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# Standardised CPUE analysis for the northern gemfish (*Rexea solandri*) fisheries in SKI 1 and SKI 2, 1989–2002

D. Ayers

New Zealand Fisheries Assessment Report 2003/34
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**Correction to *New Zealand Fisheries Assessment Report 2003/34.***

**This is the correct version of Figure 2, page 15.**

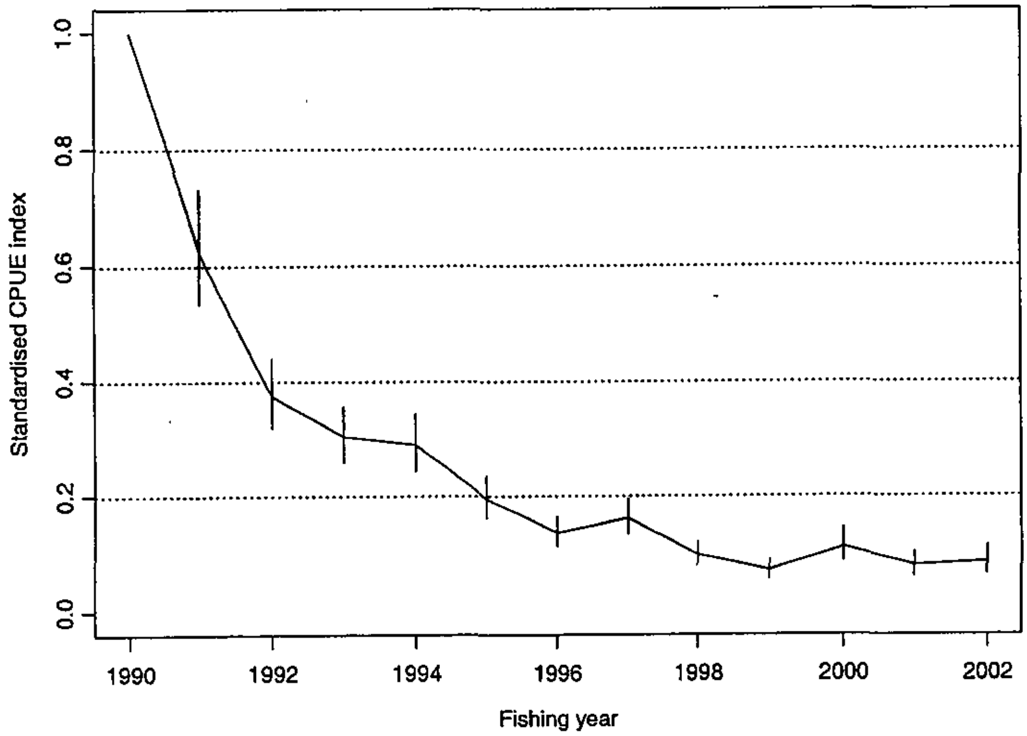


**Figure 2: Relative standardised CPUE indices for the SKI 1 target fishery**

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## EXECUTIVE SUMMARY

**Ayers, D. (2003). Standardised CPUE analysis for the northern gemfish (*Rexea solandri*) fisheries in SKI 1 and SKI 2, 1989–2002.**

*New Zealand Fisheries Assessment Report 2003/34.* **19 p.**

This report addresses objective 2 of the Ministry of Fisheries project SKI 2002/01. Catch per unit effort analyses were carried out to update the standardised CPUE indices used in the gemfish stock assessment.

The gemfish fishery peaked in the late 1980s and early 1990s. At that time the catch per unit effort in both northern fisheries (SKI 1 and SKI 2) were at relatively high levels. In the early to mid 1990s the two CPUE indices showed steep declines. By 1995 both indices had levelled off.

The addition of two new years of data and the slight modification of analysis techniques did not change the general trend observed. The CPUE indices in both fisheries continued to remain at relatively low levels (10–15% of 1989–90 levels).

## 1. INTRODUCTION

The New Zealand northern gemfish fishery occurs along the east coast of the North Island, and down the west coast of Northland. It occurs in Quota Management Areas 1, 2, and 9, and is managed as two fish stocks, SKI 1 and SKI 2.

The SKI 1 fishery covers the northern areas of the North Island (QMA 1 and 9) and consists of a pre-spawning fishery on the west coast of the North Island, and a pre-spawning fishery in the Bay of Plenty and eastern Northland. Gemfish are targeted primarily during the annual spawning migration. The fishery operates most intensively between April and June, though in some years there is a secondary fishery in August and September which targets mature fish returning from the northern spawning grounds (Annala et al. 2002).

The SKI 2 fishery operates throughout the year south of East Cape on the east coast of the North Island (QMA 2). There is often a marked decline in fishing during June and July, when fish are assumed to have moved north to spawn (Annala et al. 2002).

Both fisheries tend to stay close to the margins of the continental shelf. The locations of all trawls recorded on Trawl Catch Effort Processing Return (TCEPR) forms over the past decade are shown in Figure 1.

This analysis updates the catch per unit effort analysis presented in the last gemfish stock assessment (Dunn et al. 2001). There are few changes to the methods used, and the major results represent increased information as a result of the inclusion of two new years of data (2000–01 and 2001–02).

## 2. METHODS

### 2.1 Description of the fishery

There have been few recent changes in the times or areas fished, but there has been a trend over the past decade to lower catches and less effort expended in the fishery. This trend parallels changes in the catch limits set by the Minister of Fisheries. In the early 1990s, the Total Allowable Catch remained relatively stable at historically high levels in both SKI 1 and SKI 2. This has been followed by many reductions in the TAC since the mid to late 1990s (Annala et al. 2002). For the 2002–03 fishing year, the TAC was reduced to its current levels of 218 t in SKI 1 and 240 t in SKI 2.

### 2.2 Description of the data

The data for this analysis were acquired from the fisheries statistics database managed by the Ministry of Fisheries. The data were originally recorded on either Catch Effort Landing Return (CELR) forms or Trawl Catch Effort Processing Return (TCEPR) forms. Records from the CELR form represent an entire day's fishing for a vessel, whereas a record in the TCEPR form represents data for a single trawl. To make the two forms comparable, the TCEPR data were summed over trawls for a given vessel for each day. This produced a single record that had the total catch, total hours spent fishing (as calculated by subtracting the start time from the end time for each trawl in the TCEPR form), and the number of trawls per vessel per day. This made the TCEPR data comparable to the CELR data, which also had data for total catch, total duration of fishing effort, and total numbers of trawls per day for each vessel.

