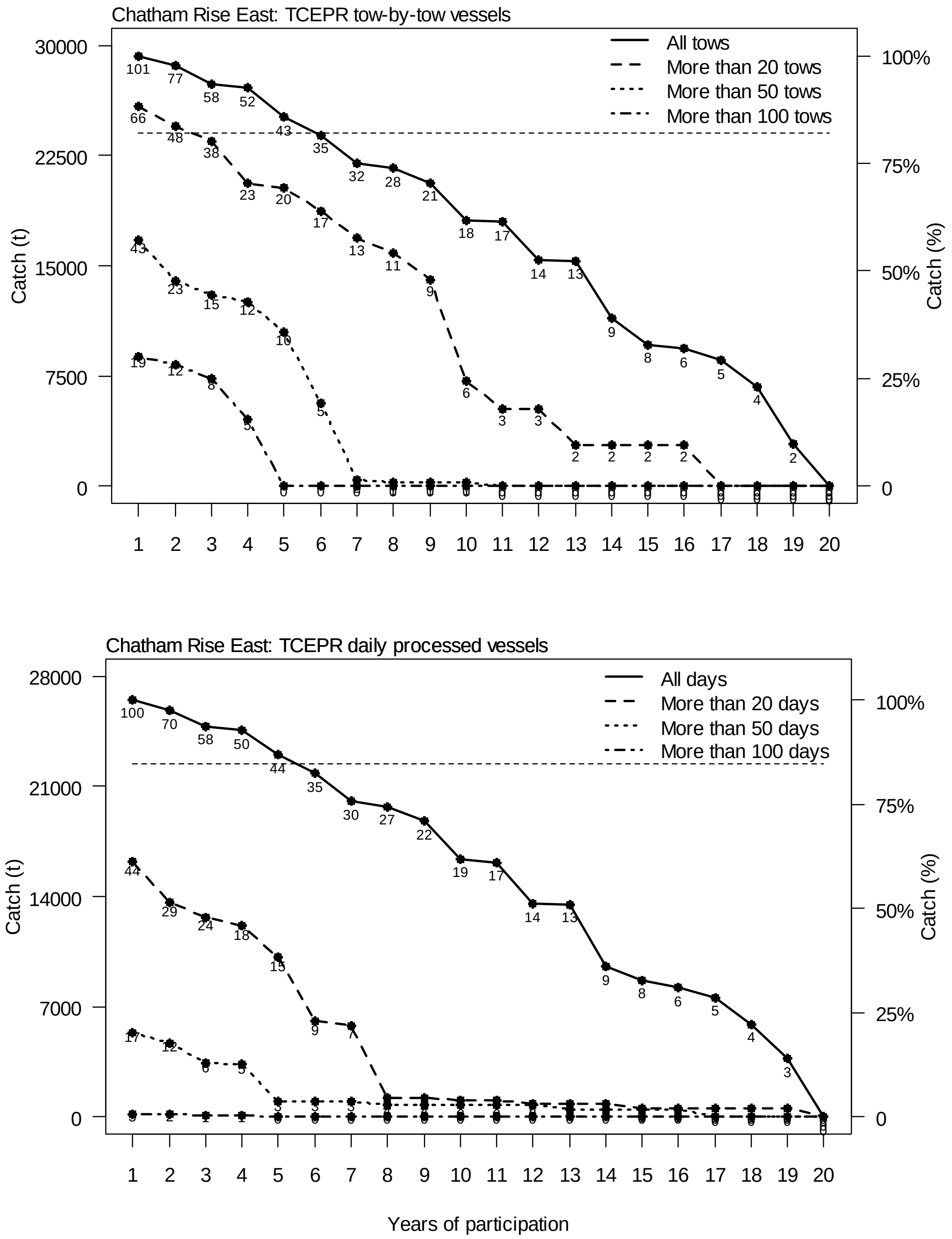


Figure 10 continued.

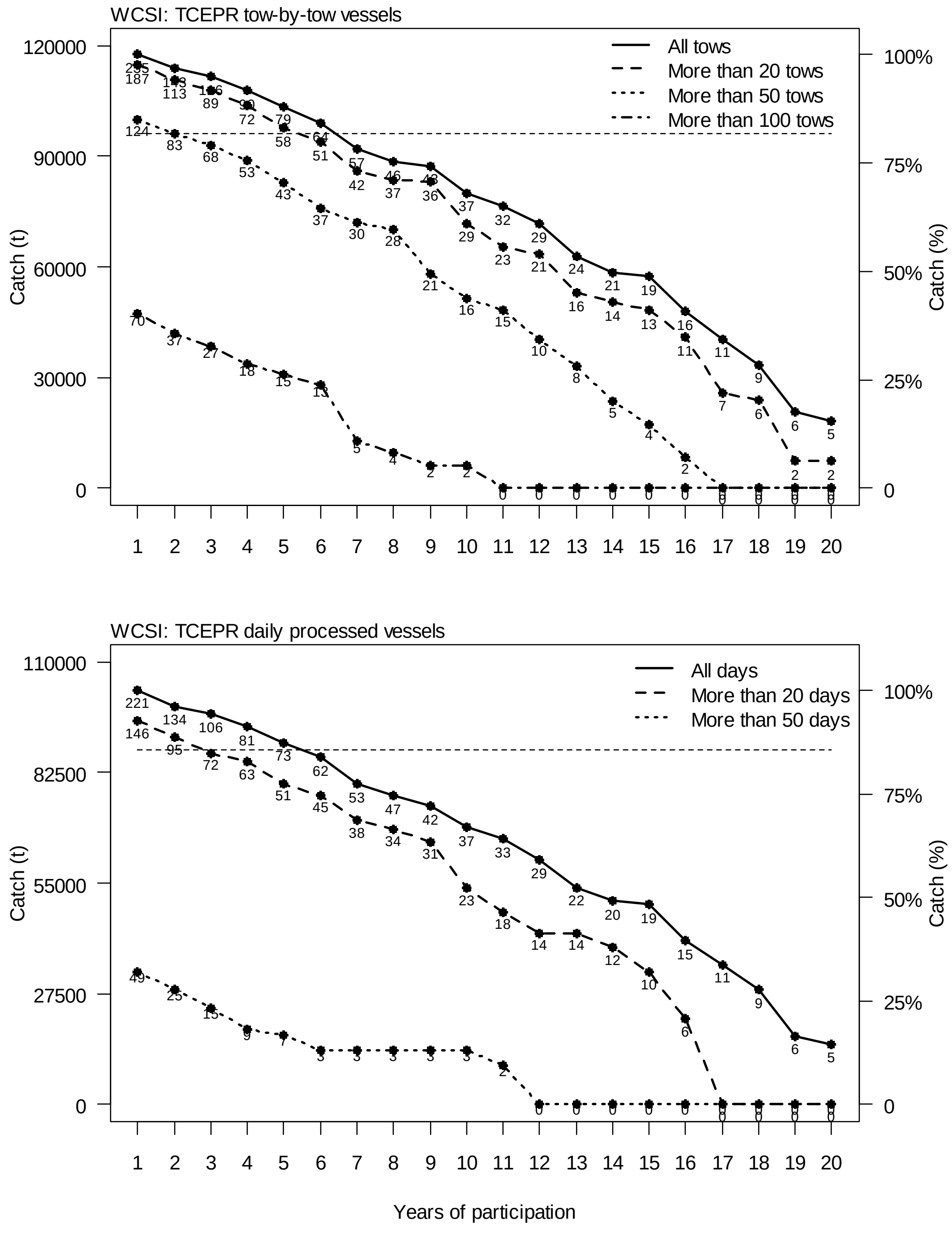


Figure 10 continued.

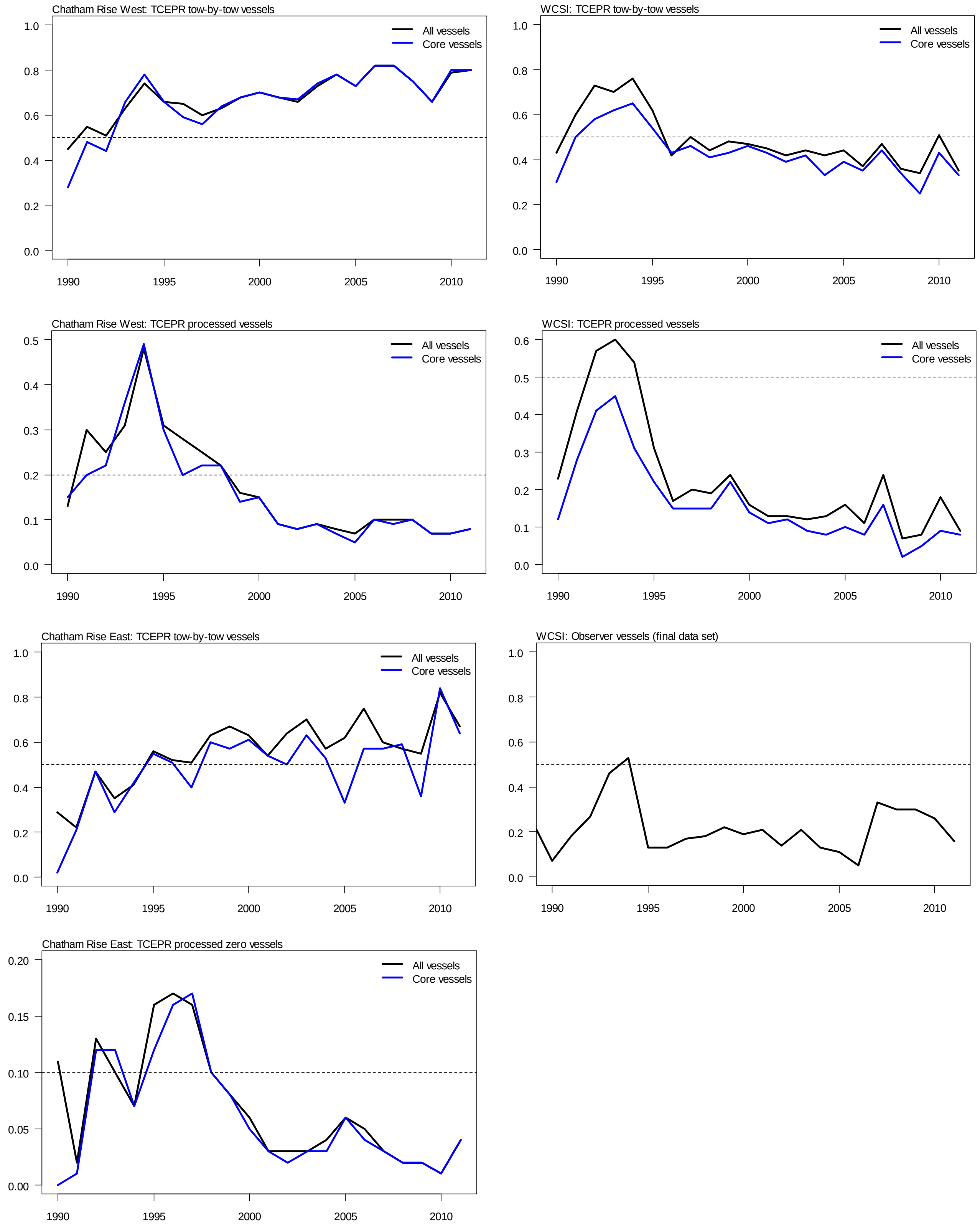


Figure 11: Proportion of zeros for all vessels and core vessels for TCEPR data and for final observed vessels by year. Year is defined as September–August for Chatham Rise data, and June–September for WCSI data.

