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Development and evaluation of catch-per-unit-effort indices for southern blue whiting (*Micromesistius australis*) on the Campbell Island Rise (1986–2002) and the Bounty Platform (1990–2002)

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This report provides standardised CPUE indices for the southern blue whiting (SBW) spawning fisheries on the Campbell Island Rise from 1986 to 2002, and on the Bounty Platform from 1990 to 2002. Indices were calculated using lognormal linear models of catch per tow, catch per hour, and catch per day for all vessels, and catch per tow for subsets of vessels based on processing type (surimi or dressed), and by relative experience in each fishery. This report summarises the data and the method of calculating the indices, and then compares the CPUE indices with the results of recent stock assessments. Finally, exploratory stock assessment runs are made fitting the CPUE indices as indices of relative abundance.

The Campbell Island Rise analysis was based on 11 853 non-zero records from 1986 to 2002. CPUE indices decreased slowly to a minimum in 1992, increased to a peak in 1996, followed by a slight decline to 2002. This trend was consistent among alternative measures of effort and among subsets of surimi and dressed vessels. *Vessel* was the most important variable, together with *day in season*, *end time of tow*, and *sub-area*. Model diagnostics indicate a poor fit to the data, and the models were unable to fit very high or very low catch rates.

The trends in CPUE for the Campbell Island Rise fishery were consistent with the trends in the 2003 NIWA assessment model. They followed the increase from 1993 to 1996 associated with the strong 1991 year class, and then followed the decline in relative abundance as this year class was fished down. Exploratory stock assessment model runs including the CPUE indices gave very similar results to those excluding the CPUE indices. We conclude the CPUE indices for the Campbell Island Rise are monitoring the stock abundance and should be used in future stock assessments. However, there can be considerable variability in the CPUE indices for individual years, and several years' data may be necessary before any trends become apparent

The Bounty Platform analysis was based on a data set of 3288 non-zero records from 1990 to 2002. The CPUE indices fluctuated considerably, peaking in 1992, 1996–1998, and again in 2002. The indices were similar between most of the CPUE models until 1997, but after 1997 they became more erratic between years and inconsistent amongst vessel subsets. Various vessel identifiers, including *nationality*, *length*, *vessel category*, *tonnage*, and *year built*, were the main variables included in the models. Some of these vessel characteristics were correlated and this may have led to some confounding with the year effects in the model. Diagnostics for most models generally indicate a poor fit to the data, and the model was unable to fit very high or very low catch rates. This indicates that the model structure may be inadequate to reliably determine the indices and their standard errors.

Trends in CPUE for the Bounty Platform fishery were consistent with trends in biomass from the 2002 NIWA assessment model, apart from the first two years and last two years. The lower indices in the first two years may be due to lack of experience, whilst the higher index in the last two years is suggestive of hyperstability. An exploratory stock assessment model fitted to one of the CPUE indices gave similar results to one of the more plausible 2002 NIWA assessment runs. We tentatively conclude that the CPUE indices for the Bounty Platform are monitoring stock abundance, at least for some of the time. A new assessment of the Bounty stock is being conducted in 2004 using CASAL, and we recommend that estimation of the CPUE indices be revisited, and the CPUE indices be more fully examined in a modelling context before they are fully endorsed.

1. INTRODUCTION

1.1 The SBW fishery

Southern blue whiting (SBW) are almost entirely restricted to subantarctic waters (QMA 6), and comprise four distinct stocks (Hanchet et al. 2003). For most of the year SBW are dispersed across much of the Campbell Plateau and Bounty Platform. However, in August and September fish aggregate to spawn on distinct spawning grounds on the Campbell Island Rise, Bounty Platform, Pukaki Rise, and Auckland Islands Shelf. Vessels have used the areas and time periods to different extents over the course of the commercial fishery.

The SBW fishery was developed by Soviet vessels during the early 1970s, with total landings in 1973 and 1974 exceeding 40 000 t (Hanchet et al. 2003). Some fishing probably took place on each of the four grounds, but the proportion of catch from each ground cannot accurately be determined before 1978. From 1978 to 1984, the entire Campbell Plateau was fished throughout the year, but highest catches were usually made while fish were spawning in September on the Pukaki Rise and the northern Campbell Island Rise. In some seasons (notably 1979, 1982, and 1983) vessels also targeted spawning fish on the Bounty Platform (Table 1).

As a result of the increase in hoki quota in 1985 and 1986, the Japanese surimi fleet increased its presence in New Zealand waters and some vessels stayed on after the hoki fishery to fish for SBW. Since then many of the Soviet and Japanese vessels which fish for hoki on the west coast of the South Island during July and August each year move in mid to late August to the SBW spawning grounds. Between 1986 and 1989, fishing was confined to the spawning grounds on the northern Campbell Island Rise. From 1990 onwards, vessels also started fishing spawning aggregations on the Bounty Platform, the Pukaki Rise, and the southern Campbell Island Rise. Fishing effort increased markedly between 1990 and 1992, culminating in a catch of over 75 000 t in 1992. The increased catch came mainly from the Bounty Platform. In 1993, a fishery developed for the first time on the Auckland Islands spawning grounds and fishing has continued there at a low level sporadically since then. Because of the differences in timing of spawning on each ground, vessels typically start fishing on the Bounty Platform before moving on to the Campbell Island Rise and the other two areas.

A catch limit of 32 000 t for all areas was introduced for the first time in the 1992–93 fishing year (1993 season). This was increased to 58 000 t in 1997, lowered to 35 140 t in 2001, and increased to 45 140 t for the last two fishing seasons (Table 1). Annual landings since 1993 have averaged about 25 000 t, most of which has been taken from the Campbell Island Rise. The fleet has comprised mainly Japanese surimi vessels, and Russian, Ukrainian, and Polish dressed vessels.

Fishing in most years since 1986–87 has started in mid August and extended into October. However, over the past two fishing years there has been an increasing amount of SBW taken outside this main spawning season. Some has been taken as a bycatch of the hoki fishery, and the remainder has been targeted. In the 2001–02 fishing year about 350 t were taken between November and March, mainly from the Pukaki stock. In the 2002–03 fishing year about 2200 t were taken between November and March, from the Campbell Island Rise, Pukaki Rise, and Auckland Islands Shelf grounds.

1.2 Previous research

Analyses of the SBW fishery on the Campbell Island Rise have evolved from a descriptive analysis in the 1980s, to an unstandardised CPUE in the early 1990s (Hanchet 1991), and a standardised CPUE by the mid 1990s (Ingerson & Hanchet 1995, Chatterton 1996). The standardised CPUE series was updated until 1998 (Hanchet & Ingerson 1996, Hanchet 1998b) but discontinued in favour of relative abundance indices derived from a series of acoustic surveys from 1993 to 2002 (Hanchet 2002). As SBW are highly aggregated in the spawning season, the degree of fishing success appears to be largely determined by ability to locate and maintain contact with these mobile spawning aggregations. Other issues such as weather, vessel daily processing capacity, and fleet dynamics (such as crowding) may also be important in determining fishing success.

The Middle Depths Working Group rejected the use of CPUE indices for the 1997 and subsequent stock assessments. However, reviews by Hanchet (2000a, 2000b) found that CPUE indices for the Campbell Plateau stock appeared to follow similar trends to the spawning stock biomass trajectories from population modelling, which suggested that standardised CPUE had potential to be a useful index of relative abundance in this fishery.

1.3 Objectives

This report briefly describes the SBW fishery and develops standardised CPUE indices for the Campbell Island Rise and Bounty Platform stocks from tow-by-tow and daily catch data, using a lognormal linear modelling approach on transformed data (Doonan 1991). The performance of these indices in monitoring relative abundance is assessed using the methods of Dunn et al. (2000) and Dunn (2001, 2002), and the standardised indices are compared to changes in stock abundance over the duration of the fishery as determined by the population models.

The report fulfils Objective 3 of Ministry of Fisheries Project SBW2001/01 "To evaluate the use of CPUE as indices of abundance in the Campbell Island Rise and Bounty Platform stocks."

2. METHODS

2.1 Data selection and definition of the fisheries

2.1.1 Data selection

Data were available from the Ministry of Fisheries TCEPR (Trawl, Catch, Effort and Processing Returns) database by calendar year from 1989 to December 2002. The time series was extended to include the 1986 to 1989 fishing years by using data from the FSU (Fisheries Statistics Unit) database. The TCEPR data record catch (kg) by species for the top five species by weight, and report effort data (location, time, duration, and distance) by tow, as well as providing vessel parameters such as length, breadth, and draught. Daily processed catch is also summarised on the TCEPR data, and describes the total greenweight of each species processed at sea to a series of gazetted processed states. Data from the FSU provide similar catch (kg) and effort data and vessel parameters for the earlier period for all species in the catch.

An extract of all tow-by-tow data were provided by the Ministry of Fisheries Information Management Group from the TCEPR database where the target species was SBW, for years

1989 to 2002, in January 2003. Also provided were data from areas defined as the Bounty Platform and Campbell Island Rise where the target species was defined as SBW but no catch was reported, and summarised daily catch data from all vessels that fished in the SBW fishery between 1989 and 2002. These data were combined with FSU data to include the 1986 to 1988 years, using linkage data provided by the Ministry of Fisheries Information Management Group. A total of 21 131 records was available for analysis (Table 2), of which 94% recorded a catch of SBW, and 6% recorded zero SBW catch. A total of 14 949 daily processing records was extracted and summarised by processed state. These data were used to identify the main processing category for each vessel by year.

2.1.2 Years used for analysis

Data analysis for the Campbell Island Rise was restricted to years 1986–2002. The fishery changed substantially in 1986 with the introduction of surimi vessels and associated changes in mean headline height, so comparison with earlier years is probably invalid (Chatterton 1996). For the Bounty Platform, analysis was restricted to years 1990–2002, as very little data (only eight tows) were available before 1990 (Table 2).

2.1.3 Definition of areas, sub-areas, and seasons for analysis

The areas defined for the analysis are based on the four stock boundaries Hanchet (1998a). Most effort is associated with the fisheries on the Campbell Island Rise and Bounty Platform, and so the analysis was restricted to these two fisheries. Although there are small spawning SBW fisheries on the Pukaki Rise and Auckland Islands Shelf in some years, these data sets include many tows targeting hoki, SBW, or other species outside the SBW spawning season.

The location of trawls made on the Campbell Island Rise and Bounty Platform used in the analyses are shown in Figure 1. For the Campbell Island Rise, the area was split into four sub-areas (1–4) as defined by Chatterton (1996) based on the start position (latitude and longitude) of each tow. Spawning typically occurs in sub-areas 2 and 4, whilst early season and late season fishing often occurs in sub-areas 1 and 3 respectively. The Bounty Platform was similarly divided into four sub-areas (Figure 1). Spawning typically occurs in sub-areas 2 and 4, whilst early season and late season fishing more commonly occur in sub-areas 1 and 3.

The spawning SBW fishery is relatively short, occurring mainly between late August and October. The timing of the start of the fishery largely depends on the availability of the fishing vessels, and the success of the west coast South Island hoki fishery, and the duration of the fishery varies between years. Catches tabulated by month for the Campbell Island Rise fishery (Table 3) indicate that most fishing takes place between August and October. To focus the Campbell Island Rise analysis on the main period of the fishery, catches were tabulated by shorter time periods during these three months (Table 4). The fishing weeks where most of the catches have been taken have fluctuated between years but have shown no overall trend through time. The core fishery for the Campbell Island Rise was therefore defined as the period from 1 September to 7 October. This core period includes 94% of the total catch for the area.

The fishery on the Bounty Platform is more protracted than on the Campbell Island Rise, typically beginning in mid to late August and ending after the first week of September (Table 5). The amount of catch taken by week during this short period is also quite variable between years. In most years the fishery operates from 22 August to 7 September. However, from 1992 to 1995 fishing started at least a week earlier. To maximise the amount of catch and effort data available – especially for those earlier years – we chose 15 August to 7 September as the core period. This core period includes 94% of the total catch for the area.

2.2 Description of the variables

The data extracted included details on fishing year, date, time, location, fishing gear parameters and vessel parameters, and catch for each tow. Additional variables were derived from the variables in the database. Most of these are self-explanatory, and variables, variable types, and descriptions are summarised in Table 6.

The recorded start date of each tow was used to determine the *day*, *month*, and *year* of each tow. *Bottom depth* is the depth of the sea floor recorded at the start of the tow in metres. *Net depth* is the depth of the groundrope in meters, while *headline height* records the net headline height above the groundrope during the tow. Because headline heights were often recorded to the nearest 10 m, headline height was also treated as a categorical variable *headline category* and separated into five categories: 0–15 m, 16–40 m, 41–75 m, over 75 m, and unknown following Chatterton (1996). *Difference* refers to the difference between bottom depth and groundrope depth. Tow *duration* was calculated as the difference (in hours) between the recorded start time and finish time of each tow. Tow *distance* was calculated as the product of *duration* and *speed* of tow.

Day of year represented the number of days since 1 January for each fishing year. *Day in season* was defined as the difference between the date of fishing and the date of the onset of spawning (defined as when 10% of the females were running ripe) in each year (Table 7). Ingerson & Hanchet (1995) noted that catch rates of SBW varied both diurnally and with height of the groundrope above the bottom, and found that a time-depth category based on the time of day and depth of the groundrope relative to the bottom was significant. Therefore, *start time of tow* and *end time of tow* were each grouped into six four-hour time categories (starting at 0001–0400). Four *time-depth* categories representing time of day (day or night) and depth of the groundrope relative to the bottom (greater than or less than 100 m off the bottom) were used following Ingerson & Hanchet (1995). The number of tows reported for the main variable categories are given in Table 8.

Vessel was included as a categorical variable in the analyses, where appropriate, following Dunn (2002) (see also Section 2.5 for more details). Vessel characteristics included *length* (length overall), *width*, *draught*, and *power*. *Year built* indicated the relative age of the vessel, and *nationality* represented nationality of registration. These two variables, combined with vessel *length*, were used to create the categorical variable *vessel category* (Ingerson & Hanchet 1995), which represented five classes of fishing vessel. Class 1 identified the smaller Japanese trawlers of the *Tomi Maru* class, class 2 represented mainly Russian and Ukrainian trawlers of the Atlantic class, class 3 represented larger, older Japanese surimi vessels (generally phased out of the fishery by 1990), class 4 represented the Soviet Super Atlantic class trawlers, and class 5 included all other vessels. *Vessel experience* represented the cumulative number of years that each vessel had completed at least five tows in that particular fishery. If a vessel fished less than five tows in a subsequent year, the level of vessel experience remained at the previous level. *Processing type* identified vessels as either 'surimi', or 'dressed' processing vessels, as defined on the MFish daily processing database, where the latter category also included catches reported as head and gut, fillet, dressed and greenweight catch.

Daily mean *wind speed* and daily *maximum wind speed* were extracted from the NIWA climate data for the Campbell Island weather station from 1986 to 2002. Surface temperature and net depth temperature were included in the data provided but were highly variable, with many zero records, and so were not included in the final analysis.

Some numerical variables may have a non-linear relationship with CPUE. Variables entered into the model as polynomials if the quadratic or cubic transformations explained more than 1% of variability in the model (D. Gilbert, NIWA, pers. comm., 2003).

2.3 Error checking and data correction

Catch and effort data commonly include many errors, such as missing or invalid codes, or implausible data. The data were plotted against raw CPUE and range checks (Table 9) were completed to identify outliers in the data (Dunn 2002). Relative frequency distribution plots were also completed to identify the ranges of variables included in the analysis (Appendix A, Figures A1–A3; Appendix B, Figures B1–B3). Error checks followed Ingerson & Hanchet (1995) and Chatterton (1996) where implausible records were checked for consistency with previous and subsequent values for each vessel, or set to missing where this was not possible.

Most errors concerned transposition of the reported net depth and bottom depth, but errors in reported tow location, speed, net depth, and bottom depth were reviewed and corrected. No corrections were made to tow duration, except to set values greater than 24 h duration to missing, and to delete tows of less than 10 minutes duration as probably representing gear failure. Tow distances greater than 100 km were set to missing, as there was usually more than one interpretation of errors in the reported values for these variables (Dunn 2002). No corrections were made to the recorded catch, except to exclude the small number of catches (seven observations) greater than 250 t from the analysis.

Of the 21 131 records available for analysis, 14 078 records were identified as from the Campbell Island Rise fishery and 12 706 records were included in the analysis. Of the 4305 records identified from the Bounty Platform fishery, 3597 records were included in the analysis.

2.4 Definition of vessel subsets

Preliminary examination of the raw CPUE data revealed that the surimi vessels had a much higher catch rate than dressed vessels in both the Campbell Island Rise fishery (Appendix A, Table A1) and the Bounty Platform fishery (Appendix B, Table B1). The distribution plots of vessel characteristics for each processing type (Appendix A, Figures A1–A3; Appendix B, Figures B1–B3) indicated that surimi vessels made tows of longer duration, and were able to achieve higher catches than dressed vessels.

A large proportion of the fleet that participated in the fishery was involved for a short period or conducted a limited number of tows. Core vessels were defined for each fishery and processing method, as those vessels that have participated in the fishery for at least three years, where a minimum of at least five tows per year were completed. This is similar to the definition of core vessels used by Dunn (2002) and Langley et al. (2001). The selection of the core criteria was sufficient to ensure overlap in the period 1990–94 in both fisheries. Numbers of vessels in each processing and core fishing category are given in Appendix A, Table A1 for the Campbell Island Rise fishery, and Appendix B, Table B1 for the Bounty Platform fishery. Insufficient data were available to separately analyse the core dressed vessels from the Bounty Platform.

2.5 Model structure

With the alternative vessel subsets, range of possible measures of effort, and range of model types in each fishery, a large number of different CPUE models were possible. We therefore took a hierarchical approach and began by using all vessels with a range of different measures of effort. As the resulting models had similar results, we chose one measure of effort for the remaining model runs. The performance of the remaining models was compared to this main model to determine the sensitivity of the results to the measure of CPUE used (catch per tow, catch per hour, or catch per day), the sensitivity to processing type (surimi vessels, dressed vessels etc), sensitivity to inclusion of zero catch records (using the binomial model), and the sensitivity to the time period included in the analysis.

A lognormal generalised linear model was used, and estimates of relative year effects were obtained from a manual stepwise multiple regression method in which the non-zero catch data were modelled following the procedure of Doonan (1991) using the Proc GLM (General Linear Modelling) procedure of the SAS statistical software (SAS 1999). Variables were progressively added to the model until less than 1% improvement was seen in r^2 (percentage of variance explained by the model) following the inclusion of each additional variable. As few observations were available for some vessel subsets, particularly for the Bounty Platform fishery, the F statistic was also examined for each additional variable. This was not significant at the 5% level for any variables included in the models.

The sensitivity of the model to the inclusion of zero tow records was examined by comparison with the 'combined' model of Vignaux (1994). This approach essentially models fishing success (non-zero catch, zero catch) using a binomial model, and combines the annual indices derived from the binomial model with the annual indices from the loglinear model of non-zero catch, scaling both indices by the proportion of zero catch in each year. The binomial analysis of fishing success was carried out using the Proc Genmod procedure of SAS, specifying a binomial distribution and a logistic link function (SAS 1999). A stepwise multiple regression procedure was followed, where the reduction in residual deviance, relative to the null deviance, was calculated for each term added to the base model, until less than 1% reduction in residual deviance was achieved by the inclusion of an additional variable.

For each model, the percentage of variance explained by the addition of each significant variable is tabulated, and the indices and their standard errors presented. The relative year effects for each model are illustrated graphically, providing comparisons where appropriate. Residual plots were examined for evidence of significant departures from model assumptions, and to determine the fit of the regression model to the data.

Preliminary analysis suggested that the categorical variable *vessel* was an important predictor of CPUE, so wherever possible this was included in the model. However, Dunn (2002) cautioned against its use for unbalanced data sets which include vessels with few records in only one or two years, because in these instances the vessel coefficients may strongly alias the year effect. To test whether the inclusion of the *vessel* variable was likely to be a problem, the year effects from the all vessels data sets were compared with the year effects from the core vessel data sets for each area (i.e., we assumed that the core vessels data sets were already balanced.) For the Campbell Island Rise the year effects were almost identical between the two data sets and there was therefore no evidence of a confounding effect between vessel and year. In contrast, for the Bounty Platform the two data sets gave conflicting results, and the vessel coefficients did appear to alias the year effect. Therefore, for all Bounty Platform models, except those using only core vessels, the *vessel* variable was not offered to the model.

However, one further potential problem emerged in the Bounty Platform analysis. For most of the all vessel model runs the variables selected for inclusion in the model invariably included several vessel characteristics (e.g., *processing type*, *nationality*, *length*, *vessel category*), many of which were highly correlated. In effect, these vessel characteristics appeared to be acting as a surrogate for the *vessel* variable. To test whether this was likely to be influencing the year effects, we carried out three further preliminary model runs. An all vessels model including the correlated vessel characteristics variables, a core vessels model including the correlated vessel characteristics variables, and a core vessels model including the *vessel* variable. Because only one core vessel was present in 1990, the analyses each covered only the period 1991 to 2002. The year effects from the three runs were similar, so we concluded that the occurrence of correlated predictor variables was not having a substantial influence on the year effects.

3. RESULTS FOR THE CAMPBELL ISLAND RISE STOCK

3.1 All vessels

A total of 183 vessels reported a positive catch of SBW in the Campbell Island Rise spawning fishery between 1986 and 2002, but the analysis was restricted to the 140 vessels that reported a minimum of five tows during this period. The number of tows targeting SBW in the main fishing period by year, the number of non-zero SBW tows, and total catch for each year from 1986 to 2002 are given in Table 10. The number of tows targeting SBW has fluctuated between 200 and 1183 per year since the late 1980s. The percentage of zero tows has ranged from 1% to 23% and averaged 6% overall.

Both surimi and dressed vessels fished in all years, although the relative importance of the two processing types has varied over the duration of the fishery. The catches and catch rates of the surimi vessels were much higher than for the dressed vessels (Appendix A, Table A1). Distribution plots for the major descriptive variables were suggestive of a change in fleet composition in the early 1990s. The new vessels that entered the fishery were visible as a discrete grouping within the *vessel experience* density plots (Appendix A, Figure A1). A trend of fishing later in the season relative to peak spawning was apparent, particularly after 1994. This is primarily because spawning has been earlier rather than a change in the onset of fishing (see Table 4). Mean *headline height* generally increased from 1986 to 2002, but little trend was apparent in *net depth, duration,* or *end time of tow* from these data.