A number of pertinent variables were not explicitly provided with the data, though they could be derived from other variables. Table 1 describes the major variables in the data set.

As we are interested in the change of the standardised CPUE index over time, the primary variable of interest pertains to the year effect. It is possible to consider this as a continuous variable, but it was treated as a categorical variable because we are primarily interested in the year-to-year fluctuations in the two fisheries. The variable fishing year was created by grouping observations by date into yearly categories. A fishing year starts on 1 October and ends on 30 September of the following calendar year.

On a finer time scale, the variable fishing day was considered. This variable takes values between 1 and 365, and represents the day on which fishing occured within the fishing year. The inclusion of fishing day in the analysis allows for the assessment of seasonal fluctuations in the fishery. The efficacy of this variable in a model is dependent upon the assumption that the seasonal patterns of fishing do not change over the years, as, for example, fishing day 30 in one year is assumed to have the same effect as fishing day 30 in the other years. Dunn et al. (2001) grouped this variable into eight distinct categories and modelled it as a factor. In this analysis fishing day is treated as a continuous variable. This change was made because the method of categorisation can affect the form of the observed seasonal effect.

There are many variables that describe the vessels involved in the fisheries, including length, breadth, draught, power, tonnage, year built, and nationality. There is also a unique vessel identification number. The vessel id was used in the main analysis as it allows for vessel specific effects to be measured and does not force a parametric form on to the vessels. Other vessel variables were examined after the analysis in an attempt to identify why particular vessels had either very high or very low catch rates.

The fishing method and statistical area were also recorded as categorical variables. Method could take values of bottom trawl, midwater trawl, or bottom pair trawl. The Ministry of Fisheries Statistical Areas were used in the analyses.

Variables that were not found in the original data set, but were derived from it, include CPUE and zero catch. The CPUE variable is the catch per unit effort, which is in this case defined as the total catch (in kilograms) per hour fished on each day that fishing occurred. This definition of CPUE is the same as that used in previous CPUE analyses. An indicator variable (zero catch) was used to identify whether there was no gemfish caught in a particular trawl (TCEPR only).

### 2.3 Data checking and validation

The data potentially contained a number of errors, and were therefore scrutinised to identify and, if possible, correct errors in recording and transcription. The data cleansing process was similar to that of Phillips (2001). Variables with invalid codes were examined, and if there was an obvious error it was corrected. Errors that were not obvious or could not be reasonably corrected were set to missing.

### 2.4 Calculation of the standardised CPUE

The methods used to generate the CPUE indices for the gemfish fisheries were similar to those used in the last stock assessment (Dunn et al. 2001).

The general framework was to use a generalised linear model to relate the CPUE to any number of potential explanatory variables, including a categorical variable identifying the fishing year, and then take the coefficients of the years (or a transformation of them) as a standardised index of the CPUE.

The most important variable in the model was the fishing year. This was considered as a categorical variable, so that each year would have a unique regression coefficient. This allowed an assessment of the relative change in the CPUE over time, after the effects of the other variables in the model were controlled for. The benefit of considering this as a categorical variable is that it allows the year effect to take any pattern, and is not constrained to some pre-specified parameterisation (i.e., linear or quadratic).

Other variables in the model were treated as either factors (if they were categorical), or were modelled with third order polynomials (if they were continuous). Third order polynomials were used because they are able to capture the curvature of the effect sufficiently for the present objectives.

The CPUE data tended to be highly variable, and very large values occurred regularly. As the CPUE is necessarily positive, this can cause the data to be notably skewed. These observations require models with lognormal error structures to be considered. In practice, this is generally a valid assumption, though the use of a lognormal distribution can introduce complexities into the model. Modelling a lognormally distributed variable generally involves taking logarithms (either explicitly modelling the logarithm of the response variable, or in the link function if the untransformed variable is to be modelled), and this results in undefined values when zeros are encountered in the response variable.

Because there were a number of zeros in the data, and because the proportion of zeros appears to change over time (Table 2), it is necessary to extend the model to account for this aspect of the fishery.

The approach taken in this analysis to deal with the zeros followed that outlined by Vignaux (1994). She used a two-stage model, where the catch was modelled as a logistic regression, with a response variable that measured presence or absence of any catch. The second stage of the analysis modelled the CPUE, with the zeros removed. Lastly, the two models were combined to produce a final standardised CPUE index. The combination of the two models was effected by multiplying the indices from the lognormal model by a factor[1] related to the corresponding index from the binomial model. Confidence intervals for the indices were calculated by bootstrapping the observations, running the analysis on the resampled data sets, and assessing the variability of the resulting sets of indices (see Vignaux (1994) for full details on the combination of the two indices and the specific bootstrapping technique).

The CPUE analyses were implemented with the use of a stepwise regression method. This type of method can be used to select variables for the model in the absence of any strict biological or functional specification of a model. The general rule is that the stepwise selection technique adds variables to the model based on the amount of variation that the variables explain. Variables that account for much of the variation are added first. Variables that explain less than a prespecified amount of variation (generally 2%) are excluded from the final model. In this case, the criterion used to eliminate variables was a change in the residual deviance of less than 2%. Variables that were allowed to enter the regression models were Fishing year (required to be in the model), Vessel key, Fishing method, Statistical area, and Fishing day.

The analyses did not use all of the data available. Subsets of the data were used in both SKI 1 and SKI 2, as it was believed that the removal of some insignificant data would lead to more reliable models.

The subset for QMA 1 included Statistical Areas 1–4, 8, 9, 10, 46, and 47 (Figure 1). The other Statistical Areas that are contained in QMA 1 (such as 101–107) were left out of the analysis, because they represented only a small fraction of both the fishing effort and catch. The excluded areas were in offshore areas. The analysis also grouped some of the statistical areas because they were physically contiguous, and showed similar patterns in the fishing history (1 and 2 were grouped, as well as 4 and 8)

[1] Combined index = lognormal index × $1/(1-\pi(1-\beta))$, where $\pi$ is the baseline probability of a non-zero observation, and $\beta$ is the index calculated from the binomial model.

The subset for QMA2 included statistical areas 11–16. Again, the non-coastal statistical areas (201–205) were excluded from the analysis for the reasons outlined above. Statistical areas 11 and 12 were considered together, as were 15 and 16.