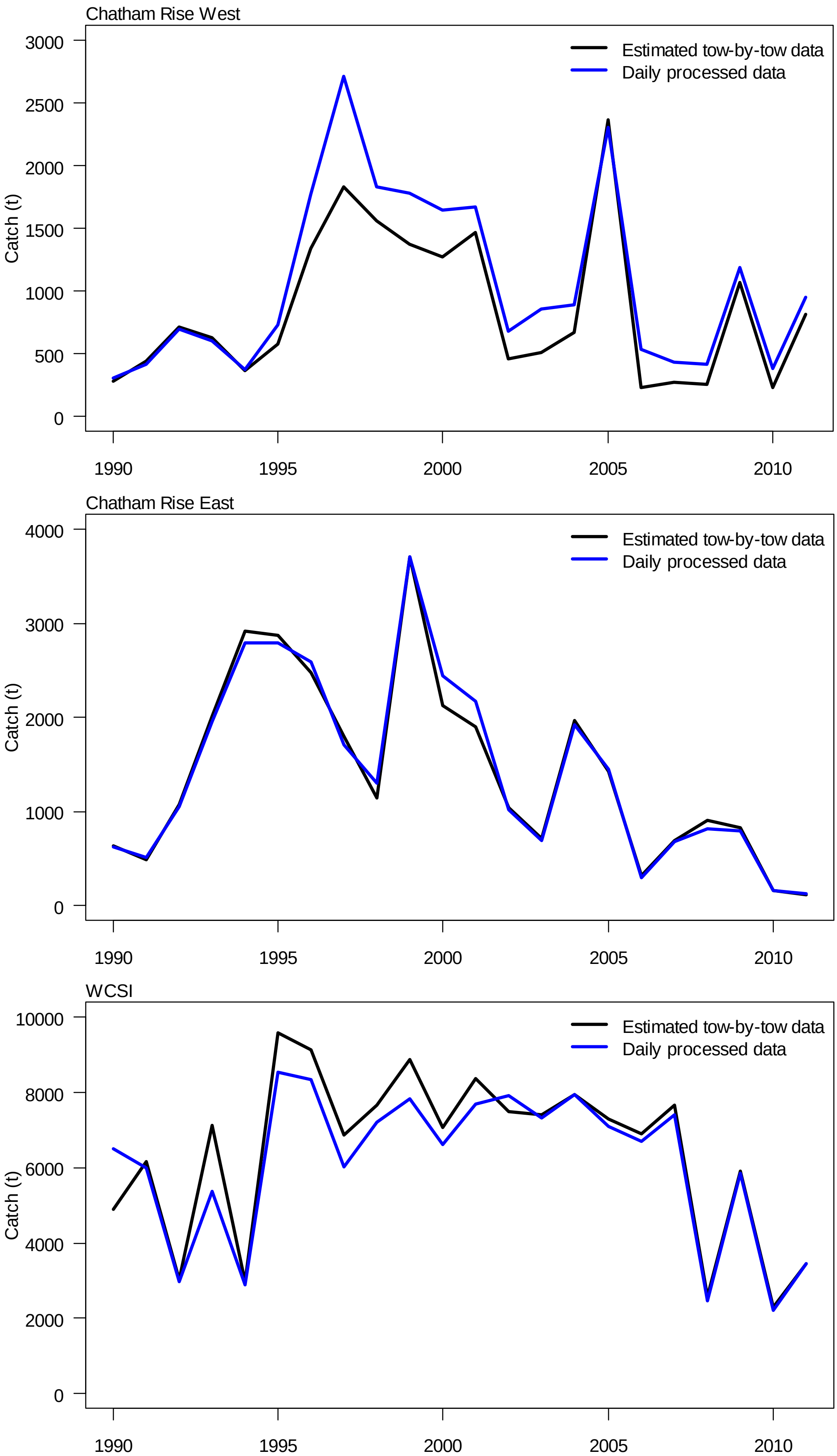
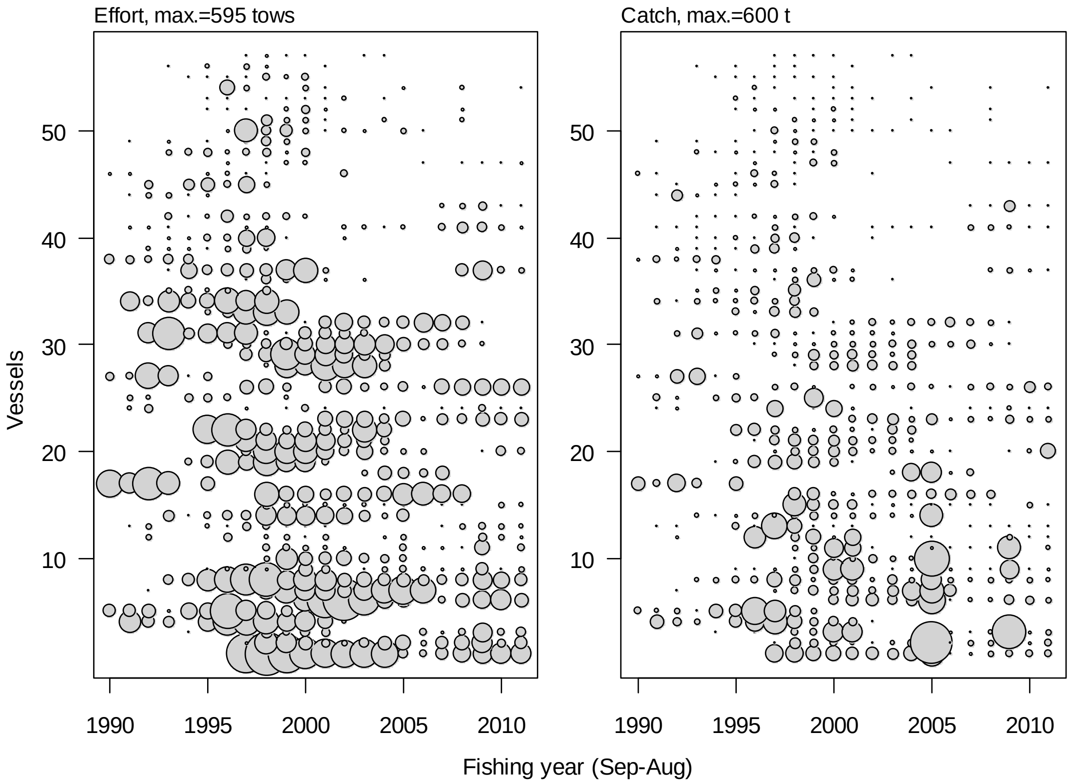


Figure 12: Estimated and daily processed catch totals by year.
(a) Chatham Rise West: TCEPR tow-by-tow core vessel data



(b) Chatham Rise East: TCEPR tow-by-tow core vessel data

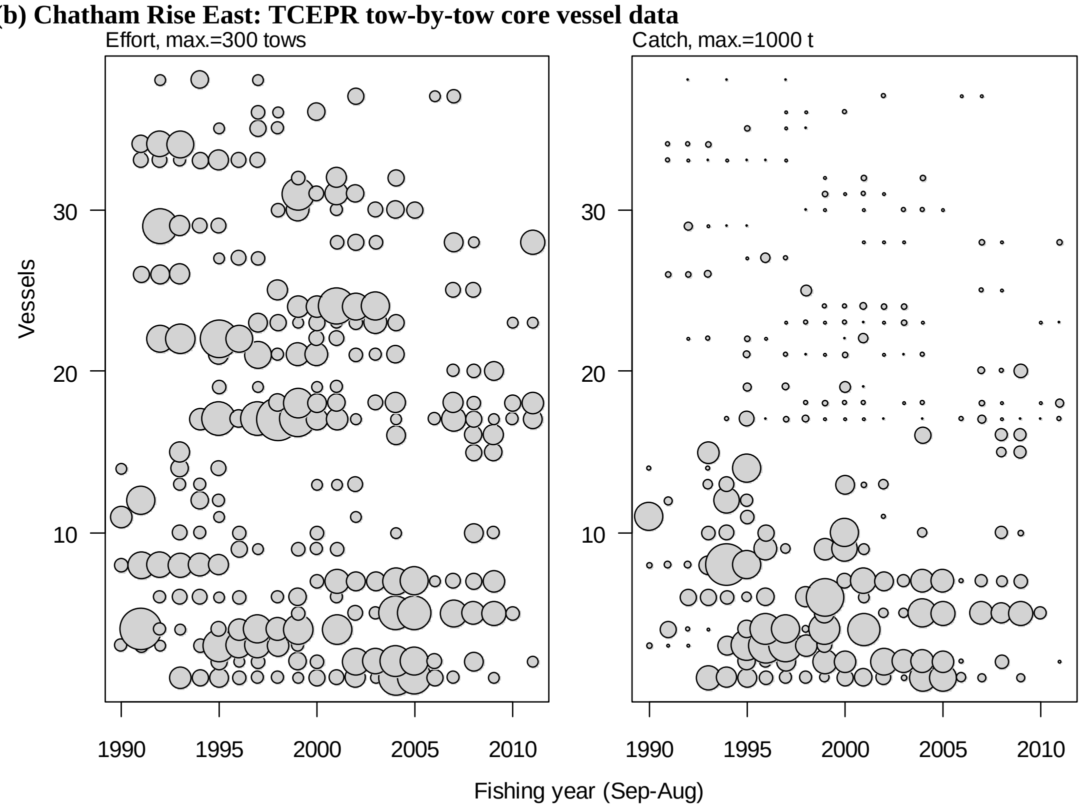
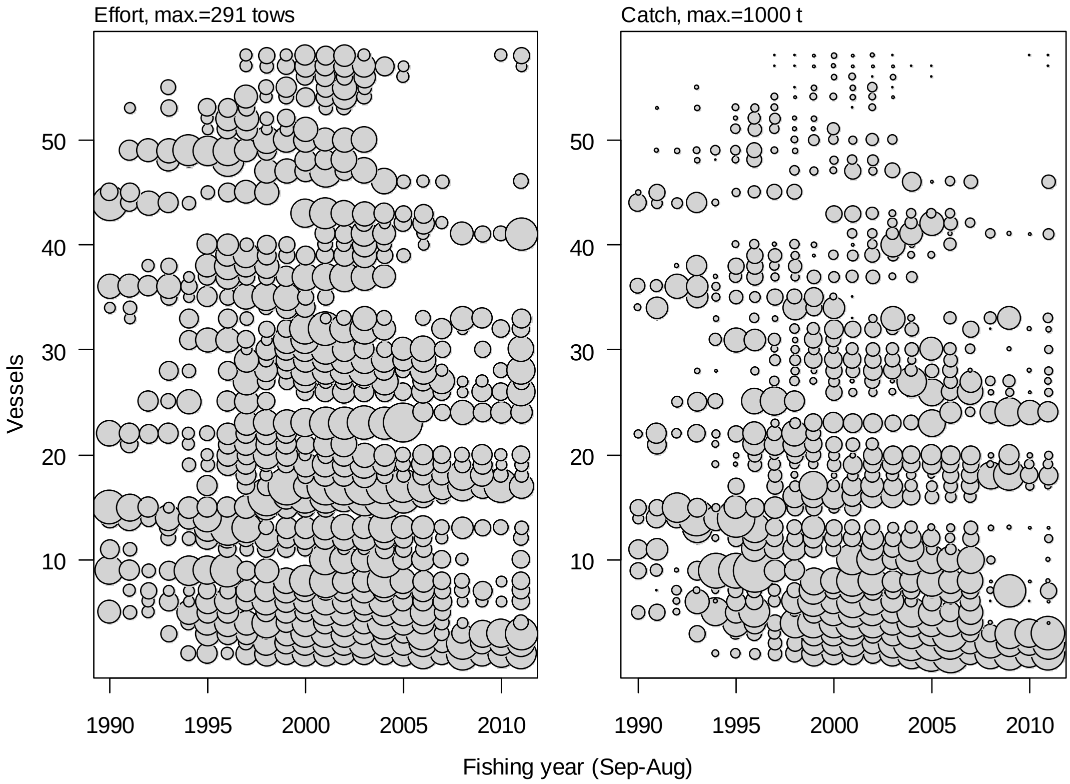


Figure 13: Trawl fishing effort and catches (where circle area is proportional to the effort or catch) by year for individual vessels (denoted anonymously by number on the *y*-axis) in final CPUE analyses for Chatham Rise West, Chatham Rise East, and WCSI.

(c) WCSI: TCEPR tow-by-tow core vessel data



(d) WCSI: Observer tow-by-tow core vessel data

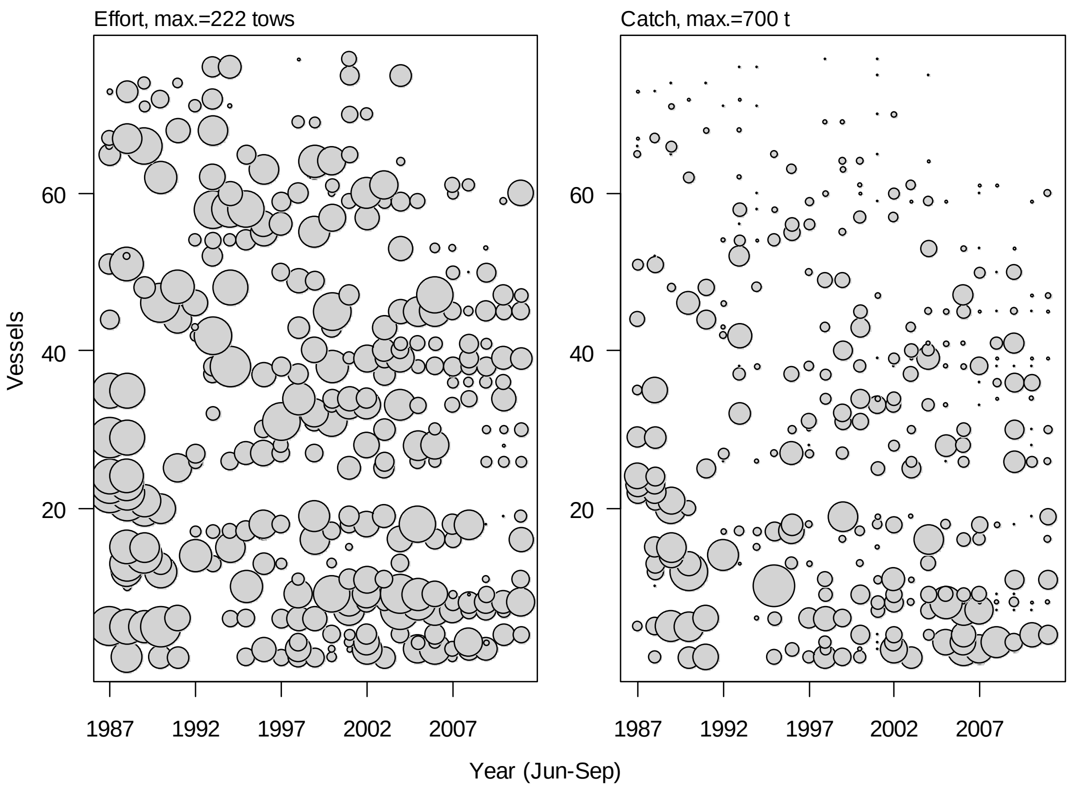


Figure 13 continued.

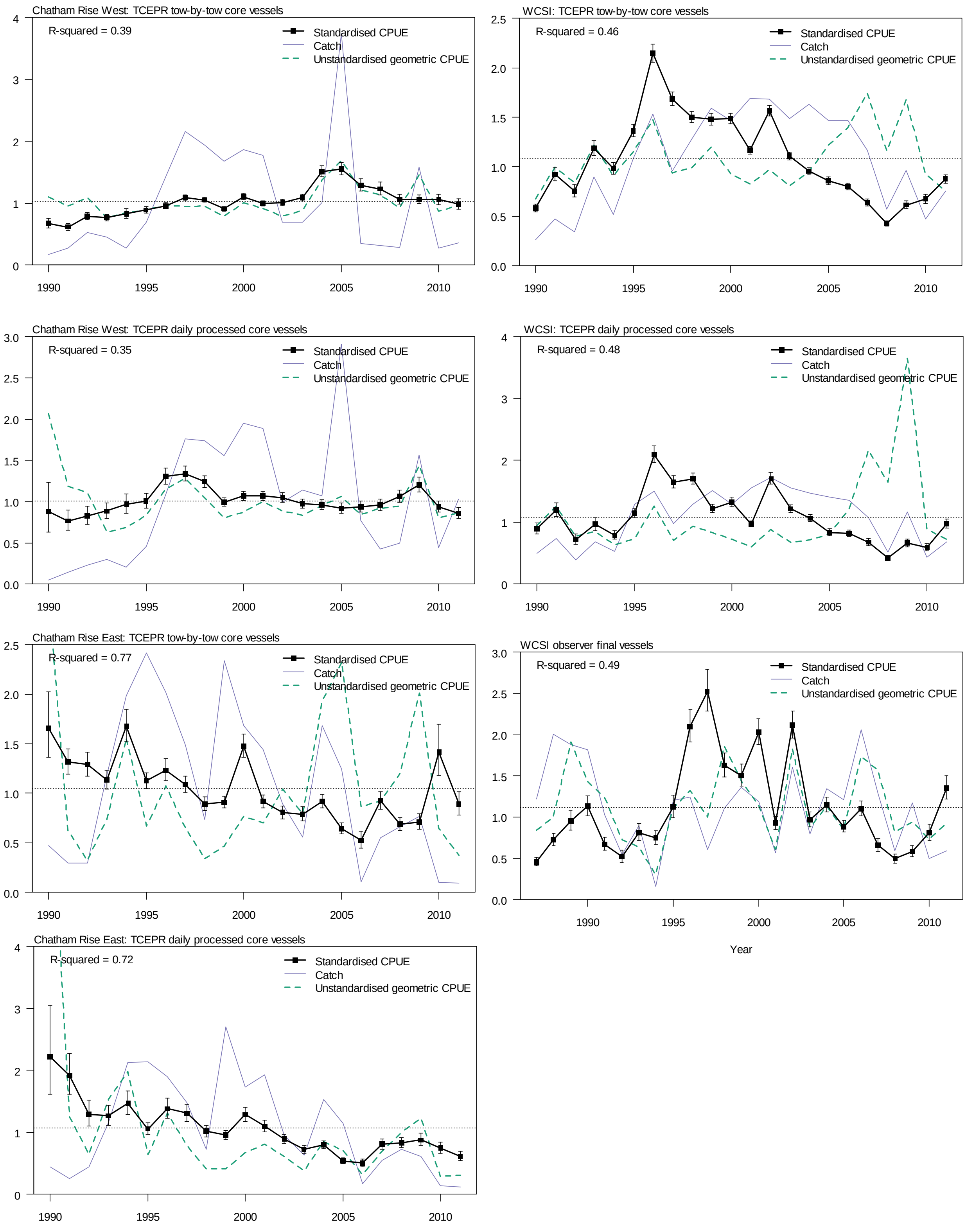


Figure 14: Standardised CPUE indices from the lognormal model for each fishery, 1990–2011 for TCEPR data and 1987–2011 for observer data. Bars indicate 95% confidence intervals. Year defined as September–August for the Chatham Rise data, and June–September for WCSI data.