3.2 Surimi vessels

A total of 23 surimi vessels participated in the fishery between 1986 and 2002. The total surimi catch has varied between 50 and 60% of the total catch (Table 10). Vessel numbers peaked at 14 in 1992, but have since declined, with only 5 surimi vessels fishing in 2002 (Appendix A, Table A1), and no single surimi vessel participated in the entire fishery. Mean catch rates for all surimi vessels are given in Appendix A, Table A1.

The 13 core surimi vessels accounted for about 75% of the total surimi catch from 1986 to 1992, and over 95% of the surimi catch in subsequent years (Table 10). Density plots (Appendix A, Figure A2) indicated a change in fleet composition in the early 1990s with a decrease in mean *length*, and a consistent increase in *vessel experience*. Mean *headline height* increased from 1986 to 1996, then remained stable. Mean *duration* of fishing and mean *catch* per tow have both more than doubled since 1986 (Appendix A, Table A1). Fishing has also occurred later in the season relative to peak spawning in recent years.

3.3 Dressed vessels

A total of 117 dressed processing vessels fished between 1986 and 2002, and these accounted for about 40% of total catch (Table 10). Most vessels fished for relatively few years, and vessel numbers peaked in the fishery from 1990 to 1992. The 25 core dressed vessels have accounted for about 60% of the non-surimi catch (Table 10). Density plots for the core dressed vessels (Appendix A, Figure A3) indicate an increase in *vessel experience* since about 1995. Also both mean *headline height* and mean *catch* per tow have increased from 1986 to 2002. A trend for fishing to occur later in the season is also apparent, except for 1993 and

1998. Mean catch rates for all dressed and core dressed vessels are given in Appendix A, Table A1. In contrast to the surimi vessels, *tow duration* and *catch* per tow have remained relatively constant over time.

3.4 Catch-per-unit-effort indices

Nine models were evaluated for the Campbell Island Rise fishery (Table 11), and details are provided below for the all vessels catch per tow model. The alternative analyses evaluated for different measures of effort (catch per hour, catch per day), processing type (surimi, dressed), inclusion of zero catch data, and years were included in the analysis as sensitivities, and are discussed where they differ from the main model. Further details of these models are provided in Appendix A, Tables A2–A6 and Figure A4.

3.4.1 All vessels catch per tow model

The variables *vessel, year, end time of tow*, and *day in season* entered the all vessels catch per tow model and explained 32% of the variation (Table 12). The *vessel* variable explained over 25% of the data variability. Year effects and standard errors are given in Table 13, and illustrated in Figure 2. The diagnostics indicate a reasonable pattern in the residuals, but the Q-Q plots indicate a deviation from the normal distribution of the residuals at the lower and upper ends, suggesting that very small and very large values of catch rate are not well predicted (Figure 3). This suggests that the models can be improved, and there may be violations of model assumptions.

Plots of the significant variables against CPUE are shown in Figure 4. The *end time of tow* variable was a proxy for fishing time, and indicated catch rates were maximised during the day. The *day in season* variable indicated CPUE was maximised at peak spawning. The *vessel* effect suggested a wide range of relative fishing powers, with expected catch rates ranging from about 3 to 25 t per tow.

3.4.2 Sensitivity to measures of effort

The variables *vessel, year, end time of tow, day in season*, and *sub-area* entered the all vessels catch per hour model, together explaining 25% of data variability (Appendix A, Table A2). The annual indices were similar to the all vessels catch per tow model (Figure 5). Patterns in the other significant variables were also similar, but the variable *sub-area* entered the model, and catch rates were higher in area 4 to the south.

The variables *vessel, number of tows per day, year, distance*, and *day in season* entered the all vessels catch per day model, together explaining 44% of data variability (Appendix Table A2). There were positive relationships between *number of tows per day* and CPUE, and between *distance* fished and CPUE. The year effects followed similar trends to the catch per tow and catch per hour models (Figure 5). The year effects, standard errors, and raw CPUE for these models are given in Appendix A, Table A3.

These models were generally similar in their regression diagnostics to the catch per tow model, but the catch per hour model was a slightly better fit at higher catch rates (Appendix A, Figure A4). All models were a poor fit to the data at low catch rates

3.4.3 Sensitivity to processing type

Models were run on the all dressed, core dressed, all surimi, and core surimi datasets. The year effects were almost identical between the all vessel and core vessel data sets for a particular processing type, so only core datasets are presented here.

Variables *year, vessel, duration, day in season, end time of tow, difference* (between headline and groundrope depth), and *sub-area* entered the core surimi catch per tow model and explained 31% of data variability (see Appendix A, Table A2). Variables *year, vessel, day in season,* and *end time of tow* entered the core dressed catch per tow model together explaining 18% of data variability.

The year effects for these models showed similar trends and followed a similar pattern to the all vessel model (Figure 6; Appendix A, Table A4). Regression diagnostics indicated these models were a less satisfactory fit to the data than the all vessels model. The model fits were poor, especially for lower and higher catch rates, and the standard errors were high for the core surimi model (Appendix A, Figure A4).

3.4.4 Sensitivity to zero catch data

The variables *vessel, year, distance,* and *nationality* entered the binomial model (Appendix A, Table A5). The variables and year effects for the non-zero tows are the same as for the all vessels catch per tow model (see Section 3.4.1). Although there was some variation in zero tows between years, the inclusion of the zeros had little impact on the year effects from the catch per tow model (Figure 7; Appendix A, Table A6).

3.4.5 Sensitivity to number of years included in analysis

There was a change in the fleet composition and fishing practices in the early 1990s (see Appendix A, Figures A1–A3), so a separate model was run for the years 1992 to 2002. Variables *vessel, year, day in season, start time of tow,* and *duration* entered the model, and together explained 39% of data variability (see Appendix A, Table A5). This model explained more variability than the all years model (33%) and model diagnostics indicated it was a slightly better fit to the data (Appendix A, Figure A4), but year effects show similar trends for both models (Figure 8). Patterns among the significant variables for these models were generally similar to the trends described for the all years model (see Section 3.4.1).

4. RESULTS FOR THE BOUNTY PLATFORM STOCK

4.1 All vessels

This fishery differs from the Campbell Island Rise fishery in that it has had large fluctuations in catch, effort, and number of vessels operating in the fishery between years. The fishery developed rapidly from a catch of 4000 t in 1990, to a peak of over 50 000 t in 1992 (Table 14). A second smaller peak in fishing occurred in 1999, with a catch of 8300 t. Of the 89 vessels that participated in the Bounty Platform fishery, most fished only during the early 1990s. These early years were characterised by large numbers of dressed vessels, and a few large, older surimi vessels. Since then the fishery has been dominated by a group of smaller, more efficient, surimi vessels (Appendix B, Table B1 and Figures B1–B3).

Total fishing effort has fluctuated considerably increasing from 252 tows in 1990, peaking at 1570 tows in 1992, then declining to 94 tows in 2002 (Table 14). The percentage of zero tows has fluctuated considerably from 4% in 1992 to 28% in 1997, and averaged 9% (Table 14). Distribution plots indicated high variation but little trend in mean *length*, *headline height*, mean *catch* per tow, and *duration* of fishing over the time period (Appendix B, Figure B1). Over the course of the fishery, mean *net depth* has decreased slightly, *longitude* has increased with vessels fishing further east, and mean *day in season* has decreased with more tows being made closer to the peak of spawning. Mean *vessel experience* has generally increased over time. One group of surimi vessels entered the fishery in the early 1990s, whilst a group of dressed vessels were present in the fishery from 1998 to 2000 (Appendix B, Figures B1–B3).

4.2 Surimi vessels

Over 20 surimi vessels participated in the Bounty Platform fishery between 1990 and 2002. The total surimi catch has varied between 35 and 100% of the total catch (Table 14). Vessel numbers peaked at 14 in 1992, but have otherwise ranged from 4 to 6 vessels per year (Appendix B, Table B1), and no single surimi vessel participated in the entire fishery. Mean catch rates for all surimi vessels are given in Appendix B, Table B1.

The core surimi fleet comprised six vessels, and has been a very consistent feature of the fishery over the past 7–8 years as shown by the steady increase in *vessel experience* (Appendix B, Figure B2). Over the course of the fishery, tow *duration* and *catch* per tow have fluctuated considerably with no trend, *day in season* and *net depth* have both decreased, whilst *longitude* has increased. The other variables have remained relatively constant since 1990.

4.3 Dressed vessels

A total of 70 dressed vessels participated in the fishery between 1990 and 2002. While 33 vessels were operating in 1992, most fished for only one or two years, and only two dressed vessels fished in 2002 (Appendix B, Table B1). This is consistent with the low mean *vessel experience* indicated in the distribution plots (Appendix B, Figure B3). The remaining data are sparse but in general show similar trends to the surimi fleet.

4.4 Catch-per-unit-effort indices

Seven models were evaluated for the Bounty Platform fishery (Table 15), and details are provided below for the all vessels catch per tow model. The alternative analyses evaluated for different measures of effort (catch per hour, catch per day), processing type (surimi, dressed), and inclusion of zero catch data were included in the analysis as sensitivities, and are discussed where they differ from the main model. Further details of these models are provided in Appendix B, Tables B2–B7 and Figure B4.

4.4.1 All vessels catch per tow model

The CPUE model for all vessels included the variables *processing type, year, vessel category, length*, and *nationality*, and explained 32% of the variation (Table 16). The year effects fluctuated considerably, peaking in 1992, 1996–1998, and again in 2002 (Figure 9, Table 17). The diagnostics indicate a reasonable pattern in the residuals, but the Q-Q plots indicate a deviation from the normal distribution of the residuals at the lower and upper ends, suggesting that very small and very large values of catch rate are not well predicted (Figure 10). This suggests that the models can be improved, and there may be violations of model assumptions.

Plots of the significant variables against CPUE are shown in Figure 11. The catch rate of surimi vessels was higher than for dressed vessels, and catch rates were considerably higher for Japanese vessels than for other nationalities. Catch rate increased with vessel *length*. CPUE also varied with *vessel category*, being higher for the newer, more efficient surimi vessels (categories 1 and 2) than for older vessels (categories 3–5).

4.4.2 Sensitivity to different measures of effort

The variables *year, nationality,* and *tonnage* entered the all vessels catch per hour model, and explained 13% of data variability (Appendix B, Table B2). The variables *nationality, number of tows per day, year, vessel category, length,* and *distance* entered the catch per day model, and explained 38% of data variability (Appendix B, Table B2). The year effects for these models generally followed similar trends to the catch per tow model (Figure 12). However, the indices for the catch per hour model were substantially different in 1991, 1994, and 2001. The reason for this is unknown. The year effects, standard errors, and raw mean CPUE are given in Appendix B, Table B3. The catch per day model showed a poor fit to the data (Appendix B, Figure B4). The catch per hour model fit to the data was similar to that for catch per tow.

4.4.3 Sensitivity to vessel processing type

Models were run on the all dressed, all surimi, and core surimi catch per tow datasets, as insufficient data were available from the core dressed dataset to provide meaningful analysis. Because of insufficient data, the all surimi dataset was restricted to the years 1991–2002, and the core surimi dataset to the years 1992–2002.

Variables *year, length, distance, vessel category, year built,* and *tonnage* entered the all surimi model, and explained 23% of data variability (Appendix B, Table B4). Variables *year, vessel, headline category, year built, distance,* and *tonnage* entered the core surimi model, and explained 28% of data variability (Appendix B, Table B4). Variables *year, length,* and *headline category* entered the all dressed model, and explained 23% of data variability (Appendix B, Table B4). From 1990 to 1997 the annual indices for these models showed similar trends, and followed a generally similar pattern, to the all vessel model (Figure 13). After 1997 the year indices were very erratic between years and inconsistent amongst vessel subsets. Annual indices, standard errors, and raw CPUE are given in Appendix B, Table B5. Regression diagnostics indicated poor fits to the data for all models (Appendix B, Figure B4).

4.4.4 Sensitivity to zero catch

The variables *year, nationality, start time of tow, processing type,* and *sub-area* entered the binomial model (Appendix B, Table B6). The variables and year effects for the non-zero tows are the same as for the all vessels catch per tow model (see Section 4.4.1). Although there was some variation in zero tows between years, the inclusion of the zeros had little influence on the year effects from the catch per tow (Figure 14; Appendix B, Table B7).

5. DISCUSSION

Dunn et al. (2000) noted that calculation of CPUE indices does not necessarily result in an index which is related to abundance. They cautioned against the use of CPUE indices in stock assessment models until several aspects of the analysis had been evaluated and the

CPUE indices themselves had been validated by fishery independent data. They recommended that CPUE analysis include discussion of:

1. definition of the relationship between CPUE and fish abundance,
2. assessment of data adequacy,
3. methods of model fitting and validation, and
4. evaluation of the CPUE index in an attempt to validate the data selection, model method, and results.

5.1 Definition of the relationship between CPUE and fish abundance

For the analysis and interpretation of the indices we have assumed a simple direct relationship between CPUE and abundance. However, the SBW fishery is a highly aggregated spawning fishery. Furthermore, fishers actively search for the dense aggregations using forward scanning sonar and then target these marks. There is, therefore, potential for there to be a hyperstable CPUE/abundance relationship (Dunn et al. 2000). A hyperstable relationship is one where CPUE remains high whilst abundance declines. The time spent searching for marks is not currently recorded on the catch and effort (TCEPR) forms. It is theoretically possible to try and take account of searching in the analysis, but in practice the time spent not fishing includes time lost due to bad weather, mechanical breakdowns, and down time whilst waiting to process the previous catch. A better way to test for a hyperstable relationship is through a fishery-independent evaluation of the model (see Section 5.4).

5.2 Assessment of data adequacy

For each area the number of tows used in the analysis is 90–95% of the total number of tows from the fishery. For the Campbell Island Rise there is a minimum of 200 tows for each year of the fishery, and good coverage of the core fishing period from 1 September to 7 October. Although there has been a tendency for more catch to be taken later in the season (Appendix A, Figure A1), this should be accounted for by the variable *day in season*. There have also been reasonable numbers of tows for each of the vessel subsets by year. For the Bounty Platform analysis the total number of tows is highly variable between years, dropping to 36 tows in 1997 and only 28 tows in 2002. The timing of the Bounty Platform fishery has also been inconsistent between years. The number of tows for the vessel subsets, in particular for the dressed vessels, has been very low or zero in several of the years. In general then, data are adequate for the Campbell Island Rise analysis, but probably less than adequate for some years for the Bounty Platform analysis.

5.3 Model fitting and model validation

Model fitting and model validation were considered by comparing the explanatory variables, the variation explained (r^2), the diagnostic plots, and the year effects between the different models.

For the Campbell Island Rise fishery, the variables *vessel*, *year*, *end time of tow*, and *day in season* were selected for most models by the stepwise regression technique and most models also included a measure of effort. Vessels operating in the fishery vary considerably in size and fishing power, and the importance of this as an explanatory variable is consistent with our understanding of the fishery. There was a strong trend in CPUE coinciding with the peak of spawning, and with time of day, as has been found in previous standardised CPUE analyses of this fishery (Ingerson & Hanchet 1995, Chatterton 1996).

The percentage of variation (r^2) explained by the models for the Campbell Island Rise fishery ranged from 18 to 45%. These values are similar to those found in other CPUE analyses. In general, the diagnostics indicate reasonable patterns in the residuals, but the Q-Q plots indicate a deviation from the normal distribution of the residuals particularly at the lower end, suggesting that very small values of catch rate are not well predicted. This suggests that the models can be improved, that there may be violations of model assumptions, and that the variance is not well estimated in the models. The year effects showed very similar trends for each of the different models.

For the Bounty Platform fishery, the variables selected for inclusion in the model included mainly vessel characteristics (e.g., *nationality*, *length*, *vessel category*, *tonnage*, *year built*). Even in the core surimi model, where *vessel* was included as a variable, *year built* and *tonnage* were still both selected for the model. Three of the models included a measure of effort (*distance*), whilst *headline category* was the only other significant non-vessel variable. The reason for the large difference between the variables entering the Bounty Platform and the Campbell Island Rise models is unknown. These could relate to the less balanced design and more patchy Bounty Platform data, or could be due to real differences in fish and fleet behaviour between the two areas.

The percentage of variation (r^2) explained by the models for the Bounty Platform fishery ranged from 12 to 38%. These values were slightly lower than those for the Campbell Island Rise fishery but similar to those found in other CPUE analyses.

In general, the diagnostics indicate reasonable patterns in the residuals, but the Q-Q plots indicate deviations from the normal distribution of the residuals at the lower and upper ends, suggesting that very small and very large values of catch rate are not well predicted. This suggests that the models can be improved, that there may be violations of model assumptions, and that the variance is not well estimated in the models. The diagnostics were worse for the catch per day and vessel subsets models. The year effects showed similar trends for each of the different models over the period 1990–97. However, after 1997 the year effects were more erratic between years and were particularly inconsistent amongst vessel subsets.

In summary, the Campbell Island Rise models were generally consistent with respect to the trends among year effects, the variables that entered the models, the proportion of variance explained by each model, and in the patterns of the diagnostics. The Campbell Island Rise analysis therefore appears moderately robust and believable. In contrast, the Bounty Platform models were not entirely consistent with respect to the trends among year effects. The variables that entered the model were mostly related to vessel characteristics and at least some were correlated. Although there was no evidence that this had a large influence on the year effects, it is not a desirable feature in regression analyses. Also in general, the proportion of variance explained by each model was lower than for the Campbell Island Rise, and the diagnostics, particularly for the vessel subsets models, were worse than for the Campbell Island Rise. This raises some doubts over the robustness and usefulness of the Bounty Platform analysis.

5.4 Evaluation and validation of the CPUE index

The calculation of CPUE indices and their use in a model assumes that the resulting index is an adequate index of true abundance. Validation of the assumption is difficult and usually relies on the use of external data for comparison – but often the ability of such external data to index the true abundance is uncertain. However, some information on abundance for southern blue whiting is known. Firstly, we compare the indices resulting from the CPUE analysis with estimates of biomass derived from recent NIWA assessments (Hanchet 2002, Hanchet et al. 2003). Secondly, we compare and contrast model biomass trajectories fitted with and without the CPUE indices.

We also examine residual patterns of fits to the CPUE indices for trends and to identify outliers. Trends in residuals might indicate changes in catchability over time.

5.4.1 Campbell Island Rise

Comparison of the CPUE indices with the assessments

For the Campbell model we decided to use the results of the most recent assessment carried out in 2003 for the comparison (Hanchet et al. 2003). Because this was a new assessment, a number of initial runs had been made to explore the sensitivity of the results to changes in the various model assumptions and priors. Four main runs captured most of the variability. These runs differed in the priors used for the adult (4+) acoustic q and in whether or not natural mortality was estimated in the model. For the final assessment the Working Group agreed to use two of those runs as base cases. In base case 1 the adult acoustic q had a log-uniform (uninformative) prior, and in base case 2 it had a lognormal (informative) prior. In both base cases natural mortality was estimated in the model with a lognormal prior. In a third sensitivity run also considered here natural mortality was fixed at 0.2 and the adult acoustic q had a log-uniform prior.

We compared the results of the CPUE indices to the estimates of mid-season spawning stock biomass (SSB) from the population model for these three assessments. The estimates of SSB came from the median estimates calculated from the Monte Carlo Markov Chain (MCMC) samples (see Hanchet et al. 2003 for details). To make the data sets comparable, the CPUE indices and the biomass estimates for each series were first standardised to their means. Preliminary examination showed that the three assessments were almost identical when standardised to their means (Figure 15), so only the plots for base case 2 are shown in other comparisons. We also wanted to plot the acoustic indices on one of these figures as estimates of mid-season spawning biomass. However, the indices are available only as biomass estimates of age 2, 3, and 4+ fish. About 50% of the fish are recruited at age 3, and about 95% at age 4. So SSB was calculated for each year by adding the 4+ biomass to half of the age 3 biomass.

The results of the comparisons are shown in Figure 16. All the CPUE indices show similar patterns to the population model, with a decline from 1986 to 1992, an increase to 1996, and a decline to 2002. The relationship between the CPUE models and the abundance over these three time periods appears to be quite different. Over the period of low abundance from 1986 to 1992, most of the CPUE models appear to show some degree of hyperstability (i.e., overestimate abundance). As an example, the all vessels catch per tow CPUE is plotted against the model abundance index in Figure 17. Values to the left of the y=x line are hyperstable. The year effect reaches its minimum in 1992 in all CPUE models, which is consistent with the population model and the perception of the stock status at that time. In that year over 50 vessels were fishing the Campbell fishery for over a month and the total catch was only 14 000 t. In the preceding month about 35 of these vessels had caught over 60 000 t of SBW on the Bounty Platform.

The stock abundance showed a large increase from 1993 to 1996 as the very strong 1991 year class recruited to the fishery. Interestingly, none of the CPUE models can match the large rate of increase in the abundance estimated by the population model, with all the 1995 year effects being substantially less than would be expected. This could be a feature of the availability and distribution of the new recruits in relation to the fishing fleet. Most fishing in that year was in latitudes 51–52°S on the northern ground (see Appendix A, Figure A1), whereas a substantial number of the new recruits would have been in the south, as confirmed by the 1995 SBW acoustic survey results (Ingerson & Hanchet 1996). By 1996 most of the CPUE indices had increased to the level of the stock abundance.

The stock abundance declined from 1996 to 2002 as the 1991 year class was fished down and no new strong year classes entered the fishery. The CPUE indices show various levels of decline over this period, with most ending up slightly above the modelled abundance. A feature of all the CPUE models is a marked peak in the year effect in 1999 – similar to those seen in 1989 and 1991. The reason for this is unclear.

Inclusion of the CPUE indices in the assessments

In this analysis the intention was to run the SBW assessment model including each of the catch per tow and catch per hour CPUE indices in turn. Two main runs were considered for each CPUE index: one where the model was fitted to the CPUE index, acoustic index, and age data; and a second where the model was just fitted to the CPUE index and age data (i.e., the acoustic indices were excluded).

Because the acoustic indices were to be excluded in one of the runs, it was not possible to use base case 2, which had the informative prior on the acoustic q. We initially tried a run based on the base case 1 assessment including only the age data and CPUE indices. However, in the MPD run the estimates of natural mortality were very low (0.12), and were not considered sensible. We therefore based all the comparisons on a model where natural mortality was fixed at 1, and where the prior for the acoustic q was uninformed (uniform-log). This is the third option considered above. The assessment was identical in all other respects to the base case assessments accepted by the Working Group. As with the main SBW assessment (Hanchet et al. 2003), the process error on each of the data sets was estimated in each run of the model.