## 3. RESULTS

### 3.1 Description of the fishery

The estimated target gemfish catch is presented in Table 2. The catch column represents the total amount of targeted gemfish caught over all trawls, all days, and all vessels in each fishing year. The number of trawls was calculated by counting the number of records in the TCEPR data, and adding the value in the number of trawls column in the CELR data. The "% zero catch by day" column was calculated from total recorded daily catches for each vessel. This is available from both the TCEPR and the CELR forms. It is worth noting that this column does not identify days that had no catch, but rather vessels that recorded no catch for an entire day's fishing effort. The "% zero catch by trawl" column represents the percentage of gemfish target trawls that recorded no gemfish catch, and was calculated from TCEPR forms only, because it is not possible to determine this information from the CELR forms. Both the catch and the number of trawls declined steadily since 1989 in both SKI 1 and SKI 2. In SKI 1 the tonnes of fish caught per trawl fluctuated over the period of this study, though there is a notable downward trend. This is matched by a general upward trend in the percentage of zero trawls. The same trends are seen in SKI 2, and are more pronounced.

Table 3 shows the relationship between target catch and the fishing method used. It is clear that bottom trawling is the preferred method. This method is used almost exclusively, with the exception of some midwater trawl effort in SKI 2 in the early to mid 1990s.

From the mid 1990s there was a trend away from the use of CELR forms, as can be seen in Table 4. This table also shows that the target gemfish catch has been a relatively consistent proportion of the total recorded landings of gemfish in SKI 1, while SKI 2 shows more variation.

The fishing effort for Gemfish in SKI 1 and SKI 2 has generally focused on the coastal areas (Table 5). The primary statistical areas fished in SKI 1 were 2, 3, 4, 8, 9, 10, 46, and 47: the offshore areas accounted for a negligible proportion of the catch. The pattern for SKI 2 is similar; with statistical areas 11, 12, 13, 14, 15, and 16 accounting for over 99.5% of the total targeted catch.

### 3.2 Estimated CPUE indices

The final model was a two-stage model that first used the stepwise procedure to select appropriate variables for modelling the proportion of zero catches per day for individual vessels. Then the non-zero catch data was modelled as a lognormal variable, with the stepCPUE function selecting appropriate variables. Finally, the results from the two models were combined to give an overall standardised CPUE index. The results are given in Tables 6 and 7. Table 6 gives the standardised CPUE indices relative to the base year (1989–90) in the analysis: Table 7 shows the canonical form of the indices.

The variables selected for the binomial models in SKI 1 and SKI 2 were not the same. In SKI 1, the fishing year and the vessel key were included in the model. This is an interesting result, because it implies that there are certain vessels that report more zero catches. The inclusion of the vessel in the binomial model serves to reduce variation, and give an "average" proportion of zero catches.

In SKI 2 the only variable included in the binomial model was the year of fishing.

The models for the CPUE given a non-zero catch were also different for the two QMAs. The statistical area and the vessel id were selected for inclusion in both models, but SKI 1 also included a polynomial function (third order) of day in the fishing year. This represents a seasonal effect in this fishery.

The inclusion of the vessel key is easily explained. Vessels have different skippers and capacities. It is likely that these factors will affect the catch (and the catch per unit effort). The inclusion of this term in the model therefore acts as a method for removing the vessel differences from the standardised indices.

Model fits in both cases were adequate. Residual plots for lognormal models are presented for both QMAs. Plots of fitted values compared with observed values are also presented for the lognormal models. There are some indications that the models do not fit perfectly, but these are minor. Models that included more variables performed slightly better than the final models, but they added little explanatory power and became unwieldy, so the decision to use the more parsimonious models was made. The relative indices for SKI 1 are presented in Figure 2.

Figure 3 shows the effect that fishing day has on catch per unit effort in the SKI 1 fishery. The effect is conditional on the other variables in the model, and the plotted curve represents the effect for "average" values of the other variables. This clearly shows that there is a period of higher catch rates about 250 days into the fishing year (early June).

Statistical area also affected the CPUE. Figure 4 shows the effect that this had on the SKI 1 fishery. There is a noticeable increase in CPUE when vessels fish in Statistical Areas 46 and 47 on the west coast of Northland.

The effect of the vessel variable is shown in Figure 5 for SKI 1. Clearly, some vessels outperform others. The higher values in this plot represent vessels that were over 65 m long.

The fit of the SKI 1 standardised CPUE model is shown in Figure 6. There were no abnormalities in this residual plot that would suggest an ill-fitting model. The model accounted for a fair amount of the variation in the system; the $R^2$ value was 42%.

SKI 2 showed similar patterns overall; the standardised CPUE indices are shown in Figure 7. Although the data from SKI 2 included midwater trawls, the method variable was not selected in the final model.

Statistical area affected the CPUE in SKI 2, and its effect is shown in Figure 8. Again, this represents the effect conditional on "average" values of the other variables. There are no obvious reasons for any differences in CPUE among these areas.

Figure 9 shows the effect of vessel on SKI 2 CPUE; most vessels had similar catch rates.

To assess the fit of the SKI 2 CPUE model, diagnostic residual plots are shown in Figure 10. As with SKI 1, the model fits well. However, the $R^2$, at 32%, was lower than that for SKI 1.

## 4. DISCUSSION AND CONCLUSIONS

The modifications made to the analysis methods have not changed the results in an appreciable way, though I believe that they are legitimate and improve the analysis. Primarily, the inclusion of the binomial model allows for a more detailed examination of the catch effort data. It is now possible to examine either component separately, or both of them combined. The combined model will provide information on the overall catch per unit effort, while the other two models provide information on either the ability to catch any gemfish, and the size of catches given that gemfish were caught.

The general trends that were seen in this analysis are very similar to those seen in previous studies. There was an obvious downward trend in both the catches and the catch per unit effort in both northern gemfish fisheries. This decline was quite sharp in the early part of the 1990s, but it appears to have slowed, and perhaps stopped, since about 1997. In 2002–03 the CPUE was about 10% of the 1989–90 level in SKI 1 and about 15% of the 1989–90 level in SKI 2.

Working Group discussions have suggested that one issue that may need resolving is the completeness of the data, due primarily to the requirements of recording data on CELR and TCEPR forms. Skippers targeting gemfish, and reporting on a TCEPR form, are not required to report their gemfish catches if the total weight of gemfish caught on any trawl is less than the weight of five other species caught on that trawl. There will therefore be a number of records that have a zero recorded where there should actually be a positive catch.