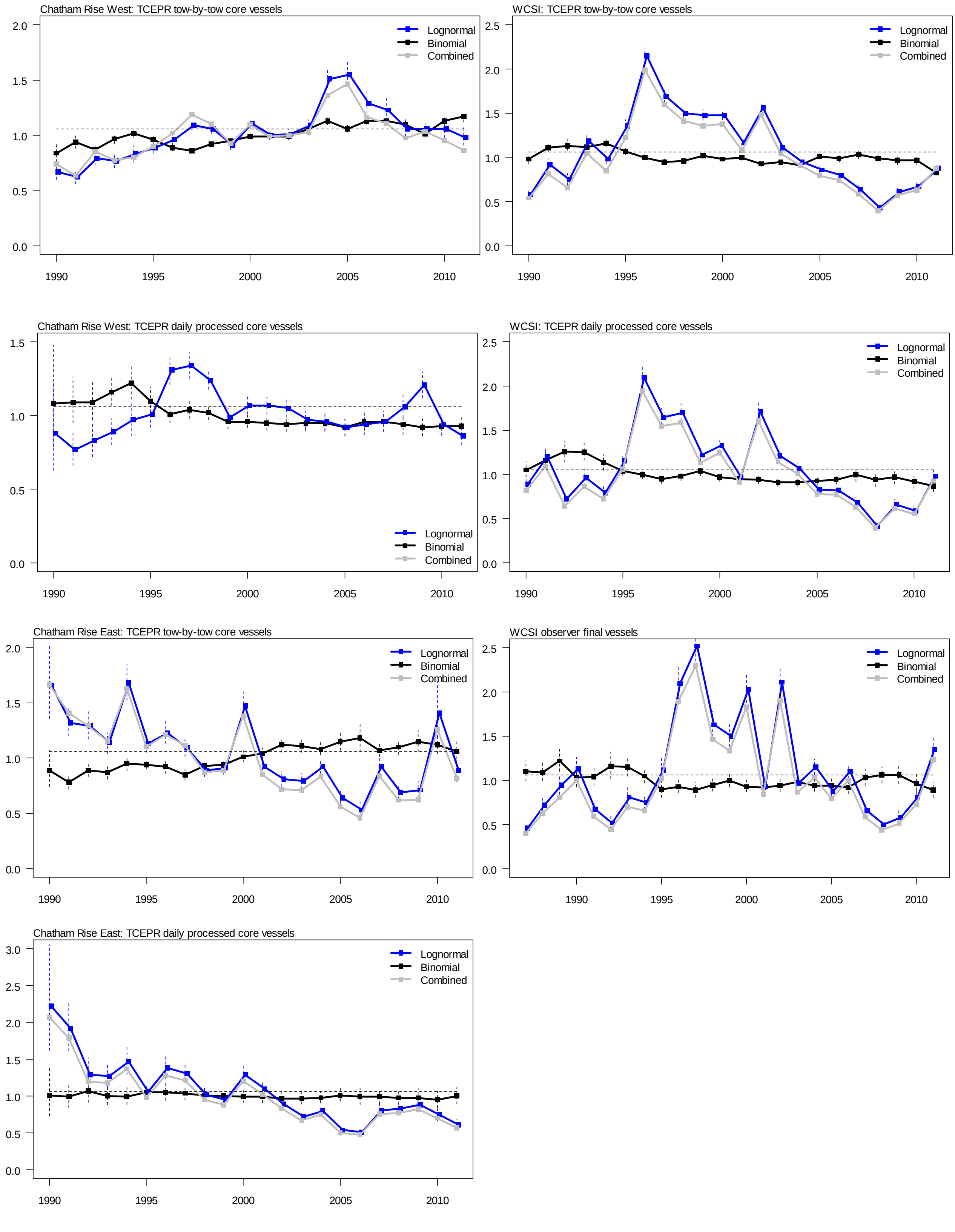


Figure 15: Standardised CPUE indices from the lognormal, binomial and combined model for each fishery, 1990–2011 for TCEPR data and 1987–2011 for observer data. Bars indicate 95% confidence intervals. Year defined as September–August for Chatham Rise data, and June–September for WCSI data.

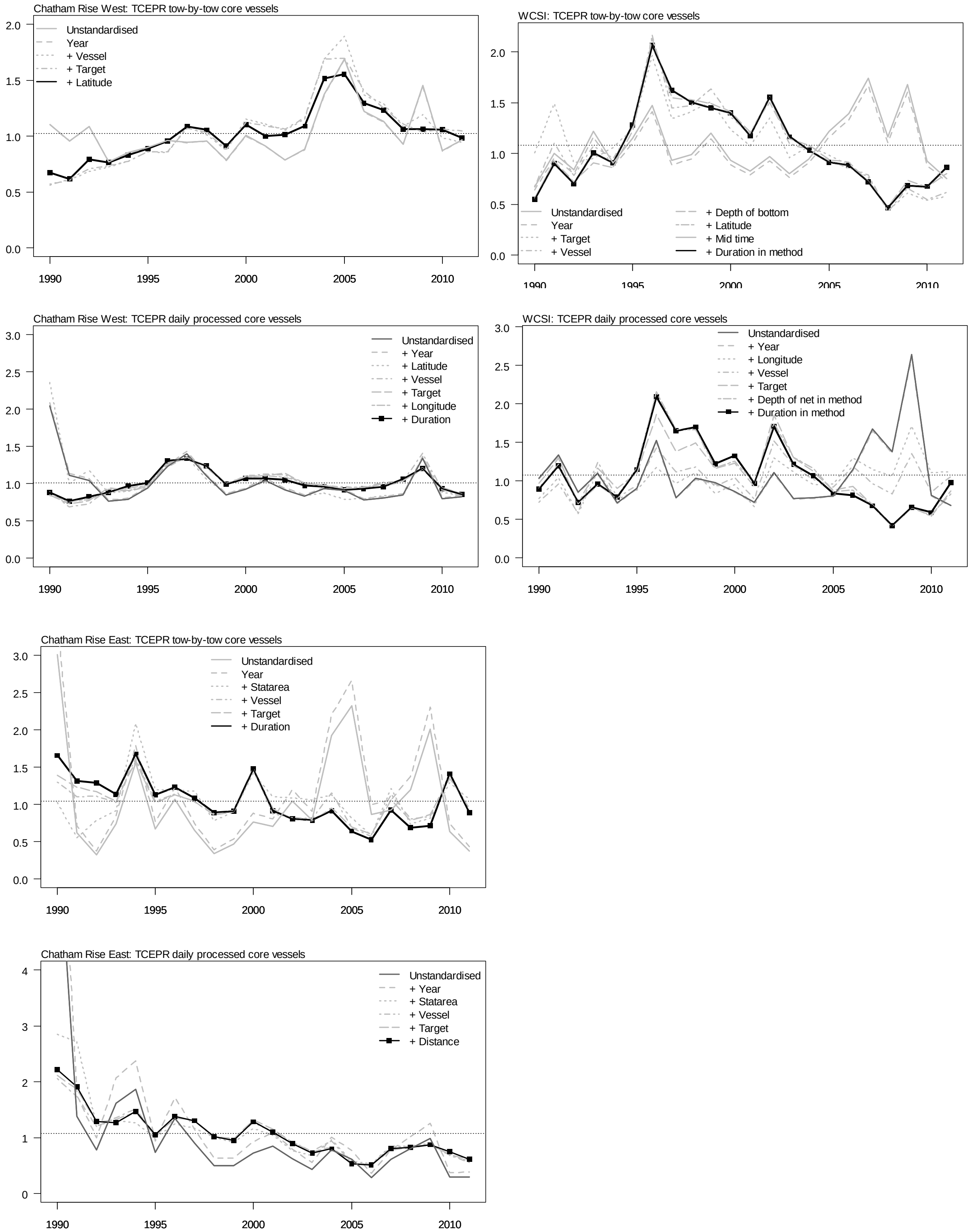


Figure 16: Standardised CPUE indices showing effect of addition of variables into the lognormal model for each fishery, 1990–2011. Year defined as September–August for Chatham Rise data, and June–September for WCSI data.

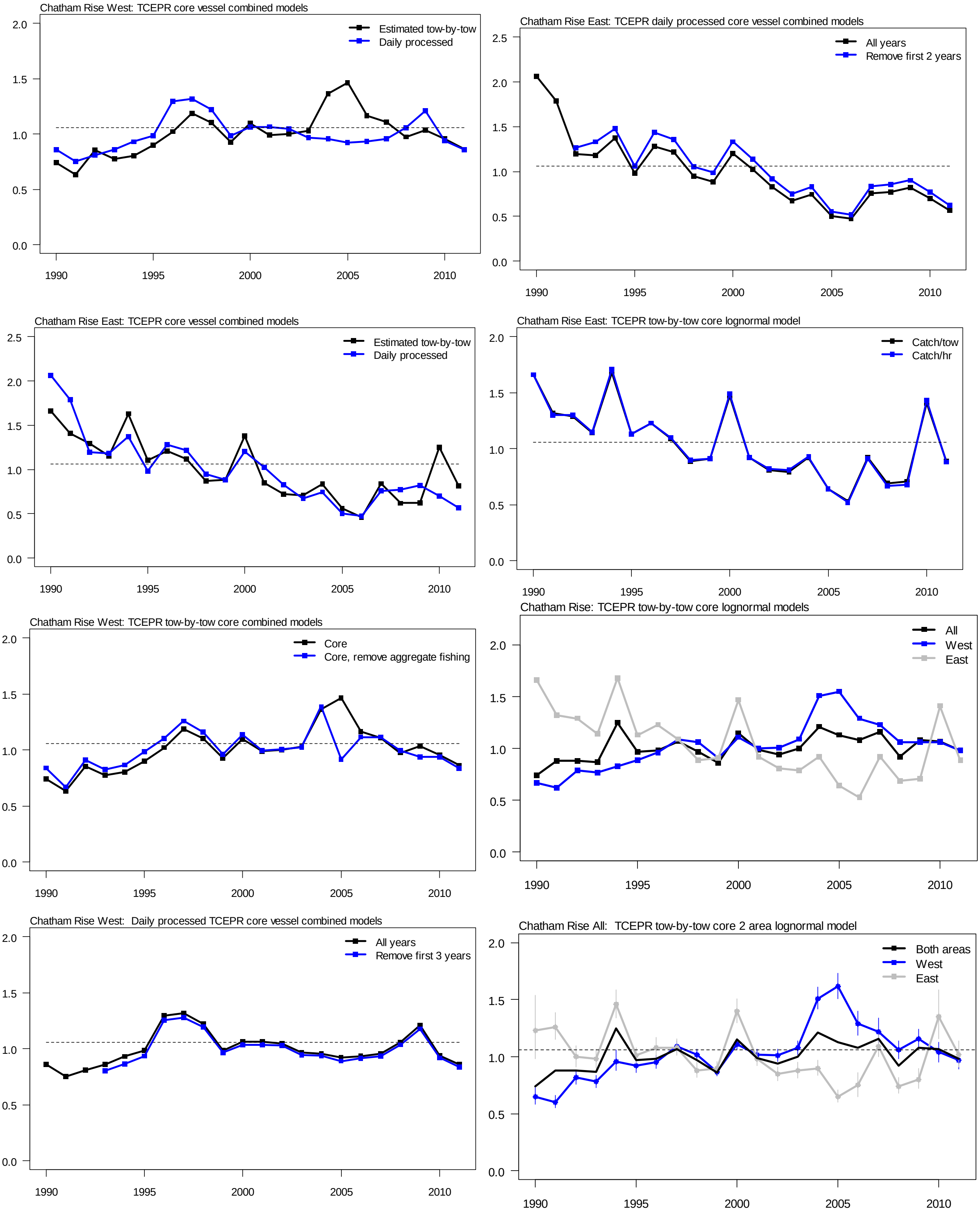


Figure 17: Comparison of CPUE indices from the lognormal models for Chatham Rise and WCSI, by year. Year defined as September–August for the Chatham Rise and June–September for the WCSI.