Mid-season spawning stock biomass trajectories for the three model runs were very similar for both catch per tow and catch per hour models, and so only the former are presented (Figure 18). The inclusion of the CPUE index resulted in a slightly lower population biomass trajectory for the models comprising all three data sets, and a further reduction when the acoustic index was excluded. The assessment model appeared to fit the catch per hour data set better – particularly in the early part of the series (Figure 19). This observation is supported by the model results where a process error c.v. of 0.22 was estimated for the catch per hour index compared to a c.v. of 0.29 for the catch per tow index.

5.4.2 Bounty Platform

Comparison of the CPUE indices with the assessments

For the Bounty Platform model we used the results of the most recent assessment carried out in 2002 for the comparison (Hanchet 2002). The 'base case' NIWA results of the 2002 Bounty assessment were very pessimistic, and so an alternative run was provided where the adult (4+) acoustic q was fixed at 1.4. At the time this was the best estimate of this parameter. The alternative assessment was more optimistic and has since been adopted by the Fishery Assessment Plenary as being a more credible assessment (Annala et al. 2003).

We compared the results of the CPUE indices to the estimates of mid-season spawning stock biomass (SSB) from the population model for these two assessments. The estimates of SSB came from the maximum likelihood fit (see Hanchet 2002 for details). Preliminary examination showed that the two assessments were very similar when standardised to their means so only the plot for the alternative assessment is presented. Estimates of mid-season spawning stock biomass from the acoustic surveys were calculated for each year by adding the 4+ biomass to one third of the age 3 biomass. This is because about 30% of the fish are recruited at age 3, and about 95% at age 4.

The CPUE indices for the three all vessels models show moderately similar patterns to the population model. They peak in the early 90s, drop to a low in 1994, and then peak again to a lesser extent between 1996 and 1998 (Figure 20). The main differences to the population model are in the first two years and in the last two years. The CPUE indices may be substantially lower in the first two years because of lack of experience. The Bounty Platform grounds are harder to fish than the Campbell grounds, and this was the first time that any of the vessels had fished the Bounty Platform. The reason for the discrepancy in the last two years is more difficult to explain. In 2001, the vessels spent a considerable amount of time searching the grounds, and were unable to find any large aggregations of SBW (Hanchet et al. 2002). The schools they did find were small and typically supported only a single nights fishing. The low acoustic survey estimate was therefore consistent with reports from the commercial vessels and also with the underlying age structure, which showed no large pulse of recruits. Perhaps because of this searching, the commercial vessels were able to maintain their high catches even if the abundance was depressed. The even higher CPUE in 2002 is again inconsistent with the predicted stock status from the population model. This apparent hyperstability can be seen in Figure 17, and is similar to that experienced in the early years of the Campbell Island Rise series.

The CPUE indices for the vessel subset models again show similar patterns to the population model (Figure 21). However, they tend to be somewhat more variable than the *all vessel* models. The all surimi vessel model in particular shows quite erratic year effects in 1993, 1999, and 2000. Trouble was experienced in deriving a stable model for the all surimi and core surimi models (Section 4.3.4), and so the early years were removed from the analysis. It is possible that the presence of older and larger surimi vessels at the beginning of the fishery might still be confounded with the year effects. Perhaps alternative parameterisation of some of these variables may improve their behaviour. The all dressed vessel indices appear to follow the population model better than the all surimi vessels model, and interestingly has a much lower 2002 index which would be more consistent with the projected population in 2002. However, the all dressed model suffers from a small amount of data and shouldn't be used by itself as an index.

Inclusion of the CPUE indices in the assessments

In this section the intention was to run the 2002 separable Sequential Population Analysis (sSPA) model including each of the catch per tow and catch per hour CPUE indices in turn. Two main runs would be considered for each CPUE index: one where the model would be fitted to the CPUE index, acoustic index and age data; and a second where the model would be just fitted to the CPUE index and age data (i.e., the acoustic indices would be excluded). However, the 2002 assessment was run using the sSPA model and does not have the functionality of CASAL. The 2002 assessment was also very uncertain and, as stated above, an alternative assessment made by fixing q at 1.4 was believed to be more credible. The weighting given to any CPUE indices included in the model would also be quite arbitrary and the assessment could be quite sensitive to this weighting. Therefore at this stage we have presented only a single run with the CPUE data in the model. This run included the age and acoustic data using the original weightings used in the 2002 assessment, and in addition the CPUE indices for the all vessels catch per tow model. The CPUE data were given a low weighting in the model equivalent to a c.v. of about 70%. The results of the run are shown in Figure 22. The population trajectory including the CPUE index is very similar to the run where the acoustic q was arbitrarily fixed at 1.4. The fit of the CPUE indices to the trajectory is moderately good – although note that the model was only run up to 2001. However, the preliminary results look encouraging and we recommend that the modelling work be continued in 2004 when a new assessment of the Bounty stock is proposed.

6. CONCLUSIONS

6.1 Campbell Island Rise

The CPUE models for the Campbell Island Rise were all remarkably consistent. The models had similar significant explanatory variables, similar r^2 values, similar diagnostics, and very similar year effects. Although we chose the all vessels catch per tow model as the main model in the report, this decision was quite arbitrary. All of the other models were very similar and could equally have been chosen.

The variables that entered into the model are consistent with our understanding of the fishery. As would be expected in this kind of fishery, *vessel* was the most important variable in most models. There was a significant relationship between CPUE and *day in season* in all models with CPUE peaking as the fish started spawning. There was also a significant relationship between CPUE and *end time of tow* in most models, with CPUE peaking during the daylight hours when the fish are more highly aggregated. Both these variables were also significant in earlier CPUE analyses of the Campbell Island Rise fishery (Ingerson & Hanchet 1995, Chatterton 1996).

All the CPUE indices show very similar trends to the population model, with a decline from 1986 to 1992, an increase to 1996, and a decline to 2002. However, the relationship between the CPUE models and the abundance over these three time periods appears to be quite different. Over the period of declining low abundance from 1986 to 1992, most of the CPUE models appear to show some degree of hyperstability. Over the period of rapidly increasing stock abundance from 1993 to 1996, the CPUE models increased but were unable to match the large increase shown by the stock. Over the period of stock decline from 1996 to 2002 the CPUE indices became more variable, with some declining and others remaining relatively stable. The indices themselves also became more erratic, with all showing peaks in CPUE in 1999, however, all ended up at a similar level to the modelled stock abundance.

When the CPUE indices were fitted in the stock assessment model (with and without the acoustics data) the results were very similar to models using only the acoustics data. Examination of the model fits suggested that the model fitted the catch per hour indices better than the catch per tow indices. This observation is supported by the model results, where the process error c.v. of 0.22 was estimated for the catch per hour index compared to a c.v. of 0.29 for the catch per tow index.

We conclude that the CPUE indices for the Campbell Island Rise are monitoring the stock abundance and should be used in future stock assessments. However, we also note that there can be considerable variability in the CPUE indices for individual years, and that several years' data may often be necessary before any trends become apparent

6.2 Bounty Platform

The CPUE indices derived for the Bounty Platform were less consistent than for the Campbell Island Rise. The Bounty Platform models had a wider range of significant explanatory variables, slightly lower r^2 values, slightly worse diagnostics, and less consistent year effects than models for the Campbell Island Rise. Although we chose the all vessels catch per tow model as the main model in the report, this decision was quite arbitrary. Many of the other models gave similar results and could equally have been chosen.

The variable *vessel* was not offered as an explanatory variable to most of the models because there was concern that it was a smaller dataset than the Campbell, and that it might lead to an unbalanced design (see also Dunn 2002). Instead, various other vessel identifiers including *nationality*, *length*, *vessel category*, *tonnage*, and *year built* were all the main significant variables in the models. The variable *distance towed* was significant in three of the models and the variable *headline category* was important in two others. Some of these vessel characteristics were correlated and there was some concern that this may have become confounded with the year effects in the model. However, the similarity of the year effects between different models run with and without the *vessel* variable allayed these concerns to some extent (see Section 2.5).

The CPUE indices for the models show moderately similar patterns to the population model. They peak in the early 90s, drop to a low in 1994, and then peak again to a lesser extent between 1996 and 1998. The main differences to the population model are in the first two years and in the last two years. The CPUE year indices may have been substantially lower in the first two years because of lack of experience. The Bounty Platform grounds are harder to fish than the Campbell grounds, and this was the first time that any of the vessels had fished the Bounty Platform. The reason for the discrepancy in the last two years is more difficult to explain, but is suggestive of hyperstability.

The results of the 2002 Bounty stock assessment were very uncertain, so we carried out only a single model run using a CPUE index. We fitted the sSPA model to the acoustics data, the age data, and the all vessels CPUE index for catch per tow. The population trajectory including the CPUE index was very similar to a run reported in the assessment where the acoustic q had been arbitrarily fixed at 1.4, and more optimistic than the original 'base case' 2002 assessment, which has since been rejected. The fit of the CPUE indices to the trajectory was also moderately good, although the model was only run up to 2001.

We tentatively conclude that the CPUE indices for the Bounty Platform are monitoring the stock abundance, at least for some of the time. The suggestion of some hyperstability in the most recent years is a concern. This could be addressed through incorporating other variables, such as time spent searching as predictor variables. However, this is a difficult variable to determine from the existing catch and effort database. We also note that there can be considerable variability in the CPUE indices for individual years, and that several years' data may often be necessary before any trends become apparent. A new assessment of the Bounty stock is being conducted in 2004 using CASAL, and we recommend that estimation of the CPUE indices be revisited, and the CPUE indices be more fully examined in a modelling context before they are fully endorsed.

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Table 1: Estimated catches (t) of southern blue whiting by area for the period 1978 to 2002–03 from vessel logbooks and QMRs. – no catch limit in place. Estimates for 2002–03 are preliminary. *, before 1997–98 there was no separate catch limit for Auckland Islands.

Fishing year	Bounty Platform (SBW6B)		Campbell Island Rise (SBW6I)		Pukaki Rise (SBW6R)		Auckland Islands Shelf (SBW6A)		Total (All areas)	
	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit*	Catch	Limit
1978*f*	0	–	6 403	–	79	–	15	–	6 497	–
1978–79+	1 211	–	25 305	–	601	–	1 019	–	28 136	–
1979–80+	16	–	12 828	–	5 602	–	187	–	18 633	–
1980–81+	8	–	5 989	–	2 380	–	89	–	8 466	–
1981–82+	8 325	–	7 915	–	1 250	–	105	–	17 595	–
1982–83+	3 864	–	12 803	–	7 388	–	184	–	24 239	–
1983–84+	348	–	10 777	–	2 150	–	99	–	13 374	–
1984–85+	0	–	7 490	–	1 724	–	121	–	9 335	–
1985–86+	0	–	15 252	–	552	–	15	–	15 819	–
1986–87+	0	–	12 804	–	845	–	61	–	13 710	–
1987–88+	18	–	17 422	–	157	–	4	–	17 601	–
1988–89+	8	–	26 611	–	1 219	–	1	–	27 839	–
1989–90+	4 430	–	16 542	–	1 393	–	2	–	22 367	–
1990–91+	10 897	–	21 314	–	4 652	–	7	–	36 870	–
1991–92+	58 928	–	14 208	–	3 046	–	73	–	76 255	–
1992–93+	11 908	15 000	9 316	11 000	5 341	6 000	1 143	–	27 708	32 000
1993–94+	3 877	15 000	11 668	11 000	2 306	6 000	709	–	18 560	32 000
1994–95+	6 386	15 000	9 492	11 000	1 158	6 000	441	–	17 477	32 000
1995–96+	6 508	8 000	14 959	21 000	772	3 000	40	–	22 279	32 000
1996–97+	1 761	20 200	15 685	30 100	1 806	7 700	895	–	20 147	58 000
1997–98+	5 647	15 400	24 273	35 460	1 245	5 500	0	1 640	31 165	58 000
1998–00†	8 741	15 400	30 386	35 460	1 049	5 500	750	1 640	40 926	58 000
2000–01#	3 997	8 000	18 055	20 000	2 864	5 500	37	1 640	24 963	35 140‡
2001–02#	2 261	8 000	29 999	30 000	230	5 500	10	1 640	32 500	45 140‡
2002–03#	7 464	8 000	31 847	30 000	321	5 500	539	1 640	40 172	45 140‡

f 1 April–30 September
\+ 1 October–30 September
† 1 October 1998–31 March 2000
\# 1 April–31 March
‡ SBW 1 (all EEZ areas outside QMA6) had a TACC of 8 t, and reported catches of 9 t in 2000–01, 1 t in 2001–02 and <1 t in 2002–03.

Table 2: Total number of tows by year and area. Sources, FSU database 1986 to 1988, TCEPR catch effort data 1989 to 2002.

Year	Auckland Islands	Bounty Platform	Campbell Island Rise	Pukaki Rise	Total
1986			1 179	180	1 359
1987	4	1	875	14	894
1988	1		803	0	804
1989	1	7	1 013	143	1 164
1990	2	265	1 046	153	1 466
1991	5	660	1 238	248	2 151
1992	4	1 835	1 592	432	3 863
1993	*19*	*434*	*424*	*326*	*1 203*
1994	19	175	482	63	739
1995	7	166	293	52	518
1996	5	72	480	9	566
1997	17	41	661	45	764
1998	26	117	971	44	1 158
1999	7	294	791	54	1 146
2000	24	98	522	247	891
2001	63	38	731	302	1 134
2002	72	102	977	160	1 311
Total	276	4 305	14 078	2 472	21 131

Table 3: Total estimated catches (t) of SBW in the Campbell Island Rise fishery by time period, 1986 to 2002. Source: TCEPR, FSU data.

Year	Jan–Mar	Apr–Jun	Jul	Aug	Sep	Oct	Nov-Dec	Total
1986				1 821	12 093	786		14 700
1987				830	10 831	487		12 148
1988				478	15 595	14		16 087
1989				283	25 807			26 090
1990			1		16 572	26		16 599
1991					21 831			21 831
1992		222	47	170	13 273			13 712
1993				631	8 297	21		8 949
1994					11 131	585		11 716
1995		17	26		9 254	885	23	10 205
1996	14			42	14 161	2 493		16 710
1997					14 110	5 689		19 799
1998					21 103	3 218	1	24 322
1999			70		25 418	1 605		27 093
2000	8	1			14 393	57	1	14 460
2001	90			2 162	21 099	1 298	17	24 666
2002	731	162	405	3 181	24 426	742		29 647
Total	853	402	549	9 598	297 394	17 906	42	308 744

Table 4: Total estimated catches (t) of SBW in the Campbell Island Rise fishery from August to October, 1986 to 2002. Core fishing season used for analysis indicated in bold. Source: TCEPR data, FSU data.

Year	Aug 1–21	Aug 22–31	Sep 1–7	Sep 8–14	Sep 15–21	Sep 22–28	Sep 29–30	Oct 1–7	Oct 8–14	Oct 15–28
1986	363	1 459	**3 026**	**3 472**	**3 819**	**1 417**	**344**	**268**	325	193
1987		830	**2 440**	**4 637**	**3 028**	**650**	**76**	**363**	40	83
1988		478	**3 510**	**6 353**	**4 955**	**672**	**103**	**14**		
1989	50	233	**1 678**	**7 429**	**16 337**	**337**	**25**			
1990			**69**	**6 476**	**2 380**	**7 247**	**356**	**26**		
1991				**5 004**	**13 650**	**2 915**	**32**			
1992	170			**6 884**	**4 367**	**1 988**				
1993		631	**327**	**3 381**	**2 219**	**2 363**		**21**		
1994			**50**	**574**	**4 011**	**5 493**	**935**	**585**		
1995			**530**	**5 586**	**2 156**	**950**	**10**	**57**	696	132
1996	42		**326**	**4 381**	**2 871**	**5 274**	**1 270**	**1 842**	469	181
1997			**1**	**2 886**	**3 795**	**4 900**	**1 802**	**5 144**	536	9
1998			**694**	**4 699**	**8 483**	**6 697**	**440**	**2 712**	428	78
1999				**10 366**	**7 864**	**6 445**	**718**	**1 384**	195	26
2000			**549**	**4 652**	**4 916**	**4 013**	**264**	**56**		1
2001	712	1 450	**4 798**	**6 091**	**6 667**	**3 347**	**190**	**150**	843	305
2002	1 700	1 481	**3 574**	**7 486**	**8 846**	**4 136**	**362**	**383**	351	8
Total	3 036	6 562	21 572	90 358	100 372	58 848	6 926	13 006	3 883	1 016

Table 5: Total estimated catches (t) of SBW in the Bounty Platform fishery, by specified time period, from 1988 to 2002. Core fishing season used for analysis indicated in bold. Source: TCEPR and FSU data.

YEAR	Jan–Jul (all)	Aug 1–7	Aug 8–14	Aug 15–21	Aug 22–28	Aug 29–31	Sep 1–7	Sep 8–14	Sep 15–30	Oct–Dec (all)	Total
1988									8		8
1989											
1990						435	3 994				4 429
1991					**336**	**2 186**	**6 648**	1 694	318		11 182
1992	436	1 450	2 700	**8 424**	**18 013**	**7 378**	**20 400**		130	84	59 015
1993		4	2 121	**4 905**	**3 893**	**432**	**65**	410	78		11 908
1994		2	327	**422**	**1 641**	**625**	**411**	106	345		3 879
1995				**1 738**	**3 934**	**661**	**40**		17	340	6 730
1996					**1 186**	**1 336**	**1 613**	78			4 213
1997					**865**	**1 048**	**130**				2 043
1998				**1**	**2 554**	**2 194**	**1 003**				5 752
1999			17	**515**	**1 507**	**1 106**	**5 183**	48			8 376
2000					**1 348**	**2 402**	**101**				3 851
2001					**536**	**1 474**	**166**				2 176
2002	4			**122**	**3 147**	**2 677**	**1 221**		1		7 172
Total	440	1 456	5 165	**16 127**	**38 960**	**23 954**	**40 975**	2 336	897	424	130 734

Table 6: Variables, variable types, and descriptions of variables used in the analysis. Derived variables are denoted by *. Primary processing code was determined by matching with the daily processed summary data. Climate variables are derived from the Campbell Island weather station.

Variable	Type	Description
Tow	Categorical	Unique tow identification number
Trip	Categorical	Unique trip identification number
Vessel	Categorical	Coded vessel identification number
Year	Categorical	Calendar year in which tow occurred
Day of year	Discrete	Number of days since the start of the calendar year
Day in season	Discrete	Number of days from the onset of spawning
*Start time of tow**	Categorical	Start of tow in 4 hourly groupings. Range 1–6
*End time of tow**	Categorical	End of tow in 4 hourly groupings. Range 1–6
Latitude	Continuous	Latitude (decimal degrees) at start of tow
Longitude	Continuous	Longitude (decimal degrees) at start of tow
Area	Categorical	Fishing ground
*Sub-area**	Categorical	Sub-area of fishing ground. Range 1–4
Gear type *	Categorical	Type of gear (midwater or bottom trawl)
Net depth	Continuous	Depth (metres) of the groundrope at the start of the tow
Bottom depth	Continuous	Depth (metres) of the sea floor at the start of the tow
Headline height	Continuous	Height (metres) of headline above groundrope at start of tow
*Headline category**	Categorical	Height category of headline. Range 1–5
Difference	Continuous	Difference between net depth and bottom depth (m)
Time-depth *	Categorical	Time of day and depth of groundrope. Range 1–4
Speed	Continuous	Recorded speed (knots) of the vessel at start of the tow
Catch	Continuous	Reported (estimated) catch of SBW (kg)
Duration	Continuous	Duration of the tow (hours)
*Distance**	Continuous	Distance of the tow (km), i.e. speed * duration
Number of tows	Continuous	Number of tows per day (only used for catch per day model)
Processing type	Categorical	Primary processing code: surimi or dressed
Vessel experience *	Continuous	Cumulative years in fishery where at least 5 tows were completed
*Core vessel indicator**	Binary	Indicator if the tow belongs to a core vessel
Nationality	Categorical	Country of registration of the vessel
Length	Continuous	Length of the vessel (metres)
Width	Continuous	Width of vessel (metres)
Draught	Continuous	Draught of vessel (meters)
Year built	Continuous	Year the vessel was built
Power	Continuous	Vessel horsepower (kW)
*Vessel category**	Categorical	Design class of vessel. Range 1–5
Mean wind speed	Continuous	Mean daily wind speed recorded on Campbell Island
Maximum wind speed	Continuous	Maximum daily wind speed recorded on Campbell Island

Table 7: Date of onset of spawning (>10% running ripe) for each area, determined from Scientific Observer data.

Year	Bounty Platform	Campbell Island Rise
1986		13 September 1986
1987		11 September 1987
1988		14 September 1988
1989		16 September 1989
1990	25 August 1990	9 September 1990
1991	28 August 1991	16 September 1991
1992	17 August 1992	7 September 1992
1993	21 August 1993	21 September 1993
1994	22 August 1994	17 September 1994
1995	24 August 1995	13 September 1995
1996	31 August 1996	8 September 1996
1997	29 August 1997	6 September 1997
1998	27 August 1998	16 September 1998
1999	1 September 1999	6 September 1999
2000	24 August 2000	3 September 2000
2001	27 August 2001	4 September 2001
2002	29 August 2002	5 September 2002

Table 8: Numbers of tows by variable category and area.

Variable	Category	Bounty Platform	Campbell Island Rise
Start time of tow	1	621	1 454
	2	629	2 732
	3	622	2 443
	4	562	2 689
	5	608	2 064
	6	555	1 324
End time of tow	1	523	1 170
	2	724	1 629
	3	573	2 964
	4	563	2 504
	5	615	2 826
	6	599	1 613
Sub-area	1	1 456	1 465
	2	896	5 859
	3	456	2 500
	4	789	2 882
Headline category	1	62	245
	2	217	1 527
	3	2 663	9 300
	4	655	1 622
	unknown		12
Time-depth	1	1 758	3 014
	2	1 649	7 686
	3	139	1 334
	4	51	672
Nationality	Japan	1 117	3 128
	Russia	2 194	8 918
	Other	107	254
	Poland	82	360
	NZ	97	46
Vessel category	1	1 058	2 091
	2	979	5 492
	3	64	800
	4	167	1 183
	5	1 329	4 671

Table 9: Error range checks completed on the raw data used in the analysis.