The effect of this reporting procedure is unclear. Because the data from the TCEPR forms was collapsed into daily records, it is possible that the total gemfish catch for that day was underestimated (if on some tows gemfish was not in the top five, but on other tows it was), or not included at all (if no tows had gemfish in the top five species). The first case will lead to an underestimate of the CPUE index, while the second case will lead to an overestimate, because of the separate handling of positive and zero tows. A method for accounting for these 'missed' records needs to be incorporated into future models.

## 5. ACKNOWLEDGMENTS

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**Table 1: Description of variables available for the analysis. Variables in bold are categorical.**

| Variable | Description |
|---|---|
| Listed variables | |
| *Form number* | Form number of the individual CELR or TCEPR records |
| *Vessel key* | Unique vessel identification number |
| *Start latitude* <br> *Start longitude* | Position at start of trawl |
| *End latitude* <br> *End longitude* | Position at end of trawl |
| *Fishing method* | Fishing method employed |
| *Target species* | Species of fish targeted |
| *Total catch* | Total weight of all fish caught (kg) |
| *Gemfish catch* | Total weight of gemfish caught (kg) |
| *Vessel nationality* | The registered nationality of the vessel at the time of the trawl |
| *Vessel length* | The overall length of the vessel in metres at the time of the trawl |
| *Vessel draught* | The registered draught of the vessel in metres at the time of the trawl |
| *Vessel breadth* | The registered breadth of the vessel in metres at the time of the trawl |
| *Vessel tonnage* | The gross tonnage of the vessel in metric tonnes at the time of the trawl |
| *Vessel power* | Power in kilowatts of the vessel engine |
| *Year vessel built* | Year in which the vessel was built |
| ***Statistical area*** | Statistical area at the start of the trawl |
| ***Fishing year*** | Fishing year (from 1 October to 30 September) |
| Derived variables | |
| *Fishing day* | Number of days since the start of the fishing year |
| ***Zero catch*** | Binary variable indicating if the catch per day was non-zero |
| *CPUE* | Catch (kg) per hour per day |

**Table 2: Estimated gemfish target catch and unstandardised CPUE.**

(a) SKI 1

| Year | Catch (t) | Number of trawls | Tonnes per trawl | % zero catch by day | % zero catch by trawl (TCEPR only) |
|---|---|---|---|---|---|
| 1989–90 | 951 | 1 176 | 0.81 | 5.79 | 4.92 |
| 1990–91 | 852 | 1 136 | 0.75 | 1.92 | 2.34 |
| 1991–92 | 738 | 1 412 | 0.52 | 6.10 | 14.87 |
| 1992–93 | 976 | 1 626 | 0.60 | 2.95 | 6.13 |
| 1993–94 | 938 | 884 | 1.06 | 3.01 | 6.40 |
| 1994–95 | 905 | 770 | 1.17 | 5.61 | 8.13 |
| 1995–96 | 648 | 1 563 | 0.41 | 7.62 | 11.34 |
| 1996–97 | 778 | 825 | 0.94 | 7.85 | 11.32 |
| 1997–98 | 499 | 816 | 0.61 | 11.93 | 20.67 |
| 1998–99 | 306 | 508 | 0.60 | 3.44 | 7.56 |
| 1999–00 | 304 | 374 | 0.81 | 10.08 | 10.27 |
| 2000–01 | 248 | 416 | 0.60 | 15.64 | 19.21 |
| 2001–02 | 115 | 256 | 0.45 | 7.98 | 15.13 |

(b) SKI 2

| Year | Catch (t) | Number of trawls | Tonnes per trawl | % zero catch by day | % zero catch by trawl (TCEPR only) |
|---|---|---|---|---|---|
| 1989–90 | 608 | 697 | 0.87 | 5.52 | 0.00 |
| 1990–91 | 444 | 732 | 0.61 | 4.19 | 0.00 |
| 1991–92 | 942 | 1 310 | 0.72 | 3.31 | 3.85 |
| 1992–93 | 670 | 1 281 | 0.52 | 6.33 | 6.49 |
| 1993–94 | 790 | 1 349 | 0.59 | 7.22 | 8.68 |
| 1994–95 | 706 | 1 074 | 0.66 | 13.97 | 16.07 |
| 1995–96 | 599 | 1 310 | 0.46 | 12.14 | 16.27 |
| 1996–97 | 671 | 1 299 | 0.52 | 9.45 | 15.91 |
| 1997–98 | 326 | 879 | 0.37 | 15.96 | 11.94 |
| 1998–99 | 229 | 582 | 0.39 | 13.81 | 20.09 |
| 1999–00 | 408 | 648 | 0.63 | 9.06 | 11.93 |
| 2000–01 | 240 | 505 | 0.48 | 13.27 | 14.07 |
| 2001–02 | 169 | 385 | 0.44 | 7.45 | 6.98 |

**Table 3: Estimated gemfish target catch by fishing method from CELR and TCEPR records. Values were rounded to the nearest tonne, with "0" indicating landings less than 0.5t, and "–" indicating no landings.**

| | SKI 1 | | | | SKI 2 | | |
|---|---|---|---|---|---|---|---|
| Year | Bottom pair | Bottom | Midwater | Total | Bottom | Midwater | Total |
| 1989–90 | 3 | 949 | – | 952 | 608 | – | 608 |
| 1990–91 | – | 851 | 0 | 851 | 444 | – | 444 |
| 1991–92 | – | 738 | 0 | 738 | 811 | 130 | 941 |
| 1992–93 | – | 976 | 0 | 976 | 607 | 63 | 670 |
| 1993–94 | 0 | 937 | 0 | 937 | 533 | 258 | 791 |
| 1994–95 | 0 | 905 | – | 905 | 279 | 427 | 706 |
| 1995–96 | – | 648 | 0 | 648 | 366 | 233 | 599 |
| 1996–97 | – | 778 | 0 | 778 | 553 | 118 | 671 |
| 1997–98 | – | 499 | 0 | 499 | 309 | 17 | 326 |
| 1998–99 | 5 | 300 | 1 | 306 | 228 | 1 | 229 |
| 1999–00 | 6 | 296 | 2 | 304 | 400 | 7 | 407 |
| 2000–01 | 17 | 231 | 0 | 248 | 221 | 19 | 240 |
| 2001–02 | – | 115 | – | 115 | 169 | 0 | 169 |