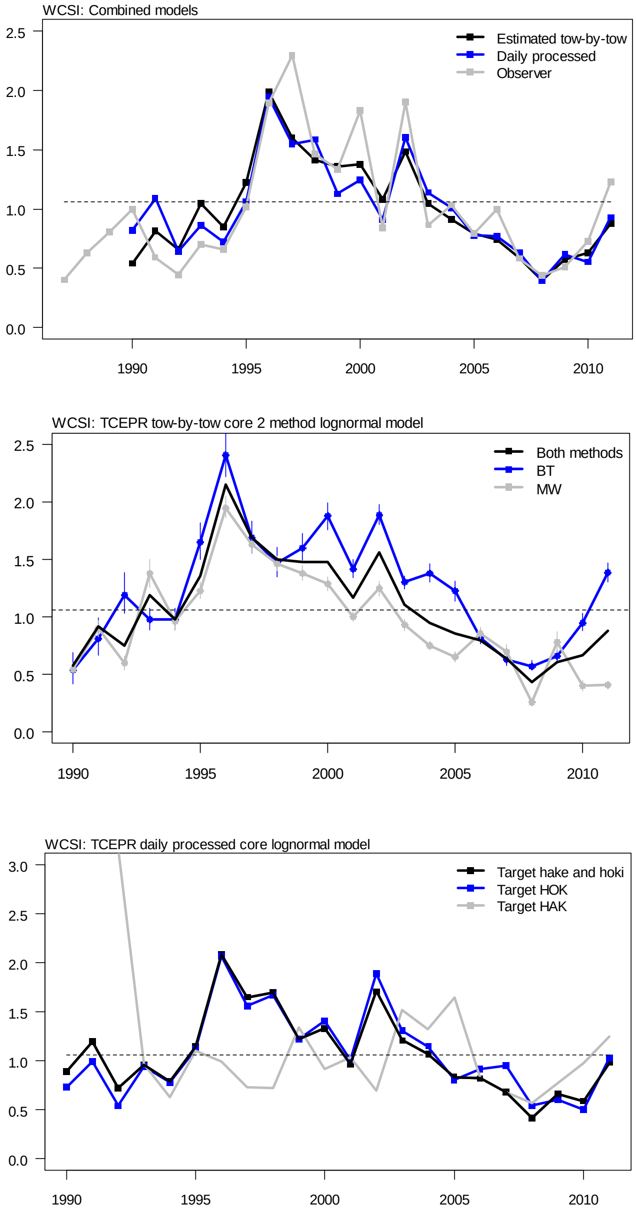


Figure 17 continued.

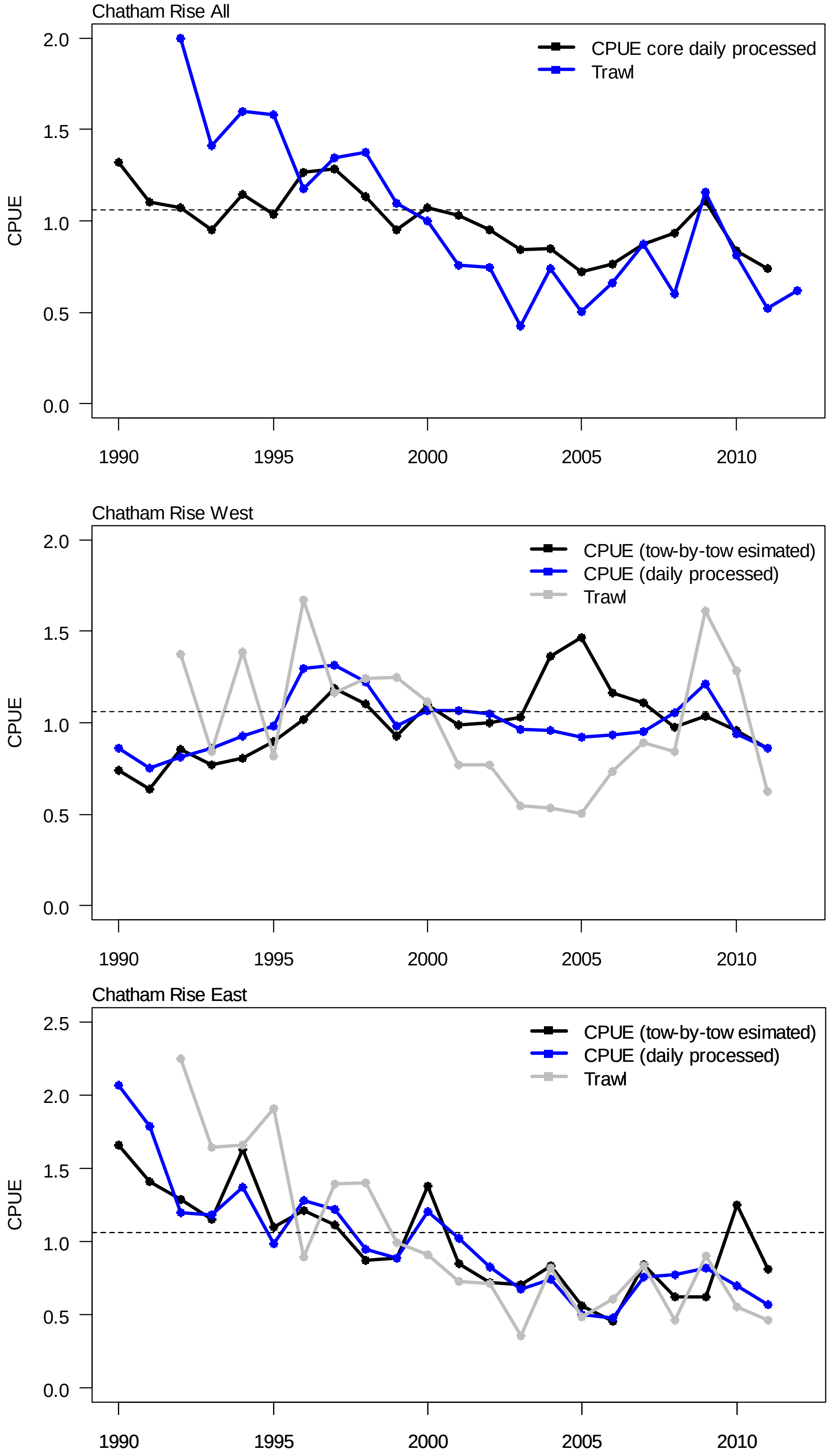


Figure 18: Comparison of Chatham Rise trawl survey hake biomass indices with combined indices from the Chatham Rise East and West fisheries targeting hoki or hake, 1990–2011. Indices have been standardised to a mean of one.

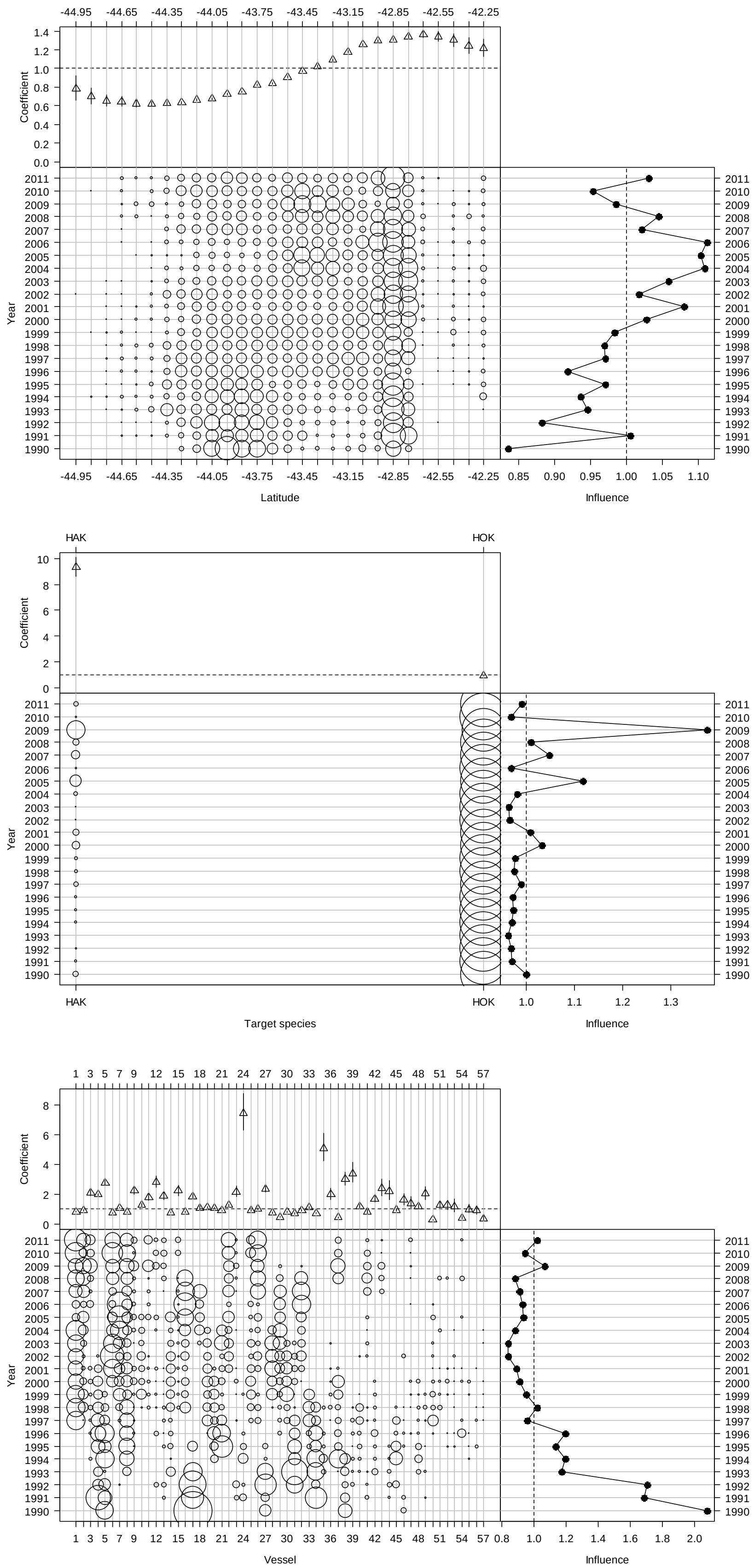


Figure 19a: Effect and influence of non-interaction term variables in the Chatham Rise West estimated tow-by-tow core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.

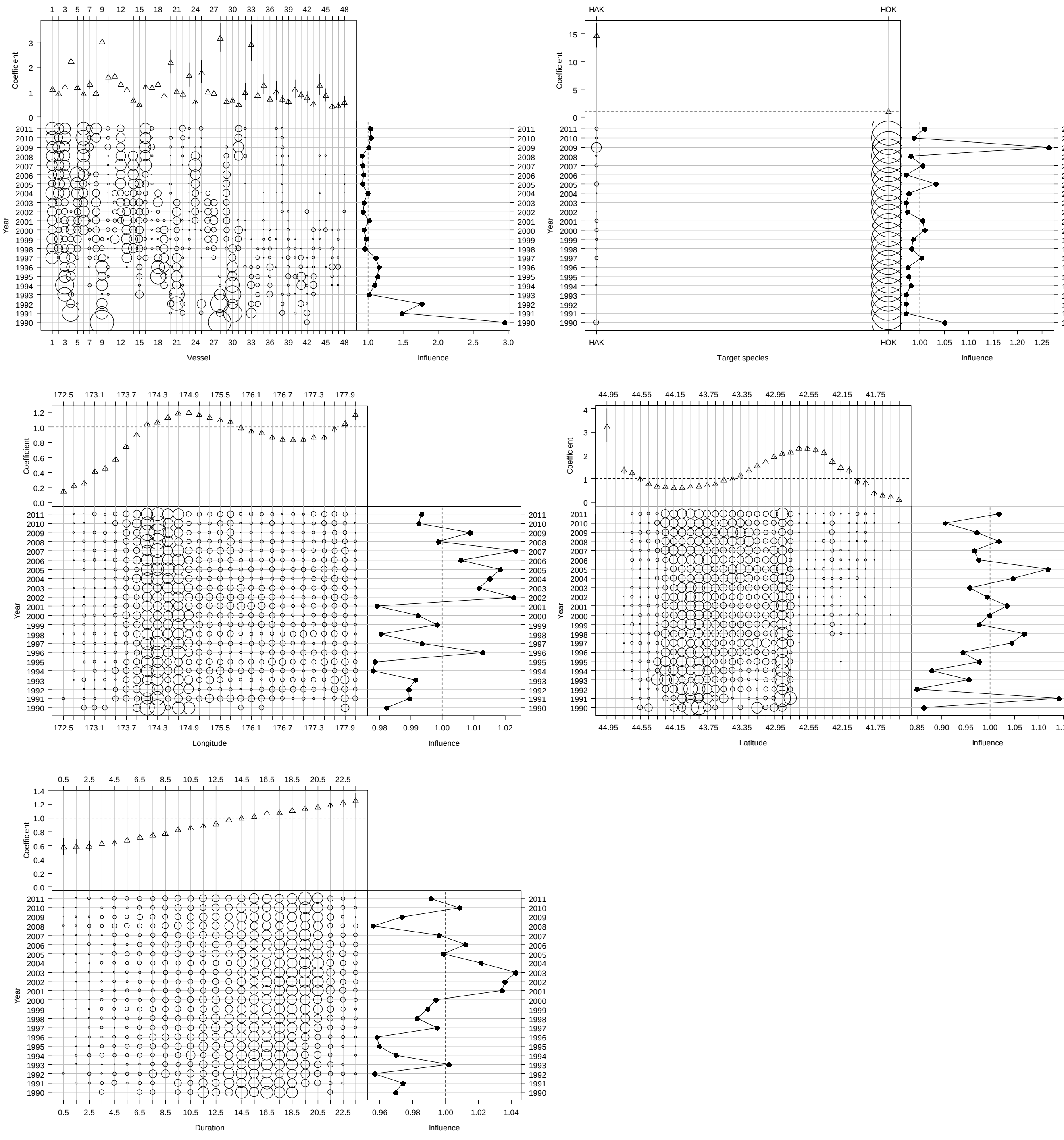


Figure 19b: Effect and influence of non-interaction term variables in the Chatham Rise West daily processed core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.