Variable	Range check
Net depth	Greater than or equal to reported bottom depth
Bottom depth	<100 m or > 900 m
Speed	< 2.5 knots or > 6.5 knots
Catch	> 250 tonnes
Duration	< 10 minutes or > 24 hours
Distance	> 100 kilometres

Table 10: **Number of tows, number of non-zero tows and total catch by vessel category and year for the Campbell Island Rise fishery, 1986–2002.**

	All vessels			All surimi vessels		Core surimi vesels		All dressed vessels		Core dressed vessels	
Year	All tows	Non -zero tows	Total Catch (t)	Non -zero tows	Total Catch (t)	Non -zero tows	Total Catch (t)	Non -zero tows	Total Catch (t)	Non -zero tows	Total Catch (t)
1986	883	827	12 347	206	4 514	104	2 817	621	7 833	171	2 309
1987	761	727	11 194	224	6 608	139	3 809	503	4 586	221	2 191
1988	796	784	15 607	319	11 187	220	8 615	465	4 420	314	2 740
1989	991	950	25 806	256	16 206	208	13 153	694	9 600	39	480
1990	1 023	933	16 553	184	7 015	122	4 480	749	9 538	220	2 823
1991	1 232	1 183	21 601	100	4 227	70	3 705	1 083	17 374	300	5 648
1992	1 463	1 132	13 239	261	5 633	142	3 494	871	7 606	362	3 727
1993	402	347	8 311	82	4 551	82	4 551	265	3 760	139	2 338
1994	479	451	11 648	114	7 123	114	7 123	337	4 525	240	3 408
1995	211	201	9 289	111	8 495	111	8 495	90	794	84	735
1996	404	380	15 964	138	12 708	138	12 708	242	3 256	195	2 774
1997	597	577	18 527	168	12 879	168	12 879	409	5 648	331	4 754
1998	892	839	23 726	157	12 793	157	12 793	682	10 933	527	8 954
1999	764	744	26 777	165	14 943	114	12 329	579	11 834	530	10 960
2000	448	442	14 449	84	8 214	84	8 214	358	6 235	326	5 775
2001	591	589	21 244	140	12 426	140	12 426	449	8 818	375	6 983
2002	769	747	24 787	146	13 110	146	13 110	601	11 676	412	7 917
	12 706	11 853	291 069	2 855	162 632	2 259	144 701	8 998	128 436	4 786	74 516

Table 11: Summary of standardised CPUE models and variance explained by each model (r^2) for the Campbell Island Rise fishery.

Vessels included	Model type	Estimator	Duration	r^2
Main model				
All vessels	LNL	t/tow	1986–2002	32.2
Sensitivity analysis				
All vessels	LNL	t/hour	1986–2002	25.7
All vessels	LNL	t/day	1986–2002	45.2
All surimi	LNL	t/tow	1986–2002	33.1
Core surimi	LNL	t/tow	1986–2002	32.2
All dressed	LNL	t/tow	1986–2002	20.8
Core dressed	LNL	t/tow	1986–2002	17.8
All vessels	Combined	Fishing success, t/tow	1986–2002	-
All vessels	LNL	t/tow	1992–2002	39.3

Table 12: Variables selected by order of selection for the all vessel catch per tow model for the Campbell Island Rise fishery, 1986–2002.

Order	Variable	r^2
1	*Vessel*	25.9
2	*Year*	29.5
3	*Day in season*	30.8
4	*End time of tow*	32.2

Table 13: Relative year effects and standard errors for the all vessels catch per tow model, and raw mean CPUE for the Campbell Island Rise fishery, 1986 to 2002.

Year	Index	s.e.	Mean catch per tow
1986	1.00		14.9
1987	0.91	0.06	15.4
1988	0.88	0.06	19.9
1989	1.38	0.12	27.2
1990	1.06	0.10	17.7
1991	1.30	0.13	18.3
1992	0.60	0.06	11.7
1993	1.03	0.13	24.0
1994	1.19	0.15	25.8
1995	1.23	0.17	46.2
1996	2.28	0.29	42.0
1997	2.28	0.29	32.1
1998	1.74	0.20	28.3
1999	2.55	0.31	36.0
2000	1.85	0.23	32.7
2001	1.83	0.22	36.1
2002	1.94	0.23	33.2

Table 14: Number of tows, number of non-zero tows and total catch by vessel category and year for the Bounty Platform fishery, 1990 to 2002.

	All vessels			All surimi vessels		Core surimi vessels		All dressed vessels		Core dressed vessels	
Year	All tows	Non -zero tows	Total Catch (t)	Non -zero tows	Total Catch (t)	Non -zero tows	Total Catch (t)	Non -zero tows	Total Catch (t)	Non -zero tows	Total Catch (t)
1990	252	221	4 289	33	1 459	4	55	188	2 830	0	0
1991	496	467	9 077	67	3 519	23	1 588	400	5 558	108	1 975
1992	1 570	1 513	53 884	371	30 698	194	18 950	1 142	23 186	221	6 090
1993	355	282	9 241	93	7 451	66	6 187	189	1 790	159	1 470
1994	98	85	3 096	43	2 758	43	2 758	42	338	5	47
1995	120	103	6 372	98	6 328	98	6 328	5	44	5	44
1996	66	59	4 135	59	4 135	59	4 135	0	0	0	0
1997	36	26	1 950	26	1 950	26	1 950	0	0	0	0
1998	112	101	5 703	52	5 142	52	5 142	49	561	31	383
1999	273	239	8 297	84	5 239	84	5 239	155	3 058	64	647
2000	97	79	3 850	37	3 501	37	3 501	42	349	27	162
2001	28	25	2 176	25	2 176	25	2 176	0	0	0	0
2002	94	88	7 167	59	6 870	59	6 870	29	297	18	116
Total	3 597	3 288	119 237	1 047	81 226	770	64 879	2 241	38 011	638	10 934

Table 15: Summary of standardised CPUE models and variance explained by each model (r^2) for the Bounty Platform fishery.

Vessels included	Model type	Estimator	Duration	r^2
Main model				
All vessels	LNL	t/tow	1990–2002	32.1
Sensitivity analysis				
All vessels	LNL	t/hr	1990–2002	12.5
All vessels	LNL	t/day	1990–2002	38.0
All surimi	LNL	t/tow	1990–2002	23.4
Core surimi	LNL	t/tow	1990–2002	28.0
All dressed	LNL	t/tow	1990–2002	23.6
All vessels	Combined	Fishing success, t/tow	1990–2002	-

Table 16: Variables selected by order of selection for the all vessels catch per tow model for the Bounty Platform fishery, 1990 to 2002.

Order	Variable	r^2
1	*Processing type*	19.1
2	*Year*	25.9
3	*Vessel category*	28.1
4	*Length*	30.1
5	*Nationality*	32.1

Table 17: Relative year effects and standard errors for all vessels catch per tow model, and raw mean CPUE for the Bounty Platform fishery, 1990 to 2002.

Year	Year index	s.e.	Mean catch per tow
1990	1.00		19.4
1991	1.20	0.12	19.4
1992	1.69	0.15	35.6
1993	0.89	0.10	32.8
1994	0.35	0.06	36.4
1995	0.57	0.09	61.8
1996	1.06	0.20	70.8
1997	0.98	0.25	75.0
1998	1.06	0.16	56.5
1999	0.68	0.08	34.7
2000	0.75	0.12	48.7
2001	0.98	0.25	87.1
2002	1.52	0.24	81.5

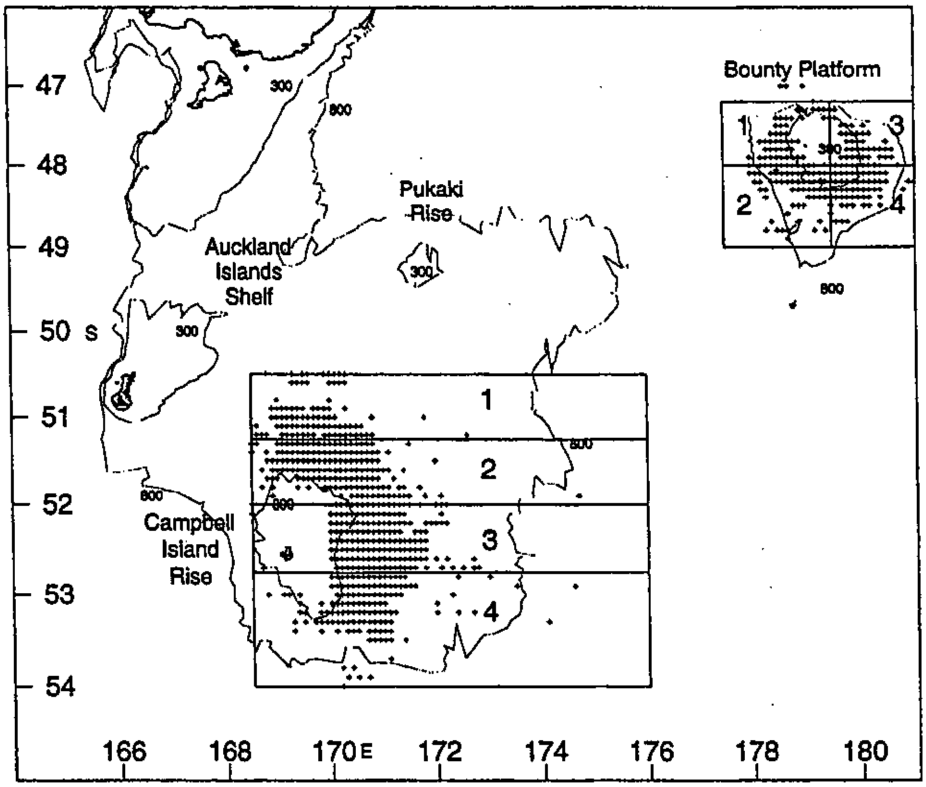


Figure 1: Location of all trawls made in the SBW fishery from 1986 to 2002 on the Bounty Platform and Campbell Island Rise used in the analysis. The sub areas 1–4 within each main area are plotted.

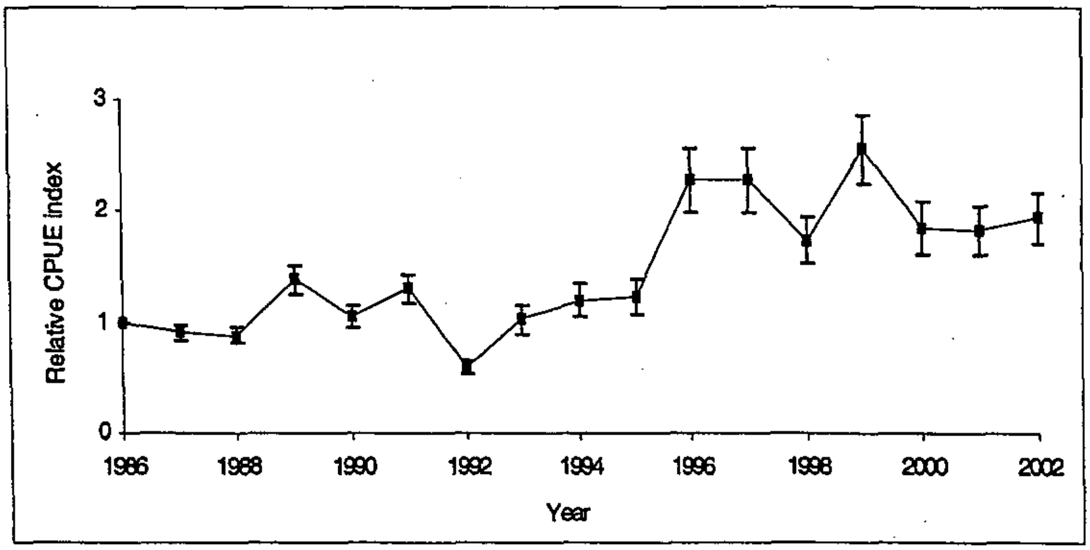


Figure 2: Relative indices (± 1 s.e.) for the all vessels catch per tow model for the Campbell Island Rise fishery, 1986 to 2002.

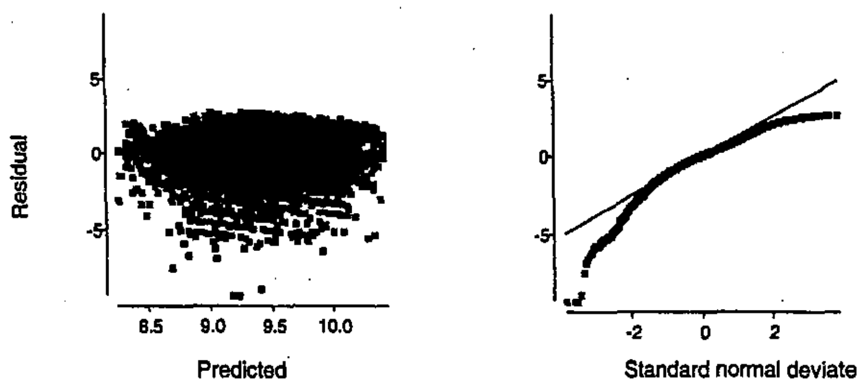


Figure 3: Model diagnostics for the all vessels catch per tow model for the Campbell Island Rise fishery, 1986 to 2002.

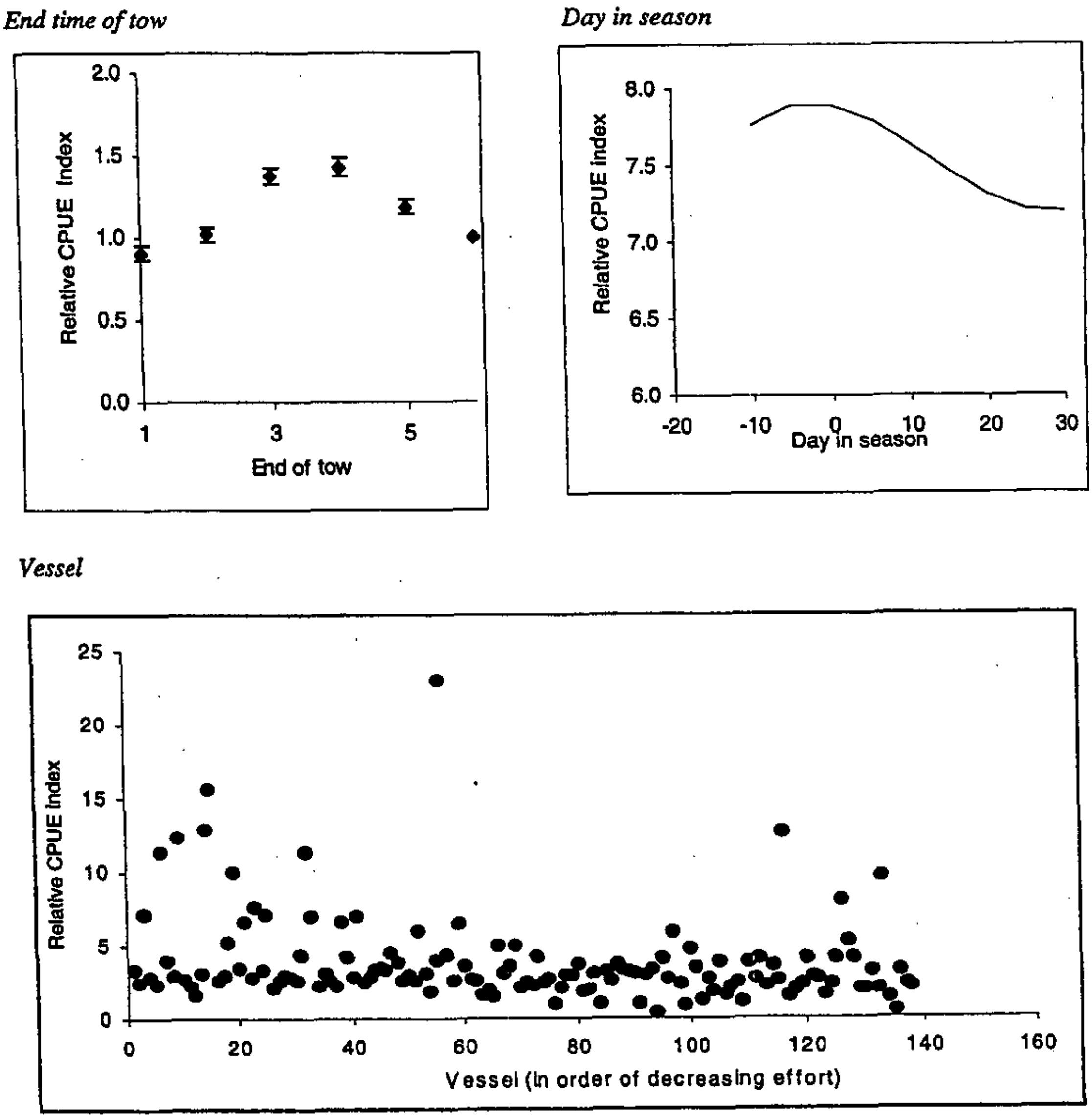


Figure 4: Relative indices (± 1 s.e.) for variables that entered the all vessels catch per tow model for the Campbell Island Rise fishery, 1986 to 2002.

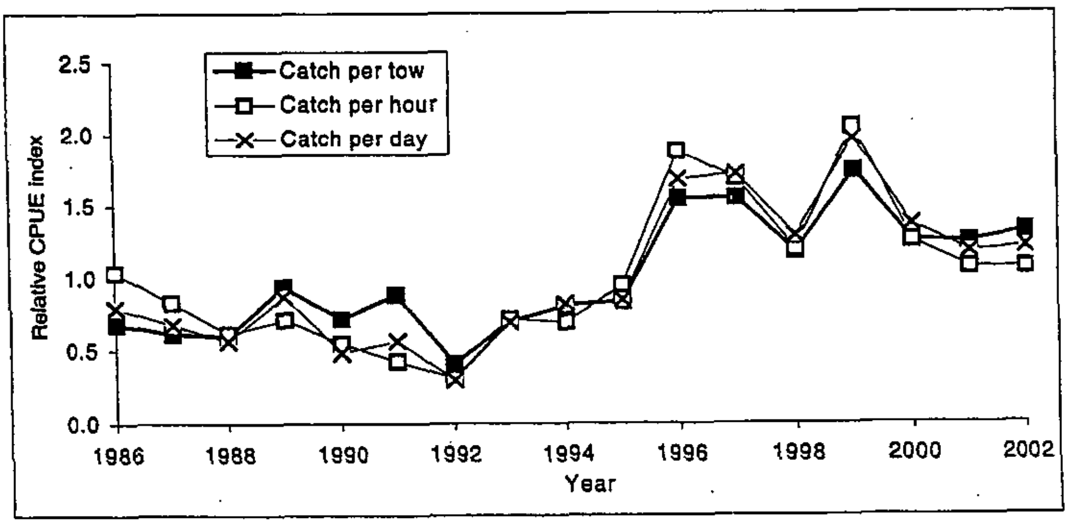


Figure 5: Relative indices (scaled to mean of 1) for the all vessels catch per tow, catch per hour, and catch per day models for the Campbell Island Rise fishery, 1986 to 2002.

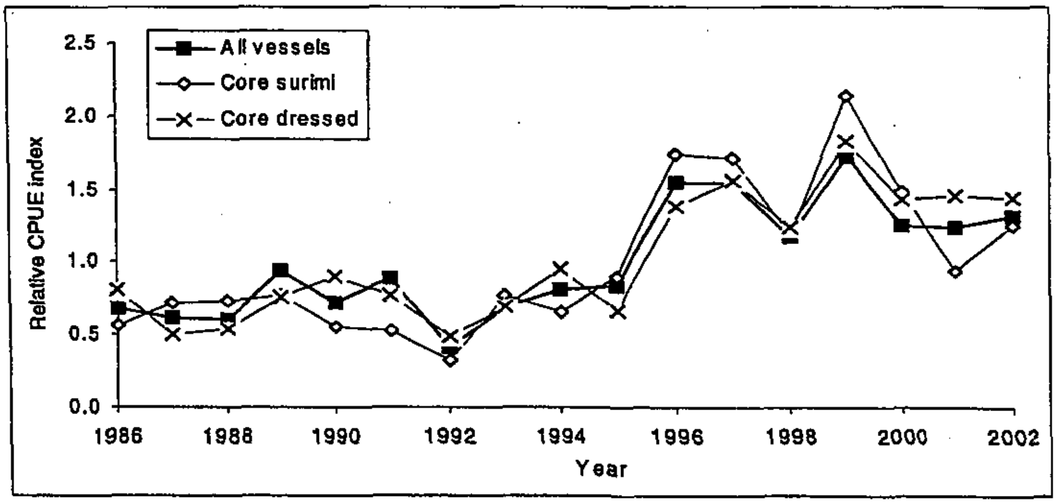


Figure 6: Relative indices (scaled to mean of 1) for the all vessels, core surimi vessels, and core dressed vessels catch per tow models for the Campbell Island Rise fishery, 1986 to 2002.

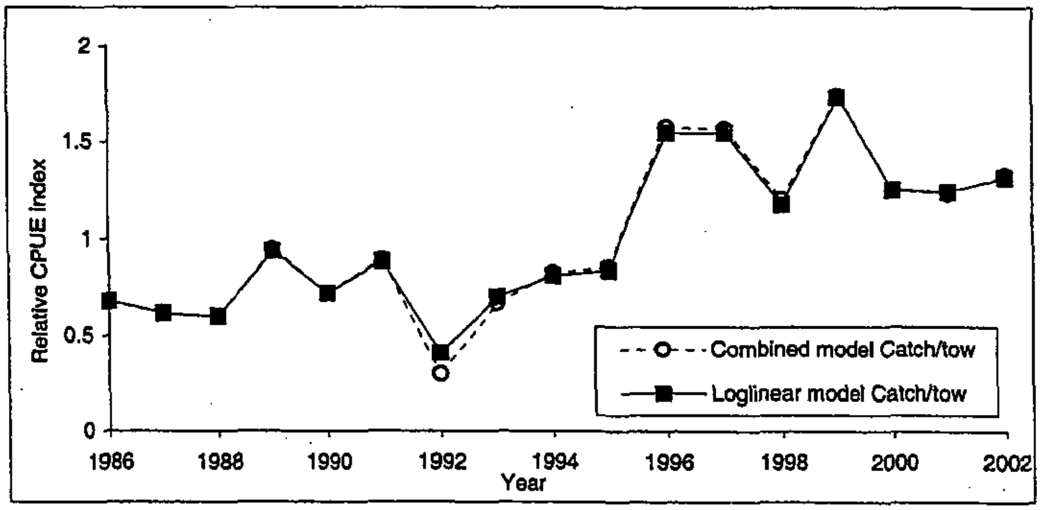


Figure 7: Relative indices (scaled to mean of 1) for the loglinear and combined all vessels catch per tow models for the Campbell Island Rise fishery, 1986 to 2002.