**Table 4: Estimated gemfish landings by record type, and estimated catch as a percentage of the total landings**

| | SKI 1 | | | | | SKI 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Landings | | | | | Landings | | |
| | CELR | TCEPR | Target | Total | % | CELR | TCEPR | Target | Total | % |
| 1989–90 | 687 | 264 | 951 | 1 230 | 77.3 | 608 | 0 | 608 | 1 043 | 58.3 |
| 1990–91 | 682 | 169 | 852 | 1 058 | 80.5 | 416 | 28 | 444 | 949 | 46.8 |
| 1991–92 | 506 | 232 | 738 | 1 017 | 72.6 | 651 | 290 | 942 | 1 208 | 78.0 |
| 1992–93 | 625 | 351 | 976 | 1 292 | 75.5 | 393 | 277 | 670 | 1 020 | 65.7 |
| 1993–94 | 299 | 639 | 938 | 1 156 | 81.1 | 185 | 606 | 790 | 1 058 | 74.7 |
| 1994–95 | 114 | 791 | 905 | 1 031 | 87.8 | 139 | 567 | 706 | 905 | 78.0 |
| 1995–96 | 25 | 623 | 648 | 801 | 80.9 | 114 | 485 | 599 | 789 | 75.9 |
| 1996–97 | 99 | 679 | 778 | 965 | 80.6 | 139 | 532 | 671 | 978 | 68.6 |
| 1997–98 | 15 | 485 | 499 | 627 | 79.6 | 27 | 300 | 326 | 671 | 48.6 |
| 1998–99 | 11 | 295 | 306 | 413 | 74.1 | 15 | 214 | 229 | 335 | 68.4 |
| 1999–00 | 11 | 293 | 304 | 409 | 74.3 | 2 | 405 | 408 | 506 | 80.6 |
| 2000–01 | 15 | 233 | 248 | 335 | 74.0 | 2 | 238 | 240 | 330 | 72.7 |
| 2001–02 | 2 | 114 | 115 | 201 | 57.2 | 4 | 164 | 169 | 268 | 63.1 |

**Table 5: Estimated gemfish target catch by statistical area. Values have been rounded, with "0" indicating landings less than 0.5 t, and "–" indicating no catch.**

| | | Fishing year | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 89–90 | 90–91 | 91–92 | 92–93 | 93–94 | 94–95 | 95–96 | 96–97 | 97–98 | 98–99 | 99–00 | 00–01 | 01–02 |
| SKI 1 | 001 | 32 | – | 15 | 28 | 7 | 4 | 6 | 21 | 2 | – | – | – | – |
| | 002 | 6 | 4 | 14 | 50 | 39 | 37 | 81 | 27 | 6 | 5 | 4 | 2 | 6 |
| | 003 | 251 | 292 | 256 | 197 | 260 | 247 | 105 | 65 | 60 | 76 | 68 | 8 | 28 |
| | 004 | 2 | – | 2 | 58 | 11 | 6 | 3 | 7 | 4 | 0 | 0 | 1 | 1 |
| | 005 | 0 | – | 0 | 1 | 1 | – | 0 | 0 | – | – | – | 0 | – |
| | 007 | 3 | – | – | – | – | – | – | – | – | – | – | – | – |
| | 008 | 227 | 81 | 152 | 405 | 152 | 72 | 81 | 102 | 55 | 18 | 2 | 14 | 13 |
| | 009 | 273 | 242 | 186 | 115 | 33 | 17 | 25 | 31 | 15 | 8 | 3 | 9 | 3 |
| | 010 | 159 | 233 | 70 | 19 | 13 | 3 | 18 | 21 | 1 | 2 | 3 | 4 | 3 |
| | 042 | – | – | 2 | – | – | – | 0 | – | 0 | 0 | 0 | 0 | – |
| | 045 | – | – | – | – | – | – | 4 | 0 | 0 | 0 | 0 | 7 | – |
| | 046 | 0 | – | – | 1 | 116 | 90 | 90 | 214 | 174 | 81 | 136 | 159 | 33 |
| | 047 | 0 | 8 | 42 | 100 | 324 | 428 | 220 | 292 | 183 | 118 | 87 | 49 | 29 |
| | 048 | – | – | – | – | – | 0 | 0 | 0 | – | – | – | – | – |
| | 101 | 0 | – | – | – | – | 1 | – | – | – | 3 | – | – | – |
| | 102 | – | – | – | 1 | – | – | – | – | 0 | – | – | – | – |
| | 104 | – | – | – | – | – | – | 1 | 0 | – | – | – | – | – |
| | 106 | – | – | 2 | – | 0 | – | – | – | – | – | – | – | – |
| | 107 | – | – | – | – | – | – | 19 | – | – | – | – | – | – |
| SKI 2 | 011 | 1 | 1 | 13 | 10 | 3 | 3 | 3 | 1 | 6 | 7 | 2 | 10 | 2 |
| | 012 | – | 11 | 8 | 0 | 1 | 16 | 116 | 138 | 20 | 11 | 37 | 49 | 40 |
| | 013 | 31 | 67 | 227 | 114 | 281 | 423 | 211 | 198 | 140 | 103 | 220 | 87 | 43 |
| | 014 | 465 | 245 | 550 | 432 | 470 | 204 | 211 | 316 | 199 | 100 | 162 | 100 | 83 |
| | 015 | 105 | 113 | 100 | 119 | 31 | 61 | 67 | 25 | 5 | 9 | 2 | 4 | 1 |
| | 016 | 5 | 2 | 32 | 0 | 3 | 2 | 2 | 0 | – | 0 | – | – | – |
| | 201 | – | – | – | 2 | 1 | – | 1 | 0 | – | – | – | – | – |
| | 203 | – | – | – | – | 0 | 0 | – | – | – | – | 5 | – | – |
| | 204 | – | 0 | 1 | 4 | 0 | 0 | 0 | – | 1 | 0 | 3 | 2 | 0 |
| | 205 | – | 4 | – | – | 0 | 0 | 0 | – | – | – | – | – | – |