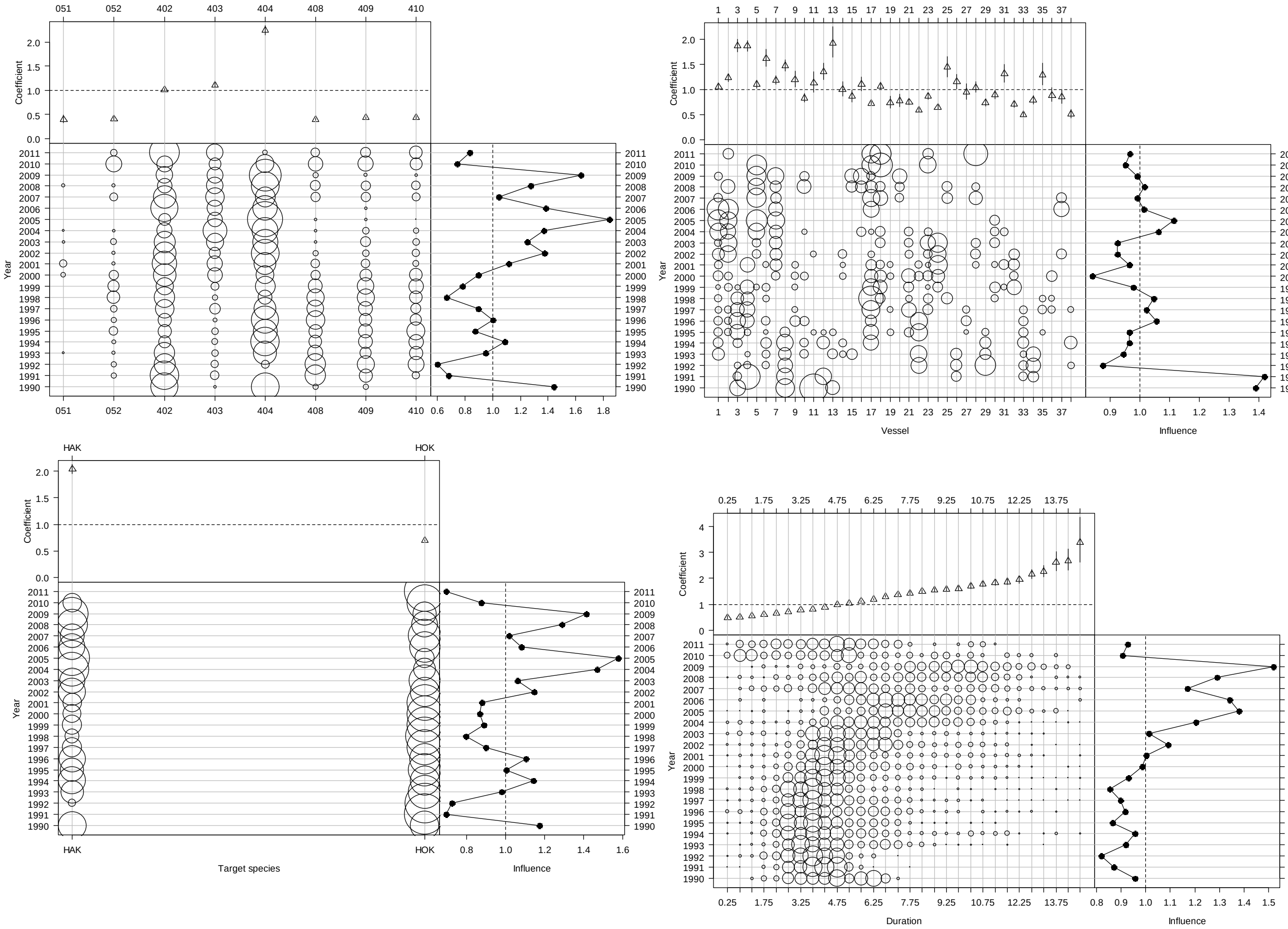


Figure 19c: Effect and influence of non-interaction term variables in the Chatham Rise East estimated tow-by-tow core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.

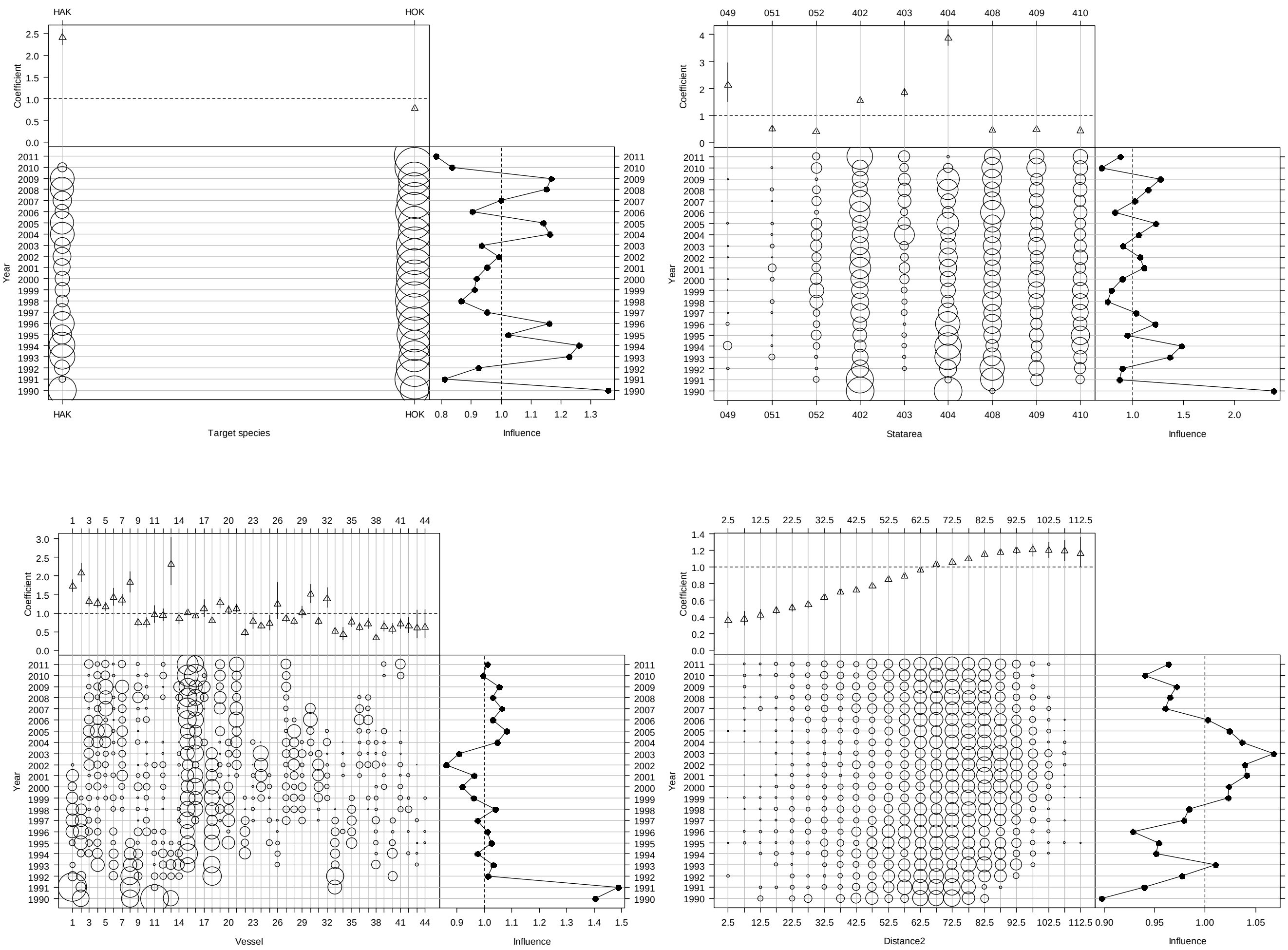


Figure 19d: Effect and influence of non-interaction term variables in the Chatham Rise East daily processed core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.

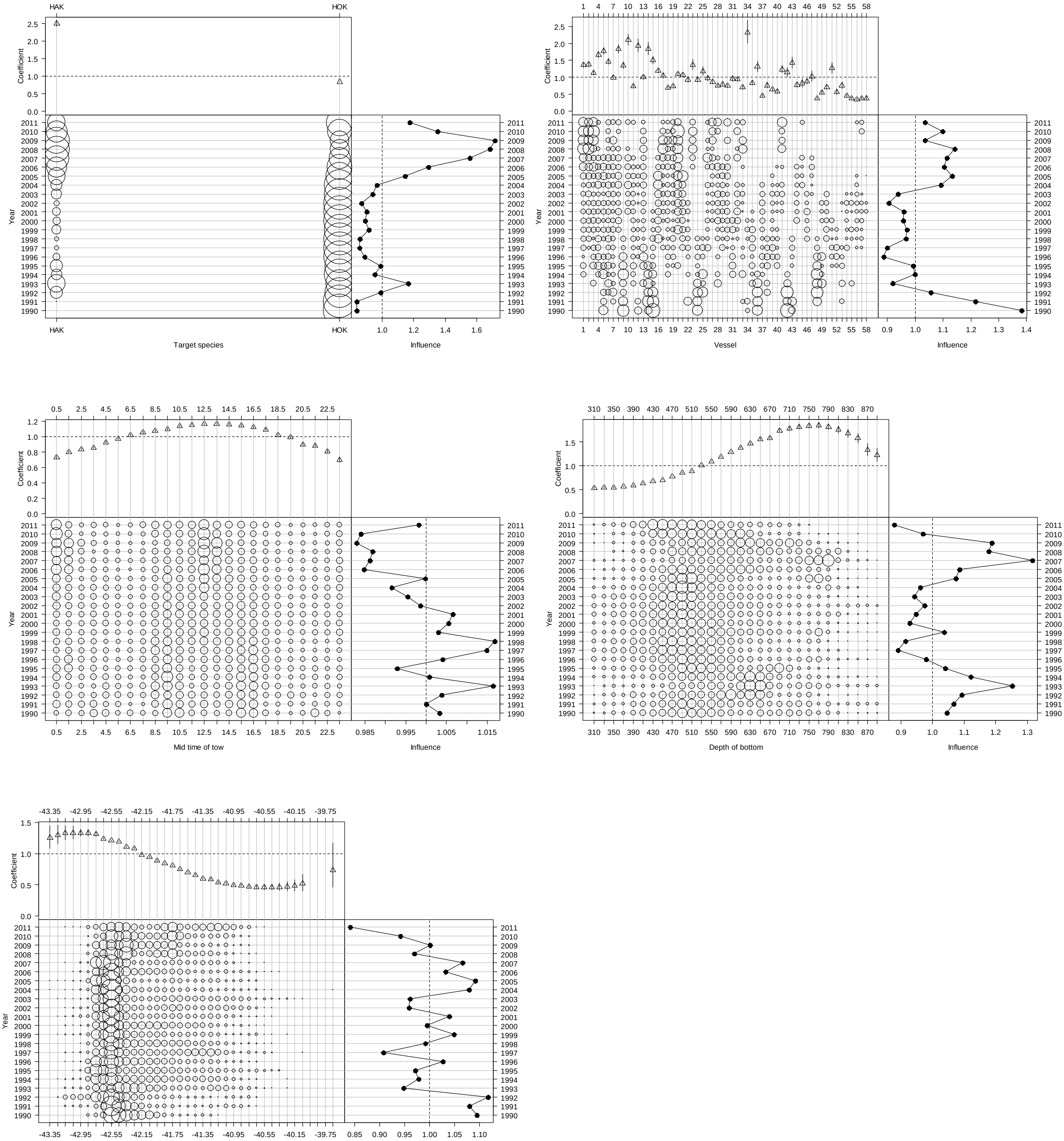


Figure 19e: Effect and influence of non-interaction term variables in the WCSI estimated tow-by-tow core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.

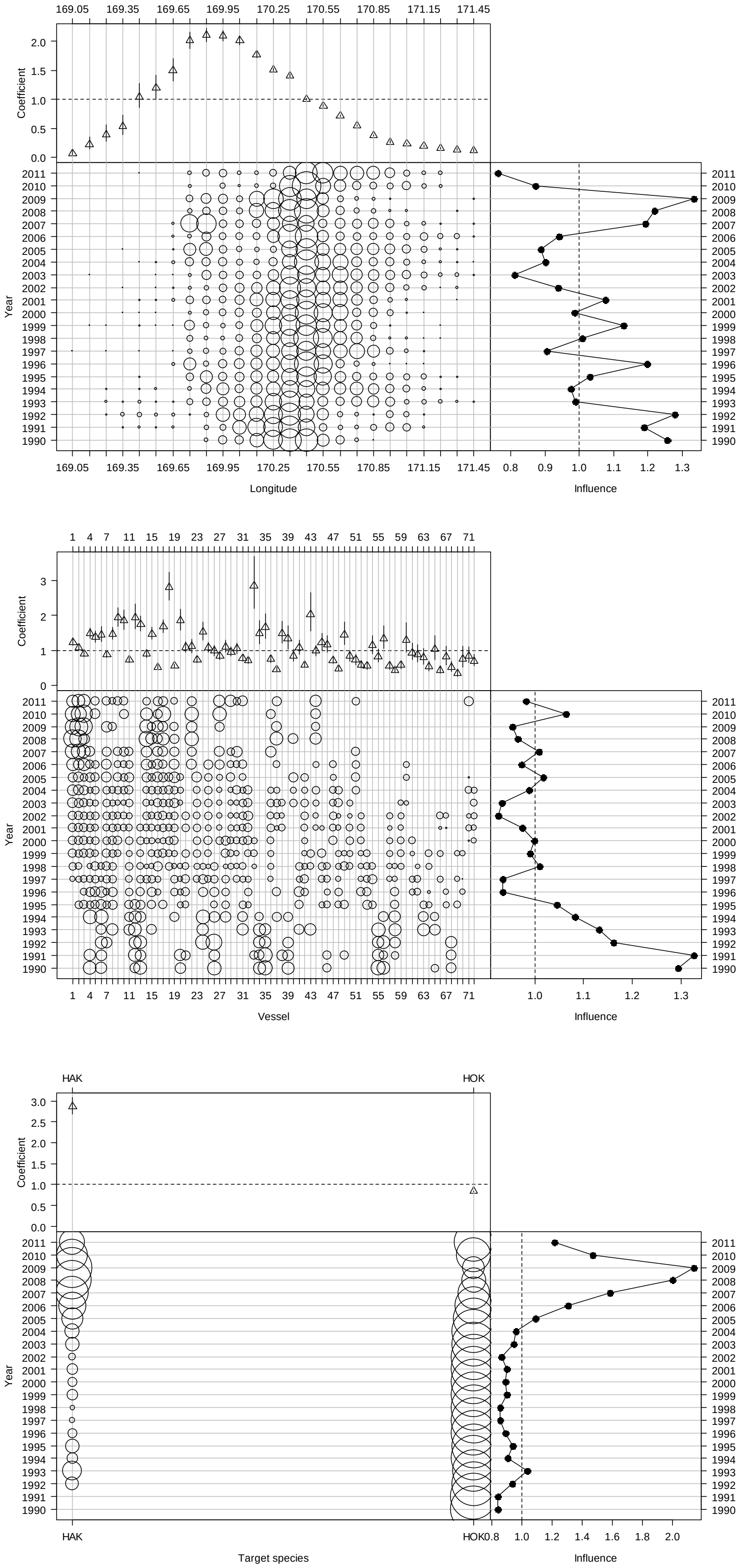


Figure 19f: Effect and influence of non-interaction term variables in the WCSI daily processed core vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.