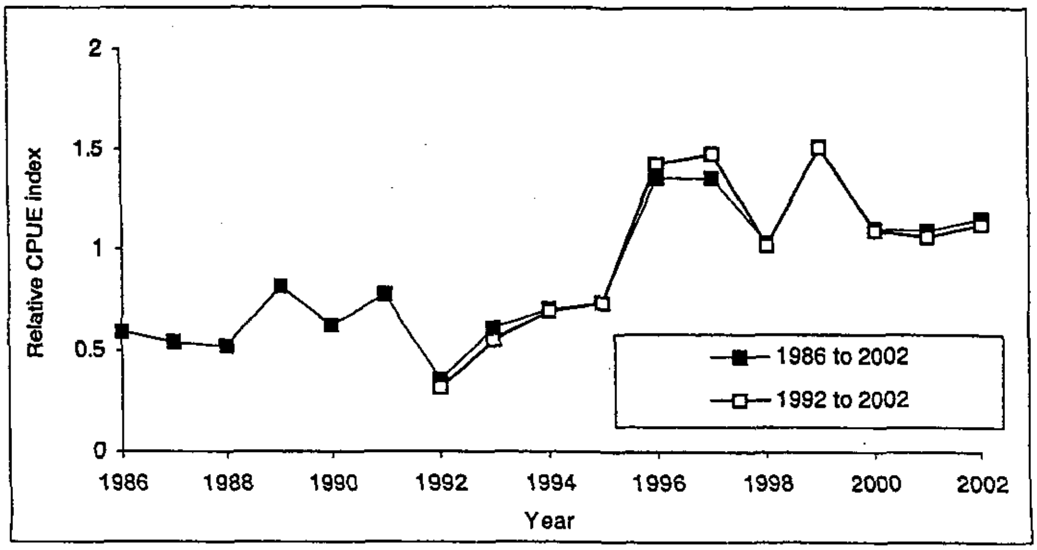


Figure 8: Relative indices (scaled to mean of 1) for the all vessels catch per tow models for the Campbell Island Rise fishery for 1986–2002 and 1992–2002.

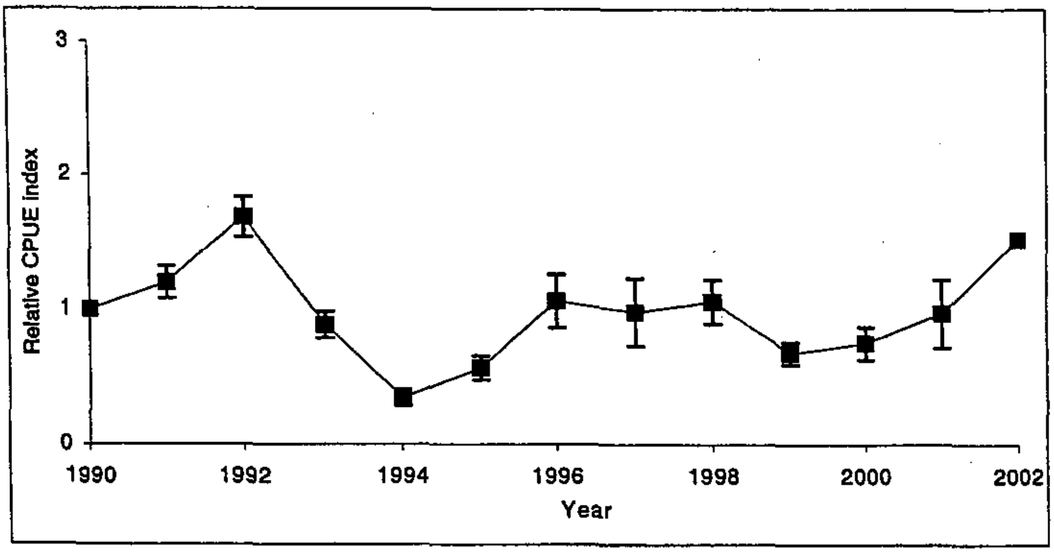


Figure 9: Relative indices (± 1 s.e.) for the all vessels catch per tow model for the Bounty Platform fishery, 1990 to 2002.

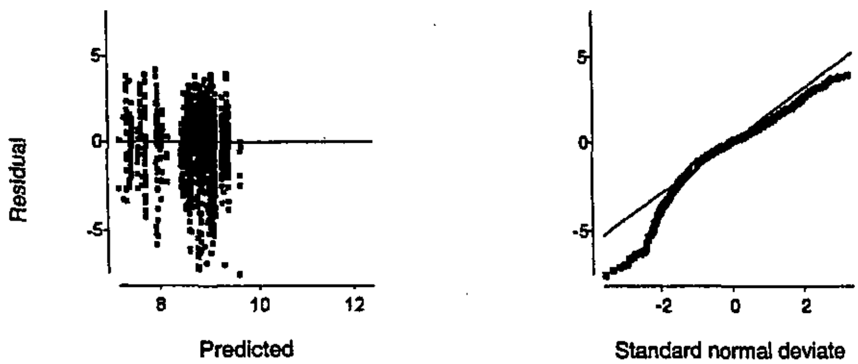


Figure 10: Diagnostic plots for the all vessels catch per tow model for the Bounty Platform fishery, 1990 to 2002.

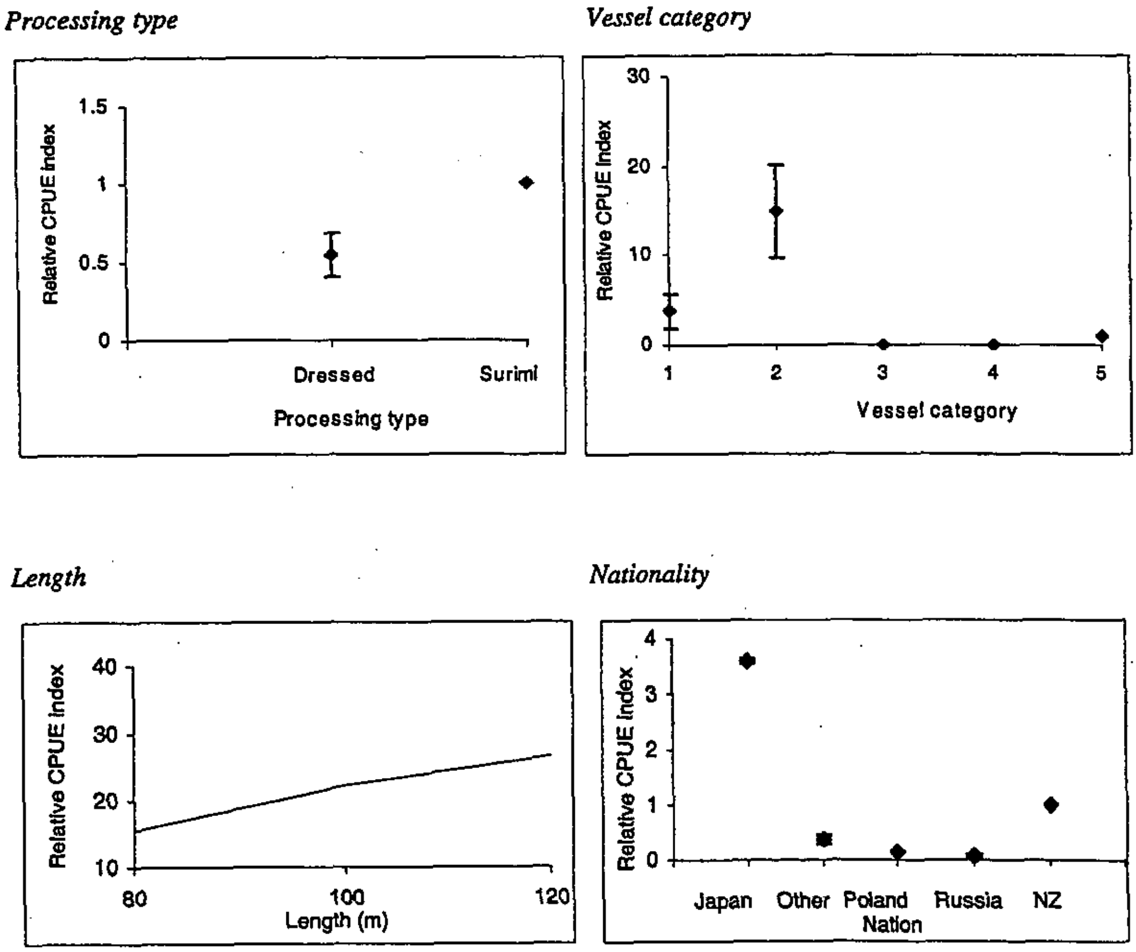


Figure 11: Relative indices (± 1 s.e.) for variables that entered the all vessels catch per tow model for the Bounty Platform fishery, 1990 to 2002.

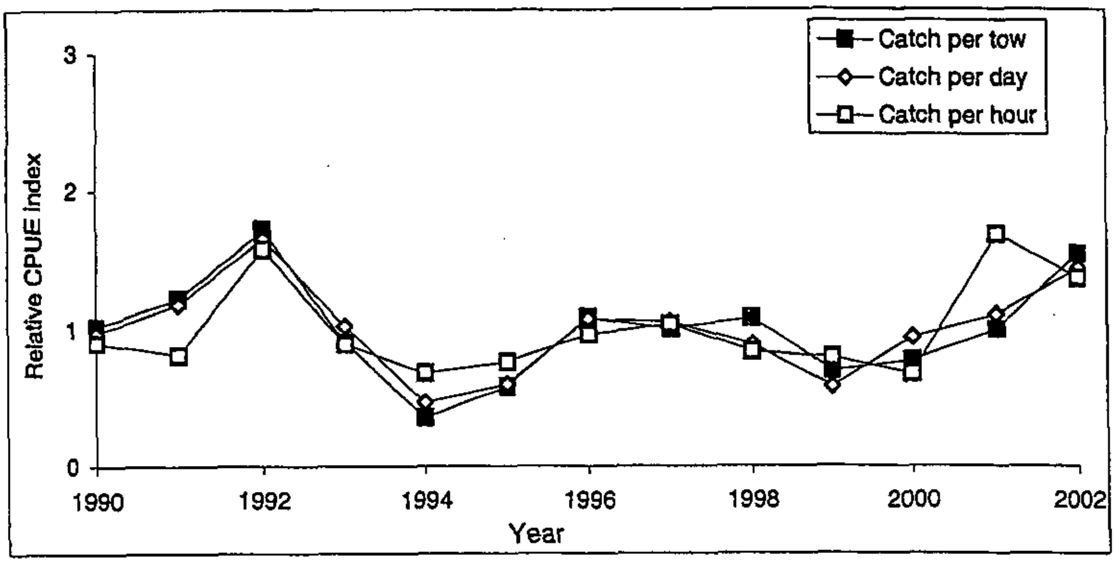


Figure 12: Relative indices (scaled to mean of 1) for the all vessels catch per tow, catch per hour, and catch per day models for the Bounty Platform fishery, 1990 to 2002.

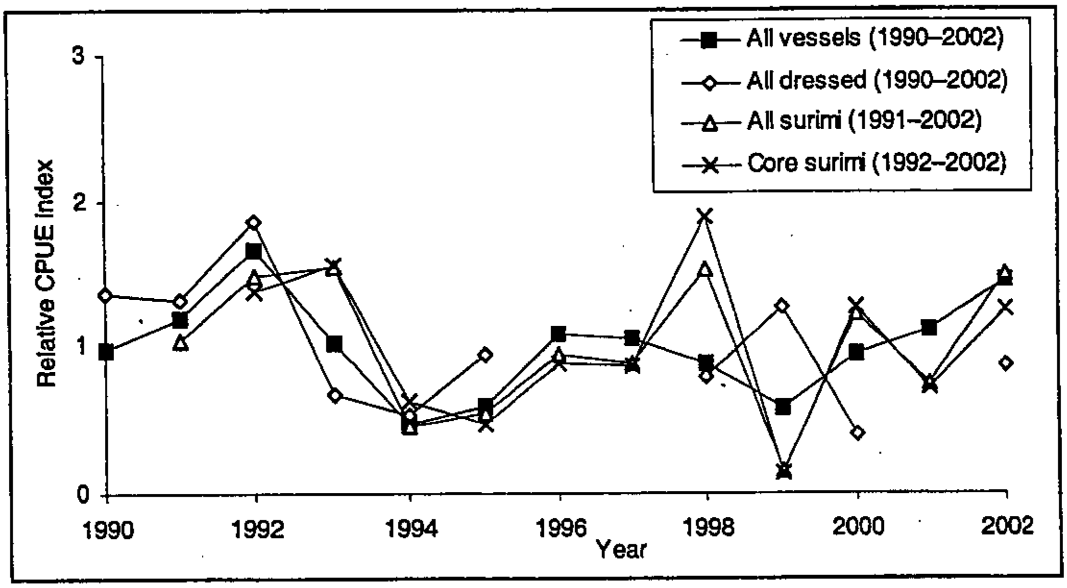


Figure 13: Relative indices (scaled to mean of 1) for the all vessels, all surimi, core surimi, and core dressed vessels catch per tow models for the Bounty Platform fishery for the specified years.

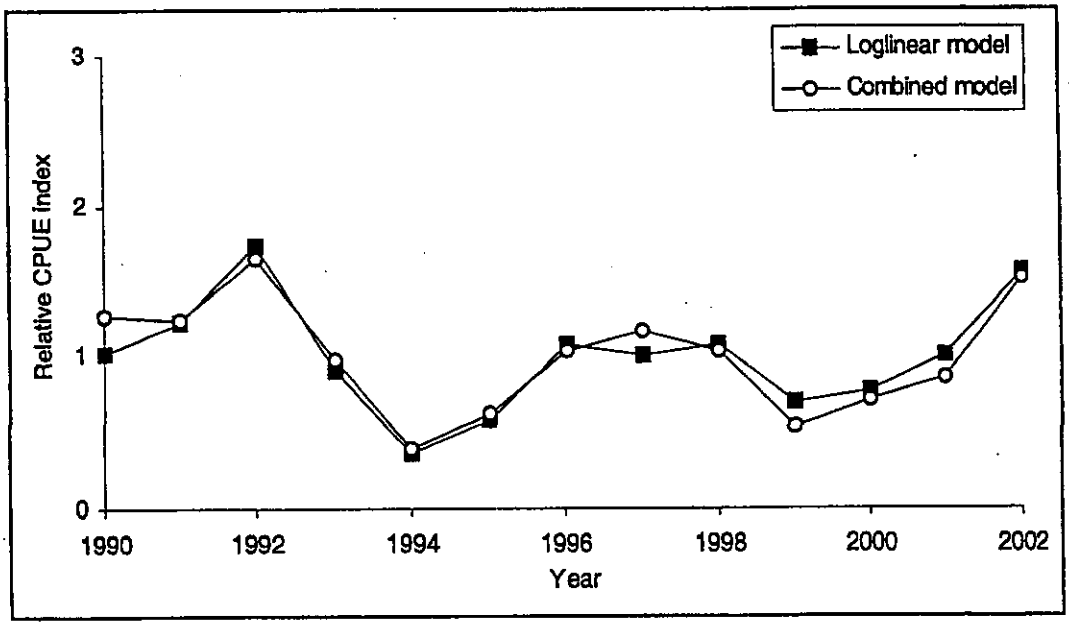


Figure 14: Relative indices (scaled to mean of 1) for the loglinear and combined all vessels catch per tow models for the Bounty Platform fishery, 1990–2002.

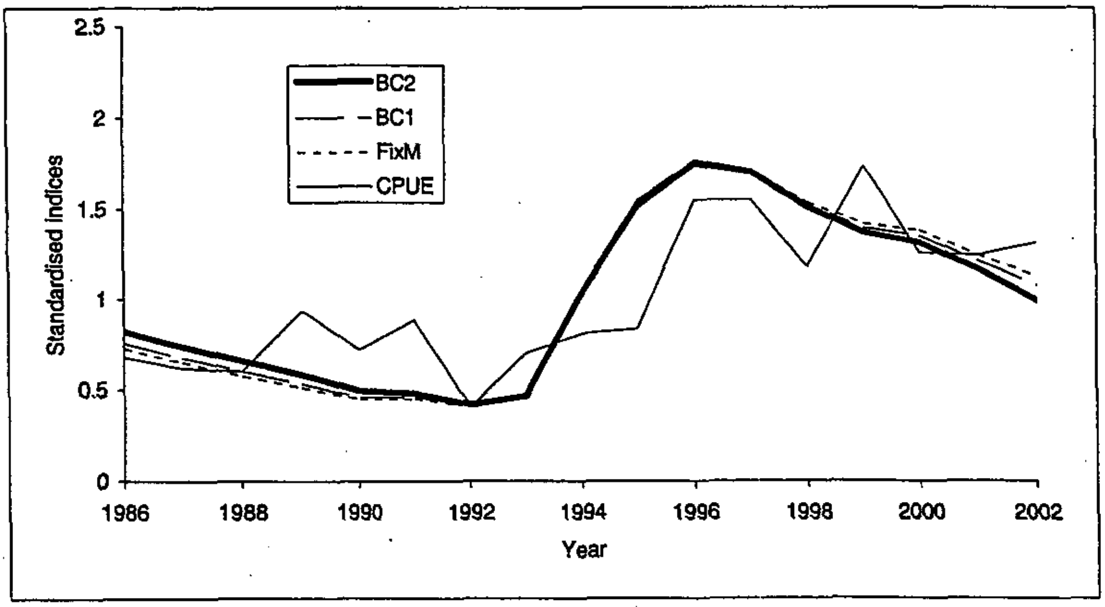


Figure 15: Comparison of the three population model trajectories (BC2, BC1, and FixM) with the all vessels catch per tow index (CPUE) all scaled to a mean of 1.

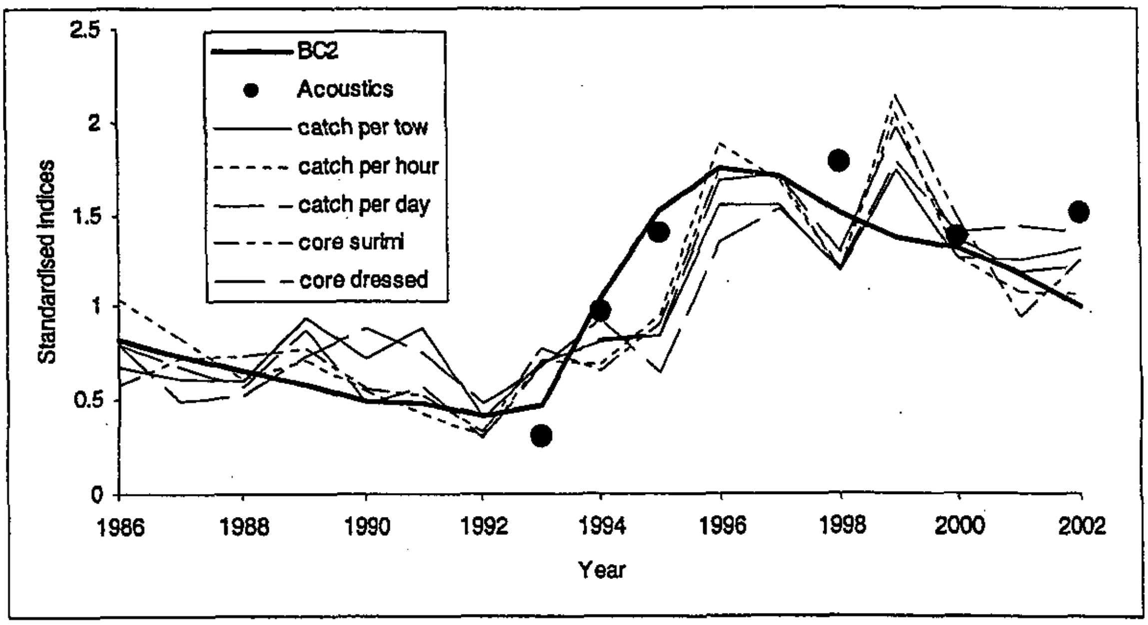


Figure 16: Comparison of the population model trajectory (BC2) with the acoustic survey estimates, and the all vessels catch per tow, all vessels catch per hour, all vessels catch per day, core surimi vessels catch per tow, and core dressed catch per tow CPUE indices, all scaled to a mean of 1.

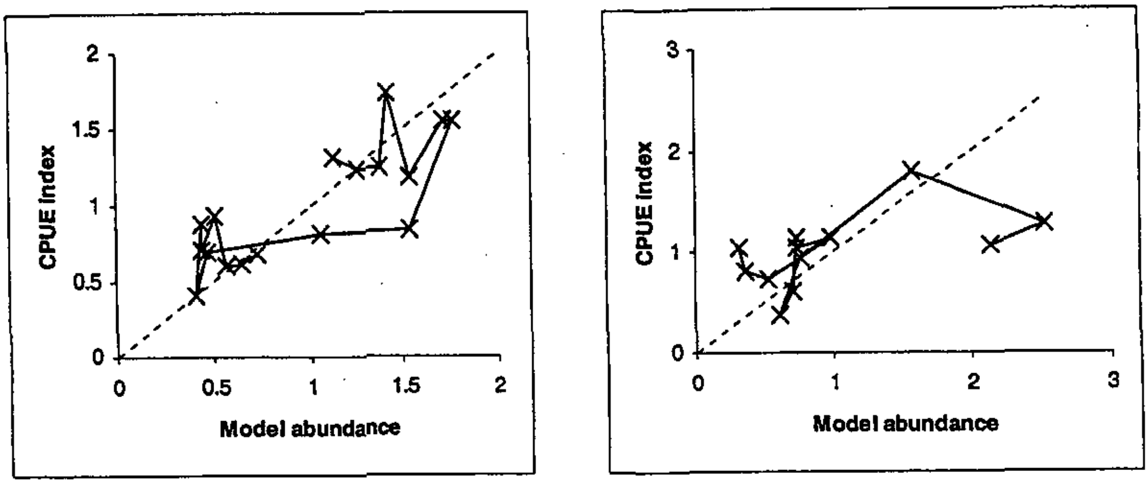


Figure 17: Plots of all vessels catch per tow CPUE indices versus model abundance indices for the Campbell Island Rise (left) and Bounty Platform (right).