**Table 6: Relative standardised CPUE indices for the SKI 1 and SKI 2 fisheries.**

| | SKI 1 | | | SKI 2 | | |
|---|---|---|---|---|---|---|
| Year | Index | c.v. | 95% CI | Index | c.v. | 95% CI |
| 1989–90 | 1.00 | – | – | 1.00 | – | – |
| 1990–91 | 0.63 | 0.054 | 0.50–0.72 | 0.67 | 0.084 | 0.54–0.77 |
| 1991–92 | 0.37 | 0.031 | 0.32–0.43 | 0.47 | 0.055 | 0.39–0.56 |
| 1992–93 | 0.30 | 0.030 | 0.23–0.36 | 0.33 | 0.036 | 0.27–0.39 |
| 1993–94 | 0.29 | 0.029 | 0.24–0.33 | 0.27 | 0.031 | 0.23–0.32 |
| 1994–95 | 0.20 | 0.020 | 0.16–0.23 | 0.23 | 0.028 | 0.19–0.27 |
| 1995–96 | 0.14 | 0.013 | 0.12–0.16 | 0.20 | 0.025 | 0.16–0.24 |
| 1996–97 | 0.16 | 0.015 | 0.14–0.19 | 0.18 | 0.023 | 0.15–0.23 |
| 1997–98 | 0.10 | 0.011 | 0.08–0.12 | 0.12 | 0.015 | 0.09–0.14 |
| 1998–99 | 0.07 | 0.010 | 0.05–0.09 | 0.17 | 0.026 | 0.14–0.22 |
| 1999–00 | 0.11 | 0.015 | 0.09–0.14 | 0.18 | 0.026 | 0.14–0.23 |
| 2000–01 | 0.08 | 0.010 | 0.06–0.10 | 0.13 | 0.018 | 0.10–0.17 |
| 2001–02 | 0.09 | 0.013 | 0.07–0.11 | 0.15 | 0.022 | 0.11–0.18 |

**Table 7: Canonical standardised CPUE indices for the SKI 1 and SKI 2 fisheries.**

| | SKI 1 | | | SKI 2 | | |
|---|---|---|---|---|---|---|
| Year | Index | c.v. | 95% CI | Index | c.v. | 95% CI |
| 1989–90 | 5.10 | 0.065 | 4.47–5.80 | 4.01 | 0.072 | 3.47–4.64 |
| 1990–91 | 3.49 | 0.062 | 3.09–3.95 | 2.75 | 0.069 | 2.40–3.16 |
| 1991–92 | 1.90 | 0.057 | 1.70–2.13 | 2.01 | 0.051 | 1.81–2.23 |
| 1992–93 | 1.77 | 0.050 | 1.60–1.96 | 1.32 | 0.051 | 1.19–1.46 |
| 1993–94 | 1.58 | 0.053 | 1.42–1.76 | 1.09 | 0.045 | 0.99–1.19 |
| 1994–95 | 1.00 | 0.058 | 0.89–1.12 | 0.89 | 0.052 | 0.80–0.99 |
| 1995–96 | 0.68 | 0.049 | 0.62–0.75 | 0.77 | 0.051 | 0.70–0.85 |
| 1996–97 | 0.81 | 0.051 | 0.73–0.90 | 0.72 | 0.051 | 0.65–0.79 |
| 1997–98 | 0.50 | 0.055 | 0.44–0.55 | 0.45 | 0.060 | 0.40–0.50 |
| 1998–99 | 0.40 | 0.064 | 0.36–0.46 | 0.68 | 0.073 | 0.59–0.78 |
| 1999–00 | 0.56 | 0.079 | 0.48–0.66 | 0.71 | 0.070 | 0.62–0.82 |
| 2000–01 | 0.39 | 0.086 | 0.33–0.47 | 0.50 | 0.072 | 0.43–0.58 |
| 2001–02 | 0.43 | 0.096 | 0.36–0.52 | 0.59 | 0.080 | 0.51–0.70 |