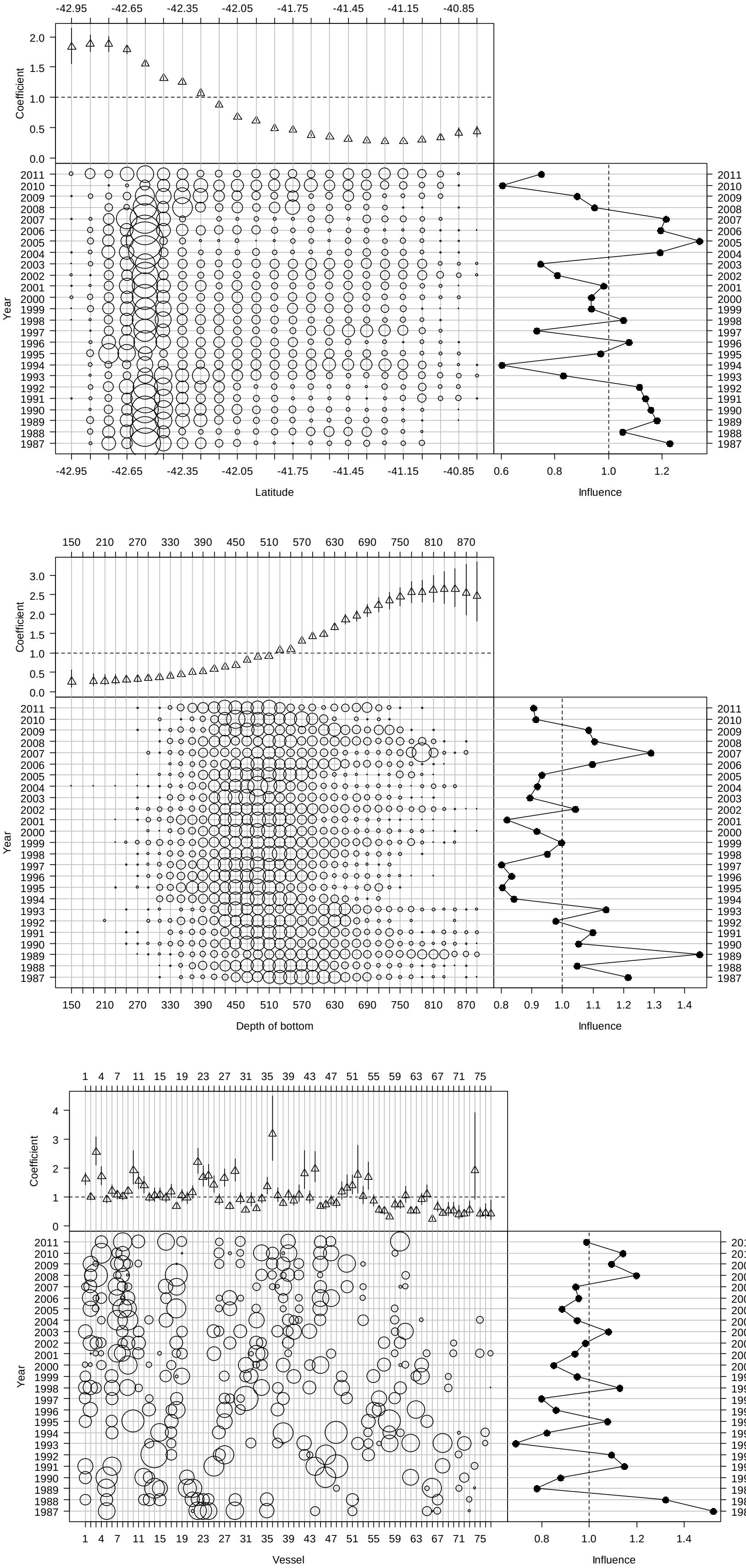


Figure 19g: Effect and influence of non-interaction term variables in the WCSI observer tow-by-tow vessel lognormal model. Top: relative effect by level of each variable. Bottom left: relative distribution of each variable by fishing year. Bottom right: influence of variable on unstandardised CPUE by fishing year.

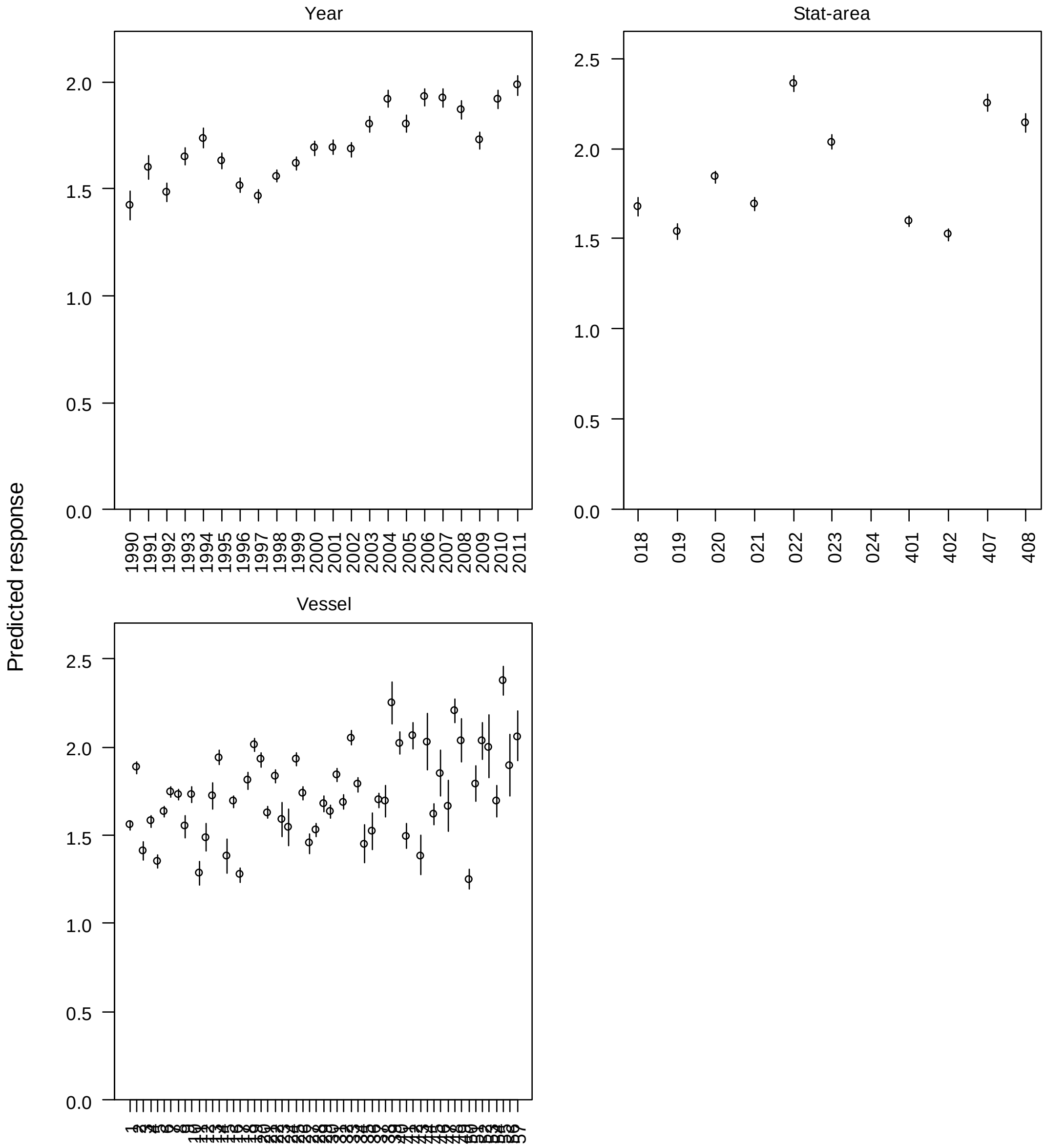


Figure 20a: Expected variable effects for variables selected into the CPUE binomial model for the Chatham Rise West TCEPR estimated tow-by-tow core vessel fishery, 1990–2011. The 95% confidence intervals are shown as bars for categorical variables and as upper and lower lines for continuous variables.

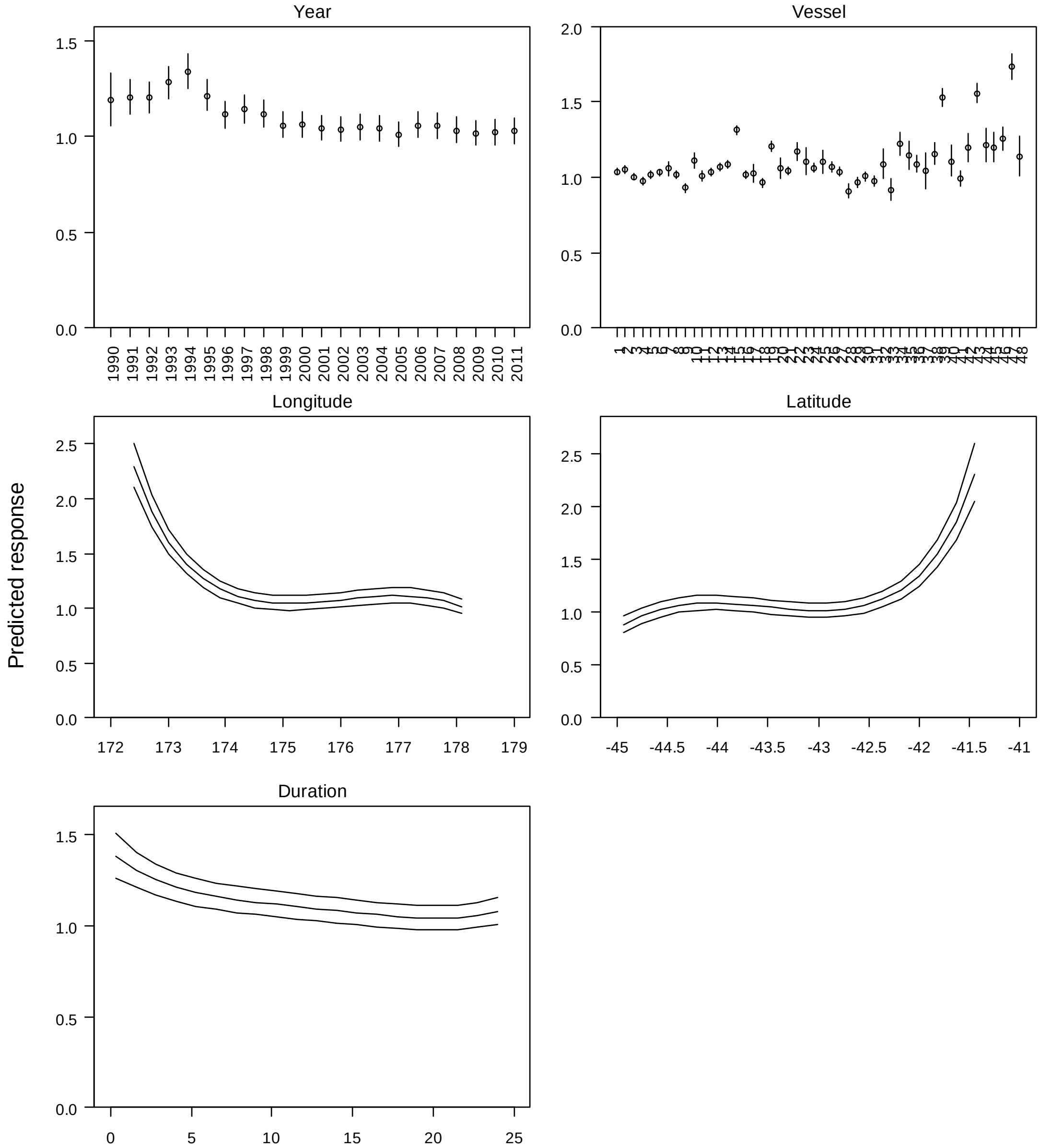


Figure 20b: Expected variable effects for variables selected into the CPUE binomial model for the Chatham Rise West TCEPR daily processed core vessel fishery, 1990–2011. The 95% confidence intervals are shown as bars for categorical variables and as upper and lower lines for continuous variables.

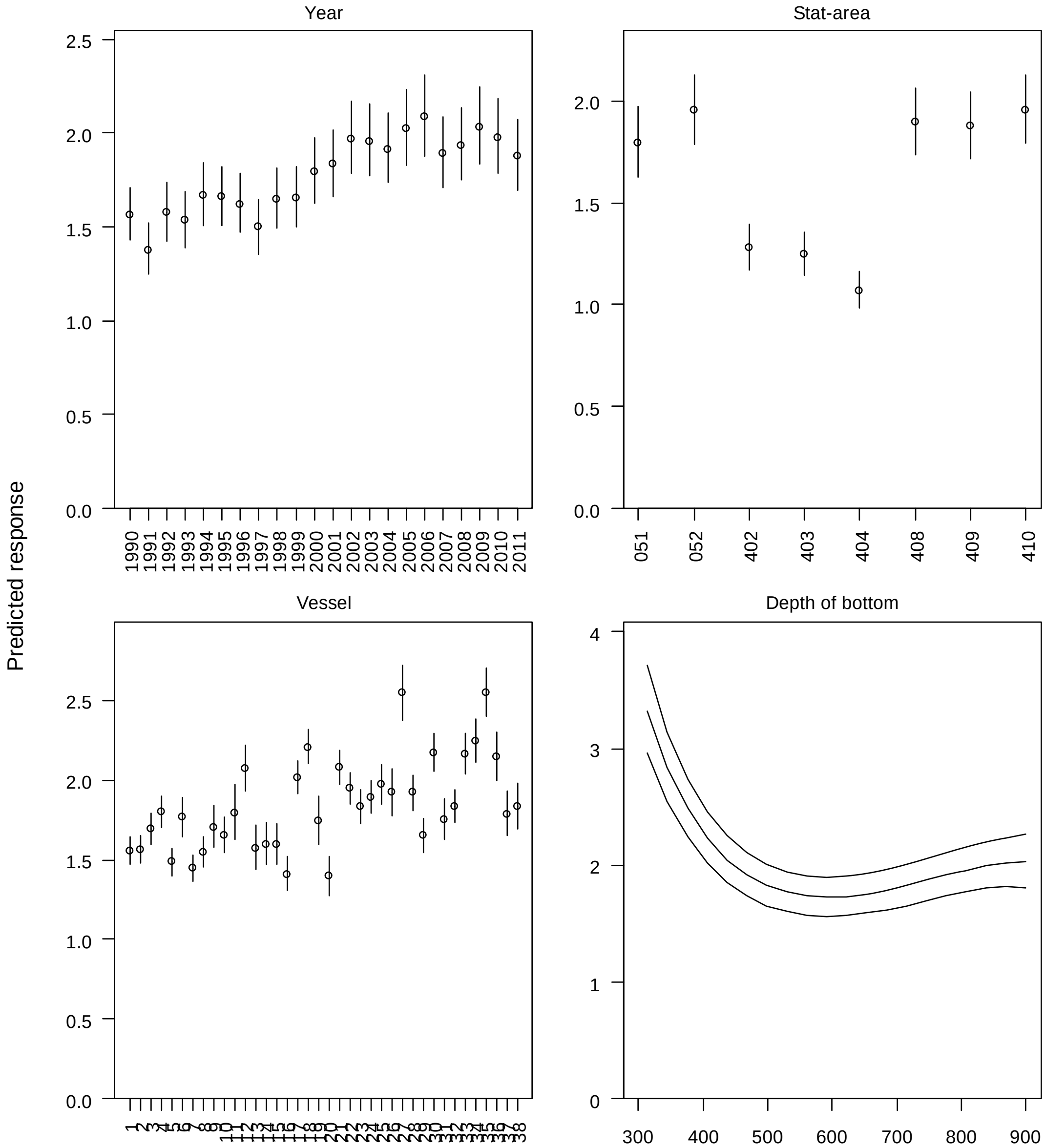


Figure 20c: Expected variable effects for variables selected into the CPUE binomial model for the Chatham Rise East TCEPR estimated tow-by-tow core vessel fishery, 1990–2011. The 95% confidence intervals are shown as bars for categorical variables and as upper and lower lines for continuous variables.