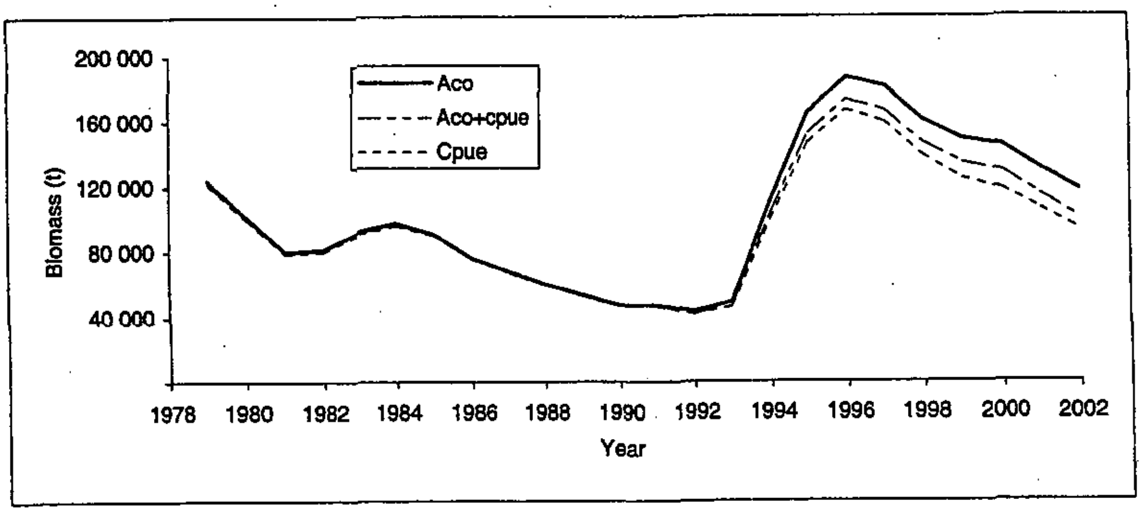


Figure 18: Results of alternative CASAL model fits to the Campbell Island Rise indices. Aco, acoustic index; CPUE, all vessels catch per tow CPUE index.

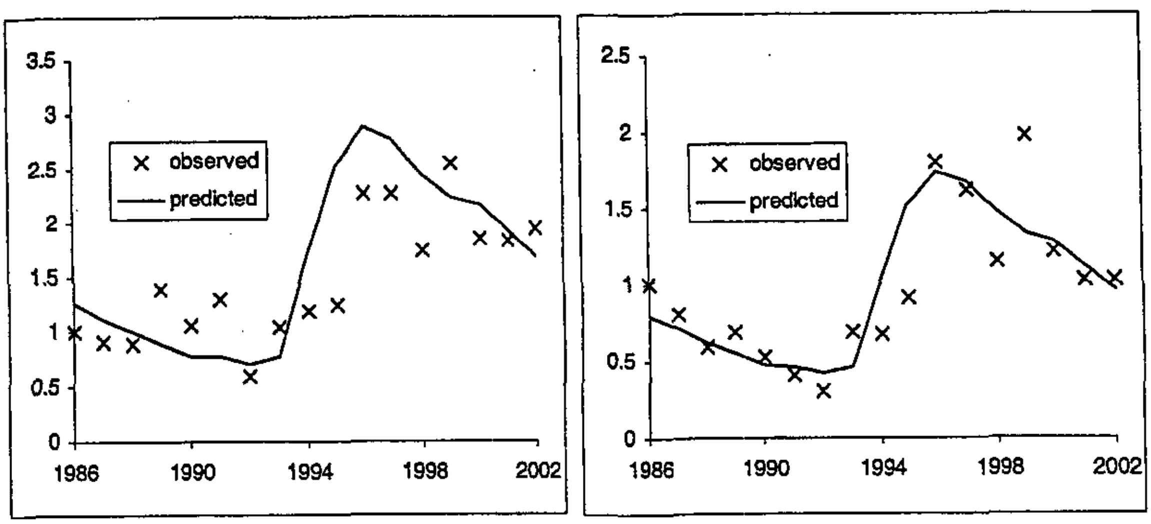


Figure 19: Fit of the observed catch per tow (left) and catch per hour (right) CPUE indices to the predicted indices from the Campbell Island Rise assessment model containing age, acoustics and CPUE data.

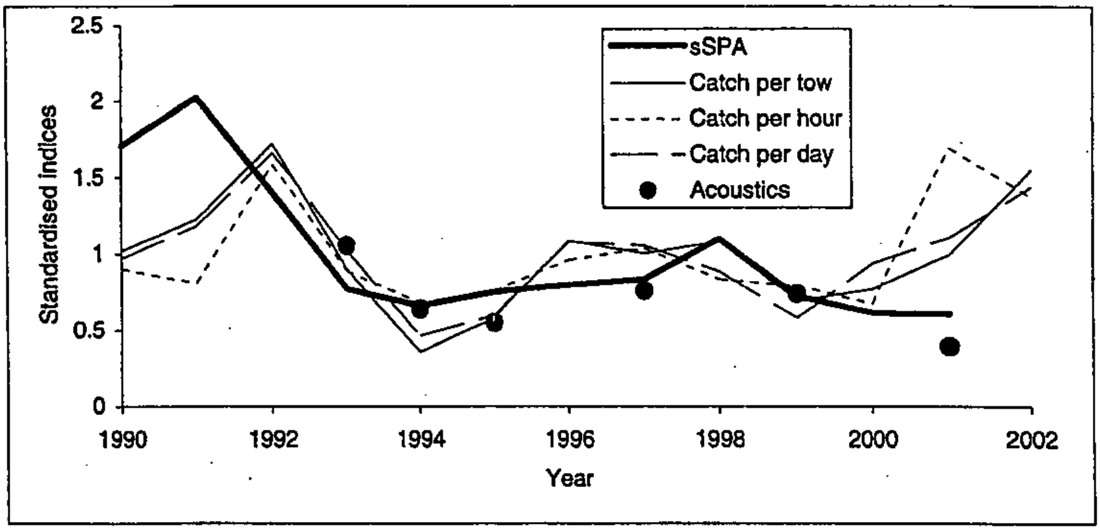


Figure 20: Comparison of the population model trajectory (sSPA) with the all vessels catch per tow, catch per hour, and catch per day CPUE indices, and the acoustic survey estimates (all scaled to a mean of 1) for the Bounty Platform stock.

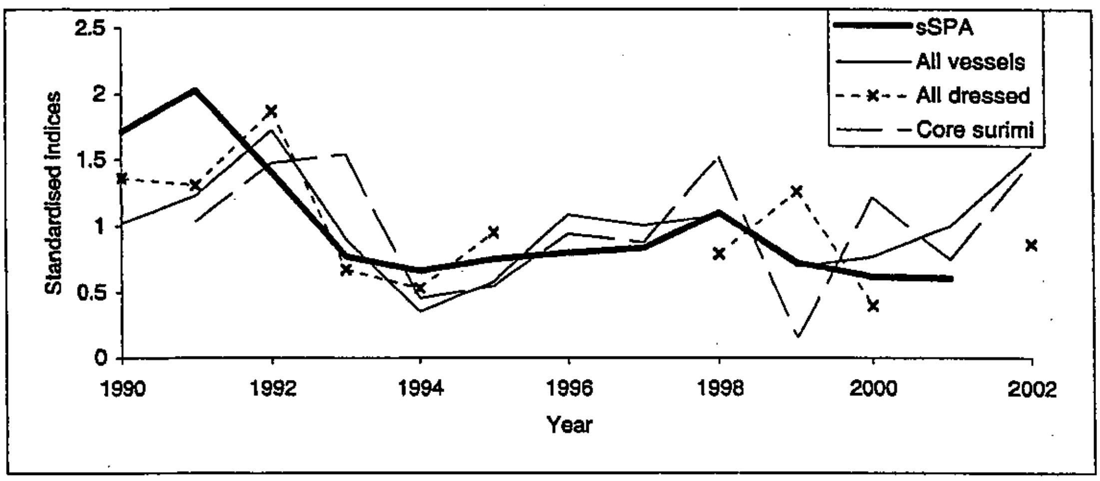


Figure 21: Comparison of the population model trajectory (sSPA) with the all vessels, core dressed, and core surimi catch per tow CPUE indices (all scaled to a mean of 1) for the Bounty Platform stock.

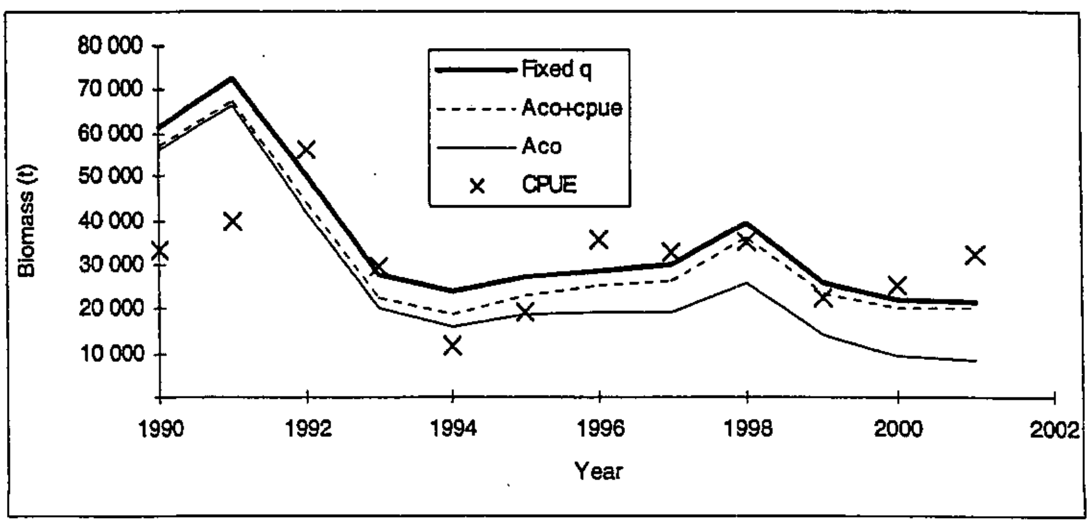


Figure 22: Model trajectories for three sSPA model runs for Bounty Platform. Aco, is the fit to the acoustics data; Fixed *q*, is the fit with the adult acoustic *q* fixed at 1.4; Aco + cpue, is the fit to the acoustics and all vessels catch per tow CPUE index. CPUE shows the observed CPUE indices.

Appendix A: Campbell Island Rise spawning fishery

Table A1: Campbell Island Rise SBW fishery. Number of non-zero tows, vessels, mean tow duration, catch per tow, catch per hour and catch per day for all vessels and vessel subgroups, 1990 to 2002.

																	Year	
All vessels	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Number of vessels	20	15	16	23	33	34	44	20	15	11	10	17	21	21	16	14	18	
Total catch (t)	12 347	11 194	15 607	25 806	16 553	21 601	13 239	8 311	11 648	9 289	15 964	18 527	23 726	26 777	14 449	21 244	24 787	291 069
Number of tows	827	727	784	950	933	1183	1132	347	451	201	380	577	839	744	442	589	747	11 853
Mean tow duration (h)	2.3	2.8	3.7	4.3	3.7	3.6	4.6	3.6	3.6	5.2	4.3	4.0	3.4	3.5	3.7	4.1	4.2	3.8
Mean catch per tow (t)	14.9	15.4	19.9	27.2	17.7	18.3	11.7	24.0	25.8	46.2	42.0	32.1	28.3	36.0	32.7	36.1	33.2	27.1
Mean catch per hour (t)	9.7	7.7	6.7	8.7	7.0	7.2	4.3	9.4	9.2	11.3	14.0	10.3	11.5	17.3	10.8	11.1	11.1	9.8
Number of days	251	229	253	317	342	411	509	152	198	108	192	274	391	330	212	254	324	4 747
Mean catch per day (t)	49.2	48.9	61.7	81.4	48.4	52.6	26.0	54.7	58.8	86.0	83.1	67.6	60.7	81.1	68.2	83.6	76.5	64.0
All surimi vessels																		
Number of vessels	4	4	6	7	9	5	14	6	5	6	5	5	5	6	4	5	5	
Total catch (t)	4 514	6 608	11 187	16 206	7 015	4 227	5 633	4 551	7 123	8 495	12 708	12 879	12 793	14 943	8 214	12 426	13 110	162 632
Number of tows	206	224	319	256	184	100	261	82	114	111	138	168	157	165	84	140	146	2 855
Mean tow duration (h)	2.5	3.4	5.1	7.5	6.0	5.6	7.5	4.1	6.6	8.0	8.8	7.9	9.0	7.7	8.6	8.6	8.6	6.8
Mean catch per tow (t)	21.9	29.5	35.1	63.3	38.1	42.3	21.6	55.5	62.5	76.5	92.1	76.7	81.5	90.6	97.8	88.8	89.8	62.6
Mean catch per hour (t)	13.1	12.8	8.7	11.8	8.7	9.4	5.4	8.9	12.7	12.7	12.9	12.6	13.0	16.6	14.6	13.4	13.9	11.8
Number of days	60	68	112	122	90	55	158	46	73	70	95	106	105	106	71	102	96	1 535
Mean catch per day (t)	75.2	97.2	99.9	132.8	77.9	76.9	35.7	98.9	97.6	121.4	133.8	121.5	121.8	141.0	115.7	121.8	136.6	106.2
Core surimi vessels																		
Number of vessels	2	2	4	6	7	4	10	6	5	6	5	5	5	5	4	5	5	
Total catch (t)	2 817	3 809	8 615	13 153	4 480	3 705	3 494	4 551	7 123	8 495	12 708	12 879	12 793	12 329	8 214	12 426	13 110	144 701
Number of tows	104	139	220	208	122	70	142	82	114	111	138	168	157	114	84	140	146	2 259
Mean tow duration (h)	2.7	3.8	5.4	7.8	5.9	5.4	7.4	4.1	6.6	8.0	8.8	7.9	9.0	8.5	8.6	8.6	8.6	6.9
Mean catch per tow (t)	27.1	27.4	39.2	63.2	36.7	52.9	24.6	55.5	62.5	76.5	92.1	76.7	81.5	108.1	97.8	88.8	89.8	64.7
Mean catch per hour (t)	16.2	8.7	9.1	11.7	7.8	11.9	6.2	8.9	12.7	12.7	12.9	12.6	13.0	14.7	14.6	13.4	13.9	11.8
Number of days	29	45	80	109	65	45	107	46	73	70	95	106	105	86	71	102	96	1 330
Mean catch per day (t)	97.1	84.6	107.7	120.7	68.9	82.3	32.7	98.9	97.6	121.4	133.8	121.5	121.8	143.4	115.7	121.8	136.6	106.3

Table A1: – continued

																	Year	
All dressed vessels	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Number of vessels	16	11	10	16	24	30	30	13	9	5	5	12	16	15	12	9	13	
Total catch (t)	7 833	4 586	4 420	9 600	9 538	17 374	7 606	3 760	4 525	794	3 256	5 648	10 933	11 834	6 235	8 818	11 677	128 437
Number of tows	621	503	465	694	749	1 083	871	265	337	90	242	409	682	579	358	449	601	8 998
Mean tow duration (h)	2.3	2.6	2.8	3.1	3.1	3.4	3.7	2.5	2.5	1.9	1.7	2.7	2.3	3.2	2.6	2.7	3.1	2.7
Mean catch per tow (t)	12.6	9.1	9.5	13.8	12.7	16.0	8.7	14.2	13.4	8.8	13.5	13.8	16.0	20.4	17.4	19.6	19.4	14.1
Mean catch per hour (t)	8.6	5.5	5.4	7.6	6.6	7.1	3.9	9.6	8.1	7.7	14.6	9.4	11.1	17.6	9.9	10.5	10.5	9.0
Number of days	191	161	141	195	252	356	351	106	125	38	97	168	286	224	141	152	228	3 212
Mean catch per day (t)	41.0	28.5	31.3	49.2	37.8	48.8	21.7	35.5	36.2	20.9	33.6	33.6	38.2	52.8	44.2	58.0	51.2	39.0
Core dressed vessels																		
Number of vessels	3	3	5	1	5	7	13	7	6	4	4	8	11	13	10	7	9	
Total catch (t)	2 309	2 191	2 740	480	2 823	5 648	3 727	2 338	3 408	735	2 774	4 754	8 954	10 960	5 775	6 983	7 917	74 516
Number of tows	171	221	314	39	220	300	362	139	240	84	195	331	527	530	326	375	412	4 786
Mean tow duration (h)	1.8	2.6	2.7	3.6	3.2	3.2	4.0	2.7	2.7	1.8	1.7	2.4	2.2	2.3	2.6	2.5	2.6	2.6
Mean catch per tow (t)	13.5	9.9	8.7	12.3	12.8	18.8	10.3	16.8	14.2	8.8	14.2	14.4	17.0	20.7	17.7	18.6	19.2	14.6
Mean catch per hour (t)	11.1	6.0	5.4	4.3	6.8	8.5	4.5	10.5	8.6	10.2	16.5	10.7	11.8	18.1	10.1	10.8	11.7	9.7
Number of days	48	61	90	11	72	94	148	59	93	35	78	126	219	199	123	116	138	1 710
Mean catch per day (t)	48.1	35.9	30.4	43.6	39.2	60.1	25.2	39.6	36.6	21.0	35.6	37.7	40.9	55.1	47.0	60.2	57.4	42.0

Table A2: Variables selected by order of selection for the all vessels catch per hour and catch per day models, and the core surimi and core dressed vessel catch per tow models for the Campbell Island Rise fishery, 1986–2002.

	All vessels catch per hour		All vessels catch per day		Core surimi catch per tow		Core dressed catch per tow	
Order	Variable	r^2	Variable	r^2	Variable	r^2	Variable	r^2
1	*Vessel*	14.0	*Vessel*	22.6	*Year*	17.3	*Year*	8.7
2	*Year*	18.6	*No. of tows*	35.3	*Vessel*	21.3	*Vessel*	13.3
3	*End time of tow*	21.4	*Year*	40.9	*Duration*	24.3	*Day in season*	15.4
4	*Day in season*	24.8	*Distance*	42.5	*Day in season*	27.2	*End time of tow*	17.8
5			*Day in season*	44.5	*End time of tow*	29.3		
					Difference	30.9		

Table A3: Relative year effects, standard errors, and raw mean CPUE by year, for the all vessels catch per hour and catch per day models for the Campbell Island Rise fishery, 1986–2002.

	All vessels catch per hour			All vessels catch per day		
Year	Index	s.e.	CPUE	Index	s.e.	CPUE
1986	1.00		9.70	1.00		49.20
1987	0.80	0.06	7.70	0.85	0.10	48.90
1988	0.59	0.05	6.70	0.71	0.09	61.70
1989	0.68	0.07	8.70	1.10	0.16	81.40
1990	0.53	0.06	7.00	0.61	0.09	48.40
1991	0.41	0.05	7.20	0.71	0.12	52.60
1992	0.30	0.04	4.30	0.38	0.06	26.00
1993	0.69	0.10	9.40	0.87	0.16	54.70
1994	0.67	0.09	9.20	1.03	0.19	58.80
1995	0.91	0.14	11.30	1.06	0.21	86.00
1996	1.81	0.26	14.00	2.11	0.39	83.10
1997	1.62	0.23	10.30	2.15	0.40	67.60
1998	1.15	0.15	11.50	1.62	0.28	60.70
1999	1.97	0.27	17.30	2.46	0.44	81.10
2000	1.21	0.17	10.80	1.71	0.32	68.20
2001	1.03	0.14	11.10	1.48	0.27	83.60
2002	1.03	0.14	11.10	1.52	0.27	76.50

Table A4: Relative year effects, standard errors, and raw mean CPUE by year for the core surimi and core dressed vessels catch per tow models for the Campbell Island Rise fishery.

	Core surimi			Core dressed		
Year	Index	s.e.	CPUE	Index	s.e.	CPUE
1986	1.00		27.1	1.00.		13.5
1987	1.26	0.22	27.4	0.62	0.06	9.90
1988	1.28	0.22	39.2	0.66	0.07	8.70
1989	1.35	0.25	63.2	0.93	0.20	12.30
1990	0.97	0.19	36.7	1.11	0.18	12.80
1991	0.92	0.23	52.9	0.95	0.17	18.80
1992	0.57	0.13	24.6	0.61	0.11	10.30
1993	1.34	0.36	55.5	0.85	0.17	16.80
1994	1.14	0.30	62.5	1.17	0.22	14.20
1995	1.57	0.40	76.5	0.82	0.17	8.80
1996	3.03	0.79	92.1	1.69	0.33	14.20
1997	3.00	0.77	76.7	1.92	0.37	14.40
1998	2.08	0.52	81.5	1.52	0.28	17.00
1999	3.73	1.01	108.1	2.25	0.42	20.70
2000	2.59	0.71	97.8	1.76	0.34	17.70
2001	1.64	0.40	88.8	1.80	0.34	18.60
2002	2.17	0.55	89.8	1.76	0.34	19.20

Table A5: Variables selected by order of selection for the binomial, lognormal (all years), and lognormal (1992–2002) for the all vessels catch per tow models for the Campbell Island Rise.

Order	Binomial model		Lognormal, all years		Lognormal, 1992–2002	
	Variable	D^2	Variable	r^2	Variable	r^2
1	*Vessel*	0.8	*Vessel*	25.9	*Vessel*	31.3
2	*Year*	0.4	*Year*	29.5	*Year*	35.2
3	*Distance*	0.3	*Day in season*	30.8	*Day in season*	37.0
4	*Nationality*	0.4	*End time of tow*	32.2	*Start time of tow*	38.3
5			*Duration*	33.1	*Duration*	39.3

Table A6: Proportion of zero tows and year effects for the loglinear, binomial, and combined all vessels catch per tow models for the Campbell Island.