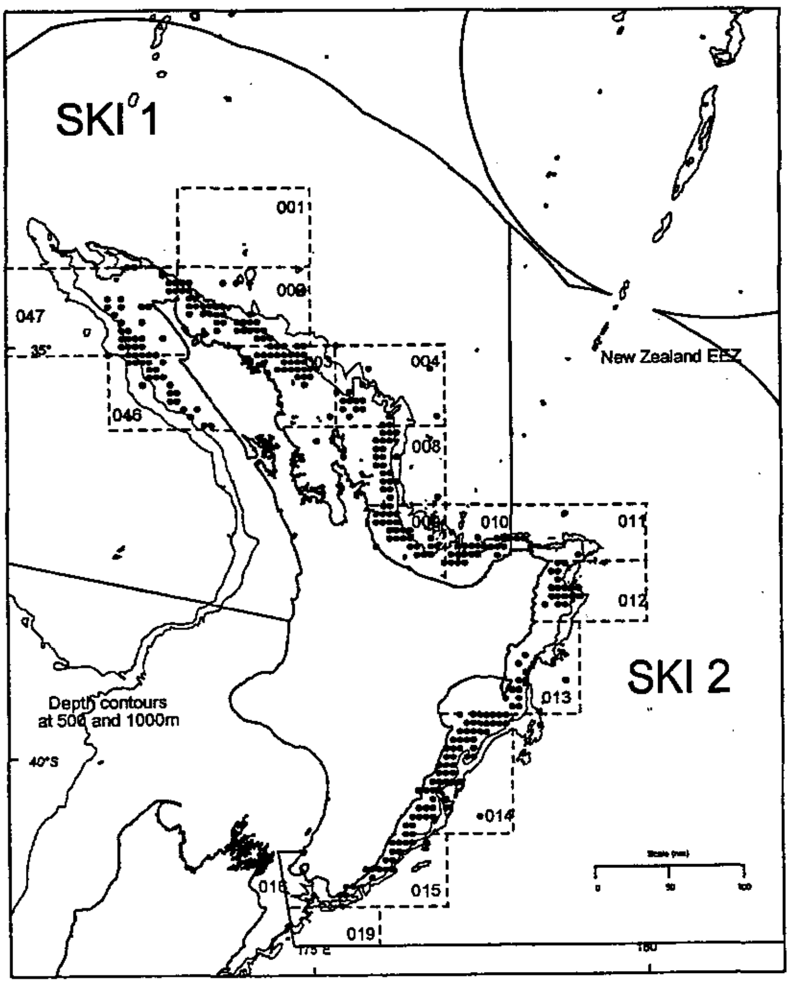


**Figure 1: Locations of trawls, QMAs, and statistical areas used in this report.**

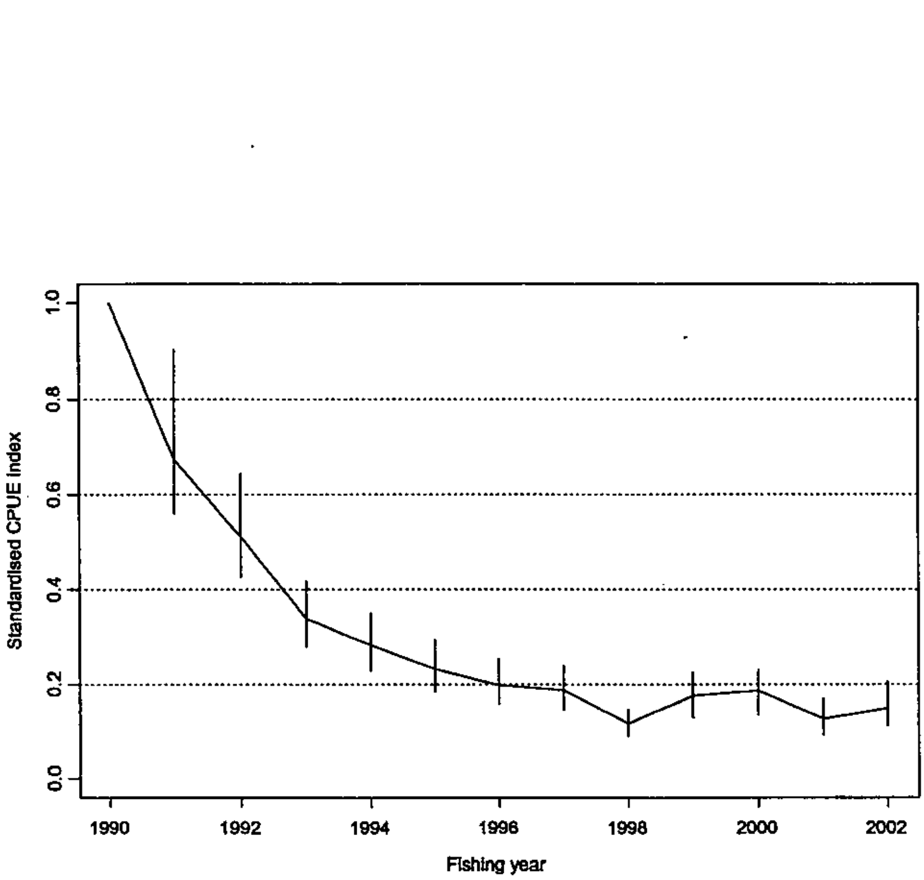


**Figure 2: Relative standardised CPUE indices for the SKI 1 target fishery.**

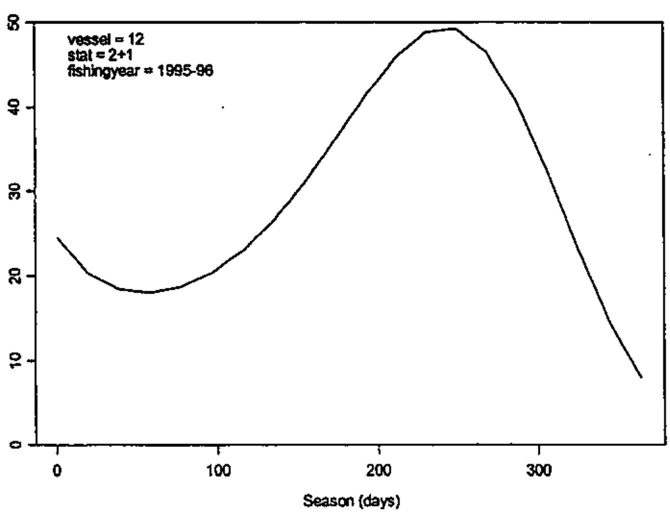


**Figure 3: Effect of fishing day in the SKI 1 fishery. Days 1–365 correspond to 1 October to 30 September. The values on the Y-axis correspond to predicted values of CPUE for "average" values of the other variables in the model.**

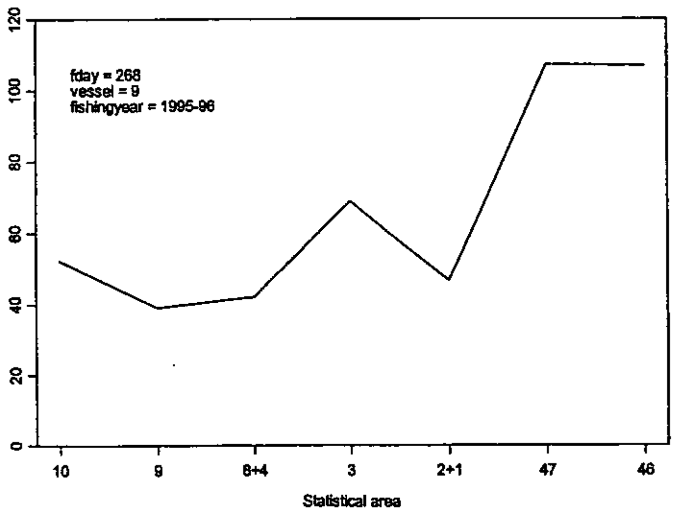


**Figure 4: Effect of statistical area in the SKI 1 fishery. The values on the Y-axis correspond to predicted values of CPUE for "average" values of the other variables in the model.**

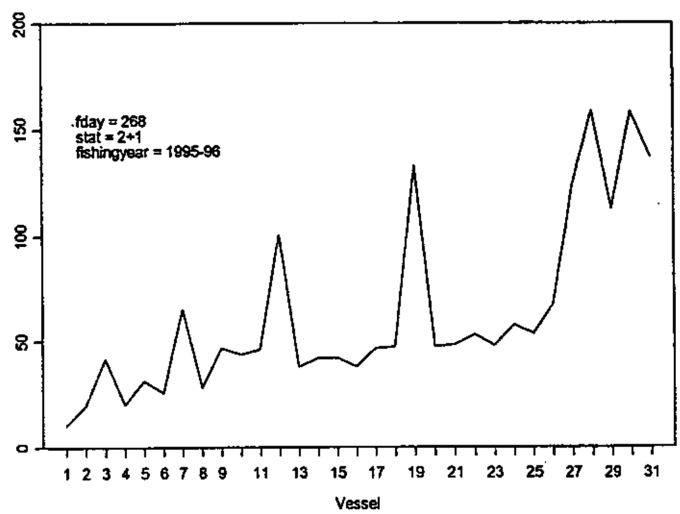


**Figure 5: Effect of vessel in the SKI 1 fishery. The values on the Y-axis correspond to predicted values of CPUE for "average" values of the other variables in the model.**

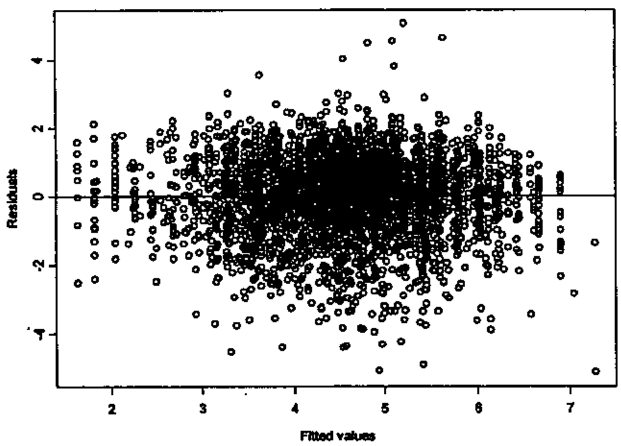


Figure 6: Diagnostic plot of residuals from the lognormal model for the SKI 1 fishery.