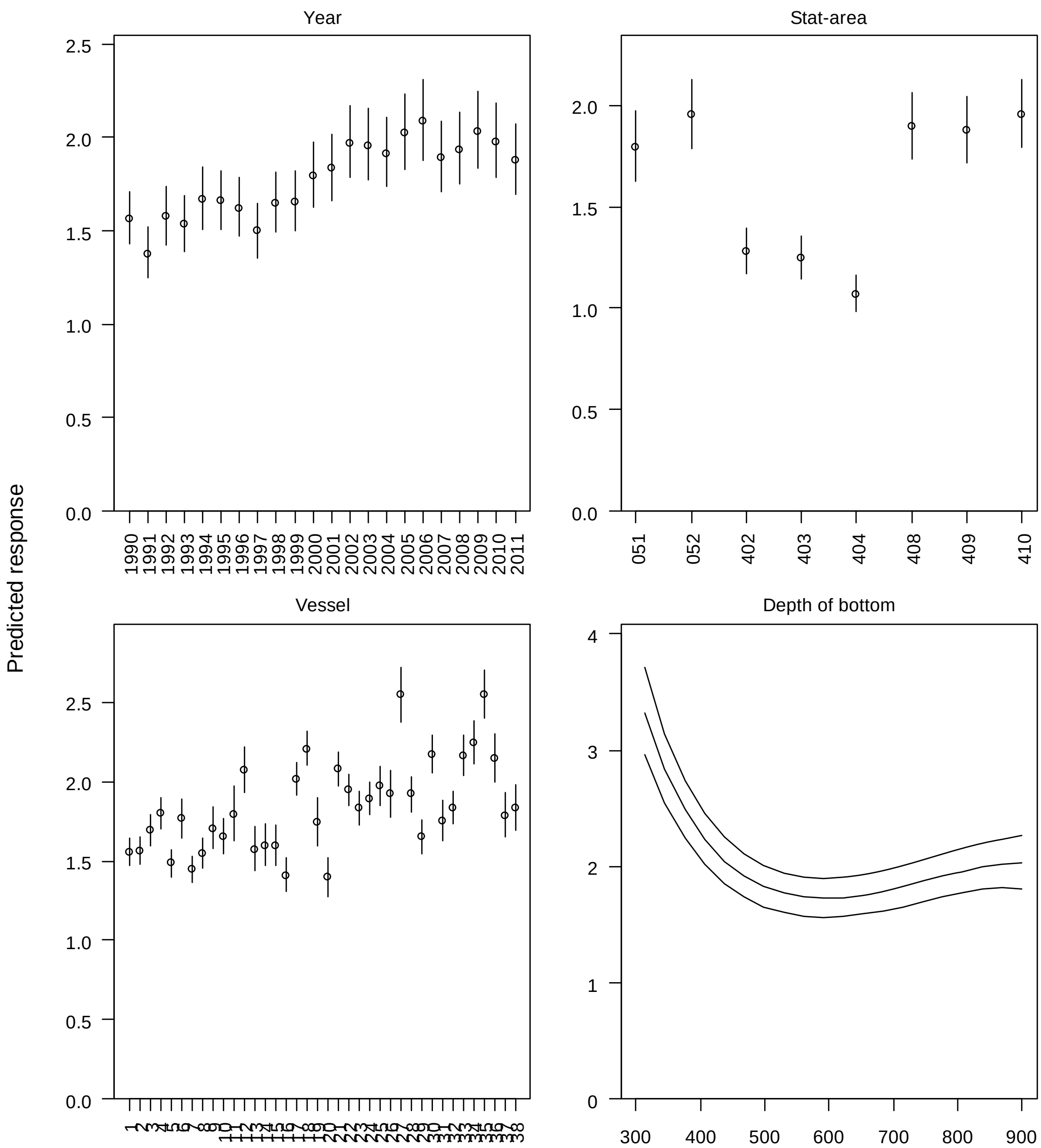


Figure 20d: Expected variable effects for variables selected into the CPUE binomial model for the Chatham Rise East TCEPR daily processed core vessel fishery, 1990–2011. The 95% confidence intervals are shown as bars for categorical variables and as upper and lower lines for continuous variables.

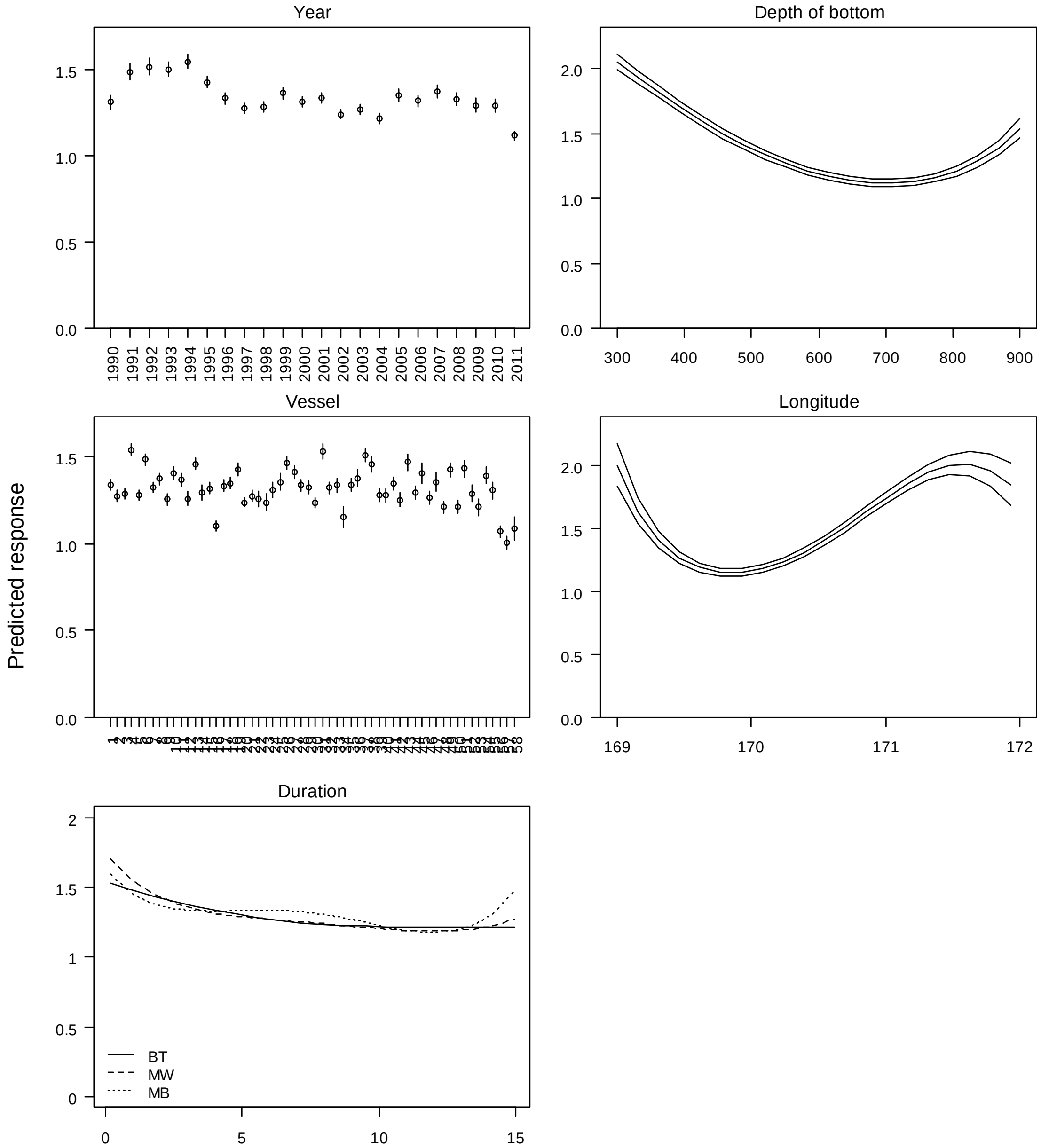


Figure 20e: Expected variable effects for variables selected into the CPUE binomial model for the WCSI TCEPR estimated tow-by-tow core vessel fishery, 1990–2011. The 95% confidence intervals are shown as bars for categorical variables and as upper and lower lines for continuous variables.

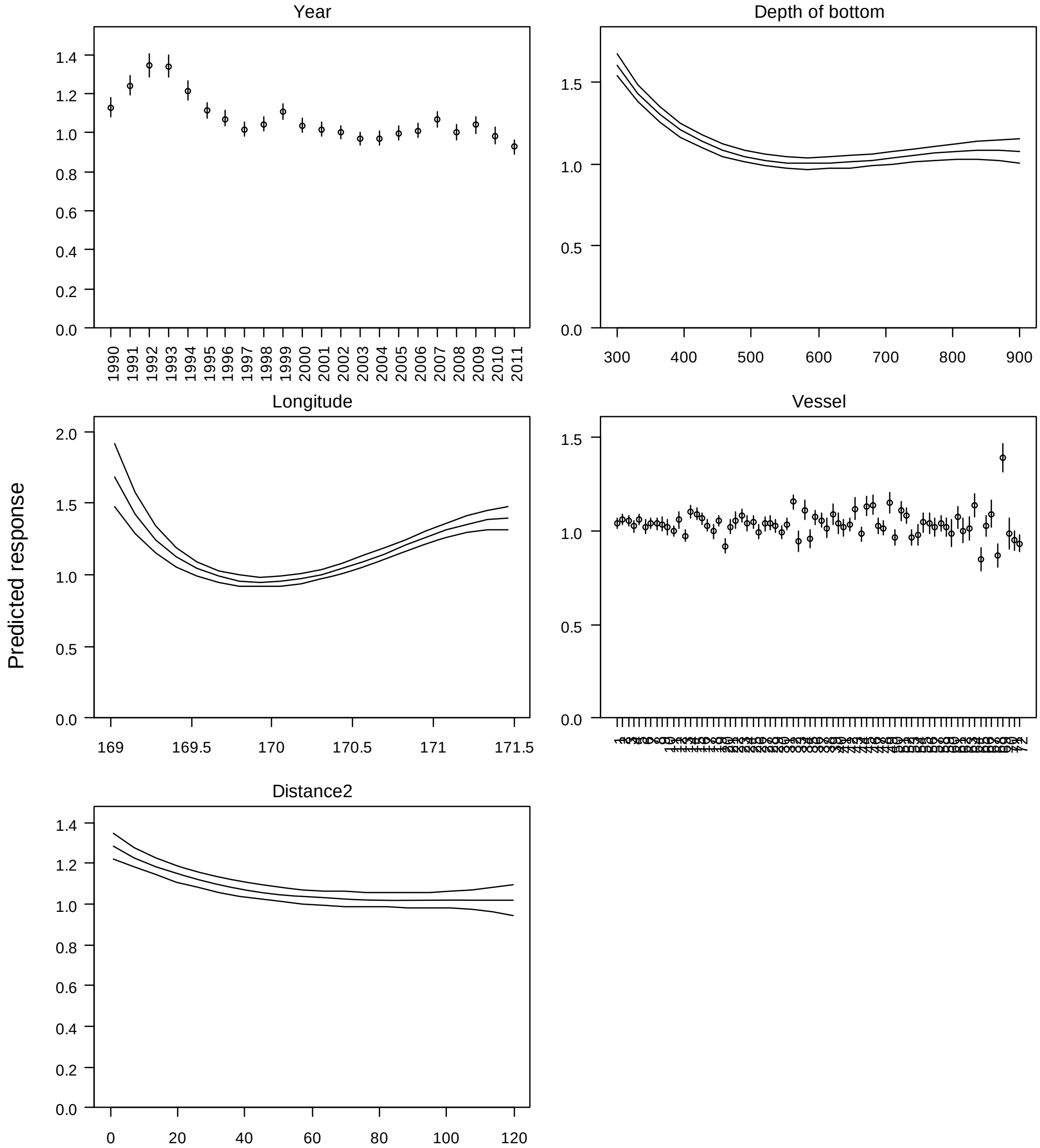


Figure 20f: Expected variable effects for variables selected into the CPUE binomial model for the WCSI TCEPR daily processed core vessel fishery, 1990–2011. The 95% confidence intervals are shown as bars for categorical variables and as upper and lower lines for continuous variables.