Year	Proportion zero tows	Loglinear model	Binomial model	Combined model
1986	0.06	1	1	1
1987	0.04	0.91	0.75	0.92
1988	0.02	0.88	0.35	0.89
1989	0.04	1.38	0.52	1.41
1990	0.09	1.06	0.84	1.07
1991	0.04	1.30	0.44	1.33
1992	0.23	0.60	2.54	0.45
1993	0.14	1.03	1.27	0.99
1994	0.06	1.19	0.52	1.23
1995	0.05	1.23	0.37	1.27
1996	0.06	2.28	0.51	2.35
1997	0.03	2.28	0.29	2.34
1998	0.06	1.74	0.46	1.79
1999	0.03	2.55	0.33	2.60
2000	0.01	1.85	0.17	1.87
2001	0.00	1.83	0.05	1.84
2002	0.03	1.94	0.32	1.98

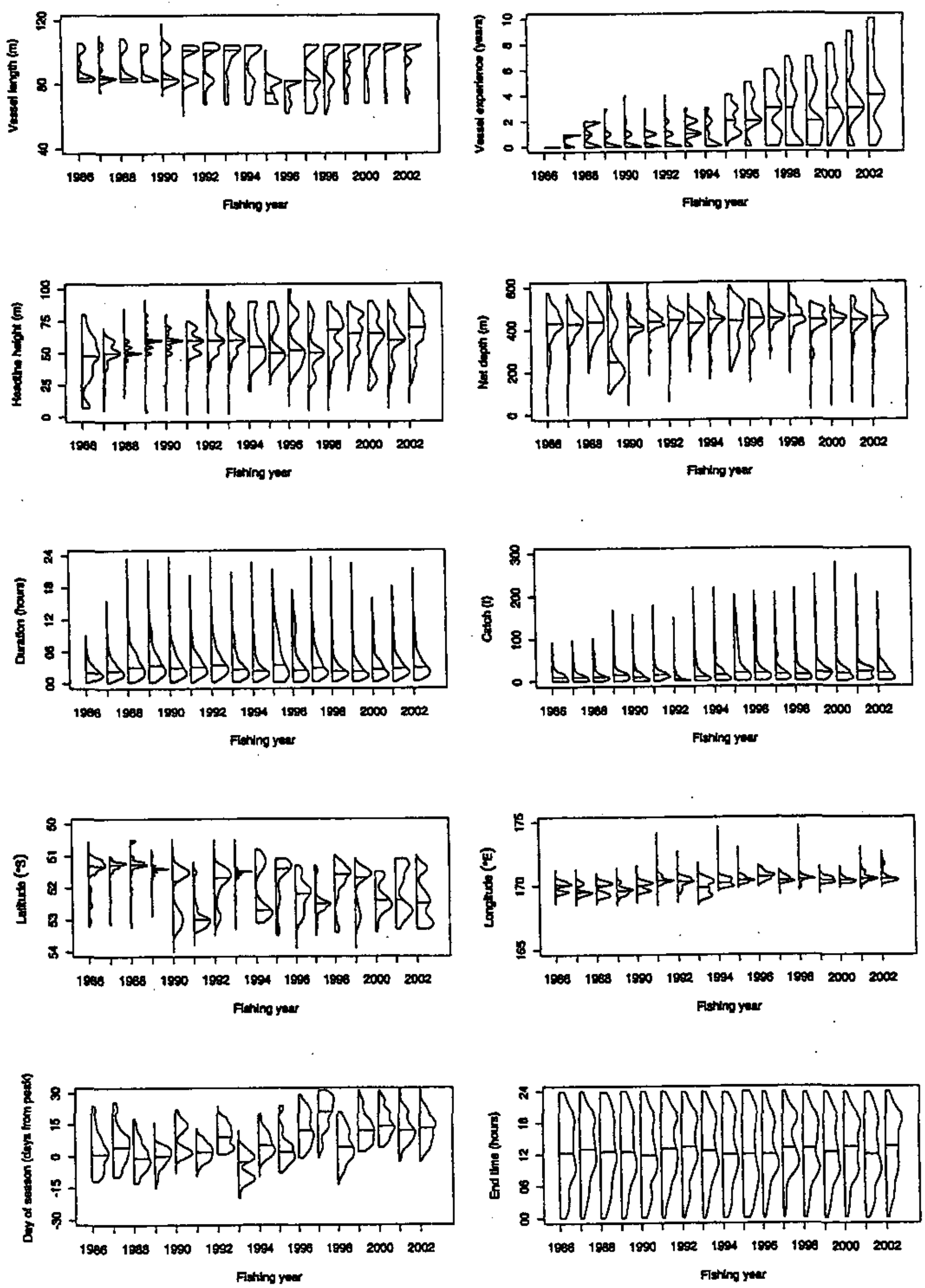


Figure A1: Distribution plots of relative frequencies for all Campbell Island Rise vessels tows for vessel length, vessel experience, net headline height, net depth, tow duration, tow catch, latitude at start of tow, longitude at start of tow, and end time of tow, 1986–2002.

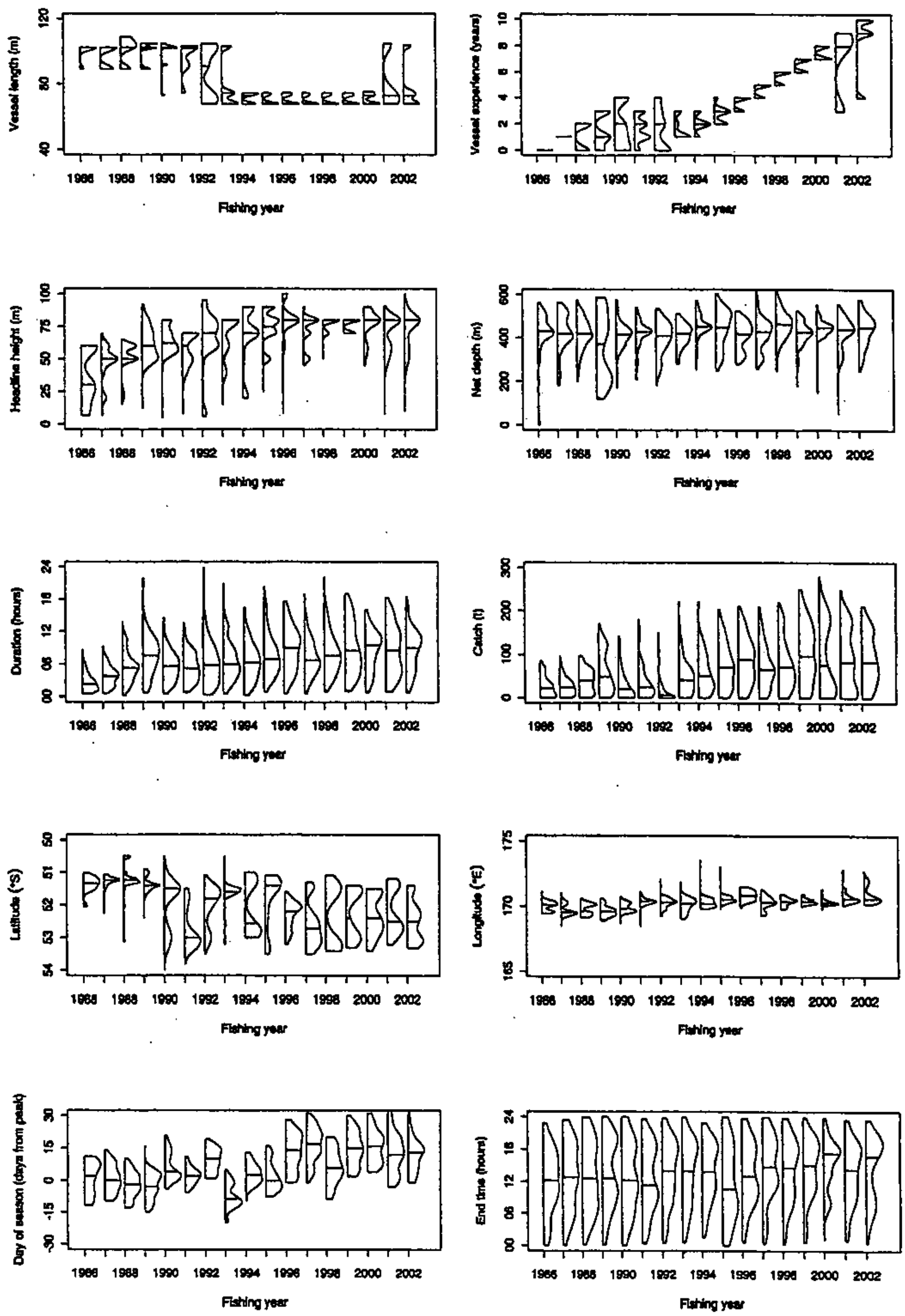


Figure A2: Distribution plots of relative frequencies for all Campbell Island Rise core surimi vessels tows for vessel length, vessel experience, net headline height, net depth, tow duration, tow catch, latitude at start of tow, longitude at start of tow, and end time of tow, 1986–2002.

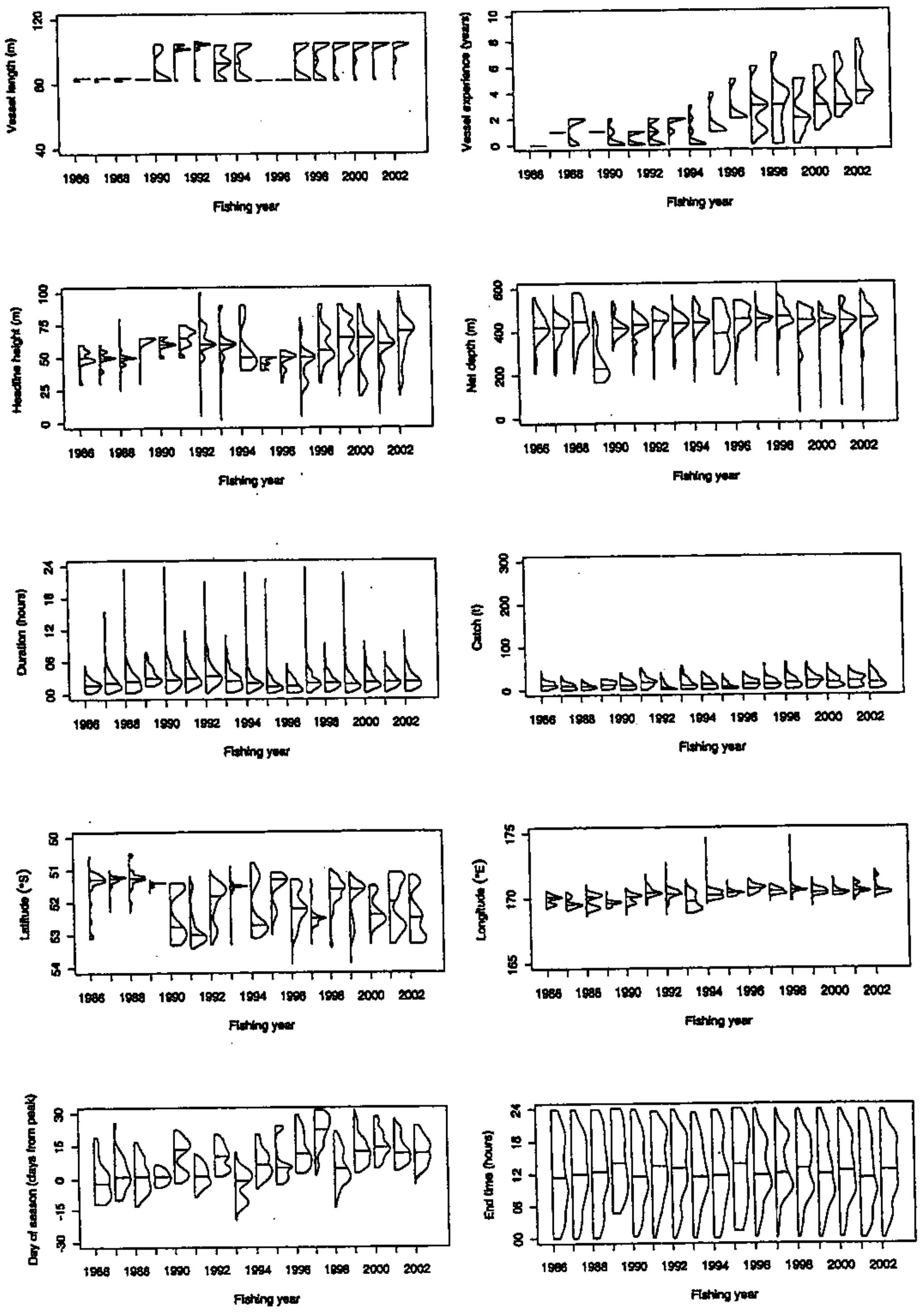
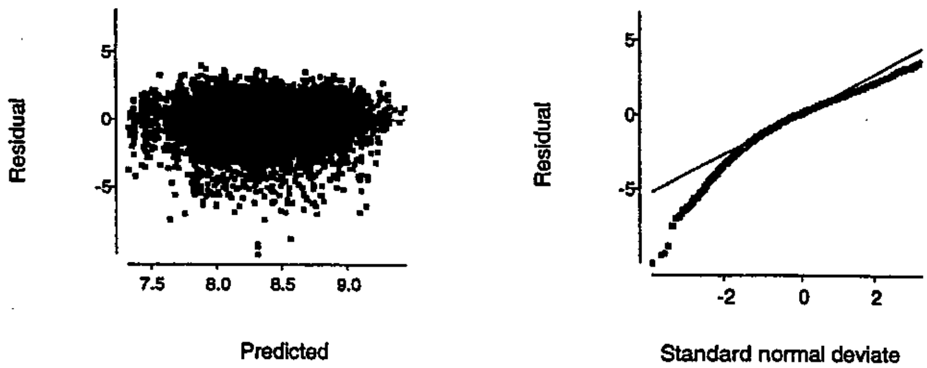
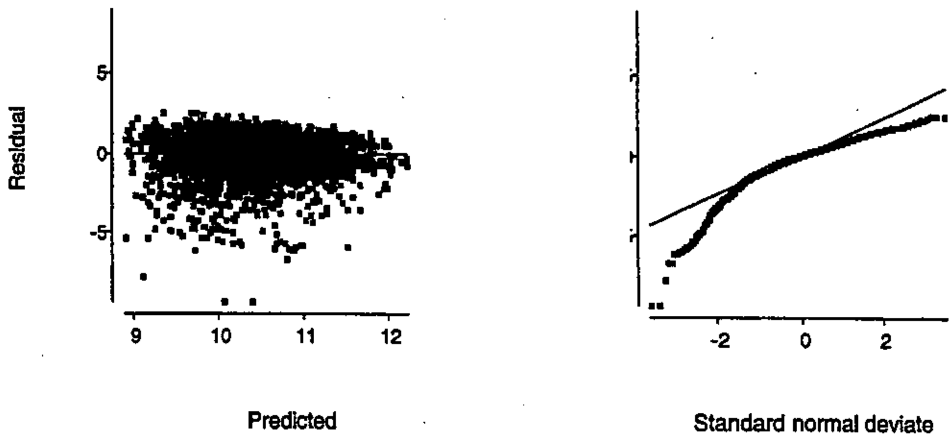


Figure A3: Distribution plots of relative frequencies for all Campbell Island Rise core dressed vessels tows for vessel length, vessel experience, net headline height, net depth, tow duration, tow catch, latitude at start of tow, longitude at start of tow, and end time of tow, 1986–2002.

All vessels catch per hour



All vessels catch per day



Core surimi vessels catch per tow

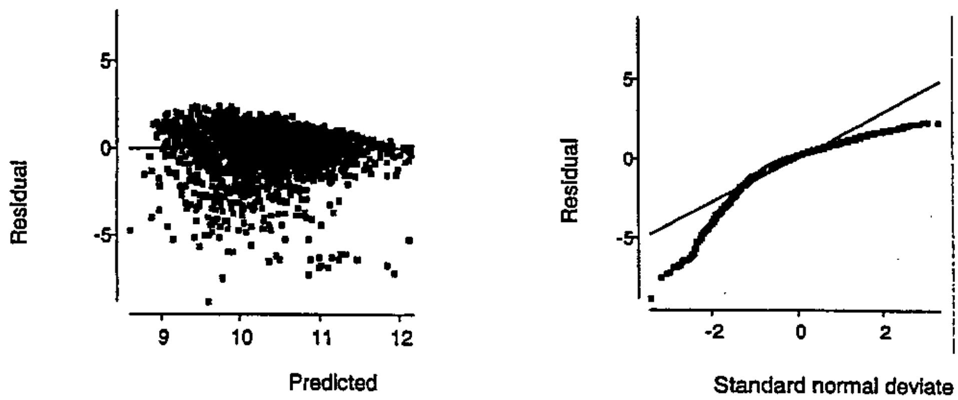
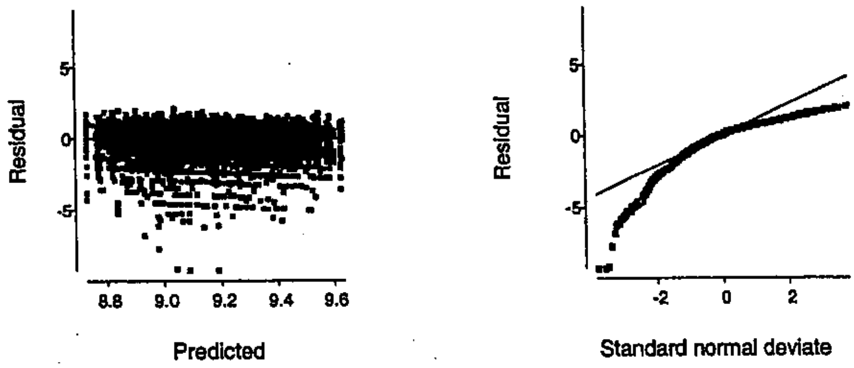


Figure A4: Diagnostic plots for CPUE models for the Campbell Island Rise fishery, 1986 to 2002.

Core dressed vessels catch per tow



All vessels catch per tow (1992–2002)

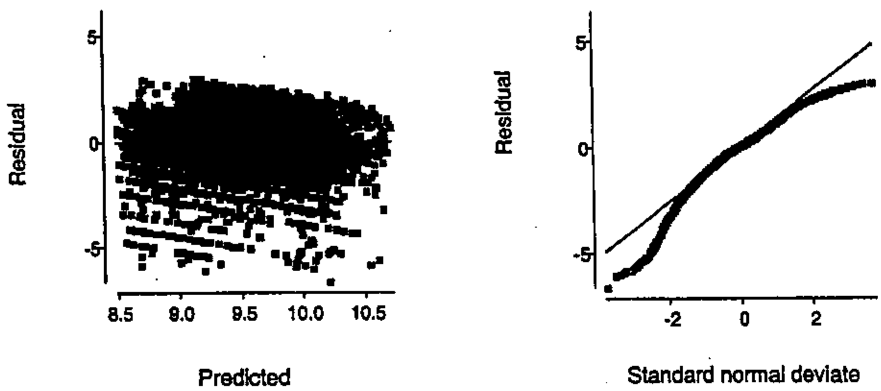


Figure A4: – continued.

Appendix B: Bounty Platform spawning fishery

Table B1: Bounty Platform SBW fishery. Number of non-zero tows, vessels, mean tow duration, catch per tow, catch per day, and catch per hour for all vessels and vessel subgroups, 1990 to 2002.

													Year	
All vessels	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Number of vessels	22	29	47	19	6	7	5	5	10	14	6	4	6	
Total catch (t)	4 289	9 077	53 884	9 241	3 096	6 372	4 135	1 950	5 703	8 297	3 850	2 176	7 167	119 237
Number of tows	221	467	1 513	282	85	103	59	26	101	239	79	25	88	3 288
Mean tow duration (h)	2.8	3.3	3.2	3.4	3.4	5.7	7.5	6.8	5.8	4.3	4.1	4.1	6.3	4.7
Mean catch per tow (t)	19.4	19.4	35.6	32.8	36.4	61.8	70.8	75.0	56.5	34.7	48.7	87.1	81.5	50.7
Mean catch per hour (t)	10.9	8.8	20.1	14.6	23.5	21.5	11.8	17.9	12.2	18.9	15.8	25.7	23.8	17.3
Number of days	74	151	547	132	46	55	40	17	57	109	40	17	50	1 335
Mean catch per day (t)	58.0	60.1	98.5	70.0	67.3	115.9	103.4	114.7	100.1	76.1	96.3	128.0	143.3	94.7
All surimi vessels														
Number of vessels	6	6	14	6	4	6	5	5	4	5	4	4	4	
Total catch (t)	1 459	3 519	30 698	7 451	2 758	6 328	4 135	1 950	5 142	5 239	3 501	2 176	6 870	81 226
Number of tows	33	67	371	93	43	98	59	26	52	84	37	25	59	1 047
Mean tow duration (h)	5.6	5.4	6.2	6.0	4.7	5.9	7.5	6.8	9.0	8.1	6.3	4.1	7.3	6.4
Mean catch per tow (t)	44.2	52.5	82.7	80.1	64.2	64.6	70.1	75.0	98.9	62.4	94.6	87.1	116.4	76.4
Mean catch per hour (t)	9.1	11.8	27.0	21.2	35.4	22.2	11.7	17.9	13.1	15.7	21.3	25.7	32.2	20.3
Number of days	15	33	201	54	28	52	40	17	30	47	24	17	37	595
Mean catch per day (t)	97.3	106.6	152.7	138.0	98.5	121.7	103.4	114.7	171.4	111.5	145.9	128.0	185.7	128.9
Core surimi vessels														
Number of vessels	1	3	6	5	4	6	5	5	4	5	4	4	4	
Total catch (t)	55	1 588	18 950	6 187	2 758	6 328	4 135	1 950	5 142	5 239	3 501	2 176	6 870	64 879
Number of tows	4	23	194	66	43	98	59	26	52	84	37	25	59	770
Mean tow duration (h)	4.3	5.4	6.9	6.6	4.7	5.9	7.5	6.8	9.0	8.1	6.3	4.1	7.3	6.4
Mean catch per tow (t)	13.8	69.0	97.6	93.7	64.2	64.6	70.1	75.0	98.9	62.4	94.6	87.1	116.4	77.5
Mean catch per hour (t)	3.3	14.8	24.5	25.1	35.4	22.2	11.7	17.9	13.1	15.7	21.3	25.7	32.2	20.2
Number of days	2	13	109	43	28	52	40	17	30	47	24	17	37	459
Mean catch per day (t)	27.5	122.2	173.9	143.9	98.5	121.7	103.4	114.7	171.4	111.5	145.9	128.0	185.7	126.8

Table B1: – continued

All dressed vessels	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Year 2002	Total
Number of vessels	16	23	33	13	2	1	0	0	6	9	2	0	2	
Total catch (t)	2 830	5 558	23 186	1 790	338	44	0	0	561	3 058	349	0	297	38 011
Number of tows	188	400	1 142	189	42	5	0	0	49	155	42	0	29	2 241
Mean tow duration (h)	2.3	2.9	2.3	2.1	2.0	1.7	0.0	0.0	2.5	2.2	2.1	0.0	4.3	1.9
Mean catch per tow (t)	15.1	13.9	20.3	9.5	8.1	8.8	0.0	0.0	11.4	19.7	8.3	0.0	10.3	9.6
Mean catch per hour (t)	11.3	8.3	17.9	11.3	11.3	6.3	0.0	0.0	11.3	20.6	10.9	0.0	5.3	8.8
Number of days	59	118	346	78	18	3	0	0	27	62	16	0	13	740
Mean catch per day (t)	48.0	47.1	67.0	22.9	18.8	14.7	0.0	0.0	20.8	49.3	21.8	0.0	22.8	25.6
Core dressed vessels														
Number of vessels	0	4	5	8	1	1	0	0	3	4	1	0	1	
Total catch (t)	0	1 975	6 090	1 470	47	44	0	0	383	647	162	0	116	10 934
Number of tows	0	108	221	159	5	5	0	0	31	64	27	0	18	638
Mean tow duration (h)	0.0	2.9	2.6	1.8	1.9	1.7	0.0	0.0	2.4	2.1	2.3	0.0	2.5	1.6
Mean catch per tow (t)	0.0	18.2	27.6	9.3	9.4	8.8	0.0	0.0	12.4	10.1	6.0	0.0	6.5	8.3
Mean catch per hour (t)	0.0	10.3	15.8	12.5	7.5	6.3	0.0	0.0	13.4	9.0	3.4	0.0	3.9	6.3
Number of days	0	32	66	57	2	3	0	0	14	22	10	0	6	212
Mean catch per day (t)	0.0	61.7	92.3	25.8	23.5	14.7	0.0	0.0	27.4	29.4	16.2	0.0	19.3	23.9

Table B2: Variables selected by order of selection for the all vessels catch per hour and catch per day models for the Bounty Platform fishery, 1990 to 2002.