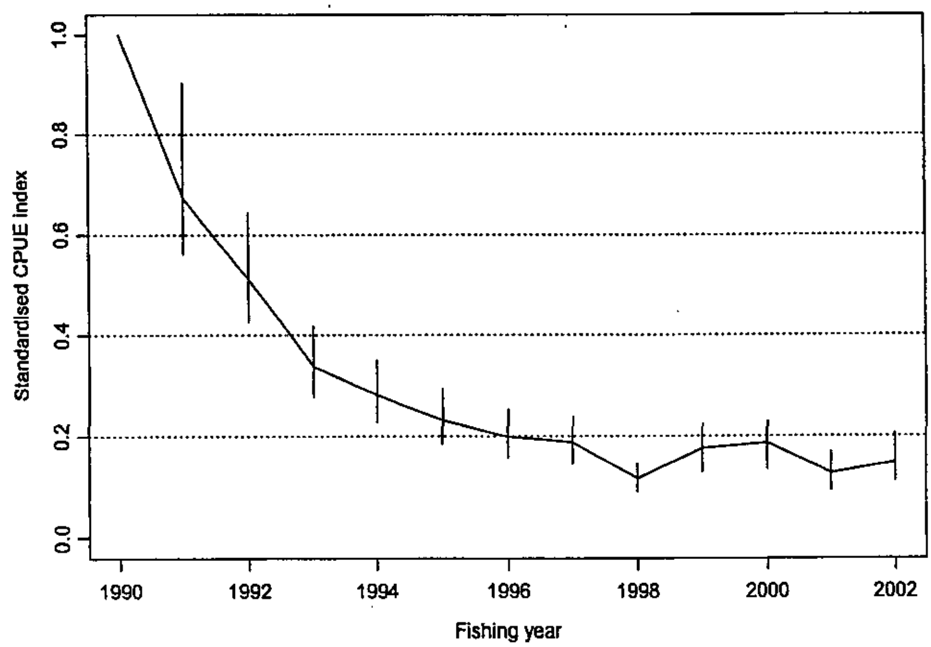


Figure 7: Relative standardised CPUE indices for the SKI 2 target fishery.

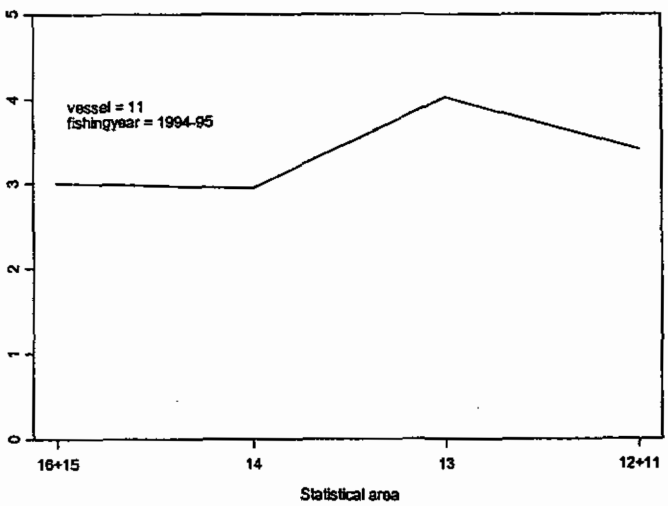


**Figure 8: The effect of statistical area in the SKI 2 fishery. The values on the Y-axis correspond to predicted values of CPUE for "average" values of the other variables in the model.**

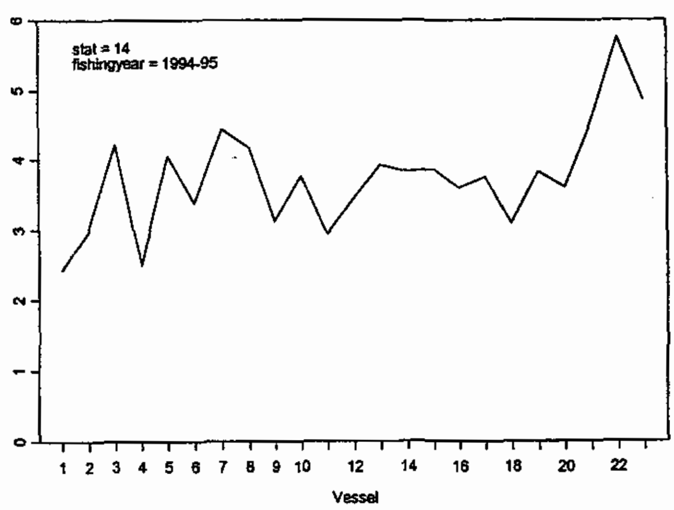


**Figure 9: The effect of vessel in the SKI 2 fishery. The values on the Y-axis correspond to predicted values of CPUE for "average" values of the other variables in the model.**

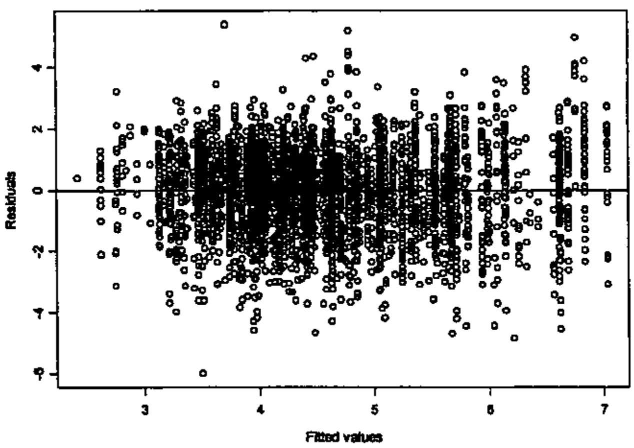


**Figure 10: Diagnostic plot of residuals from the lognormal model for the SKI 2 fishery.**