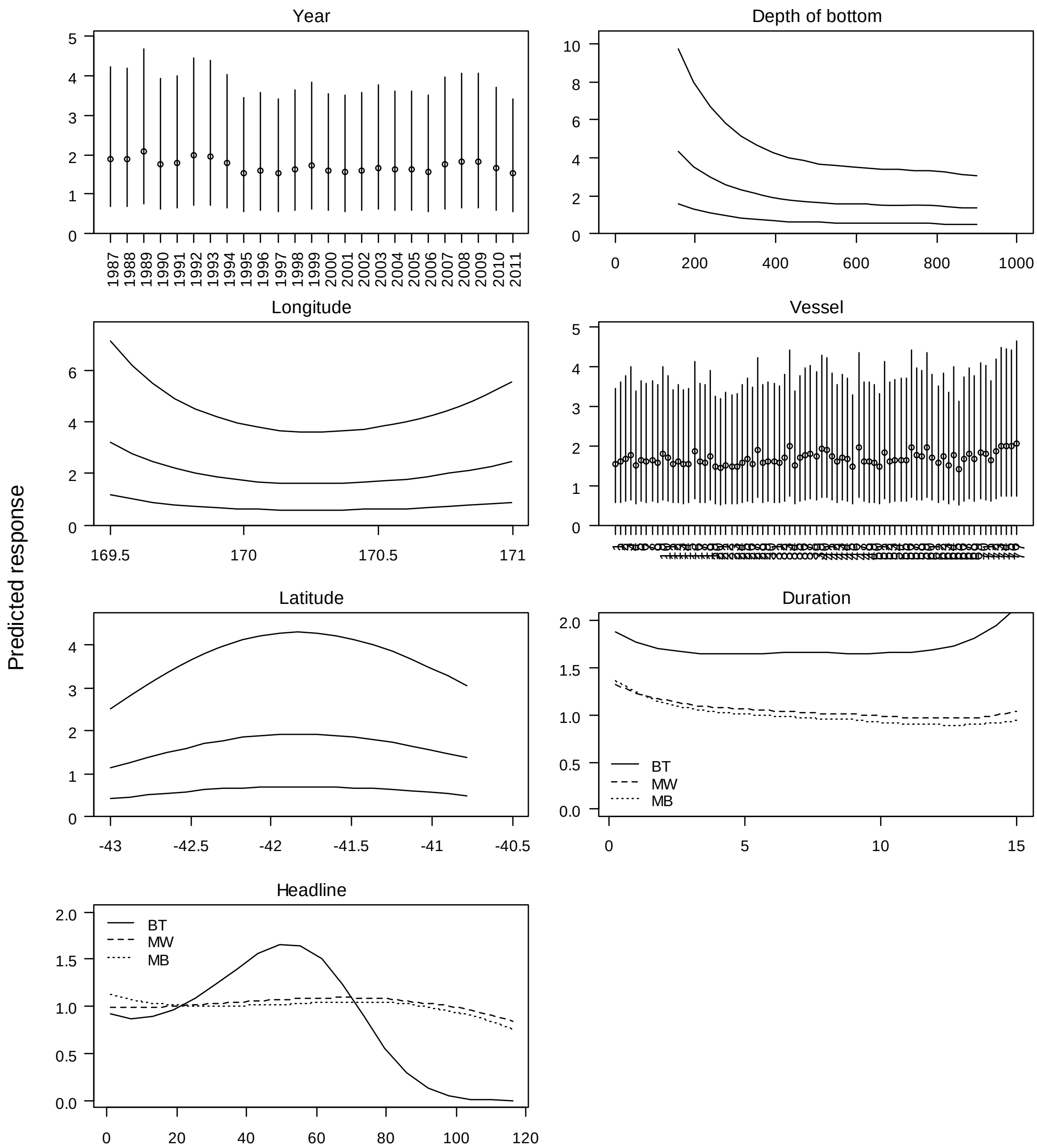
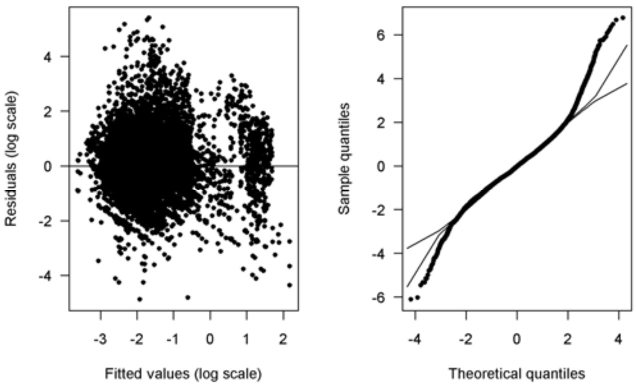
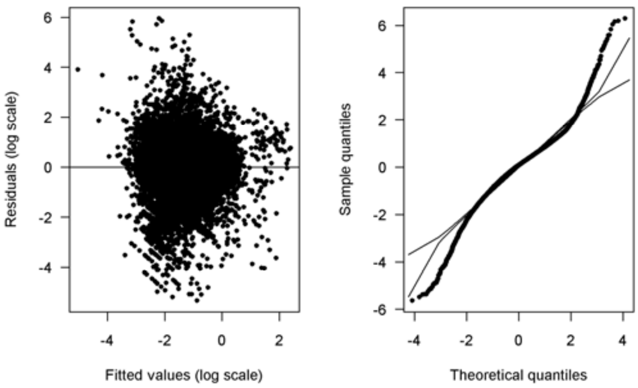


Figure 20g: Expected variable effects for variables selected into the CPUE binomial model for the WCSI observer tow-by-tow vessel fishery, 1987–2011. The 95% confidence intervals are shown as bars for categorical variables and as upper and lower lines for continuous variables.

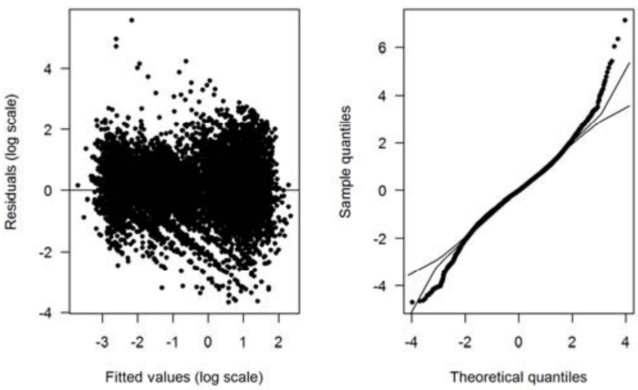
(a) Chatham Rise West: TCEPR tow-by-tow core vessels



(b) Chatham Rise West: TCEPR daily processed core vessels



(c) Chatham Rise East: TCEPR tow-by-tow core vessels



(d) Chatham Rise East: TCEPR daily processed core vessels

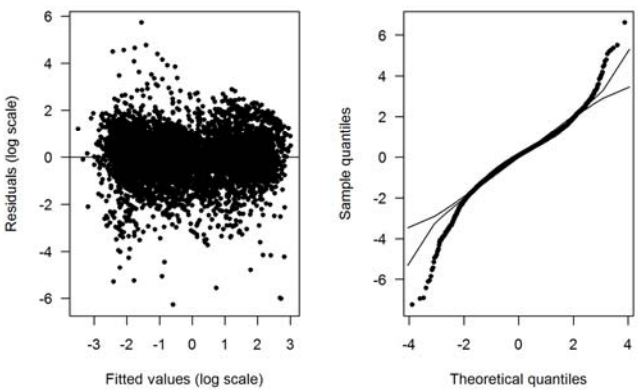
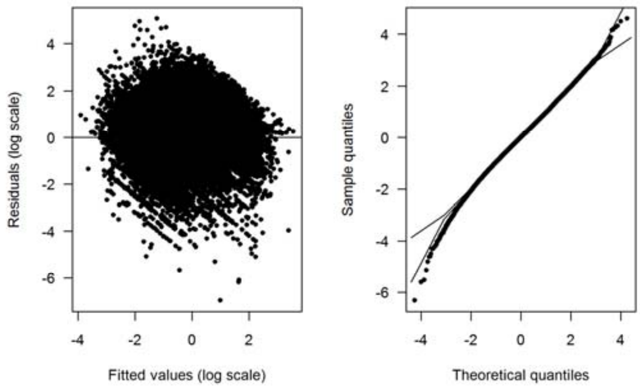
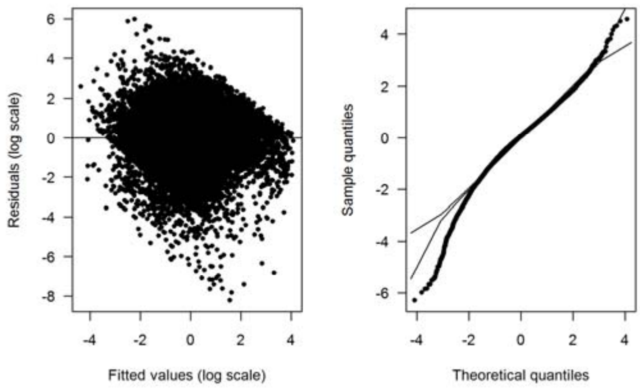


Figure 21: Diagnostic plots for the lognormal CPUE models.

(e) WCSI: TCEPR tow-by-tow core vessels



(f) WCSI: TCEPR daily processed core vessels



(g) WCSI: Observer tow-by-tow core vessels

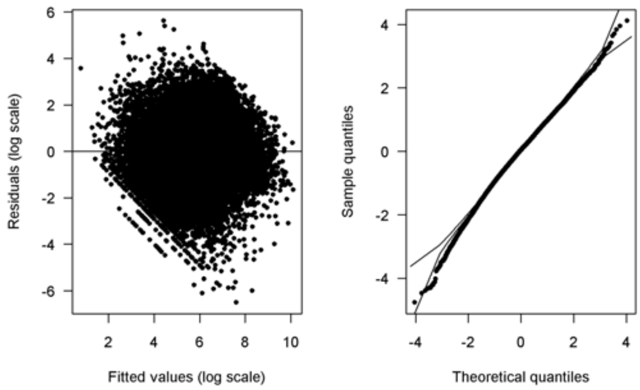
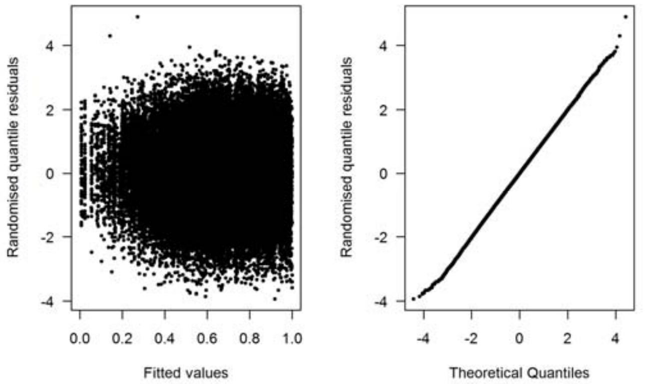
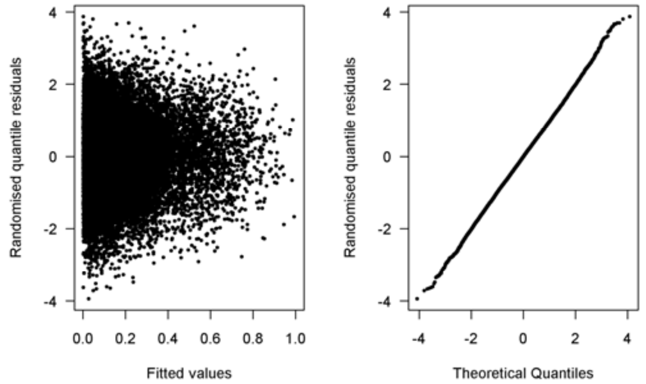


Figure 21 continued.

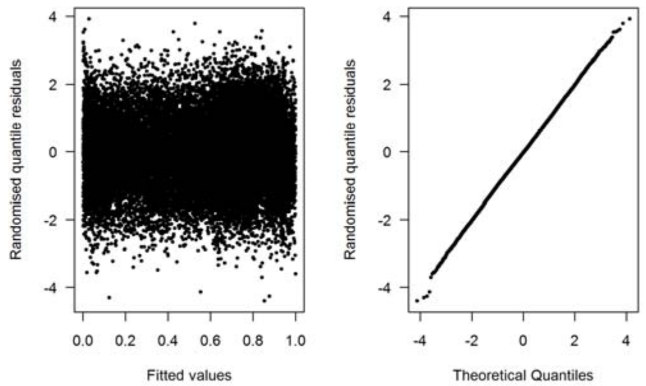
(a) Chatham Rise West: TCEPR tow-by-tow core vessels



(b) Chatham Rise West: TCEPR daily processed core vessels



(c) Chatham Rise East: TCEPR tow-by-tow core vessels



(d) Chatham Rise East: TCEPR daily processed core vessels

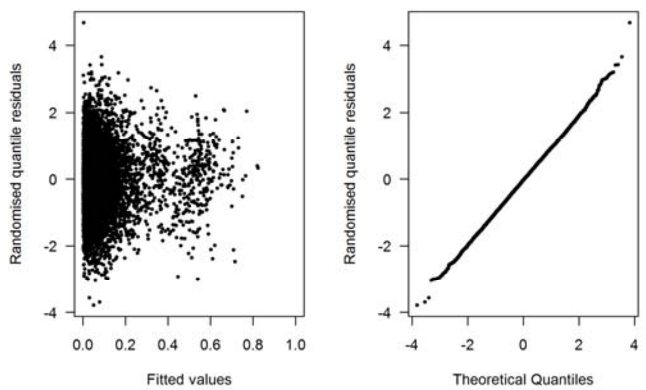
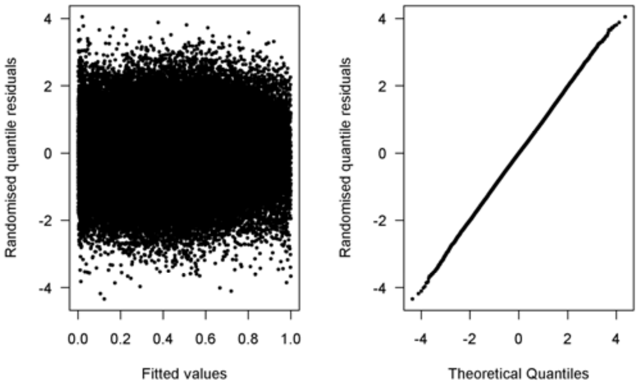
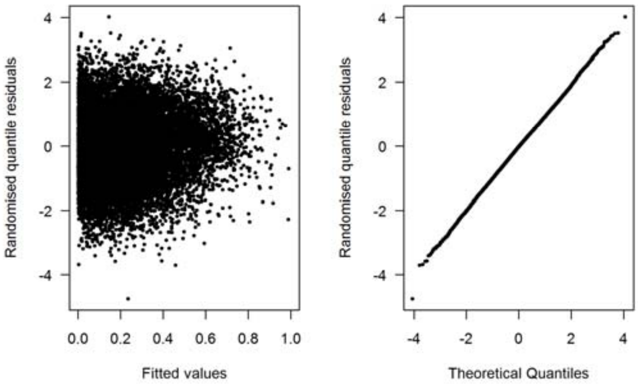


Figure 22: Diagnostic plots for the binomial CPUE models.

(e) WCSI: TCEPR tow-by-tow core vessels



(f) WCSI: TCEPR daily processed core vessels



(g) WCSI: Observer tow-by-tow core vessels

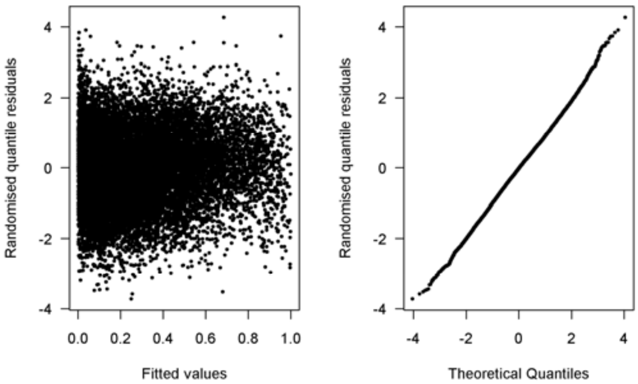


Figure 22 continued.