	All vessels catch per hour		All vessels catch per day	
Order	Variable	r^2	Variable	r^2
1	*Year*	5.3	*Nationality*	13.1
2	*Nationality*	10.3	*Number of tows*	26.3
3	*Tonnage*	12.6	*Year*	32.6
4			*Vessel category*	34.1
5			*Length*	36.4
6			*Distance*	38.0

Table B3: Relative year effects, standard errors and raw mean CPUE by year for the all vessel catch per hour and catch per day models for the Bounty Platform fishery, 1990 to 2002.

	Catch per hour			Catch per day		
Year	Index	s.e.	CPUE	Index	s.e.	CPUE
1990	1.00		10.9	1.00		58
1991	0.90	0.11	8.8	1.22	0.20	60.1
1992	1.76	0.19	20.1	1.71	0.25	98.5
1993	0.99	0.13	14.6	1.06	0.18	70
1994	0.76	0.16	23.5	0.48	0.11	67.3
1995	0.85	0.16	21.5	0.62	0.13	115.9
1996	1.07	0.24	11.8	1.11	0.26	103.4
1997	1.15	0.36	17.9	1.09	0.34	114.7
1998	0.93	0.18	12.2	0.91	0.19	100.1
1999	0.88	0.13	18.9	0.60	0.11	76.1
2000	0.75	0.15	15.8	0.96	0.22	96.3
2001	1.88	0.59	25.7	1.14	0.36	128
2002	1.52	0.29	23.8	1.48	0.33	143.3

Table B4: Variables selected by order of selection for the all surimi (1991–2002), core surimi (1992–2002), and all dressed (1990–2002) vessels catch per tow models for the Bounty Platform fishery.

	All surimi vessels		Core surimi vessels		All dressed vessels	
Order	Variable	r^2	Variable	r^2	Variable	r^2
1	*Year*	10.6	*Year*	14.5	*Year*	15.6
2	*Length*	15.8	*Vessel*	18.0	*Length*	20.0
3	*Distance*	17.9	*Headline category*	22.1	*Headline category*	23.6
4	*Vessel*	19.4	*Year built*	25.0		
5	*Year built*	22.2	*Distance*	27.0		
6	*Tonnage*	23.4	*Tonnage*	28.0		

Table B5: Relative year effects and standard errors, and raw mean CPUE for the all surimi (1991–2002), core surimi (1992–2002), and all dressed (1990–2002) vessels catch per tow models for the Bounty Platform fishery.

	All surimi vessels			Core surimi vessels			All dressed vessels		
Year	Index	s.e.	CPUE	Index	s.e.	CPUE	Index	s.e.	CPUE
1990	-	-	44.2	-	-	13.8	1.00	-	15.1
1991	1.00		52.5	-	-	69.0	0.96	0.09	13.9
1992	1.43	0.30	82.7	1.00	-	97.6	1.37	0.11	20.3
1993	1.49	0.37	80.1	1.14	0.24	93.7	0.49	0.05	9.5
1994	0.44	0.13	64.2	0.46	0.13	64.2	0.39	0.08	8.1
1995	0.53	0.13	64.6	0.34	0.06	64.6	0.70	0.32	8.8
1996	0.91	0.25	70.1	0.65	0.14	70.1	-	-	-
1997	0.85	0.29	75	0.63	0.19	75.0	-	-	-
1998	1.47	0.42	98.9	1.38	0.36	98.9	0.58	0.10	11.4
1999	0.15	0.04	62.4	0.10	0.02	62.4	0.93	0.10	19.7
2000	1.18	0.37	94.6	0.92	0.27	94.6	0.29	0.05	8.3
2001	0.72	0.26	87.1	0.52	0.17	87.1	-	-	-
2002	1.44	0.41	116.4	0.91	0.26	116.4	0.64	0.13	10.3

Table B6: Variables selected by order of selection for the all vessels binomial model for the Bounty Platform fishery, 1990 to 2002.

	Binomial model	
Order	Variable	D^2
1	*Year*	-
2	*Nationality*	4.6
3	*Start time of tow*	2.2
4	*Processing type*	1.2
5	*Sub-area*	1.0

Table B7: Proportion of zero tows and relative year indices for the lognormal linear, binomial, and combined models for the Bounty Platform fishery, 1990 to 2002.

Year	Proportion of zero tows	Loglinear model	Binomial model	Combined model
1990	0.12	1.00	1.00	1.00
1991	0.06	1.03	1.93	0.98
1992	0.04	1.48	4.82	1.30
1993	0.21	0.66	0.35	0.76
1994	0.13	0.30	0.76	0.31
1995	0.14	0.46	0.51	0.49
1996	0.11	0.79	0.68	0.82
1997	0.28	0.72	0.23	0.91
1998	0.10	0.81	0.91	0.82
1999	0.12	0.40	0.65	0.42
2000	0.19	0.50	0.39	0.57
2001	0.11	0.65	0.56	0.68
2002	0.06	1.20	1.12	1.19

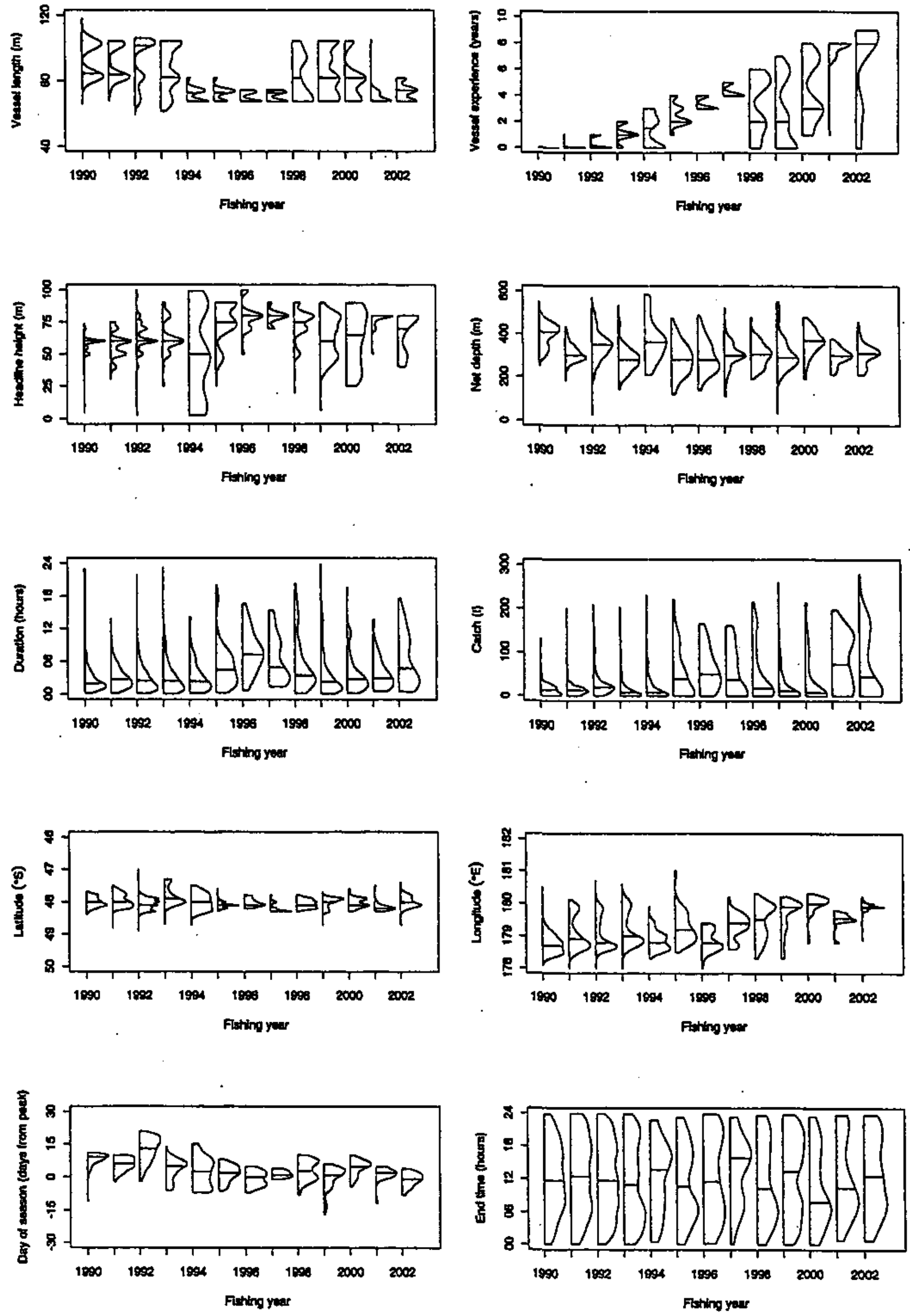


Figure B1: Distribution plots of relative frequencies for all Bounty Platform vessels tows for vessel length, vessel experience, net headline height, net depth, tow duration, tow catch, latitude at start of tow, longitude at start of tow, and end of tow time, 1990–2002.

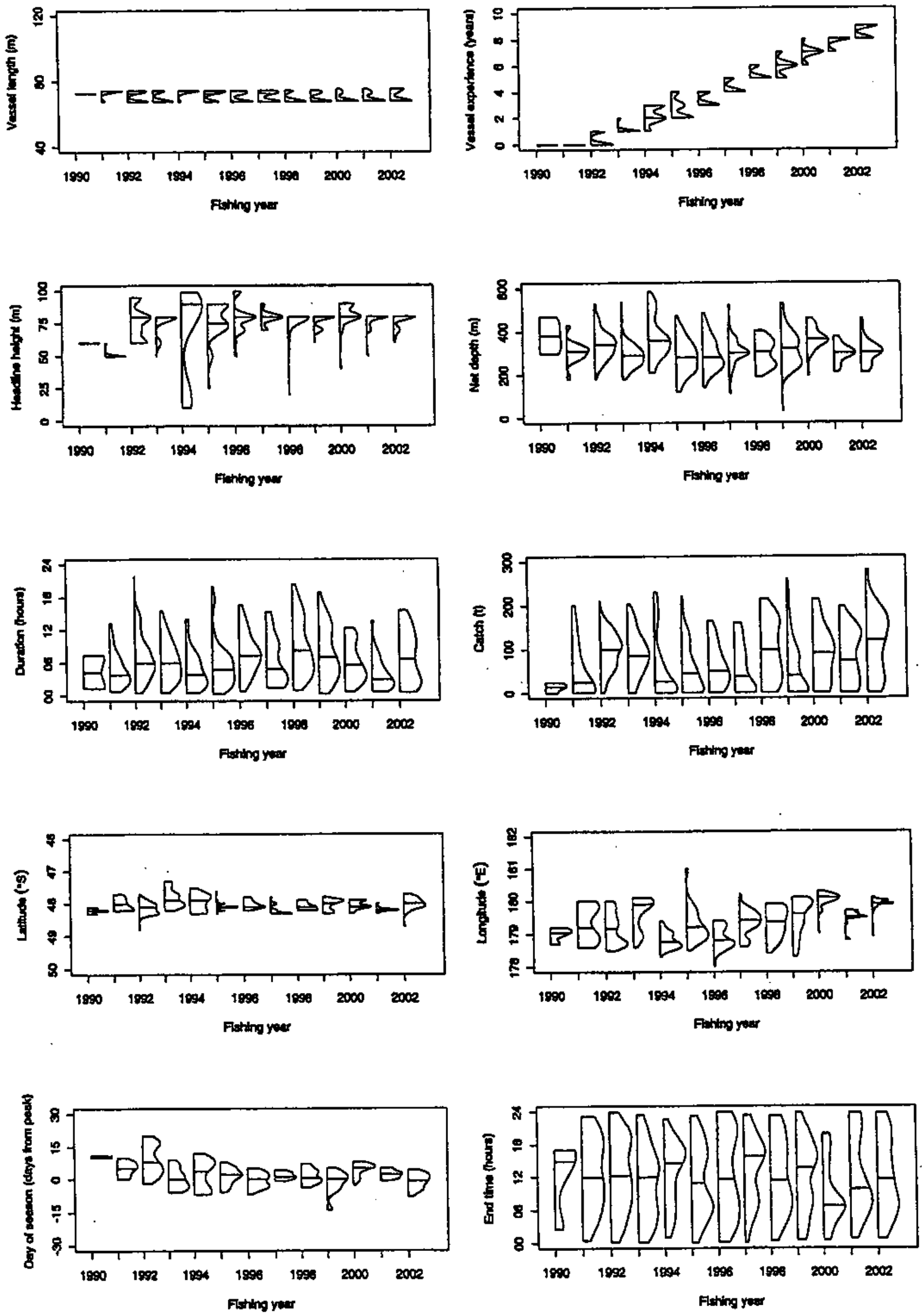


Figure B2: Distribution plots of relative frequencies for all Bounty Platform core surimi vessels tows for vessel length, vessel experience, net headline height, net depth, tow duration, tow catch, latitude at start of tow, longitude at start of tow, and end time of tow, 1990–2002.

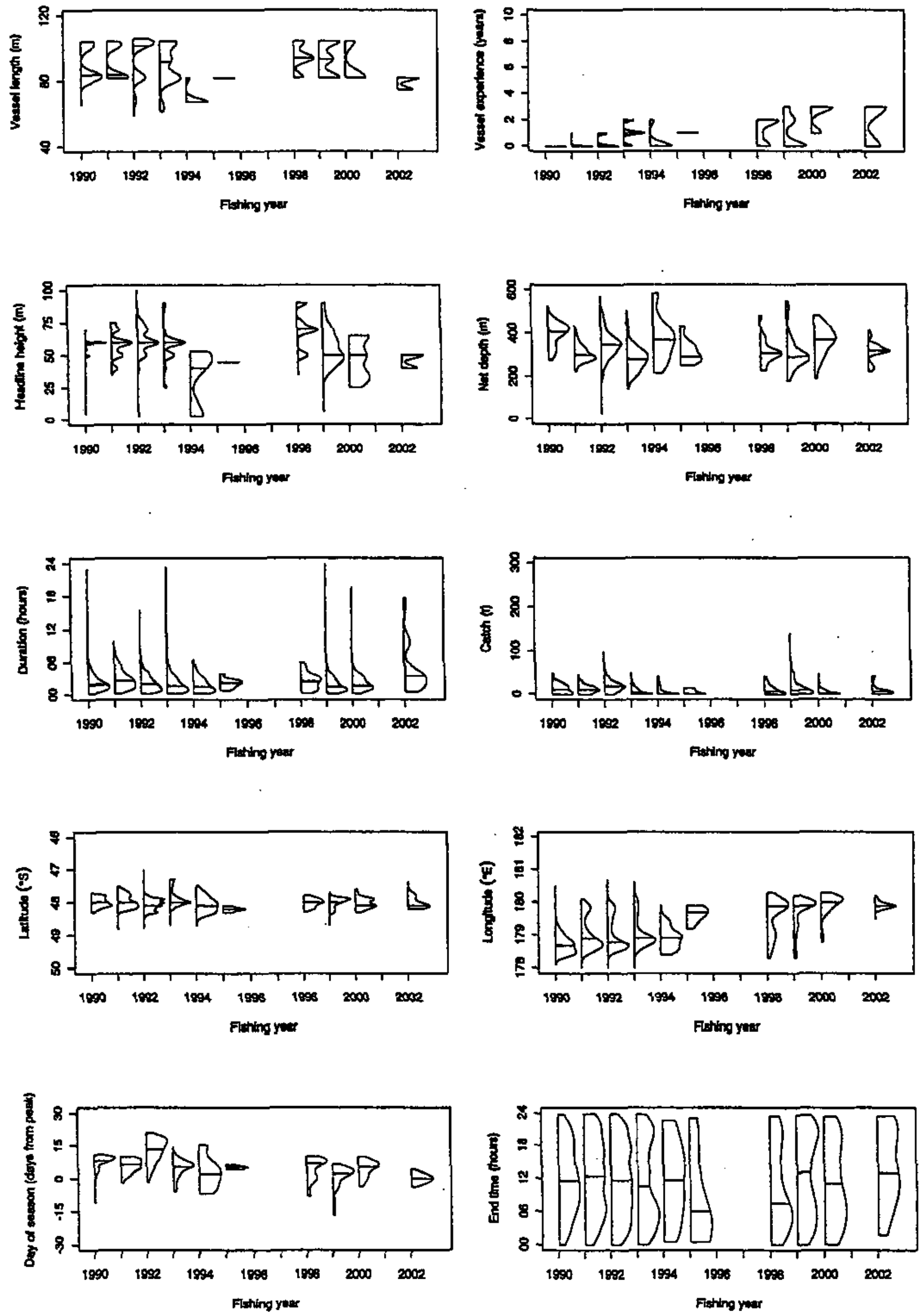
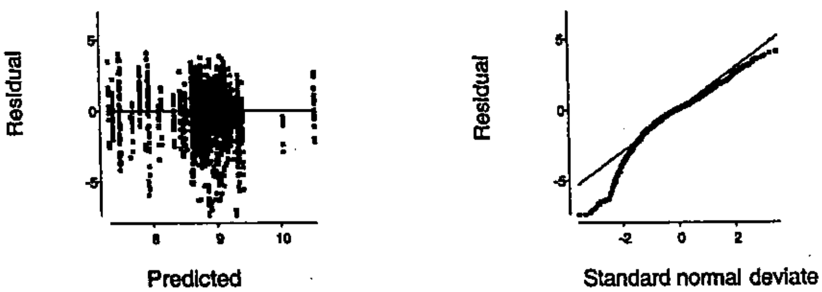
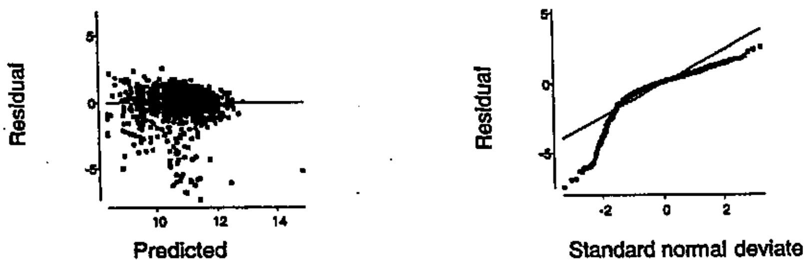


Figure B3: Distribution plots of relative frequencies for all Bounty Platform dressed vessels tows for vessel length, vessel experience, net headline height, net depth, tow duration, tow catch, latitude at start of tow, longitude at start of tow, and end time of tow, 1990–2002.

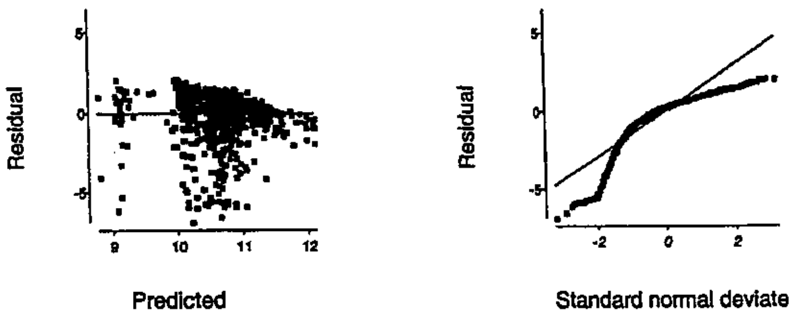
All vessels catch per hour



All vessels catch per day



All surimi vessels catch per tow (1991–2002)



Core surimi vessels catch per tow (1992–2002)

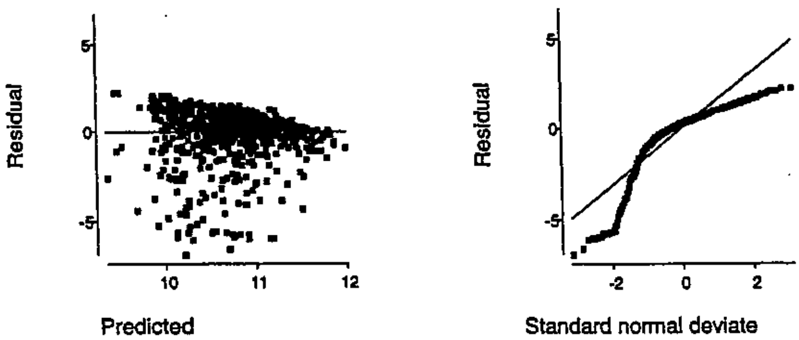


Figure B4: Diagnostic plots for various models for the Bounty Platform fishery, 1990 to 2002.

All dressed vessels catch per tow (1990–2002)

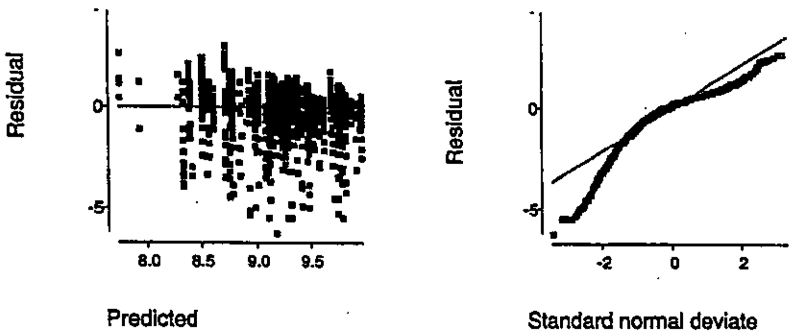


Figure B4 continued.